Light-Weight Composite Environmental Performance Indicators (LWC-EPI)

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Zusammenfassung

Schnelle ökologische Veränderungen erfordern eine geänderte Haltung bezüglich ökologischer Nachhaltigkeit, angefangen bei Einzelpersonen bis hin zu Unternehmen und Regierungen. Daher ist eine nähere und kritischere Überprüfung des Umgangs mit aktuellen umweltpolitischen Themen erforderlich. „Environmental Management Information Systems“ (EMIS) (Teuteberg, Et Al., 2010 s. Xxi-Xxiii) spielen eine wichtige Rolle bei der Bereitstellung von Informationen, die es Benutzern ermöglicht aktuelle Umweltauswirkungen ihrer Prozesse und Vorgänge zu bewerten. Im letzten Jahrhundert hat eine enorme Entwicklung in diese Richtung statt gefunden, die sich positiv auf die Gesellschaft und die Umwelt ausgewirkt hat. Beispiele dafür sind die Organisation von Fachkonferenzen (enviroInfo, ITEE, etc.), neue IT-Lösungen (Gabi ®, SimaPro ®, SAP Sustainability Performance Management (SuPM ®), Umberto ®, etc.), die Einführung von neuen umweltrelevanten Gesetzen sowie andere Entwicklungen, die im Rahmen dieser Dissertation diskutiert werden. Davon ausgehend, dass die ökologischen Probleme die gleichen bleiben, ob in Fertigung, Logistik, IT oder Dienstleistung, gehört der Umgang mit den Auswirkungen auf die Umwelt heutzutage zu einer der anspruchsvollsten Aufgaben.

Die Forschung zu Light-Weight Composite Environmental Performance Indicators (LWC-EPI) zielt auf eine angemessene Art und Weise darauf ab, die Verwendung von EMIS in Kleinen und Mittelständischen Unternehmen (KMU) zu erhöhen. Diesem Ziel folgend enthält diese Dissertation sieben Kapitel, die dem verfolgten Forschungs-Zyklus entsprechen.

Viele der in dieser Dissertation vorgestellten und diskutierten Forschungsarbeiten wurden auf internationalen Fachkonferenzen und als begutachtete wissenschaftliche Publikationen veröffentlicht. Darüber hinaus wurden basierend auf dem LWC-EPI Konzept Projekte entwickelt, die von Studenten in Teams bearbeitet wurden. So enstand z.B. die in Kapitel sechs erwähnte prototypische Implementierung im Rahmen einer studentischen Projektarbeit.
Zusammenfassend lässt sich sagen, dass die LWC-EPI Forschung zum Bereich der EMIS folgende neue Konzepte und Artefakte beiträgt, wie z.B:

- Als wichtigstes Artefakt bietet das LWC-EPI Konzept ein neues Framework, das als Basis für die Entwicklung von neuen EMIS dient und dabei die Anforderungen von KMU berücksichtigt. Dies fördert KMU darin, sich stärker für Nachhaltigkeit aus einer ökologischen Perspektive heraus zu engagieren.
- Der LWC-EPI Prototyp zeigt eine validierte Möglichkeit der Datenverarbeitung, indem er Daten aus verschiedenen Quellen unter Nutzung von Webservices extrahiert.
- Wiederverwendbarkeit: Das Framework besteht aus Modellen, die alle einen eigenen Mehrwert mit sich bringen. Dies gewährleistet ein hohes Maß an Wiederverwendbarkeit, z.B.:
    - Das ECET Assessment Modell bietet ein kohärentes Bewertungsmodell, welches der Organisation Verbesserungspotentiale zeigt, um mehr Nutzen aus der Verwendung der LWC-EPI Lösung zu erzielen. Dieses Modell kann die Basis für eine eigenständige Bewertung sein.
    - Im Zusammenhang zur EPI Modellerstellung wurde ein neues umfassendes Modell zur EPI Klassifikation vorgeschlagen. Dieses Modell kann für Projekte,

die zu einer besseren EPI Standardisierung führen, für die Forschung oder für die Verbesserung des EPI Wissens in der Gesellschaft verwendet werden.

- Benchmarking: Die Funktionalitäten zur Berichterstattung, die der LWC-EPI Prototyp bietet, dienen organisationsinternen (intra-organizatinal) und organisationsübergreifenden (inter-organizational) Aspekten des LWC-EPI Konzepts. Dadurch kann der Benutzer seine Ergebnisse mit den Ergebnissen anderer Kollegen sowie mit den Ergebnissen von anderen registrierten Organisationen vergleichen.

Aus dieser Dissertation lassen sich verschiedene Ansätze für eine ergänzende Forschung ableiten. Beispielsweise kann durch den angegebenen Java Code (parsing) nach minimaler Modifikation das LWC-EPI Konzept mit weiteren EPIs von verschiedenen externen Datenbanken (z.B. ELCD oder A +) ergänzt werden. Dieser Schritt gewährleistet den registrierten Organisationen eine größere Vielfalt in der EPI Zusammenstellung.

Dennoch weist die Forschung nach wie vor viele offene Fragen auf, die beantwortet werden müssen. Eine davon bezieht sich auf das Sicherheitsmuster (security pattern), das in dieser Arbeit nicht berücksichtigt wurde. Die Angabe eines geeigneten Geschäftsmodells ist eine anspruchsvollere Forschungsfrage, die in Zukunft bearbeitet werden muss.

Der Schwerpunkt dieser Dissertation lag darin, ein neues EPI Framework, genannt LWC-EPI Framework, vorzustellen, das die KMU in der Einhaltung ihrer Verantwortung gegenüber der ökologischen Nachhaltigkeit und Kommunikation über ihre ökologische Performance fördert. Das LWC-EPI Konzept wurde durch eine prototypische Implementierung geprüft und durch einen Business Use Case bewertet, welcher von einem potenziellen Endnutzer validiert wurde. Abschließend lässt sich feststellen, dass das LWC-EPI Framework zu einer umfangreichen Verwendung von Umweltdaten in Form von EPIs führt und eine Grundlage dafür legt, die KMU in Bezug auf Nachhaltigkeit einzubinden.

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Abbreviations

CEMIS	**C**orporate **E**nvironmental **M**anagement **I**nformation **S**ystem
DJGTSMI	**D**ow **J**ones **G**lobal **T**otal **S**tock **M**arket **I**ndex
DJSI	**D**ow **J**ones **S**ustainability **I**ndex
DSR	**D**esign **S**cience **R**esearch
EC	**E**uropean **C**ommission
Eco 92	United Nations Conference on Environment and Development
EIA	**E**nvironmental **I**mpact **A**ssessment
ELCD	**E**uropean reference **L**ife **C**ycle **D**atabase
EMAS	**E**co **m**anagement and **a**udit **s**cheme
EMIS	**E**nvironmental **M**anagement **I**nformation **S**ystem
EMS	**E**nvironmental **M**anagement **S**ystem
EPD	**E**nvironmental **P**roduct **D**eclarations
EPM	**E**nvironmental **P**erformance **M**easurement
ERP	**E**nterprise **R**esource **P**lanning
EU ETS	**E**uropean **U**nion **E**mission **T**rading **S**cheme
EU	**E**uropean **U**nion
GHG	**G**reen**h**ouse **G**as
ICT	**I**nformation and **C**ommunication **T**echnology
IS	**I**nformation **S**ystem
ISO	The **I**nternational **O**rganization for **S**tandards
IT	**I**nformation **T**echnology
LCA	**L**ife **C**ycle **A**ssessment
LWC-EPI	**L**ight-**W**eight **C**omposite **E**nvironmental **P**erformance **I**ndicators solution
MiFID	**M**arkets in **F**inancial **I**nstruments **D**irective
MIS	**M**anagement **I**nformation **S**ystem
NGO	**N**on-**g**overnmental **o**rganization
OEPI	Solution and Services Engineering for Measuring, Monitoring, and Management of **O**rganizations' **E**nvironmental **P**erformance **I**ndicators
PCR	**P**roduct **C**ategory **R**ules
PLS	**P**artial **L**east **S**quares
SAM	**S**ustainable **A**sset **M**anagement
SME	**S**mall **M**edium **E**nterprise
SOA	**S**ervice **O**riented **A**rchitecture
UDK	**U**mwelt**d**aten**k**atalog
US-EPA	**U**nited **S**tates **E**nvironmental **P**rotection **A**gency
VSDB	**V**irtual **S**hared **D**ata**b**as

1 Introduction

Rapid ecological changes have necessitated a widely changing attitude regarding environmental sustainability, starting from individuals all the way to corporations and governments. Therefore, a closer and more critical review of how to handle current environmental issues is needed. Environmental Management Information System (EMIS) can play a major role in providing information that enables users to assess the current environmental impact of their processes and operations (Rautenstrauch, 1999 p. 11). In the last century, enormous developments in this direction have been witnessed that have positively impacted society and the environment, such as organizing specialized conferences (enviroInfo[1], ITEE[2], etc.), proposing new IT-solutions (Gabi®, SimaPro®, SAP Sustainability Performance Management (SuPM®), Umberto®, etc.), introducing new environmental related laws, and other actions that will be discussed later in this dissertation. Today, in almost every field, dealing with environmental effects are one of the most challenging tasks, given that environmental problems remain the same whether they are related to manufacturing, logistics, IT, service providers, etc.

One of the most important topics is global warming, which is defined as the increase in the average temperature of the Earth's troposphere and oceans since the mid-20th century and its projected continuation (Mendelsohn, et al., 1994 pp. 753-755). The ozone layer depletion and the resulting ozone hole are one example of the rapid ecological changes happening, and researchers claim that Greenhouse Gas (GHG) emission is one of the basic reasons for this climate change (Houghton, et al., 2001), (Meinshausen, et al., 2009).

In power stations, fossil fuel (coal, petroleum, natural gas, etc.) is used for energy generation, and it emits large amounts of GHG. Similarly, corporations do not fully implement environmental standards, nor do they properly dispose of their waste materials (e.g. chemicals, hazardous, e-waste, etc.) in an environmentally friendly way. This conduct not only pollutes water resources, but also affects the agriculture sector as well.

Starting in the early 1960s and mid-1970s, an observed emersion of environmental concerns was noticed. In 1972, Meadows' book 'The Limits to Growth', which was written for the Club of Rome, was one of the earliest publications that pointed out the rapidly growing world population compared to the finite supply of resource (Meadows, et al., 1972 pp. 17-24). In their article, "The Globalisation Timeline" Rennen and Martens mentioned the growing awareness of the exhaustion of the natural environment through human activities on local, regional, and global levels (Rennen, et al., 2003 pp. 137-138). The effects of environmental disasters, such as Hiroshima and Nagasaki, Chernobyl, the Bhopal gas tragedy,

[1] The International Conference on Informatics for Environmental Protection is specialized conference taking place yearly since 1986, organized by the German Informatics Society (GI). It is developed to provide a communication platform for experts in sustainability and environmental protection. http://www.enviroinfo2014.org/

[2] Information Technologies in Environmental Engineering (ITEE) are the topic of a conference-row, taking place every two years since 2003. http://www.itee2013.org/

the Fukushima-Daiichi nuclear power plant damage (March 11, 2011), and others still play a major role in the adoption of new environmental regulations targeting pollution reduction. The need to ensure conformity with quickly increasing environmental legislation in the mid-1980s led many companies in the United States to adopt more sophisticated management systems that support the realization of environmental strategies and control their environmental risks (Steger, 2000 pp. 24-26).

The United Nations Conference on Environment and Development, known as the Rio Summit or the Earth Summit (referred to as Eco 92, hereafter), held in Rio de Janeiro in June, 1992, is a good example that shows the worldwide increasing concern for environmental issues. Representatives of 172 governments from all over the world participated, with 108 sending their heads of state (Eco92, 1997). Some 2,400 representatives of non-governmental organizations (NGOs), together with around 17,000 interested attendees and consultants, participated in the NGO "Global Forum" that was happening simultaneously (Eco92, 1997). The audience discussed many environmental issues, e.g. the systematic examination of some production models, or how to improve social environmental awareness. Some of the sub-topics were discerning which alternative energy sources are available to replace the use of fossil fuels, and finding the best way to encourage people to use public transportation. This aims to reduce the air pollution caused by vehicle emissions and the waste of finite energy. In addition, Eco 92 points out the threat coming from the decrease of potable aqueous resources worldwide. The most significant achievement of the Eco 92 was initiating the Kyoto Protocol that started as an agreement on the Climate Change Convention and improved over almost five years to become as it is known today. In addition, the principle 22 endorses a decision to save the lands of indigenous people from actions that cause environmental or cultural degradation (Eco92, 1997 p. AnnexI).

After Eco 92, policy makers have given more attention to how businesses and industries try to achieve sustainable development. The International Organization for Standards (ISO) is charged with developing international standards of environmental performance to ensure that companies are operating in an environmentally friendly way (Waters, 1998 pp. 3-4). The European Union (EU) has also been an important driver for the promotion of sustainable development. The Single European Act and the Fifth Environmental Action Program require environmental considerations to be incorporated into all EU policy (Smith, et al., 2000 pp. 24 -25). For example, the EU introduced the EU ETS (Emission Trading Scheme), the largest multi-national emissions trading scheme in the world (Ellerman, et al., 2007 pp. 66-67), (Aruvian's Research, 2010). It is a major pillar of EU climate policy. In 2008, the ETS covered more than 10,000 installations in the energy and industrial sectors, which are collectively responsible for close to half of the EU's emissions of CO_2 and 40% of its total GHG emissions (Aruvian's Research, 2010), (EU-ETS, 2008). Currently, it includes more than 11000 power stations and industrial plants[3].

For easier access to environmental databases for the public and for companies, German and Austrian authorities introduced an environmental data catalogue (Umweltdatenkatalog, UDK)[4] for public, industrial, and governmental institutions. In the beginning of the new

[3] https://www.gov.uk/participating-in-the-eu-ets

[4] http://www.lung.mv-regierung.de/insite/cms/umwelt/umweltinformation/udk_gein_publi.php

century, the UDK has been merged in the new internet portal of the German environmental authorities known as "PortalU[5]", where the "U" stands for "Umwelt", the German word for the environment. Another EU initiative, in addition to Eco-taxes, is the Eco-Management and Audit Scheme (EMAS), where around 5,500 certifications have been issued as of 2008, and currently (2014) it covers around 7,800 sites[6].

The Green500 program is another example that comes from the United Kingdom, and it was started by the mayor of London with the aim of enlisting London's top 500 organizations and mentoring them through their carbon reduction commitments (Green500, 2009). The program's committee argues that their objective is not only reducing carbon emissions, but that it is also about changing the industries' behaviors regarding the environment. Some of the abovementioned standards will be detailed in Chapter 3.

Information system (IS) can be defined as a "set of interrelated components that collect (or retrieve), process, store, and distribute information to support decision making and control in an organization" (Laudon, et al., 1994 p. 8). K.C.Laudon and J.P.Laudon provide a four level pyramid classifying IS types presented in Figure 1. In addition, it reflects the enterprise hierarchy.

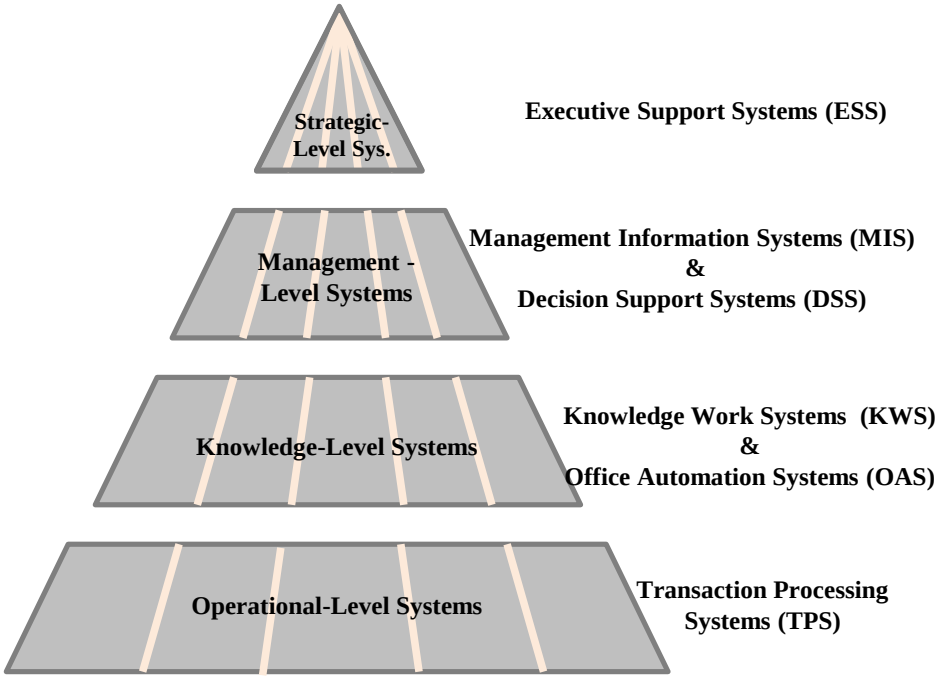


Figure 1: Classical Types of Information Systems (Laudon, et al., 1994 p. 13)

As a type of Management Information System (MIS), the concept of Environmental Management Information Systems (EMISs) is not new, especially considering that the discussion about the architecture of these systems started in the 80s, and the topic has been continually attracting more attention over the past few decades (DEFRA, 2006).

Environmental performance has increasingly come under scrutiny, and many organizations have started to recruit environmental experts and consultants. Information technology is a key part of today's corporations/enterprises (with different fields/domains) and focuses on

[5] PortalU provides access to government-owned environmental information in Germany. URL: www.portalu.de

[6] http://ec.europa.eu/environment/emas/about/index_en.htm

environmental topics, as in (Rautenstrauch, 1999) and (Gómez, 2004). To carry out their operations, companies define various processes that are not only related to the finished product, but also include processes for all materials, new and used. Besides the economic issues of the finished product, social and environmental factors are vital, as product manufacturing, usage, and disposal all affect the environment and society.

Corporate environmental action takes many forms. One example is implementing an Environmental Management System (EMS) to establish the framework for setting targets that allow an organization to evaluate and improve its environmental compliance and performance (Welford, 1996) cited in (Tinsley, et al., 2006 pp. 15-16). Most companies that adopt an EMS either follow industry standards, e.g. Responsible Care[7] in the chemicals sector, or international guidelines such as ISO 14000 series, EMAS, or BS 8555. Another possibility is participating in a voluntary or mandatory environmental reporting scheme that aims to assess and reduce organizational emissions or other environmental aspects. Environmental reporting improves environmental performance by encouraging companies to measure their impacts and communicate them to stakeholders.

To allow organizations to compare the environmental impacts of alternatives in a meaningful way, they should be presented with quantitative Environmental Performance Indicators (EPIs), which describe environmental impacts at an organizational, product, and process level in a comprehensive and concise manner (Jasch, 2000 p. 82). This is still challenging due to the lack of common business platforms that collect EPIs from various companies and provide them upon request in different business scenarios, as it will be explained in Chapter 3.

Protecting the atmosphere is a global responsibility that should be a common objective, and reaching ecological sustainability requires a widely changing attitude at the individual, corporate, and governmental level. Those three groups should coordinate and harmonize their steps together for speeding the movement towards a sustainable environment, as it is presented in Figure 2. Environmental issues have increasingly become an important public policy goal globally, and the preservation of environmental sustainability and energy efficiency are becoming new challenges for today's companies (Günther, 1998 pp. 1-2).

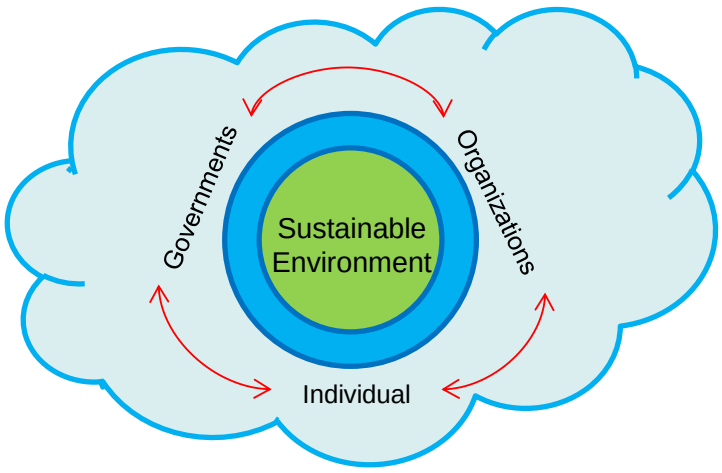


Figure 2: The main three actors for a sustainable environment

[7] Responsible Care is the American Chemistry Council's (ACC's) initiative. http://www2.dupont.com/inclusive-innovations/en-us/sites/default/files/RC101__2008_version_-_FINAL.pdf

To reach this level of ecological sustainability, a closer and more critical review of current environmental policies is needed. As it was mentioned, IT plays a major role in speeding up the change in attitude by providing information that enables users to assess the current environmental impact of their processes and operations.

The U.S. Energy Information Administration (EIA) of the Department of Energy published the International Energy Outlook 2010 in July. The report presents international energy projections until 2035, including outlooks for major energy fuels and associated carbon dioxide emissions (EIA, 2010)[8]. Table 1 and Figure 3 present the ratios of renewable to non-renewable electrical energy used in the world. We can directly see the huge gap between Central & South America, with an average of 83%, compared to the other regions.

Region // Year	1980	1990	2000	2007	Avg.
Central & South America	0.764	0.881	0.865	0.819	0.832
Europe	0.233	0.196	0.225	0.227	0.220
Eurasia	0.157	0.158	0.221	0.203	0.185
Africa	0.354	0.200	0.207	0.194	0.239
North America	0.225	0.204	0.179	0.167	0.194
Asia & Oceania	0.229	0.200	0.159	0.148	0.184
Middle East	0.114	0.047	0.021	0.038	0.055

Table 1: The ratio of renewable to non-renewable electricity used in the world by region, sorted by 2007 data (EIA, 2010)

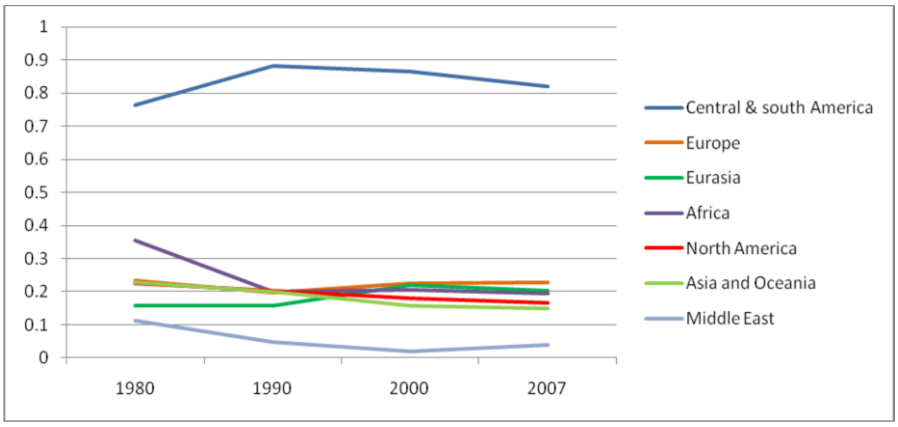


Figure 3: Graph of Table1

Table 2 and Figure 4 show the tons of carbon produced per person per year. The data cover the span from 1980 to 2007. Due to the increasing public awareness of these issues, it has also become a brooding topic in governments' and companies' politics and policies. For example, it is uncommon today to see an election campaign without a proposed environmental policy.

[8] The 2013 outlook report doesn't show significant changes. http://www.eia.gov/forecasts/ieo/index.cfm

Region // Year	1980	1990	2000	2007	Avg.
Africa	1.125	1.152	1.109	1.153	1.135
Central & South America	2.150	2.006	2.364	2.582	2.275
Asia & Oceania	1.442	1.796	2.131	3.175	2.136
Europe	8.875	8.202	7.719	7.876	8.168
Middle East	5.166	5.395	6.455	8.048	6.266
Eurasia	11.631	13.292	8.082	9.183	10.547
North America	17.126	16.015	16.495	15.913	16.387

Table 2: Tons of carbon produced per person per year in the world by region, sorted by 2007 data

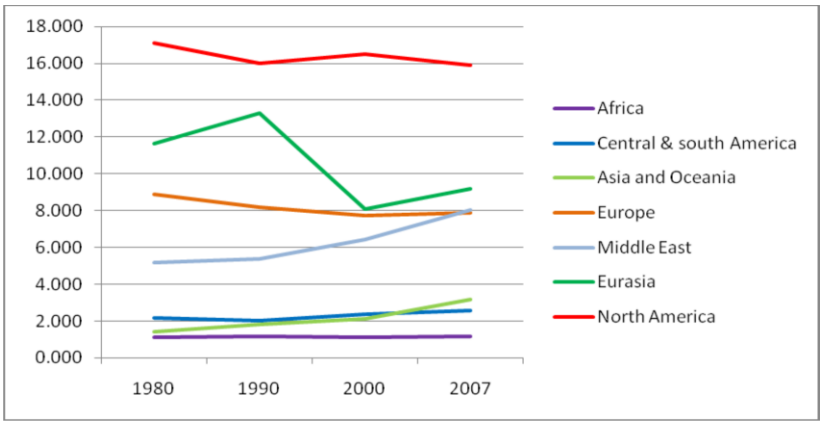


Figure 4: Graph of Table 2

After a quick look at the above tables and figures, the direct governments' policies influence on environmental sustainability can be noted. For instance, if a country reduces its GHG emissions, but a trade partner does not conform to the same standards, this may have an effect on the trade relations between them.

Emergent social awareness, public interest in environmental issues, and governmental policies, all together also have their effects on business' policies in many ways. Green IT, Green Logistics, insurance of environmental sustainability, and energy efficiency are becoming new challenges for today's companies that feel the emergent legislative pressure. The same holds true for the mass media and society as a whole.

This research focuses on Small and Medium Enterprises (SMEs), the biggest business sectors in the world. Around twenty million SMEs operated in 2012 in the European Union (EU), and this represents 99.8 % of total numbers of enterprises operating in the EU (Gagliardi, et al., 2013 p. 10).

There are different views and definitions of SMEs, which are also known as Small and Medium Businesses (SMBs) in the USA. In this dissertation, the EU definition is followed, which states: an SME is an enterprise that has a certain maximum number of employees and/or has an annual turnover that does not exceed a certain amount of money (Commission, 2005 pp. 12-26). These limits change over time, and they are not the same all over the world,

e.g. in Germany an SME is a company with up to 499 employees (IFM-bann, 2002) while in New Zealand the number is as low as 19 employees. For this research, the European Union standard was used, which set the maximum number of employees to 249 (Commission, 2005). Most organizations, especially SMEs focus on the short-/medium- term benefits and take actions accordingly, ignoring environmental issues. In fact, a recommendation system or dashboard would support the organization's management to become well informed about the impact of their decisions on the environment. Companies that see the future and plan accordingly will earn a competitive advantage in the market. Society has started to realize these environmental issues, and they have shown interest in knowing more about the environmental performance of companies before they purchase products. Similarly, the companies also market their products with environment friendly slogans and details.

Companies that fail to follow environmental standards may risk losing potential markets and customers in the future. For example, in the near future, certain directives will be passed that only allow products that are compliant with environmental standards to be freely traded, like in CE marking (Conformité Européenne)[9]. Therefore, environmental directives would not only benefit the environment, but also companies by using reusable materials, reducing costs, and improving business processes, as well as making them flexible to changes in the market, which will make the company more competitive and profitable. In this vein, the Light-Weight Composite Environmental Performance Indicators (LWC-EPI) research is proposed.

1.1 Objectives

Organizations define various processes to carry out their operations. These processes are not always related to a finished product or service, but they include processes for all new and used materials. In addition, they have necessary processes for running the organization in general. Along with economic issues, social and environmental factors are important as well because product manufacturing or service providing, their usage, and their disposal are all related to the environment and societies. Reaching sustainable development has become a target in today's business as a response to the increasing pressure from society, governments, and Non-Governmental Organizations (NGOs). The report by the World Commission on Environment and Development (WCED) "Our Common Future" used Norwegian Prime Minister G. Brundtland's definition of sustainable development in the 1980s as: "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987 pp. 11-12), cited in (Porter, et al., 2006 p. 3). As an abstraction, sustainability has more than one dimension; it is not just about preserving the environment (Hart, 1997 p. 70). Economic, environmental, and social sustainability are the three dimensions that comprise the concept of sustainability as it is depicted in Figure 5. Our actions affect these three dimensions with different ratios since they are interconnected, and each dimension affects the other dimensions and vice versa. (Porter, et al., 2006). This work focuses on supporting environmental sustainability.

Acquiring environmental information is expensive and time consuming in most cases. Information Systems and their underlying technologies are a main part of today's businesses, and they are a major pillar in providing information that enables users to assess the current

[9] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31993L0068:en:HTML

environmental impact of their processes and operations. Section 3.3 provides the result of reviewing the current state of EMISs. This study concludes that none of these tools are designed to fulfil the growing needs of SMEs for such systems.

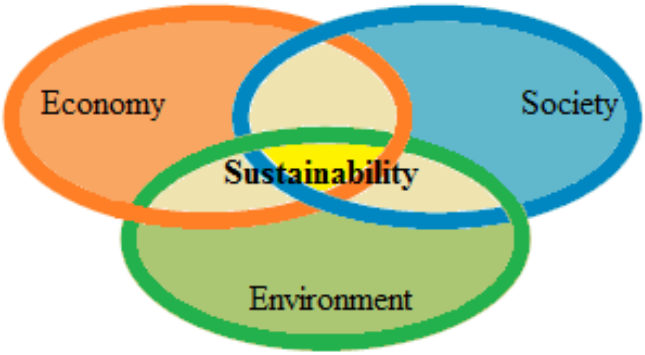


Figure 5: Sustainability Development Dimensions

Considering the growing needs of SMEs for EMIS with regard to the relatively expensive available software solutions, the aim of this research is to propose a new framework for EMIS named the ***Light-Weight Composite Environmental Performance Indicators solution (LWC-EPI)***. Its main target is the SMEs, taking into consideration the size and type of an organization, as well as its needs and priorities. It should provide any organization with information regarding its current impact on the environment. Furthermore, it helps this organization answer whether regulations are followed or not. If the answer is no, then the organization must ask itself: How can we identify what is missing? How should we react? What should we improve to meet those regulations?

In other words, the ***(LWC-EPI)*** objective is to provide a base to enable the development of an efficient EMIS that can help any SME in selecting, creating, calculating, comparing, and reporting selected EPIs at the enterprise level. This will lead a reduction in the gap between estimated values and current running values for the environment not just on yearly or quarterly basis, but even more frequently. For example, these values can be the energy consumption, the CO_2 emissions from the organization's transporters, or the disposal of waste material that harm the environment. Based on these EPIs, the organization can then define its strategy. In short, the LWC-EPI vision is:

"Supporting SMEs to comply with environmental responsibility"

Some of the new ideas that will be presented in this work are:

- A new EMIS's framework targeting SMEs will be the main artifact provided.
- The framework will consist of sub-artifacts, such as a new assessment model, database model, process model, and system architecture.
- A new way of data processing extracted from different sources.
- Move from n:1 to m:n relation:
  - As is model:
    - Input → Mediator → Output
      Same data in another representation form, e.g. report.

  - LWC-EPI model:
    - Input →Mediator → Output

Provides new information using different sources of data enhanced by additional expert knowledge, and then presents the needed processed data to the end user.

- A new semantic approach by deploying the OEPI ontology (Löschner, 2013) as it is explained in Section 4.5.

Research methodology framework:

The aim of this work is to propose a new EMIS framework incorporating the environmental, societal, and economic aspects of sustainable development. The framework will provide a complete picture for a combination of sub-conceptual models and sub-frameworks suitable for any organization, especially SMEs.

The major method employed in this work is Design Science Research (DSR) (Hevner, et al., 2004), one of the major research streams within the European IS disciplines (Österle, et al., 2010), (Carlsson, et al., 2011). The main goal of DSR is to propose a solution for a specific relevant problem by constructing new artifacts, keeping in mind the human purpose in research (Hevner, et al., 2004). Under the main DSR framework, the research follows the Literature Research Method (Seuring, et al., 2005) with a behavioral approach, exploring the likely effects of ecological changes on the business environment, as well as the societal, political, and technical challenges that result from these changes. Therefore, the research work applies a mixed-methods research approach, having a behavioral orientation in some parts and following a constructive approach in others.

The followed research framework will be detailed in Chapter 2.

1.2 Outline

This dissertation comprises seven Chapters, as shown in Figure 6. Starting with *Chapter 1* the introductory part of the thesis, it gives a general idea about the research topic, motivates the work, defines the problem, and specifies the research objectives. *Chapter 2* presents the research methodologies that have been followed, with a detailed explanation on how the LWC-EPI applied the Design Science Research (DSR) method.

The literature review, the state of the art, and the main related concepts, technologies, and solutions are explained and placed in *Chapter 3*. Overviews of significant Environmental Management Systems (EMSs) have been presented. The Environmental Performance Indicators (EPIs) have been studied in detail (concept, types, standards, classifications, etc.). The Chapter closes with the EMIS state of the art, open research issues, and the most important related work. *Chapter 4* illustrates the main artifacts of this dissertation by detailing the LWC-EPI framework and its five components. The needs and barriers, the requirements, and the background concepts all have been mentioned in this Chapter. *Chapter 5* demonstrates the LWC-EPI system architecture, its lifecycle of services, and the system expectations from the end-user perspective. *Chapter 6* describes LWC-EPI prototypical implementation together with its testing process. Moreover, the conducted evaluation's steps and their results using a detailed business use case have been articulated in this Chapter. The thesis ends with *Chapter 7* that summarizes the main findings and contribution of this work, and mentions the possible and recommended future work.

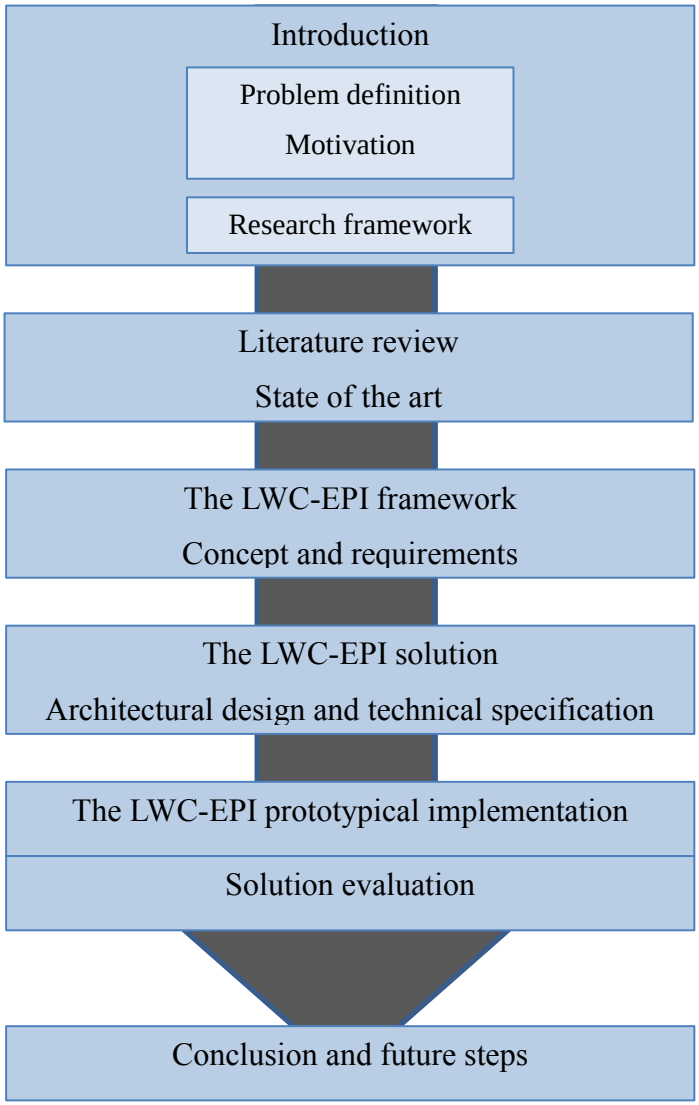


Figure 6: Thesis structure

2 The Research Framework

In this chapter, the research methodologies applied in this work will be presented. First, a brief look at the literature review that has been conducted will be given. Then the Design Science Research (DSR) process in the business information systems domain will be detailed. The third part is dedicated to explaining how the service design process has been used in this work. Applying these methodologies in the LWC-EPI research will be explained throughout those paragraphs.

2.1 The literature study

The LWC-EPI research project employed a literature review process that includes a deep revision of the state of the art in the related topics, combined with a set of related terms and definitions. Reviewing scientific publications in relation to the Environmental Management Information System (EMIS), environmental sustainability and its standards, the Environmental Performance Indicators (EPIs), the Service-Oriented Architecture (SOA), the Web Services technologies, and lightweight annotation frameworks were conducted. In addition, the related EMIS solutions in the market were studied.

The systematic literature review approach proposed by Webster & Watson in their publication: "Analyzing the past to prepare for the future: writing a literature review" (Webster, et al., 2002) and the Literature Research Method proposed by (Seuring, et al., 2005) were followed in conducting the literature review of this work.

Many research papers were reviewed within the mentioned research fields to define the main problems in the EMIS research world. More specifically, the Supporting Compliance Management and Environmental Management tools and the sustainability reporting tools were investigated. Some notable works in this field were the publications of (Welford, 1996), (Hilty, et al., 1997) (Rautenstrauch, 1999), (Hey, 2005), (Teuteberg, et al., 2009), and (Teuteberg, et al., 2010-I). Based on This study, the problem definition had been initiated and that continued to specify the main aspects of this work, and the gap to be bridged.

2.2 The Design Science Research

The Design Science in Information Systems Research by (Hevner, et al., 2004) shapes the backbone of this thesis' research structure. In addition, the design science research methodology by (Peffers, et al., 2007) has been followed as a clear research process to conduct this work. Hereafter, both research processes and how each of their steps was applied are explained.

2.2.1 Information Systems Research Framework

The major method employed in this work is the Design Science in Information Systems Research proposed by (Hevner, et al., 2004). It aims to propose a solution for a specific relevant problem by constructing new artifacts, keeping in mind the human purpose in research (Hevner, et al., 2004 pp. 76-81). This approach is widely considered as one of the main reference sources in the whole information systems research because of its high quality,

guidelines, and criteria it presents in the design science (Mahmoud, 2013 p. 47). Figure 7 presents the method framework of DSR.

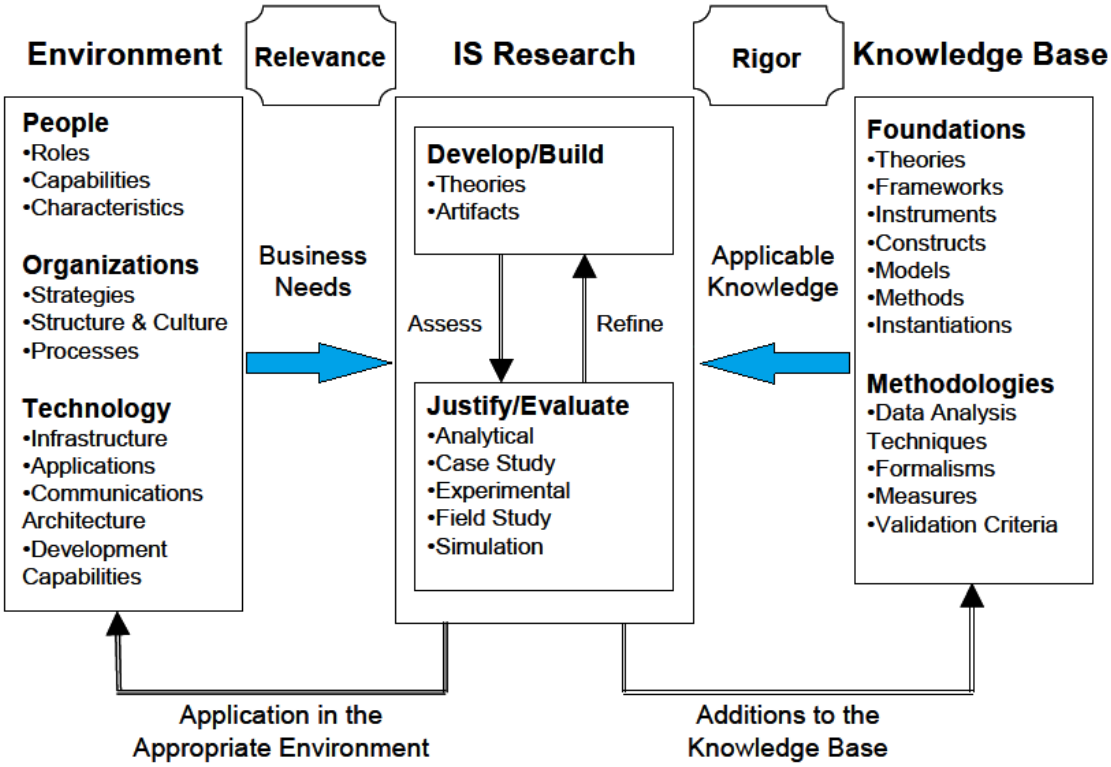


Figure 7: Information Systems Research Framework (Hevner, et al., 2004 p. 80)

Hevner, et al. claim that any IS research derives its relevancy from the business need derived from the environment that it targets. This environment consists of people, organizations, and technology (Silver, et al., 1995) cited in (Hevner, et al., 2004 p. 79).

Perceiving the goals, tasks, problems, and opportunities of an organization by its members defines the business needs of the environment. These business needs are developed based on the roles, capabilities, and characteristics of those members. Organization's strategies, structure, culture, and business processes support the evaluation of these business needs. Shaping, assessing and evaluating the business needs, selecting the appropriate technology infrastructure, applications, communication architectures, and development capabilities altogether define the research problem. The last pillar is framing research activities in a way that ensures research relevancy (Hevner, et al., 2004 p. 79).

"Design science addresses research through the **building** and **evaluation** of *artifacts* designed to meet the identified the business needs" (Hevner, et al., 2004 pp. 79-80). Truth is the aim of behavioral science, and it can be reached by developing and justifying the theories. Whereas utility is the aim of design science, and it can be achieved by building and evaluating artifacts serving the business needs. Those two complementary methods are required to form a comprehensive Information Systems (IS) research.

The knowledge base ensures the rigor of the IS research as it is illustrated in the right side of Figure 7. It consists of the prior theories, frameworks, instruments, constructs, models, methods, or instantiations used to build/develop the foundations of the research and the methodologies to complete the IS research. In addition, the data analysis techniques,

formalisms, measures, or validation criteria as the methodologies all together guide the research (Hevner, et al., 2004 p. 80).

Figure 8 shows how these principles have been applied in the LWC-EPI research. As it was mentioned in Chapter 1, SMEs are the targeted environment of the LWC-EPI research, and the objective is to provide an appropriate EMIS framework serving them effectively (more frequent reports), and to be easy to use by non-expert end users.

This was decided based on the extracted results from the literature reviews and the field

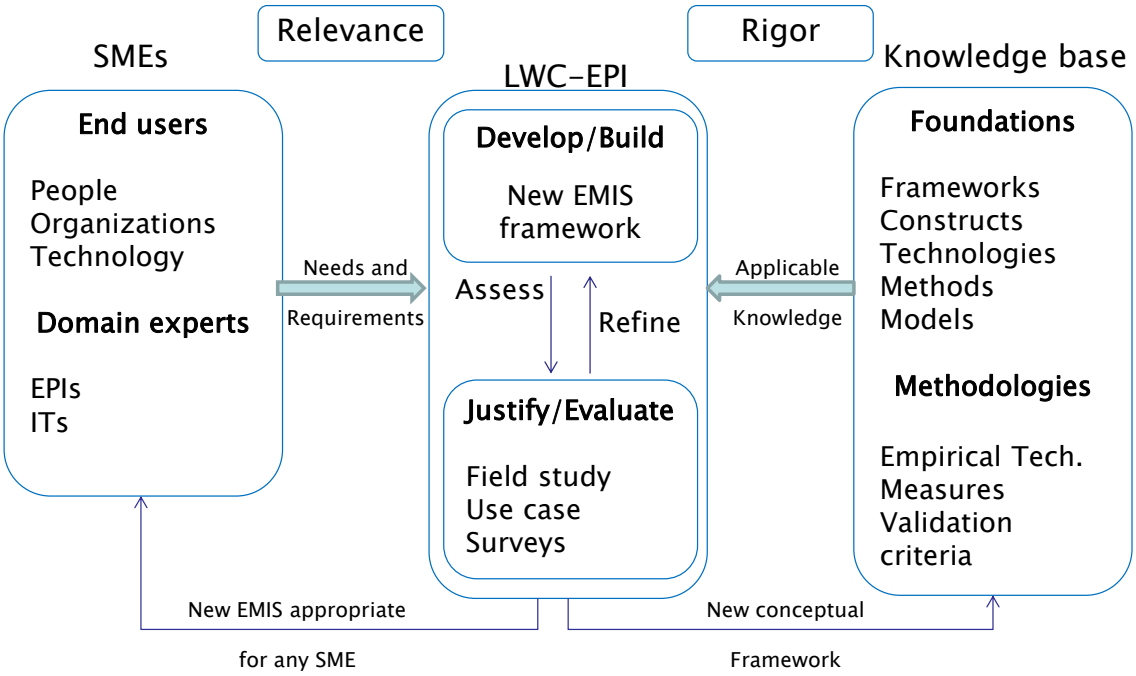


Figure 8: The LWC-EPI Research Framework based on (Hevner, et al., 2004) Model

studies conducted through different types of surveys. The delivered artifacts serve the Information and Communication Technology (ICT) Environmental Sustainability research domain; precisely, they belong to the EMIS topic.

To determine the research relevancy, prototypical implementations were developed using appropriate technology and development capabilities such as the SOA architecture, standardized XML-based Web Services, SQL database, Java and C# programming languages. The presented prototypes focus on usability and reporting capabilities for non-expert users. To ensure the rigor of the research, a systematic research approach was developed based on the literature study conducted. In addition, the important works' outputs were published in highly ranked scholarly publications about Environmental Sustainability service solutions, Web Service based tools, SOA-based solutions, Ontology conceptual frameworks, etc.

Hevner et al. derived seven guidelines to be followed in conducting any Design Science Research (DSR) in Information Systems domain (Hevner, et al., 2004) shown in Table 3. The next paragraphs explain how this work did follow the seven guidelines.

Design as an Artifact:

"Design-science research must produce a viable artifact in the form of a construct, model, method, or an instantiation." (Hevner, et al., 2004 p. 83). To develop new artifacts, IS research should start by reweaving current and previously related research and build on top of the aggregated knowledge (Mahmoud, 2013 p. 49). Following this, a comprehensive literature

review together with similar solutions' specifications has been conducted in order to find out what is still needed. The detailed study is presented hereafter in Chapter 3.

Guideline Description	Guideline Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Table 3: "Design-Science Research Guidelines" (Hevner, et al., 2004 p. 83)

As a result, the LWC-EPI research will propose a new EMIS conceptual framework targeting SMEs as a main artifact. In addition, a complementary artifact - new environmental sustainability assessments model - will be provided, serving the social aspect of the research for a better environmental awareness within organizations. These artifacts will help SMEs to satisfy the increased requests for environmental data coming from customers, governments and NGOs. Artifacts will be supported by prototypical implementations that can be used by any SME "not industry specific," allowing it to measure and report its EPIs more frequently, and giving the option to create new EPIs with no need of extra domain expert knowledge.

Problem Relevance:

Information Systems' researches aim to provide the market with technology-based solutions that support in resolving vital business problems. Behavioral science followers believe that this can be reached by the development and justification of theories, explaining, or predicting phenomena that occur. Design science researchers approach this aim by constructing innovative artifacts that can change certain phenomena (Hevner, et al., 2004 p. 84).

Hevner et al. argue that artifacts' acceptance by the organizations can be achieved by a combination of:

- "technology-based artifacts (e.g., system conceptualizations and representations, practices, technical capabilities, interfaces, etc.),

- organization-based artifacts (e.g., structures, compensation, reporting relationships, social systems, etc.), and
- people-based artifacts (e.g., training, consensus building, etc.)" (Hevner, et al., 2004 p. 84).

As it was argued in Chapter 1, the rapidly changing environment calls for a wide change in attitudes. The lately "IT for Green" research domain, also known as Corporate Environmental Management Information Systems (EMIS) can play a major role helping the enterprises to assess the current impact of their business on the environment, and if they are following the regulations (Teuteberg, et al., 2010-I pp. xix - xxiii).

Field study, different types of surveys, and scholar publications such as (Hillary, 2004), (Teuteberg, et al., 2009), (Cooper, 2011), (Freundlieb, et al., 2009), and (Teuteberg, et al., 2010-I) showed the growing importance and needs of SMEs for such system, and that most of the existing solutions failed to serve such organizations. The LWC-EPI objective is to provide this efficient EMIS solution model, based on a new framework, to support any SME in selecting, creating, calculating, comparing, and reporting there EPIs more frequently.

Design Evaluation

"The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods." (Hevner, et al., 2004 p. 83). This means that clear metrics of each artifact should be defined, and an appropriate evaluation method should be followed, to ensure the research accuracy. Hevner et al. summarize the essential evaluation methodologies presented in the knowledge base (see Table 4).

Method	Technique
Observational	Case Study: Study artifact in depth in business environment
	Field Study: Monitor use of artifact in multiple projects
Analytical	Static Analysis: Examine structure of artifact for static qualities (e.g., complexity)
	Architecture Analysis: Study fit of artifact into technical IS architecture
	Dynamic Analysis: Study artifact in use for dynamic qualities (e.g., performance)
Experimental	Controlled Experiment: Study artifact in controlled environment for qualities (e.g., usability)
	Simulation - Execute artifact with artificial data
Testing	Functional (Black Box) Testing: Execute artifact interfaces to discover failures and identify defects
	Structural (White Box) Testing: Perform coverage testing of some metric (e.g., execution paths) in the artifact implementation
Descriptive	Informed Argument: Use information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact's utility
	Scenarios: Construct detailed scenarios around the artifact to demonstrate its utility

Table 4: "Design Evaluation Methods" (Hevner, et al., 2004 p. 86)

A systematic research approach has been followed, and the main metrics were defined as: The aim of the LWC-EPI is to enable the SMEs to provide their EPIs more *frequently* and *easily* by any end users. In addition, SMEs should be able to define, create, share, and rank any EPI. All resulting artifacts from the LWC-EPI research passed different types and steps of testing and evaluations, as it was recommended by (Hevner, et al., 2004). As is highlighted in grey in Table 4, these activities involved field study and related research review to observe the business and user requirements, and they prove the framework's acceptance and utility. In addition, mathematical analysis was employed to validate the assessment model, followed by black and white box testing of a prototypical example which has been built on top of the proposed framework. Finally, end user evaluation has been conducted.

Research Contributions

"Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies." (Hevner, et al., 2004 p. 83). The resulting artifacts should be novel, generalizable, and significant for its research domain. Hevner et.al. mentioned three possible contributions, where at least one of them must be provided by the design science research's project (Hevner, et al., 2004 p. 87):

1. *Artifacts*: in most of the cases, the research's contribution is the artifact itself, wherein it delivers considerable value to the IS community by providing a solution for an unresolved problems. For example, an artifact can be a new system development methodology, or an extension of an existing one, a new tool's design, or a prototypical implementation of a new or existing model.
2. *Foundations:* proposing a new model, paradigm, method, etc. or a vital extension of an existing foundation is a valid contribution to the design-science knowledge base. For example, a foundation can be reference models, ontologies, or design algorithms.
3. *Methodologies:* conducting an evaluation method in a creative way that provides new usable evaluation metrics can be a research contribution to the IS knowledge base. Proposing a new evaluation method of the solution usability in a specific industrial field using a set of key performance indicators is an example of such contribution.

The LWC-EPI research proposes a new framework model for EMIS solution targeting SMEs. Within this framework, a new assessment model is presented and mathematically verified. Even though the model will not provide new equation or method to calculate EPIs, it will enable SMEs to create new EPIs. In this vein, the research will contribute to the IS knowledge base by providing artifacts (prototypical implementation), an extended EMIS framework, and a new methodology to assess the organization's situation before it adopt an EMIS.

Research Rigor

"Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact." (Hevner, et al., 2004 p. 83). The LWC-EPI followed a systematic research framework that will be articulated in Chapter 4. It contains continuous justification and evaluation of the research output in order to ensure a rigorous contribution to the IS knowledge base. For example, all of the requirements and specifications were gathered from end users, IT and environmental sustainability experts, and field studies. This has been guided using surveys, questionnaires, and enhanced through direct meetings, the publications' feedback in related workshops and conferences.

Design as a Search Process

"The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment." (Hevner, et al., 2004 p. 83). The research investigates in the area of EMIS, more specifically, LWC-EPI digs into the matter of environmental sustainability reporting on the enterprise level, and the compliance and environmental management in SMEs. Based on preliminary findings collected from the field study, together with the business requirements gathered from domain experts and users, the research provides an EMIS framework targeting SMEs in order to support them follow the environmental regulations and satisfy the increasing demand of the market for environmental information about their business. Step by step, comparison of different use cases has been used to evaluate the resulting artifacts against the predefined constrains.

Communication of Research

"Design-science research must be presented effectively both to technology-oriented, as well as management-oriented audiences." (Hevner, et al., 2004 p. 83). The research concepts and artifacts have been communicated to the scientific community through a number of peer-reviewed publications in conferences' proceedings, books, and specialized journals. In addition, business use cases have been presented to satisfy the needs and are understandable from both IT-oriented and business-oriented parties. Through these two channels, different questions have been addressed, such as; present details of the proposed LWC-EPI framework and the related assessment model, the evaluation method and activities, the prerequisite knowledge needed to adopt the model in the market, and the added values of the research contribution to the knowledge base and the market.

More details about the above mentioned steps will be followed in the coming chapters of this work.

2.2.2 The Design Science Research Methodology (DSRM) - Process Model

Based on the DSR model proposed by (Hevner, et al., 2004), and some other earlier publications, Peffers et. al. proposed a Design Science Research Methodology (DSRM) for information system research that provides a clear activities' sequence on how to conduct DSR in IS (Peffers, et al., 2007). The model is composed of six activities presented in Figure 9.

- *Problem identification and motivation:* It defines a specific research problem in a certain domain, and then, it should explain its importance. This activity aims to increase the problem's comprehensibility, and promote the solution's acceptance by both researcher's and business's communities (Peffers, et al., 2007 p. 55). Research that starts from this activity - which is the case in this research - and goes through all of the other five activities is called problem-centered initiation (Peffers, et al., 2007 p. 56)
- *Define the objectives for a solution:* based on the result of the previous activity, and the domain knowledge base, the solution's aim can be defined. It is important in this step to set the research's metrics that show the advantage of the current research comparing to what exists (Peffers, et al., 2007 p. 55). As it is represented in Figure 9, research can start the DSRM process model from this activity and go through all of the

other four activities. In this case it called objective-oriented solution (Peffers, et al., 2007 p. 56).

- *Design & development:* after choosing the problem that the research will handle and defining the solution and its metrics, the third DSRM activity is to design and develop the needed artifacts. As it was mentioned in Section 2.2.1, there are a variety of artifact types such as frameworks, methods, models, etc. (Peffers, et al., 2007 p. 55).
  The design and development activity is another entry point for a research to the DSRM process model. In this case, the research is design & development-centered initiation (Peffers, et al., 2007 p. 56).
- *Demonstration:* is the phase when the resulted artifacts must be presented by running an exemplary instance or more. Use cases presentations, lab's experiments, and mash-ups are some of the demonstrations' types that are possible (Peffers, et al., 2007 p. 55). If a research started the DSRM activities at this phase, it will be a client / context initiation (Peffers, et al., 2007 p. 56).
- *Evaluation:* is the phase when the resulted artifact is tested and checked if it achieved its objectives or not. Again, as it was explained in Section 2.2.1, the evaluation has different approaches such as analytical, observational, experimental, and descriptive forms. One of the possible reactions or recommendations after the evaluation is to iterate the second or the third activity as it was mentioned in Figure 9 (Peffers, et al., 2007 p. 56).

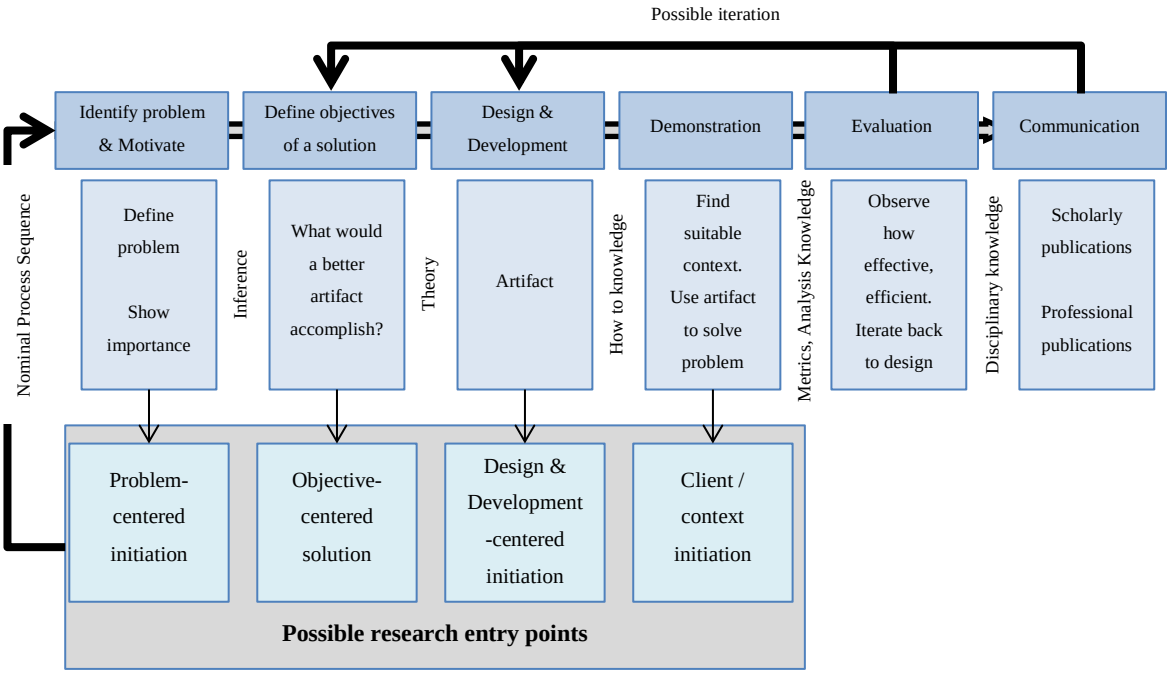


Figure 9: The DSRM (Peffers, et al., 2007 p. 54)

- *Communication:* (Hevner, et al., 2004), (Archer, 1984) cited in (Peffers, et al., 2007 p. 56), and other related publications argue that communicating the research is an important step. Researchers should communicate their results to the appropriate scientific communities through publications, conferences, and journals. In addition, the resulted artifacts should be presented to the addressed business communities.

Feedback can enrich the research, and it can lead to further iterations as it is depicted in Figure 9 (Peffers, et al., 2007 p. 56).

The LWC-EPI research followed the DSRM, and runs all of its activities. At first, and as a response to the (*Problem identification and motivation)* activity, the LWC-EPI conducted a comprehensive literature review, studied the current IT-solutions, and gathered requirements through field study as it will be explained in the next chapters. The results shaped the main research's objective to integrate the SMEs in the environmental sustainability movement. This leads to the second activity of the DSRM (*Define the objectives for a solution*). To reach its main objective, the LWC-EPI provides a new EMIS framework's solution targeting the SMEs. This framework and its components are the main artifacts of this work, and it is considered the third DSRM activity (*Design & development*). The results were (*demonstrated)* in a prototypical implementation as a proof of concept, and possible business use cases have been executed on top of it. The (*evaluation*) activity was composed of many justifications, testing, and analyzing steps that will be explained later. Last but not least, the outcome of this work has been (*communicated)* to the IS and business communities through scholarly publications in specialized journals, scientific conferences, workshops, etc. plus, direct meeting and presentations with possible end users. Figure 10 illustrates the above mentioned explanation.

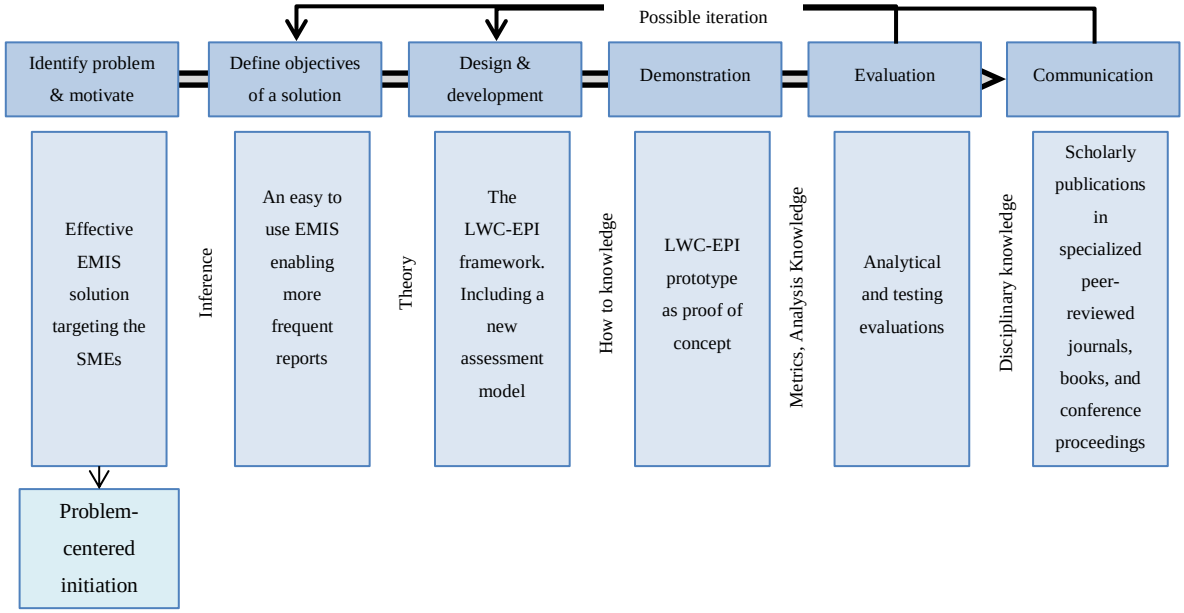


Figure 10: The LWC-EPI's DSRM Model based on (Peffers, et al., 2007 p. 54)

2.3 Summary

This chapter started with a short explanation of the literature review. The main purpose of this chapter was to explain the LWC-EPI research's method. The Design Science in Information Systems Research (DSR) (Hevner, et al., 2004) was employed to conduct a systematic research. The research framework was presented and described. Then, the seven guidelines of the DSR in IS proposed by (Hevner, et al., 2004) were detailed. Moreover, it has been clarified how each of these guidelines was followed in this thesis. The DSRM is a method that provides a process sequence model on how to conduct a DSR in IS. All concepts associated with the DSRM (Peffers, et al., 2007) have been named and explained. Likewise, it has been explained how the LWC-EPI research applied it.

3 Management Information Systems and Environmental Sustainability

Increasing profits has been one of the main goals of enterprises. “The Principles of Scientific Management” by F. Taylor was one of the earliest publications in this regard. It describes how a company could increase its profit without consuming more resources while still optimizing its workflow, an action which he called “efficiency” (Taylor, 1911 pp. 5-6). Coelli et.al. define “productivity” as the ratio between the two efficiency factors (output and consumed resources) (Coelli, et al., 2005 p. 2).

Estimation (e.g. product’s demand, increase in the raw material cost, etc.), and control are key factors that guide management teams to the appropriate actions or the needed changes in order to increase productivity and be more efficient. For this reason, computer scientists developed application systems to support enterprises by facilitating the estimation process. Nowadays, enterprises use so called Enterprise Resource Planning (ERP) systems to deal with the data and to generate information. Based on those ERPs, enterprises run special software and applications which enable them to obtain more precise estimations.

Environmental sustainability and energy efficiency are creating new challenges for today’s companies (Günther, 1998 pp. 1-2). Enterprises aim to be more eco-efficient, which is a complex task to be realized, since more indicators and factors should be taken into consideration. Those indicators could be relatively simple, e.g. energy consumptions, or more complicated, e.g. the overall contribution to climate change.

Eco-efficiency is the basic strategy in sustainability management (Möller, 2010 pp. 2-3); Schaltegger et al. introduce “sufficiency” and “consistency” as another two important terms to be used in this field. They define sufficiency as “When an individual has enough of something, then demand ceases and unnecessary use of resources is curtailed” (Schaltegger, et al., 2003 p. 25). Where they defined consistency as: “a composition of matter streams and energy forms that is able to exist permanently in an industrial ecology” (Schaltegger, et al., 2003 p. 26). Enterprises seeking better environmental sustainability should optimize their environmental performance, which could be covered by three categories: energy, resources, and eco-efficiency. These “new efficiency types situate global environmental problems and damage categories, especially human health, ecosystem quality, climate change, and scarcity of resources” (Jolliet, et al., 2003 p. 324), cited in (Möller, 2010 p. 2).

In order to measure and indicate the gap between the damage categories (e.g. climate change) and the human activities, special kinds of indicators called midpoint indicators are used by the organizations. One of the well-known midpoint indicators is “climate change”, which is referred to as global warming, and is measured by carbon dioxide equivalence (Möller, 2010 p. 2).

In this chapter, the literature review and the main related concepts and solutions will be discussed and presented. It will start with an overview on significant Environmental Management Systems (EMSs). Then, the Environmental Performance Indicators (EPIs) will be demonstrated details (concept, types, standards, classifications, etc.). The chapter will close with the EMIS state of the art, open research issues, and the most important related work.

3.1 Environmental Management Systems (EMSs) - Policies and Standards

Environmental management has become a core business issue for many organizations. With an Environmental Management System (EMS) in place, a firm establishes a framework for setting objectives and targets that allows it to evaluate its environmental compliance and performance (Welford, 1996) cited in (Tinsley, et al., 2006 p. 26). In other words, EMS support managers find a rigorous and systematic method to integrate aspects of environmental issues into the organization's decision-making process. EMSs require appropriate data, indicators, and tools so that the organization can improve its environmental programs and general performance. For example, minimizing the amount of produced waste, reducing energy consumption, and making more efficient use of resources can all lead to financial cost savings. In addition, it helps in saving and enhancing the environment (IEMA, 2009). This section focuses on the standards of EMSs as a framework; however, indicators and tools are also covered.

EMS provides the backbone for corporate environment reporting, which is quickly becoming one of the key channels for companies to communicate their environmental performance. It has become an effective tool in demonstrating company-wide integrated environmental management systems, corporate responsibility, and the implementation of industry voluntary codes of conduct (UNEP, 1994). This section reviews three environmental standards and initiatives associated with environmental management: the ISO14000 Series of International Organization for Standardization (ISO), the Eco-Management and Audit Scheme (EMAS), and the British Standard BS8555.

3.1.1 ISO14000 Series of International Organization for Standardization (ISO)

The International Standardization Organization (ISO) is a non-governmental organization (NGO) established in 1947 which carries out its operations from Geneva, Switzerland.[10] ISO has formed a Technical Committee (TC 207) aimed at developing voluntary international environmental standards (ISO, 1996). This committee's objective is to increase the worldwide acceptance and use of the ISO 14000 series of standards for an environmental management system, providing an effective means to improve the environmental performance of organizations and their products, facilitate world trade, and ultimately contribute to sustainable development (Olsthoor, et al., 2001 pp. 454-456).

Membership in ISO/TC 207 is made up of Participating members "P"; Observing members "O"; and Liaison organizations "L". The "P" members represent countries who wish to vote, participate actively in discussions, and have access to all relevant documentation. The "O" members represent countries not wishing to vote, but rather only to participate in discussions and receive all relevant information. The "L" organizations are international or broadly based regional organizations that are invited to take part in discussions and are permitted to receive all information from the TC, but are not granted voting status (ISO/IEC, 2012 p. 13). As a

[10] http://www.iso.org/iso/home/about.htm

requirement, once the organization is registered in ISO 14000 series, it should follow up environmental audits. These audits can be carried out by the organizations' own staff, and/or by external parties chosen by the organization itself to evaluate the situation in an objective manner. The ISO 14000 series consists of standards of environmental management systems. It also covers environmental auditing that can be categorized in three main levels: audits of environmental statements, environmental management audits, and compliance audits (Jamous, et al., 2013-I p. 9).

The ISO 14001 standard defines an EMS as: ''The part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes, and resources for developing, implementing, achieving, reviewing, and maintaining the environmental policy'' (ISO, 1996) revised by (Matthews, 2003 p. 99).

The ISO 14001 standard does not set absolute environmental performance requirements or specific criteria for performance. It applies only to those environmental aspects that the company can control and over which it can be expected to have an influence. Most organizations that attempt ISO 14001implementation seek external help with verification and registration. This may relate to the desire to legitimize the environmental activities of the organization and enhance public perception of environmental performance. ISO 14001 requires that a company establishes and maintains compliance with five key requirements[11]:

- Environmental policy
- Planning
- Implementation
- Checks and Balances
- Review

There are several sub-requirements associated with the five key requirements. Examples are listed below:

- Environmental Policy:
    - Develop a statement of the organization's commitment to the environment.
- Planning:
    - Environmental Aspects and Impacts: identify environmental attributes of products, activities, and services and their effects on the environment.
    - Legal and other Requirements: identify and ensure access to the relevant laws and regulations.
    - Objectives and Targets and Environmental Management Program: set environmental goals for the organization and plan actions to achieve targets.
- Implementation:
    - Structure and Responsibility: establish roles and responsibilities within the organization.
    - Training, Awareness, and Competence: ensure that employees are aware and capable of their environmental responsibilities; if necessary, provide them with proper training.
    - Communication - Develop internal and external communication of environmental management issues.

[11] http://www.iso.org/iso/iso14000

- Checks and Balances:
    - Monitoring and Measuring: Monitor key activities and track performance, including periodic compliance evaluation.
    - Non-Conformance and Corrective Action: identify the problems and prevent recurrences.
    - Evaluation of compliance: develop procedures to periodically evaluate compliance with legal and other requirements.
- Review:
    - EMS Documentation: Maintain information about the EMS and other documents.
    - Document Control: Ensure effective usage of management procedures and documents and accessing them by a single authority.
    - Emergency Preparedness and Response: Develop procedures for preventing and responding to emergency situations.
    - Records: keep adequate records of EMS performance.
    - EMS Audit: Periodically verify if EMS is effective and able to achieve desirable targets.
    - Management Review: review the EMS.

The ISO 14000 series encourages internal and external communication, too. ISO 14001 states that an organization can communicate environmental information in a variety of ways (Epstein, et al., 1998 pp. 28-29):

- Externally, through an annual report, regulatory, and government records, industry association publications, the media, and paid advertising
- Organization of open days, the publication of telephone numbers where complaints and questions can be directed
- Internally, through bulletin board postings, internal newspapers, meetings, and electronic mail messages

Today, organizations should report the environmental performance of their products or product life cycles. ISO provides the standards ISO 14025 and ISO 14040 to which many frameworks, product life cycles, and reporting standards refer. The Greenhouse Gas Protocol (GHG Protocol) is one example. In addition, many other standards are available on Environmental Product Declarations (EPD). They provide quantified environmental data using predetermined parameters and additional environmental information where it is appropriate (Santos, 2014 p. 90). Those parameters have been agreed upon and verified by an independent third party, which is typically industry associated and is defined by so-called "Product Category Rules" (PCRs). A PCR is a set of specific rules, requirements, and guidelines for developing Type III environmental declarations for one or more product categories to provide comparable EPIs. It consists of the following definitions (Jamous, et al., 2010-II p. 16):

- Functional unit
- System boundaries
- Inputs/Outputs to be considered
- Data collection process
- Data sources

- Data quality
- Data units
- Calculation methods
- Allocation methods
- Environmental impact categories to be reported

Based on this PCR, the EPD Type III is conducted. The Type III declaration also requires data based on Lifecycle Assessments according to ISO 14040. The LCA data and the EPD itself shall be certified and verified by an independent third party. Therefore EPIs reported and data used shall include a characterization according to the PCR definitions above (Jamous, et al., 2010-II p. 16).

3.1.2 The Eco-Management and Audit Scheme (EMAS)

As described on the website of the Institute of Environmental Management and Assessment (IEMA),[12] EMAS is a voluntary initiative designed to improve companies' environmental performance. The main objective of EMAS is to promote and reward those organizations making continuous improvements in environmental performance by systematic, objective, and periodic evaluation of organization performance. It was initially established by European Regulation 1836/93, which has been replaced by Council Regulation 761/01 (IEMA, 2009).
EMAS is used as a guide for organizations to produce public environmental statement reports, by establishing an environmental management system and reporting publicly on their performance (Hillary, 1995 p. 35). In order to complete those reports, information on organizations' behavior and their environmental contributions has to be provided. Discussions among the public, the interested parties, and the active organizations' employees are also recommended.

Sustainability reports usually contain environmental information reviewed and checked independently by environmental experts as verifiers. In this way, EMAS ensures accuracy and reliability that give participating organizations credibility and recognition. Released in June 1993, EMAS has been adopted by many European countries, and it is available worldwide (Hillary, 1995 p. 38). Today, the scheme is globally applicable and open to all types of private and public organizations. EMAS III is the most recent revision. The EU parliament adopted it on the December 22nd, 2009 as a new regulation, and it went into effect on January 11th, 2010 (EMAS, 2012). It contains 21 articles and 5 annexes that cover a range of issues such as:

- Objectives
- Environmental statements
- Accreditation and supervision of accredited environmental verifiers
- List of accredited environmental verifiers
- Registration of sites

Companies participating in EMAS register with the national body titled for that purpose. The registration critera require an initial environmental review of the company's sites and the established environmental protection system that covers all sites' activities. Companies have to prepare an environmental statement validated by authorized environmental auditors, and

[12] http://ems.iema.net/emas/regulation

carry out environmental audits at least every three years and publish the results as a report covering all its business's activities. The annex of EMAS includes a number of criteria that can be applied to measure the environmental protection system; these criteria can be retrieved from the EMAS official website.[13] Furthermore, under EMAS, companies should have an environmental policy, and to have quantifiable targets for the continuous improvement of performance. "Fundamental to EMAS is the public environmental statement and its validation by accredited environmental verifiers" (Hillary, 1995 p. 37). In brief, the EMAS objective is to encourage continuous environmental performance improvements. This could be specified by three main acts:

- Establish and implement environmental policies, programs, and management systems.
- Periodically, systematically, and objectively evaluate the performance of site's elements.
- Provide environmental performance information to the public, e.g. environmental sustainability report.

As in most of the EMSs, voluntary participation is one of the main drawbacks of an EMAS, followed by unspecified performance standards and the absence of a standardized report to be issued. Also, an EMAS does not address disclosure issues, such as the problems of the quality of environmental information and environmental indicators (Ntoskas, 2006 p. 13). EMAS has many approaches and tools, so as to highlight the EMAS' advantages and drawbacks in detail; analyses of each approach and tool are required. For example, one of EMAS's weaknesses is that it focuses on the production (or other core) activities of firms and there is little attention paid to the environmental aspects of subsidiary activities such as procurement, logistics etc. that can amount to significant impacts (Jamous, et al., 2013-I p. 7). Furthermore, it is difficult to assess service providing SMEs (EMAS-Easy, 2006).

In general, EMAS is a demanding system requiring both internal and external auditing for environmental issues and publishing the results of these audits (Honkasalo, 1998) cited in (Ntoskas, 2006 p. 13). As a result, many companies, especially the SMEs are afraid of the effort, time, and costs associated with the EMAS implementation and the required auditing activity.

3.1.3 The British Standard (BS 8555)

The full name is: Guide to the phased implementation of an environmental management system including the use of environmental performance evaluation.[14] It is a guideline published in April 2003 by the British Standard Institute "BSI", based on the Acorn Trust's supply chain project findings.[15] Its objective is to provide guidance to all type of organizations, especially SMEs, to achieve externally certified environmental management systems using a phase-in rather than all-or-nothing approach to implementation (ENDS340, 2003) cited in (Chen, 2004 p. 18). The BS 8555 links the EMS ISO 14001 and Environmental Performance Evaluation ISO 14031, focusing on training, auditing, and implementation at

[13] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009R1221:EN:NOT

[14] http://ems.iema.net/acorn_scheme/bs8555

[15] http://ems.iema.net/acorn_scheme

each level and supporting relationships between suppliers and customers (IEMA, 2009). The environmental performance focus of BS 8555 is valuable within the supply chain and concentrates on (IEMA, 2009):

- Delivery of measurable benefits for participants
- Delivery of performance data for internal/external reporting
- Maximum credibility and competitive advantage

The phase-in EMS implementation approach used by BS 8555 breaks down the process of implementing a formal EMS into six phases. The first five phases are focused on the installation process itself, and the sixth allows organizations to develop systems while seeking recognition from an internationally accepted EMS standard e.g. ISO 14001, or registering under the European EMAS regulation. This process is designed around a generic EMS, but it is also in line with ISO 14001 and EMAS. In addition, the standard guides the development of EPIs to reflect the environmental aspects of activities, products, or services. These EPIs can be used within the context of an EMS and as part of the performance evaluation and reporting frameworks. The six phases of the standard are (BS-8555, 2003), (Chen, 2004 pp. 19-20) :

1. Establishing and committing to the baseline
2. Identifying and ensuring compliance with legal and other requirements
3. Developing objectives, targets, and programs
4. Implementing and operating the environmental management system
5. Checking, audit, and review
6. EMAs acknowledgement

For some organizations, particularly micro-companies, a full EMS may not be appropriate. In this situation, organizations can choose to stay at a specific phase and not transition to a full formal EMS or ISO 14001certification. The company would still need periodical auditing to ensure that it is continuing to meet the requirements of the relevant phase, and is able to demonstrate continual improvement on its environmental performance (Ntoskas, 2006 p. 10). However, as Dixon et al. points out, BS 8555 is more an internal management system without external reporting requirements, even though it gives a foundation for compliance with the EMAS. BS 8555 describes audits as assessments of the effectiveness of the environmental management system as well as the achievement of environmental objectives (Dixona, et al., 2005) cited in (Ntoskas, 2006 p. 10).

The BS 8555, as with EMSs in general, does not establish specific requirements for environmental performance; it just necessitates companies to apply some legislation with a commitment to continuous improvement. Thus, BS8555 failed to form a standard way for companies to carry out their activities that can facilitate comparability. In addition, it is hard to identify a specific EPI's methodology that is able to support companies' internal and external disclosure (Ntoskas, 2006 p. 10). The following section will discuss the EPIs types, classifications, and their reporting schemas in detail.

3.2 Environmental Performance Indicators

Indicators can be defined as quantitative or qualitative variables that provide simple and reliable means to measure achievement, monitor performance, or reflect changes (UNAIDS, 2008). Decision makers use these indicators to support managing complex issues, trying to

represent these issues by simple units of measures condensed information for decision-making (Jamous, et al., 2010-I p. 225).

The natural environment is a typical example of such complex issue that necessitates appropriate indicators. The precise nature of the information required for decision-making varies with the type of decision to be made, the context of decision-making and the stakeholders involved. For example, a simple patch that indicates whether this product is "green" or not can satisfy the need of the regular consumer, but not an expert consultant that needs to guide specific strategies. Table 5 gives examples of various functions that environmental indicators may have in different contexts (Olsthoor, et al., 2001 p. 454).

User/decision context	**Function for the user**
Corporate manager	• To monitor a firm's "environmental" development in relation to strategic targets (derived from concern about future impacts of environmental developments) • To identify the most harmful wastes and emissions • To communicate corporate environmental performance/attitude to stakeholders (shareholders, environmental authorities, and clients) • Reference performance in preceding periods/years
Production plant manager	• To identify opportunities for improvements of efficiency • To convey information on the efforts to limit environmental impact of plant operations
Market manager	• To identify new market opportunities • To defend market positions; reference point competitors
Purchasing manager	• Accountability; business-to-business relations
Environmental authorities (compliance situation)	• To test compliance of firm with permits
Authorities (national)	• In voluntary agreements; communicating a firm's effort to environmental improvement. • Useful for constructing databases that are helpful in developing and implementing a government's environmental policy
Investors and shareholders	• Indicator for financial performance • May indicate environmental liabilities that could affect a firm's financial performance
Consumers	• To meet needs of green consumer

Table 5: "Different users and functions of environmental indicators inside and outside the firm" (Olsthoor, et al., 2001 p. 454)

The choice and use of environmental indicators by an organization depends on its type, business domain, size, proximity to environmentally sensitive consumer markets, the time horizon involved, type and degree of external environmental regulation, and the corporate culture of the organization (MEPI, 2001). The definition of an "*environmental indicator*" is frequently ambiguous, and it should be noted that the main reason for standardization of data is the need to make (a better) sense of environmental information. For example, a report statement saying: 20,000 kW of electricity has been used in specific period of time. This does not have a concrete meaning without giving more information (Metadata) such as how, why, and where this electricity has been used (Jamous, et al., 2010-I p. 225). In any case, providing standardized environmental information as indicators supports the organization in fulfilling its

environmental plan. Since different stakeholders with different decision-making paradigms are usually involved is such a plan, different standardization schemes are required to make the environmental information more suitable for the decisions making process (Olsthoor, et al., 2001 p. 454). In general, each indicator should have three main characteristics, (Skillius, et al., 1998 pp. 21-22):

- *Relevancy*: any indicator should be relevant to its purpose of use. To reach this, the reporter should specify beforehand what should be measured, where it will be used, and when.
- *Measurability*: measurability is still an unsolved practical problem that lies on the border between technology and management. Theories often measure what is not measurable in practice. Nowadays, monitoring systems (if they are even available for the desired application) are expensive. A common example is indicators for CO2 emission resulting from the ground transport of an enterprise. In most of the cases, a company, especially an SME, has one vehicle "van, car, etc." that serves a number of different activities. It thus becomes difficult to construct an indicator for CO2 emission on a business process level.
- *Comparability*: comparability is a central issue for any enterprise investing in extracting an indicator using an IT solution or human resources. (Skillius, et al., 1998 p. 22) argue that comparability has the following levels:
    - With an earlier time period
    - With other sites in the same enterprise
    - With other enterprises in the same business domain
    - With all other enterprises

Today, a variety of indicators are in use. For this research, the Environmental Performance Indicators (EPIs) are relevant. As (Bartolomeo, 1995) cited in (Olsthoor, et al., 2001 p. 454) claim, all EPIs have a set of common requirements; such as (Jamous, et al., 2010-I p. 25):

- Objective, so indicators could be tested independently
- Understandable for users
- Comprehensive, covers all relevant aspects
- Responsive to stakeholder expectations, and allow for meaningful comparisons at a reasonable cost
- Workable, so all required data to implement them are available in practice

The concepts of environmental indicators, environmental impacts, and physical indicators are not clear in public. Environmental impact is defined by ISO 14001 as "any change in the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products, or services" (ISO, 1996 p. Sec.3.4). Since the term "impact" has different implications and interpretations in each community, it should be clarified that in this case, the term impact describes changes in the environment.

The term *environmental pressure* is often used in discussions of indicators concerning sustainable development (Kuik, et al., 1991) cited in (Olsthoor, et al., 2001 p. 454). The definition of *environmental aspect as an element* of an organization's activities, products, or services that can interact with the environment is used in the ISO community (ISO 14001) (ISO, 1996 p. Sec.3.3). The term *stressor* is used to imply the view of the environment as a system under stress. The term *environmental intervention* is proposed in the LCA community,

and it is defined as "exchange between the anthropic sphere (the 'economy') and the environment including resource use and emissions to air, water, or soil" (Bennett, et al., 2000).

The terms "Physical" indicator and "Environmental" indicator are often confused. Therefore, it should be clearly defined in advance; for example, physical indicators are concerned with gas usage so that their unit of measurement is L/year or L/week etc. This is also unambiguous. Normally, a physical indicator is not normative; a number for gas consumption in itself is neither good nor bad. It has to be evaluated, and then it becomes an environmental indicator as well as an indicator of the evaluated impact of an activity. In contrast, an environmental indicator is concerned with the measurement and tracking of firm output to the physical environment. For example, the gas consumption is a physical indicator; thus, the sum of GHG emissions expressed in carbon equivalent is an environmental indicator.

The appropriate questions for environmental policy-making are: Is a certain change in the environment good or bad? And, how good or how bad is? Environmental indicators must be able to provide the appropriate informative support to allow such a value judgment, ideally based on explicit value systems (Olsthoor, et al., 2001 p. 455).

3.2.1 Environmental Indicators Classifications

Nowadays, enterprises, NGOs, and governments use the environmental indicators as simple measures in order to know what is happening in the environment. The environmental indicators have been defined in many ways, one of which was introduced by the United States Environmental Protection Agency (US-EPA). It defines the environmental indicator as "A measurement, statistic, or value that provides a proximate gauge or evidence of the effects of environmental management programs or of the state or condition of the environment"[16] (US-EPA, 2010). Indicators are developed based on quantitative measurements or statistics of environmental conditions that are tracked over time. Environmental indicators can be developed and used on a wide variety of geographic scales, from local to regional to national levels." (US-EPA, 2010). In order to measure the interaction between business and the environment, Environmental Performance Measurements (EPMs) are used (Bennett, et al., 2000). In this work, the term Environmental Performance Indicators (EPIs) will be used to mention the EPMs. It can be analyzed on three main levels:

- The level of individual EPIs
- The level of the overall performance measurement system
- The level of the relationship of this system with the external environment

Loew and Kottmann present in their publication "Kennzahlen im Umweltmanagement" (1996) an example of classification at an individual indicator level (Loew, et al., 1996 pp. 10-12). They classify the Environmental Performance Indicators (EPIs) according to:

- Environmental protection areas (energy, transport, emissions, waste, packaging, production, stock-keeping, and water management)

[16] http://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do;jsessionid=O0r65rzJ8GtsD8Q5ci3vsCXU9EWxAk5JJD2yW1XwbQY5JXhTNaG7!-2101461079

- System boundaries (site/company, process, or product)
- Analysis/representation:
    - Level of material and energy flows: includes flow quantities extracted from site/company, process, and product balances
    - Level of pollutants: represents the basis of energy and material flows
    - Level of cost: material and energy flow level provides this data if the flow causes costs, therefore we can derive the cost level's EPIs
    - Level of effect: Effects of material and energy flow on the environment should be represented in an aggregated way. Overlapping classifications are the main problem which rarely can be avoided, such as in Life-Cycle Analysis (LCA) impact categories (global warming, acidification, ozone depletion, etc.).

In their research report, "Environment under the spotlight: current practice and future trends in environment-related performance measurement for business" Bennett and James present EPIs classification example on the overall performance measurement system level (Bennett, et al., 1998) cited in (Henri, et al., 2008 pp. 167-169) and (Olsthoor, et al., 2001 p. 455). They describe three generations of environment-related performance measurement that correspond with groups of key indicators:

- First-generation indicators describe the business process, indicators of regulated emissions and wastes, and indicators for costly resources and compliance management.
- Second-generation indicators reflect energy and material usage/efficiency and significant emissions and wastes, as well as financial and implementation indicators.
- Third-generation includes relative indicators, eco-efficiency, stakeholder, environmental condition and products indicators, and the use of a balanced scorecard of these indicators.

Fiksel proposed a close related classification approach to Bennett and James approach. According to Fiksel, EPIs can be classified based on their functions (Fiksel, 1996), cited in (MEPI, 2001) and (Olsthoor, et al., 2001 p. 455). The three classes are: EPIs for performance tracking, EPIs for decision making, and EPIs for external reporting. As a comparison to the three generation approach, the research report conducted by the EC Environment and Climate Research Program "Measuring the Environmental Performance of Industry (MEPI)" concluded that "the main objective in the first generation is risk management, whereas the second generation is predominantly concerned with continuous improvement and can be related mainly to performance-tracking. The third generation has a broader set of internal and external objectives and broadly incorporates all three of Fiksel's categories" (Olsthoor, et al., 2001 p. 455). Table 6 summarizes the previous EPIs classification's examples and how they could be connected.

During the last three decades, a variety of reporting standards and initiatives have been established covering different aspects and levels aiming to fulfil the need of a variety of company stakeholders in diverse combinations. Some of well-known initiatives are:

- ISO 14031 - Environmental Performance Evaluation (ISO14031, 1996)
- The Sixth Environment Action Program of the European Community 2002-2012
- Global Reporting Initiative (GRI)

- Association of Chartered Certified Accountants (ACCA) Report on Environment-Related Performance Measurement
- Guide to Corporate Environmental Indicators by the German Federal Environmental Agency (BMU/UBA, 1997)
- Corporate Sustainability Assessment of SAM Research
- EU Eco-Management and Audit Scheme (EMAS)
- World Resources Institute (WRI) Report
- National Round Table on the Environment & the Economy (NRTEE) (NRTEE, 1997)

Levels of EPMs	Authors	PI classifications	Notes
Individual EPI	Loew and Kottmann	Level of material and energy flows	• Flow quantities • Process and product balances
		Level of polluters	• Energy and material flows
		Level of cost	• Derive the cost level's EPIs
		Level of effect	• Present the effects of material and energy flows on environment
Overall performance measurement system	Bennett and James	First generation indicators	• Risk management
		Second generation indicators	• Continuous improvement
		Third generation indicators	• Internal and external objectives • Incorporate all of Fiksel's categories
	Fiksel	EPIs for performance tracking	• Related to First generation indicators
		EPIs for decision making	
		EPIs for external reporting	
System relationship with the external environment			• Mainly useful for reporting

Table 6: Examples of EPIs classifications

Each approach focuses on a different level; for example the focus of EMAS and ISO focus is more towards internally oriented performance management, while other initiatives such as the WRI and the ACCA target the external performance measurement. Each initiative has its strengths and weaknesses. In the next section, a study on commonly used EPIs and some of the current practice in applying and reporting them will be demonstrated.

3.2.2 Environmental Performance Indicators Reporting Standards and Initiatives

This section presents a summary of the most used reporting standards and initiatives for applying and reporting EPIs. In order to demonstrate a board range of global, national, organizational, and product specific aspects, three standards and initiatives have been studied. They were selected out of a variety of reporting standards and initiatives that focus on different aspects and levels:

- The European Environmental Action Program (EAP)
- The Global Reporting Initiative (GRI)
- The Dow Jones Sustainability Index (DJSI), based on the Corporate Sustainability Assessment of SAM Research

3.2.2.1 The European Environmental Action Program (EAP)

In 1972 in Stockholm, Sweden, the United Nations held its first conference concerning the environment. After this conference, the European Community started a series of Environmental Action Programs (EAP). Over the last four decades, the European Commission (EC) has announced six EAPs that will be briefly demonstrated hereafter.[17] Recently, the 7th EAP "Environment Action Program to 2020" has been announced and entered into force in January 2014,[18] but it is not included in this work.

The ***1st EAP*** covered the period 1973-1975 and started the discussion of how the community could protect the environment. As it was presented in the EU Environmental Policy Handbook, the most important objectives were (Hey, 2005 p. 18):

- The prevention, reduction, and containment of environmental damage
- The conservation of an ecological equilibrium
- The rational use of natural resource

The ***2nd EAP*** was announced to cover the period 1977 - 1981. It was a continuous step of the ***1st EAP*** for the most part, but it gives more importance to the protection of nature. Subsequently, the ***3rd EAP*** (1982-1986) was announced with significant changes on the policy level. From its name "Towards the Internal Market", it has proposed a new policy approach towards the completion of the Internal Market more than the previous ones (Hey, 2005 p. 19). The 3ed EAP gave special attention to:

- The relation between the internal markets and the environmental policies, emphasizing the risk and benefits of adopting such police or avoiding it.
- Developing and providing environmental emissions standards.
- Setting new environmental laws: This step was strongly supported by some governments and political parties like the Green Party, who pushed the German government to adopt the clean-air policies requiring emission reductions from large

[17] This work has been conducted based on the EU Environmental Policy Handbook, published in Sep. 2005 by the European Environmental Bureau (EEB).

[18] http://ec.europa.eu/environment/newprg/index.htm

combustion plants and cars. Another example is the new reform of chemical policies in Scandinavian countries.

The ***4th EAP*** (1987-1992) "Towards environmental policy integration" has been considered as a defining point in EC environmental policy. It was the first time in which environmental protection received its own chapter in the agreement. As in the 3ed EAP, the environmental policies in the EU were the cornerstone of the 4th EAP, therefore it has been counted as a continuation of the 3ed EAP to some extent. In addition to covering the earlier approaches of the environmental policies such as quality policy and emissions orientation after updating it, the 4th EAP proposed a much wider view. It concentrates on harmonizing the objectives of the internal markets with environmental protection. For example, integrating environmental protection activities within the business processes of the organizations was a notable shift. In addition, it was the first time where sectorial analysis was presented using new instruments. According to C. Hey, four main external factors supported the new policy approach (Hey, 2005 pp. 21-22):

- The appearance of new global threats
- The United Nations Conference on Environment and Development, known as the Rio Summit or Earth Summit (Eco 92)
- The new legislation that led to wider support for economic instruments adaption
- The increased popularity of the Green parties all over Europe that directed the environmentalism wave in Europe

Based on the active movement mentioned previously, the ***5th EAP*** was formulated for the period (1992-1999) under the name "Towards Sustainability". It focused more on the global level than its predecessors. With regards to The 5th EAP, sustainability has four characteristics:

- "To maintain the overall quality of life
- To maintain continuing access to natural resources
- To avoid lasting environmental damage
- To meet the needs of the present without compromising the ability of future generations to meet their own needs" (EC-Environment, 1998).

In addition, the 5th EAP proposed structural changes for the five sectors it covers (industry, energy, transport, agriculture, and tourism). To reach the required changes, a range of instruments were required, including legislation as well as scientific and financial support.

It was a comprehensive program that incorporated seven different themes, including climate change, waste management, acidification, and air quality. It focused on several types of policy instruments to improve: environmental data through scientific research and technological development; public awareness and educational level; as well as professional education and training (see A.1). The 5th EAP's philosophy states all of the necessary elements of a policy oriented towards "ecological structural change" (Hey, 2005 p. 23).

Since the late 90s, a new environmental regulation reform has begun. In 1997, the European Commission launched the Cardiff Process as a new initiative for environmental policy integration after the Amsterdam Treaty (Kraemer, 2001 p. 3). In this period, the EC started to be more focused on identifying key problems, setting the objectives and providing a road map to achieve these objectives. According to the German Advisory Council on the Environment (SRU), the EC overlooked some important key environmental issues (see:

(SRU, 2002 pp. 13-14). Nevertheless, the environmental legislation's revival touches new technical and political issues for the first time. These include new complex and holistic framework legislations (e.g. the Ambient Air Quality Directive (96/62), and the Water Framework Directive (2000/60)); new target-oriented legislations like the NEC-Directive (2001/81); the completion, revision, and modernization of existing legislative programs, such as the daughter directives on air quality (1999/30; 2000/69; 2002/3); and the three Aarhus pillars: freedom of information, participation rights, and access to justice (Directives 2003/4,2003/35 and CEC Directive proposal 2003/624) (Hey, 2005 p. 26) . After this regulation reform, the European Parliament and the Council adopted the ***6th EAP*** for the period of 2002-2012. It was named "towards a thematic strategy on the sustainable use of natural resources", and it identified four areas:

- Climate Change
- Nature and Biodiversity
- Environment and Health
- Natural resources and Waste
- Environment and the Economy
- Implementation

A notable action was The Annual Environment Policy Review (EPR) that was designed to report the progress towards the EU's key environmental goals set out in the 6th EAP. Thirty key indicators (see A.2) have been defined to cover the previous areas, and they are divided into five types according to the DPSIR framework (Kristensen, 2004 pp. 2-4):

- **D**riving Force indicator e.g. wood harvesting intensity
- **P**ressure indicator e.g. Amsterdam Treaty
- **S**tate indicator e.g. forest area change
- **I**mpact indicator e.g. energy intensity
- **R**esponse indicator e.g. managed forest area ratio

It is used to structure environmental information for State of Environment Reporting. This characterization of indicators is used to build a better understanding of the interactions within society, the economy, and the environment (see Figure 11).

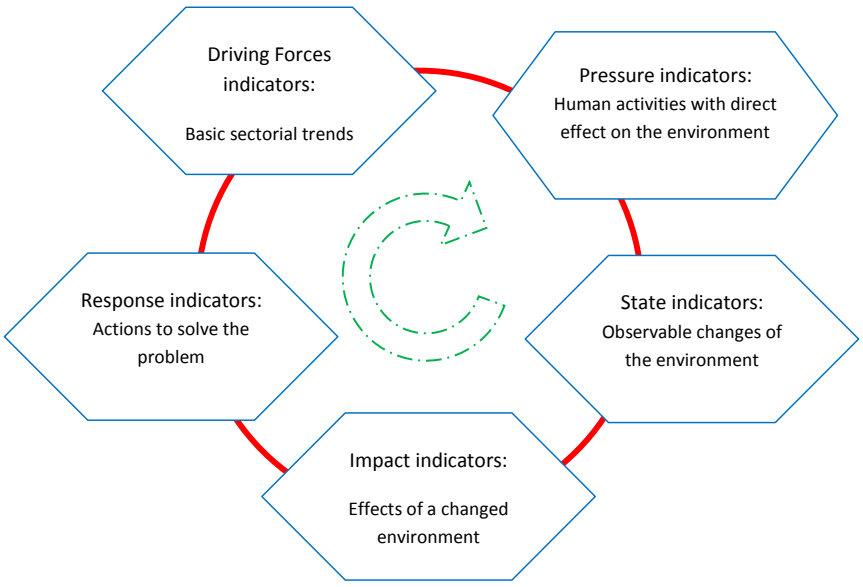


Figure 11: DPSIR Framework (Kristensen, 2004 pp. 2-3)

It aims to inform the organizations about the underlying social and economic driving forces behind the pressures, and reports what action has been taken as a response to mitigate these pressures or driving forces. This provides a secondary level of analysis mainly for use by policy-makers or decision-makers (Jamous, et al., 2010-II p. 11).

Recently, the EC announced the 7th EAP for the period 2012-2020. It has four key themes (Hey, 2010 p. S.15):

- Climate
- Biodiversity
- Resources
- Health and Quality of Life

3.2.2.2 Global Reporting Initiative (GRI)

The Global Reporting Initiative (GRI©) is a network-based organization that provides a sustainability reporting framework. The framework supervises enterprises to build their sustainability reports in six main areas: Economy; Environment; Social: Labor practices and Decent work; Human rights; Society; and Product Responsibility (GRI, 2011). In 2006, GRI released the G3 "the 3rd. Generation" guideline for sustainability reporting. This report introduced thirty indicators structured into nine categories based on its aspects. The main aspects are: Materials; Energy; Water; Biodiversity; Emissions, Effluents, and Waste; Products and Services; Compliance; and Transport as it is illustrated in Table 7.

In addition to the main indicators' classification, the GRI differentiates between core indicators and additional ones suitable for some specific type of enterprises. The indicator defines the parameter to be reported and whether it is an absolute or relative value (mostly by weight or volume produced), for more detailed information, please check (GRI, 2007).

To better understand the use of these indicators by companies, sustainability reports of nineteen companies were analyzed. At least two reports for each company were studied (before 2010 vs. 2010 reports) (see A.3). Unfortunately, some companies have deleted their older reports, and some others are not accessible (archived, deleted, or not published).

The study was conducted from March 2011 to September 2011, and a second update was made on January 2013. Thirteen large companies and six SMEs were investigated. Table 8 illustrates a short description about the studied companies.

It was noticed that many organizations began applying more indicators over time. Table 9 lists the indicators based on how many times they were used, e.g. the EN3 (Direct energy consumption by primary energy source) appeared 24 times. More details are represented in Table 9. The result of this study can inform the users (stakeholders, customers, etc.) about which indicators are most used for different business sectors. In addition, it will guide the prototypical implementation part in this thesis, and it can support any future development plan.

Aspect	Indicator	Description	Type
Materials	EN1	Materials used by weight or volume	Core
	EN2	Percentage of materials used that are recycled input materials	Core
Energy	EN3	Direct energy consumption by primary energy source	Core
	EN4	Indirect energy consumption by primary source	Core
	EN5	Energy saved due to conservation and efficiency improvements	Additional
	EN6	Initiatives to provide energy-efficient or renewable energy based products and services, and reductions in energy requirements as a result of these initiatives	Additional
	EN7	Initiatives to reduce indirect energy consumption and reductions achieved	Additional
Water	EN8	Total water withdrawal by source	Core
	EN9	Water sources significantly affected by withdrawal of water	Additional
	EN10	Percentage and total volume of water recycled and reused	Additional
Biodiversity	EN11	Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity outside of protected areas	Core
	EN12	Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity outside protected areas	Core
	EN13	Habitats protected or restored	Additional
	EN14	Strategies, current actions, and future plans for managing impacts on biodiversity	Additional
	EN15	Number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk	Additional
	EN16	Total direct and indirect greenhouse gas emissions by weight	Core

Emissions, Effluents, and Waste	EN17	Other relevant indirect greenhouse gas emissions by weight	Core
	EN18	Initiatives to reduce greenhouse gas emissions and reductions achieved	Additional
	EN19	Emissions of ozone-depleting substances by weight	Core
	EN20	NO_x, SO_x, and other significant air emissions by type and weight (Additional)	Core
	EN21	Total water discharge by quality and destination	Core
	EN22	Total weight of waste by type and disposal method	Core
	En23	Total number and volume of significant spills	Core
	EN24	Weight of transported, imported, exported, or treated waste deemed hazardous under the terms of the Basel Convention Annex I, II, III, and VIII, and percentage of transported waste shipped internationally	Additional
	EN25	Identity, size, protected status, and biodiversity value of water bodies and related habitats significantly affected by the reporting organization's discharges of water and runoff	Additional
Products and Services	EN26	Initiatives to mitigate environmental impacts of products and services, and extent of impact mitigation	Core
	EN27	Percentage of products sold and their packaging materials, reclaimed by category.	Core
Compliance	EN28	Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with environmental laws and regulations	Core
Transport	EN29	Significant environmental impacts of transporting products and other goods and materials used for the organization's operations, as well as transporting members of the workforce	Additional
Overall	EN30	Total environmental protection expenditures and investments by type	Additional

Table 7: Environmental Performance Indicators based on the GRI (GRI, 2007)

Companies' Names	Description	Studied reports	Country
ABB group	Global leader in power and automation technologies	2007 till 2010	Switzerland
Anheuser-Busch InBev.	Multinational beverage and brewing company	2009 and 2010	Belgium-Brazil
Australian Ethical Inv.	Financial Services	2008 till 2010	Australia
Baxter International Inc.	American health care company	2005 till 2010	USA
BHP Billiton	Multinational mining and petroleum company	2009 and 2010	Australia
Crown Van Gelder N.V.	Paper manufacturer, listed on Euronext Amsterdam	2009 and 2010	Netherlands
Deutsche Post DHL	Courier services company	2010	Germany
Fuji Xerox	Xerographic & document-related products & services	2009, 2010,2011	Japan
H. J. Heinz Co.	Food production	2009 and 2010	USA
Henkel AG & Co. KGaA	Global company with brands & technologies in: Laundry & Home Care, Beauty Care, and Adhesive technologies	2009 and 2010	Germany
ING Group	Global financial institution, currently offering banking, investments, life insurance, and retirement services	2009 and 2010	Netherlands
NetBalance	Sustainability and social responsibility	2010 and 2011	Australia
Nike Inc.	Footwear, apparel, equipment, and accessories.	2005 till 2009	USA
Origin energy	Energy company	2010 and 2011	Australia
Pacific hydro	Renewable energy company, producing clean power from natural resources	2009 and 2010	Australia
RecycleBank	Subsidiary of Recycle Rewards, Inc.	2004-2008	USA
Royal Dutch Shell plc.	Anglo–Dutch multinational oil and gas company	2010 and 2011	Netherlands
Volkswagen	Automobile manufacturer	2009 and 2010	Germany
Workspace Group plc.	Real estate investment	2006 and 2007	England

Table 8: List of studied organizations use the GRI

Aspect	Indicator	Description	Repetition
Emissions, Effluents, and Waste	EN16	Total direct and indirect greenhouse gas emissions by weight	**27**
Energy	EN3	Direct energy consumption by primary energy source	**25**
Emissions, Effluents, and Waste	EN22	Total weight of waste by type and disposal method	**21**
Products and Services	EN26	Initiatives to mitigate environmental impacts of products and services, and the extent of impact mitigation	**21**
Energy	EN4	Indirect energy consumption by primary source	**21**
Compliance	EN28	Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with environmental laws and regulations	**21**
Energy	EN6	Initiatives to provide energy-efficient or renewable energy based products and services and reductions in energy requirements as a result of these initiatives	**20**
Emissions, Effluents, and Waste	EN17	Other relevant indirect greenhouse gas emissions by weight	**19**
Materials	EN1	Materials used by weight or volume	**19**
Materials	EN2	Percentage of materials used that are recycled input materials	**18**
Emissions, Effluents, and Waste	EN18	Initiatives to reduce greenhouse gas emissions and reductions achieved	**18**
Energy	EN5	Energy saved due to conservation and efficiency improvements	**16**
Water	EN8	Total water withdrawal by source	**15**
Emissions, Effluents, and Waste	En23	Total number and volume of significant spills	**15**
Energy	EN7	Initiatives to reduce indirect energy consumption and reductions achieved	**14**
Transport	EN29	Significant environmental impacts of transporting products and other goods and materials used for the organization's operations, as well as transporting members of the workforce	**14**
Emissions, Effluents, and Waste	EN20	NO_x, SO_x, and other significant air emissions by type and weight (Additional)	**14**
Biodiversity	EN12	Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity outside of protected areas	**12**
Biodiversity	EN13	Habitats protected or restored	**10**
Emissions, Effluents, and Waste	EN19	Emissions of ozone-depleting substances by weight	**10**

Emissions, Effluents, and Waste	EN21	Total water discharge by quality and destination	**10**
Biodiversity	EN11	Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas	**9**
Biodiversity	EN14	Strategies, current actions, and future plans for managing impacts on biodiversity	**9**
Products and Services	EN27	Percentage of products sold and their packaging materials that are reclaimed by category	**7**
Overall	EN30	Total environmental protection expenditures and investments by type	**7**
Water	EN10	Percentage and total volume of water recycled and reused	**6**
Biodiversity	EN15	Number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk	**5**
Emissions, effluents, and waste	EN24	Weight of transported, imported, exported, or treated waste deemed hazardous under the terms of the Basel Convention Annex I, II, III, and VIII, and percentage of transported waste shipped internationally.	**4**
Water	EN9	Water sources significantly affected by withdrawal of water	**3**
Emissions, effluents, and waste	EN25	Identity, size, protected status, and biodiversity value of water bodies and related habitats significantly affected by the reporting organization's discharges of water and runoff	**2**

Table 9: List of the GRI indicators sorted based on how many times were used and appeared in the studied reports

3.2.2.3 Dow Jones Sustainability Index (DJSI)

Customers, shareholders, governments, and NGOs request ecological sustainability ratings for companies. Electronic- and paper-based questionnaires were developed to score and benchmark companies in a specific sector (Jamous, et al., 2013-I p. 10).

The Dow Jones Sustainability Index (DJSI) is a well-recognized comprehensive index used worldwide for sustainability. It was launched in 1999 as a cooperative work with Sustainable Asset Management (SAM) Research. The work was based on the Corporate Sustainability Assessment of SAM Research, whereby the SAM questionnaires were the major source of the information (DJSI, 2010) (SAM, 1999). In 2002, the DJSI reported the sustainability performance of 2,500 large companies listed on the Dow Jones (DJSI, 2002), whereas in 2013, the number of invited companies reached 3300 (RobecoSAM, 2013 p. 5)

In 2008, the DJSI introduced two blue-chip indexes as a subset of itself, the Dow Jones Sustainability World 80 (DJSI World 80) and Dow Jones Sustainability World ex US 80 (DJSI World ex US 80). In addition to the DJSI World, there were four other indexes - with subset indexes for each, distributed based on five geographical regions (DJSI, 2010):

- The European indexes: contain the Dow Jones Sustainability Europe Indexes (DJSI Europe), include a pan-European and a Eurozone index, and also include two blue chip indexes, the Dow Jones Sustainability Europe 40 index (DJSI Europe 40) and Dow Jones Sustainability Eurozone 40 Index (DJSI Eurozone 40).
- The North American indexes: contain the Dow Jones Sustainability North America Index (DJSI North America) and the Dow Jones Sustainability United States Index (DJSI United States). Plus, it has two blue chip indexes, the Dow Jones Sustainability North America 40 and the Dow Jones Sustainability United States 40 Index.
- The Asia Pacific indexes: comprise the Dow Jones Sustainability Asia Pacific Index (DJSI Asia Pacific). In addition, it contains two blue chip indexes, the Dow Jones Sustainability Asia Pacific 40 and the Dow Jones Sustainability Japan 40 Index.
- The Korea indexes: include the Dow Jones Sustainability Korea Index (DJSI Korea) and as the other indexes it introduced a blue chip index, the Dow Jones Sustainability Korea 20.

In 2013, two new indexes were introduced:

- The DJSI Emerging Markets: includes companies from Brazil, Chile, China, Colombia, the Czech Republic, Egypt, Hungary, India, Indonesia, Malaysia, Mexico, Morocco, Peru, the Philippines, Poland, Russia, South Africa, Taiwan, Thailand, and Turkey (RobecoSAM, 2013 p. 26).
- The DJSI Australia: formerly known as Australian SAM Sustainability Index. It contains Australians leading companies in sustainability. In 2013, 200 companies were listed from 43 Industries (RobecoSAM-AG, 2013 p. 6)

To understand better how the ranking system works, an example from the 2010 annual review report will be taken (please check (DJSI, 2010)).

Based on the information derived from a conducted SAM questionnaire completed by enterprises participating in the annual review of 2010, a defined set of criteria and weightings was used to assess the opportunities and risks derived from economic, environmental, and social dimensions for the eligible companies shown in Table 10. In order to calculate the corporate sustainability score for a company, SAM research uses multiple sources to gather the needed information, such as the company documents, media, stakeholders, and direct contact with the company in addition to the web based questionnaire. After collecting and analyzing the gathered data, the SAM corporate sustainability assessment applies the appropriate criteria (general or industry specific) to calculate the company's total corporate sustainability score in the SAM Sustainability Information Management System (SIMS) based on the predefined scoring and weighting structure. Based on the results, companies are ranked within their industry group and selected for the DJSI if they are among the sustainability leaders in their field.

For the LWC-EPI research, only the appropriate criteria related to the “Environment” dimension are considered. For example, “Environmental Performance” covers measurable indicators while “Environmental Reporting” contains a number of questions regarding environmental policies and needs more communication. Companies can also choose one of the predefined answers (see A.4).

Dimension	Criteria	Weighting (%)
Economic	Corporate Governance	6.0
	Risk & Crisis Management	6.0
	Codes of Conduct/Compliance/Corruption & Bribery	5.5
	Industry Specific Criteria	Depends on Industry
Environment	Environmental Performance (Eco-Efficiency)	7.0
	Environmental Reporting	3.0
	Industry Specific Criteria	Depends on Industry
Social	Human Capital Development	5.5
	Talent Attraction & Retention	5.5
	Labor Practice Indicators	5.0
	Corporate Citizenship/Philanthropy	3.0
	Social Reporting	3.0
	Industry Specific Criteria	Depends on Industry

Table 10: SAM Corporate Sustainability Assessment Criteria (DJSI, 2010)

3.2.3 Common practice in applying the standards

In order to better understand how organizations apply and use the previous standards, around 15 different sustainability reports from various enterprises and some related publications were analyzed, e.g. (Jasch, 2000), (Teuteberg, et al., 2009), (Tsoulfas, et al., 2008), and (Humphreysa, et al., 2003). This study supported the research to derive the market common practice.

Today, many **P**roduct **C**ategory **R**ule (PCR) initiatives are available. They are generated from the Global Type III Environmental Product Declarations Network (GEDnet) members such as the Norwegian EPD-program, the Japan Ecoleaf Type III Environmental labelling program, the South Korea EDP program, and the Swedish EPD-program. The OEPI team (OEPI, 2010), together with the VTT Technical Research Centre of Finland,[19] have analyzed the international EPD® system member of the GEDnet including 156 PCRs registered or under development. For these, 15 PCRs related to machinery, steel coating, and electrics were selected.[20] Based on the results of this study, the following findings were extracted.

[19] http://www.vtt.fi

[20] This study has been conducted for the OEPI project "Solution and Services Engineering for Measuring, Monitoring, and Management of Organizations' Environmental Performance Indicators". http://www.oepi-project.eu/

3.2.3.1 Sustainability Reports

As it was mentioned, sustainability reports from various enterprises have been analyzed and compared in order to derive the common practice in applying the standards (see A.3). Food and Beverage, Automotive, Clothing, Finance, Petrochemicals, Currier services and Logistics, and Electronics are some of the considered business sectors.

By analyzing the reports and the used EPIs in these reports, the study basically identified eight aspects: Emissions, Material, Energy consumption, Transportation, Water consumption, Waste, Savings per Product efficiency, and Environmental protection that are closely related to the aspect used in the GRI (please check Table 7).

Each of these aspects was represented by a number of different EPIs, e.g. more than 40 different "emission" EPIs were counted. The EPIs were reported in different dimensions that have to be considered when describing the EPI in a formalized manner:

- Units reported (e.g. metrics tons CO_2 eq., MWh, etc.)
- Type of reporting (consumption or reduction value)
- Dimension of reported value (absolute or relative value)
- Base of reported value: i.e. per organizational activity, per employee, per production volume, compared to previous years, compared to a defined baseline year

3.2.4 EPIs Structures, Goals, and Objectives

Each industry uses a variety of EPIs for different purposes. This resulted a list of thousands unstructured EPIs that were not easy to find or use. Understanding the objectives of a list of EPIs brings additional information which supports a structuring activity in accordance to their contribution to the goals, and finding criteria to evaluate the effectiveness of these indicators. Based the findings of Section 3.2, and the studies mentioned within it, it was concluded that each EPI aims to serve one of the following categories:

- **EPIs for compliance & risk management:**
    - Benchmarking and assessing performance with respect to laws, norms, codes, performance standards, and voluntary initiatives
    - Technical support for the EMS used in the organization like ISO 14.001, the EU-EMAS regulation, etc.
    - Assessing the potential risks and opportunities related to climate change
- **EPIs for reporting & controlling:**
    - Communicational tool for environmental reports
    - Demonstrating how the organization influences and is influenced by expectations about environmental development
    - Derivation and pursuit of environmental target
    - EPIs for corporate reporting
- **EPIs for comparing & improving:**
    - EPIs for product life cycle reporting and improving, e.g. GHG reduction opportunities in the supply chain of a product

  - Comparing performance within an organization and between different organizations over time
  - Highlighting optimization potentials
  - Driving product and service innovation
  - Identifying market chances and cost reduction potentials:
    - Cost savings and productivity gains
    - Improved sales
  - Feedback and communication instrument for information and motivation of the workforce
  - Increased attractiveness to the investment community
  - Attracting talents and recruiting employees
  - Gain preferred supplier status

This categorization matches a previous one demonstrated in (Jamous, et al., 2010-II p. 19). In addition, the following facts were noticed during the investigation of the environmental sustainability reports and should be considered in any new EPI creation or other environmental sustainability reports analysis:

- Each EPI represents a *direct impact* or a *lifecycle impact*:
  - A direct impact EPI has a level which belongs to this hierarchy:
    World → Industry → Organization → Facility → Product line
  - Roll-ups to upper levels of the hierarchy are allowed.
  - A lifecycle impact relates to a material in a material hierarchy.
    - This hierarchy is industry related and should be defined per industry.
- An EPI has exactly one environmental aspect – with input or output flows – that has a set of possible units:
  - Materials (kg, tons, pounds, etc.)
  - Energy (J, kWh, MWh, etc.)
  - Water (Liter, Gallon, etc.)
  - Biodiversity (area of land)
  - GHG Emissions (kg CO2-eq, tones CO2-eq, etc.)
- A direct impact can be *absolute* or *relative,* whereas a lifecycle impact can only be relative.
  - Relative EPIs need a *base unit* and the EPI value usually is expressed as an EPI unit per base unit.
  - Direct impact of relative EPIs can have any of these base unit categories:
    - Euro (€), Dollar ($), Pound (£) etc.
    - Employee
    - Square meter of facility
  - EPIs can have one of these base unit categories:
    - Functional unit: used for products that can be expressed as a whole – this should be specified in the material hierarchy, e.g. fridge, car, engine, etc.
    - Per unit mass or volume (kg, liter, etc.): used for products commonly available on a variable unit size basis, e.g. meat, beverages, steel, etc.

- Each EPI has a timeframe specifying the period when the impact was generated, e.g. year, quarter, month, day, etc.

As an example, EPI instances in Bosch® can be: [21]

- Direct impact | Organization, e.g. Bosch® | Aspect, e.g. GHG emissions | Units, e.g. Tones CO2-eq | Absolute | Timeframe, e.g. 2ed quarter 2010
- Lifecycle impact | Material, e.g. stainless steel | Aspect, e.g. energy consumption | Units, e.g. kWh | Timeframe, e.g. Feb. 2011.

All these outcomes will be used in building the LWC-EPI framework, especially its EPI's model that will be detailed in Chapter 4.

3.3 Environmental Management Information Systems

Environmental issues have become an important public policy concern throughout the world, and the preservation of environmental sustainability and energy efficiency is creating new challenges for today's companies (Günther, 1998 pp. 1-2). Business activities of all enterprises, whether they manufacture products or provide services, have an impact on the environment, and these impacts must be identified and measured. The main objective of sustainable development is the realization of the resource conserving technological progress, including the implementation of a circular flow economy integrating environmental protection into production, processing, and products (Liberatore, 1997 pp. 111-114).

The increased social awareness and the growing attention of environmental issues from societies, governments, and company stakeholders motivate the enterprises to be more eco-efficient. IT, in supporting solutions for a wide range of problems, has become an indispensable tool in recent decades. Starting in the late 1980s and early 1990s, a new Information Systems' category was founded to meet corporations' needs in complying with environmental goals and regulations (Teuteberg, et al., 2010-III p. xxi). Those systems are well-known as Environmental Management Information Systems (EMISs). Recently, some environmental IT researchers added the word "Corporate" to be (CEMIS) instead of EMIS to highlight the strategic dimension of these solutions (Teuteberg, et al., 2010-III p. xix).

EMISs support the organizations to assess, optimize, and report the current impact of their processes and operations on the environment. Its concept emerged with the discussion about the architecture of environmental systems which begun in the 80's (DEFRA, 2006 p. 14).

Computer scientists and developers provide EMISs to help enterprises be more environmentally sustainable. Some companies have developed their own EMIS to monitor their own data, albeit not comprehensively, and others have utilized third parties as environmental consultants. Nowadays, many EMISs are on the market, such as Gabi®, SimaPro®, SAP Sustainability Performance Management (SuPM®), and Umberto®. Enterprises use EMISs to support business strategies, R&D, as well as input in process design, education, and product labelling (Jamous, et al., 2010-I).

EMISs have evolved from serving limited external environmental requirements to being an important tool used on a corporate management level. Thus, some experts and scientists have started to use the term CEMIS, emphasizing the corporate aspect and character of these

[21] This is just an example, it does not depend on any internal or external document from Bosch®

systems. CEMIS as a specialized type of EMIS support the strategic, tactical, and operative management by planning, monitoring, controlling, and processing organizations' environmental issues measures (Teuteberg, et al., 2010-III p. xix).

The literature and scientific discussions use and provide many traditional definitions for the EMISs. N. Allam et.al. presented five well-used definitions in their publication (Classification of EMIS Standard Software available on the German Market) (Allam, et al., 2011 pp. 190-191):

- The definition most used in the scientific community is that provided by C.Rautenstrauch: EMIS are "organizational-technical systems for systematically obtaining, processing, and making environmental relevant information available in companies." (Rautenstrauch, 1999) cited in (Allam, et al., 2011 p. 190)
- "EMIS are a summary of all information systems which serve the corporate environmental management." (Kramer, 1996), revised by (Allam, et al., 2011 p. 190).
- "EMIS serve the IT support of corporate environment protection." (Hilty, 1997), revised by (Allam, et al., 2011 p. 191).
- EMIS "is a corporate instrument for anticipatory, […], strategic, and innovative acting, which detects environmental opportunities and risks. Such a system is not only for documentation, it is also for planning, monitoring, and controlling." (Schulz, et al., 2001) mentioned in (Allam, et al., 2011 p. 191).
- M.Gómez provided a classification definition for the EMIS inherited from the definition created by Rautenstrauch which has been previously mentioned. For Gómez, the EMIS are information systems used for external sustainability reporting (for government, or society), Eco-controlling for on-site decision making process (using performance indicators), as well as for integrating environmental preservation planning in production systems. EMIS can be input-oriented, output-oriented, or process-oriented systems. These systems aim to optimize the material and energy efficiency of the processes, and to ensure reduction or avoidance of unwanted output from environmental perspective (Gómez, 2009). Table 11 summarizes this definition.

<table>
<tr><th colspan="7">Environmental Management Information Systems</th></tr>
<tr><td colspan="2">Reporting and informing system</td><td colspan="2">Eco-controlling systems</td><td colspan="3">Systems for production-integrated environmental</td></tr>
<tr><td>Government</td><td>Society</td><td>Performance indicators systems</td><td>Eco-balancing systems</td><td>input-oriented systems</td><td>process-oriented systems</td><td>output-oriented systems</td></tr>
<tr><td colspan="3">Inter-organizational sustainability reporting</td><td colspan="4">Environmental information management</td></tr>
</table>

Table 11: EMIS manifestations as for (Gómez, 2009)

All of the previous definitions are focusing more on the operative task of the EMIS. Today, with all the developments that have been witnessed positively impacting social awareness in almost every environmental issue, companies are increasingly moving towards setting strategic environmental policies. In this regard, a holistic approach of information

management and highlighting the strategic aspect of the EMIS is still missing in the traditional definitions.

Teuteberg and Straßenburg (2009) conducted a thorough literature review on the topic of EMIS (Teuteberg, et al., 2009). This report gives an overview of the current state of the art in EMIS, as well as on-going and missing research in this field. New concepts for EMIS envision a strategic orientation for an integrative and holistic approach. Traditional EMIS tend to be isolated, operation-oriented information systems (for example, they merely serve to ensure legal compliance on the basis of KPIs, disregarding the concept of sustainability). In contrast, EMIS of the next generation (CEMIS 2.0) should follow an integrated approach in line with the concept of strategic management. In this spirit, CEMIS 2.0 is an information system that takes a comprehensive approach to (Gómez, 2010 pp. 1-2):

- material and energy efficiency
- minimization of waste and emissions
- disposal of waste
- stakeholder support
- compliance with legal requirements
- strategic environmental management

Currently, EMIS provide two groups of software systems for companies: *Compliance driven EMIS* and *eco-efficient oriented EMIS*. The compliance driven EMIS informs the enterprises whether the environmental regulations - which were either chosen freely by the decision makers' board or set as an obligation by authorities - are followed and fulfilled. On the other hand, an eco-efficiency oriented EMIS have more analytical role that investigates the matter of analyzing the environmental sustainability of the business activities and material flow in an enterprise (Teuteberg, et al., 2009 p. 2).

C. Rautenstrauch provides a morphological box for EMIS classification (Rautenstrauch, 1999 p. 19) presented in Table 12. The environment and organization, as well as the EMIS specific aspects were the two main categories used to classify the criteria and their attributes. Taking a look at the morphological box, it can be noted that EMIS form an information systems category by itself, and they could not be a part of another type of information system (e.g. Accounting or CRM Information Systems) due to its special complex features and characters. The first category (environment and organization), contain five criteria:

- Strategy: determines which type of task the enterprise should support. It is called **maintenance** in case, and it is sufficient to support tasks encouraging passive environmental management. It is called **precautionary** when it supports tasks that encourage proactive environmental management.
- Business objective: verifies the business objective of using an EMIS in an enterprise. An objective could be obtaining an Environmental Management Standards (EMS) certification e.g. ISO, EMAS, BS 8555, etc. Another objective is to support the enterprise to achieve environmental optimization or to be more eco-efficient. Tasks related to legal compliance issues are considered as part of passive environmental management "compliance with environmental legislation". In addition, reporting the environmental performance of the enterprise using specific indicators (EPIs) is an important category in the passive environmental management.

- Time frame: identifying the time frame of the decision is an important criterion that should be stated. Is it a long-term strategy? Middle-term policy? Or short-term operation?
- Function level: five organizational functions were mentioned in the morphological box: strategic function, controlling function, information function, communication function, and commercial function.
- Addressed unit: Knowing the function level allows us to address the task to the appropriate organizational units or departments. For example, tasks related to strategic functions should be addressed by management. Tasks with a controlling nature (controlling function) address the ecology department and/or production/material management, whereas the information function tasks could be distributed to a variety of units and departments within the organization. Tasks connected to communication or commercial functions basically target external bodies. A communication function's tasks address public authorities and insurance, whereas suppliers and customers are addressed by all tasks related to commercial function.

The second part of the morphological box "EMIS specific aspects" consist of seven criteria:

- Type: EMIS have many types, mainly categorized into six types:
    - The key performance indicator (KPI) based systems: provide key ratios that enable business companies to control and monitor business operations in regard to ecological aspects. Since EMIS have different targets than the "classic" Management Information Systems (MIS), different KPIs and KPIs' systems should be used. These KPIs are usually called Environmental Performance Indicators (EPIs), and so is the case in this thesis.
    - The environmental accounting systems: Organizations use these EMIS to monitor the environmental damage caused by a company as well as for the planning and controlling of environmental measures that have financial effects. The environmental accounting systems need to use special EPIs and KPIs.
    - The sustainability reporting systems: used to satisfy different parties' needs that have different interests (different information should be provided).
    - The input-oriented systems
    - The process-oriented systems
    - The output-oriented systems
- Database: Each type of EMIS uses different database/s as source/s. Databases could be operational master data, structural data, process data, data on energy flows, organizational data, etc. Plus, EMIS must deal with a variety of storing locations and types, e.g. data stored internally on the company server, data existing on the internet, data stored in a cloud, etc.
- Object: identifying the material type which an EMIS deals with as an object is always needed. Six main objects have been mentioned: material flows, waste, emission, energy, hazardous material, and facilities.
- Methods/tools: EMIS follow an array of methods and provide different functionalities and tools. Active data warehouses, model development and simulation, environmental databases, knowledge-based systems, document management, artificial intelligence

(e.g. neuro-fuzzy techniques), and meta-information are some examples stated in the morphological box.

- Application area: Generally, EMIS can be classified as reporting and information systems for external reporting or eco-controlling systems for internal operations research. Under those two dimensions, EMIS provide applications covering eight areas as it is shown in Table 12. In general, eco-controlling systems are designed to provide ecologically relevant information to company's decision makers by making the ecological effects of business operations transparent (Lang-Koetz, 2006).
- Integration level: EMIS have three main integration levels. It could be a stand-alone solution, add-on application, or fully integrated with the enterprise information system.
- System boundary: As in any system, each EMIS has a boundary which it covers. It starts from the product level all the way to the process level, department level, and enterprise or company level, and it could even reach an inter-corporate level.

According to (Teuteberg, et al., 2009 p. 3), there are nine different tools' types that can form an EMIS:

1. Reporting and information systems for external reporting
2. Eco-controlling systems for internal operations research
3. Life cycle assessment systems
4. Key performance indicator based systems
5. Sustainability reporting systems
6. Input-oriented systems
7. Output-oriented systems
8. Process-oriented systems
9. Production related EMIS

In a previous work under the European project named Solution and Services Engineering for Measuring, Monitoring, and Management of Organizations' Environmental Performance Indicators (OEPI) (OEPI, 2010), EMIS were grouped in five main categories (Jamous, et al., 2010-II p. 32):

- Sustainability Reporting Tools: such as SAP Carbon Impact, SoFi and Credit360
- Tools Related to Distribution and (Green) Logistics: e.g. In-house Solutions, myWMS LOS, and Perishable Logistics
- Tools for Waste Management and Recycling Planning: Waste Manager, Wizard, and david.net are some examples
- Tools Supporting Compliance Management and Environmental Management: e.g. SAP EHS Management, SoFi, and Inteles EMS
- Life Cycle Assessment and Material Flow Analysis Tools: e.g. Gabi, Umberto, and SimaPro

For more details about this study, please see appendix A.5 including a list of the references of the studied tools.

	Criterion	Value							
Environment & Organization	Strategy	Precautionary				Maintenance			
	Business objective	EMAS/ISO certification		Environmental optimization/ eco-efficiency		Compliance with environmental legislation		Presentation of environmental performance	
	Time frame	Long-term strategy			Medium-term policy			Short-term operation	
	Function level	Strategic function		Controlling function		Information function		Communication function	Commercial function
	Addressed unit	Company management	Ecology department	Production / material management	Other organizational departments	Public authorities	Insurances	Investors	Suppliers and customers
EMIS Specific Criteria	Type	KPI based systems		Environmental accounting Sys.		Sustainability reporting Sys.		Input-oriented Sys.	Process-oriented Sys.	Output-oriented Sys.
	Database	Material master data		Structural data		Process data		Data on energy flows	Organizational data
	Object	Material flows		Waste		Emission		Energy	Hazardous material	Facilities
	Methods/ Tools	Active data warehouses	Model development & simulation	Environmental databases		Knowledge-based systems		Document management	Artificial intelligence (e.g. neuro-fuzzy techniques)	Meta-information
	Application area	Procurement	Environmentally friendly production		Distribution/ ecologistics	Recycling planning		Waste management	Life cycle assessment	Reporting
	Integration level	Stand-alone			Add-on			Integrated	
	System boundary	Product		Process		Department		Company	Inter-corporate level

Table 12: EMIS classifications provided by (Rautenstrauch, 1999 p. 19) revised by Teuteburg & Strassenburg (Teuteberg, et al., 2009 p. 5)

3.3.1 Solutions Review

As mentioned before, the LWC-EPI system targets SMEs and will most likely be used more frequently by non-expert end-users for basic environmental sustainability reporting and basic environmental management issues. It will basically be a recommendation and a reporting tool that focuses on EPIs on the enterprise level. Therefore, tools that are grouped under these two categories were reviewed. Hereafter is a demonstration of this review.

3.3.1.1 Sustainability Reporting Tools:

"Sustainability seeks to provide the best outcomes for the human and natural environments both now and into the indefinite future" (Schroll, et al., 2006) cited in (White, 2009 p. 1). The GRI defined sustainability reporting as "the practice of measuring, disclosing, and being accountable to internal and external stakeholders for organizational performance towards the goal of sustainable development" (GRI, 2006 p. 3). Enterprises report their environmental performance as part of their sustainability report. On the market today, many tools to report environmental sustainability are available such as Enablon SD-CSR©, SAP Carbon Impact©, SoFi©, Credit360©, and STORM© (Sustainability Online Reporting Module).

Several standards for creating sustainability reports have been evolved, too. The most prominent within this realm are the GRI Sustainability Reporting Framework that has been presented in Section 3.2.2, and the Eco Management and Audit Scheme (EMAS), which includes much more than just a sustainability report as it was explained in Section 3.1. After comparing both, it can be argued that following the GRI guidelines for creating reports is sufficient for what EMAS demands. In this way, the GRI emerged as de facto standard (Jamous, et al., 2010-II p. 33). In Section 3.2.2, a detailed study was provided about the GRI and other well-known EMSs. Table 13 shows the sustainability reporting tools' specifications extracted from the EMIS classification morphological box.

Environment & Organization	Strategy	Maintenance
	Business objective	Certification/Presentation
	Time frame	Medium-term
	Function level	Information/Communication
	Addressees	Management/Public
Specific criteria	Type	KPI/Sustainability reporting/Accounting
	Database	Organizational/Material/Energy
	Environmental medium	All
	Object	Waste/Emission/Energy
	Methods/Tools	Data warehouse
	Integration level	Stand-alone
	System boundary	Company

Table 13: Placement of sustainability reporting tools according to the EMIS classification (Jamous, et al., 2010-II p. 36)

In the previous work by (Jamous, et al., 2010-II) and (Jamous, et al., 2012), a study of five specialized sustainability reporting tools was demonstrated. The tools are: SAP Carbon Impact®, Enablon SD-CSR®, SoFi®, and Credit360®:

SAP® Carbon Impact:

In the last few years, SAP has provided a sustainability map covering many needs to deal with specific environmental topics using different solutions. One of these solutions closely related to environmental sustainability reporting concerning carbon management is the SAP® Carbon Impact solution. The software has been part of the official SAP portfolio since June 2009 (SAP, 2011). It enables companies to reduce carbon-based emissions through the following methods:

- Establishing an inventory of emissions
- Comparing energy intensity across operations
- Managing a portfolio of actions

SAP Carbon Impact has been updated to monitor energy usage, waste, and emissions, as well as supply chains. Companies can benefit from SAP® Carbon Impact through analyzing and reducing their worldwide energy and GHG emissions (Jamous, et al., 2012 p. 661). One of its drawbacks is that it cannot be integrated with any other system than SAP's ERP. Another weakness is that the solution is not yet integrated in certain daily business tasks (Jamous, et al., 2010-II p. 34).

Enablon® SD-CSR:

Enablon® is a software solution provider that focuses on Sustainability Performance Management Software. It provides services in Corporate Responsibility, QEHS (Quality, Environment, and Health & Safety) Management, Risk Management, and Corporate Governance.[22] The Enablon® SD-CSR (Sustainability Reporting & Management) is one of the corporate responsibility products offered by the company. It is an integrated web-based solution software that collects, reports, and manages sustainable development.[23]

It has four main functional categories: data collection, consolidation, reporting, and management. For data collection, Enablon SD-CSR covers the following methods during this process: [24]

- Collection of quantitative and qualitative data
- Automated questionnaire production
- Personalized questionnaires tailored to individual user functions
- System interfacing
- Data validation workflow

Enablon® SD-CSR enables automated consolidation of the collected data throughout all the management levels in the company representing its organizational structure. The software allows the creation of automated or customized reports using several standards such as the GRI, and it also offers advanced analytical functions. In addition, it includes a management module that offers extra functions using processed data such as a performance dashboard,

[22] http://enablon.com/company/overview.aspx

[23] http://enablon.com/products/corporate-responsibility-ehs-management/CSR-reporting.aspx

[24] http://enablon.com/products/corporate-responsibility-ehs-management/CSR-reporting/functionalities.aspx

benchmarking, goal management, action plan, notification, and alerts (SD-CSR, 2011) cited in (Jamous, et al., 2010-II p. 34).

SoFi®:

Together with GaBi® and CPM® (Compliance Process Manager), PE International[25] provides the SoFi® software system not just as a sustainability reporting solution, but also to be a comprehensive EMS following the ISO 14001 and EMAS standards.

SoFi® consists of a centralized platform with decentralized data collectors and can be combined with the material flow and LCA functions (Jamous, et al., 2010-II p. 35). For corporate sustainability performance improvement, SoFi provide special components: carbon management, corporate carbon footprint, CSR and sustainability strategy, energy management, environmental management, sustainability reporting, sustainability supply chain, and water footprint (SoFi, 2011).

What is important for the scope of this research is the sustainability reporting functionality. It incorporates the collected data, processes it, and stores it. Using its supported interfaces to ERP systems, it enables the users to create standardized reports in compliance with the requirements of an EMS (i.e. EMAS, ISO 14064, or the GHG protocol). The data used is based on environmental, social, and economic indicators that can be defined and customized by the system administrator and stored in the SoFi system (SoFi, 2011).

Credit360®:

Unlike SoFi and Enablon SD-CSR, Credit360® follows the Software as a Service principle. It is a web-based software solution that facilitates data collection and aggregation management for corporate social responsibility like reporting and communication (Credit360, 2011). According to the Credit360 website, the software is based on five features (Credit360, 2011):

- Energy and carbon management
- Compliance
- Supply chain management
- Environment health and safety
- Corporate social responsibility

It collects information, analyses it, interprets it, and then communicates it to all stakeholders in the organization. In contrast to other systems, it allows clients to focus on specific issues such as carbon emissions, waste management, employee diversity, human rights in the company, or a combination of more than one issue. The Credit360 web application allows the importing of data into the system using customized or template HTML forms as well as CSV or Excel files, which is then stored on the provider's servers. The data used to generate special indicators based on incorporate standards. Indicator values and data can then be used to create dashboards, charts, and/or tables either directly in the browser or as a hard copy (printed report). In addition, Credit360 has some limited compliance management features.

As a result, all the tools have some common and missing features, e.g.:

- The tools provide similar reporting capabilities.
- Data needs to be imported into the system (using different approaches e.g. XML, CSV, xlsx etc.).
- The Extract, Transform, and Load (ETL) process is not always supported.

[25] http://www.pe-international.com/deutsch/index/

- Extension packages or customization is available by contacting the vendors (due to the expensive licenses, they support the customers well). For example, they provide specialized input methods using customized approaches (e.g. connecting to ERP systems).
- The integration process needs to be assisted by experts.
- The tools store company related data in a centralized place which has its disadvantages with regard to system isolation, extensibility, and data security.
- A semantic approach to support the indicator creation process – if it is exists – is missing. This hinders the standardization of those indicators.
- In some cases, gathered and processed data have some kind of structure using one of the common reporting standards like ISO 14001 or the GRI.
- The tools offer the possibility to create traditional printable document reports as well as web interfaces to access the data in real time.
- A standard for the exchange of indicator ontologies or reports does not exist.
- No tool is designed for SMEs and their special needs.

3.3.1.2 Tools Supporting Compliance Management and Environmental Management

Nowadays, organizations have to deal (voluntarily or obligatorily) with an enormous volume of environmental information flooding from their daily processes and with external actions influencing them, directly or indirectly. As a recommended solution, S. Sackmann emphasizes the companies' need for automated compliance management in his paper "Automatisierung von Compliance" (Sackmann, 2008 pp. 39-40).

This automation supports companies accomplish several regulatory requirements faster and cheaper. Especially in the environmental field that links national or international regulatory requirements with many additional voluntary standards. Plus, organizations need to keep track of indicators and information in order to retain environmental norms and certifications such as the European EMAS or one of the several ISO 14000 series' standards.

In the last year, many providers improved their EMSs to support users in compliance management. The Australian Standard™ Compliance program AS3806-2006 identifies compliance as adhering to the requirements of laws, industry, and organizational standards and codes, principles of good governance, as well as accepted community and ethical standards (SAI-Global, 2006 pp. 5-6). The AS 3806-2006 standard defines four principles for compliance (SAI-Global, 2006 p. 7):

- Commitment
- Implementation
- Monitoring and measuring
- Continual improvement

Enterprise risk management by definition is a "process, effected by an entity's board of directors, management, and other personnel, applied in a strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives" (Zoellick, et al., 2005 p. 6). Although compliance management is a component of regulatory risk management, it still effects the management of operational, financial, and even strategic risks (Zoellick, et al., 2005 p. 6). Financial institutions

continuously assess and modify their products, services, and operations to follow their business strategy that should comply with new legislations enacted in the marketplace. Under the compliance management topics, tools and documentations have been provided to assist compliance initiatives and support the companies to sustain profitability. IT developers, especially EMIS providers, address this issue by a variety of IT solutions. Intelex EMS, SAP EHS Management, and SoFi are three examples of many EMIS that support Compliance Management and Environmental Management. Even though each solution has its special features, all of these tools have common specifications that are presented in Table 14. Here after, the three above mentioned tools will be described briefly based on the previous study by (Jamous, et al., 2010-II pp. 43-45) .

Environment & Organization	Strategy	Maintenance
	Business objective	Certification/Compliance
	Time frame	Medium
	Function level	Information/Controlling
	Addressees	Public authorities/Ecology department
Specific criteria	Type	KPI
	Database	Organizational data
	Environmental medium	All
	Object	All
	Methods / tools	n/a
	Integration level	Stand-alone
	System boundary	Company

Table 14: Placement of compliance management tools according to the EMIS classification (Jamous, et al., 2010-II pp. 44-45)

SoFi®:

SoFi solution was presented in the previous sub-section as "tool for sustainability". In general, its main focus lies on supporting EMSs adoption and implementation. For example, the implemented EMS using SoFi is compliant to the ISO14001 and EMAS standards.

Intelex EMS®:

Intelex is an IT solutions provider specialized in environmental, health and safety, and quality management systems.[26] They offer more than fifty specialized management solutions, more than ten of said solutions are related to the environment,[27] e.g.

- Environmental Management System (EMS)
- Air Emissions Management

[26] http://www.intelex.com/about.aspx

[27] http://www.jazdsupplychain.com/supplytech/company/Intelex-Technologies/Environmental-Management-System-EMS.htm?supplierId=80000040&productId=11164

- Audits Management Audit Management System
- EHS Management System
- Environment Sustainability Metrics Environmental Management
- Environmental Incidents Reporting
- Safety Policy Safety Management
- Waste Management Environmental Management

An evaluation conducted in the late 2010 and presented in March 2011 by the URS Corporation[28] (Mann, 2012 pp. 21,23) evaluated five EMIS vendors. Regarding the Intelex, it concluded that it is based on Microsoft technology, supports Microsoft SQL Server in multiple versions. Even though Intelex offers many other software solutions that increase the integration possibilities, it does not provide a rich application programming interface (API) that supports data integration with other systems (Mann, 2012 p. 44). Regarding legal and compliance management Intelex follows mostly American guidelines of the Environmental Protection Agency (EPA).

SAP® Environment, Health, and Safety Management (SAP EHS Management):

The SAP EHS management systems cover the needs for environmental compliance management in the SAP Sustainability Landscape. It offers the following capabilities (Jamous, et al., 2010-II pp. 43-44):

- Tracking, measurement, and monitoring of emissions and pollutant discharges by processes
- Implementation of compliance processes into workflows
- Management of exceptions and incidents
- Modelling of cost impact of adjusting variables
- Provision of reports
- Adoption of regulation schemes
- Integration into existing SAP solutions.
- Compliance on a product level considers the following:
    - Registration, evaluation, and authorization of chemicals (REACH) legislation
    - Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)
    - Directive on waste from electrical and electronic equipment (WEEE)
- Documentable in several systems

This solution emphasis is on the production level, while the holistic management of sustainability and environmental information inside the organization is not covered. This drawback, together with the high cost (product cost, implementations, customization, etc.) makes it an improper choice for SMEs.

Based on the above mentioned reviews it has been found that all the current tools have some common shortcomings and missing features such as:

- No tool is designed for SMEs and their special requirements (detailed requirements' analysis is provided in Section 4.2).

[28] http://www.urs.com/

- The tools are mostly aimed to be used by domain experts and not the business users who take decisions that can lead to environmental improvements (Nawrocka, et al., 2009) Cited in (Dada, 2013 p. 33).
- Today's tools provide a much higher focus on the intra-organizational aspects of EPIs, whereas most emissions are known to occur within supply chains, i.e. beyond single-company walls (Scipioni, et al., 2010), Cited in (Dada, 2013 p. 33).
- The data-related challenges such as adequate availability, transparency, format, and quality were not sufficiently addressed.
- Some tools are integrated into a larger software architecture which has to be used by the company and this will increase the cost (time and resources).
- The tools support the user in fulfilling several different compliances tasks that:
    - Concentrate on a company level to fulfil EMS standards (i.e. EU-EMAS or one of the ISO 14000 series).
    - Support reaching compliance on a production level (i.e. REACH or RoHS).
- Some tools focus more on the EU market, while others focus on the American market based on the popularity of the standards in the region.
- Data privacy is a main handicap for achieving certain compliance tasks when the ERP system does not allow assessing and accessing the desired information on a specific level.
- A semantic approach is missing, and there is no standard to support exchanging data or information between different systems. This always needs to be customized by the organizations.
- The integration process needs to be assisted by experts.

3.3.2 Open Research Issues

Many research projects have tried to create concepts for facilitating the EMIS acceptance and use by the organizations, and the integration of these systems with the used ERP systems; therefore, frameworks, models, and prototypical examples have been developed and published for this purpose. Unfortunately, these concepts have not yet found their way into practice yet (Lang, 2007 pp. 23-24). The ECO-Integral reference model by (Krcmar, et al., 2000), the works on the integration of production and recycling planning by (Rautenstrauch, 1997), and the proposed system's models for EMIS as an integrated system in business process by (Arndt, 1997) are some examples of these reference models. The holistic approach, meaning an integration of economical, ecological, and social objectives jointly into a single framework or reference model, is missing. According to Gray et al., there is currently a lack of software that integrates environmental modelling, stakeholder knowledge, and decision making investigation (Gray, et al., 2013 pp. 965, 971-972). Ahmed, et al. mentioned a number of attempts to measure and report the sustainability of businesses with various indices, frameworks, and indicators in their publication "Sustainable Business Transformation" (Ahmed, et al., 2011 p. 356). They argue that these approaches focus on external reporting of the sustainability, but failed to support the business lifecycle. Furthermore, most of the existing frameworks are only suitable for organizations that already follow sustainable business practices, and are therefore not helpful for organizations that decide to start their sustainability development (Ahmed, et al., 2011 p. 357). In general, research projects fail to

support companies in learning how to contribute to a reduction of environmental impacts caused by their business activities. Traditional EMIS have not yet taken the whole concept of sustainability into account; future EMIS - or EMIS as for Teuteberg, and Gómez - are supposed to consider the following issues (Teuteberg, et al., 2010-II p. 11):

- materials efficiency
- energy efficiency
- emission and waste reduction
- disposal
- support of all stakeholders
- fulfilment of legal regulations
- strategic environmental management

Bridging all these issues together is currently the challenge in the EMIS scientific research, and so far it is just a concept. Getting these concept systems to the market still requires intensive research work, especially in engaging the SMEs direction (Teuteberg, et al., 2010-II p. 11). The new generation of EMIS, known as EMIS 2.0, aims to reach this integration that supports the idea of a sustainable development in a company (Gómez, 2010 p. 3). As a result of surveys, interviews, and discussions with representatives from industry and local authorities conducted under the (ertemis)[29] project, a list of open issues and challenges for upcoming research and development has been presented in (Teuteberg, et al., 2010-II pp. 12-14). Some of the issues which are relevant to the LWC-EPI research are:

- A variety of international and national regulations for data collection
- The absence of calculation standard calls for a standardized specification for defining and describing (new) EPIs
- Encouraging the SMEs to start using such systems
- A long training time with a high effort investment is needed due to the limited experienced staff in the field of environmental management. This demands the automation of calculation processes and provides efficient and easy to use tools.
- High cost of software interfaces development
- The absence of the environmental responsibility in the business culture. Guidelines for environmental management and the support from the management are often missing.
- Sharing data along the supply chain often fails due to privacy issues (protection of business data), effort of coordination, lack of interest in the sustainability of business partners, missing links, missing documentation, ambiguous responsibilities, insufficient data quality, etc.
- Technical functionality:
    - Data is collected extensively, but the figures are not automatically created.
    - Reducing interface problems:
        - Heterogeneous software environment
        - Operational data
        - Supplier systems

[29] The European Research and Transfer Network for Environmental Management Information Systems (ertemis) is a network of researchers in the field of (EMIS), URL: http://www.ertemis.eu/ertemis/

        - Municipality
    - Reducing manual data collection:
        - Master data
        - Eco-indicators
- Dashboards for deriving actions in the field of environmental controlling are missing.
- Non-traceable data in reports hinder the understanding and the identification of the action needed.

Aside from these specific issues, usability, efficiency (e.g. automatic generation of environmental reports and automated creation of input / output balance), modifiability (e.g. modular design), transferability or customizability, the cost/value ratio, finding an easy integration into existing (in-house) ICT infrastructure, and providing all necessary interfaces are all issues which must be kept in mind. Another list of open issues can be found in the Table 15 by (Teuteberg, et al., 2009 p. 18). Out of this list, the LWC-EPI research tries to find solutions for selected issues that have been highlighted in gray.

Unsolved problems/open issues in EMIS research	
Technological Category	
How can material flow networks be optimized?	(Schmidt, et al., 2007)
How can service oriented architectures (SOA) help to integrate EMISs?	(Král, et al., 2005)
How can EMIS and automatic reporting be combined?	(Grünwald, et al., 2005), (Süpke, et al., 2008).
How can users give feedback to companies via web based communication systems, involve stakeholders in the processes of structuring and discuss a company's sustainable reports and public appearance?	
How can environmental metadata be enhanced?	(Bischof, et al., 2008), (Rizzoli, et al., 2007)
How can an EMIS be modularized to integrate itself into existing information systems?	(Viere, et al., 2006)
What could be the characteristics of a proactive Environmental Data Warehouse?	
Organizational Category	
What could be the characteristics of parameterizable reference models for EMIS?	
What could be the features of a risk-oriented approach to environmental management information systems research?	(Funk, et al., 2007)
How can carbon footprints be calculated on the basis of data that are received directly from suppliers and customers, which would enable all partners of a supply chain to concentrate on their operational sphere without having to conduct a complete Life Cycle Assessment?	(Funk, et al., 2008)
How will interactive, dialogue-oriented and customized internet-based corporate environmental reporting change the workflow of environmental reporting?	
How can the sustainability balanced scorecard be integrated into EMIS?	(Möller, et al., 2005)
How can an EMIS for sustainability networks function?	(Posch, 2002)
What characteristics could a reference model for the integration of ERP-, production planning, accounting and environmental management information systems have?	
Legal Category	
What are the impacts of the WEEE-directive on EMIS?	
Economical Category	
What could reference models for risk evaluation in environmental management look like?	
What is the cost-benefit balance of EMIS use?	
What is the current state of EMIS usage outside of German-speaking countries, i.e. in Europe and overseas?	(Molloy, 2007)
Psychological Category	
How do people think about the application of EMIS?	
Is agency theory useful as a theoretical underpinning for both research and practical applications in environmental management?	

Table 15: Unsolved problems/open issues in EMIS research (Teuteberg, et al., 2009 p. 18).

3.3.3 Related work

Proposing a new framework for EMIS targeting any SME is the main goal of this work. In the field of environmental sustainability and its related topics, several frameworks and reference models have been proposed in the last fifteen years. C. Rautenstrauch's publication in 1997 "Fachkonzept für ein integriertes Produktions-, Recyclingplanungs- und Steuerungssystem (PRPS-System)" (Rautenstrauch, 1997) was one of the earliest publications where a reference model in the field of sustainability and ecology was proposed. Table 16 lists some of the proposed frameworks and models in this field, sorted based on the year of publication. The listed models – except the SCOR model – are theoretical models in the research phase; they need to be implemented by companies in order to become widely accepted as reference models in the market. Although there is a real need, none of the models were designed specifically for SMEs to cover their special needs that were briefly mentioned before, and that will be detailed in the next chapter. For the most part, they focus on the product lifecycle or the business process, whereas the organizational structure aspect is missing, except in the model proposed by Freundlieb & Teuteberg (Freundlieb, et al., 2009 p. 132) where it can be argued that it is the closest framework to the LWC-EPI framework. Despite this, the LWC-EPI framework proposed significant changes that are important to fulfil its objective. In general, many of the listed models in Table16 vary considerably from this research.

The model of Freundlieb & Teuteberg (Freundlieb, et al., 2009 p. 132) deals with environmental compliance management, please see Figure 12. Another important source is the EMIS framework proposed by the UN Centre for Human Settlements (Habitat) (Habitat, 1995 p. 3) that proposes a guideline for organizations that intend to implement EMIS. Both are partially connected to the LWC-EPI research aim; therefore, we used these models as a base to build the new LWC-EPI framework, and many of their proposed aspects have been integrated into this research, such as the use of a multidimensional data model concept used in (Freundlieb, et al., 2009 p. 134). This data model was originally presented by Goeken & Knackstedt in 2008 as an example of compliance reporting in relation to the EU Financial market directive, called the Markets in Financial Instruments Directive (MiFID) (Goeken, et al., 2008 p. 51). Goeken & Knackstedt basically focused on the process of capturing the requirements on contextual definition, making it usable for the company's reporting system, and supporting the integration of them in their used reporting instruments (Amberg, et al., 2009 p. 145).

Publication / model name	Reference	Focus	Note
Community-based Environmental Management Information System (EMIS) Module No.4	(Habitat, 1995 p. 3)	Guidelines for assessing effecting demand of communities for Environmental infrastructure	
PRPS-System	(Rautenstrauch, 1997 pp. 61-99)	Integration of the recycling aspect into IT systems for production planning and control	
Environmental Management Information Systems (EMIS): design and implementation of a core system	(Arndt, 1997 p. 186)	An EMIS that integrate the business activity. A focus on waste and energy management	"Betriebliche Umweltinformationssysteme (BUIS): Gestaltung und Implementierung eines BUIS - Kernsystems"
ECO- Integral	(Krcmar, et al., 2000)	Reference model of an EMIS	
OPUS	(Bullinger, et al., 2000)	Development of an organization and information model as well as IT architecture for production-integrated environmental protection Integration of environmental aspects into the functional areas of construction, work scheduling, production planning, and controlling	Mentioned in (Lang, 2007 p. 23) & (Freundlieb, et al., 2009 p. 130)
Conceptual Models and Architectures for Advanced Information Systems	(Kerschberg, et al., 2000)	Focus on showing how conceptual modeling of information resources can be used to integrate information obtained from multiple data sources, including both internal and external data.	

CORE reference model for environmental information exchange network	(Beaulac, et al., 2003)	Create common business framework for sharing environmental information on an exchange network.	
Dienstorientierung im Business Engineering	(Winter, et al., 2005)	Integrating information processing A business model and process model for integrating the company aim, the organization architecture, and the application system	
SCOR 9.0 / GreenSCOR	(Supply-Chain-Council, 2008)	Reference business processes for supply chain management	
Building an Environmental Management Information System (EMIS)	(HABITAT, 2008 pp. 21, Part B)	Setting an EMIS with the focus on Geographical Information System (GIS)	
Referenzmodellgestütztes Compliance Reporting am Beispiel der EU-Finanzmarktrichtlinie MiFID	(Goeken, et al., 2008)	Reference model for compliance reporting system Relevant for financial service providers	
Towards a Reference Model of an EMIS for Compliance Management	(Freundlieb, et al., 2009 p. 132)	Reference model for a compliance management EMIS	
Sustainable Business Transformation	(Ahmed, et al., 2011 p. 360)	Proposes a multi-level sustainability business transformation (SBT) roadmap.	

Table 16: Frameworks and references models in the field of environmental sustainability and its related topics

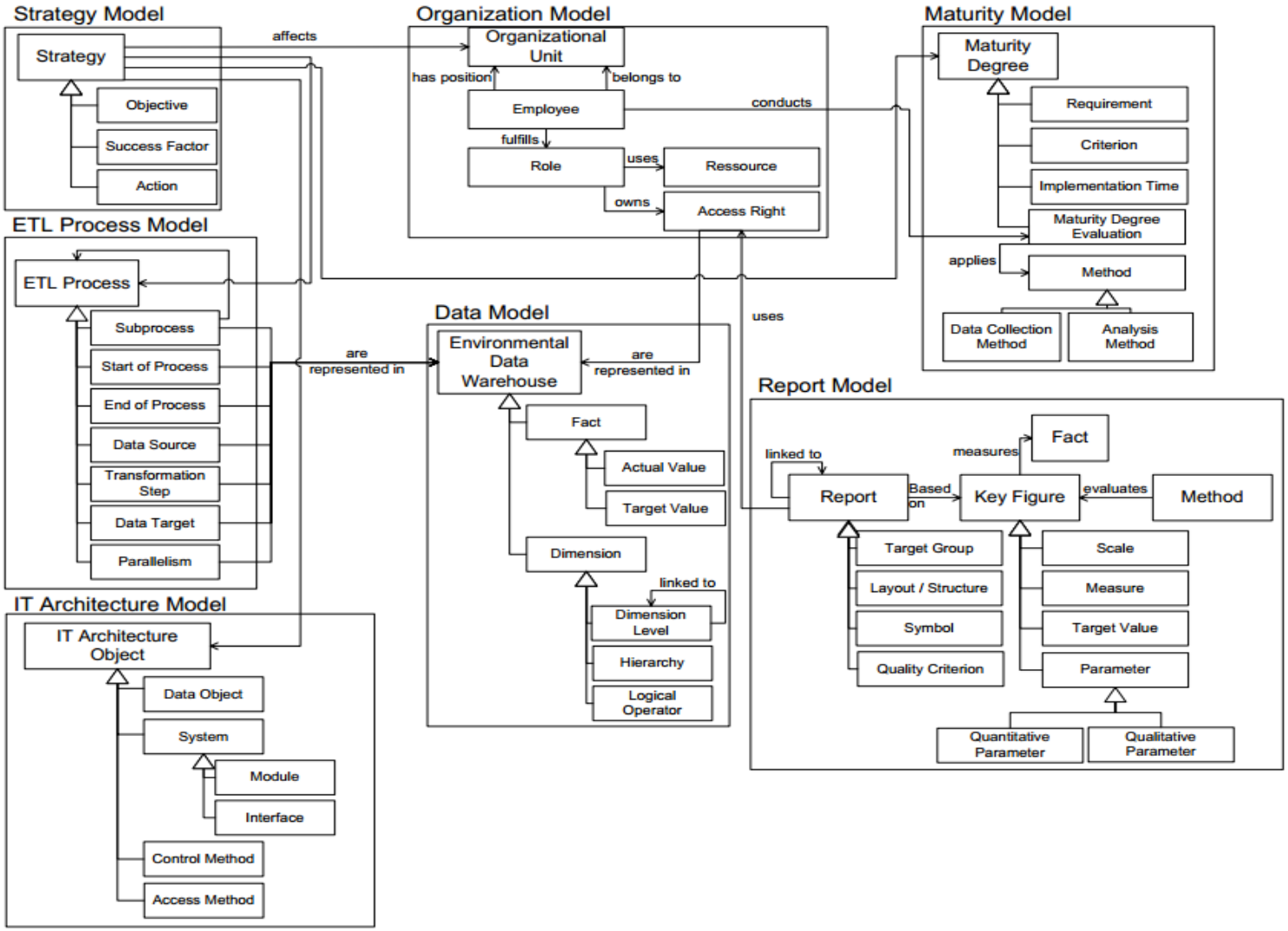


Figure 12 Meta-Reference Model of Compliance Management proposed by (Freundlieb, et al., 2009 p. 132)

In summary, several related works have already been published and discussed in the scientific communities and lobbies. Even though some of their ideas have been incorporated into this thesis, no widespread EMIS framework for environmental sustainability reporting and compliance management targeting SMEs can be found. In addition, the field of environmental sustainability offers a cluster of regulations and certifications that need to be reviewed and monitored. Therefore the LWC-EPI framework presented in this research will be an added value to the ICT Environmental Sustainability research domain, specifically to the EMIS topic, and it can facilitate and improve the acceptance of EMIS by the market's enterprises, especially the SMEs.

3.4 Summary

In this chapter, the literature review was presented in full, and there was a highlight placed on the importance for corporations to be more environmentally aware. The problem of how companies can achieve this goal was also addressed. The chapter began by introducing EMSs and then explaining three environmental standards: ISO 14000, the EMAS, and the BS 8555. These standards have all been critically examined, naming advantages and disadvantages when applying them in a company setting. In the next section, Environmental Performance Indicators (EPIs) were discussed. It has been concluded that each indicator should have at least three characteristics: relevancy, measurability, and comparability, and all EPIs have a set of common requirements. It was noted that while EPIs are often used in different organizations for different reasons, they generally fit into one of the following categories: compliance and risk management, reporting and controlling, and comparing and improving. Furthermore, certain facts that should be considered during the creation of any new EPI were listed and an example was provided.

The Chapter continues by introducing the concept of the EMIS, and clarifying the term EMIS as an EMIS's type referring to the corporate environment. EMIS were presented as good solutions for companies in helping them to become more eco efficient. Five of the most commonly accepted definitions of the EMIS were given. It was noted that the LWC-EPI - as a new EMIS - will mainly be used by non-expert end users, therefore, related recommendation and reporting tools were reviewed. In this regard, a study of five sustainability reporting tools, and environmental compliance management tools was conducted, and a summary of the study was provided. As a next step, the problems and open research issues of the EMIS were examined. It was mentioned that there is still much work to be done before such a system could be brought to the market and implemented in SMEs. In the conclusion part of this chapter, related work was examined. It was argued that several related studies have been published, although none in particular presented an EMIS framework for environmental sustainability reporting and compliance management that especially targeted SMEs.

4 Light-Weight Composite Environmental Performance Indicators

The chapter begins with a highlight on the gap to be bridged with the LWC-EPI Framework and the systematic research approach to be followed. Before providing the LWC-EPI Framework and the system's approach, a presentation of the requirements and specifications will be demonstrated.

Studies as in (Arndt, 2012), (Elliot, 2011), (Gómez, 2010), and (Melville, 2010) reinforced the role of information technology on improving environmental sustainability in terms of information, representation, organization, innovative strategies, and evaluation of systems that break new ground in environmental responsibility. Since acquiring environmental information is expensive and time consuming in most cases, the deployment of EMIS in companies is counted as a necessity in today's businesses (Jamous, 2013 p. 26). Following the review presented in Chapter 3, it has become clear that none of the reviewed models and solutions have successfully targeted the growing needs of the SMEs for such a system, even though they reflect more than 98% of Europe's enterprises, with 92.2% of them employing fewer than 10 people (Wymenga, et al., 2012 p. 15). As such, a daunting challenge is to find a cost-effective solution while taking the size and type of an organization into consideration as well as its needs and priorities. Seeking a way to help enterprises find the appropriate EPIs in addressing their most significant environmental impact, namely one which the enterprise can influence through its operations, management, and products and services depicts yet another big challenge. The main objective of the LWC-EPI is to provide an efficient EMIS framework, which can help any SMEs in selecting, creating, calculating, comparing, and reporting their environmental performance indicators (EPIs) on the enterprise level, taking the environmental, economic, and social aspects into consideration.

4.1 Systematic research development approach

The LWC-EPI aims to serve the three sustainable development aspects (economic, environmental, and societal) in any SME -not industry specific- to satisfy the increased requests of the customers, governments, and NGOs for environmental data. In this work, the proposed workflow provided by (Cheesman, et al., 2000) for component-based development process has been followed. As it is depicted in Figure 13, (Cheesman, et al., 2000) proposed six steps: requirements, specification, provisioning, assembly (or integration), test, and deployment (Filho, et al., 2004 p. 3).

Gathering the requirements and the specifications for such a system from end users (SMEs) and domain experts through field study, direct meetings, and different types of questionnaires was the first step. Then, all the requirements and the specifications have been structured to be used in developing the use cases with the guidance and usage of the OEPI ontology (Löschner, 2013) as it is shown in Figure 14. Continuous test and evaluation of the developed prototypes and use cases against the defined requirements and specifications have been applied in order to validate the proposed framework as a proof of concept. Figure 14 summarizes the developmental approach that has been followed.

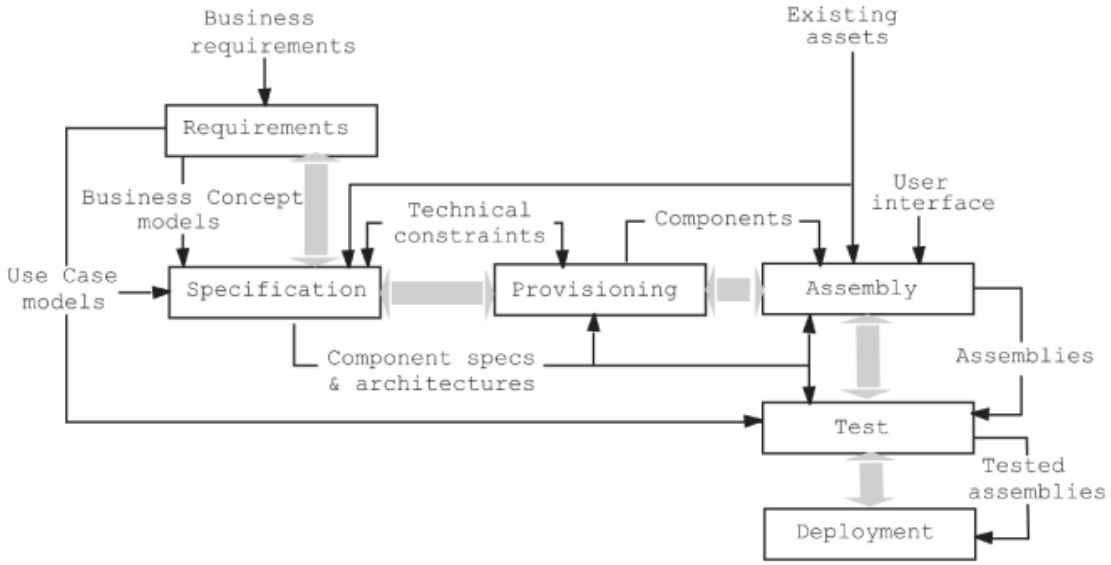


Figure 13: Workflow for a Component-based Development Process provided by (Cheesman, et al., 2000) cited in (Filho, et al., 2004 p. 3)

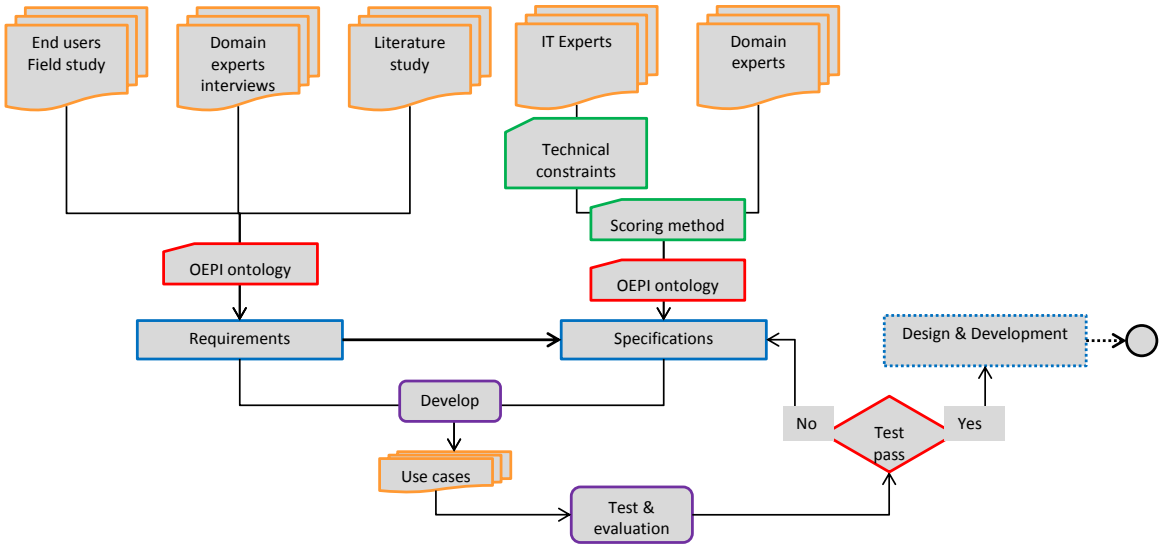


Figure 14: Systematic Approach behind the LWC-EPI

4.2 The Barriers and the requirements

There are many barriers that the SMEs face to start, follow, and adopt an EMS, and/or deploy and use an EMIS. Researchers have tried to better understand these handicaps. Field study, direct meetings, and different types of questionnaires have been conducted with end users (SMEs) and domain experts within this field. In addition, the available related publications were reviewed. All of these factors together support the research to investigate the right answers for some questions, such as: how can we assure that more SMEs will participate in protecting the environment actions? What is still missing? Who is responsible?

4.2.1 Barriers of SMEs in following EMS

Organizations follow the Environmental Management System (EMS) as the International Standard ISO 14000 series or the European Eco-Management and Audit Scheme (EMAS) to direct their actions. Those EMSs are prototype frameworks to support enterprises in setting objectives and targets, which allow them to evaluate their environmental compliance and performance and conceive a plan for improvement (González, et al., 2008 pp. 1024-1025).

The British Standard Institute defined EMS as "the organizational structure, responsibilities, practices, processes, and resources for determining and implementing environmental policy" (Zorpas, 2010 p. 1547). Even though following or adopting EMSs differs across organizations (Darnall, et al., 2008 p. 32), there are common features that are summarized as the following:

- Undergoing internal assessments of the organization's environmental impacts - including quantification of those impacts and how they have changed over time
- Quantifiable goals are created to reduce environmental impacts
- Resources provisioning
- Employee training
- Checking the implementation progress through systematic auditing to ensure that goals are being reached.
- Correcting deviations from goal attainment and undergoing management review.

"Implementing an EMS means looking at everything from the environmental impacts associated with getting you raw materials to impacts associated with ultimate disposal of the product you produce – and everything in between" (Waters, 1998 p. 2). The question to be answered is: *Is it important for an SME to follow an EMS?* EMSs allow organizations to systematically manage their environmental related issues, and they have environmental and financial added values for the organization, such as:

- Improve the environmental performance of the organization, e.g. reduce the pollution and preserve the resources. This reduces the costs, increases the efficiency, and mitigates risks.
- Improve the employees' awareness of their environmental responsibilities (Zorpas, 2010 p. 1555).

Researchers, e.g. (Ramayah, et al., 2013), (Pandaya, 2013), (Nee, et al., 2010), and (Hillary, 2004) tried to study the barriers for SMEs to adopt an EMS. R. Hillary sheds a light on this issue in her paper "Environmental management systems and the smaller enterprise," which focused on SMEs adaption of the European Eco-Management and Audit Scheme (EMAS) or the ISO 14001 (Hillary, 2004). She summarizes the drawback of implementing an EMS in SMEs based on the conducted survey, into (Hillary, 2004 pp. 564 - 565) cited in (Jamous, et al., 2013-II p. 233):

- Resources: SMEs should invest more money, time, and skills.
- The lack of rewards: Most of the SMEs do not believe that the market will reward this effort.
- Overload the SME with extra documentation and paper work instead of focusing on environmental performance.
- Problems meeting different stakeholders' demands

- Over-complicated system and complex approach

According to Hillary, barriers of SMEs adopting EMSs can be categorized into two aspects: internal and external factors, where the internal factors have more weight than external factors (Clausen, 2004 p. 50). Table 17 summarizes the most important internal and external barriers as for (Hillary, 2004 p. 566).

Internal barriers			
Resources	Understanding and Perception	Implementation	Attitudes and Company Culture
The lack of human resources rather than financial ones is the major internal barrier to EMS implementation and becomes increasingly important as the size of the company decreases.	EMS implementation is an intermittent and interruptible process in SMEs.	EMS implementation is an intermittent and interruptible process in SMEs. Practical problems with the implementation exist and include how to determine environmental aspects and assign significance and how to achieve internal auditor independence in small and micro firms.	SMEs are largely ill-informed about EMS, how they work and what benefits can be gained from their implementation.
External barriers			
Certifiers/Verifiers	Economics	Institutional Weaknesses	Support and Guidance
SMEs face inconsistencies and barriers from the certification and verification systems and complain bitterly about the high costs associated with being certified to ISO 14001 and registered to EMS.	Many SMEs experience is insufficient for EMS adoption and are uncertain about the market benefits of such systems.	Lack of promotion of EMSs and the absence of a central source of information on environmental legislation are some examples.	SMEs need support and guidance to implement EMS but experience difficulties gaining consistent quality information and experienced consultants of good quality. The lack of sector specific guidance and material tailored to different sizes of firms is an added problem.

Table 17: Internal and external barriers of SMEs adopting EMSs (Hillary, 2004 p. 566)

Examining other related works, e.g. the works by (Cooper, 2011), (Ammenberg, et al., 2003), and the previous mentioned studies ((Ramayah, et al., 2013), (Pandaya, 2013), (Nee,

et al., 2010), and (Hillary, 2004)), eight main obstacles SMEs that face in applying an EMS have been concluded as:

- **Cost (money and time)**: SMEs are enterprises run on short-term investment with small to middle budgets, and they are not willing, or even they cannot afford, to invest a huge budget to be ISO certified. In many cases, the SME's aim will be to run its business with the minimum expenses possible. Since the cost of adopting an EMS is relatively high and also time consuming, it would not be applied by SMEs unless it could be made a Bottom-Line for the companies to establish EMS. In addition, the certification process increases the overall cost of adopting an EMS, and this makes it a primary barrier.
- **Lack of training and awareness:** SMEs are weakly informed about EMS and there is a real lack of awareness of the importance and benefits caused by improved environmental performance. This issue is considered as a barrier obstructing SMEs to apply EMS. Relatively, the lack of training arises and this leads to reduction of the employees' perception towards EMS.
- **Lack of legislative assistance:** Environmental legislation is a set of rules that are made to be followed for the protection of natural environment. SMEs have a lack of the knowhow to apply the environmental legislation. In addition to the need of communicating actual laws and regulations with them, SMEs need to understand the impacts of anticipated legislation and international agreements on their activities.
- **Lack of industrial specific support for SMEs:** Environment Management Strategies are standards that are similarly set for both SMEs and large enterprises irrespective of the size of industry. This fact hinders SMEs to get special needed support required to adopt an EMS.
- **Lack of relevant information:** The problem with SMEs is that they either do not have access to environmental information, or they have access to an overwhelming flood of data that cannot be properly identified.
- **Expert's advice:** For successful adoption of EMS, qualitative advice is a key factor and could only be given by an expert in the field. SMEs face a major problem employing experts due to the economic constraints.
- **Human Resource:** SMEs have limited number of employees. Thus, providing manpower and resources specifically to deal with the EMS' adoption is not feasible. Thus, the human resource provision stands as one of the major barriers that obstruct SMEs from adopting EMS.
- **Return on investments:** Any enterprise looks forward to promotion and appreciation while implementing any new technique, as they lead to profits and growth in its sector. EMS is a sector where in the scope of appreciation from clients is very minimal, especially in the short run. As a result, the enterprise that expects recognition would not be gained in implementing EMS.

4.2.2 Barriers of SMEs in applying an EMIS

Starting in the early 80's, Information Technology (IT) started to play a major role in providing corporations/enterprises with relevant environmental related information using Environmental Management Information Systems (EMIS) (Gómez, 2004 pp. 5-7). Companies

employ EMIS for many purposes, such as assessing, optimizing, or reporting their processes and operations' impact of the environment using specific kinds of performance indicators named Environmental Performance Indicators (EPIs).

Currently, as it was determined in Section 3.3, it is still hard for SMEs to implement and use an EMIS. To investigate the barriers that the SMEs face when implementing an EMIS, some related works were analyzed, such as the papers of (Vasilenko, et al., 2012), (Jamous, et al., 2011-II), (Antoni-komar, et al., 2010), the UN Human Settlements Program (UN-HABITAT) report on building an EMIS (HABITAT, 2008), (Hillary, 2004), (Hitchens, 2003), (Morrow, et al., 2002), and others. As a result, the following obstacles that face SMEs in implementing and using an EMIS have been concluded:

- Financial barriers: Four components are required to implement and start using an EMIS: hardware, software, data, and human resources (HABITAT, 2008 pp. 28-37). First and foremost, SMEs face a shortage of money that is needed to implement the EMIS, such as the onetime investments (e.g. software cost, implementation fees, and special hardware), and the continuous cost (e.g. staff cost, and maintenance cost). The most expensive component is the staff (users), especially when the software should be used by experts.
- Time constraints: SMEs are enterprises that concentrate on daily processing activities, whereas adopting an EMIS is a mid- to long-term activity. Although it can be used directly after the installation, it does not give effective data instantly, as it needs time to collect, transform, and update the data. Another issue is the time needed for staff training, which SMEs think is not valuable. In addition, replacing and engaging staff members are costly processes for SMEs.
- SMEs lack the knowledge of evaluating the possible business benefits of EMIS in addition to its environmental added values, e.g.: publishing environmental sustainability reports would improve the company image. In other words, SMEs do not believe in the value of EMIS in the market.
- A common problem of all the organizations, including the SMEs, is the lack of demanded expertise, suitable environmental educations, professional training centers, and qualified verifiers.
- The absence of environmental legislations in many underdeveloped countries and the lack of the environmental legislations' awareness in others are other common barriers.
- From the providers' side, there is a shortage of generic Environmental Management Applications/Solutions in alignment with the nature and needs of SMEs.
- As for any new software, SMEs have anxiety form the unknown problems that can appear by applying an EMIS.
- Public reporting components in EMIS intimidate SMEs.
- In SMEs, there is weak top management support for such an idea, and the cultural attitude of the SMEs is negative toward EMIS.
- SMEs do not think about the whole process or steps involved in establishing an innovative tool such as EMIS. This lack of lifecycle thinking (Loiseau, et al., 2013 pp. 1533-1534) and (Vasilenko, et al., 2012 p. 61) hinders an efficient implementation of EMIS, which needs continuous improvements and developments processes that should not be stopped immediately after implementation.

4.2.3 Common Barriers and Requirements

Based on the findings of the Chapters 4.2.1 and 4.2.2, it can be argued that the obstacles in adapting an EMS or implementing and using an EMIS in an SME are correlated. Here are some common barriers that should be taken into consideration:

- Cost problem: In relating the cost barriers with EMS, it is mainly invested for the establishment and certification costs. In the EMIS case, money is mainly invested for installing the tools, customization, training and maintenance. As it is software that requires continuous learning, professionals with high wages should be recruited.
- Time problem: Time consumption in EMS is divided based on two factors: Implementation and Certification. Comparatively, certification requires much more time than implementation, and all together the SMEs are not in the position, nor are they willing to spend the required amount of time. EMIS mainly requires time to install the tools and upgrade them, but this is not all. It requires continuous training, updating and implementing as well. In addition, data collection and upgrading processes consume lots of time.
- Training and awareness: A common barrier that both EMS and EMIS face with similar features is lack of training and awareness. For the implementation of any new method, awareness regarding process is essential. It takes a large amount of effort in teaching the employees about the processes involved and steps to be performed in maintaining the systems.
- Lack of experts: for implementing a new system, enterprises prefer to get expert's (technical) advice, which is expensive. SMEs are not able to employ those experts even if they are available, which can be difficult.
- Human resource problem: As SMEs are sectors with a limited number of employees, either implementing EMS or EMIS allotting specific staff for maintenance and other purposes is not practical, and this is a major obstruction.

4.3 The ECET assessment model

After the literature study, two surveys were conducted between January 2012 and April 2013 (see (A.6) and (A.7)) as a complementary step. The surveys were enhanced by direct meetings with experts and companies' representatives. Besides strengthening the findings in the Section 4.2, this step supports the LWC-EPI research by mathematically confirming its findings about EMIS adoption requirements and key success factors for using it in an SME. Continuous assessment and evaluation of the developed prototype and the use cases against the defined requirements and specifications have been applied before and through the design and development phase.

The user requirements for EMIS adoption were studied and analyzed through end user examination using an exploratory approach. The outcome of the first survey was analyzed using an Exploratory Factor Analysis (EFA) (Child, 2006), and relevant variables were derived and constructed to establish a conceptual assessment model named ***The ECET Model*** (please see Section 4.3.4).

In order to evaluate the ECET model, a second analysis as a confirmatory study was conducted by applying the Partial Least Squares (PLS) method (Gefen, et al., 2000) on the

results of the second survey, which was built based on the findings of the first one. Figure 15 shows the research approach followed to derive and prove ***The ECET Model.***

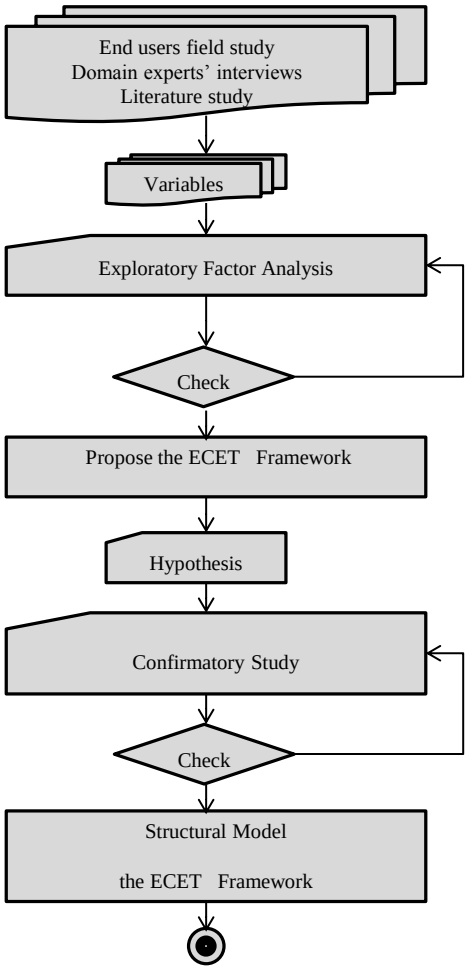


Figure 15: Research Approach to derive and prove the ECET Model

4.3.1 The Requirements - Descriptive Analysis

The first survey (A.6) was conducted between January and May 2012. It was paper-based and used a questionnaire, which was developed in alignment with the OEPI ontology (Löschner, 2013) and checked by domain experts to ensure the appropriate assessment of information for the business domain. In total, 272 valid responses coming from around 30 different countries and more than 30 different business fields were obtained, with more than 80% of these responses coming from SMEs, please see Figure 16.

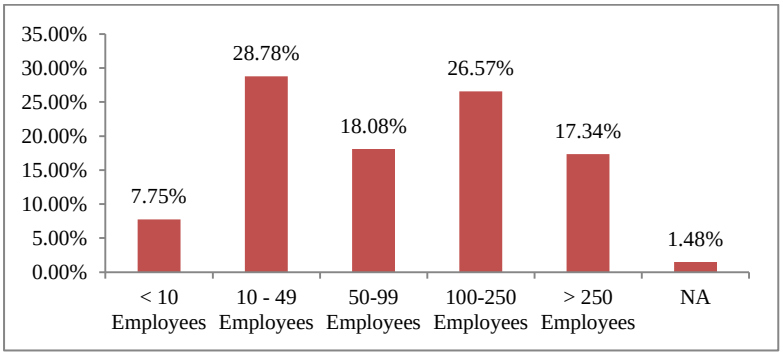


Figure 16: Distribution based on the number of employees (Jamous, et al., 2013-III)

Many requirements and facts have been extracted directly from the answers. In addition, the results were studied and analyzed through end user examination. Even though around 80% of the organizations' representatives said that they are motivated to make environmental improvements within their organizations, less than 24% said that they have a detailed awareness of the current environmental legislation within their organization.

As for reporting, less than 16% of the interviewed organizations' representatives mentioned that they are publishing or have published any kind of environmental/sustainability reports where around 66% answered "No" and around 19% said that they are planning to publish one (see Figure 17).

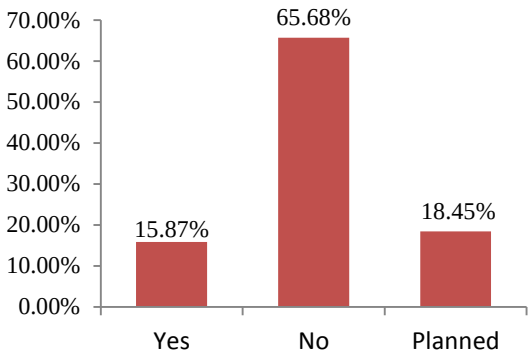


Figure 17: Publish environmental/ sustainable reports in the surveyed organizations

(Jamous, et al., 2013-III)

In connection to the previous questions, around 60% of the interviewed organizations' representatives mentioned that they do not have any EMS in their organizations (please, see Figure 18). Here we should note that most of those representatives asked for an explanation of what the EMSs are as well as what they are used for.

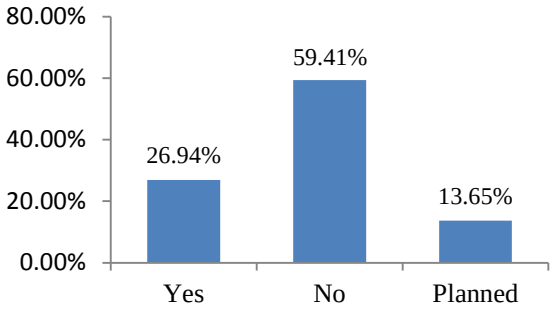


Figure 18: EMS in place

The same problem applies to many other questions, such as having an EMIS in place, using an ERP, or applying an environmental improvement program. For the latter, four environmental improvement programs were given as examples (energy efficiency, design for environment, resource efficiency, and waste reduction). More than 50% of the representatives said that they do not follow any special program, or they plan to have one, but they did not specify either the program or the date when they will start following it. In these organizations, almost 74% do not have any environmental experts working in house, and we can find an environmental unit or department in in less than 13% of the surveyed organizations (see Figure 19). This percentage decreases to almost zero if we take out the answers of the organizations with more than 250 employees.

The first part of the survey presented in the last paragraph focuses on the organizations' readiness for playing a role in preserving the environment. The gathered information highlights the necessity of bringing more ecological and social awareness within these organizations.

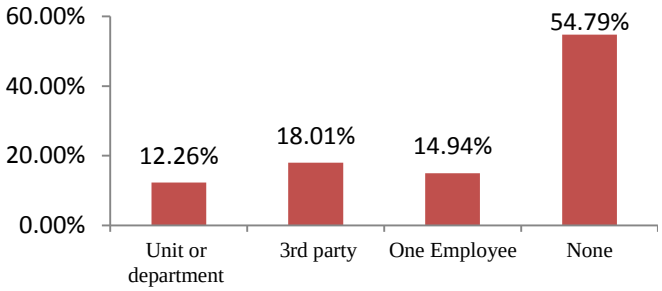


Figure 19: Environmental experts in the organization

The second part of the survey digs more into the technical infrastructure readiness. First, around 57% of the organizations are using an information system, e.g. Enterprise Resource Planning system (ERP), 9% are planning to, and around 34% do not have any plan to start using one, please see Figure 20 (Jamous, et al., 2013-III p. 949).

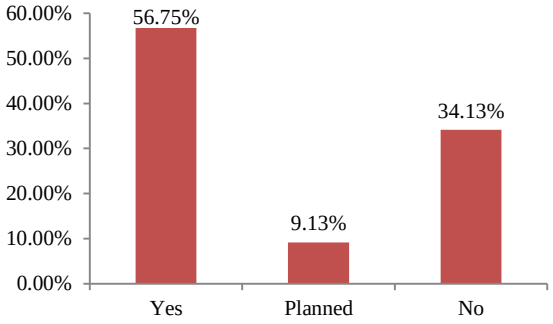


Figure 20: IS in place

To get an overview about how many organizations already have an EMIS in place or are planning to install one, we asked the organizations' representatives if they are using any kind of EMIS. As before, many representatives asked what an EMIS is, and after a brief explanation, 240 valid answers were obtained. Compared to the question regarding the IS, a remarkable increase in the "No" answer was received where it reached around 77%, and less than 10% of the representatives answered with "Yes" where the percentage of the organizations that are planning to have one had a small increase, 13.75% compared to 9.13%, see Figure 21.

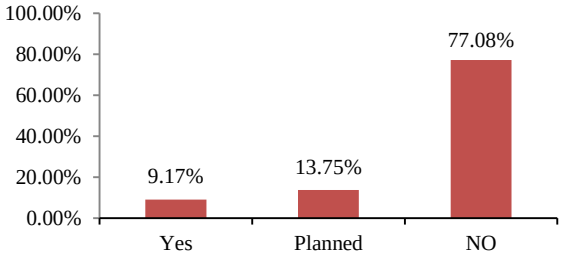


Figure 21: EMIS in place

As it has been mentioned in Section 3.2, Environmental Performance Indicators (EPIs) can be classified into three levels: EPIs on enterprise level, EPIs on product level, and EPIs on processes & activities level. Table 18 presents which EPIs are the most vital for SMEs, based

EPIs level / Importance	Enterprise	Product	Process & Activities
High	42.31%	32.42%	25.27%
Middle	20.34%	35.59%	46.85%
Law	40.54%	29.73%	29.73%

Table 19: EPIs importance (Jamous, et al., 2013-III p. 949)

on the answers gathered from 211 representatives. Around 42% said that monitoring environmental data/information on the enterprise level is the most important, whereas almost 47% think that monitoring environmental data/information on the process/activity level comes in second place. Regarding data types, representatives were asked to rank the importance of the data that the system should deal with based on three types: Static/statistical data, Dynamic data automatically updated, and Real time data. The results were close as it is shown in Table19.

Data type / Importance	Static / statistical data	Dynamic / automatically updated	Real time data
High	47.41%	40.74%	43.70%
Middle	15.22%	47.83%	20.63%
Law	39.68%	13.49%	32.54%

Table 18: Data types importance

Around 40% of the representatives who claimed that they are checking their environmental data (without specifying how or what), said that they are doing this on demand, or they prefer to (see Table 20).

On demand	Daily	Monthly	Quarterly	Semi yearly	Yearly
39.63%	12.20%	17.68%	12.80%	4.27%	15.24%

Table 20: Checking environmental data/information frequency

One of the most important questions in the survey was: How would you prefer your EMIS as an end user? Representatives had the chance to choose one or more alternatives out of eight given characteristics. Many representatives asked for a small explanation of some characteristics. Figure 22 illustrates the results of 251 valid answers gathered. EMIS as Web application, designed for any end user, and to be a lightweight solution were the top three chosen characteristics with a clear break between these three characteristics and the other options.

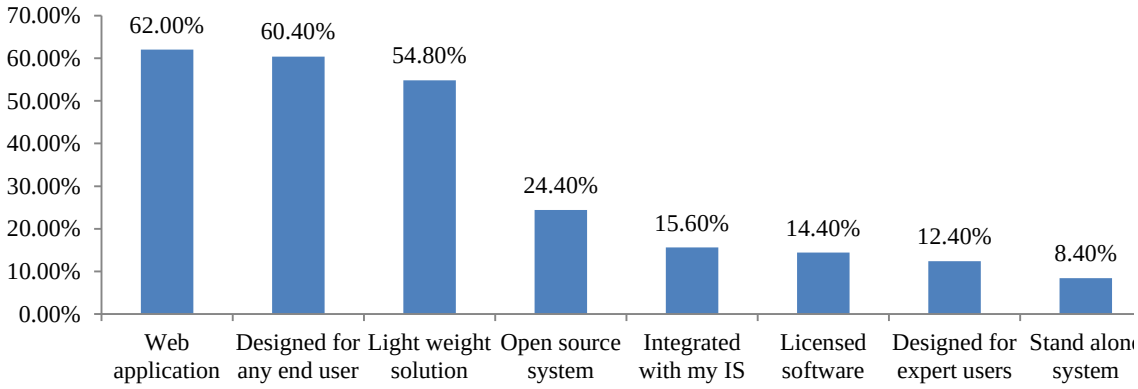


Figure 22: EMIS characteristics' preference

Budget is always an important factor, and it is a critical issue for SMEs. After gathering information about the organizational readiness knowledgeably and technically, determining an estimate for how much money these organizations are intending to spend on such issues was the focus. In this vein, two questions have been included asking about the total yearly budget reserved for the IT infrastructure in general, and for collecting, monitoring, and reporting environmental data, or having an EMIS. Figure 23 and Figure 24 illustrate the results, respectively. Even though the organizations are interested and motivated, it is clear from the results that most of them are not willing to spend money on EMIS or its related issues (Jamous, et al., 2013-III p. 950).

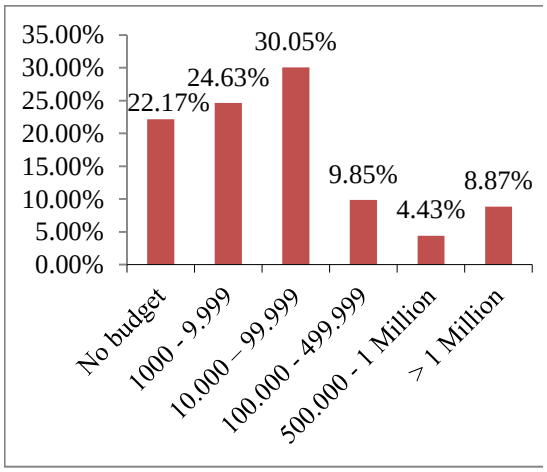


Figure 23: Yearly budget for IT

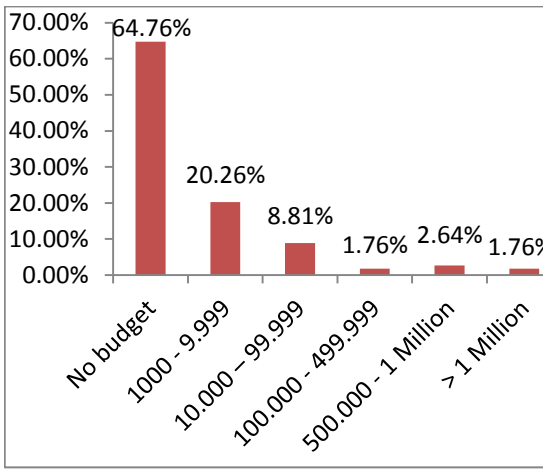


Figure 24: Yearly budget for an EMIS

Based on the findings in the previous sections, SMEs need more guidance in order to start using an EMIS, taking all of the preparatory steps into consideration. For this purpose, the LWC-EPI framework contains an assessment model named the ECET model. The model will enable the organizations to determine the level of environmental performance measurements at which they are operating, and which developments are necessary to achieve a higher level of environmental performance measurements. Therefore, when using this model, companies will be able to follow a systematic path towards EMIS adaption and implementation.

For better assessment, it is important to understand the organizational architecture of the user organization to support any recommended transformation to bridge the gap between the

business and the IT (Aier, et al., 2011 p. 645). The LWC-EPI framework will fulfil this task by an organizational architecture model as one of the main models in the framework.

As for data, Environmental Performance Indicators (EPIs) are the main data type to be handled. The LWC-EPI framework will contain an EPI model where all EPIs can be created or extracted, sorted, classified, and be prepared to be used. To report the selected EPIs (internally or externally), the LWC-EPI framework will enable the organizations to run their standard or customized report easily and more frequent by using the report model. Figure 25 represents the main conceptual models needed for the LWC-EPI framework. In the coming sections, each model of the framework will be detailed, and all the relations will be explained.

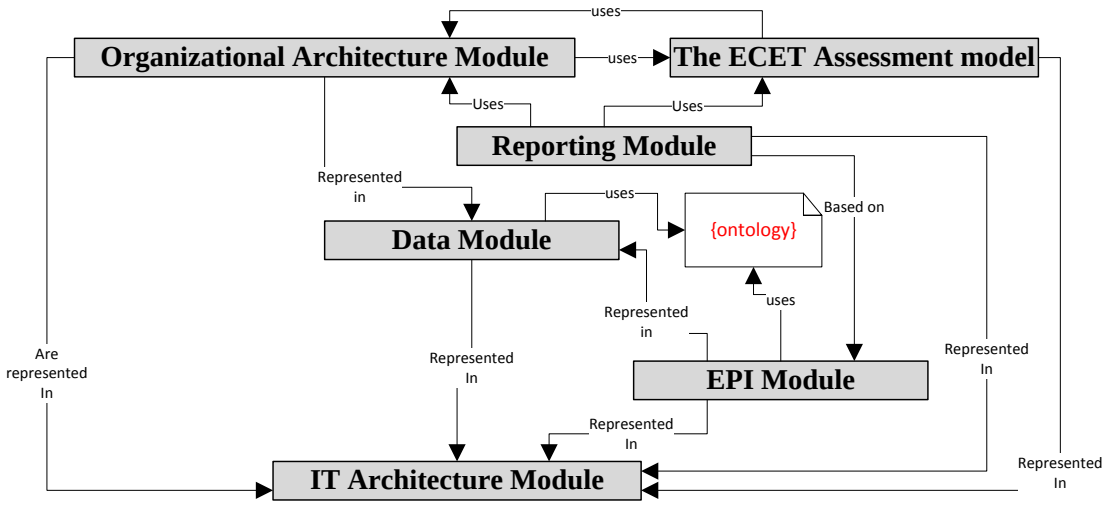


Figure 25: The LWC-EPI Framework needed models

4.3.2 The Exploratory Factor Analysis

As mentioned in the beginning of this section, the results were used to develop an assessment framework that supports any organization in positioning itself based on its determining factors and gain knowledge about how to achieve a successful adoption of an EMIS. This model named ***The ECET Model,*** has been developed based on Exploratory Factor Analysis (EFA), which was followed as a result of the few related researches conducted in the area. Thus, there were no assumptions for a possible model structure. EFA is a variable reduction technique used to identify the number of latent constructs and the underlying factor structure of a set of variables (Child, 2006 pp. 151-153). It may be used for identifying relevant dimensions in a group of variables as well as a criterion for retaining or deleting variables (Lee, et al., 2002 p. 21).

As a first, preparatory step, the twenty questions of the questionnaire (A.6) were transformed into 37 variables to make all of the data accessible for the factor analysis. Next, all of the variables were transformed into numerical form to represent the collected data. The coding for every variable leads to discrete values for each variable representing the possible answers from the questionnaire.

Using the Pearson correlation coefficient (see Figure 26), validity of the variables was tested where three variables were dropped since they had less than 0.01 total correlations with the other variables. These variables were the name of the company (Variable 1), number of

employees in the organization (Variable 3), and preference of EMIS designed for any end user (Variable 30). In order to discover the common variances between the variables, an EFA was

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

Figure 26: Pearson's Correlation Coefficient Equation (Bronstein, et al., 1991 p. 692)

conducted on the remaining 34 variables. The technique used attempts to take out as much of the common variance as possible in the first factor, then the maximum amount of the remaining common variance go to the subsequent factors in turn until no more common variance remains. The analysis was conducted using the PLS-graph software and the results were validated by running the same analysis in the R-software. Table 21 shows part of the Matrix Pearson correlation table.

	VAR2	**VAR5**	**VAR6**	**VAR7**
VAR2				
Correlation Coefficient	1	-0.135350808	0.030789138	0.11893135
Nr. Of valid samples	272	272	272	272
Significance	0	0.012798746	0.306579686	0.025033413
VAR4				
Correlation Coefficient	0.082663703	0.110757173	0.193447764	0.275182044
Nr. Of valid samples	272	272	272	272
Significance	0.087014092	0.034086842	0.000672813	2.0449E-06
VAR5				
Correlation Coefficient	-0.135350808	1	-0.009125773	-0.032831103
Nr. Of valid samples	272	272	272	272
Significance	0.012798746	0	0.440454858	0.294903355
VAR8				
Correlation Coefficient	0.074855386	0.018169892	0.338511104	0.423403723
Nr. Of valid samples	272	272	272	272
Significance	0.109238433	0.382733247	5.10736E-09	1.47243E-13
VAR9				
Correlation Coefficient	0.018379866	-0.02265178	0.401863187	0.381756148
Nr. Of valid samples	272	272	272	272
Significance	0.381418275	0.354979934	2.79351E-12	3.622E-11
VAR10				
Correlation Coefficient	-0.005272738	0.087710416	0.090010052	0.077352136
Nr. Of valid samples	272	272	272	272
Significance	0.465510492	0.074555721	0.06934936	0.101730051
VAR11				
Correlation Coefficient	0.073915765	-0.038297539	0.269978656	0.395548597
Nr. Of valid samples	272	272	272	272
Significance	0.112164218	0.264693791	3.14738E-06	6.36448E-12

Table 21: Part of the Pearson correlation matrix table

Direct extraction methods obtain the factor matrix directly from the correlation matrix by application of specified mathematical models. Adjustment to the frames of reference by rotation methods improves the interpretation of factor loadings by reducing some of the ambiguities that accompany the preliminary analysis (Child, 2006). The process of manipulating the reference axes is known as rotation. An orthogonal rotation where the axes are held to each other at 90º has been applied. In order to get a better idea on the quality of the provided data, the normal distribution calculation was used. The Kolmogorov-Smirnov and the Shapiro-Wilk methods of calculations have been applied (Bronstein, et al., 1991 pp. 692-693). The result of the calculation is presented in Table 22.

	Kolmogorov-Smirnov	**Shapiro-Wilk**		**Kolmogorov-Smirnov**	**Shapiro-Wilk**
	Dist.	**W**		**Dist.**	**W**
VAR2	0.368696173	0.666351529	VAR20	0.376941102	0.629337106
VAR3	0.188462599	0.911124939	VAR21	0.348488596	0.636160041
VAR4	0.467789729	0.538356302	VAR22	0.340899128	0.636474738
VAR5	0.403318929	0.658709371	VAR23	0.414682025	0.605852827
VAR6	0.406305326	0.648564178	VAR24	0.397750221	0.61853158
VAR7	0.349559286	0.725179039	VAR25	0.393973837	0.620872397
VAR8	0.273612704	0.771880126	VAR26	0.535941532	0.113232671
VAR9	0.350966002	0.721980965	VAR27	0.420296426	0.600822226
VAR10	0.299413993	0.760841755	VAR28	0.515116863	0.416368825
VAR11	0.4805301	0.506074479	VAR29	0.525854514	0.368138239
VAR12	0.301489579	0.746128394	VAR30	0.369357745	0.632035284
VAR13	0.277913325	0.788500837	VAR31	0.536330374	0.294467799
VAR14	0.319402149	0.763860534	VAR32	0.515116863	0.416368825
VAR15	0.297396071	0.746200758	VAR33	0.342796432	0.636455074
VAR16	0.305092679	0.784339514	VAR34	0.376941102	0.629337106
VAR17	0.317121754	0.73620458	VAR35	0.479994574	0.514887746
VAR18	0.393973837	0.620872397	VAR36	0.229465889	0.814095587
VAR19	0.357975769	0.63488002	VAR37	0.400887871	0.57362906

Table 22: The Normal Distribution Calculation result

In order to determine the number of the factors resulted from the EFA, The Kaiser's criterion suggested by Guttman and adapted by Kaiser has been applied. The Kaiser's criterion considers factors with an eigenvalue higher than one as common factors (Nunnally, 1978). As it is shown in Table 23 (the Exploratory Factor analysis results), the factor structure consists of four factors with eigenvalues greater than one. The four factors together account for 40.12% of the variance, which is acceptable for an exploratory analysis. Each factor included five to eleven variables, and there are no cross-loaded variables. After determining the factors of the model, it was important to check the analysis' reliability, which means checking the internal consistency of the variables within each factor. This was checked by calculating the mean value, standard deviation, and the item-total correlation for each variable. In addition, the Cronbach's alpha and the Scott's homogeneity were calculated for each factor. The summary of the results of this step is presented in Table 24.

	Factor 1	Factor 2	Factor 3	Factor 4
VAR25	**0.825**	0.094	0.012	0.079
VAR21	**0.819**	0.111	0.043	0.050
VAR24	**0.786**	0.035	0.083	0.102
VAR22	**0.784**	0.158	0.023	0.028
VAR20	**0.766**	0.115	0.213	-0.045
VAR23	**0.763**	0.103	0.147	0.040
VAR27	**-0.750**	-0.249	-0.178	0.001
VAR19	**0.732**	0.155	0.169	-0.068
VAR16	0.073	**0.810**	0.114	0.123
VAR14	0.066	**0.776**	0.063	0.065
VAR15	0.137	**0.770**	0.075	-0.014
VAR13	0.076	**0.743**	-0.001	0.002
VAR17	0.059	**0.707**	0.136	0.108
VAR12	0.054	**0.703**	0.115	0.105
VAR35	0.063	**0.268**	0.006	0.162
VAR28	0.108	**0.225**	0.149	0.086
VAR5	0.096	**0.219**	-0.045	-0.005
VAR9	0.078	-0.014	**0.640**	-0.043
VAR7	-0.024	0.004	**0.593**	0.054
VAR18	0.228	0.170	**0.557**	0.127
VAR8	-0.026	0.095	**0.556**	-0.013
VAR11	0.239	-0.038	**0.545**	0.111
VAR37	0.163	0.082	**0.517**	0.008
VAR6	0.004	0.018	**0.508**	-0.050
VAR4	-0.078	0.105	**0.372**	0.047
VAR36	0.157	0.201	**0.312**	0.017
VAR32	0.161	-0.096	**0.284**	0.025
VAR29	0.137	0.031	**0.173**	0.011
VAR34	-0.016	0.106	-0.076	**0.781**
VAR33	-0.005	0.058	-0.173	**0.761**
VAR26	-0.010	0.011	0.071	**0.201**
VAR2	0.031	0.061	0.096	**0.155**
VAR31	0.057	0.114	0.026	**0.139**
eigen value	6.497	3.151	2.302	1.291
% of variance	15.580	11.709	8.538	4.295

Table 23: The Exploratory Factor Analysis results (Jamous, et al., 2013-III p. 951)

Variable	Mean Value	Standard Deviation	Item-Total correlation	Cronbach's alpha	Scotts Homogenity
VAR25	0.397	0.490	0.825	0.794	0.325
VAR21	0.485	0.501	0.819		
VAR24	0.390	0.489	0.786		
VAR22	0.050	0.501	0.784		
VAR20	0.430	0.496	0.766		
VAR23	0.357	0.480	0.763		
VAR27	0.346	0.476	-0.750		
VAR19	0.467	0.500	0.732		
VAR16	0.875	0.987	0.810	0.848	0.433
VAR14	0.908	1.091	0.776		
VAR15	0.982	1.179	0.770		
VAR13	0.930	1.055	0.743		
VAR17	0.835	1.079	0.707		
VAR12	0.904	1.119	0.703		
VAR35	0.224	0.418	0.268		
VAR28	0.143	0.351	0.225		
VAR5	1.544	0.691	0.219		
VAR9	0.879	1.189	0.640	0.732	0.250
VAR7	0.585	0.734	0.593		
VAR18	0.603	0.490	0.557		
VAR8	0.688	0.661	0.556		
VAR11	0.324	0.681	0.545		
VAR37	0.522	1.023	0.517		
VAR6	0.529	0.791	0.508		
VAR4	0.750	0.434	0.372		
VAR36	1.324	1.482	0.312		
VAR32	0.143	0.351	0.284		
VAR29	0.114	0.318	0.173		
VAR34	0.569	0.496	0.781	0.055	0.112
VAR33	0.496	0.501	0.761		
VAR26	0.018	0.135	0.201		
VAR2	5.430	7.126	0.155		
VAR31	0.077	0.268	0.139		

Table 24: The reliability of variances (Jamous, et al., 2013-III p. 951)

Factor one and factor three have a Cronbach alpha of 0.794 and 0.732, respectively, which indicated a satisfactory level of reliability. The second factor with a Cronbach alpha of 0.848 indicates a high level of reliability. The fourth factor has a Cronbach alpha of 0.055, which is too low from the viewpoint of reliability. Taking into consideration the exploratory nature of the study, the factor was not dismissed and remained in the study results.

For more reliability, the EFA was conducted with two different tools (the R-software and the PLS graph add-on MS- Excel), and both tools conclude the same results. Based on these results of the EFA, the ECET model was proposed. It consists of four relevant dimensions which form a foundation for a successful EMIS's implementation in any corporate environment. The four dimensions are (Jamous, et al., 2013-III pp. 952-953):

- Environmental Maturity Level (EML): presented as Factor 3 in Table 23
- Current Environmental Situation (CES): presented as Factor 1 in Table 23
- Environmental Footprint Expectation (EFE): presented as Factor 2 in Table 23
- Technological Experience Level (TEL): presented as Factor 4 in Table 23

Environmental Maturity Level (EML): This dimension interprets the environmental maturity level of the organization. It covers aspects such as organizational environmental expertise, EMIS usage, and its motivation for EMIS. It consists of eleven factors:

- Motivation (Var4)
- Publishing environmental/sustainability reports (Var6)
- EMIS in place (Var7)
- Environmental improvement programs in place (Var8)
- Number of environmental experts employed (Var9)
- EMIS usage (Var11)
- Monitoring and checking environmental data / information (Var18)
- Preference of an EMIS designed for expert users (var29)
- Preference of an EMIS as licensed software (var32)
- Yearly budget for collecting, monitoring, and reporting environmental data (var36)
- Yearly budget for IT (Var37)

Current Environmental Situation (CES): This dimension summarizes the current situation in the organization on different issues related to EMIS implementation. In particular, it consists of eight factors:

- Current situation of environmental expertise (Var19)
- Environmental reporting situation (Var20)
- Current situation of data availability (Var21)
- Current IT support situation (Var22)
- Current situation of environmental monitoring (Var23)
- Current situation of time-line preferences (Var24)
- Current situation of data accuracy (Var25)
- Satisfaction with organization's current environmental sustainability situation in general (Var27)

This concept includes the base factors for a successful implementation of an EMIS in a corporate context.

Environmental Footprint Expectation (EFE): This dimension represents the attitude of the organization towards the outcome of an EMIS. It helps to know what the organization wants to achieve by using an EMIS. This concept consists of nine factors:

- Awareness of environmental legislation (country: society, laws, and regulations) (Var5).
- The importance of the EPIs on enterprise level (Var12)

- Importance of the EPIs on a product level (Var13)
- The importance of the EPIs on process and activity level (Var14)
- Importance based on data type: static/ statistical data (Var15)
- Importance based on data type: dynamic data automatically updated (Var16)
- Importance based on data type: Real time data (Var17)
- Level of integration (Var28)
- Preference of an EMIS as an open source system (Var35)

This concept summarizes aspects of the importance of EMIS for the organization and some advanced technical issues such as the use of dynamic data and implementation forms.

Technological Experience Level (TEL): The fourth dimension based on the EFA has been interpreted as technological experience. This factor was not reliable considering the very low Cronbach alpha of 0.055. Nevertheless, as this is an exploratory study, this factor has been investigated further on the level of domain expertise. Following this, the variables contained in this dimension are mostly related to technical issues of EMIS implementation, such as preferences in provisioning an EMIS and cultural and regional perspectives. In particular, it contains five factors:

- Enterprise's country (Var2)
- Current situation on other related issues (Var26)
- Preference of an EMIS as standalone system (Var31)
- Preference of an EMIS as a light-weight solution (Var33)
- Preference of an EMIS as a web application (Var34)

Figure 27 represents a condensed graph of the ECET model based on the four extracted dimensions. It gives companies the opportunity to position themselves based on the determining factors, and gain knowledge about how to achieve a successful implementation and use of an EMIS (Jamous, et al., 2013-III p. 652).

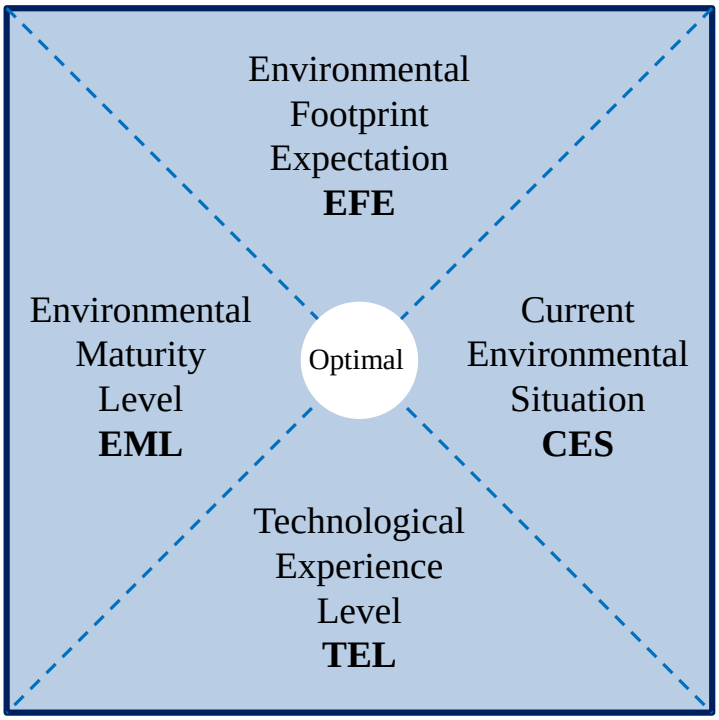


Figure 27: The ECET Assessment Model (Jamous, et al., 2013-III p. 953)

4.3.3 The Confirmatory Study

The ECET Model has been proofed by a confirmatory study presented in this section. The study used the data gathered from a survey conducted between Oct. 2012 and March 2013 (see A.7), supported by direct meetings with experts and companies' representatives. The survey was paper-based and used a questionnaire, which was developed based on the result of the EFA. In total, 152 valid responses were gathered from 138 organizations from 24 different countries, working in more than 35 different business fields such as IT-solution providers, food industry, electronics industry, consulting, renewable energy domain, and marketing. Approximately 84% of the responses were coming from SMEs as it is shown in Figure 28.

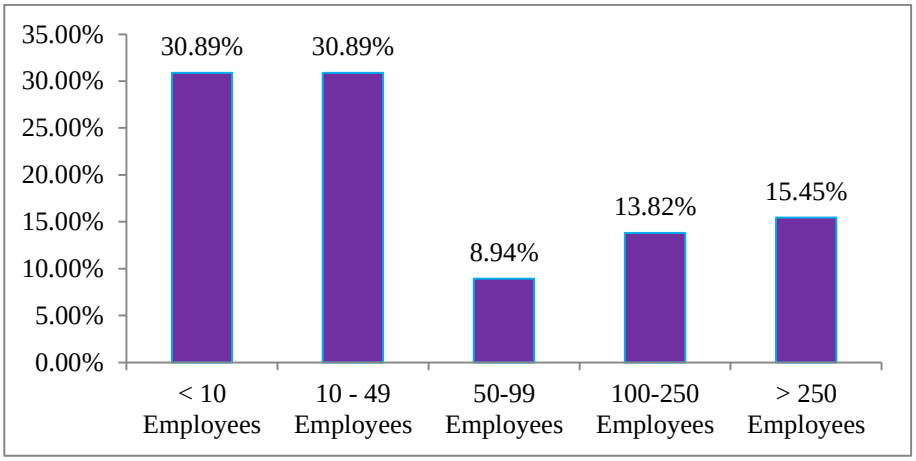


Figure 28: Distribution based on the number of employees in the confirmatory study

After a quality check, 29 responses have been excluded due to incompleteness or incorrectness. In total, 123 responses were valid for the analysis.

In this analysis, four hypotheses that reflect the interdependencies between the identified factors of the ECET framework were formulated. The formulations of the hypotheses were based on experts' opinions of the dependencies and influential factors on Information Systems implementation in general and business scenarios, in particular, were taken into consideration. The interviewed experts were experienced project managers in IT departments/units of SMEs from different industry sectors, IT researchers, and consultants specialized in EMIS. The experts' opinions have been enriched with findings from literature studies focused on IT project success in SMEs, and the success factors of Information System, business application adaptation or enrolment.

For the operationalization of the hypotheses, the method of Structural Equation Modelling (SEM) has been used. The SEM is a method for multi-variant data analysis that investigates dependencies between variables that cannot be observed or measured directly (Schumacker, et al., 2004 pp. 56-58). The data acquisition for testing the structural model was done by interviews and surveys. A survey questionnaire was developed based on the hypothesis, enhanced by knowledge from practical experience and opinions from expert interviews. The results of the survey were analyzed using the Partial-Least-Square method (PLS) (Gefen, et al., 2000). It is a convenient method of analysis because of the minimal demands on measurement scales, sample size, and residual distributions, and it can therefore be used for theory confirmation. When the research is based on a strong prior theory and the goal of the analysis is the further development of the model, it is more appropriate to use covariance

based estimation methods like Maximum Likelihood or Generalized Least Square (GLS) (Gefen, et al., 2000 pp. 18-21, 28).

For application, a PLS based approach is more suitable. The assumptions for this approach are that the measured variance is a useful variance and should be explained, and that all latent variables are linear combinations of the observed measures. Sample size may be smaller than in a similar analysis. A rule of thumb suggests that the sample size should be equal to the larger of the following: ten times the scale with the largest number of causal indicators, or ten times the largest number of structural paths directed at a particular construct in the structural model (Tabachnick, et al., 2006 pp. 7,201,217).

Before proposing the hypotheses and their proofs, the results of the survey have been examined to support the formation of the ECET model's dimensions. In the case of the EML dimension, more than 77% of the organizations' representatives agreed or strongly agreed that the eight sub-factors that form the EML dimension represent and help to measure the environmental maturity level expectation of the company. Furthermore, they agree that these factors affect the success rate of implementing and adapting an EMIS in an organization. The detailed answers distribution is presented in Figure 29.

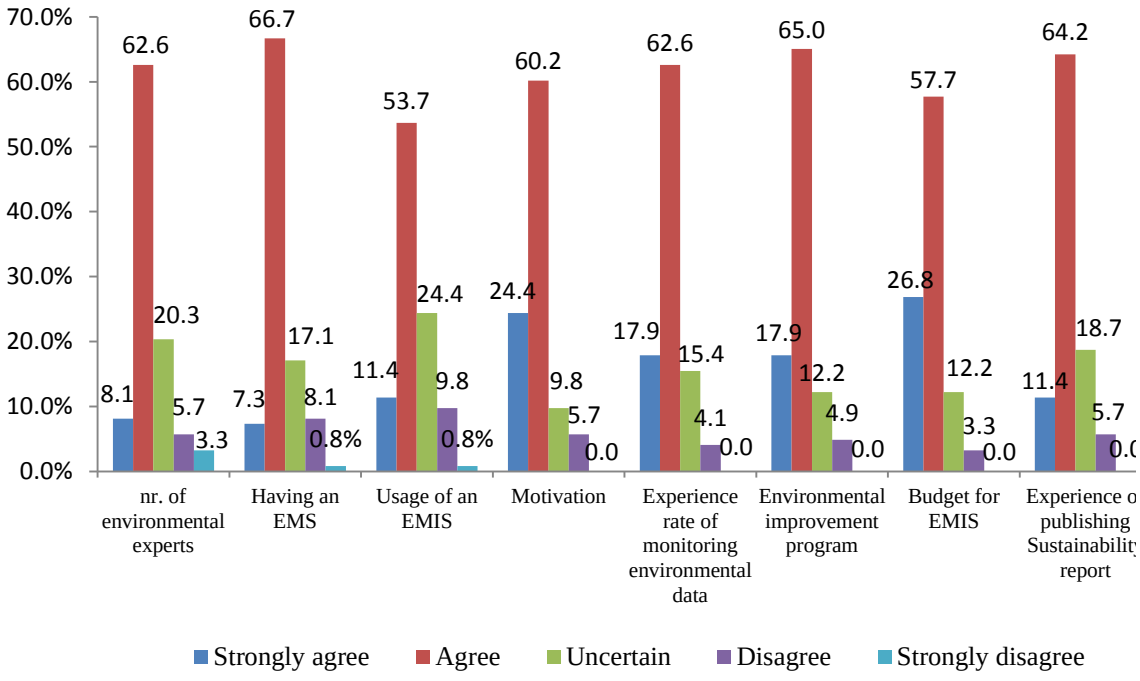


Figure 29: The EML dimension solidity

On average, more than 72% of the surveyed organizations agreed, or even strongly agreed, that the six sub factors that form the CES dimension represent and help to measure the current environmental situation. These factors affect the implementation and adaptation process of an EMIS in the organization. The detailed distribution of answers is presented in Figure 30.

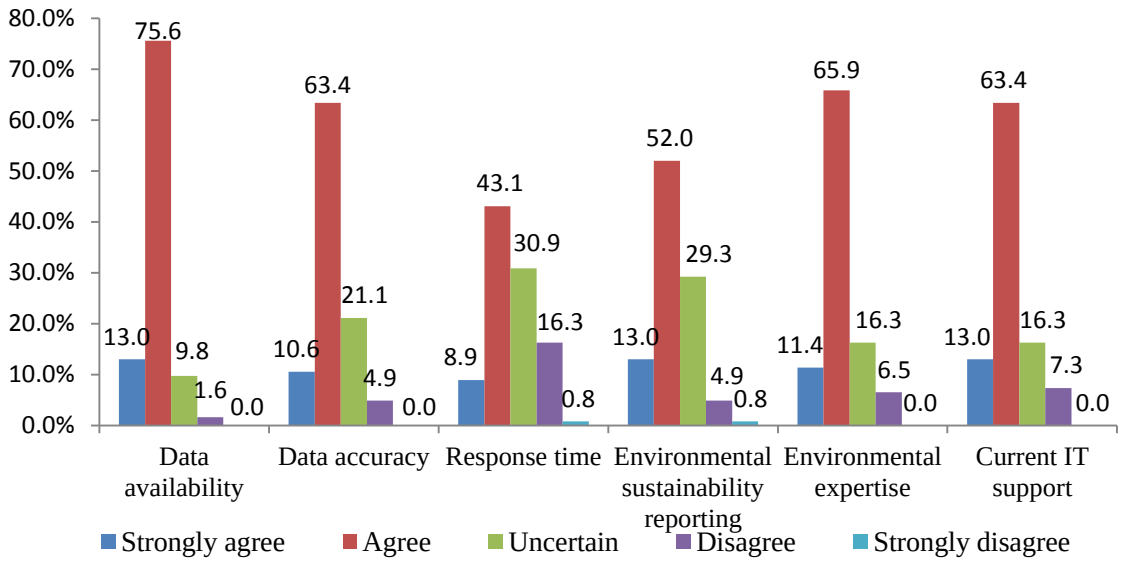


Figure 30: The CES dimension solidity

As for the EFE dimension, more than 57% of the representatives agreed or strongly agreed that the six sub-factors that form the EFE dimension represent and help to measure the environmental footprint expectation of the company. In addition, they do agree that these factors affect the success rate of implementing and adapting an EMIS in an organization. The detailed distribution of answers is presented in Figure 31.

The construction of the TEL dimension received the highest acceptance rate. More than 75% of the representatives agreed or strongly agreed that the four sub-factors help to evaluate

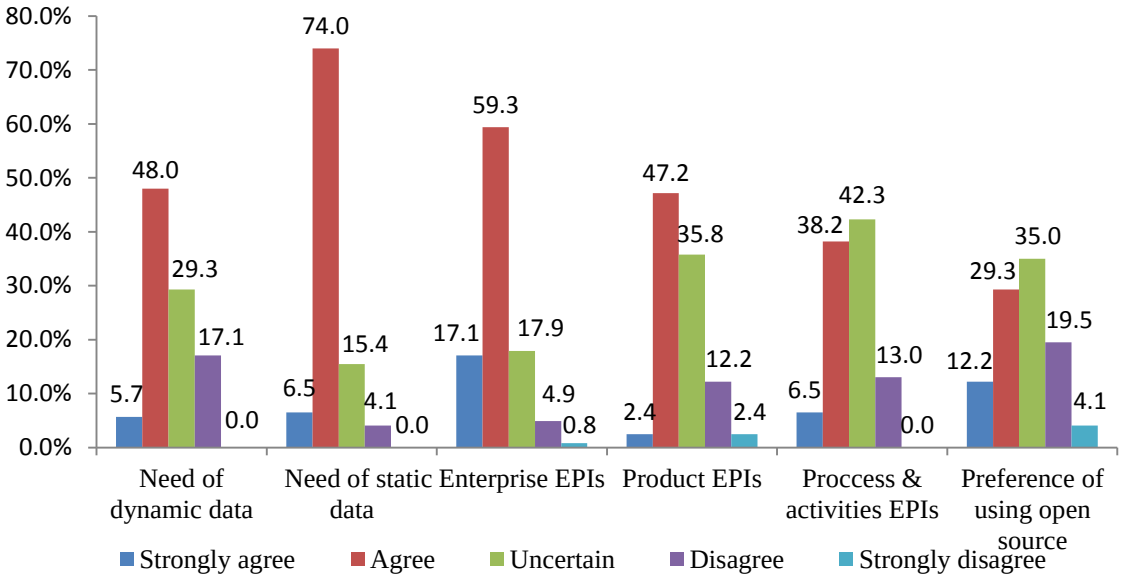


Figure 31: The EFE dimension solidity

the technological experience level of the company. In addition to this fact, they agree that these factors, especially the social aspects (country, society, laws, etc.), affect the success rate of implementing and adapting an EMIS in an organization. Moreover, this dimension helps EMIS' developers to know what the main solution specifications are. The detailed answers distribution is presented in Figure 32.

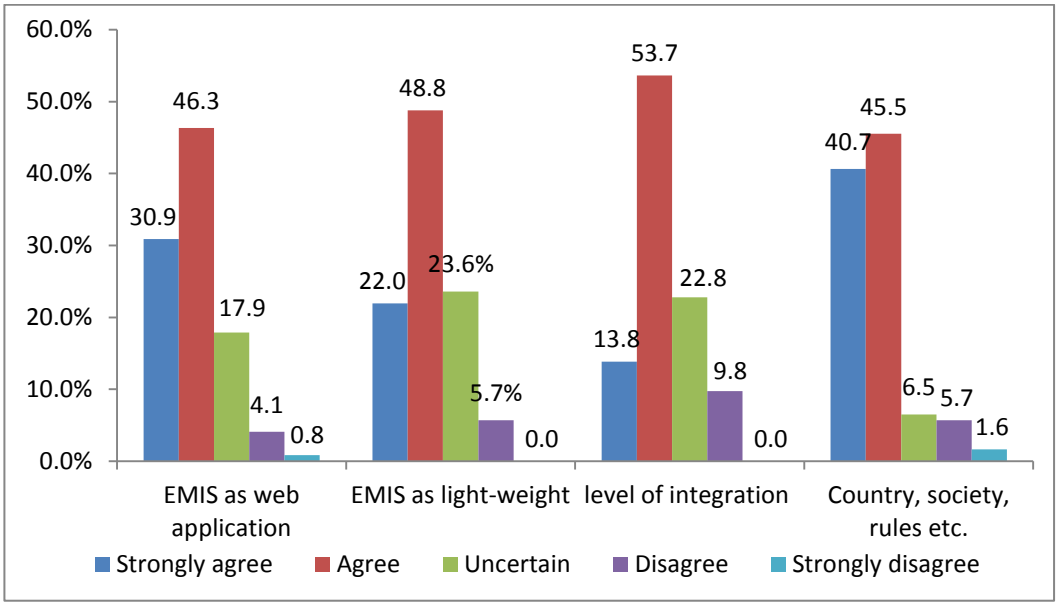


Figure 32: The TEL dimension solidity

Table 25 shows the avarage acceptance of each variable and each dimenssion of the ECET model. As it is presented, more than seventy percent of the organizations' representatives agreed with the proposed formation of the ECET model, and that the mentioned variables affect the implementation and adaption process of an EMIS in their companies. Around twenty percent were uncertain, and less than nine percent disagreed.

	Variable name	Agree	Uncertain	Disagree
EML	Nr. of environmental experts	70.70%	20.30%	8.90%
	Having an EMS	74.00%	17.10%	8.90%
	Usage of an EMIS	65.00%	24.40%	10.60%
	Motivation	84.60%	9.80%	5.70%
	Experience rate of monitoring environmental data	80.50%	15.40%	4.10%
	Environmental improvement program	82.90%	12.20%	4.90%
	Budget for EMIS	84.60%	12.20%	3.30%
	Experience of publishing Sustainability report	75.60%	18.70%	5.70%
CES	Data availability	88.60%	9.80%	1.60%
	Data accuracy	74.00%	21.10%	4.90%
	Response time	52.00%	30.90%	17.10%
	Environmental sustainability reporting	65.00%	29.30%	5.70%
	Environmental expertise	77.20%	16.30%	6.50%
	Current IT support	76.40%	16.30%	7.30%
EFE	Need of dynamic data	53.70%	29.30%	17.10%
	Need of static data	80.50%	15.40%	4.10%
	Enterprise EPIs	76.40%	17.90%	5.70%
	Product EPIs	49.60%	35.80%	14.60%
	Process & activities EPIs	44.70%	42.30%	13.00%
	Preference of using open source	41.50%	35.00%	23.60%
TEL	EMIS as web application	77.20%	17.90%	4.90%
	EMIS as light-weight	70.70%	23.60%	5.70%
	level of integration	67.50%	22.80%	9.80%
	Country, society, rules etc.	86.20%	6.50%	7.30%
	Average	**70.80%**	**20.85%**	**8.38%**

Table 25: The solidity of the ECET model's factors

The ECET hypothesis:

To investigate and understand the inter-dependencies between the identified dimensions of the ECET model, four hypothesizes were formulated supported from related literature.

H1: The Technological Experience Level (TEL) influences positively the Environmental Maturity Level (EML)

The core concept of the structural model, the environmental maturity level, is interdependent directly with the three other constructs or dimensions of the ECET model. These first three hypotheses formulate the core of the structural model.

Interviewed experts agreed that the technological experience level of a company has a significant impact on any Information System implementation project and the maturity level of a company. This claim is widely supported by several findings in the literature such as (Martin, et al., 2002), (Siegenthaler, et al., 2005), (Lee, et al., 2008), and (Bi, et al., 2008).

H2: The Environmental Maturity Level (EML) influences positively the Environmental Footprint Expectation (EFE)

When implementing an EMIS, an appropriate understanding of the business processes and environmental key indicators is required. This is done by understanding the environmental issues related to the business processes in the company and the high level of environmental competence influences the implementation and adoption of an EMIS. This leads to a higher expectation from using the EMIS, and a better environmental footprint expectation. This hypothesis is supported in the literature as well, for example (Watson, et al., 2011) and (Dao, et al., 2011).

H3: The Current Environmental Situation (CES) positively influences the Environmental Maturity Level (EML)

Achieving a certain environmental maturity level strongly depends on the engagement of environmental circumstances of the company. Having low pressure to apply special environmental programs leads to a lower commitment of engagement in the implementation. Therefore, the current environmental situation of an organization has a significant impact on the engagement to achieve a certain environmental goal. This improves the environmental maturity level of the organization. Searching the literature, similar interdependencies can be found in other areas. For examples, in business process management (Rohloff, 2011), in IT project management, such as in (Mas, et al., 2011), and in ERP systems research, such as in (Bernroider, 2008).

H4: The Technological Experience Level (TEL) positively influences the Environmental Footprint Expectation (EFE)

Technological experience leads to a high confidence in implementing an Information System in general, with high expectations from using it. Based on their technological experience, companies are able to design, implement, or adopt IT solutions to fulfil their high expectations. Therefore, it is assumed that higher technological experience leads to higher expectations on the environmental footprint level. Research and publications such as (Fisher, et al., 2004), (Dietz, et al., 2007), and (Gandhi, et al., 2006) support this assumption.

Figure 33 depicts the four hypotheses between the factors of the ECET model. The PLS approach to Structural Equation Modelling (SEM) has been used to operationalize the confirmatory factor analysis. This approach “offers an alternative to covariance based SEM, which is especially suited for situations when data is not normally distributed” (Monecke, et

al., 2012). In terms of the SEM method, the ECTE model's factors (constructs) have been used as latent variables. To reproduce the latent variables, a measurement model was implemented to assign one or more indicator variables to one latent variable. These indicator variables can be measured and are connected to the latent variables.

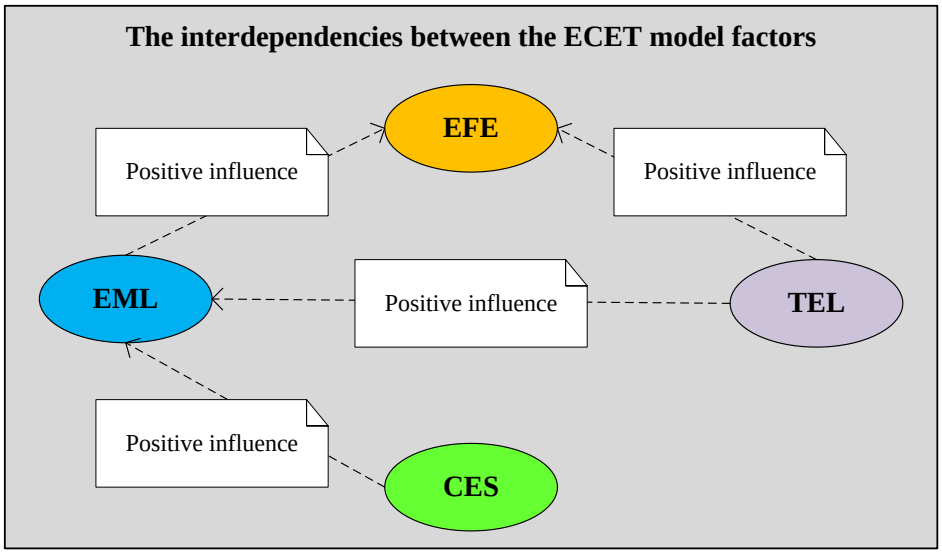


Figure 33: The interdependencies between the ECET model factors

For the analysis of the measurement model, SmartPLS© Version 2.0.M3 has been used. SmartPLS© provides the possibility to calculate different factors and interdependencies for the measurement model and the structural model.[30] Based on these factors, a statement of the model quality can be drawn. The hypotheses can be tested and, based on the model calculations, the rejection or acceptance decision can be made.

As it can be seen in Table 26, all latent variables have quality measures that allow the structural model to be considered as reasonable. The constructs "Current Environmental Situation" and "Environmental Maturity Level" have a Cronbach Alpha higher than 0.6, which is acceptable for the constructs. The factor "Technological Experience" has a Cronbach Alpha of 0.566, which is close enough to 0.6, but the construct "Environmental Footprint expectation" only has a Cronbach Alpha of 0.475, which might lack consistency. Due to the

	AVE	Composite Reliability	R^2	Cronbach Alpha
Environmental Maturity Level (**E**ML)	0,475	0,877	0,462	0,839
Current Environmental Situation (**C**ES)	0,322	0,699	0	0,638
Environmental Footprint Expectation (**E**FE)	0,212	0,023	0,405	0,475
Technological Experience Level (**T**EL)	0,461	0,716	0	0,566

Table 26: Quality measures for the structural model

[30] www.smartpls.de

nature of the research and the early, explorative aspect of it, it has been decided to leave this construct in the further analyses, but it is advised to take care of it in future research steps.

Looking at the structural model, the calculation of the correlation between the latent variables can be seen. These correlations lead the research to the discussion of the hypothesis. The correlations between the latent variables vary from 0.209 to 0.580. This means that all four hypotheses cannot be dismissed. With the lowest correlation of 0.209 between the Technological Experience Level (TEL) and the Environmental Maturity Level (EML) (hypothesis H1), this hypothesis supports the experts' collective opinion that environmental maturity is more a business topic than a technological topic. Technological expertise serves as a foundation, but it does not lead to maturity in this specific topic. The correlation between Technological Experience Level (TEL) and Environmental Footprint Expectation (EFE)

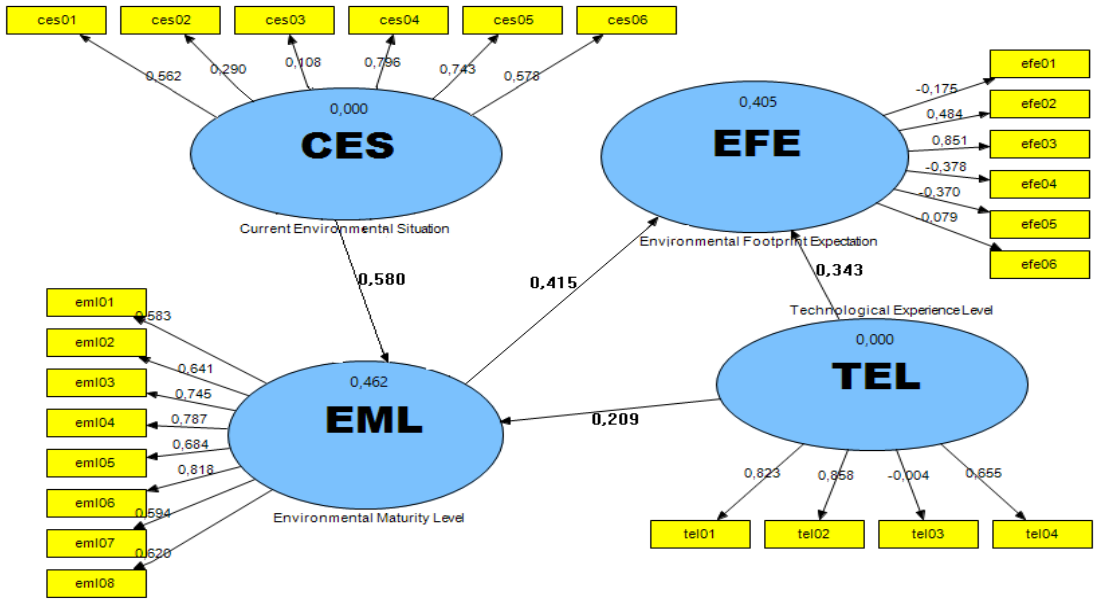


Figure 34: The four hypothesis between the ECET model factors

(hypothesis H4) with 0.343, and Environmental Maturity Level (EML) and Environmental Footprint Expectation (EFE) (hypothesis H2) with 0.415, show that with a certain level of technology experience and maturity, the expectation increases for the environmental footprint communication. This result is well aligned with the observation that for environmental issues within a company, there has to be a mindset for environmental measures. The excitement of this mindset or attitude increases the expectation constantly. The highest correlation is between the Current Environmental Situation (CES) and the Environmental Maturity Level (EML) (hypothesis H3) with a path coefficient of 0.580. This correlation is as strong as expected by the experts. Figure 34 visualizes the result of the measurement model.

4.3.4 The ECET Model

Enterprises use assessment methods and tools to evaluate and control their operations toward reaching their goals, and to support decision-making. Starting with the new millennium, environmental assessment has gained more importance worldwide. For example, based on the

European directive 2001/42/EC of 27 June,[31] strategic environmental assessment has become mandatory for plans and programs in Europe (Loiseau, et al., 2013 p. 1534).

The LWC-EPI assessment model has been established based on the findings presented in Chapter 2 and Section 4.3, and in accordance to the principle of the Life Cycle Assessment (LCA) presented in scholar publications, e.g. (Curran, 2006), and (Bengtsson, 2000). In addition, it was enriched using different objective assessment models' understanding, such as the ISO ISO/IEC 15504-1:2004, and the ISO/IEC TS 15504-8:2012 (ISO, 2012). Using the Unified Modeling Language (UML)[32], Figure 35 presents this model as an assessment model for organizations that intend to implement an EMIS.

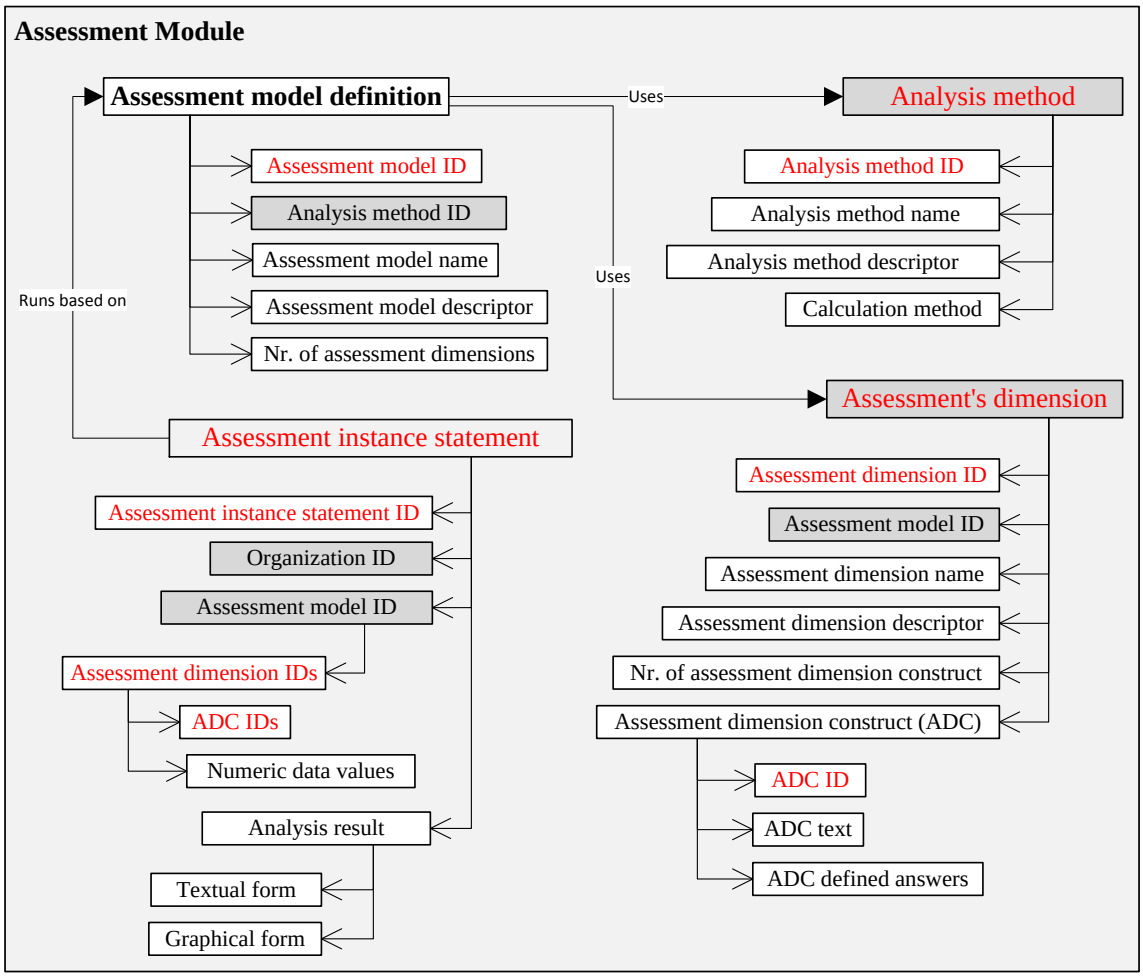


Figure 35: The LWC-EPI assessment model

The LWC-EPI assessment model proposed that each assessment method should at least have the following:

1. A *name* such as the Life Cycle Assessment (LCA) model, or the Building Environmental Performance Analysis System (BEPAS) (Zhang, et al., 2006 pp. 672-673).

[31] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:197:0030:0037:EN:PDF

[32] http://www.uml.org/

2. An *assessment model descriptor* used to enhance the users' information about the model. It is a formalized description of the assessment model. It can be extracted from a reference document or entered manually by the user as text.
3. The used analysis method such as the SWAT analysis, or exploratory data analysis (EDA). The analysis method itself needs some extra attributes, such as:
    a. *Analysis method name,* it can be one of the common methods e.g. exploratory data analysis (EDA), Structured Equation Modelling (SEM), or proposed by the user e.g. the ECET model.
    b. *Analysis method descriptor* explains the method in textual form. For example, it defines the used technique if it is normal distribution, multivariate data analysis, observations, etc.
    c. *Calculation method* specifies the calculation method which should be used to obtain the analysis result. For example: average values, weighted values, aggregated values, etc.
4. The *assessment dimensions* or factors which are used in the assessment model, e.g. time needed to deliver, or technological maturity of a company. These dimensions need some extra attributes to explain and differentiate them, such as:
    a. Each dimension should be linked to the *Assessment model* that it is used for. One dimension can belong to more than one model, and one model can have more than one dimension.
    b. *Assessment dimension's name,* it can be a common name from specific field e.g. fuel liter per 100 km, or a proposed name by the user e.g. the current environmental situation that is used in the ECET model.
    c. *Assessment dimension's descriptor* explains the dimension as a textual form. For example it defines its aim, the used technique, and its type (common or new created by user).
    d. *The number of the assessment dimension's constructs (ADC)* that specifies how many constructs (or secondary attribute) the dimension has. Each ADC should be explained in textual or numeric form, and its possible values should be specified.
5. The *assessment instance statement* is a concrete quantitative set of information about a certain assessment's instance, runes by a specific user (organization) based on a particular assessment model and all its related dimensions. This transaction executes the assessments' analysis results of the user's organization. This result should be presented in textual and graphical forms.

The LWC-EPI framework will use the ECET model to give any organization the opportunity to assess its readiness for adopting an EMIS based on determined factors and dimensions, and gain knowledge about how to achieve a successful implementation and use of an EMIS. Using the LWC-EPI assessment model presented in Figure 35, The ECET model will contain four components as it is presented in Figure 36.

- The ECET assessment model definition
- The ECET analysis method
- The ECET assessments' dimensions:
    - The Environmental Maturity Level (EML) assessment's dimension

  - The Current Environmental Situation (CES) assessment's dimension
  - The Environmental Footprint Expectation (EFE) assessment's dimension
  - The Technological Experience Level (TEL) assessment's dimension
- The ECET assessment instance statement

The ECET assessment model definition:

This component defines the model, and links it to its other attribute. It contains five attributes.

1. The *assessment model ID* which runs automatically by the system and can be used as a primary key.
2. The *analysis method ID*, taken from the analysis method component. It links the assessment model with the data analysis method that it uses. As for this case, it will be the ECET data analysis method.
3. The assessment model *name.* In this case it will be the ECET assessment model.
4. The assessment model *descriptor*. It is a formalized description of the assessment model in textual form, used to enhance the users' information about the ECET model, e.g. the model's aim, how to use, etc.
5. The last attribute is the *number of assessment's dimensions* that belong to this model. As for the ECET model, it uses four dimensions as it was specified in Section 4.3.2 & 4.3.3. This attribute can support the solution developers and the users.

The ECET analysis method:

This component defines the analysis method. As for the LWC-EPI framework, the ECET analysis will be used. It contains four attributes.

1. The *analysis method ID* which runs automatically by the system and it can be used as a primary key.
2. The *analysis method name*, in this case it will be the ECET analysis method.
3. The *analysis model descriptor*. It is a formalized description of the assessment model in textual form, used to enhance the users' information about the ECET analysis method.
4. The last attribute is the *calculation method* that is applied to get the result. Basically, it is a weighted average value, built based on the domain experts' knowledge and the analysis results presented in Section 4.3.2 and 4.3.3.

The four ECET assessment dimensions:

The Environmental Maturity Level (EML) assessment's dimension

As it has been explained in Section 4.3.2, this dimension interprets the environmental maturity level of the organization. It covers aspects such as organizational environmental expertise, EMIS usage, and its motivation for EMIS adoption. As component, it consists of six main attributes:

1. The *assessment's dimension ID* runs automatically by the system, and it can be used as a primary key.
2. The *assessment model ID* taken from the assessment model definition component. It references the assessment dimension to the assessment model to which it belongs. Here it will be the ECET assessment model.

3. The *assessment's dimension name,* in this case it is the Environmental Maturity Level (EML).
4. The *EML descriptor* is a formalized description of the EML dimension in textual form, used to enhance the users' information about this dimension.
5. The *number of EML constructs*. As it is presented in Section 4.3.3 the EML has eight constructs extracted from eleven factors.
6. Each construct should have three attributes:
    a. The *Construct ID*, runs automatically by the system and it used as a primary key for this construct.
    b. The *Construct text* describes the construct in textual form. In the ECET model, the constructs are represented as simple questions to be answered by normal users who do not have the field experts' knowledge.
    c. The *Construct answers,* a set of defined possible answers for the question mentioned in the *Construct text*.

The Current Environmental Situation (CES) assessment's dimension

As it was explained in Section 4.3.2, this dimension summarizes the current situation in the organization on different issues related to EMIS. This concept includes the base factors for a successful implementation of an EMIS in a corporate context. As a component, it consists of six main attributes:

1. The *assessment's dimension ID* runs automatically by the system, and it can be used as a primary key.
2. The *assessment model ID* taken from the assessment model definition component. It references the assessment dimension to the assessment model to which it belongs. Here it will be the ECET assessment model.
3. The *assessment's dimension name,* in this case it is the Current Environmental Situation (CES).
4. The *CES descriptor* is a formalized description of the CES dimension in textual form, used to enhance the users' information about this dimension.
5. The *number of CES constructs*. As it is presented in Section 4.3.3 the EML has six constructs extracted from eight factors.
6. Each constructs should have three attributes:
    a. The *Construct ID*, runs automatically by the system and it used as a primary key for this construct.
    b. The *Construct text* describes the construct in textual form. In the ECET model, the constructs are represented as simple questions to be answered by normal users who do not have the field experts' knowledge.
    c. The *Construct answers,* a set of defined possible answers for the question mentioned in the *Construct text*.

The Environmental Footprint Expectation (EFE) assessment's dimension

As it was explained in Section 4.3.2, this dimension represents the attitude of the organization towards the outcome of an EMIS. It helps to know what the organization wants to achieve by using it. This concept summarizes aspects of the importance of EMIS for the organization and some advanced technical issues such as the use of dynamic data and implementation forms. As component, it consists of six main attributes:

1. The *assessment's dimension ID* which runs automatically by the system and can be used as a primary key.
2. The *assessment model ID* taken from the assessment model definition component. It references the assessment dimension to the assessment model to which it belongs. Here it will be the ECET assessment model.
3. The *assessment's dimension name,* in this case it is the Environmental Footprint Expectation (EFE).
4. The *EFE descriptor* is a formalized descriptions of the EFE dimension in textual form, used to enhance the users' information about this dimension.
5. The *number of EFE constructs*. As it is presented in Section 4.3.3 the EML has six constructs extracted from nine factors.
6. Each constructs should have three attributes:
    a. The *Construct ID* runs automatically by the system and is used as a primary key for this construct.
    b. The *Construct text* describes the construct in textual form. In the ECET model, the constructs are represented as simple questions to be answered by normal users who do not have the field experts' knowledge.
    c. The *Construct answers,* a set of defined possible answers for the question mentioned in the *Construct text*.

The Technological Experience Level (TEL) assessment's dimension

As it was explained in Section 4.3.2, this dimension interprets the technological maturity level of the organization, and it has been investigated further on the level of domain expertise. Its variables are mostly related to technical issues of EMIS implementation, such as preferences in provisioning an EMIS and cultural and regional perspectives. As component, it consists of six main attributes:

1. The *assessment's dimension ID* runs automatically by the system, and can be used as a primary key.
2. The *assessment model ID* taken from the assessment model definition component. It references the assessment dimension to the assessment model to which it belongs. Here it will be the ECET assessment model.
3. The *assessment's dimension name,* in this case it is the Technological Experience Level (TEL).
4. The TEL *descriptor* is a formalized description of the EML dimension in textual form, used to enhance the users' information about this dimension.
5. The *number of TEL constructs*. As it is presented in Section 4.3.3 the TEL has four constructs extracted from five factors.
6. Each constructs should have three attributes:
    a. The *Construct ID,* which runs automatically by the system and is used as a primary key for this construct.
    b. The *Construct text* describes the construct in textual form. In the ECET model, the constructs are represented as simple questions to be answered by normal users who do not have the field experts' knowledge.
    c. The *Construct answers,* a set of defined possible answers for the question mentioned in the *Construct text*.

The ECET instance statement:

The ECET instance statement is a concrete quantitative set of information about a specific assessment's instance using the ECET model, and relates to an observed unit (entity) according to the assessment model definition. The statement includes information that qualifies how the model has been applied and fulfilled to support its aim by assessing the user's organization and leads to an appropriate interpretation and use of the quantitative data. ECET instance statement includes fore main attributes:

1. The *ECET instance statement ID* which runs automatically by the system and can be used as a primary key.
2. The *Organization or* unit *ID* which references the observed unit that has been assessed. This is extracted directly from the organization model (see Section 4.4).
3. The *assessment model ID* taken from the assessment model definition's component. It references the instance statement to the assessment model with which it complies (here is the ECET model).
    - Through this attribute, the user reaches the required assessment dimensions and runs an ECET analysis for his/her organization by going through the ECET dimensions' constructs (ADCs) and selects the appropriate answers. These answers are saved as numerical data values to be used in the analysis.
4. The *analysis result* displays the assessment analysis results in both textual and graphical forms.

Using the UML, Figure 36 illustrates the described ECET assessment model as a part of the LWC-EPI framework.

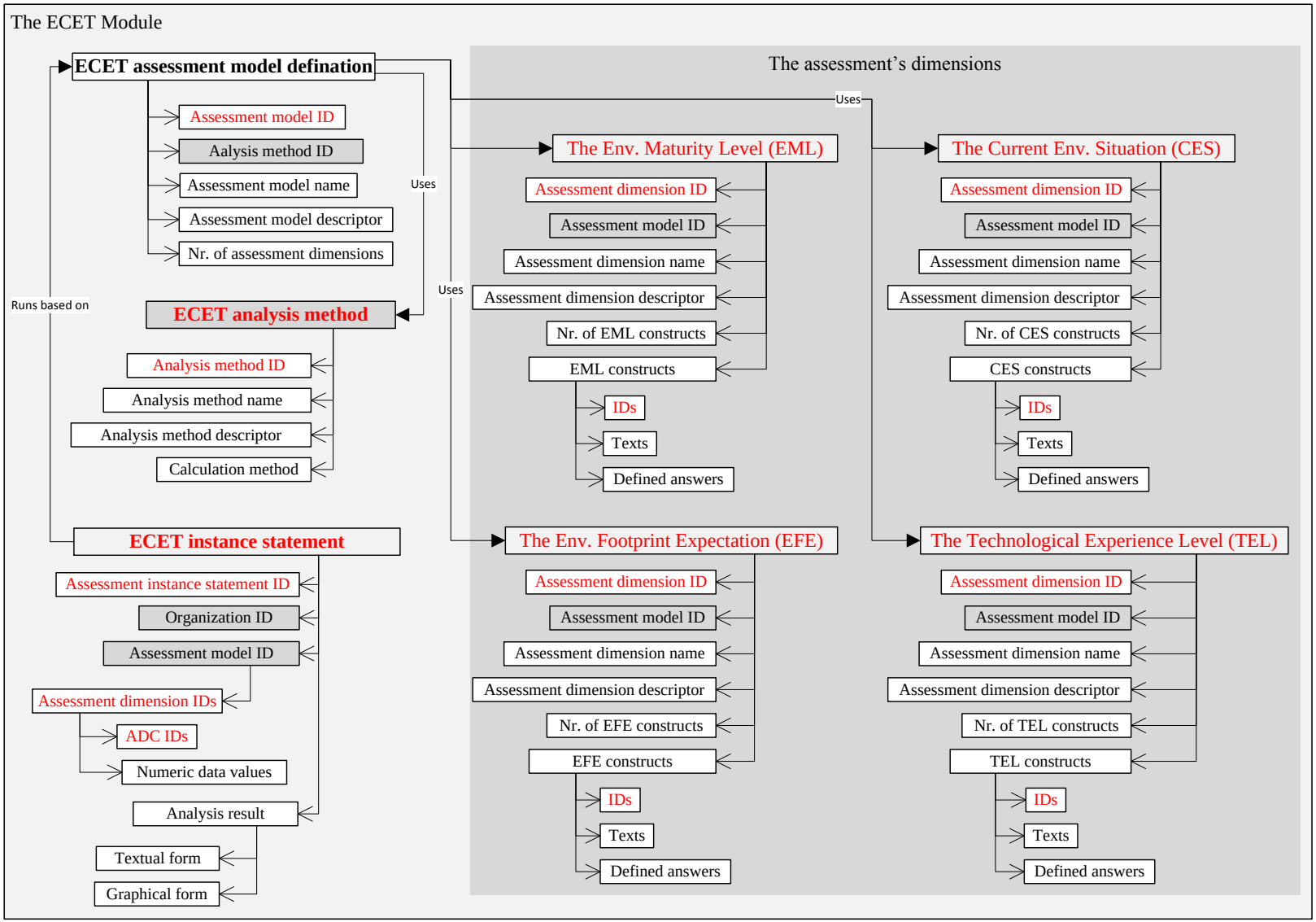


Figure 36: The ECET assessment module as part of the LWC-EPI framework

4.4 The Organization Model

The hierarchical model view of an organization is important in understanding the organization's decisions and processes flow. According to Kieser and Walgenbach, the organizational structure is a collection of systematic regulations used to manage and control the performance of an organization, and it is applied by its members to reach its objective (Kieser, et al., 2010 p. 21). J. Child mentioned three factors that affect the organizational structure: environment, technology, and size (Child, 1972 pp. 2-3). The Organizational structure guides the allocation of responsibilities in different functions and processes of different organization's entities, such as the branch, department, workgroup, and individual (Pride, et al., 2011 p. 504).

Although, it is not the main focus of this work, a simple conceptual organization model is part of the LWC-EPI framework. This model has been designed based on the common knowledge gathered from IT-solutions such as SAP® and OpenERP®[33]. The model has three main components:

- The organization definition
- The organization structure
- The organization instance statement

The organization definition:

Each organization should have a unique definition containing seven attributes:

1. The first attribute is the *organization ID* which runs automatically by the system and can be used as a primary key.
2. The *organization structure ID* imported from the organization structure component. It links the organization definition to the structure it uses.
3. Each organization has an identifying *name*.
4. Each organization has a *country* that it is located in.
5. Each organization belongs to a *business field,* such as IT-service, gastronomy, chemical industry, etc.
6. Each organization should have at least one *address*.
7. Each organization should specify its *number of employees*.

The organization structure:

Each organization should have a defined structure that can help in presenting its hierarchy. This component has six main attributes:

1. The *organization structure ID* which runs automatically by the system and can be used as a primary key.
2. The *organization ID* imported from the organization definition component. It links the organization structure to the organization to which it belongs.
3. Each organization has one or more identified *unit*. Each unit should be specified by four attributes:

[33] https://www.openerp.com/

a. The *unit ID,* unique and runs automatically by the system and can be used as unit's primary key
b. The *unit name,* such as Human Resource Dept., or Logistics unit, or City Centre point of sales etc.
c. The *unit descriptor* is a textual description written by the user (creator) to enhance the other users' information about the unit.
d. The *unit type*, can be:
    i. Organizational unit e.g. HR dept., Finance Dept., or CEO office, etc.
    ii. Physical unit e.g. production machine, transporter, furniture, etc.
e. The attribute named *hierarchy* shows the hierarchical dependencies between the company's units. It enables introducing flat, vertical, and complex organization's structure.

4. Each organization structure contains *positions* that belong to certain units and have defined tasks. It consists of six attributes:
    a. The *position ID* is unique, runs automatically by the system and can be used as position's primary key
    b. The *unit ID,* exported from the unit attribute and it links the position to the unit to which it belongs.
    c. *The task ID,* exported from the task attribute and it shows which tasks belong to this position.
    d. The *position name,* such as manager, driver, or designer.
    e. The *position descriptor* is a formal description of the position, written in textual form to enhance the users' information about it e.g. required skills and the job description.
    f. The *position resources,* describes the resources needed or used by this position. It could be a physical unit (e.g. laptop, car, or office) or a defined resource entered as text.
    g. The *position access right* specifies the position user's right based on the organization regulations.
5. For each organization should be more than one *task* which contains six attributes:
    a. The *task ID* is unique, runs automatically by the system and it can be used as task's primary key
    b. The *unit ID,* exported from the unit attribute and it links the task to the unit to which it belongs.
    c. The *task name,* it can be an action (drawing, selling, consulting, etc.) or a specific position (track driver, web designer, sales manager, etc.).
    d. The *task descriptor* is a formal description of the task, written in textual form to enhance the users' information about the task.
    e. The *task resources* define the resources needed or used by this task. This could be a physical unit so it can be expressed by the unit ID, otherwise it will be entered as text.
    f. The *task access right* specifies the task's user right based on the organization rules.
6. Each organization's employees are recognized as "*Personal"* by the system. The "*Personal"* has three attributes:

a. The *personal ID* is unique, runs automatically by the system, and can be used as personal's primary key.
b. The *position ID*, exported from the position attribute and links the "Personal" to his/ her position.
c. The *task IDs*, exported from the task attribute and link the "Personal" to the task he/she has. One employee can have more than one task and one task can have more than one personal.
d. The *Personal data* is set of data about the employee such as name, date of birth, address, contact, skills, etc.

Table 27 summarizes the organization conceptual model's components and attributes that will be used in the LWC-EPI framework and Figure 37 sketches the model using the UML as a modelling language.

Org. Component	**Attribute**	**Notice**
Organization definition	Organization ID	Primary key
	Organization structure ID	From the organization structure component
	Name	
	Country	
	Business field	
	Address	
	Nr. of employees	
Organization structure	Organization structure ID	Primary key
	Organization ID	From the organization definition component
	Unit	
	Position	
	Task	
	Personal	

Table 27: The components and attributes of the EPI module

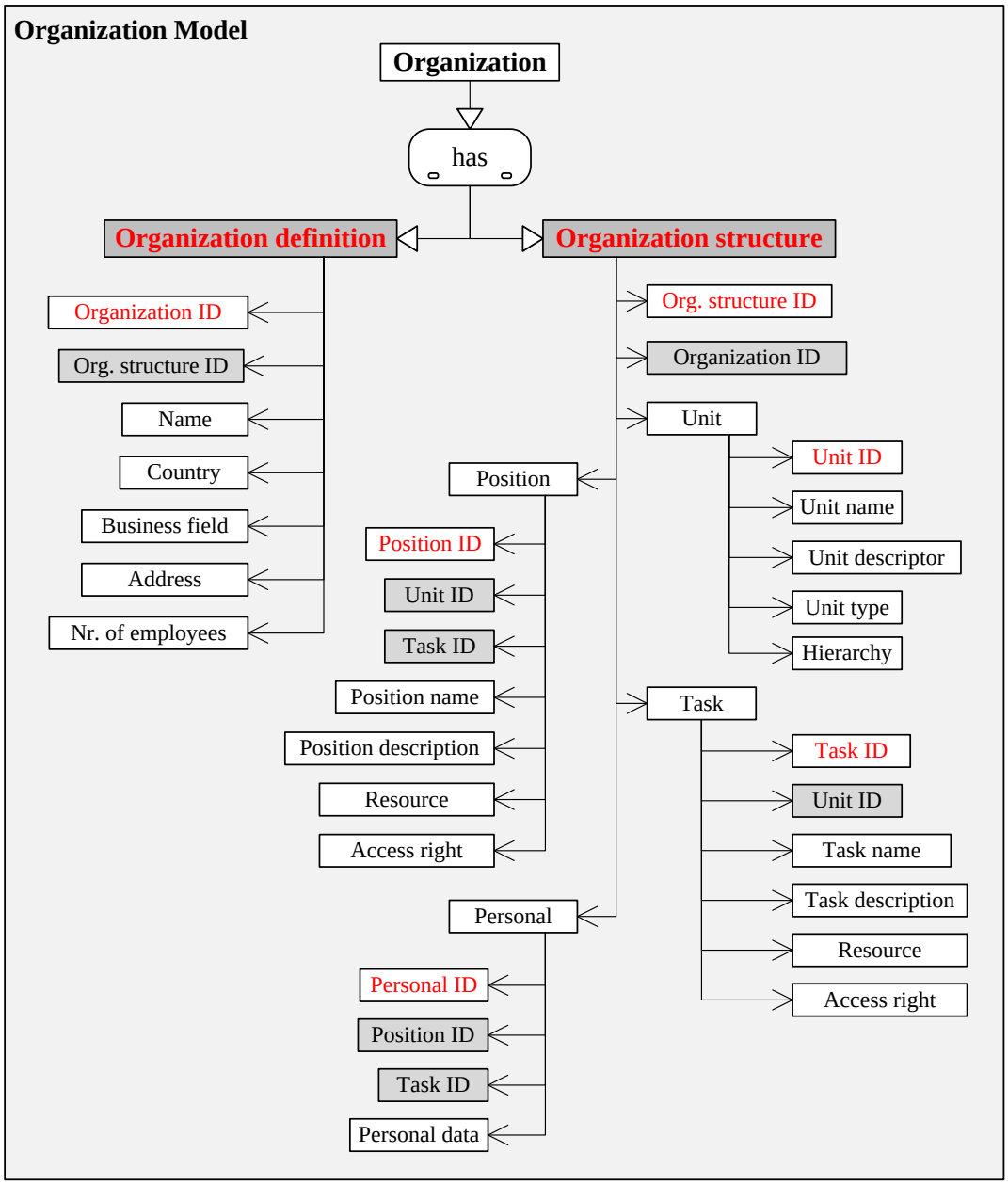


Figure 37: The conceptual organization model of the LWC-EPI framework

4.5 The EPI Model

Environmental Performance Indicators (EPIs) are the main data type examined by the environmental sustainability reporting and compliance management solutions. Today, thousands of EPIs are used in different business fields for a variety of purposes. These EPIs are the central assets for the LWC-EPI solution. Therefore, the LWC-EPI framework will contain an EPI model where all EPIs can be created or extracted, sorted, classified, and prepared to be used.

Understanding the origin of the indicators and how they were aggregated is an important factor to organize a set of indicators. Therefore, the resulting information, including connections between different issues, can be better understood (Jamous, et al., 2013-I pp. 4-5). Sorting indicators into categories will quickly show which issues are being covered and which issues have been overlooked. EPI structure, dimension, quality, and data type are the four main dimensions used by (Jamous, et al., 2013-I pp. 13-15) to build a comprehensive EPIs aggregation requirements' model, which will be followed in this work.

EPI structure:

An indicator framework is a way to organize a set of indicators. The Driver-Pressure-State-Impact-Response (DPSIR) list, used by the Environmental Protection Agency (EPA), the category or issue lists, followed by GRI, and the goal-indicator matrix are some sorting criteria that can be followed. Other EPIs' structures combine the category or issue based approach with the system boundary approach e.g. the input/output streams used by (Jasch, 2000 pp. 84-85) presented in Figure 38. Furthermore, the differentiation between Management Performance Indicators (MPIs) and Operational Performance indicators (OPIs) is commonly used (see A.8).

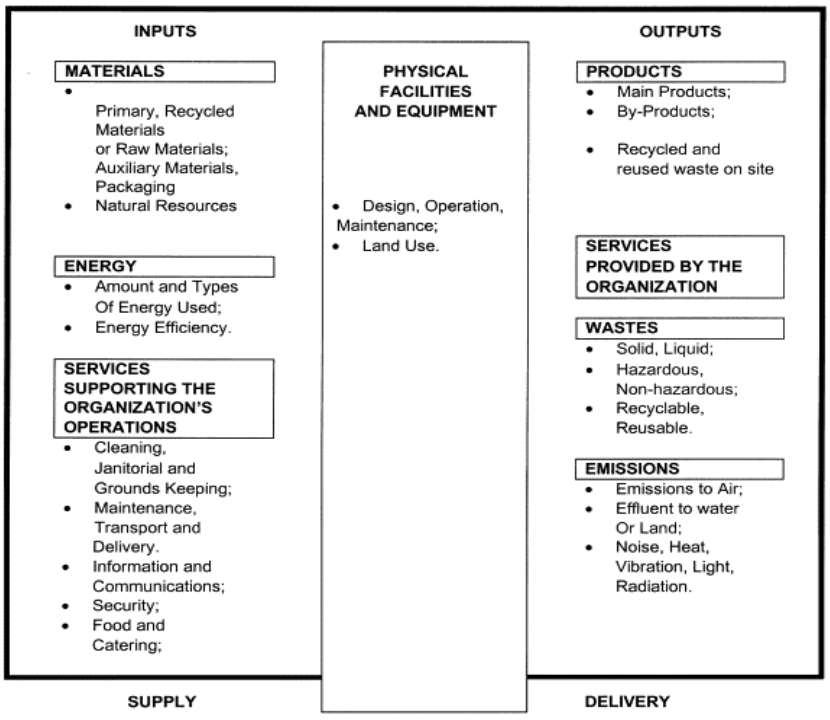


Figure 38: The organization's operations adopted from ISO/DIS 14.031 (Jasch, 2000 pg.84)

EPI dimension:

Based on the findings of the literature studies, presented in Section 3.2 of this work, in (Jamous, et al., 2013-I), in (Jasch, 2000) and other research works, EPIs have five different dimensions:

- Absolute indicators: usually extracted from an input–output analysis. These indicators have base units such as tons of raw material, emissions, or liters.
- Relative indicators: These indicators present values in reference to other variables such as water per liter, detergent per m^2, or Silver per piece.
- Indexed indicators: where Figures are expressed as a percentage with respect to a total, or as a percentage change to values of previous years etc.
- Aggregated depictions: from their names, these indicators represent Figures of the same base unit gathered and summed over more than one production step or product life cycle.
- Weighted evaluations: These indicators illustrate figures of varying importance by means of conversion factors.

EPI quality:[34]

EMSs such as ISO14040, ISO14025, or GHG protocol use five accounting and reporting principles to ensure the indicators' quality:

- **Relevancy:** each EPI's description should indicate its environmental aspects, the environmental problem that it measures, and the relevancy to the decision-making needs of users – both internal and external.
- **Completeness:** Based on its description, the EPI should cover all the activities within the chosen inventory boundary.
- **Consistency**: Consistent methodology should be reserved in calculating or processing the EPI to allow useful comparisons over time.
- **Transparency**: EPI's description should address all relevant issues in a factual and coherent manner, such as the origin of the EPI, the calculation method used, the data source used, geographical coverage, and the timeframe.
- **Accuracy:** This principle focus on ensuring that the EPI value is as accurate as far as the measurement tools and technologies can guarantee. This will enable decisions makers to rely on data with a reasonable level of accuracy, where uncertainty is reduced as far as possible.

EPI data types:[35]

Organizations collect EPIs' data for organizational accounting, or product lifecycle accounting (Jamous, et al., 2013-I p. 15). As for the data types collected for organizational accounting, the following hierarchy has been observed:

- Primary data:
  - Product-level data
  - Process-level data
  - Facility-level data
  - Business-unit data

[34] This paragraph is based on (Jamous, et al., 2010-II), for more details please see the appendix A.9

[35] This paragraph is based on (Jamous, et al., 2010-II), for more details please see the appendix A.10

- Corporate-level data
- Secondary data
- Extrapolated data
- Proxy data

As for the data types collected for product lifecycle accounting, it has the following hierarchy:

- Primary data, which can be:
  - Measured data
  - Calculated data
  - Estimated data
- Secondary data
- Process data
- Input-Output data
- Extrapolated data
- Proxy data

Figure 39 is a graphical representation of the four dimensional model used to build a comprehensive understanding of EPIs aggregation requirements, as it has been explained in the previous paragraph. This model, together with its Metadata represented in appendixes A.8, A.9, and A.10, help any user to better understand, use, or create an EPI.

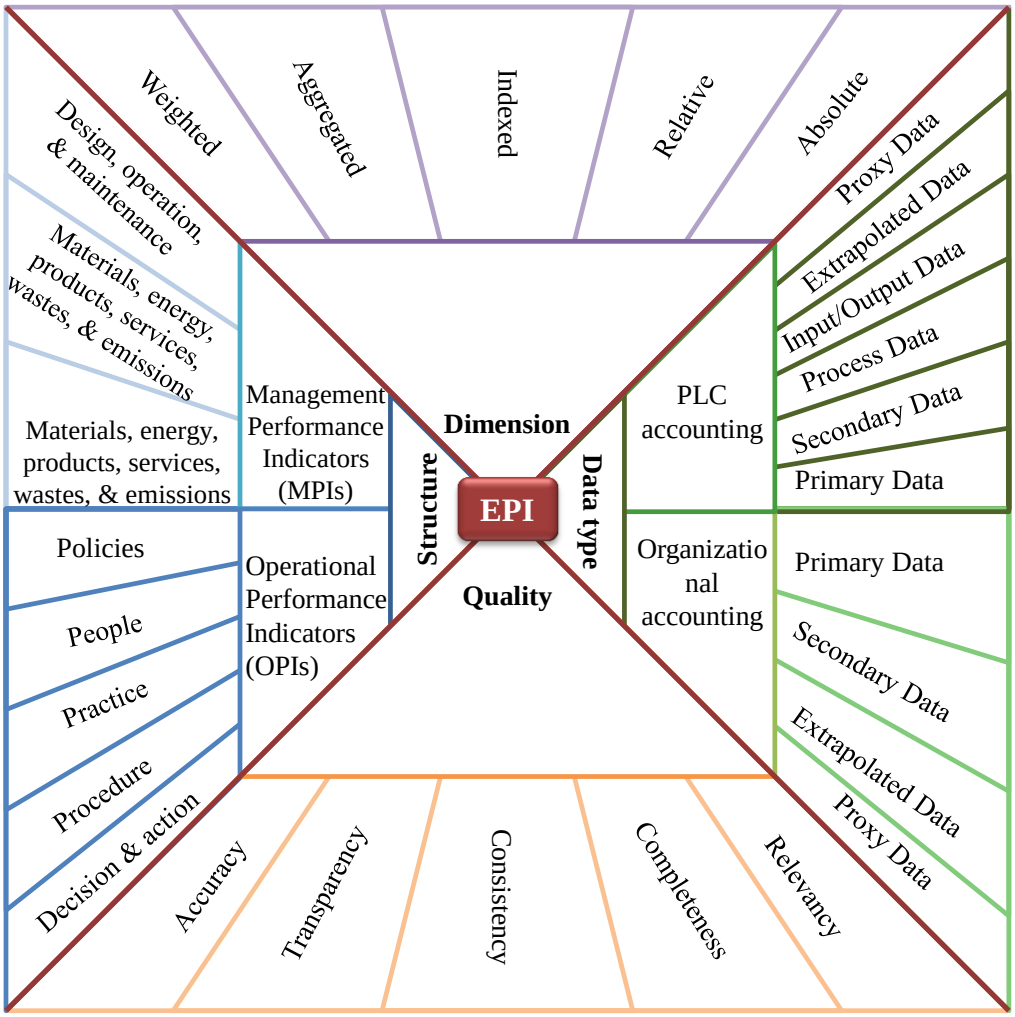


Figure 39: A comprehensive EPI aggregation requirements model

Determining a meaningful use for the variety of unstructured and unrelated EPIs that originate from various sources, and which resulted from different collection or calculation methods with a huge diversity of underlying assumptions and modelling decisions, is a challenging task. For this, there is a need to create a deep "common understanding" concerning the semantics of data, such as their origin, applicability, and comparability in business use cases (Löschner, 2013 p. 85). This step can help to ensure the proper use of the data by any business user, without having the environmental sustainability expert knowledge. For this, the EPI- model will use the *OEPI domain ontology* proposed within the framework of the OEPI project (OEPI, 2010).

The *OEPI ontology* aims "to provide sufficient concepts and a formalism to describe environmental data with their relevant aspects in a common, computer-readable way." (Löschner, 2013 p. 86). This can enable proper access, use, and interpretation of the data in the EMIS solutions. The *OEPI ontology* was inspired by known methodologies such as the publications of Uschold and King (Uschold, et al., 1995), Grüninger and Fox (Grüninger, et al., 1995), (Staab, et al., 2001), and Noy and McGuinness (Noy, et al., 2000), all cited in (Löschner, 2013). It was derived in two steps: extracting the requirements phase and the design phase. First, the requirements were gathered from the environmental sustainability experts. Table 28 presents the main attributes of *OEPI ontology* requirements that were used to describe OEPI ontology requirements. They were selected in order to foster discussion, track the background information, and to ensure knowledge exchange.

Attribute	Explanation / examples
ID	XXXXXXX / 0000001
Project	Ontology/Platform/User requirement
Date Submitted	20XX-MM-DD at hh:mm
Last Update	20XX-MM-DD at hh:mm
Reporter	Name of person (expert)
Priority	high – normal - low
Status	proposed - assigned
Assigned To	name of person (expert)
Summary	short description
Description	full description
Type	functional - non-functional
Reason	Rationale
Source	reference to external document
Links	reference to web resource
Notes	Discussion

Table 28: The main attributes of OEPI ontology requirements (Löschner, et al., 2011 p. 22)

In the two phases (the requirements capture, and the analysis), the requirements were classified, interrelated, and then split to usable size entities. As a final result, 49 requirements were derived as it is shown in Table 29 hereafter.

Nr.	Summary
1	Provide concept for definition of Environmental Performance Indicators
2	Support data source integration (semantics)
3	Support DPSIR classification of EPI definitions (Driving force, Pressure, State, Impact, Response indicator)
4	Support consumption and reduction types of EPI values
5	Support specification of covered lifecycle stage(s) for EPI values
6	Support specification of data collection method of EPI values
7	Support quality rating of EPI values by quality aspects and rating values
8	Provide references to normative documents for EPI definitions
9	Support usage directives for EPI definions
10	Support hierarchical composition of EPI definitions
11	Support classification of required/optional EPI for industrial sectors or products
12	Ensure usability for intended ontology users
13	EPI may specify deviation rate / signaling threshold
14	Support modelling of information transmission
15	Support handling of information trigger
16	Compliance with taxonomy
17	Support absolute and relative EPI values
18	Support mapping to / integration of EPI standards
19	Represent stakeholder groups (e.g. Creator, Owner, Quality rater)
20	Support guidelines for measurement
21	Support selection of measurements
22	Support specification of calculation rules for EPI values
23	Support specification of EPI-related parameters that can be used in search queries
24	Support concept for compatibility of EPIs
25	Support concept for specification of assumptions related to EPI values

Nr.	Summary
26	Support impact categories with different levels (world, industry, organization, ...)
27	Include related environmental aspect in EPI definition
28	Include possible EPI unit(s) matching enviromental aspect in EPI definition
29	Describe “scope” in the sense of “what is included” in EPI definition
30	Support specification of data origin of EPI values
31	Support specification of the creator of an EPI definition
32	Support description of the methodology how an EPI value can be determined
33	Support aggregation of EPI values in a specified time range
34	Support concept of comparability of EPI values
35	Support specification of “uncertainty” as part of data quality
36	Support international use
37	Support specification of reporter of EPI quality
38	Support description of time scope for EPI values (measurement period)
39	Support specific levels of primary data for product EPI (product, facility, organization)
40	Support different GHG scopes of organizational EPI values
41	Support specification of applied allocation principles in EPI value calculation
42	Support specification of applied allocation principles for GHG scope 3
43	Support specification of base unit of relative EPI values
44	Support relative EPI values with respect to other EPI values
45	Support material efficiency as product or process EPI
46	Provide concept to describe to which object an EPI value is related
47	Support specification of an owner of related object of EPI value
48	Support specification of input aspects of EPI (energy, water, material, ...)
49	Support specification of output aspects of EPI (emissions, liquid waste, solid waste, etc.)

Table 29: The OEPI ontology requirements (Löschner, et al., 2011 p. 24)

Based on the gathered requirements, the ontology design phase started with concept definition’s activity, followed by an iterative process of ontology design. The concept definition extracts all concepts from the requirements definition that have to be represented in the ontology, and provides a glossary with a description for every concept. This glossary was reviewed by environmental sustainability domain experts. The iterative ontology design

repeats activities to define and to review the *OEPI ontology* until the documented requirements were met. For the definition of the ontology the guideline provided by (Noy, et al., 2000) has been used, and the review process of the ontology included the domain experts as well as the developers of the *OEPI platform and services* (Löschner, et al., 2011 p. 94).

The core concept of the OEPI ontology is represented using a combination of EPI statement and EPI definition. The *EPI statement* represents the concrete occurrences (the data), and the *EPI definition* captures the underlying meaning and rules associated with one kind of EPI. The *EPI data source* is used to trace the origin of the EPI statement as an EPI data evaluation step. Figure 40 represent this core concept (Löschner, 2013).[36]

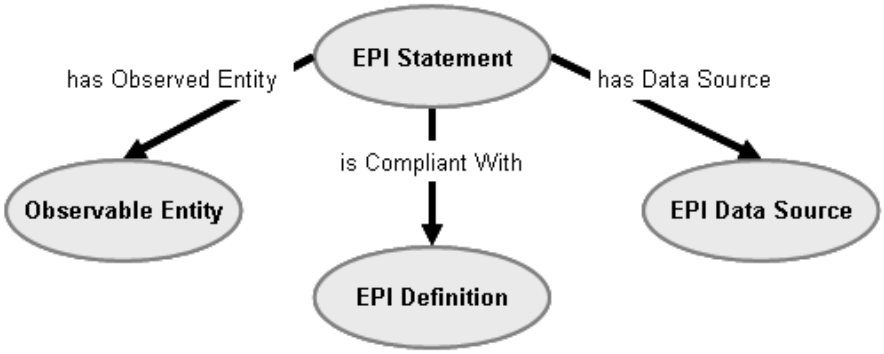


Figure 40: The core concepts of the OEPI ontology (Löschner, 2013 p. 90)

The LWC-EPI framework will contain a comprehensive EPI model, built based on the previous findings in Section 2.1, 2.2, and this section together with the knowledge extracted from the OEPI ontology. This model consists of four components:

- The EPI definition
- The EPI classifier
- The EPI instance statement
- The EPI evaluator

Figure 41 sketch the EPI model's concept and its components.

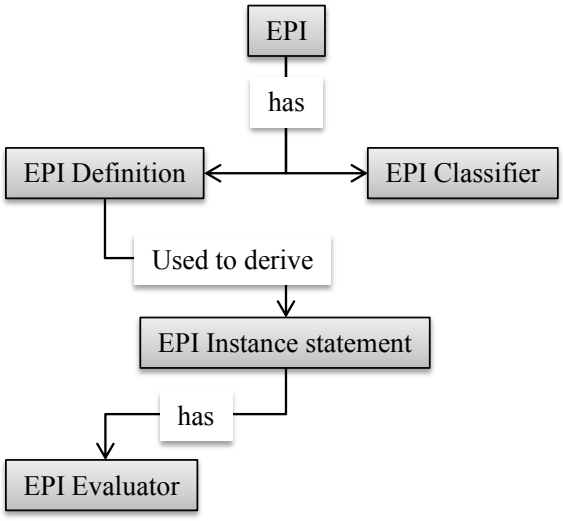


Figure 41: The EPI module's concept in the LWC-EPI framework

[36] For more detail about the OEPI Ontology please check (Löschner, et al., 2011) and (Löschner, 2013)

The EPI definition:

Each EPI should have a unique definition containing seven attributes.

1. The first attribute is the *EPI ID* which runs automatically by the system and it can be used as a primary key.
2. The *EPI classifier ID* taken from the EPI classifier component. It references the EPI to the EPI class to which it belongs.
3. Each EPI should have a *name*, such as Energy Expense per Capita, Waste Water Disposal per Capita, or Total Quantity of Electronics Equipment Recycled per Year. Names can be entered as strings in the databases, and it is always better to use a common name used in EMSs such as EMAS or ISO 14001.
4. In general, each EPI definition should include a *reference document* clarifying which EMS, law, protocol, guideline, initiative, etc. it relates to. In case that the EPI is created internally by the organization for a specific purpose, this should be mentioned too.
5. The fourth attribute of the EPI definition, is a *textual description of the EPI*. This can either be extracted from the reference document or manually entered by the user. It helps internal or external users who do not have expert knowledge to better understand the EPI.
6. The *EPI's calculation equation* together with its settings should be stated. For example, calculating the emissions from energy sources using the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (Waldron, et al., 2010):

$$Emissions = \sum_j (Fuel_{ij} * EF_j)$$ (Waldron, et al., 2010)

- Emissions = Emissions (kg)
- $Fuel_j$ = fuel consumed (as represented by fuel sold) (TJ)
- EF_j = emission factor (kg/TJ)
- j = fuel type

Another example is to calculate the Vehicle Specific Power (VSP) that is used in calculating GHG emissions of a transporter using the MOVES (Motor Vehicle Emissions Simulator) (Matute, 2010):

$$VSP = (a(1+\varepsilon) + g * grade + g * C_R) + 2\rho * C_d * A * {}^{v^3}/_{m}$$

- VSP : Vehicle Specific Power
- v is vehicle speed (assuming no headwind) in m/s
- a is vehicle acceleration in m/s2
- ε is mass factor accounting for the rotational masses
- g is acceleration due to gravity
- grade is road grade
- C_R is rolling resistance
- ρ is air density
- C_D is aerodynamic drag coefficient
- A is the frontal area
- m is vehicle mass

7. The EPI's *values units*, to mention the possible units of the EPI, such as liter, meter, Kw/hr, or Emissions (kg) as in the previous example.

The EPI classifier

The EPI classifier characterizes each EPI in the equivalent class, where a class can contain more than one EPI, but an EPI belongs to exactly one class. It is built based on the environmental domain knowledge, which has been captured during the previous analysis. The EPI classifier describes relevant EPI's elements to decompose it into atomic characteristics with predefined possible values or ranges in order to provide a uniform and formalized description mechanism for different systems. It is composed of seven attributes:

1. The *EPI classifier ID* runs automatically by the system, and can be used as a primary key.
2. The EPI *Environmental aspect* determines one of eight predefined environmental aspects that the EPI covers. The predefined aspects are:
    a. energy consumption
    b. material consumption
    c. water consumption
    d. emissions
    e. liquid waste
    f. solid waste
3. The *EPI's Business field* specifies in which business field/s can this EPI used, e.g. IT-service, gastronomy, and chemical industry. An EPI can be general and applicable in more than one business field, or it can be specific for a certain field.
4. The *DPSIR category* which assigns the EPI to one category of the DPSIR framework (driving force, pressure, state, impact, response).
5. The *EPI's level aspect* shows on which layer the EPI will be applied. The user can choose one of four predefined levels:
    a. Product level
    b. Process level
    c. Unit level
    d. Corporate level
6. Each EPI has one or more impacts on the environment. The *EPI Impact* determines the categories of the environmental impact quantified by the EPI, such as global warming, acidification, eutrophication, or ozone depletion. In addition, it mentions if it is a direct or indirect impact.
7. The *EPI Equivalence* describes a potential equivalent substance that can be used to express the combined impact related to the EPI, for example, carbon dioxide or nitrous oxide equivalents. Another possibility is that it identifies a specific contribution to the EPI impact, for example: carbon dioxide, hydro fluorocarbon, or methane. Another option can be the Greenhouse gas (GHG) protocol scope which can be used for related GHG's EPIs. Here one of the predefined GHG scopes 1, 2, or 3 can be selected.

The EPI instance statement:

The EPI instance statement is a concrete quantitative set of information about a specific EPI's instance, and relates to an observed unit according to the EPI definition. The statement includes information that qualifies how the definition has been applied and fulfilled to support the appropriate interpretation and use of the quantitative data. In other words, it is a specialization of a general EPI definition and EPI classifier. EPI instance statement consists of seven attributes:

1. The *EPI instance statement ID* which runs automatically by the system and can be used as a primary key.
2. The *EPI ID* taken from the EPI definition component. It references the EPI instance statement to the EPI definition with which it complies.
3. The unit *ID* which references the observed unit that has been assessed. This can be taken automatically from the organization structure model if it is available.
4. The *numeric data item* representing the quantitative value of the EPI instance statement.
5. The *obtain time* attribute is a time statement references the time period when the quantitative value has been obtained.
6. The *EPI's owner* should be mentioned, e.g. an employee, a unit, or a department. The owner is, by default, the user who creates the EPI, and he will be able to change the users' rights.
7. The *EPI privacy* specifies if the EPI refers to specific group such as stockholders, the human resource units, or it is a public EPI.

The EPI Evaluator:

The main concept of the EPI Evaluator is to assess the different qualitative aspects of one *EPI instance statement*, focusing on the data and methods used to derive it. Therefore, it should support in evaluating the relevancy, completeness, consistency, transparency, and accuracy of the *EPI instance statement* and its data quality. In addition, the EPI Evaluator can provide information for inferring validity or applicability of the data in specific use cases. Furthermore, to gain more credibility, the evaluator's writer or reporter should be mentioned. The EPI Evaluator composed of seven attributes according to the requirements of domain experts:

1. The *Evaluator ID* which runs automatically by the system and can be used as a primary key.
2. The *EPI instance statement ID* taken from the EPI instance statement component. It references the EPI evaluator to the EPI instance statement with which it complies.
3. The *EPI instance statement's reporter* should be mentioned, e.g. an employee, an extern expert, or an official agency. The default will take the user who runs the instance, and this can be changed
4. The *Data calculation method* describes which calculation method have been used to obtain the data value. for example:
    - Average values: applied on a defined sample of values with a given specification.
    - Weighted values: use a specific factor to express the importance of each value.

- Aggregated values: used for figures of the same kind, aggregated according to some rule or formula.

5. The *Data collection method* describes relevant information about the data collection method used to acquire the data value. Based on the previous findings, organizations can apply the following hierarchy of data types in collecting data:
   - Primary data: used in organizational accounting and product life cycle accounting. It is direct measurements or collection of activity's data from specific sources within the organization's operations, or a specific process related to a specific product manufactured by a company or another company in its supply chain. When collecting primary data from value chain partners, organizations should obtain the most product-specific data available, according to the following hierarchy:
     - Product-level data
     - Process-level data
     - Facility-level data
     - Business unit-level data
     - Corporate-level data
   - Secondary data: used in organizational accounting and product life cycle accounting. It is data that are not measured or collected directly from specific sources within the organization but rather from external source such as industry averages, data published in databases, in literature studies, or in official's reports. Secondary data may be process data or non-process data.
   - Extrapolated data: used in organizational accounting and product life cycle accounting. It can be primary or secondary data extracted from data related to a similar process, input, or activity, and then customized or adapted to a different case to make it more representative. For example, by customizing the data extracted from similar process to the relevant period of time.
   - Proxy data: used in organizational and product life cycle accounting. It can be primary or secondary data extracted from data related to a similar process, input, or activity, and then directly transferred or generalized to a different case to make it more representative.
   - Process data: used only for product life cycle accounting and it is a physical flow data associated with an individual process within a defined system boundary. Process data may consist of site specific primary data, generic or average secondary data, secondary data from literature studies, expert estimations, or impact assessments
   - Input-Output data: This data type used just for product life cycle accounting. It is non-process data derived from an environmentally extended input-output analysis (IOA). The IOA method used to allocate environmental impacts such as CO2 or GHG emissions. It is associated with upstream production processes to groups of finished products by means of inter-industry transactions. Surveys and questionnaires are the main data sources for the IOA.
6. The *certifier* indicates the external certification or validation of the collection method if it is available (e.g. ISO 14001 certified). In addition, it can mention the

environmental impact assessment (EIA) method that has been applied to obtain the EPI instance statement's data.

7. The *data qualifier* indicates the data quality used to express the EPI instance statement. The data qualifier contains five indicators:
    - Technological representativeness: used for both primary and secondary data, and it measures to which degree the datasets have reflected the actual technologies.
    - Time representativeness: used for both primary and secondary data. It measures to which degree the data sets have reflected the actual time or age of the activity or the processes investigation. Another option is to examine whether an appropriate time period is used, e.g. for textile products annual/seasonal averages or average of several seasons may be appropriate to smooth out data variability due to factors such as weather conditions.
    - Geographical representativeness: used for both primary and secondary data. It measures to which degree the datasets have reflected the actual geographic location of the activity or the processes under investigation.
    - Completeness: applied for primary data. It measures to which degree the datasets have represented the relevant activity, process, or product. The percentage of locations for which site specific or generic data are available and used out of the total number that relate to a specific activity, process, or product.
    - Precision: used for primary data. It measures the variability of the data points used to derive the environmental impact e.g. GHG emissions from an activity or process (Jamous, et al., 2010-II p. 26).
    - Data source evaluator: used to evaluate the data source used to derive the EPI instance statement. It reply the following questions:
        - How long has the data source existed already?
        - How long has its provider been in business?
        - How extensively has the database been used?
        - How frequently is the database updated?
        - Can uncertainties be estimated for the data?

Table 30 summarizes the EPI model's components and attributes to be used for the LWC-EPI framework and Figure 42 sketches the model following the UML as modeling language.

EPI Component	Attribute	Type	Notice
EPI Definition	EPI ID	M	Primary key
	Classifier ID	M	From the EPI classifier
	Name	M	
	Reference document	O	
	Textual description	M	
	Calculation equation	M	
	Value's units	M	
EPI Classifier	Classifier ID	M	Primary key
	Environmental aspect	M	
	EPI's Business field	M	
	EPI's level aspect	M	
	DPSIR category	M	
	Impact	M	
	Equivalence	O	
EPI Instance Statement	EPI instance statement ID	M	Primary key
	EPI ID	M	From the EPI definition
	unit ID	M	From the Organization Module
	Numeric data item	M	
	Obtain time	M	
	Owner	M	
	Privacy	O	
EPI Evaluator	Evaluator ID	M	Primary key
	EPI instance statement ID	M	From the EPI Instance Statement
	Reporter	M	
	Data calculation method	M	
	Data collection method	M	
	Certifier	O	
	Data qualifier	O	
* M = Mandatory		**O = Optional	

Table 30: The components and attributes of the EPI module

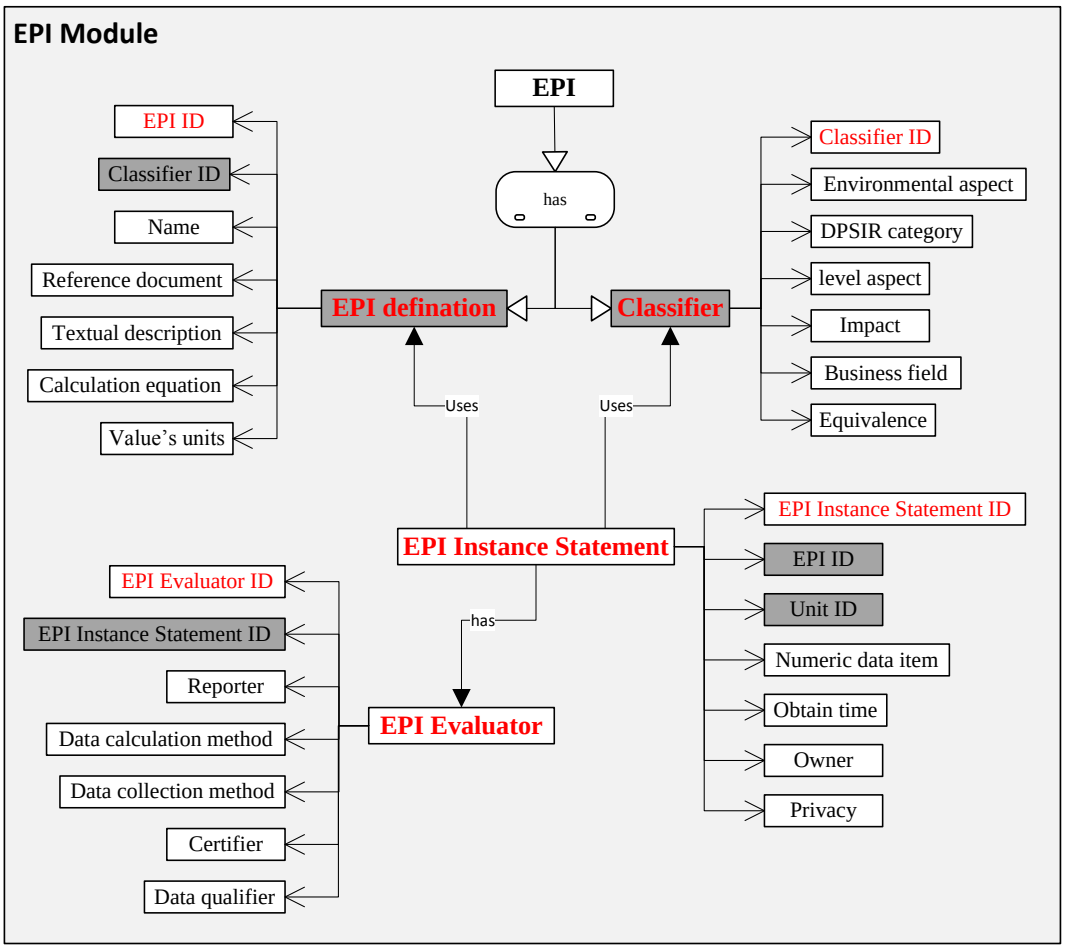


Figure 42: The conceptual EPI module of the LWC-EPI framework

4.6 The Data Model

Information Systems such as Enterprise Resource Planning (ERP) or Customer Relations Management (CRM) Systems offer solutions that support most of the business processes in an enterprise. Outcome data from business processes are processed by the ERP-system and saved/stored in a central database. In most cases, this data is more relevant to business economics and does not pertain to environmental indicators directly.

Keeping in mind the main goal of the LWC-EPI framework, the concept of the LWC-EPI data model combines the operational databases of the enterprises together with outsource-data, for example the specialized databases spread over the internet. This model consists of three components:

- The data sources
- The data processor
- The data container

The data source:

The main concept of the data source is to represent the source of the data (operational, environmental, etc.) which has been or can be accessed to originate an *EPI instance statement*.

Providing enough information about the data source supports an effective and appropriate use of the data. For example, presenting common data characteristics of all retrieved data from the same source can enable the user to maintain these data once instead of replicating them for each single *EPI instance statement*. The data source component composed of four attributes:

1. The *Data source ID* which runs automatically by the system and can be used as a primary key.
2. The *EPI instance statement ID* taken from the EPI instance statement component. It references the data source to the EPI instance statement for which it is used. In addition, it links the data model with the EPI model.
3. The *Data source name* such as the enterprise OLTP system, or an external source such as the European reference Life Cycle Database (ELCD). Names can be entered as strings in natural language in the databases, and it is always better to use a clear common name.
4. *The Data source textual descriptor* is a formalized description of the data source. It can either be extracted from the reference document or entered manually by the user by means of a reference to the used data source. This enhances the users' information about the data source such as the access type (URL, protocol, formats, etc.), legal information (owner, terms of use, etc.).

The data processor:

The main concept of the data processor is to represent and document how the data was managed and which steps have been or can be taken to deliver the requested output. This systematic data processing documentation enables the system and the users to better understand, manage, trace, and control these processes.

The data processor component is composed of eight attributes:

1. The *Data processor ID* which runs automatically by the system and can be used as a primary key.
2. The *Data source ID* taken from the Data source component. It connects the data processor with all the data sources needed by the process. Here, it is important to note that a data processor can contain more than one data source ID. This can be defined automatically by the system or manually by the user.
3. The *Data processor textual descriptor* is a formalized description of the data processor. It can either be entered manually by the user by means of a reference to the used data processor or extracted from the system based on its previous knowledge. This attribute enhances the users' information about the data processor.
4. The *Data processor hierarchy* states if the process is main or sub-process. In the case that it is a sub-process, the *Data processor ID* of its main process should be mentioned.
5. The *Data processor type* determines one of the predefined types which the system can support. For example, data processor type can be:
    a. acquire
    b. extract
    c. configure
    d. transform
    e. integrate
    f. load, etc.
6. The *Data processor timer* is a time statement that indicates the starting and ending time and date of the process.
7. The *Data processor value item* represents the output value of the data process. This value can be numerical or textual.
8. The *Data container ID* where this value will be saved should be mentioned. This attribute is taken from the data container component (will be explained hereafter), and connects the data processor with the data container.

The data container:

The main concept of the data container is to identify where do the processed data stored and in which form. This component is composed of four attributes:

1. The *Data container ID* which runs automatically by the system and can be used as a primary.
2. The *Data container name* such as the database name, or the table name. It can be entered as string in natural language.
3. The *Data container descriptor* is a formalized description of the data container in normal language.
4. The *Data container type* determines one of predefined types which the system can support, such as data cubes (in case of using data warehouse) or normal tables.
    a. In case the type is table, then the table's characteristics should be specified, such as columns, rows etc.
    b. In case it is a data cube, then its characteristics should be specified, such as fact or dimension table. If it is dimension table, then the fact table with which it is connected should be stated.

Table 31 summarizes the data model's components and attributes to be used for the LWC-EPI framework. Using the UML as a modeling language, Figure 43 sketches the model.

Data Component	Attribute	Type	Notice
Data source	Data source ID	M	Primary key
	EPI instance statement ID	M	From the EPI Module
	Data source name	M	
	Data source textual descriptor	M	
Data processor	Data processor ID	M	Primary key
	Data source ID	M	From the data source
	Data container ID	M	From the data container
	Data processor textual descriptor	M	
	Data processor hierarchy	M	
	Data processor type	M	
	Data processor timer	M	
	Data processor value item	M	
Data container	Data container ID	M	Primary key
	Data container name	M	From the EPI definition
	Data container textual descriptor	M	
	Data container type	M	
* M = Mandatory		**O = Optional	

Table 31: The components and attributes of the data module

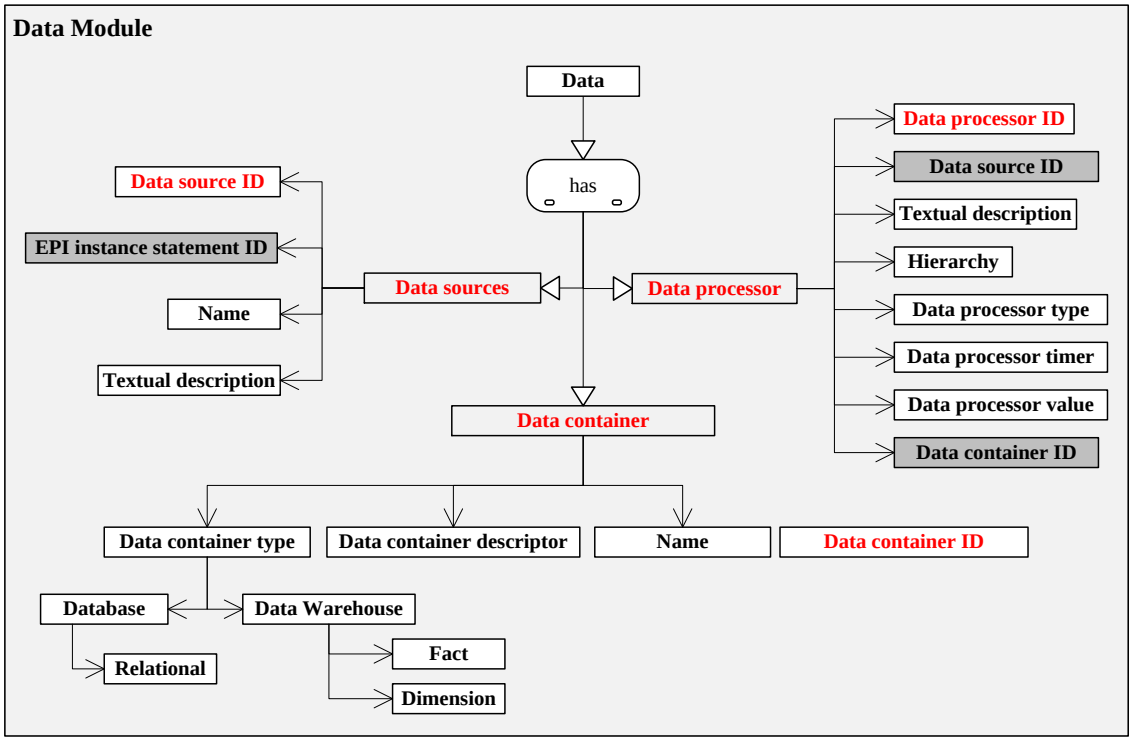


Figure 43: The conceptual data module of the LWC-EPI framework

4.7 The Report Model

A report is where the calculated values and the analysis result are visualized and presented to an end user. The following report conceptual model has been designed based on the common knowledge gathered from IT-solutions such as Gabi®, SAP®, SimaPro®, and OpenERP®, as well as from the main requirements of EMSs and environmental reporting standards, such as ISO 14000 series, the GRI, and the EMAS that have been presented in Chapter 3. The model has three main components:

- The report definition
- The report instance statement
- The report evaluator

The report definition:

Each report has a unique definition containing four attributes:

1. The first attribute is the *report ID* which runs automatically by the system and can be used as a primary key.
2. Each report has a *name*.
3. Each report has a *descriptor* that explains the aim of the report and its specifications in a textual form.
4. The report *template* represents a layout showing the report structure and what it contains.
5. Each report has *evaluation criteria* that explain how the report can be evaluated or ranked.

The report instance statement:

The report instance statement is a concrete, quantitative set of information about a specific report's instance and relates to a certain unit in a specified organization. Mainly, it visualizes selected EPI's calculation results in the appropriate template in accordance with the report definition. The report instance statement consists of eight main attributes:

1. The *report's instance statement ID* which runs automatically by the system and can be used as a primary key.
2. The *report ID* taken from the report definition component. It links the report instance statement to the report definition with which it complies.
3. The *organization ID* which references the recognized user's organization. It is extracted from the organization model.
4. The *unit ID* which references the observed unit to be assessed. It is extracted from the organization model.
5. The *time period* attribute is a statement that specifies the time space of the report, and it can have different forms, e.g. March 2012 to August 2013 or the 12th of July 2014.
    - In accordance to the time period, the system can retrieve all the relevant *EPI instance statements* and make its *numeric data item* available.
6. The *report instance statement's owner* should be mentioned, e.g. an employee, a unit, or a department. The default will take the user who runs the instance, and this can be changed.

7. The *report instance statement privacy* states to whom the statement refers, e.g. specific group (such as the managers, the stockholders, or the human resource units), a public report, or it is for a governmental agency, etc.
8. The *report instance statement form* specifies the report form e.g. the layout, graphical form, textual form, etc.

The report instance statement evaluator:

The main concept of the evaluator is to assess the different qualitative aspects of one *report instance statement*, focusing on the data and methods used to originate it. As for the EPI evaluator, the report instance statement should support evaluating the relevancy, completeness, consistency, transparency, and accuracy of the instance statement and its data quality. In addition, to gain more credibility, the reporter should be mentioned. The component composed of five attributes:

1. The *report instance statement evaluator ID* which runs automatically by the system and can be used as a primary key.
2. The *report instance statement ID* derived from the report instance statement component to reference the evaluator to the instance statement which it evaluates.
3. The *report instance statement's reporter* should be mentioned, e.g. an employee, an extern expert, an official agency, or an NGO. The default will take the user who runs the instance, and this can be changed.
4. The *report instance statement's certifier* indicates the reporting standards that have been followed e.g. (GRI, EMAS, ISO 14042), if it is available. In other case, it can be mentioned that the organization used its own standard.
5. The *report instance statement's qualifier* indicates the data quality presented in the report. For example, this can be the attribute where it ranks the report based on the previous attribute in this component.

Table 32 summarizes the report model's components and attributes to be used in the LWC-EPI framework and Figure 44 represent the model as an UML model.

Report Component	Attribute	Type	Notice
Report definition	Report ID	M	Primary key
	Name	M	
	Descriptor	O	
	Template	M	
	Evaluation criteria	M	
Report Instance Statement	Report instance statement ID	M	Primary key
	Report ID	M	From the report definition
	Organization ID	M	From the Organization Module
	Unit ID	M	From the Organization Module
	Time period	M	
	Owner	M	
	Privacy	O	
	Form	M	
EPI Evaluator	Report instance statement evaluator ID	M	Primary key
	Report instance statement ID	M	From the report Instance Statement
	Reporter	M	
	Certifier	O	
	Report qualifier	M	
* M = Mandatory		**O = Optional	

Table 32: The components and attributes of the report conceptual module

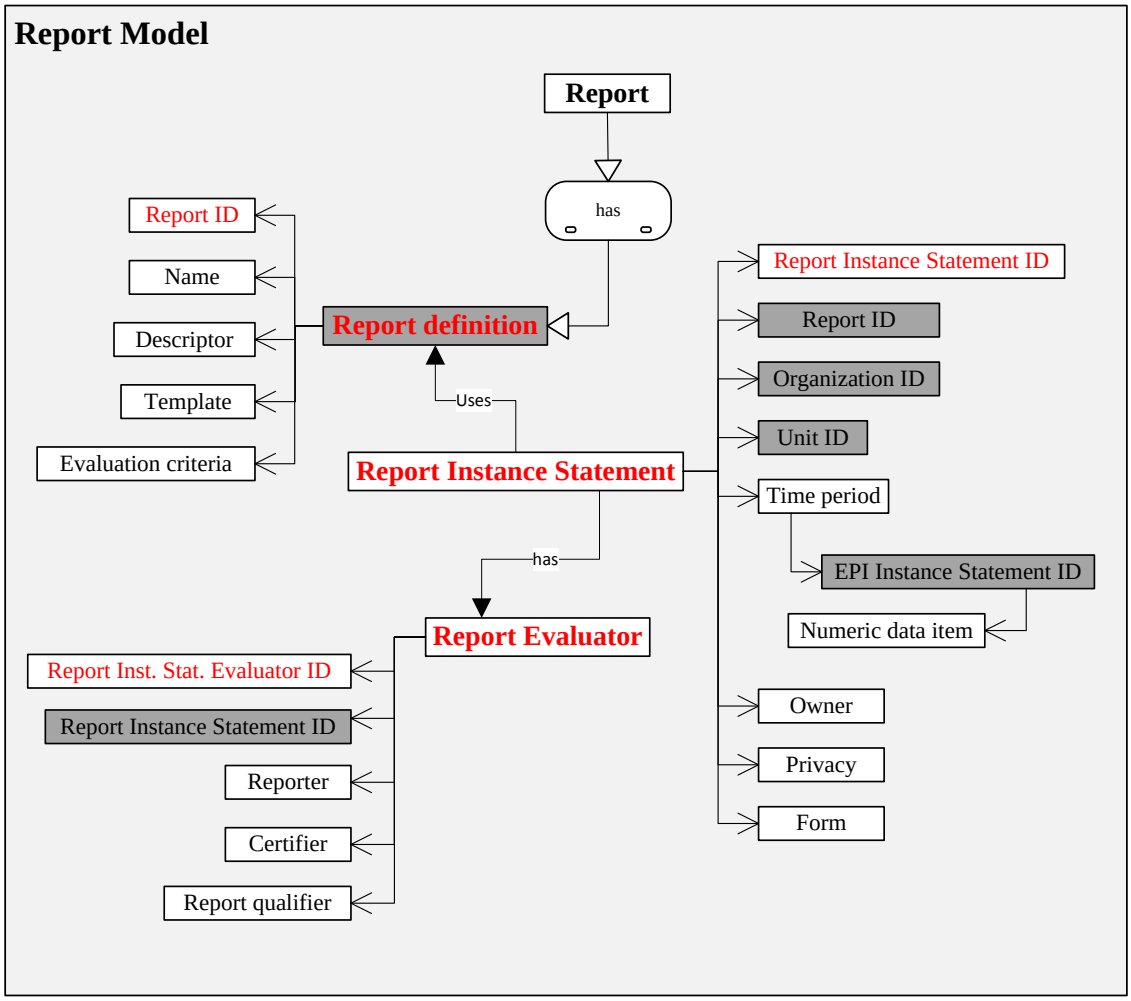


Figure 44: The conceptual report model of the LWC-EPI framework

4.8 The LWC-EPI Framework

After explaining the five conceptual models that compose the LWC-EPI framework, this section presents a holistic view of the framework. The organization conceptual model is a central model that defines all users' organizations, and all the other models' need to extract information from it. In this way, defining the organization will be the first step to be completed by any user wanting to use the system.

The second model is the ECET assessment model where the organization can assess its readiness to start using an EMIS based on determined factors and dimensions, and gain knowledge about how to improve itself to be more sustainable, environmentally speaking, and achieve a successful implementation and use of an EMIS.

As a main part of this work, the new EPI conceptual model supports defining, classifying, calculating, evaluating, and comparing organizations' EPIs and provides the needed understanding to be used even by users that lack the field experts' knowledge. As one can see from its name, the data model organizes the data extracting, possessing, and storing. Visualizing the results is managed in the report model as it is explained in section 4.7. Using the UML modelling language, Figure 45 represents the LWC-EPI framework and its five conceptual models.

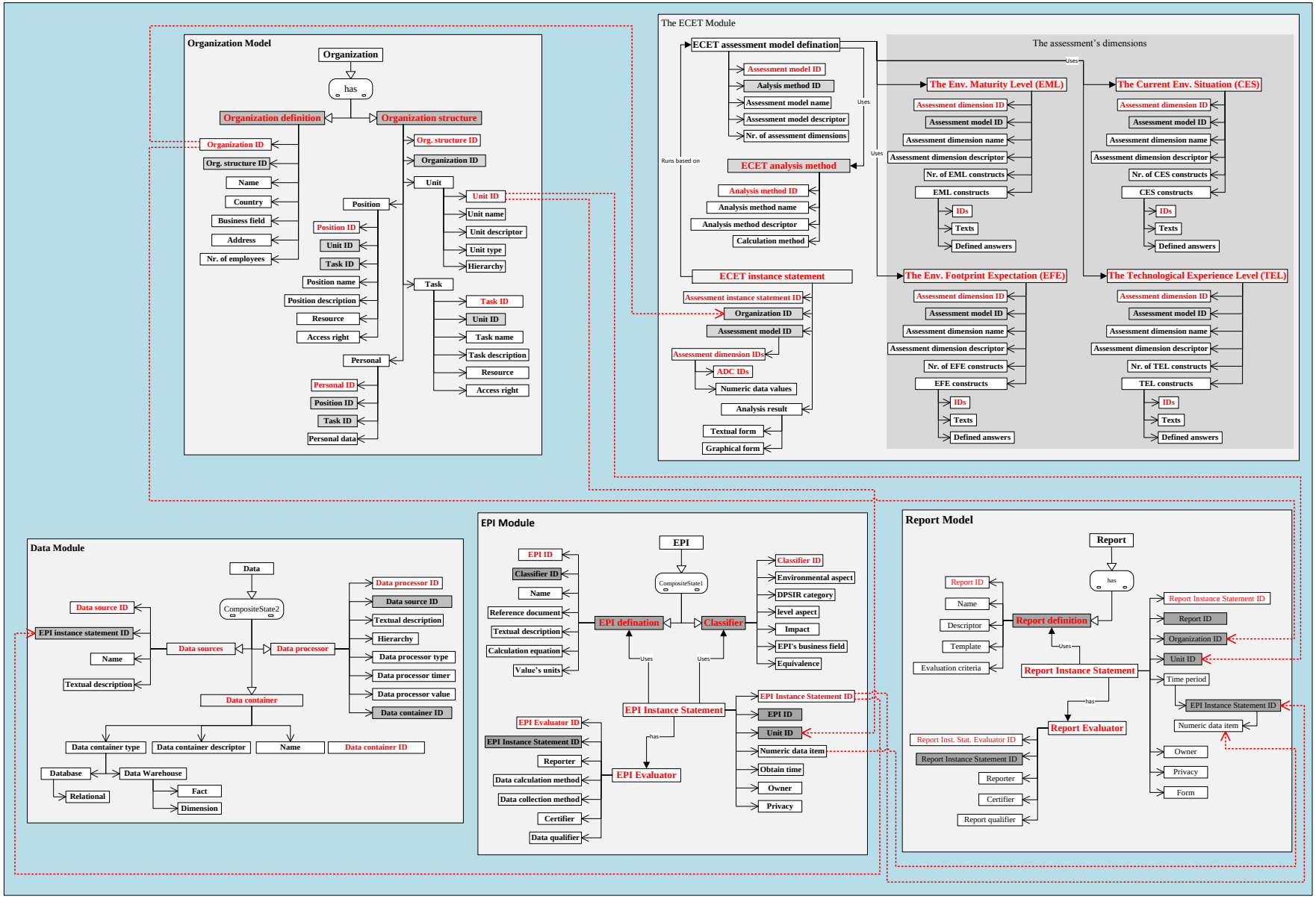


Figure 45: The LWC-EPI framework

4.9 Summary

This Chapter presented the LWC-EPI framework and its requirements and specifications. One of the main questions asked in this chapter was how more SMEs could implement EMIS. Therefore, barriers the SMEs face when implementing such systems were examined. First, barriers of SMEs in following EMS were examined. It was noted that EMSs help support enterprises in setting goals which can help them to evaluate their environmental performance and that although EMSs differ across organizations, they typically share common features. It was noted that it is important for SMEs to follow an EMS because it allows organizations to manage issues related to the environment with added environmental and financial benefits. However, it was still stated that there are barriers to adopt EMSs in the SME. These barriers were categorized as either internal or external and there were eight main barriers named. In addition, similar barriers were found when implementing an EMIS in an SME, and it was argued that both applying an EMS and EMIS share common barriers.

In the next section, two surveys were conducted that strengthened previous findings in the LWC-EPI research. The results of the first survey were analyzed using an Exploratory Factor Analysis in order to establish the ECET model and the second survey was analyzed using the Partial Least Squares method in order to evaluate this model. The ECET model is an assessment model within the LWC-EPI framework, which guides SMEs in maximizing the benefit of using an EMIS. The first survey determined the organization's readiness to be more environmentally friendly. This questionnaire found that although many organizations appear to be motivated to improve their environmental impact, many feel the costs of implementing an EMIS are too high.

The ECET model was developed based on an Exploratory Factor Analysis. Four important dimensions were found that formed a foundation for the successful implementation and use of an EMIS within an organization. The second study was a confirmatory study where four hypotheses were formed that reflected the connections between the factors of the ECET framework. The following subsection described the ECET Model, where it was noted that this model should have four components.

The next model addressed was the organization model, which is noted as important in order to understand the organizations' structure and processes. A simple organization model was noted as part of the LWC-EPI framework and it has three components. The next section introduced the EPI model, and EPIs are seen as central assets for the LWC-EPI framework. This model is designed so that all EPIs can be created, sorted, and prepared to be used. Furthermore the EPI structure, dimension, quality and data types were explained. The next model that was discussed was the data model, which consists of three main components. This concept combined operational databases of enterprises with outsource-data. The final model that was discussed in this chapter was the report model, which also consists of three components. This model was designed based on the common knowledge from IT-solutions. Finally, the chapter closes with a holistic overview of the LWC-EPI framework, which is the main artifact of this thesis.

5 The LWC-EPI solution

This chapter begins with a proposed system structural design that can be built based on the LWC-EPI framework and its requirements. Then, the appropriate lifecycle of services will be explained. In the third part, the system expectations from an end-user perspective will be presented. The chapter ends with an explanations and demonstration of the prototypical implementation of the LWC-EPI solution as a proof of concept.

5.1 LWC-EPI Structural Design

In the "IEEE1471 2000" standards, system architecture is defined as: "The fundamental organization of a system embodied in its components, their relationships to each other and to the environment, and the principles guiding its design and evolution". (IEEE, 2000 p. 9).
The aim is to provide a system structural design based on the requirements gathered and the framework explained in the previous sections. This solution should be able deal with an array of challenges, such as:

- A user interface designed for the use of non-experts users
- A variety of internal and external distributed data sources with different types
- Interaction with external systems
- Private and public spaces of information
- User's collaboration and rating functionalities

As stated in the first chapter, the LWC-EPI aims to enable any SME to build its environmental sustainability knowledge and improve its contribution to the environment.
The solution serves individual organizations' needs (inter-organizational approach) while also placing the general focus on environmental issues. For this, it should not lack an interoperable functionality.

The LWC-EPI solution consists of three main layers: the presentation layer, the application layer (the platform), and the database layer. To link the three layers, service oriented architectures (SOA) (Papazoglou, et al., 2007 p. 389) are used, as shown in Figure 46. As a suitable alternative for any SME, the concepts and architectural principles described in this chapter identify important elements supported in the construction of the system to address the requirements previously defined. The solution:

- Follows a light-weight design.
- Provides easy graphical user interface, for any end user.
- Supports integration with existing systems, such as open databases or different user interfaces.
- Is component-based.
- Has a modular design.
- Has a loose coupling between components.

The set of user requirements presented previously supports outlining the interactions between the LWC-EPI system and its users. In order to deal with the architectural design of a services solution, the technical requirements and interactions should be clarified. A technical analysis conducted by a group of the LWC-EPI developers, using the knowledge of experts from the OEPI project (OEPI, 2010), leads to a list of principals that should be followed as it is described hereafter:

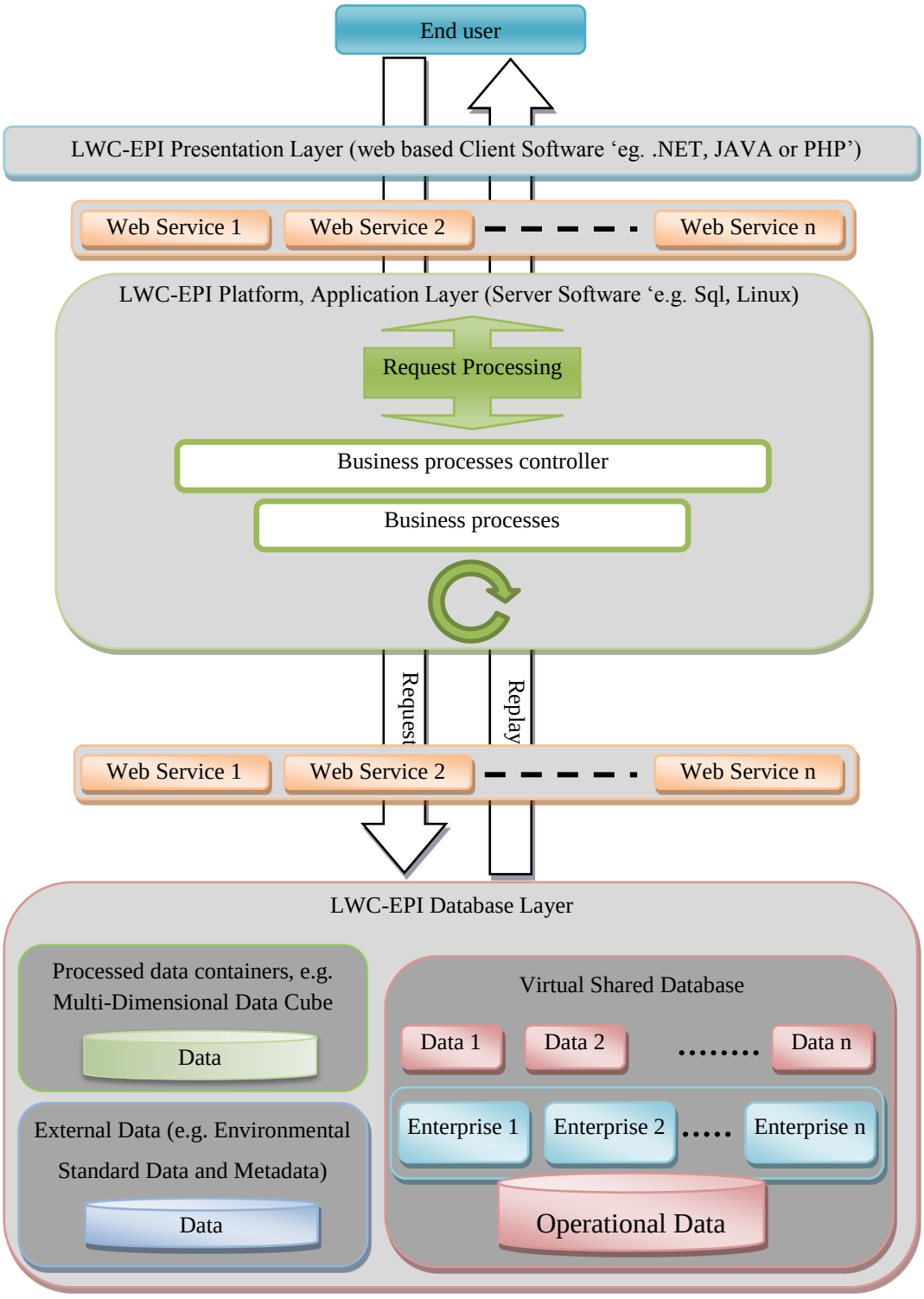


Figure 46: LWC-EPI Structural Design

- Communities and organizations
    - The system should reflect the inter-organizational approach of the LWC-EPI framework. This can be done by building users' groups that can interact within the system.
- Space personalization
    - Users can personalize their space (add, remove, rank, reposition content, etc.). In addition, they can choose different privacy polices for the space (private, share with group, public, etc.).
- Services integration
    - The system should allow admin users to integrate content and services from other system such as ERPs, CRMs, SCMs, or other legacy applications. Since the EPIs are the key item within the LWC-EPI, the system should ensure the access to the set of EPI related tools such as unit converters, template wizard, and EPIs' catalogs.
- Role based content delivery
    - Due to different users' roles in the participated organizations, access and creation rights must be controlled.
- Search, share, evaluate
    - Users should be able to search and select relevant information within specific space, domains, communities etc. They can evaluate contents, documents, sources, etc. and share the important data with the other system users.

The next paragraphs clarify how this has been achieved.

5.1.1 The Database Layer

In concept, Information Systems (for example, ERP-systems) offer solutions that support most of the business processes in an enterprise (Zachman, 1987 p. 277). The input data is processed by the ERP-system's business processes and saved/stored in the database as output data. This data is calculated to be more relevant to business economics, not to leverage environmental indicators directly. The LWC-EPI database layer is designed to enable the use of the operational data available in the organization's database and enhance this data by the use of external database, such as data accessible via internet or from other organizations' databases. This data can be general/common or specific to sector/domain. The combinations of the internal and external data are used to calculate, implement, and present selected EPIs.

The *virtual shared database* is an important term mentioned in Figure 46 and needs to be explained. The LWC-EPI database contains a repository of data sets collected from all interested and registered enterprises' databases. As a prerequisite, each enterprise that aims to use the LWC-EPI solution must provide an access link to its database as web service. The LWC-EPI solution does not have to load all the accessed data to the system database physically. Instead, using the provided web services, the data will be –*virtually*- in the LWC-EPI's database. The data sets are collected from all recorded organizations and used to serve all of these enterprises. In this way, this repository will be called the *virtual shared database* "VSDB". The latter will be the main source of the operational data.

As it will be detailed in the next section, external data is mainly used to support the transformation, integration, and restoration of the available operational data in order to bring

it to an appropriate shape to calculate the EPIs. The word "*composite*" in the (LWC-EPI) name is to point out the various data sources that have been used to calculate an EPI. This composition results in a certain EPI as a reply for the user request. A pertinent example is VSDB where data has been compiled from many enterprises with external data sourced from the internet. Hence, the use of "composite" precedes the word EPI in the nomenclature, LWC-EPI system (Jamous, et al., 2011-II p. 296). Service oriented architectures (web services) will be used to link this layer with the platform layer, as it is depicted in Figure 46.

5.1.2 The Platform or Application Layer:

The LWC-EPI platform is the system application layer, and it works as the middleware layer between the database and the presentation layers where the user request will be fulfilled (Braun, et al., 2005 p. 66). It contains the business logic and processes of the applications, e.g. the *business domain* business process, the *list EPI* business process, and *EPI compare* business process. In addition, the preparation, transformation, and integration of singular data sources are done in this layer.

The business process controller receives the requests, selects the appropriate business process to be activated, sends the data, receives the results, and sends them back to the presentation layer to be sent to the end user.

Nine main processes are configured in the system:

- recognize/acquire the appropriate data source
- select the needed data set
- data quality check
- extract it
- if there is a need, transform it (filtering, harmonization, aggregation, restoring, or enriching)
- after transformation check (quality and completeness)
- calculate the requested EPI
- integrate and consolidate the result in the appropriate database
- send it to the presentation layer for analysis and presenting matters

The system is operated by a mediator that hosts and drives the system, and will be the responsible party for the service (Asfoura, et al., 2010 pp. 157-158). This matches the LWC-EPI objective of being a light-weight solution. The SMEs (end users) deal with this mediator, and they access the user interface offered by the presentation layer (Jamous, 2013 p. 30).

5.1.3 The Presentation Layer:

It is mentioned in the Microsoft Developers Network (MSDN) that "The presentation layer contains the components that implement and display the user interface and manage user interaction. This layer includes controls for user input and display, in addition to components that organize user interaction." (MSDN, 2010 p. 1).

Following the same logic, the LWC-EPI systems' presentation layer comprises the user interface "UI" and the presentation process components as the communication path between the user and the system application layer. The user enters its request using the UI component; the presentation process components do the formatting and filtering process before they send the request to the application layer (the platform) for processing the data using the appropriate

business logic. At the end, the UI's components use graphing and visualization of results in order to facilitate the usage of the system by any end user who lacks the domain experts' knowledge. This way facilitates driving the quality of the user inputs, the quality of the displayed information (the output), and increases user acceptance (Jamous, 2013 p. 30).

As it was previously mentioned, the LWC-EPI aims to offer a light-weight solution for any SME. Serving this, the system services are provided through a web application that forms the UI components, and it is easily accessible from any endpoint station. The presentation logic components ensure the logical behavior implementation and the structure of the application, independently. This makes it autonomous from any specific user interface implementation, and the presentation layer can reach the system's platform using a web service provided by the mediator, or directly through the system API.

Since the system UI will become part of SMEs' information systems, the presentation layer components have to be developed against a rigorous application layer specification and on top of ideally platform-independent components (Jamous, 2013 p. 30). Today, many technologies and platforms for developing presentation layers are available on the market, such as Java Server Faces (JSF), Apache Wicket (Wicket), Google Web Toolkit (GWT) and Microsoft.Net. More details about the technical specifications and how to select the appropriate technologies follow in the next sections.

5.2 LWC-EPI Lifecycle of Services

The LWC-EPI general lifecycle of services can be expressed as a sequence of five phases:

- Acquisition
- Preparation
- Transformation
- Integration / execution
- Analyze and presentation

Hereafter, each step will be explained. To better understand the flow of each step, an example is provided with the following scenario: An organization has two transporters and wants to compare their fuel consumption and CO_2 emissions. The Unified Modeling Language (UML) has been used to draw the following activity diagrams.

5.2.1 Acquisition

Environmental Performance Indicators (EPIs) are the main data type for the LWC-EPI. Various sources can originate valuable EPIs data, e.g. service providers, governments, and NGOs. This data should be acquired and exposed to the system so that it can be processed. The acquisition step involves searching for suitable data, and capturing/collecting the data to make it available for the system platform.

Environmental data is complex and unstructured (Löschner, 2013 p. 85), therefore special combinations of data structures and algorithms are required to form a well-structured database (datasets and clusters). To facilitate this step, a set of requirements and descriptions for each EPI is provided, and this is guided by the OEPI ontology.[37]

[37] For more detail on the OEPI Ontology, please check (Löschner, 2013)

Back to the example, after receiving the user request, the system starts searching for suitable data sources. For this, there are two scenarios:

- The data is available internally in the organization's database.
- The data is available externally in another organization's database (uses the same transporter) or in an open environmental database e.g. the ELCD (European reference Life Cycle Database).[38]

The second step is to check the data source relevancy, and here there are two options:

- The recognized source is not relevant, so the activity will terminate.
- The recognized source is relevant, so the process moves to check the accessibility.

Again there are two options:

- The recognized source is not accessible, so the activity will be terminated.
- The recognized source is accessible, so the process moves to check the accessibility method.

Two options will be considered (other options can be added as an extension):

- Direct access from the organization's database.
- Access via webservices from recognized external source. Here, two scenarios are considered:

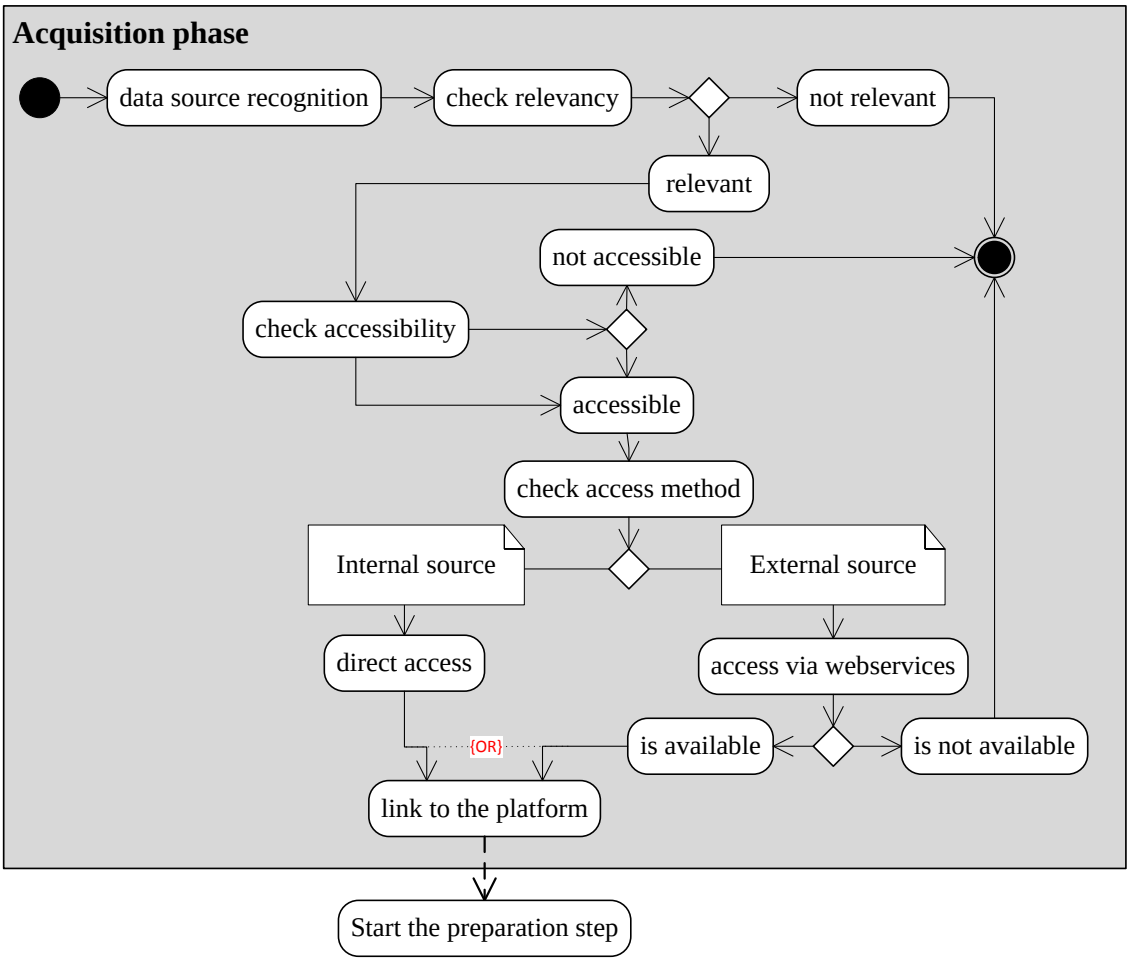


Figure 47: Acquisition, the first phase in the lifecycle of a service

[38] http://eplca.jrc.ec.europa.eu/?page_id=126

- There is no web service available, the activity ends.
- The web service is available, and appropriate for the system platform. Then, it is linked to the platform and the data preparation step is started.

Figure 47 (in the previous page) presents the acquisition phase's activity model as the first phase in the lifecycle of services.

5.2.2 Preparation

As it was explained in Section 4.5, the EPI calculations may require data from different sources. This data should be prepared to semantically fit the integration phase. The preparation phase starts by recognizing and selecting all the needed data records in their source by configuring data sources. These data sources point out which sets and clusters of data have to be extracted and matched semantically in order to calculate a certain relevant aspect for the requested EPI. The data quality, meaningfulness, measurability, and comparability checks are conducted in this phase, before the data records are sent to the integration phase.

Returning to the example, after recognizing the appropriate data source to the platform, the system starts recognizing and selecting certain needed data sets and testing their appropriateness. After selecting the data record, the system checks the quality of the data, for this, two scenarios are possible:

- The data has a poor quality, so the activity will be terminated.
- The data quality is accepted, so the system moves to check the meaningfulness of the data. This step can be semi-automated.

As a result of the second possibility, three different options are available:

- The data is not meaningful, so the activity will terminate.
- The data is meaningful but not ready to use as it is, e.g. the company provides the transporter's fuel consumption as Euro paid per month for the diesel.
- The data is meaningful and ready to use. The system moves to check the measurability.

The two possible paths for the third choice are:

- The data is not measurable, so the activity will terminate.
- The data can be measured, the system moves to check the comparability.

Again, three options can be considered:

- The data is not comparable, so the activity will terminate.
- The data can be compared to another data set, but it is not ready to be used as it is, e.g. the company provides the transporter's fuel consumption as miles per gallon instead of km per liter.
- The data is comparable and ready to use. The system extracts the data record, and matches it semantically. After that, the integration phase started.

If the data reach the "not ready" status - meaningful or measurable but not ready to use - data transformation will be applied. Figure 48 illustrates the preparation phase's activity model as the second phase in the lifecycle of services.

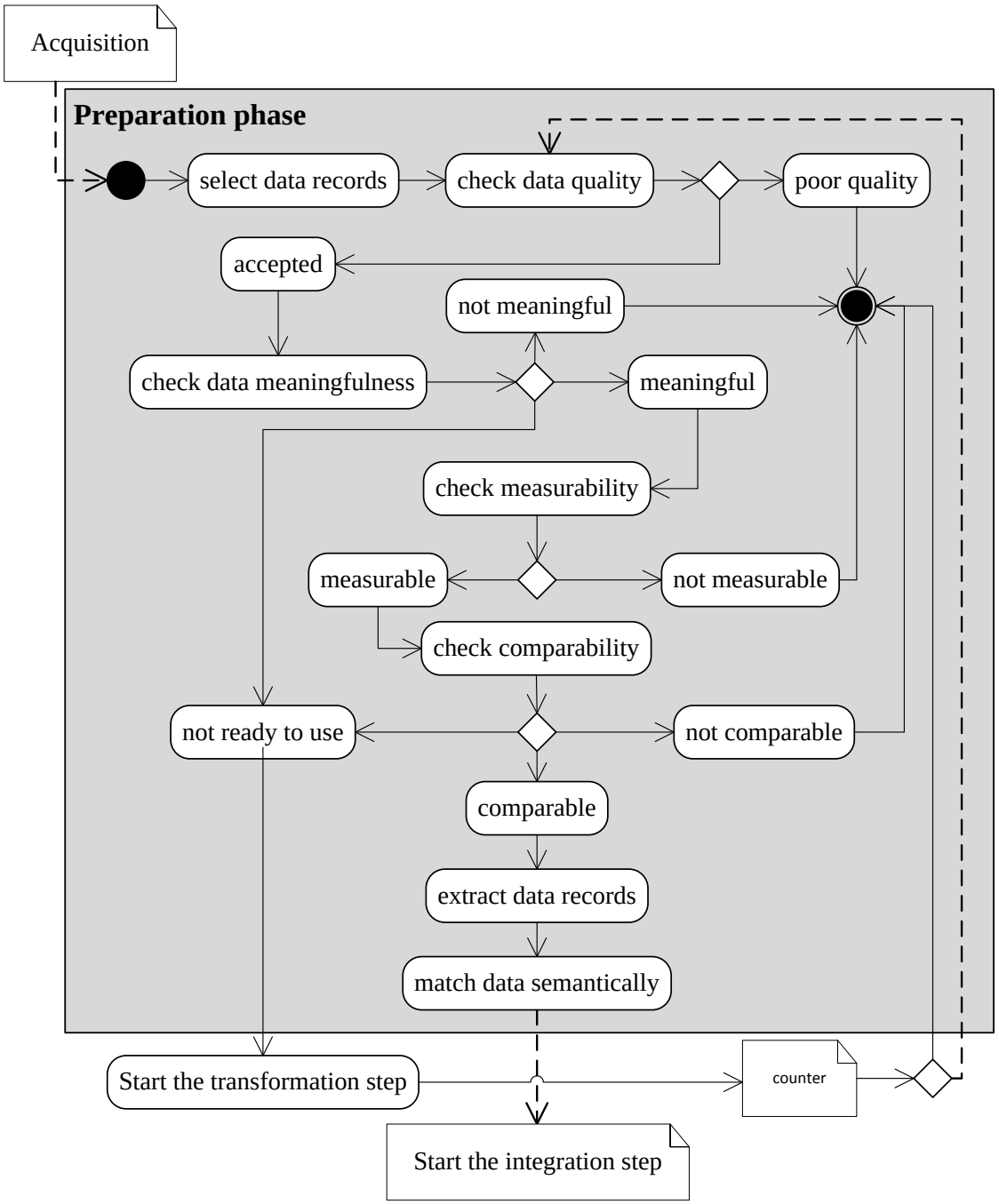


Figure 48: Preparation phase in the lifecycle of a service

5.2.3 Transformation

Organizations usually save their operational data to be processed for economical use in most cases. The transformation step is essential in order to extract the environmental means to be used for EPIs' calculation. This can be done by converting or extending the data formats or values to fulfil the user request by special processes and techniques such as filtering, harmonization, aggregation, and enriching (Baars, et al., 2009). It is like looking at the same data from different angles.

If and when the transformation step has been reached, in addition to the mentioned processes, external environmental databases can be accessed using web services techniques,

for example. These databases provide important information in order to calculate the EPIs, such as the physical properties/characteristics of materials, the appropriate unit for a specific EPI, or its calculation equation. In addition, this step enables the restoration and reparation of missing data needed to create or calculate an EPI. In this case, the transformation can be seen as an extension of the preparation phase enabled to fulfil specific user request.

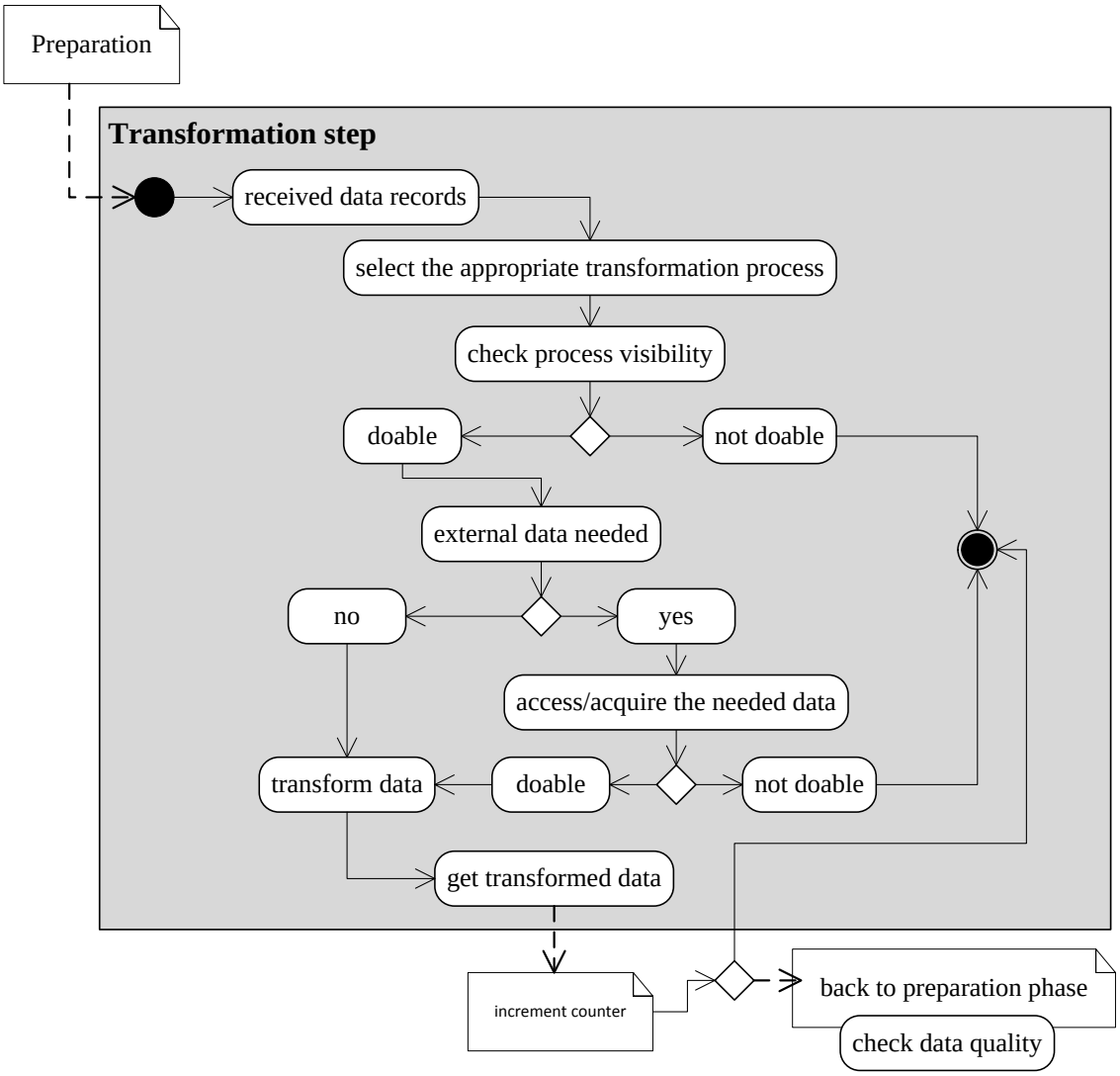


Figure 49: Transformation step in the lifecycle of a service

As it has been mentioned, the "not ready" data needs to be transformed. Back to the example, after receiving the data record by the transformation work process, the system selects the appropriate process to be applied based on the user request. For example, the unit manager wants to know the average diesel consumption of the organization's transporters during the last three months. The data needs to be aggregated, and the average should be calculated. The system checks if this is possible or not:

- The process cannot be conducted, so the activity will be terminated.
- The process is doable; the system checks if there is a need for external data:
    - The data is completed and there is no need for any extra data, so the system starts the transformation, and pushes the transformed data back to the preparation phase after incrementing the counter to avoid the infinite loop case.

- There is a need for extra data to complete the transformation. The system searches and tries to access the external data source to restore or complete the data. Here, two scenarios are presented similar to what has been explained the acquisition phase:
  - It is not possible to acquire the data (no webservice is provided, the system cannot find the data, etc.), then the activity will be terminated.
  - The access/acquire step is possible. At this point, the system extracts the needed data and completes the transformation. Then, it pushes the transformed data back to the preparation phase after incrementing the counter to avoid the infinite loop case.

Figure 49 demonstrates the transformation step's activity model as part of the lifecycle of services.

5.2.4 Integration / Execution

The processed data can be integrated in the database using different techniques. For example, using the Extract, Transform, and Load (ETL) techniques, the processed data can be integrated in multidimensional models of a data warehouse. Each multidimensional model deals with a certain EPI and emphasizes a specific environmental standard. More examples will be demonstrated in the next chapter (The LWC-EPI prototypical implementation). The processed data – integrated in or accessible through the system platform – is delivered to the user through the user interface of the presentation layer.

In the context of the example, assume that the engine producer has an open online database where the transporter's specifications are saved, and can be provided via webservice as a service. The system can deliver this information (service) via a web service and provides it to users upon their requests.

At first, the user sends a request to the system platform through a user interface. Then the platform checks if the required combination is available directly or through an aggregation of different web services. Three different scenarios are considered:

- The system finds the requested service (e.g. the fuel consumption average for March 2014) in the database, so it exposes the results directly.
- The system Application Programming Interface (API) is able to aggregate and configure a new web service (i.e. the combination) semi/automatically. In this case the result is exposed to the user after the manipulation.
- The system API is not able to fulfil the task using the available services. Two possibilities are considered:
  - The system administrator develops and implements a new service by a (glue code) (Liu, et al., 2006 p. 40), to enable the API to fulfil the task and exposes the result.
  - The system is not able to fulfil the request, so the activity will be terminated.

The system configures the services (e.g. web services) to be obtained through its services' repository (e.g. link to the online store of the engine producer). In this way, different users can be served using a variety of endpoint types, such as web application, the organization's ERP system, or a mobile application. Figure 50 illustrates the integration/execution phase's activity model as part of the lifecycle of services.

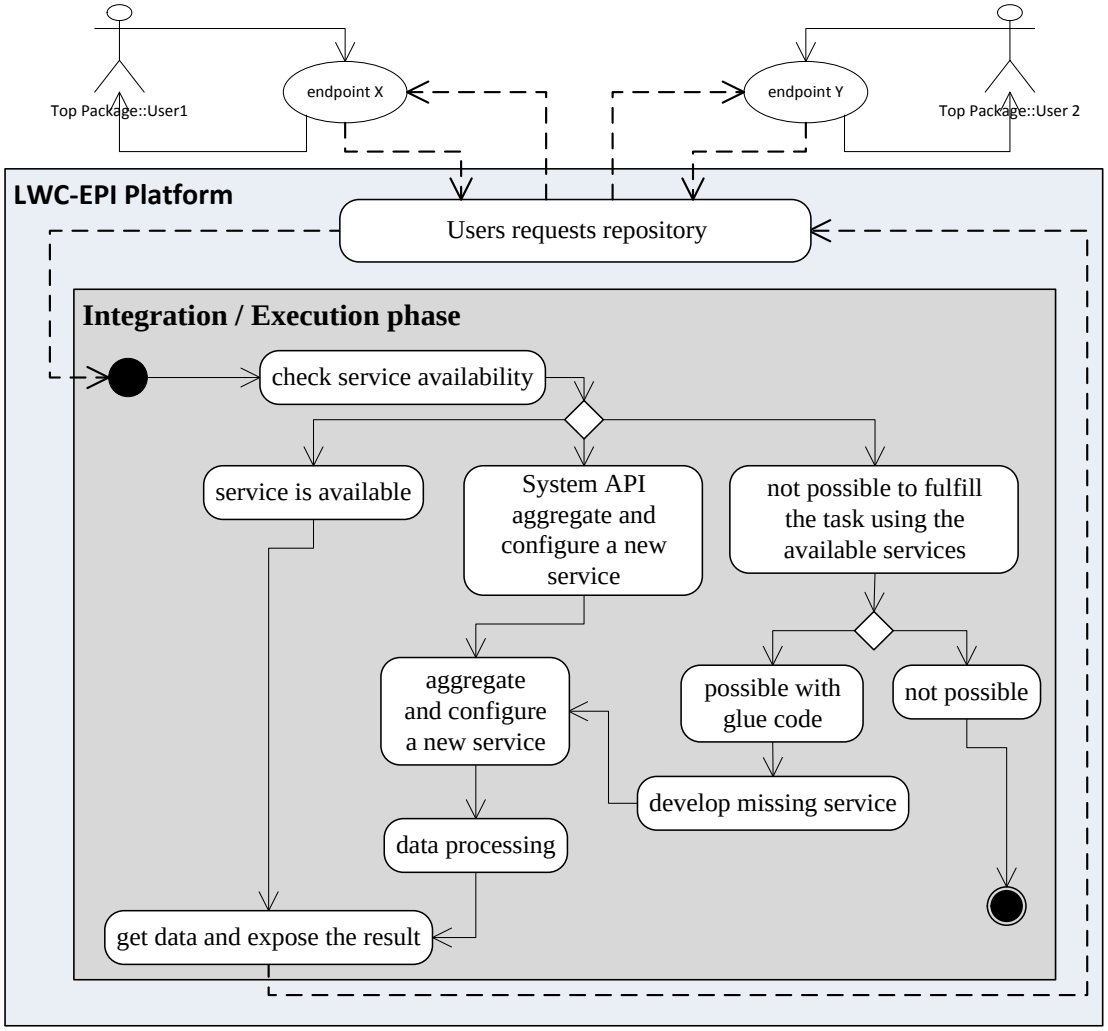


Figure 50: Integration / Execution phase in the lifecycle of a service

5.2.5 Analysis and Presentation

The end user can access the system's services via web applications provided by the LWC-EPI's presentation layer. The special service delivery "monitoring and reporting functions" ensures quality of service and provides business process intelligence. Based on the analysis result, the reply message (a service) can continue to be delivered or may need to be modified. Services' modifications can enhance the reply data with external data (new service) that is not already available on the system's platform, or supplementing it with another service that is already available. In addition, the system offers a reconfiguration service. These modifications send back the service to an earlier phase in the lifecycle of services, as it is illustrated in the system lifecycle of services (see Figure 51).

Using the system's user interface, each end user can analyze and monitor his services. The system administrator and the end users can monitor if the requests if and their replies (services) are running as they should be. Furthermore, they can generate performance and usage reports. The system administrators can modify, add, or delete services based on recommendations coming from the end users or domain experts. Back to the example, if an

expert of the engine producer company recommends deleting service D (e.g. the engine's weight) since it is a part of service C already (e.g. calculating the average engine weight for certain transporters' type). The system administrator can accept the recommendation and react accordingly or ignore the request based on the overall system services view. Figure 51 illustrates the system lifecycle of services as it was explained in the previous paragraphs.

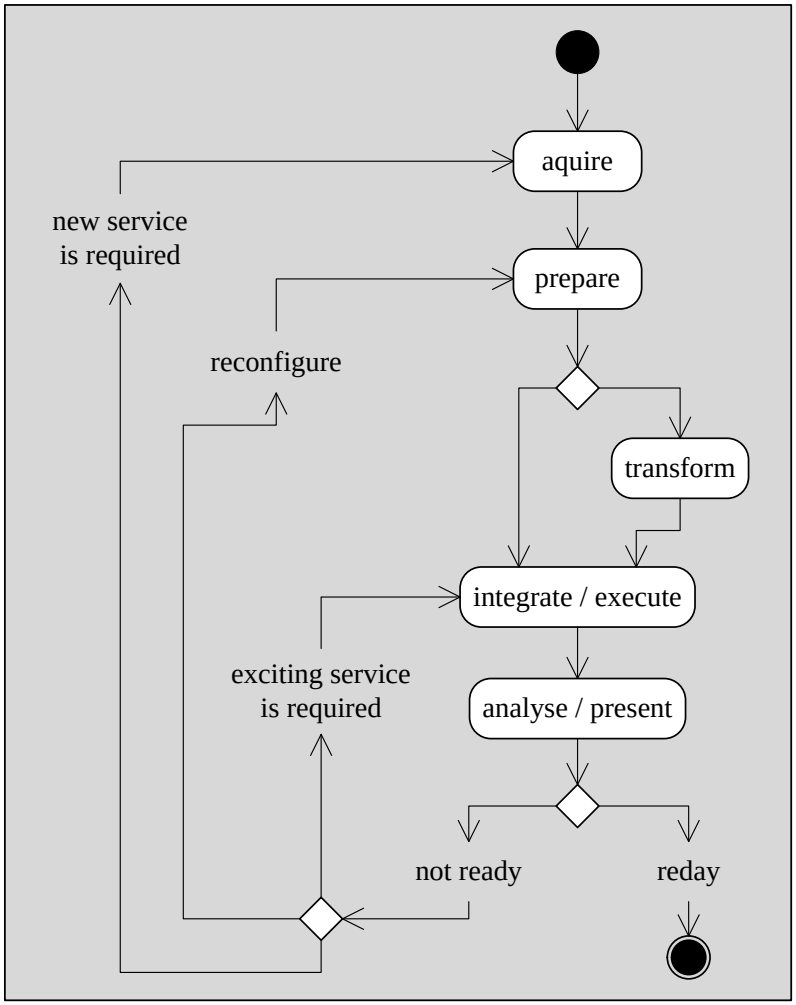


Figure 51: The LWC-EPI lifecycle of services

5.3 System Expectations from an End User Perspective

The LWC-EPI will be provided for the end user as a web application, and, as for any computer-based solution (ERPs, web applications, etc.), user participation and satisfaction are two critical success factors as (Sun, et al., 2005 p. 192), (Liu, et al., 2000 pp. 24-25), and (Yap, et al., 1992 p. 598) argued and proofed. This section presents an overview of the basic services that will be provided for the LWC-EPI end users.

First, the system will differentiate between two types of users:

- *Unregistered user*: the LWC-EPI system bears a social responsibility toward increasing the environmental issues' awareness in society. For this, the system seeks to provide general environment-related information that is presented in a simple way

for the public, a step in the right direction to help raise social awareness. In order to be able to access all the system features, the user should be registered.

- *Registered user:* Using the registration system, any user could get a username and password to unlock all the system features. The user will be able to register his organization and build its structure, get an assessment report about the organization's readiness to start using the LWC-EPI, generate an environmental report based on his selected EPIs, and compare the results to other registered organization.

In the next paragraph, an explanation about each of the mentioned activities will be demonstrated. Figure 52 depicted a general Unified Modeling Language (UML)[39] use case diagram for the LWC-EPI system from a user's perspective.

Eight main activities are expected to be provided by the LWC-EPI system. Hereafter are brief explanations of each of these activities. More detailed examples will be provided in the LWC-EPI prototypical implementation's section.

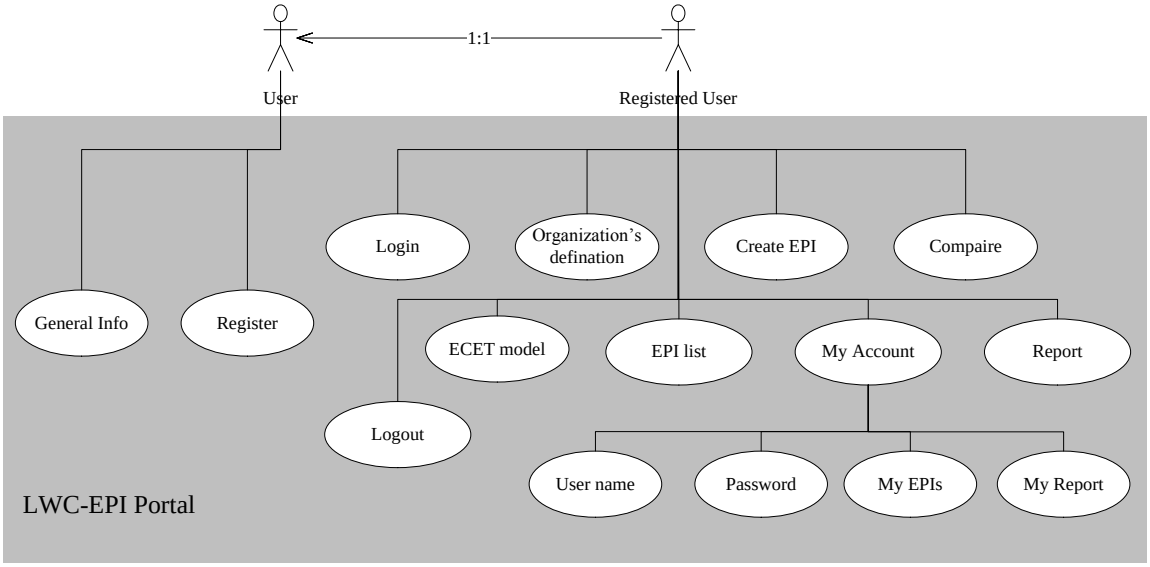


Figure 52: LWC-EPI use case diagram

Activity 1: User registration process

As it was explained, the user should register before starting to use the LWC-EPI system. After checking the content and the objectives on the open pages, the user has two options:

- He decides to leave the web page without registration, so the process ends here.
- He decides to register as a new user, and then he should create an account by filling the required registration form. The system checks if the data is complete:
  - If it is not complete, the user will receive an error message with the required changes.
  - If it is complete, the user will receive a confirmation message with his account details.

Figure 53 illustrates the user registration activity as an UML activity diagram.

[39] http://www.uml.org/

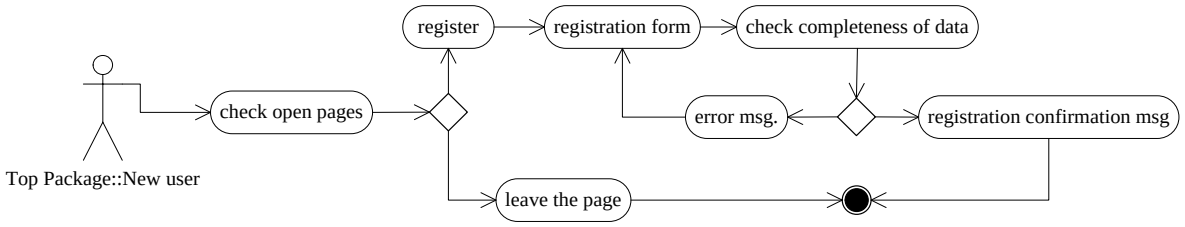


Figure 53: User registration activity diagram.

Activity 2: Login/-out process

After completing the registration, the user can login and start using the system. To login, the user must enter his login data, the system checks this data:

- If it is not correct, the user will receive an error message with the required action, e.g. password is wrong, or this is an unregistered user name.
- If it is correct, the user is logged in and can start to use the system. After finishing, he can logout.

Figure 54 shows the login/out activity as an UML activity diagram**.**

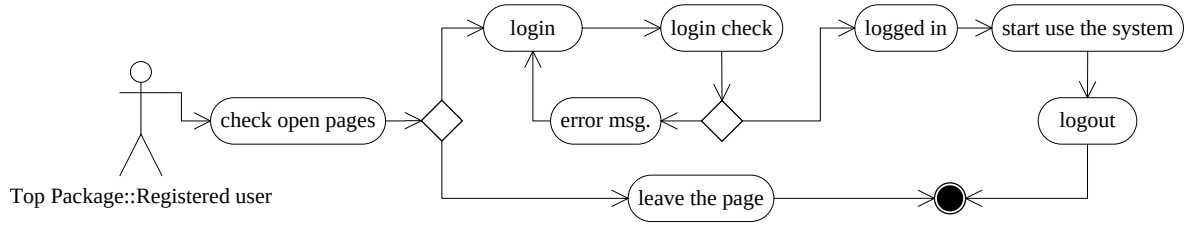


Figure 54: Login/-out activity diagram.

Activity 3: Organization definition

As it was mentioned, one of the LWC-EPI challenges is to make the system suitable for any SME, independent from its business field. The user interface will guide the user in a simple way to what is relevant for his organization and recommend the appropriate EPIs accordingly.

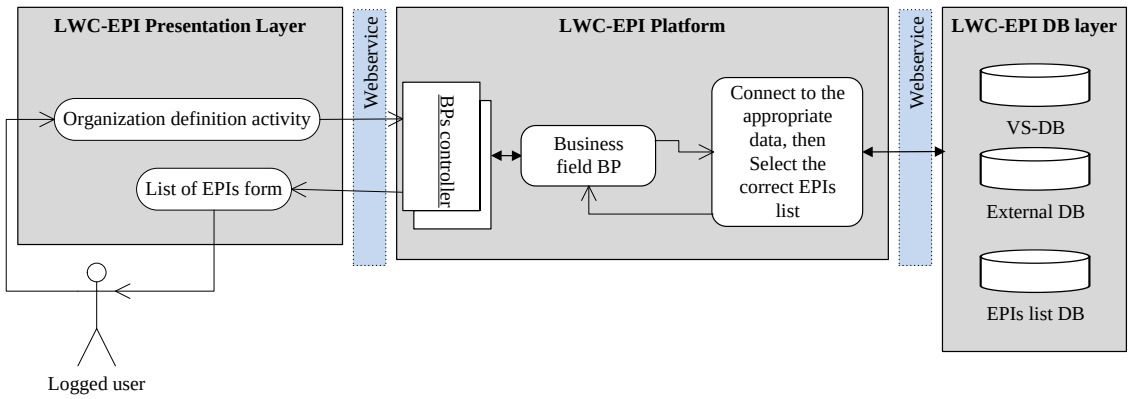


Figure 55: An example of the organization definition activity diagram

To enable the system to provide the appropriate selection, the user should define his organization by filling the appropriate E-forms that should be built base on the LWC-EPI organization model presented in Section 4.4. This should be the first activity to be completed after the registration. For example, provide the organization name, number of employees,

select one business field from a simple dropdown list, create units in registered organizations, etc. This action supports the Business Processes (BPs) of the platform. For example the business domain BP uses this information to connect to the right data, and provide the user with a recommended EPIs list appropriate for his organization. In addition, it assists the reporting and comparing BP in many ways that will be demonstrated later. Figure 55 shows an example of the transactions between the system's layers in this activity as an UML activity diagram.

Activity 4: Organization assessment

As it was mentioned, the LWC-EPI framework provides an assessment model named the ECET model (see section 4.3) to inform all the organizations about their readiness to adopt the LWC-EPI solution. This activity must be the second step after defining the organization.

To enable the system to provide the correct evaluation and recommendation, the user must answer some straightforward questions extracted from the ECET model dimensions and factors. As a result, the user will receive a recommendation message on what should/could be changed in the organization in order to improve its readiness. After defining the new organization (registration), the user will not be able to use the system before he completes the ECET's questions. The answers will be analyzed and an evaluation graph will be demonstrated illustrating the organization position from an environmental sustainability perspective. In addition, the user will receive a recommendation message mentioning what needs to be improved. Figure 56 shows the ECET activity as an UML activity diagram.

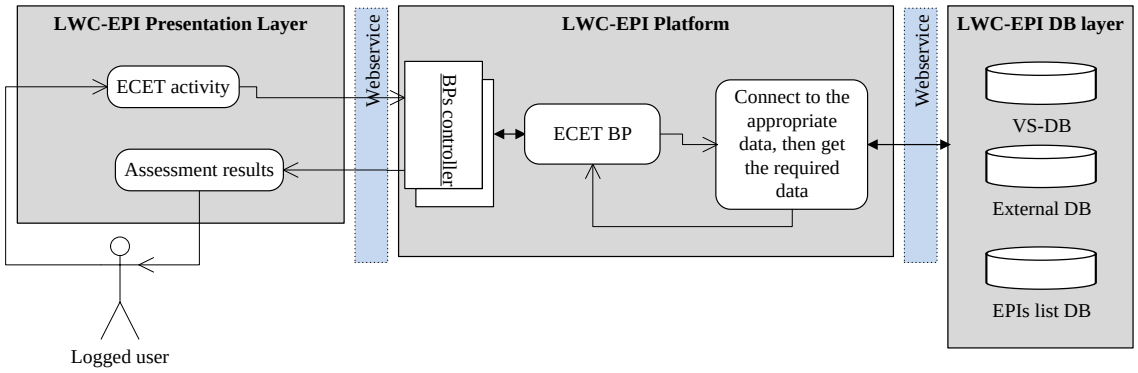


Figure 56: The ECET activity diagram

Activity 5: Select and calculate the EPIs

After completing the previous steps, the user can start using the other features in the system. For example, he can select specific EPIs to be calculated from a recommended EPI list provided by the system platform based on the organization business domain as it was described in the previous paragraph. The main business process to be activated is the *EPI calculator PB*. It checks the accessibility and availability of the EPIs calculation requirements based on each EPI definition. The main data sources that should be checked are:

- The enterprise's DB: mainly operational data, the system can access it using a web service.
- The virtual shared DB: where all interested enterprises provide an access link to the LWC-EPI platform to their DBs. Here the system can use the DB of the other enterprises coming from the same business domain or sector.

- External data: this is accessible via the internet and provides general/common specific sector/domain data. Through this data, the system is using the experts' knowledge.

After checking, two potential scenarios present themselves:

- In case the data is incomplete or the data quality is poor, the *EPI calculator* BP sends a message to the user about the missing data that is required.
- In case the data are complete and have good quality, the *EPI calculator* BP calculates the EPIs, and shows it to the user using the appropriate format.

Figure 57 shows the transactions between the various systems' layers supporting this activity as an UML activity diagram.

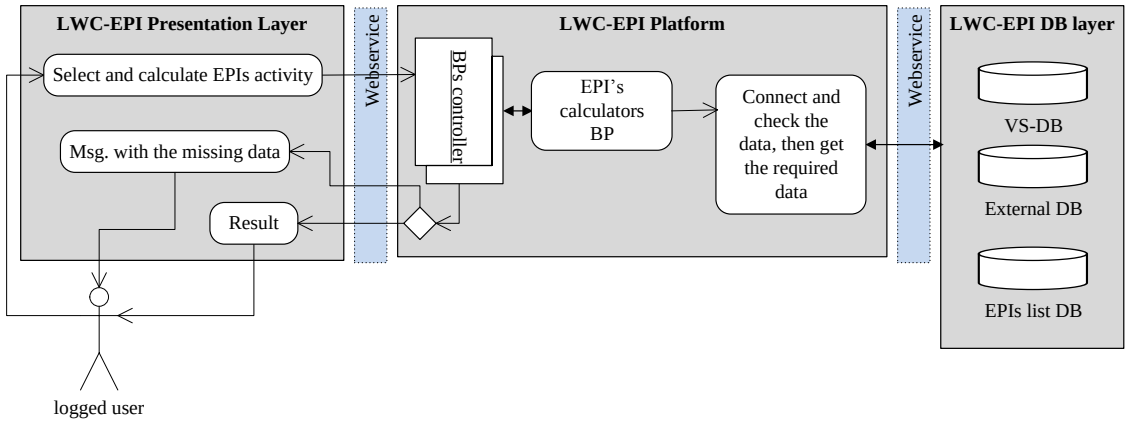


Figure 57: Select and calculate the EPIs activities.

Activity 6 – Create new EPIs

Another important feature that must be provided by the LWC-EPI system is enabling any user to create a new EPI after checking the recommended EPIs' list. This activity can be split into two phases, depending on personal preference. In the first phase, the user chooses to create a new EPI. The system generates a template in order to add new EPI following the same built-in structure as shown in Figure 58.

As it was argued, the LWC-EPI potential users are not just expert users. Thus, a duplication check is a must. The second phase starts after filling out the template and sending it to the system by the user. The *new EPI BP* runs a "duplication check" to check against similar EPI in the data repository "library." Two potential scenarios emerge:

- The first where the *new EPI BP* finds a similar EPI and sends it back to the user. Again two scenarios can appear:
  - The user decides to use the similar EPI recommended by the system, in this case the process goes back to the "Activity 5: Select and calculate the EPIs" and proceeds from there.
  - The user decides to create the new EPI, and in this case adopt the similar EPI recommended by the system; in particular the *new EPI BP* creates the new EPI and adds it to the data repository "library." The system should flag this EPI with the hint of duplication.
- In the second main scenario, the *new EPI BP* does not find a similar EPI, and in this case the new EPI will be created and added to the data repository "library."

Figure 58 demonstrates the transactions between the system's layers in this activity as a UML activity diagram.

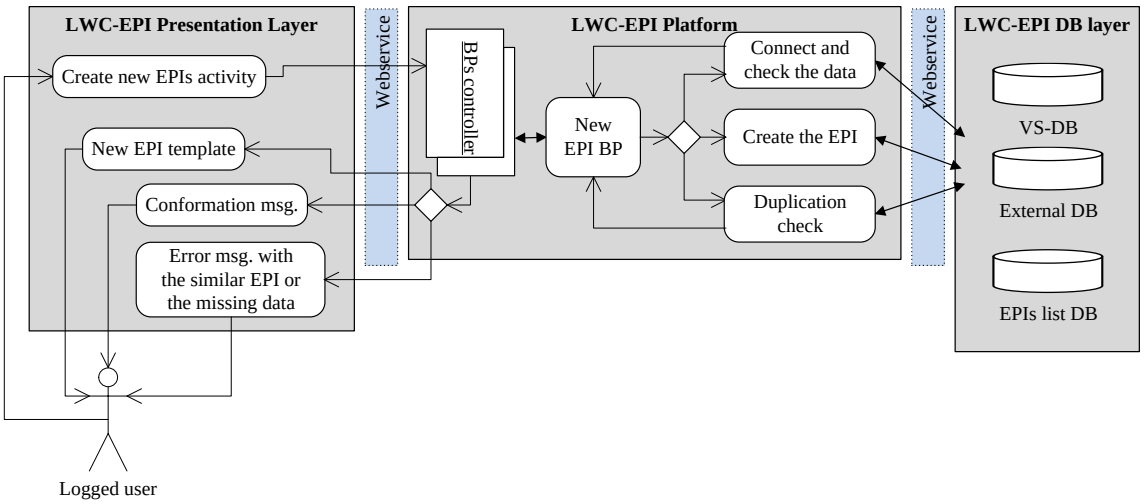


Figure 58: Create new EPI activity diagram

Activity 7: Report generation and execution

The LWC-EPI solution should facilitate different types of reports. In general, after calculating the EPIs, user can save or drop the results. By generating the report, the *generate report BP* asks the user to specify the form he prefers, e.g. period specific, geographic location specific, private EPIs, or public EPIs, etc. Afterward, the user receives the report and can save it, print it, or drop it. Figure 59 shows the transactions between the system's layers in this activity as an UML activity diagram.

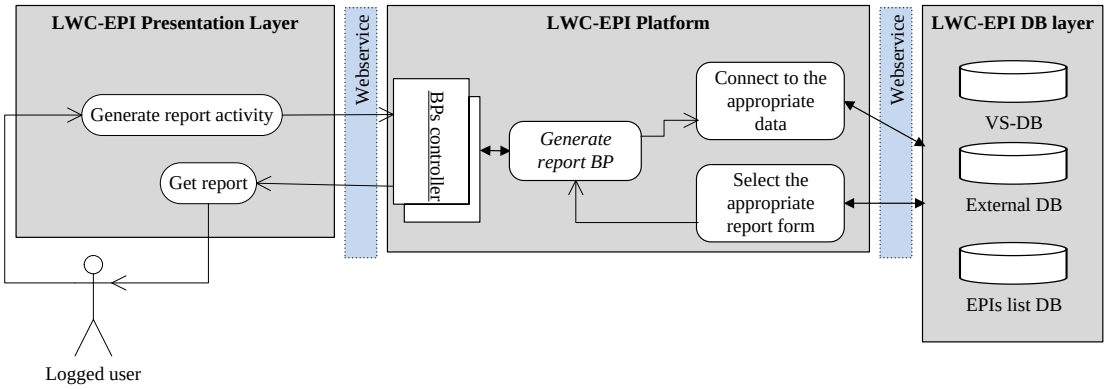


Figure 59: Report execution activity diagram

Activity 8: Comparison

The LWC-EPI solution enables the user to compare his EPI values to other registered organizations' EPIs values. By activating the comparison feature, the comparison *BP* inquires the user to specify the form he prefers, e.g. compare to other units in the organization, compare to previous period, compare to organizations from the same business field, etc. To maintain data privacy in each organization, the comparison report should not include any details about the data source. Thus, the user will be able to evaluate his organization's environmental performance against its competitors without breaking their privacy. Figure 60

depicts the transactions between the system's layers in this activity as an UML activity diagram.

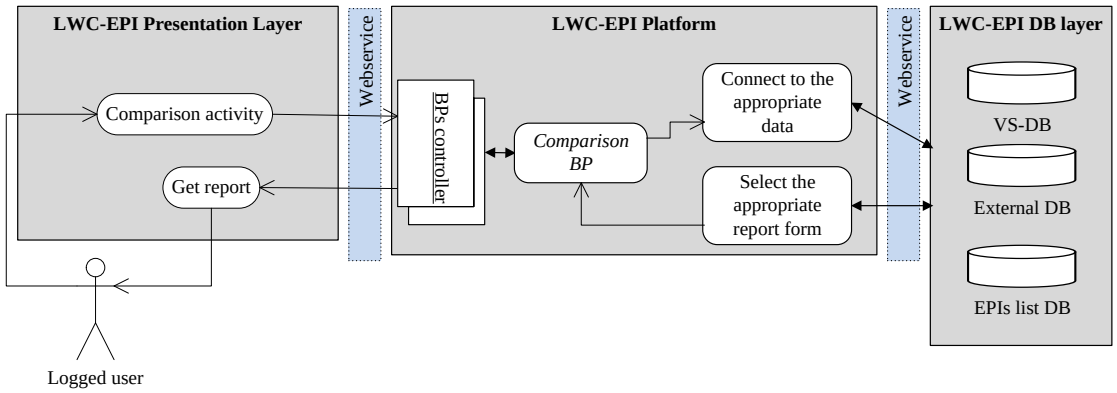


Figure 60: Comparison execution activity diagram

5.4 Summary

This chapter begins by explaining the LWC-EPI structural design. The solution consists of three layers: the database layer, the platform or the application layer, and the presentation layer, which are all linked by service-oriented architectures. The database layer enables the use of the operational data that is available in the organization's database. The application layer is where the user request is to be fulfilled, and this layer contains the business logic and processes of the applications. Finally, the presentation layer is comprised of the user interface and the presentation process components.

The next section discussed the LWC-EPI lifecycle of services, which is a sequence of five phases. Furthermore, an illustrative example is also provided. The five phases named were acquisition, preparation, transformation, integration/execution, and analyze and presentation. The chapter ends with the expectations from the perspective of the end user. The LWC-EPI is provided as a web application, and the system has two types of users: unregistered and registered users. There are eight main activities that are provided by the system. The first is the user registration, next is the log in and out process, and then, the organization should be defined. The user should define the organization by filling out the fitting E-form. The next activity is the organization assessment, which allows the system to evaluate the correctness of the organization definition. This activity is then followed by selecting and calculating the EPI. The next step is creating a new EPI. After this activity comes report generation and execution, where the user can choose to either save or delete the results. Finally, the LWC-EPI solution allows the user to compare his values with other registered organizations.

6 The LWC-EPI prototypical implementation

Following the research method presented in Chapter 2, a prototypical implementation of the LWC-EPI solution will be demonstrated as a proof of concept. The chapter begins with an overview on the prototype architecture and its adopted technologies. Then, business use cases will be detailed. Moreover, the system characteristics will be demonstrated through a user story accompanying the explained use cases. The chapter ends with an evaluation section of the proposed artifacts, and if they meet the metrics that have been defined in the first two chapters of this thesis.

6.1 The prototype's architectural design and technical specification

After demonstrating the LWC-EPI prototype's architectural design, this section presents an insight into its technical specifications. It highlights the evaluation methodology that has been used to make the technologies decisions. Then, it demonstrates the techniques that have been used to implement the prototype. In addition, it explains how the internal components of the LWC-EPI reference architecture have been implemented.

Proceeding from the objective of the LWC-EPI solution that has been defined in the first chapter of this work as providing an efficient EMIS to support any SME, the LWC-EPI solution is counted as an analysis and reporting system. Technically, such systems are characterized as (Jamous, et al., 2011-III p. 670):

- Read-only operation
- Inquiring into huge amounts of data with different dimensions, characteristics, and measures (e.g. EPIs) over the time
- Ad hoc querying to allow the users to create or run queries
- A flexibility to allow the users to define and change data models, e.g. structure of an EPI

In any project, selecting the technologies to be used in developing a computer-based solution is a process that depends on a variety of factors; these factors include maturity, compatibility, platform dependency, performance, licensing, etc. In this work, shaping the search process within the huge amount of available tools and technologies that support such system was a meaningful step. It has been directed by the definition of the targeted end users that "they are mostly non-expert end-users employed by SMEs." Thus, the first constraint was that the adopted technologies must allow for the development of a web application without putting too many restrictions on the client side of the application. The second constraint was that the technologies should be enterprise ready, so that they can match important enterprise's criteria on their own (Jamous, et al., 2011-III p. 671).

The end users will access the LWC-EPI prototype using web application. For this, the result of web application frameworks' comparison that was conducted by (Jamous, et al., 2011-III pp. 671-676) has been used during the technologies' selection process. The study selected 13 products, "or tools," of web application frameworks based on different technologies, such as PHP framework, ASP.Net, Web-application, and Java-based web application frameworks. The evaluation categories considered the programming paradigm, the

architectural and design patterns, the programming language, the development environment, and the strategic perspective. Each category was defined, and recommended decisions were promoted based on the result of Value Benefit Analysis (VBA) (Schulze, 2006), cited in (Jamous, et al., 2011-III p. 678).

Taking into consideration the results of the latter mentioned evaluation, the opinion of the LWC-EPI prototype's developer team, and the system constrains mentioned in the previous Chapters (3, 4, and 5), it was decided to use the Microsoft products to develop the prototype. Moreover, the C#, Java programing languages, and the webservice techniques have been utilized. The next paragraphs represent the related details.

The LWC-EPI prototype follows the recommended structural design presented in the previous chapter (Figure 46), with light modifications. As it is demonstrated in Figure 61, The LWC- EPI prototype follows a three tier architectural deployment style. This facilitates distributed deployment, physical separation of the layers, and decomposition of applications, which are a necessity in this work. Moreover, it assures maintainability, scalability, flexibility, and availability. The LWC-EPI prototype encompasses a presentation layer, application layer, and database layer. The Web Application as user interface allows the end user to communicate with the system, and uses its business logic. All business logic's classes and functions were placed in the system platform that forms the application layer. Enterprises' databases, external environmental databases, and the system repository compose the database layer.

The ASP.Net has been used as a platform to develop the web application. This empowers the creation of full-scale web application by using code and the provided design tool, all without mixing the script with HTML. The C# as an Object Oriented Programming (OOP) language has been used for coding most of the components in the Microsoft Visual Studio 2010 design tool. All ASP.NET code executes as web server in The Microsoft Internet Information System (IIS).

The separation between the user interface (in the presentation layer) and the functional code (in the application layer) is visible during the run time. On the web, the application resides on a remote server, with the client using only a browser; while during the design phase, ASP.NET brings the two layers a bit closer together.

In this prototype, all of the business logic and processes have been configured in the LWC-EPI platform, which plays the role of the middleware layer between the database and the presentation layers. One of the important concepts in the LWC-EPI is to personalize the interface according to the user's activities and data. For this, so called "session" objects,[40] provided by the ASP.NET, have been deployed. The platform contains eight Business Processes (BPs) provided as services for the end user through the web application. As it was explained in Chapter 5, the business process controller is the component that receives all the requests, selects and activates the appropriate BP, sends the data, receives back the results, and sends it to the presentation layer to be visualized for the end user.

[40] Session is a dictionary (array of pair items) used for state management in web applications, http://msdn.microsoft.com/en-us/library/ms972338.aspx

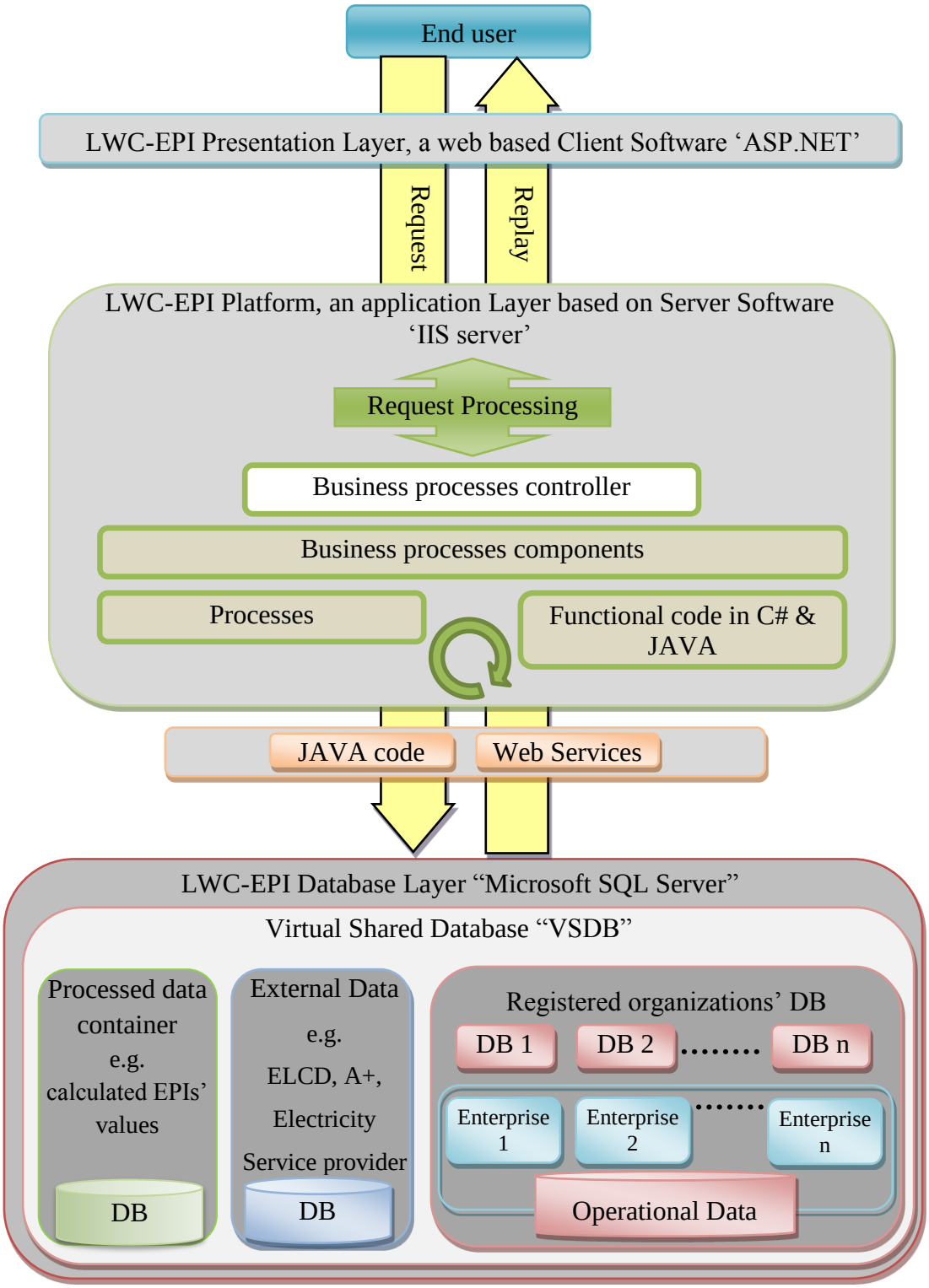


Figure 61: LWC-EPI prototype's structural design

In the database layer, the Windows Express SQL server 2008 has been used as the database management system (DBMS). The LWC-EPI prototype's database design followed the Virtual shared database (VSDB) concept that has been defined in the previous chapter. In principle, it is divided into three sub-databases as it is shown in Figure 61: the registered organizations' DB, the specialized external database, and the processed data container. Each

of these DBs contain tables connected with each other through defined relationships using SQL statements. As it is depicted in Figure 62, using the ADO.NET[41] and the Language-Integrated Query (LINQ),[42] all of the business logic classes and functions have been developed, database connectivity logic has been created, and queries were managed.

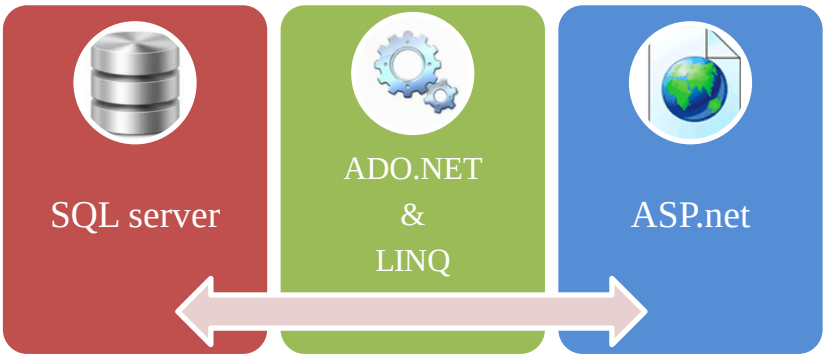


Figure 62: ADO.NET and LINQ deployment in the LWC-EPI prototype

The heart of the resultign prototype is the web-based application that communicates with enterprises' data sources and environmental data sources using web services. This application can be accessed via different web browsers, such as Google Chrome, Mozilla Firefox, or Microsoft Internet Explorer. Thus, the user will not have direct access to the underlying technologies.

As Integrated Development Environment (IDE), the prototype was developed in Microsoft Visual Studio 2010[43] following the .NET framework 4. This formulates the technological base of most of the implemented functionalities in the prototype.

Visual Studio provides a variety of web project templates that ease creating, testing and deploying web-based projects.[44] Out of these templates, the "ASP.NET Web Forms Application" has been used. As it is stated in the Microsoft Developer Network (MSDN) website, this template can be used to build applications based on ASP.NET Web Forms pages.[41] It includes various features that developers can choose to use or not, such as master page, navigation that uses a menu control, and login security. Templates such as data folder (App_Data); web pages named Default.aspx, Contact.aspx, and About.aspx; and global application class (Global.asax file) are provided by default for any ASP.NET web application project.[41]

The ASP.NET is designed as a server-side technology, where all its code executes on the Microsoft Internet Information Services (IIS) as a web server (Mueller, 2008 pp. 39-40). By executing the code, the user receives an ordinary HTML page that can be accessed using any web browser as it is shown in Figure 63.

[41] http://msdn.microsoft.com/en-us/library/e80y5yhx(v=vs.110).aspx, msdn.microsoft.com., 2014.

[42] LINQ is a specific Microsoft Visual Studio feature

[43] http://www.visualstudio.com/

[44] http://msdn.microsoft.com/en-us/library/ee377605%28v=vs.110%29.aspx, msdn.microsoft.com., 2014.

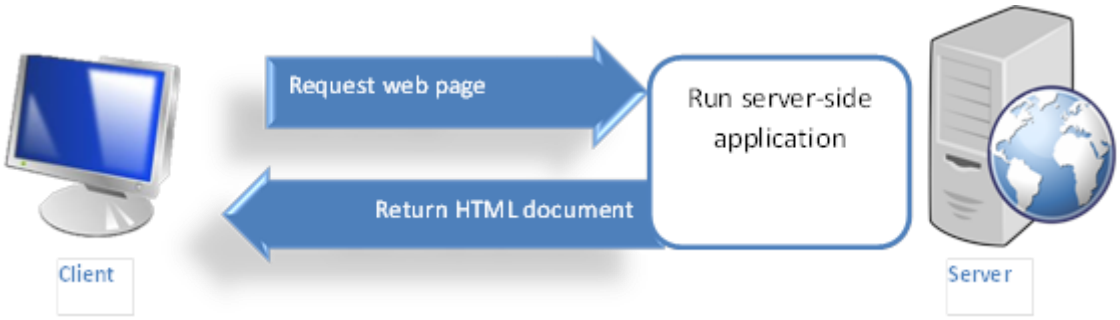


Figure 63: Server-side web applications

The Microsoft SQL Server 2008 R2 (version 3.5) has been used as database server for the system. As an administrative tool, the Microsoft SQL Server management studio 10 has been used to develop, access, manage, and work the SQL Server's components. Using the ASP.NET supports validating the system's RDF[45] with the W3C validation service.[46] As it was explained, the ADO.NET has been used as database connectivity creation and for query management. Furthermore, the LINQ business logic classes and functions have been built. As the programing language, the C# was the main one used for the system's development. In addition, Java was used to write the code that connects the system with external sources (the ELCA, and the A+). The Windows Communication Foundation (WCF) has been used to establish the communication between the LWC-Portal and other external clients. The WCF is a distributed API that serves as web service, and facilitates the communication between two systems. All the Web Services were developed using the ASP.NET 4.0 and the WCF 4.0. Both were configured using XML configuration files to support the publishing on any server or client.

Table 33 lists all the technologies that have been used in developing the LWC-EPI prototype, and it shows the layer in which they have been deployed.

Technology	Version	Layer	Note
ASP.NET	4.0	Presentation layer	It is used to build the main web applications.
W3C RDF Validation Service	1.0	Presentation Layer	W3C RDF validation service was followed by using the ASP.NET, and the XHTML.
C#	4.0	Presentation Layer	As main programing language for the system
Java script	1.8	Presentation Layer	As a client-side scripts
XHTML	1.0	Presentation Layer	It has been used to display presentation elements. It was used implicitly by visual studio.
Microsoft Visual C# 2010	4.0	Application layer	It has been used as the main programming language in the platform.

[45] RDF: Resource Description Framework

[46] http://www.w3.org/Consortium/, the World Wide Web Consortium (W3C), 2014

Microsoft WCF	4.0	Application layer	WCF is used to design and deploy the system's distributed applications following SOA paradigm.
Java	JRE 7	Application layer	Programing language to write a code that connects the system with external sources.
Microsoft Visual Studio 2010 Professional	10.0	Presentation layer Application layer	Is the IDE used.
Microsoft IIS	7.5	Web server	It is the used web server.
Microsoft SQL Server 2008 Professional	Pro.	Database layer	It has been used as a relational database server.
Microsoft SQL Server management studio	10	DBMS	It has been used as DBMS tool
ADO.Net	3.5	Database Tech.	As database connectivity creation, query technology
LINQ	2.0	Database Tech.	As a query tool to query the system's database.
.NET Framework	4.0	The 3 layers	It has been used to facilitate the interoperability between the applications.

Table 33: The used technologies in the LWC-EPI prototype

6.2 The LWC-EPI prototype description[47]

The LWC-EPI prototype has been implemented with the aim of proving the LWC-EPI framework. It follows the recommended models and processes to provide a holistic perception of a web-based EMIS serving different types of organizations, especially SMEs that lack the needed knowledge. The main five models of the LWC-EPI framework and most of their attributes were implemented in tables. Out of those tables, the LWC-EPI portal classes were extracted. Figure 64 depicted the solution class diagram where the Unified Modeling Language (UML)[48] had been used as a modeling language. This diagram consists of seventeen classes as it is explained in Table 34.

Class name	Role
Organization	Represents the organization information such as the name, the address, and the organization size
Organization unit	Represents the organization's units, which can be either a physical or an organizational unit
ASPNET user	Represents the portal user's data

[47] This prototype has been developed with the help of group of students in "Wissenschaftlicher Teamprojekt" at the Business Informatics chair, Faculty of Computer Science at the Otto-von-Guericke-Universität Magdeburg.

[48] http://www.uml.org/

ASPNET membership	Represents the portal user credentials such as the encrypted password and the email
EPI	Environmental performance indicators with their equations, descriptions, and in/out parameters
EPI classifier	The EPI class representing its impacts, business fields that it belongs to, etc.
Business field	Defines the available business fields in the portal
ECET questions	The ECET Assessment model questions
ECET answers	Organizations' answers on the assessment model
Instance statement	Represents one instance's data such as the calculated EPI values, owner, etc.
Input material	Defines the input materials in an EPI's equation (parameters)
Output material	Defines the output material of the EPI's equation (parameters)
Impact	Defines the environmental impacts of each EPI
Equivalence	Defines the potential equivalent substance that can be used to express the combined impact related to the EPI
Environmental aspect	Defines the main focus or aspect of each EPI
Level aspect	Defines the potential levels of the EPI classifier, take such value (Corporate, Process, Product, Unit)
DPSIR category	Defines the available categories of the DPSIR framework

Table 34: The components and attributes of the data module

The system's users will represent different organizations and their units. The system distinguishes two types of users:

- The guest: are those visitors that are still unregistered users. Mainly, they can check some open pages that provide general information about the system and its aim. In addition, related information on environmental sustainability is provided with hyperlinks to related webpages, such as the webpages of the GRI, the ELCD, and the EMAS. After checking the open pages, the guest can start the registration process.
- The registered user: represents an organization. This type of user will be able to use the system's modules, such as:
    - Evaluate the organization's readiness to start using the system.
    - Calculate selected EPIs.
    - Create new EPIs.
    - Rank the EPIs.
    - Run customized reports, with the option of comparing the results with other organizations.

The next paragraphs demonstrate the LWC-EPI web application and its functionalities.

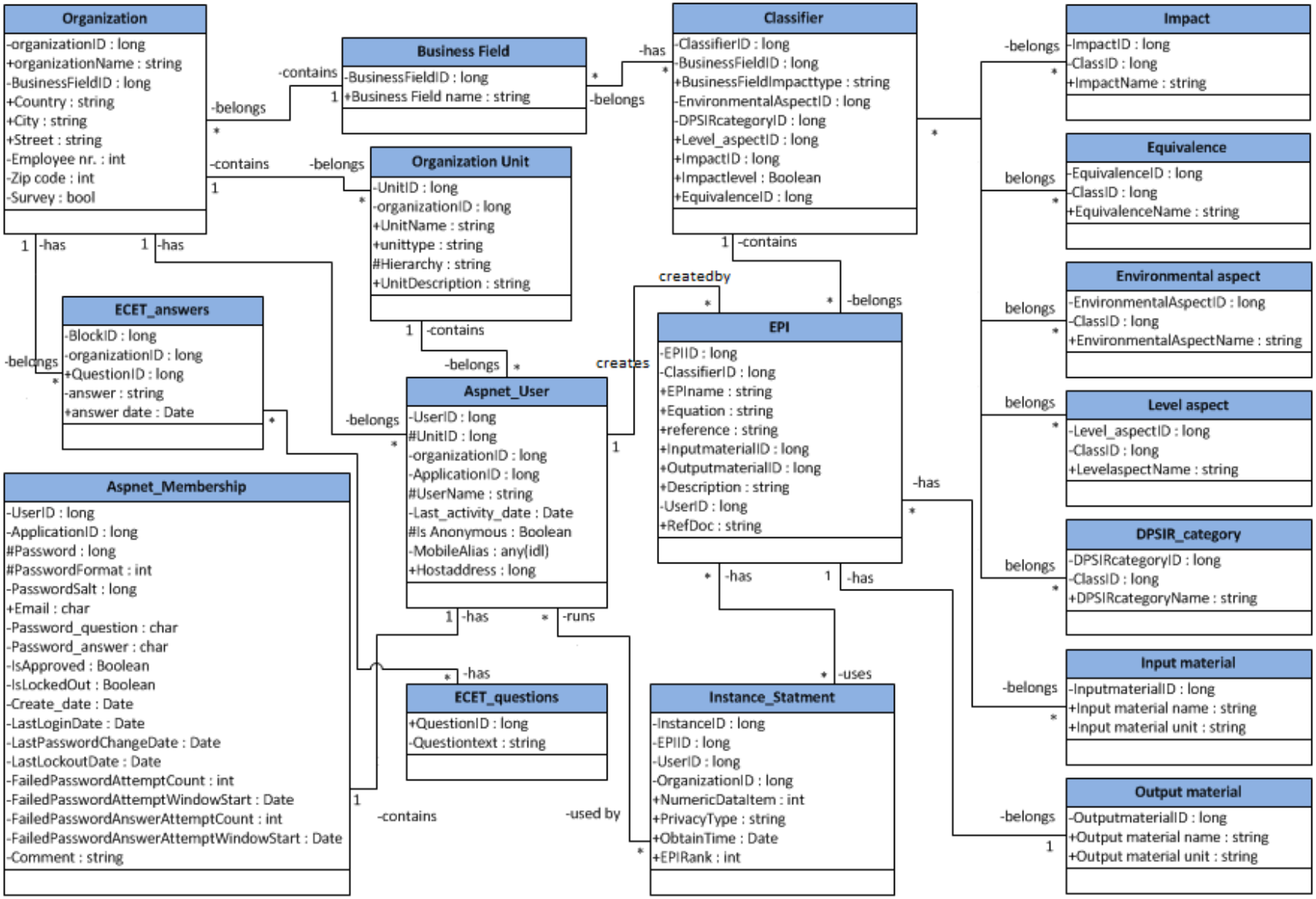


Figure 64: LWC-EPI prototype's class diagram

6.2.1 The Home Page

The home page is the main page where all the system features can be accessed through. As it is depicted in Figure 65, for a new guest user, two tabs will be visible. Under the "Home" tab, general information about the LWC-EPI solution and team is provided. The second tab is "About;" it provides general information about sustainability, environmental development, EMISs, etc. Moreover, useful links to enrich the guest knowledge are included as it is illustrated in Figure 65.

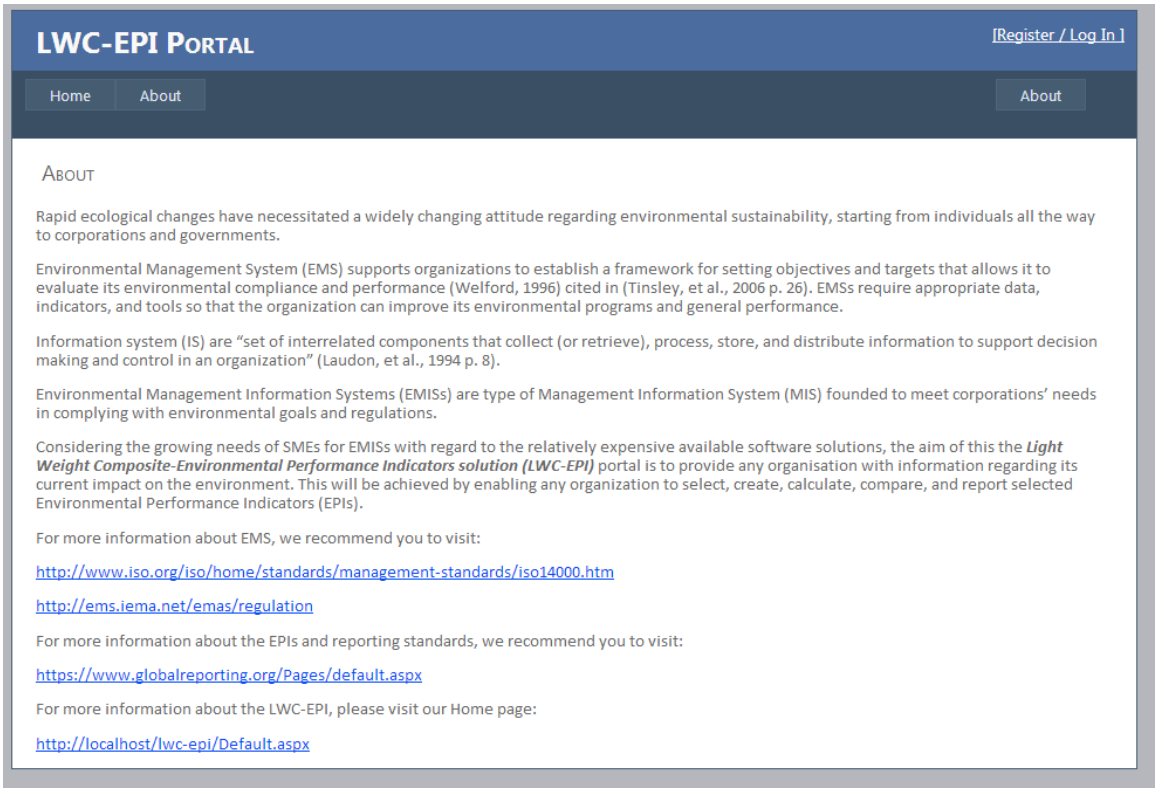


Figure 65: LWC-EPI prototype's home page, offline mode

In addition, the home page includes a registration button and a login button placed in the upper-right corner of the page. After completing the registration, all the features' buttons will appear on the home page as it is shown in Figure 66.

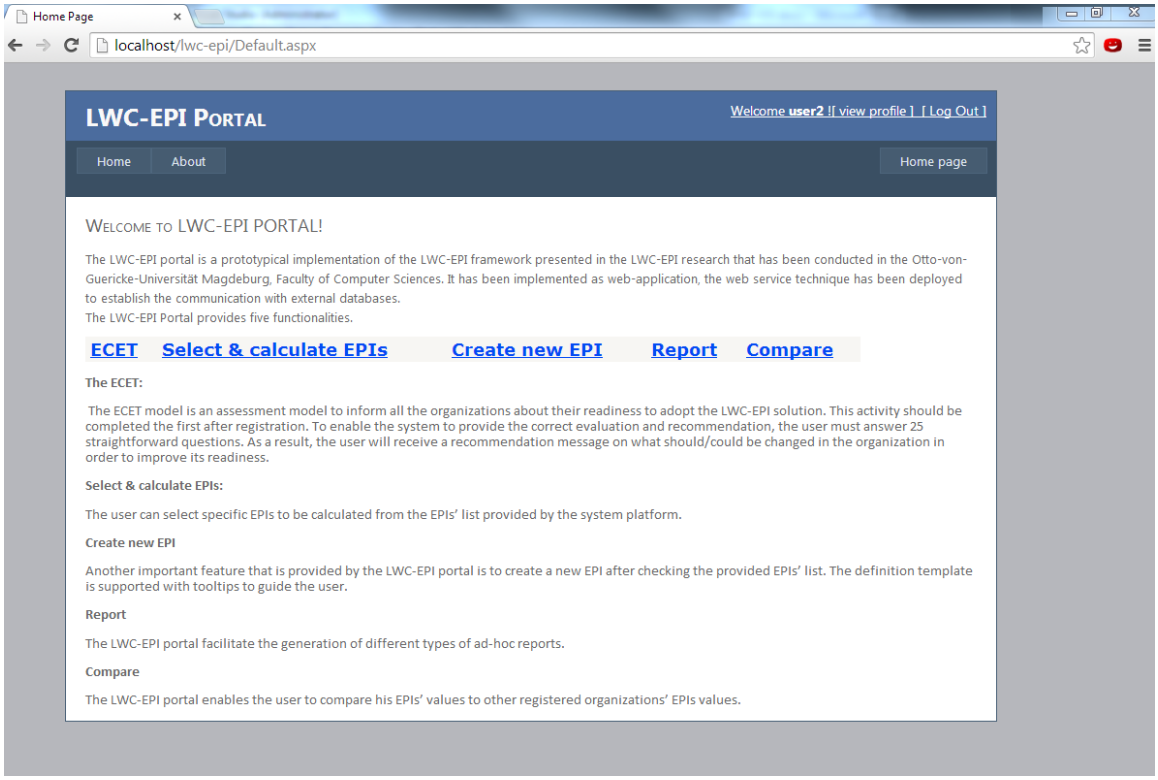


Figure 66: LWC-EPI prototype's home page, logged-in mode

6.2.2 The Registration Page

The LWC-EPI registration page can be accessed directly from the homepage with one click, and every user should be registered to start using the system features. The registration process includes three steps:

- Step one, register an organization: The new user should first register his organization by choosing "add new company" from the dropdown list, then he should provide the following information:
  - The organization name: as text, and it is mandatory
  - The business field: a mandatory field represents the business field of the organization. Here the user should choose one of the provided options from the drop down list.
  - The organization address: includes four input boxes for the country (mandatory), the city (mandatory), Zip/postal (optional), the street (optional).
  - The number of employees: as a number, and it is mandatory.

By clicking the "Next" button, the system will check the data completeness; if there is something missing, an error message box will appear telling the user what is wrong. Otherwise, the user will move to the second step, which is defining the organization structure. Figure 67 shows the LWC-EPI registration page, step one (register an organization).

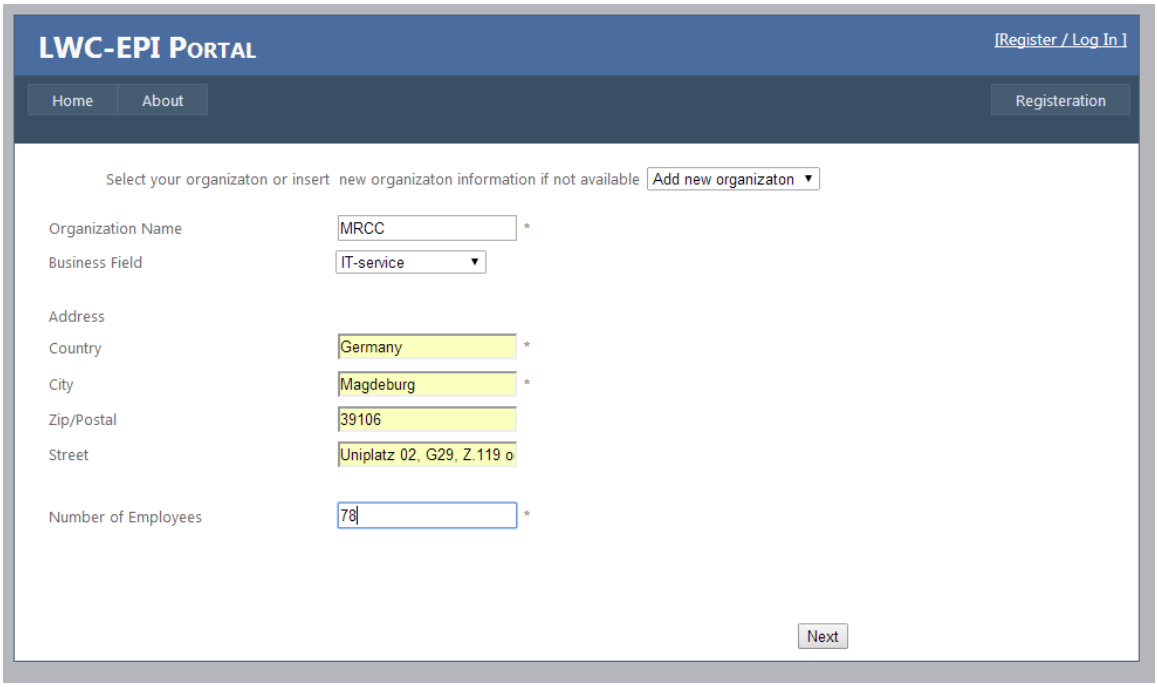


Figure 68: LWC-EPI prototype's registration page, first step

Users that belong to a registered organization can skip this step by choosing their company and move directly to the second phase. For security issues, they should provide the "Company Identification," which is a unique number provided from the system to the first user of the organization (initial user) as it is represented in Figure 68. By clicking the "Next" button, the system will check the entered ID. If it is wrong, an error message will appear as it is shown in Figure 68; otherwise, the user will proceed to the next step.

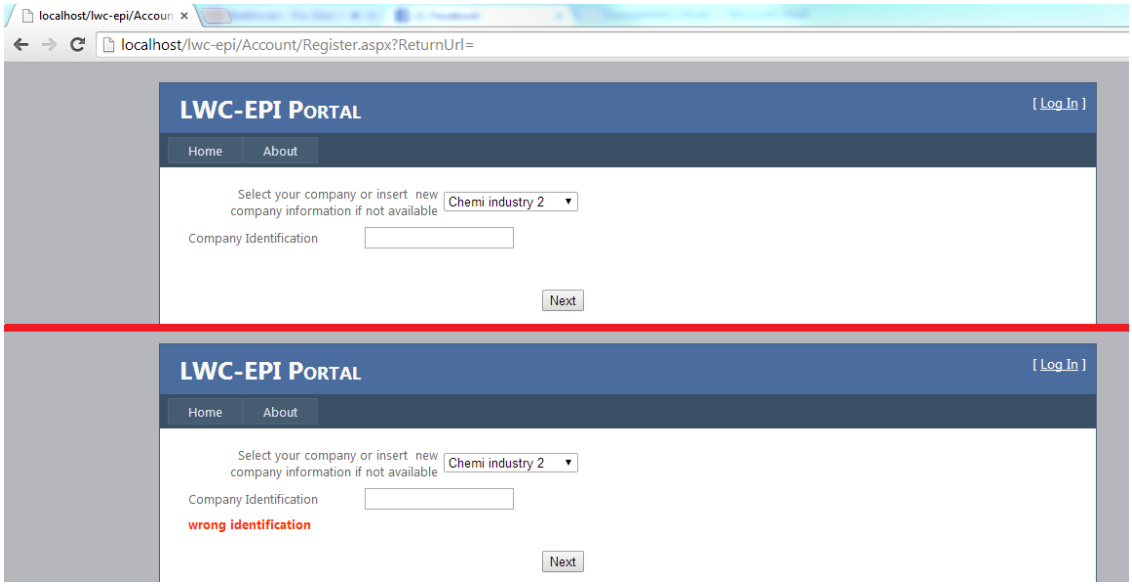


Figure 67: Company Identification check in the LWC-EPI prototype's registration page

- Step two, define the organization' units: after registering the organization, the user should define at least, the unit that he belongs to. Here he can decide to define just one unit, or build the whole organization structure. By clicking on "Add Unit", the defined

unit will be added, and the user can add new unit of the organization. To define a unit, the user should provide the following information:

- The unit name: as text, and it is mandatory
- The unit description: an optional field that allows the user to provide a small description of the unit.
- The unit type: here the user should choose one of the two provided options from the drop down list. It differentiates between units that are physical entities (transporter, building, machine, etc.) and organizational units, such as department, board of trustees, shareholders, etc.

By clicking the "Next" button, the system will check the data entries; if there is something missing or wrong, an error message will appear telling the user what is wrong. Otherwise, the user will move to the third step, which is setting the login data. Figure 69 is a snapshot of the second step of the LWC-EPI registration process (define the organization' units)

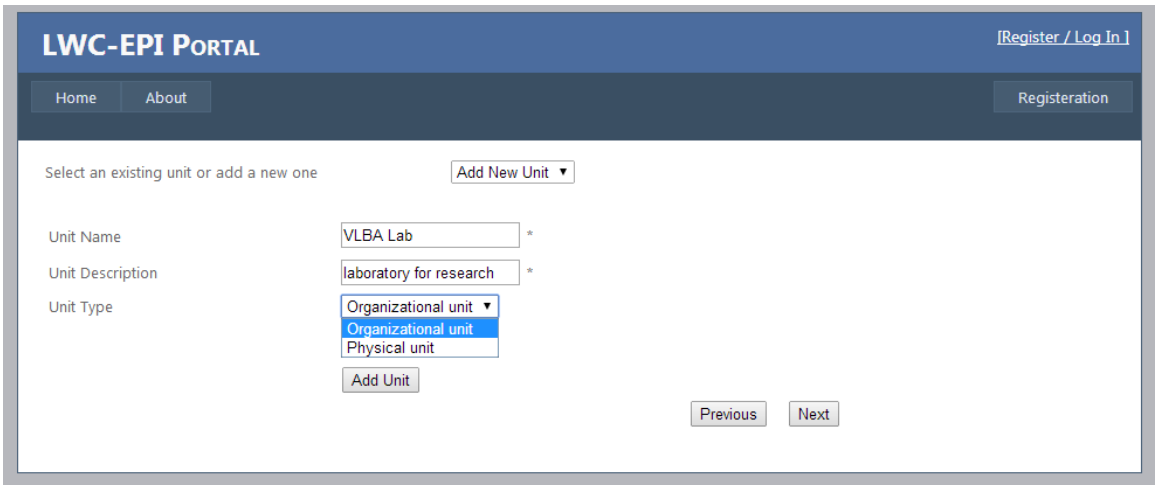


Figure 69: LWC-EPI prototype's registration page, second step

- Step three, setting the login data: after defining the unit/s, the user can move to set his login data. To do so, seven mandatory data input boxes should be filled out:
  - The user name: is a unique user name to be used for the login.
  - The password: it should have at least eight characters including at least one numerical digit or special characters, e.g. !, ?, @, etc.
  - The password confirmation: it should be exactly the same as the entered password.
  - E-mail address: is an E-mail address that will be used from the system in case it is needed.
  - Security question and answer: specified by the user, and it can be used by the system for security issues, such as changing password, editing some special field in the user profile.
  - The host address: the user should provide an access link to the organization data source by submitting the URL of his web service. This field has a "help" button to guide the user.
  - The Unit name: The user should specify to which of the organization's units he belongs to.

By clicking the “Create User” button, the system will check the data entries; if there is something missing or wrong, an error message will appear alerting the user to the problem. Otherwise, the user account will be created and the user can start using the system. Figure 70 depicts the LWC-EPI registration page on the third step (setting the login data).

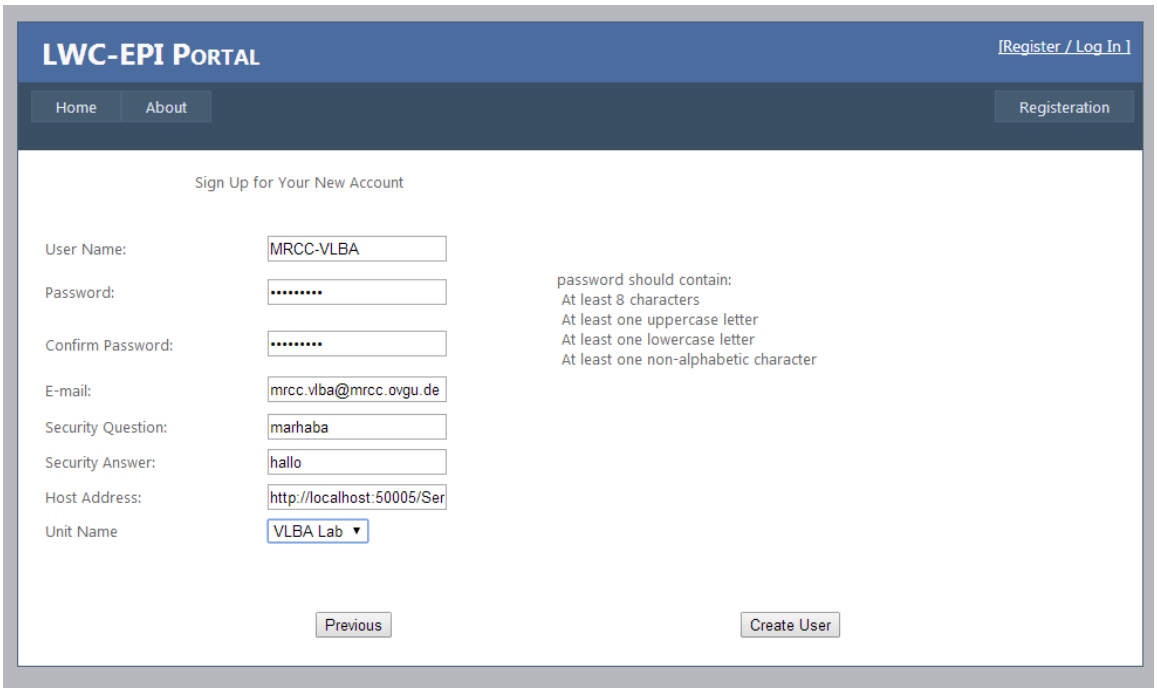


Figure 70: LWC-EPI prototype’s registration page, third step

6.2.3 The ECET Model Page

Following the ECET assessment model that has been explained in Chapter 4, the LWC-EPI prototype provides a web page for this model. After completing the registration, the first user of an organization (initial user) must complete the ECET assessment process as it can be seen in Figure 71. Each registered organization must answer 25 straightforward questions grouped into four dimensions as it was proposed in section 4.3. All questions are proposed in a way that the user should evaluate the organization, its knowledge, maturity level, etc. The questions are multiple-choice, with radio buttons including five choices: Excellent, Good, Acceptable, Weak, and Very weak.

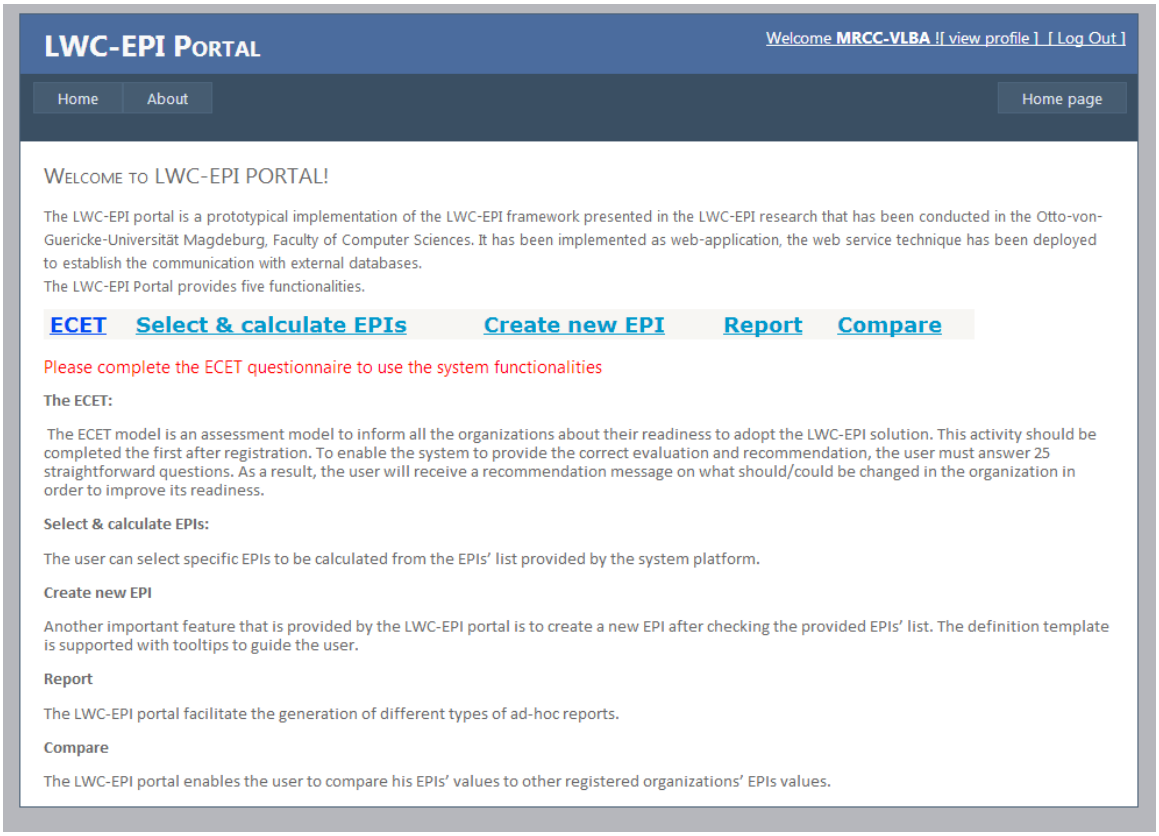


Figure 71: LWC-EPI prototype's home page after successful registration page

Figure 72 presents the ECET questioner page. On top of the page, the user will be notified if there is already an old result, or if it is the first obligatory time for the organization he belongs to. The user can decide to do the assessment another time, or just check the old result by clicking on "show the old result" button. To complete the assessment, the user answers the questions and then clicks on the "complete" button. The system analyses the answers and represents the result as a graphical chart along with textual recommendation letter as it is demonstrated in Figure 73. The analysis and the recommendation processes are guided by the findings of Chapters 3 and 4. As it was mentioned, it supports the organization to assess its readiness to start using the system, and what is missing. In addition, it can show in which area the organization performs well, and where it needs work, so that it knows where to start. After completing the ECET model process, the user can start using the other portal functionalities.

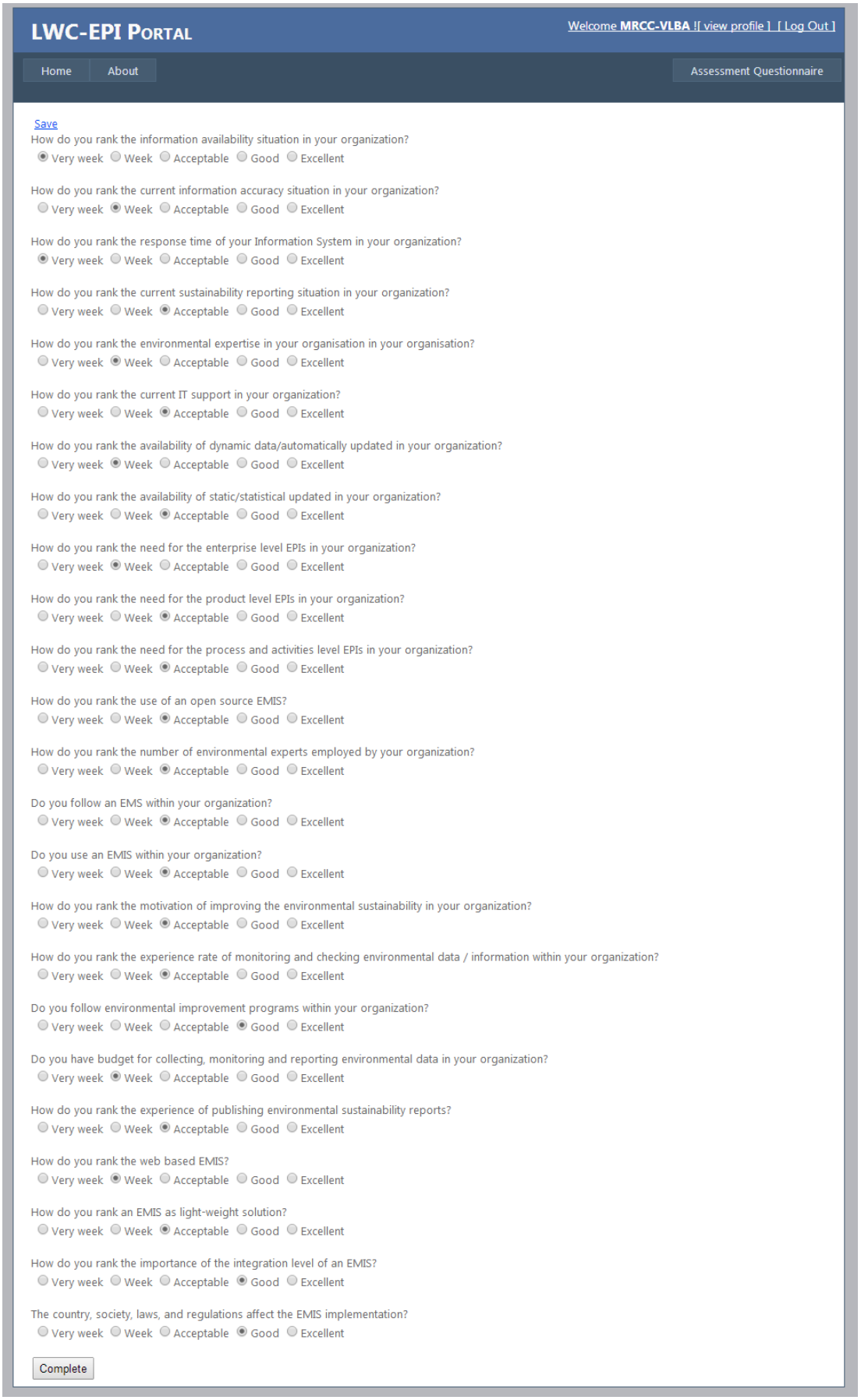


Figure 72: The ECET questioner's page

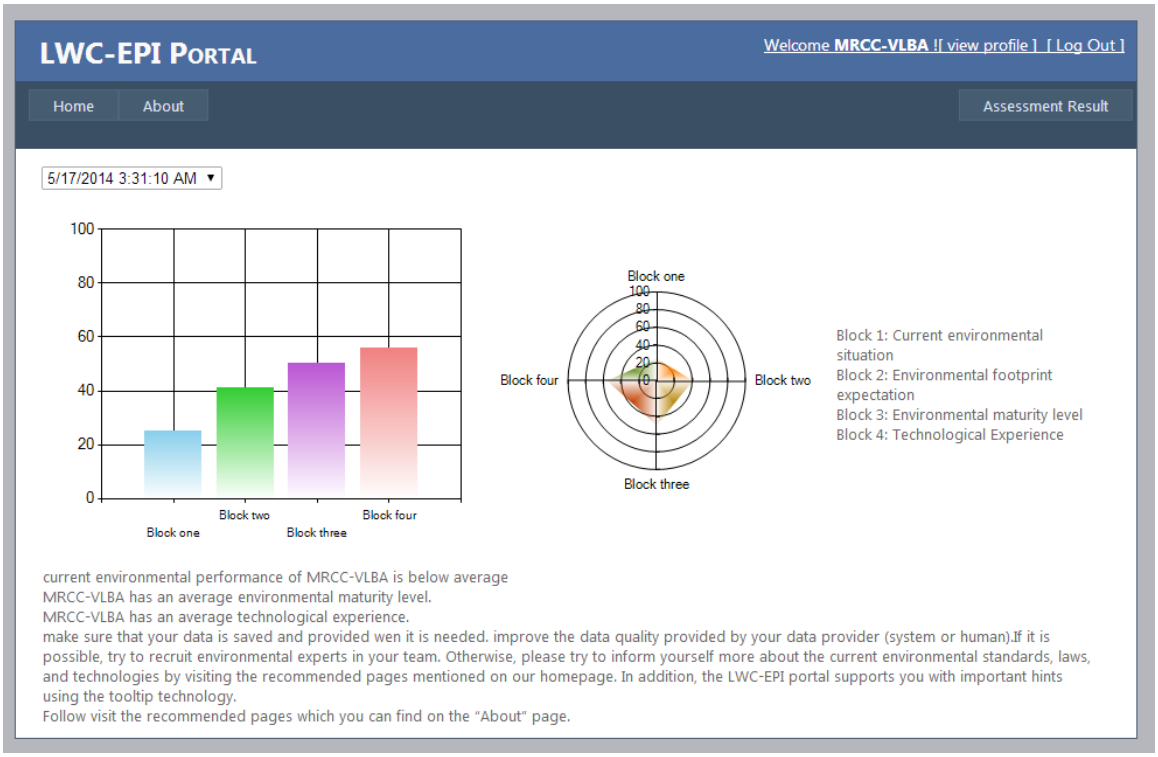


Figure 73: The ECET results representation page

6.2.4 Select and Calculate the EPI Page

As it was recommended by the LWC-EPI framework, the prototype will facilitate the EPIs' selection process and provide different options to calculate the selected EPIs. By clicking on the button "select and calculate EPIs" from the homepage, the user will receive a list of recommended EPIs based on the system knowledge. The user can choose one or more EPIs from the list to be calculated, or he can decide to expand the list to check all of the defined EPIs in the system by clicking on "show me all". Figure 74 shows the LWC-EPI Portal in this phase.

Figure 74: The "select and calculate EPIs" page, the EPIs' list

When an EPI is selected, a short description will automatically appear. If it is not clear enough, the user can click on the "Full description" button to get more information. Moreover, directly under the short description, the calculation method will be shown to help the user in understanding the required inputs for completing the calculation. This is shown as a table containing the input parameters and their units, followed by the expected output parameter and its unit. All these data are retrieved from external databases' providers using web services or Java script.

For the calculation, the user can choose to use the system data sources, or to provide the input manually. In the first case, the system will use the database of the user's organization as a main source. In addition, other external databases will be connected to restore the missing data and retrieving important complementary data. Using the appropriate Java script, EPI's value is calculated on-the-fly, and the value will be provided to the user.

If the user chooses to provide the required input values manually, he should enter the values as it is explained in the calculation method table. These inputs are checked by the system, and if they are correct and complete, the system will provide the result.

After getting the result, the user can decide to save the value or not. If he chooses to keep it, the system will save it in the dedicated part of the system's database "the processed data container." Otherwise, it will be deleted. Figure 75 presents the "select and calculate EPIs" page in the LWC-EPI portal.

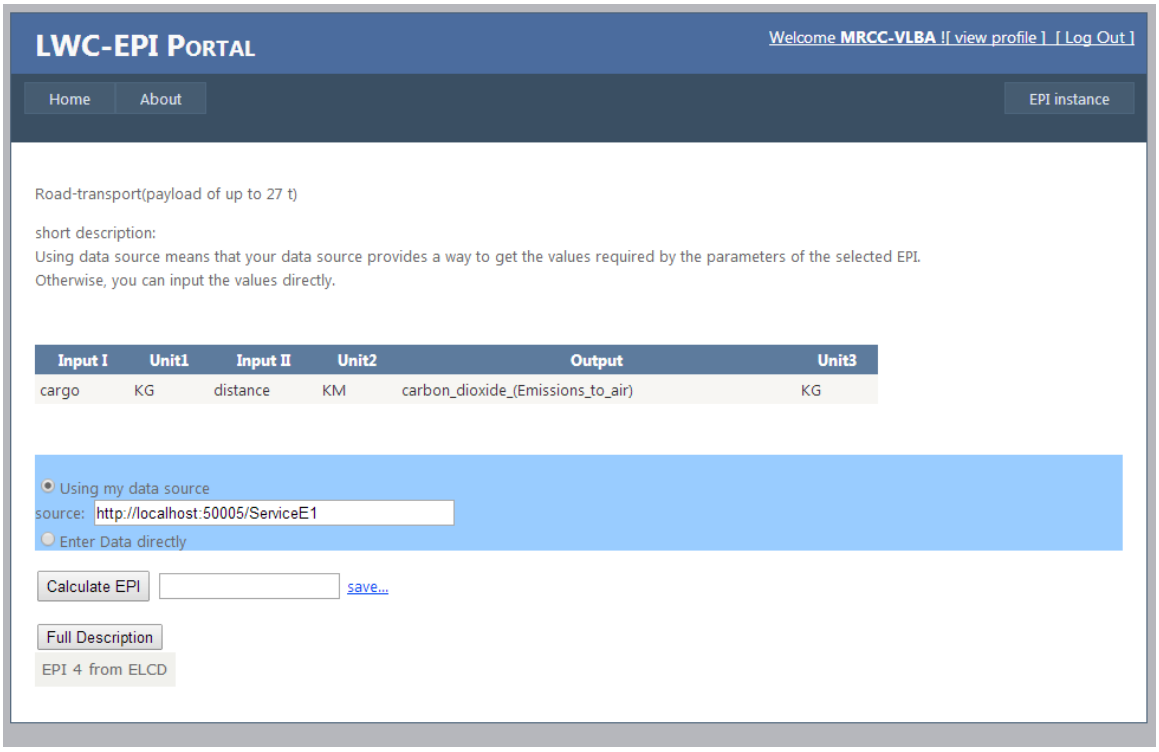


Figure 75: The "select and calculate EPIs" page in the LWC-EPI portal

Saving the calculated values is done by clicking the "save" button next to the value (as it can be seen in Figure 75). In this case, the system will ask the user to specify if the result is private, open for the other organization's users, or open to public. In addition, the user should rank the used EPI from his perspective considering its provided description, importance, relevancy etc. These EPIs' policies and ranking will be used in the reporting and comparing processes. The user will receive a confirmation message if the EPI's value has been

successfully saved as it is illustrated in Figure 76. If something was missing or wrong, an error message will pop up.

Figure 76: The "select and calculate EPIs" page, save the calculation's results

It should be mentioned here that in this process, nothing will be loaded to the organization's database, and the system will not change it. In addition, giving the user more than one way to calculate his EPI will decrease the possibility of reaching a process termination without getting the required answer. The system will automatically move to the next selected EPI which the user chose in the previous step. After calculating all the selected EPIs, the user will be directed to the "Home" page again.

6.2.5 Create new EPI's Page

The LWC-EPI portal enables any user to define new EPI by providing the appropriate definition and class that it belongs to. By clicking on the button "create new EPI" on the homepage, the user will be directed to the EPI creation page. This has been built based on the proposed EPI structure presented in Chapter 4.5 (see Figures 39, and 42).

As it is shown in Figure 77, the user should define his EPI by entering the following:

- The EPI name: it is a string input such as energy consumption per capita.
- The input materials, their names, and units: these encompass the calculation's equation parameters.
- Calculation equation: represents the EPI calculation equation. It supports the four basic operations (+, -, *, and /). For example, an equation can be: (input 1 * input 2) / 0.132.
- The output material, its name, and unit: specify what the result of this EPI is.
- Reference: here the user can mention if he built this EPI based on specific standard such as the GRI, or ISO 14036. If not, the system will count it as an EPI built based on the user's organizational standard by default.
- Description: is a textual description of the EPI.

After defining the EPI, the user should classify this EPI by selecting the appropriate choices for six to eleven predefined attributes. Each of these attributes provides the user with predefined choices to ease the selection method. Moreover, all the fields are supported with

tooltip,[49] so short textual explanations will pop-up when the user points with his mouse to the input space.

As it can be seen in Figure 77, the EPI classification's attributes simulate the recommended EPI model provided by the LWC-EPI. It consists of:

- Environmental aspect: a dropdown list includes emissions, energy consumption, material consumption, water consumption, liquid waste, or solid waste.
- DPSIR category: user should specify if it is driving force indicator, pressure indicator, state indicator, impact indicator, or response indicator.
- Level aspect: contains four options: corporate, product, process, or unit.
- Impact: the user can set up to three impacts for an EPI. He can choose whether the impact is direct or indirect, and the impacts can be acidification, eutrophication, global warming, or ozone depletion.
- Business domain: the user can choose more than one business domain that the EPI can belong to, or leave it as general. These business domains usually reflect the business domains of the registered organization. Moreover, the user can add a new business domain to the list directly from this page.
- Equivalence: it describes a potential equivalent substance that can be used to express the combined impact related to the EPI, to identify a specific contribution to the EPI impact, or the Greenhouse gas (GHG) protocol scope, which can be used for related GHG EPIs. This dropdown list contains eight choices: carbon dioxide equivalent, nitrous oxides equivalent, carbon dioxide, hydro fluorocarbon, or methane, GHG scopes 1, 2, or 3.

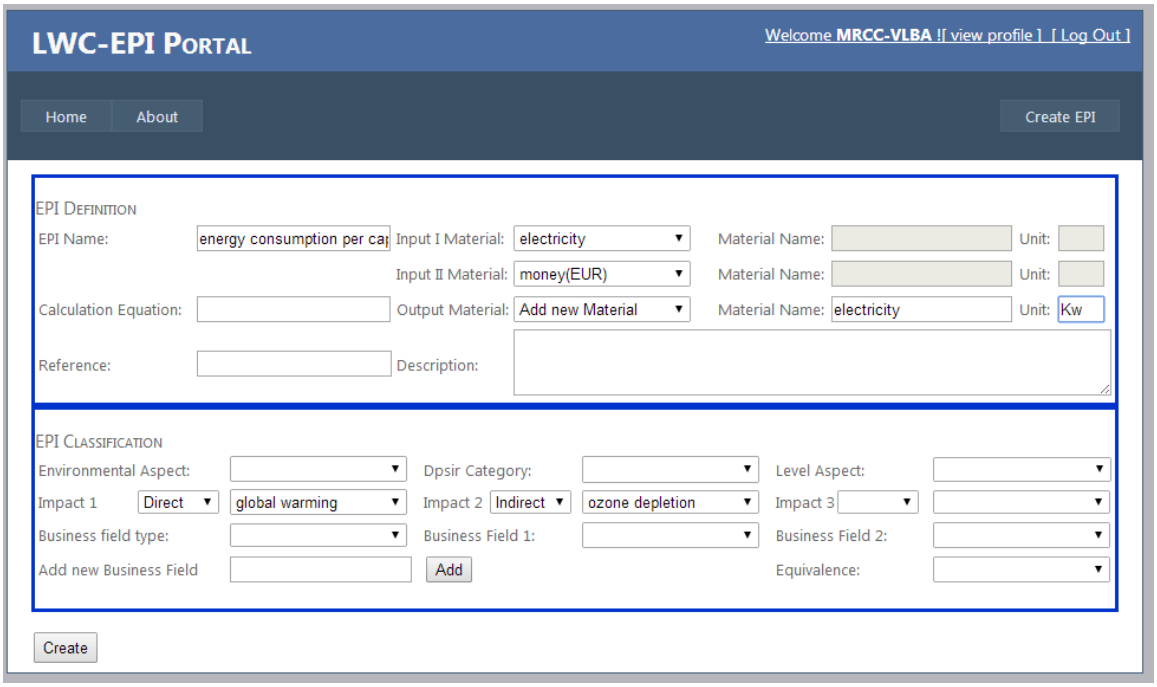


Figure 77: The "create new EPI" page in the LWC-EPI portal

By clicking the "create" button, the system will check the data entries; if there is something missing or wrong, an error message will appear telling the user what is wrong. If not, a

[49] http://msdn.microsoft.com/en-us/library/system.windows.forms.tooltip(v=vs.110).aspx

duplication check will be conducted where the system scans if there is a similar EPI in its repository to the requested EPI. This test focuses on comparing the EPI calculation's equation. If there is a similar EPI, the system will recommend it to the user, and he can decide to proceed with the creation or use the recommended EPI.

6.2.6 Run Report Page

The LWC-EPI prototype provides its user with a seamless reporting feature where the calculated EPIs' values and the analysis results are visualized. By clicking on the button "Report" on the homepage, the user will be directed to the report definition page presented in Figure 78. The user should specify the period of time that he wants to report, and which types of EPIs should be included. The portal supports three EPI levels for reporting: private, organization, and public. The user can select one or more options as follows:

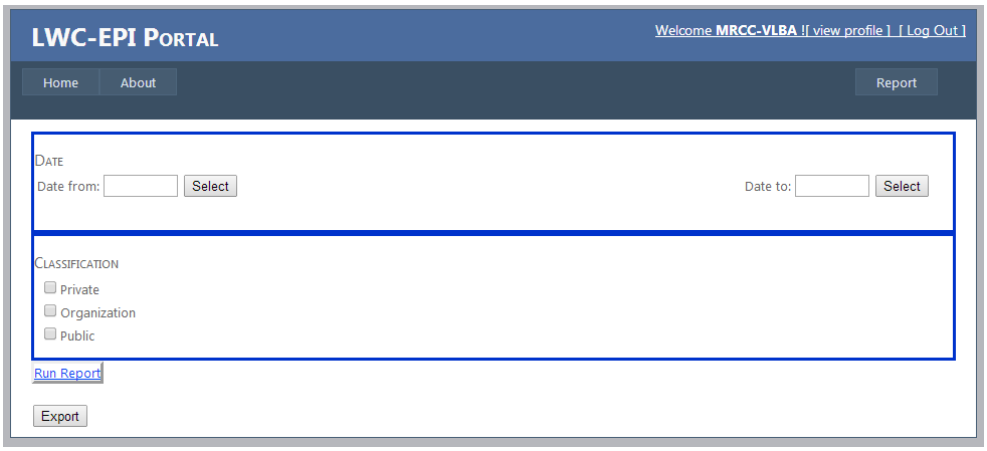


Figure 78: The report definition page in the LWC-EPI portal

- If he chose to run a report for public EPIs, the user will be provided with all the EPIs' values that have been calculated and saved during the specified time frame.
- If he selected to run a report for organization EPIs, the user will be provided with the EPIs' values that have been calculated during the specified time frame, and saved as organization EPI, (see section 6.3.4).

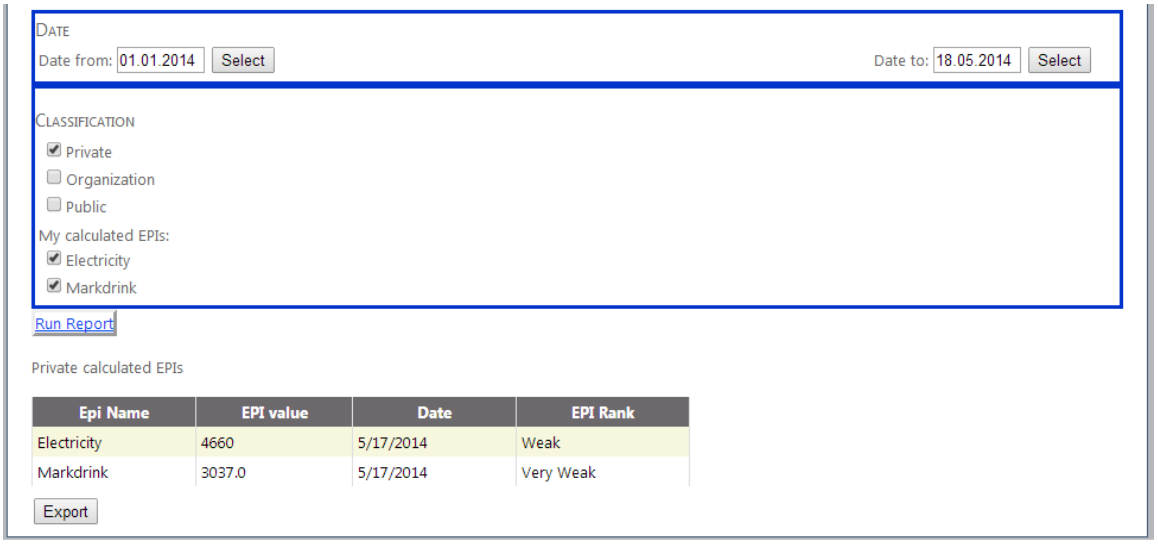


Figure 79: Private EPI report example

- If he decided to run the report for the private EPIs, the system will provide a list of the EPIs that have been calculated during the specified time frame, then the user can select one or more EPIs to run the report including these selected EPIs. Figure 79 demonstrates an example of this option, while Figure 80 shows an example of a report of multilevel EPIs.

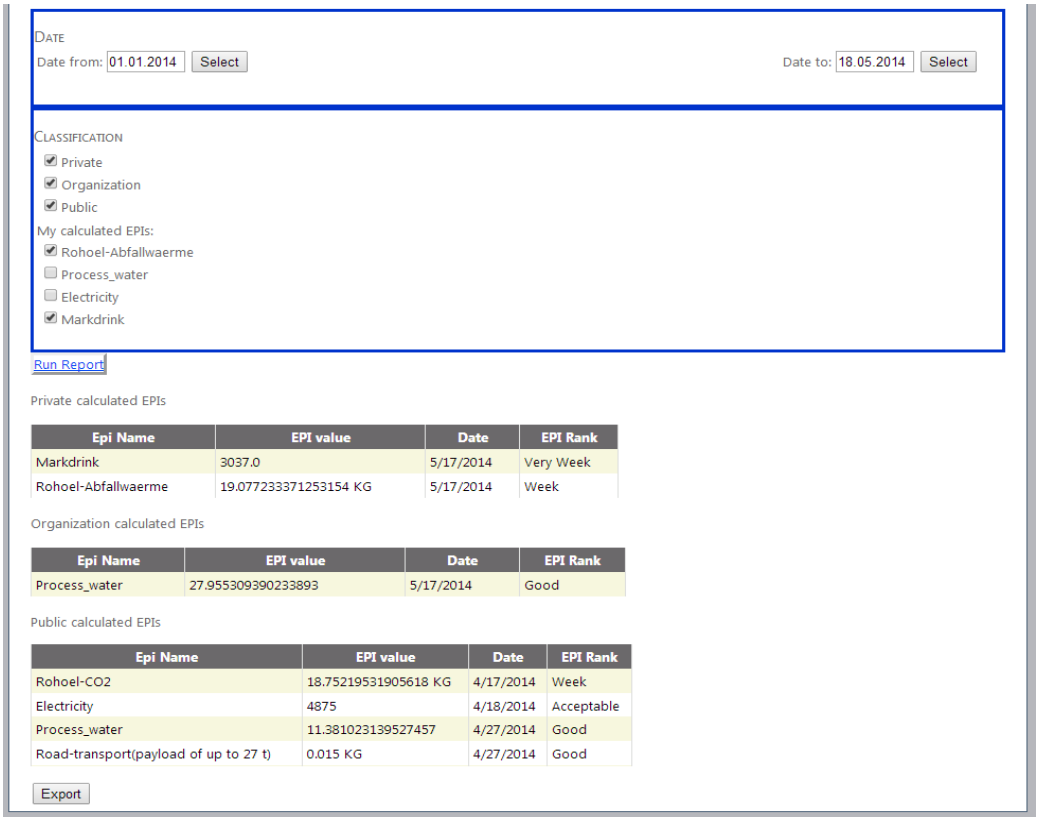


Figure 80: Multilevel report example

6.2.7 Comparison Report Page

Registered organizations will be able to assess their progress, and compare their EPIs' results to other organizations. The LWC-EPI portal facilitates this benchmarking by providing an easy to use comparison webpage. By clicking on the "Compare" button on the homepage, the user moves to the comparison report page presented in Figure 81.

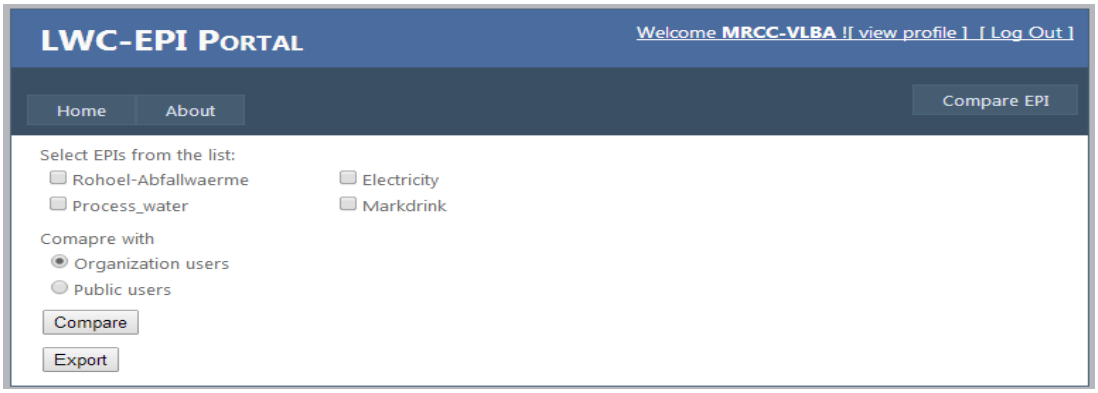


Figure 81: The comparison report definition page in the LWC-EPI portal

The user should define the comparison report metrics. These include:

- Specifying the time frame
- Select the EPIs that he wants to compare. Here, the EPIs' list includes all the EPIs that this user had calculated during the specified time.
- Decide with which group he wants to compare his EPIs. For this, two choices are supported:
    - Compare his performance with the other users belong to the same organization.
    - Compare his performance with the other organizations' users. In this case, he should specify if he wants to compare the results with organizations from the same business field or with all the registered organizations in the system.

After setting the three metrics, the user can run the comparison report. The system illustrates the report as it is depicted in Figure 82. Moreover, the system provides export functionality, so the user can export his report to MS Excel to save, print, or modify it.

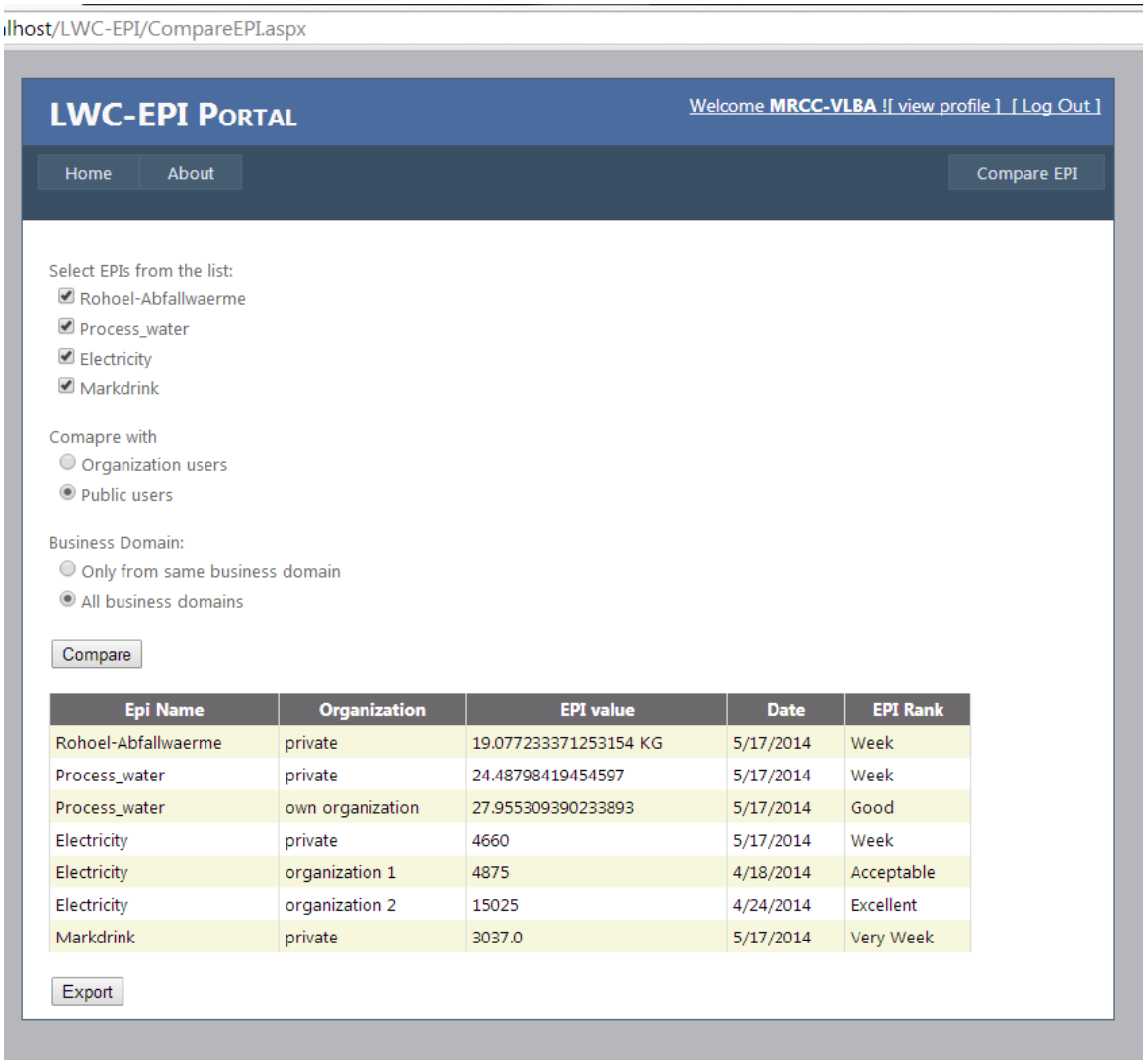


Figure 82: The comparison report provided by the LWC-EPI portal

6.3 Prototype Testing

The first phase in evaluating the LWC-EPI prototype was to test its functionalities based on the defined use cases presented as activity diagrams in Chapter 5 and to use test cases to check the corresponding roles. Moreover, continuous code testing, black box, and white box testing, in addition to continuous assessment activities, have been used. This section summarizes the testing phase applied for this prototypical implementation.

The system was developed following multi-tier architecture. This is why the code has been reviewed separately for each tier at the beginning of the development process. In later phases, a comprehensive code review was accomplished. Appendix 11 represents the code that has been used for developing the LWC-EPI prototype, please see A.11. The functional black box testing approach was used for testing the presentation tier and the data tier that includes the user interface and the data storage and access. The white box testing approach was used for testing the logic tier that contains the functional processes' logic and business rules.

The test results have been linked to various aspects that have an impact on the proposed solution. The *usability and graphical user interface aspect* has been evaluated: as it has been mentioned, the system targets the SMEs, with the ability to provide an easy to use interface as an important success factor. That is why the LWC-EPI portal has been developed as web application, and enriched with assisting messages such as tooltip or information popup messages. Moreover, using web portal gives the users more accessibility without required installation of any additional software. Since the solution has been developed as web portal, the web browser was the access platform from the user side. For this, the portal's functionality has been tested using three different browsers, which were the Google Chrome©, Mozilla Firefox©, and Internet Explorer© 10. The project consists mainly of eight activities (use cases) that appear on the portal home page. As for an end-user functionality test, ten potential end-users - most of them students with different backgrounds - have been asked to check the portal's functionalities, the system performance, and ease of use. It has been decided to perform this test without any assisting material such as a tutorial or user manual.

Each tester has been asked to complete seventeen tasks, as it can be seen in A.12, depending on his common knowledge of using websites aside from the portal assistance services. The evaluation has been considered successful if the tester completed the tasks within one hour, without facing any bug, and without asking for help. Furthermore a well-designed system should give accurate results to configure a reliable evaluation. Table 35 represents the test form that has been used, including the seventeen tasks to be conducted, the number of clicks needed to complete the task, the minimum and maximum needed time that have been used to complete each task by the testers and their remarks, if any. As it can be seen in Table 35, some users were able to check all the functionalities and completed the tasks in less than ten minutes, and all of them were able to complete the tasks without any assistance in less than 30 minutes.

Nr.	Task	Nr. of clicks	Time needed	Note
1	What is the first step you have to do in order to start using the system functionalities	1	4 - 5	Registration
2	Please complete the registration step	22	145 -	Not easy to

			300	find the host
3	Log out and try to log in with your user name and wrong password	2	15 - 60	Error
4	Please log in with the right data	2	10 - 21	2 data entries
5	Try to calculate an EPI	1	4-15	ECET result is required
6	Complete the ECET assessment model and check the result	27	71-205	
7	Try to change three of your answers and save the new result	5	21-50	
8	Calculate three EPIs using the webservice you offered, and save the results with different privacy	8 + 6+6	38 - 160	
9	Try to define new EPI	2	45 - 240	10 to 21 entries
10	Try to calculate the new created EPI using manual data entry	8 - 9	45 - 80	
11	Try to generate a report with wrong dates	4	10 - 40	Error
12	Try the same with the right date, and select all of the options	5 - 8	16 - 40	
13	Can you see all of your correct results?		1 - 6	8Yes / 2 No
14	Try to export the report and save it on your computer	1	5 - 10	
15	Try to generate a comparison report with the right date, and select all of options wrong dates	5 - 8	12 - 24	
16	Can you see all of your correct results?	1	1 - 5	8Yes / 2 No
17	Try to export the report and save it on your computer	1	4 - 12	

Table 35: User test result

6.4 The LWC-EPI business use case: Linking external EPIs' sources and facilitating ad-hoc reporting (LEPI-R)

After presenting the LWC-EPI proof of concept as a prototypical implementation, in this section the business use case will be detailed to support evaluating and validating the system. This step has been enriched by engaging a potential user (SME) in the evaluation process and building a user story based on its business processes and data.

As it was previously discussed, dealing with environmental issues within enterprises is becoming increasingly essential in today's business. Organizations need to indicate their performance from an environmental perspective. For this, there is no simple comparative method that can support the complete chain of processes that communicates businesses' environmental performance. As it is has been explained in Chapter 5, this cycle starts with the data acquisition, then to data preparation and transformation, followed by the data integration phase, and finishes with the results' analysis and presentation. The LEPI-R is a business use case accompanying the LWC-EPI prototype to demonstrate how the later processes have been implemented and executed.

This use case is more focused on two integral parts of the environmental sustainability activities in any organization, especially the SMEs. Finding a standard way to define, calculate, and use the EPIs by searching and deploying external sources is one pillar. These external sources support the system in providing the indicators' calculations methods and equations, coupled with comprehensive information about the EPIs themselves. Communicating the results in a suitable, dynamic way is the second pillar of this work.

The resulting prototype implements this chain of processes in a web application that has been made available to the registered organizations to start their EPIs' communication. As it was explained in Chapter 5, the process starts once the guest user decides to register his organization and send a registration request. Organization's definition and assessment and EPIs selection, definition, and calculation are, in addition to generating multilevel report including comparison option, the main activities that have been realized following the service orientation concept. In this business use case, the following features have been implemented:

- Registration order, including organization's definition activity
- Log in/out functionality including password's policy
- Assessment's functionality that shows the organization situation from environmental perspective.
- Recommend EPIs for each organization, enhanced with vital information about these EPIs
- Comprehensive EPI's creation E-form
- EPI's calculation using one of two supported options:
    - fully automatic, based on web services
    - manual, based on user data entry
- Generated reports that can be customized by the user.
- Generated comparison's reports that enable each organization to compare itself to other organizations on different levels

All of the above mentioned functions have been implemented taking the system requirements presented in Chapters 3 and 4 into consideration, such as the end users types, the

data availability and quality, the lack of environmental awareness in the organizations, etc. These organizations have to be registered in the system's database and provide web services that enable the system to access their data. Moreover, the system should be able to repair, complete, or transform the organizations' data to fulfill the users' request.

In general, environmental sustainability activities are complex. Thus, they are conducted, supervised, or controlled by environmental experts. For example, the current process of the Life Cycle Assessment (LCA) is described as time-consuming information retrieval from different data and information sources that are difficult to gather. Data processing manipulation necessitates expert users to make assumptions based on the data derived from across organizational boarders. Moreover, they should deal with the resulting models from the used tools, build what-if scenarios, and conduct sensitivity analyses (Müller, 2013 p. 46). Another related example is the organizations environmental performance communication.

Regular or ad-hoc reporting requires considerable efforts and understanding from the group that prepares these reports. Some environmental reporting tools are designed for specific environmental data such as the Beeline Carbon (Thies, et al., 2013 pp. 64-65). Thus, generating environmental sustainability report requires data extracted from different databases and information sources.

As it has been argued, the LWC-EPI framework aims to facilitate the use of EMIS by the SMEs to be able to measure their impact on the environment, and it communicates this using environmental sustainability reports. Starting from the abovementioned information, the next paragraphs will evaluate how the LWC-EPI prototype can reach this goal.

As an evaluation of the LWC-EPI concept, the "newcycle Kunststofftechnik GmbH"[50] has been chosen as a potential organization to adopt the resulting prototype. The newcycle Kunststofftechnik GmbH (mentioned to as newcycle hereafter) is a processing polymers and food ingredients company, located in Sangerhausen, Germany. It runs different activities such as:

- Shredding and grinding polymers
- Pulverization, sieving, and mixing polymers
- De-coating of polymers / recycling CDs
- Compounding polymers
- Pulverizing food ingredients

Newcycle is a registered SME in Germany with 45 employees and has annual turnover of less than 50 million Euros.[51] This makes it a potential user of the LWC-EPI system. After direct contact with Mr. Christoph Osterroth, the Managing Director of the company, it has been agreed to evaluate the LWC-EPI concept and discuss different possible scenarios on how the LWC-EPI implemented prototype can be applied at newcycle.

A meeting has been held with Mr. Osterroth in April 2014. First, a general overview of the LWC-EPI framework was presented, highlighting its models and reference architecture, followed by a small introduction to the newcycle IT-infrastructre. Then, the LWC-EPI prototypical implementation was demonstrated using the user story that will be detailed in the next paragraph.

[50] http://www.newcycle.de/

[51] http://www.ifm-bonn.org/mittelstandsdefinition/definition-kmu-des-ifm-bonn/

A discussion was held with the aim of deciding how newcycle could benefit from using the LWC-EPI system. After the discussion, Mr. Osterroth approved that, as a recycling company, they have the interest to adapt a new solution like the demonstrated prototype. This can assist its management team to measure, control, and communicate the corporate environmental performance. Even though the requirements of the LWC-EPI solution are not too complex, due to time and budget limitations, it was agreed that implementing and using the system will be part of the future plan.

The use case goal and requirements:

The high-level goal of this use case is to show how the non-expert users within the newcycle can use the LWC-EPI prototype to calculate a set of EPIs using standard external sources. Furthermore, they should be able to generate certain set of reports, and benefit from some benchmarking activities.

After calculating the selected EPIs, the user must be able to use the system to:

- Select individual EPIs to be stored in his organization's space on the system database. In addition, these EPIs should be saved along with additional related information such as the input parameters, the organization data, the time period, or the consumption usage.
- Visualize the results by generating reports using selected EPIs.
- Export the reports.
- Allow the user to compare his result with other users within the organization or from another organization. This activity serves the benchmarking aim of the system.

As it was mentioned, today there are many EPIs that are applicable to diverse industries. For this use case, the following five EPIs have been considered:

- Electricity consumption (KWh)
- Water consumption (Liter)
- Processed water (KG)
- Road-transport (payload of up to 27 t)
- Rohoel-CO2 (MJ)

The use case story:[52]

The new EU council's decision encourages all the SMEs operating in the EU to start communicating their environmental performance based on predefined EPIs. As a response, the newcycle managing director assigned Mrs. Boeuf to start this project in the company.

After analyzing the company's current situation, Mrs. Boeuf was undecided about the starting point. Her main objective was to report how the newcycle improved its environmental performance using the five abovementioned EPIs, even though she lacks the domain experts' knowledge.

For this, she was searching for an easy and cost effective solution that supports her in fulfilling the task. This solution should ensure the access to any data in a smart way that assists in promoting environmental performance measures undertaken by her company. She was not sure about the data availability in which form the data should be reported, and how could she compare newcycle to competitors. While surfing the internet, Mrs. Boeuf visited the

[52] This story does not depend on any real information or data.

LWC-EPI website. After reading about its provided functionalities, she decides to start using the LWC-EPI system. Following the UML use case diagram, Figure 83 demonstrates the LEPI-R use case diagram using newcycle as an example.

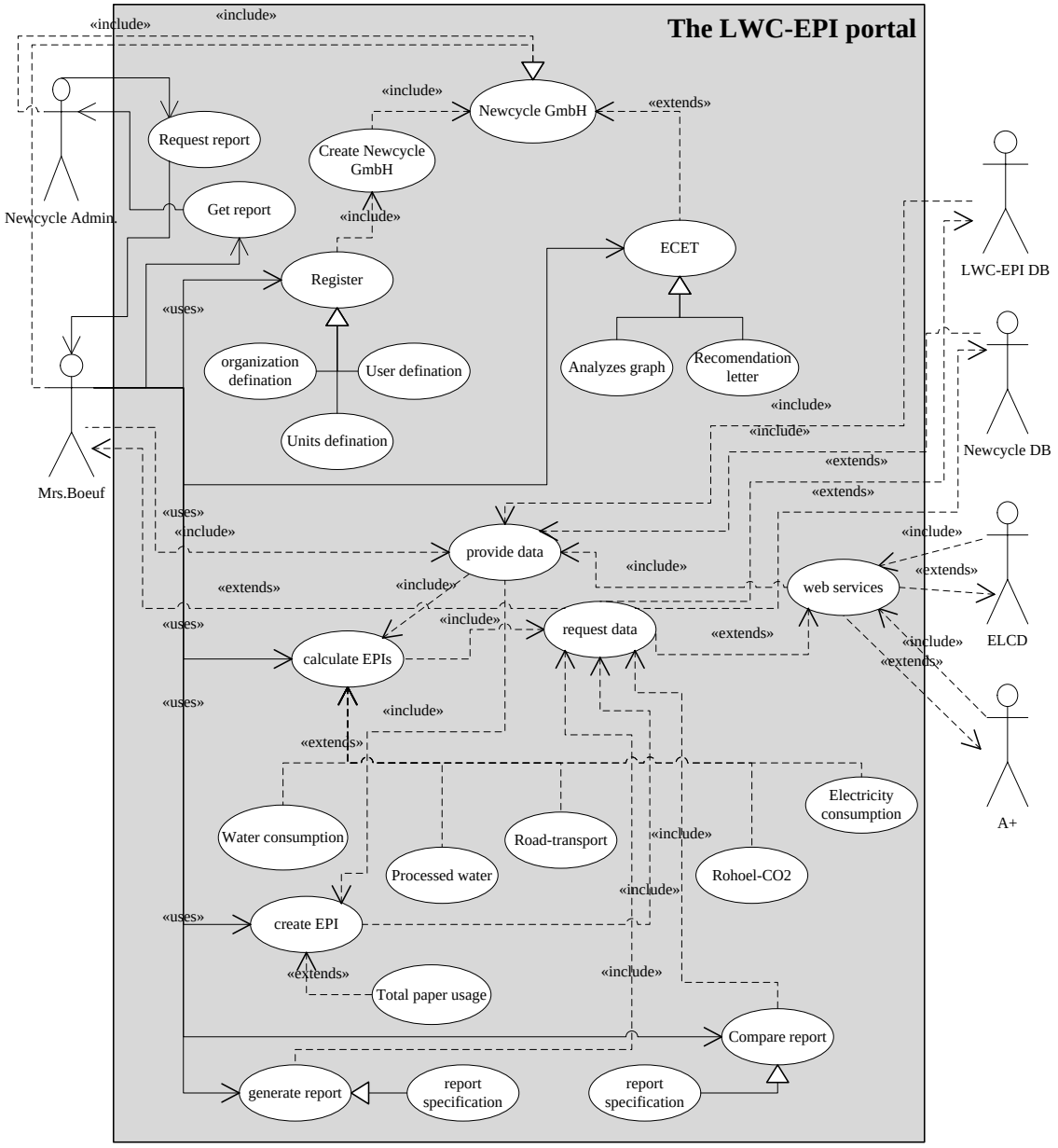


Figure 83: The newcycle GmbH use case diagram

The registration:

The first step that should be completed is the registration. The LWC-EPI registration page is accessed directly from the homepage in one click as it has been presented in Figure 65.

Mrs. Boeuf started the registration process that includes three steps, including eighteen entries. Since she was the first user from newcycle, she completed all of the required information:

- The organization name: Newcycle Kunststofftechnik GmbH
- The business field: "Industrial," from the provided drop down list
- The organization address: Germany, Sangerhausen, 06526, Julius-Hornung-Str.12
- The number of employees: 45

By clicking the "Next" button, the system checked the data completeness, and since there was nothing missing or wrong, Mrs. Boeuf moved to the second step to define the organization's structure. Figure 84 shows the newcycle registration data in step one.

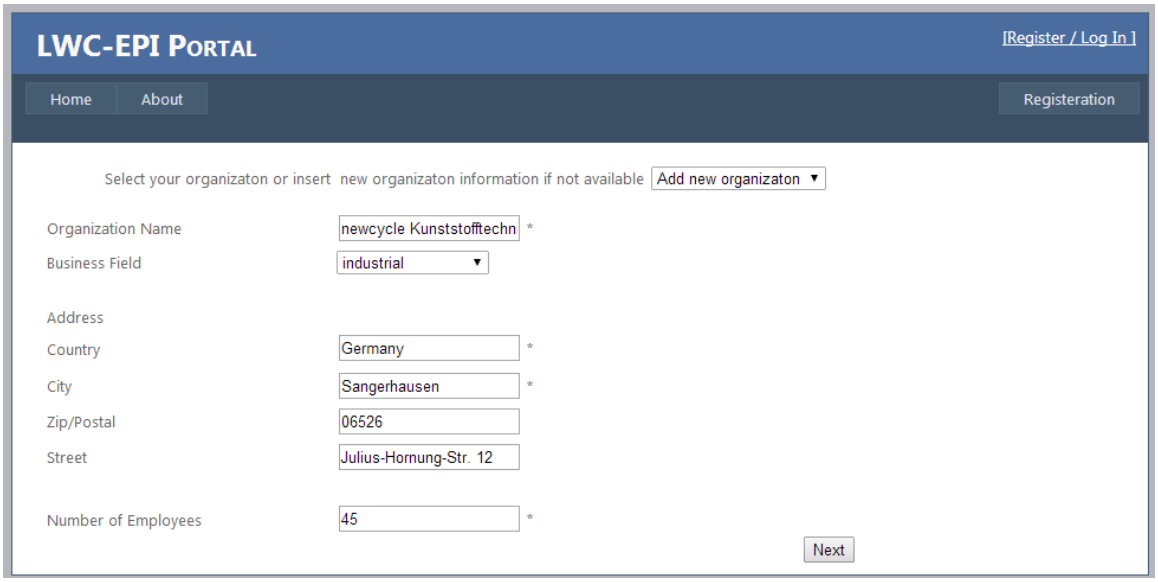


Figure 84: The newcycle's registration, first step

Mrs. Boeuf decided to define just her unit. For this, she provides the following information:

- The unit name: Director Dept.
- The unit description: this unit represents the managing director department.
- The unit type: "Organizational unit," from the provided drop down list

By clicking the "Add Unit" button, the defined unit will be added to temporary file, and Mrs. Boeuf can define another unit. As a second unit, she provides the following information:

- The unit name: Transporter 033SH
- The unit description: Grand wagen NNC - Hybrid.
- The unit type: "Physical unit," from the provided drop down list.

Figure 85 displays the newcycle registration data in step two, showing the data entered for both units. By clicking the "Next" button, the system checked the data entries, and since there was nothing missing or wrong, Mrs. Boeuf moved to the third step to define her log in data.

In this step, Mrs. Boeuf filled out the seven mandatory fields with the following data as it is shown in Figure 86:

- The user name: newcyclebe
- The password: Password!
- The password confirmation: Password!
- E-mail address: newcyclebe@newcycle.de
- Security question and answer: Hallo world, Ahlen
- The host address: http://localhost:8087/ServiceE1
- Unit Name: Director Dept.

By clicking the "Next" button, the system checked the data entries, and Mrs. Boeuf received a confirmation massage that her user has been created and the company is registered in the system. The user name appeared immediately on the top right corner.

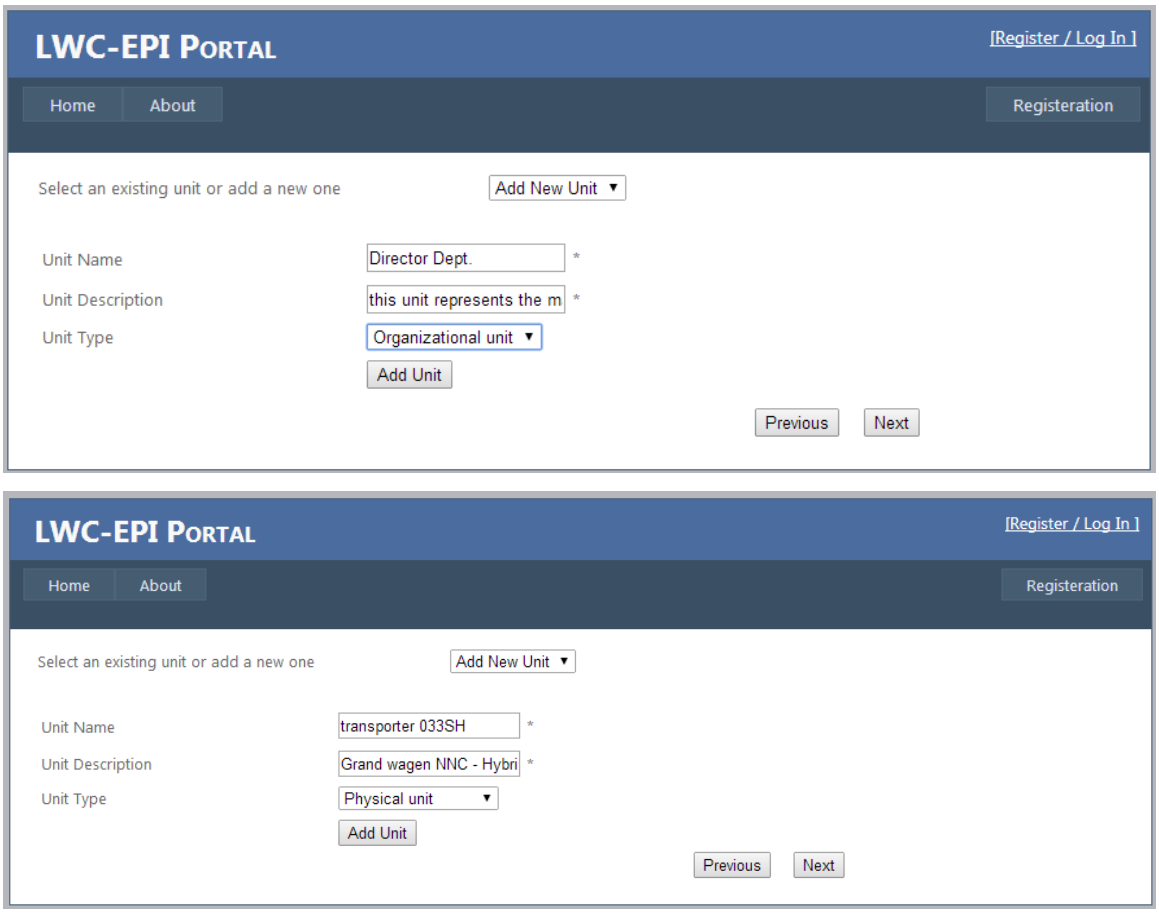


Figure 85: The newcycle's registration, second step

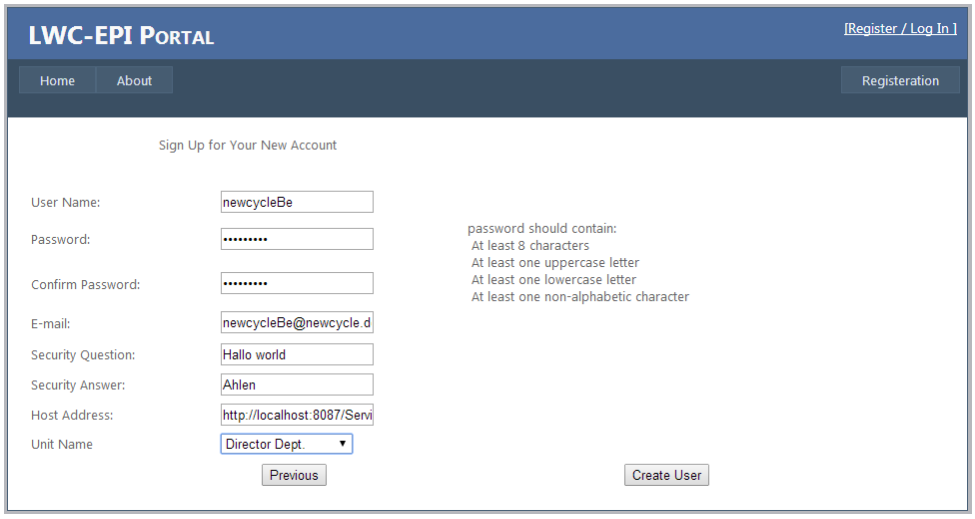


Figure 86: The newcycle's registration, third step

The ECET model:

After completing the registration, Mrs. Boeuf was trying to select her EPIs to be calculated when she noticed that she must complete the ECET assessment process as it can be seen in Figure 87. This is because she is the initial organization's user. By clicking on the ECET button, she starts answering the 25 multiple choices questions.

Since she did not have current answers for all the questions, she needed some help from her manager. Figure 88 illustrates her answers, while Figure 89 represents the analysis results and the textual recommendation letter. In general, newcycle has good potential successfully use the LWC-EPI portal.

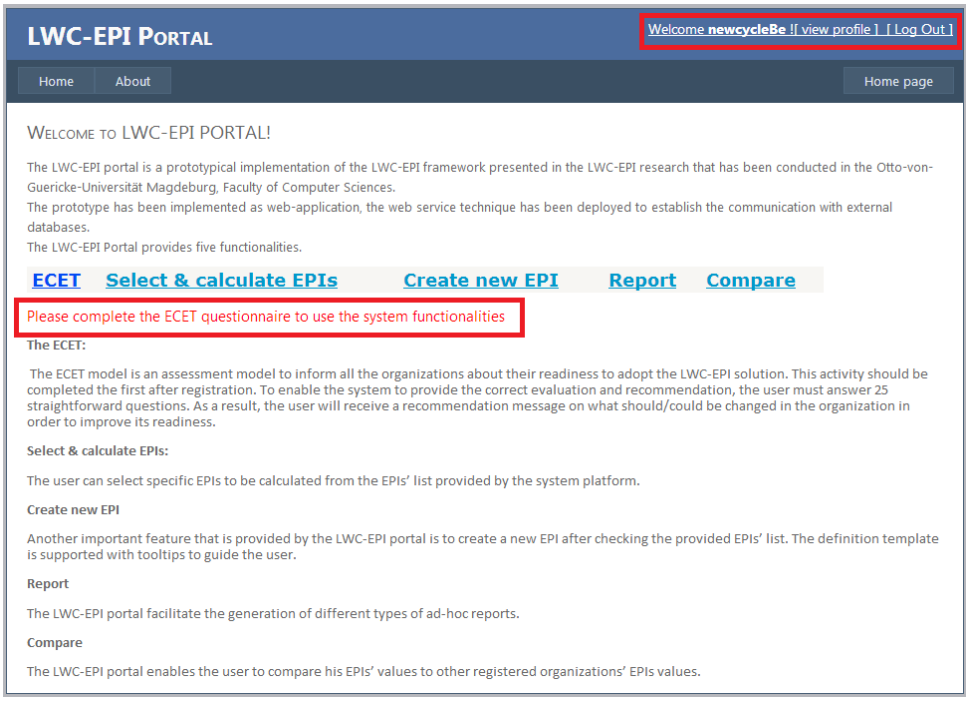


Figure 87: The LWC-EPI portal home page after the newcycle registration

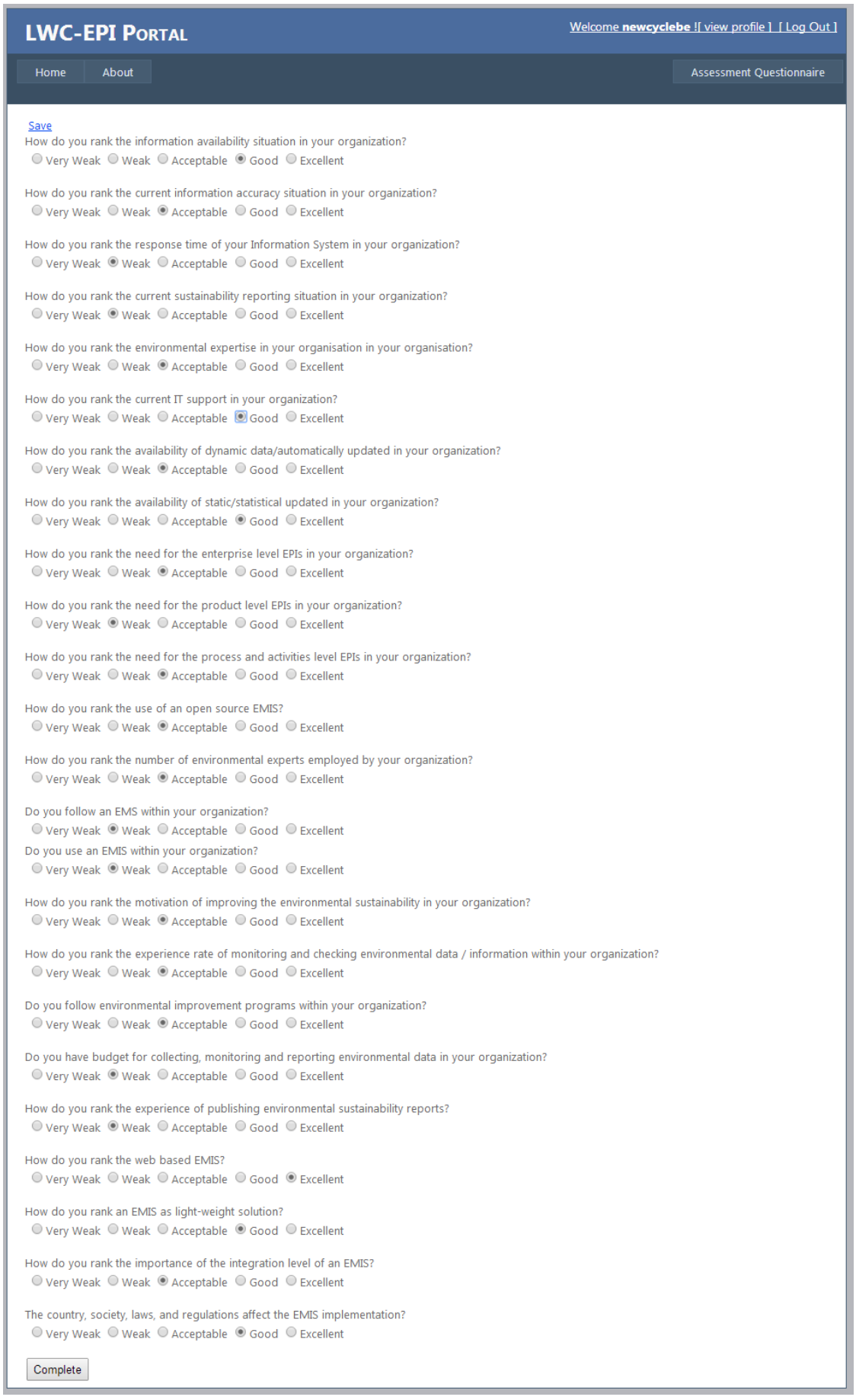


Figure 88: The Newcycle answers on the ECET page

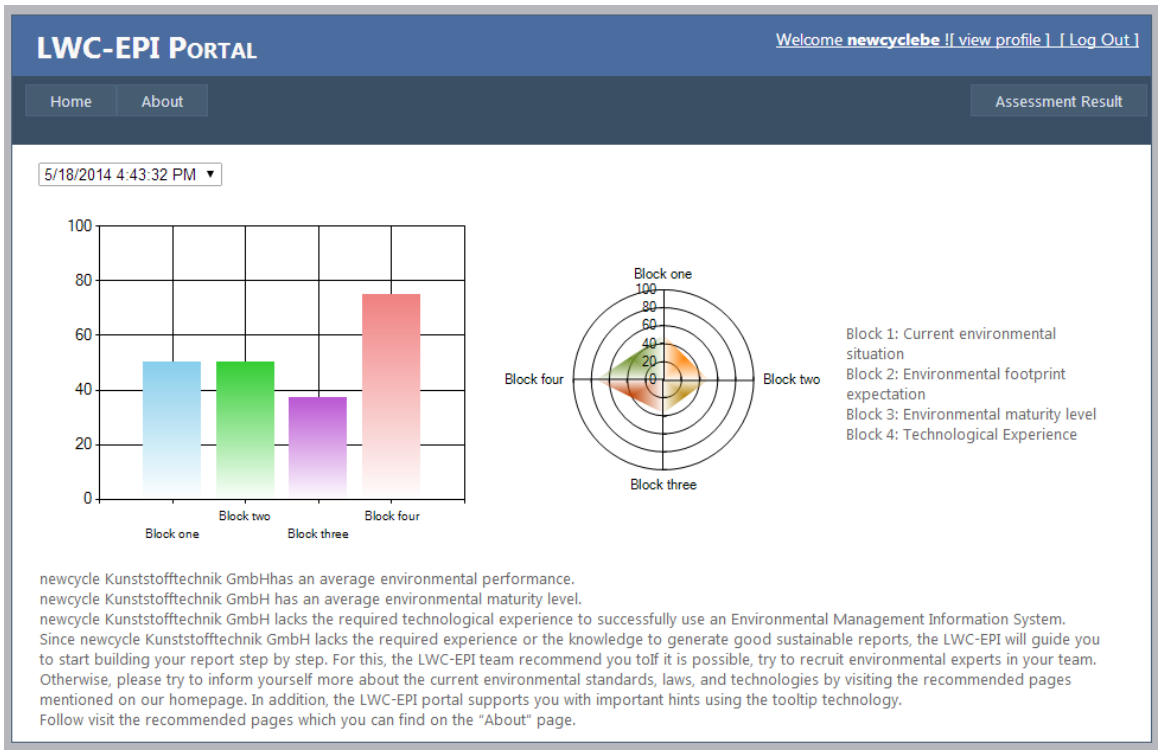


Figure 89: The ECET results representation page

Select and calculate the EPIs:

Based on the new EU council's decision that Mrs. Boeuf had been asked to follow, she began to calculate the five required EPIs:

- Water consumption (Liter)
- Processed water (KG)
- Road-transport (payload of up to 27 t)
- Emitted Co2 reffered as (Rohoel Co2[53]) (MJ)
- Electricity consumption (KWh)

In addition, newcycle's management team asked Mrs. Boeuf to add an EPI that indicates the usage of paper after the company's decision to use the electronic form for all internal communications and documentations.

By clicking on the button "select and calculate EPIs" from the homepage, Mrs. Boeuf reached a list of recommended EPIs that had extended by clicking on "show me all." She chose the abovementioned EPIs from the list to start the calculation as it is illustrated in Figure 90. By hitting the "continue" button, the system will demonstrate the first selected EPI to be calculated and after finishing with the calculation it will automatically shows the next selected EPI.

The first selected EPI was the Rohoel-Co2 (MJ), and since she lacks information about it, Mrs. Boeuf was reading the full EPI's description, which was retrieved from the EPI's source (in this case was the ELCD) by clicking on "Full description" as it is illustrated in Figure 91.

[53] Using the Rohoel AG. Standard

Figure 90: The EPIs selected by Mrs. Boeuf to be calculated

Using the provided webservice "ServiceE1" (Figure 92), the system was able to calculate the first four EPIs with the help of the ELCD, A+, and newcycle databases. Mrs. Boeuf saved all the results as "Public", and ranked all the EPIs.

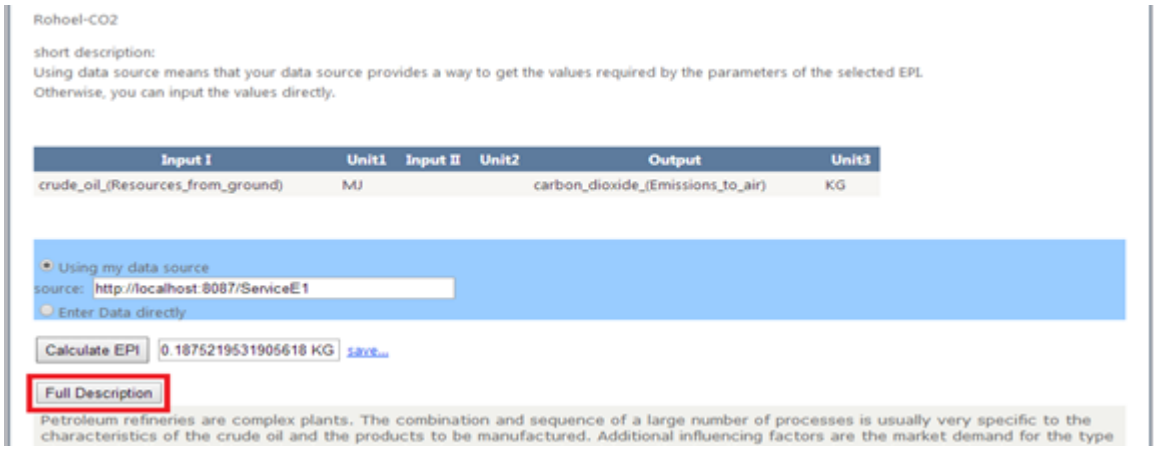


Figure 91: Select and calculate the Rohoel-CO_2 EPI with its full description

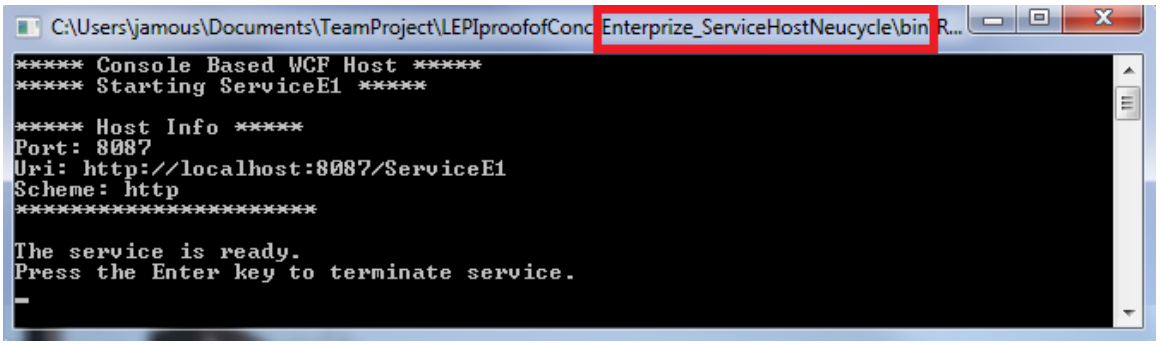


Figure 92: The "ServiceE1" webservice provided from the Newcycle GmbH

As for the "Electricity consumption", the system was not able to find the required data to complete the calculation. Thus, Mrs. Boeuf chose the second option offered by the system, which is to enter the data manually. By selecting the "Enter Data directly" radio button, the system asked for two inputs that were explained in a table above the input box to facilitate this step for non-expert users as it is depicted in Figure 93. The first input is the amount of money

that the company paid for the electricity bill, and the second input was to specify the electricity provider that they deal with.

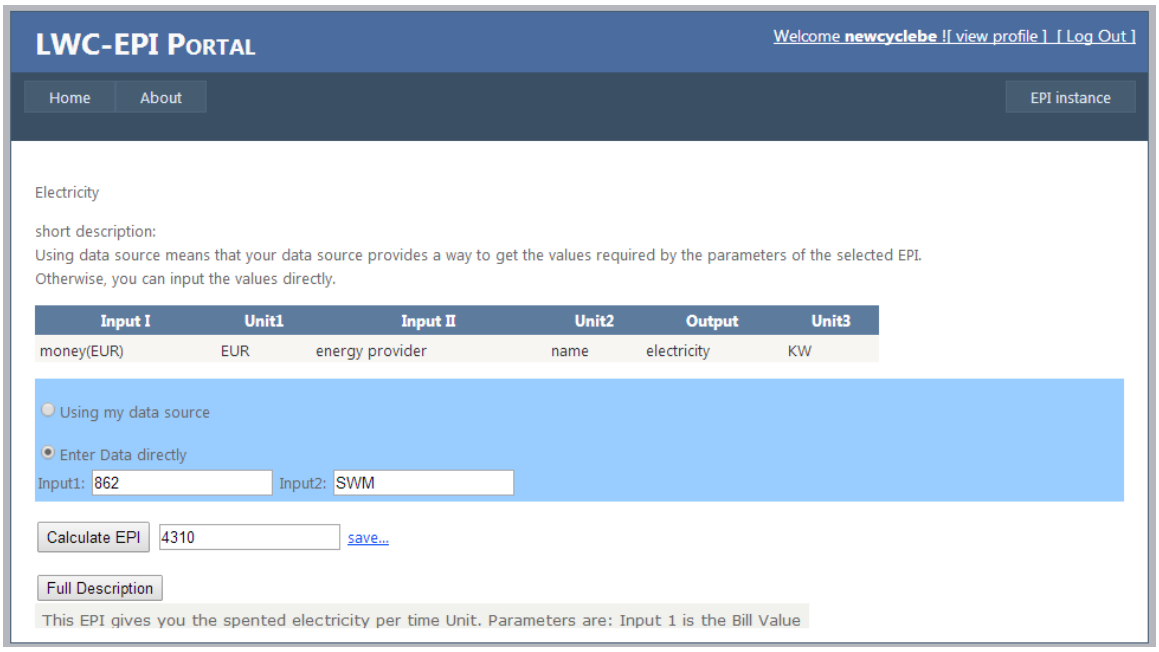


Figure 93: An example for manual calculation, the electricity consumption EPI

Since Mrs. Boeuf aims to prepare a report based on the calculated EPIs, she should save these calculated values by clicking on "save" after each calculation process. Mrs. Boeuf can decide the result owner, and the users that she would like to share the result with. For the electricity consumption she chose to be the owner of the results, and she made the result public as can be seen in Figure 94. Moreover, she select "1" as ranking for this EPI.

Figure 94: Saving the electricity consumption EPI's value of newcycle

Create the paper usage EPI

After receiving the saving confirmation messages, Mrs. Boeuf searched for an EPI that could calculate the usage of paper in the company. As she could not find the required EPI, she chose to create it as a new one.

As definitions, Mrs. Boeuf entered the following data as it is shown in Figure 95:

- The EPI name: total paper usage.

- The input materials: since she could not find the needed material, she chose to add new material.
    - Material name: Money paid for paper
    - Units: Euro

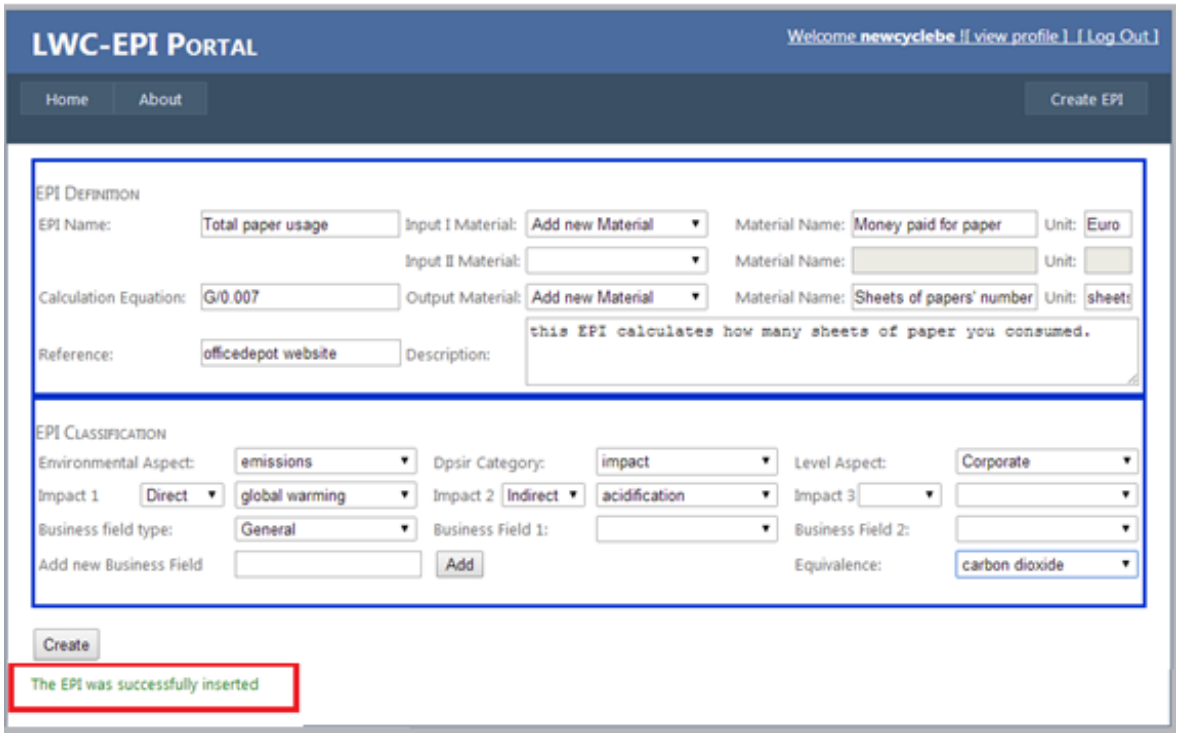


Figure 95: The Creation of the "paper usage EPI", and the Confirmation message

- Calculation's equation: G/0.007 where G is the input material.
- The output material: Add new material
    - Material name: Sheets of papers' number
    - Units: sheets
- Reference: the company's supplier web site, where the list of the prices can be found.
- Description: this EPI calculates how many sheets of paper you consumed.

After defining the EPI, Mrs. Boeuf classified this EPI based on her knowledge gathered from the recommended references that are provided on the portal homepage. Her inputs were:

- Environmental aspect: emissions
- DPSIR category: impact indicator
- Level aspect: corporate
- Impact: direct global warming and indirect acidification
- Business domain: general
- Equivalence: carbon dioxide equivalent

By clicking on the "create" button, Mrs. Boeuf received the confirmation message that the "paper usage EPI" was created. Then, she tried to calculate the latter EPI, and she got the result that the company had used 557142.8 sheets of paper during the specified period (Quarter 1 of 2014) as it is shown in Figure 96.

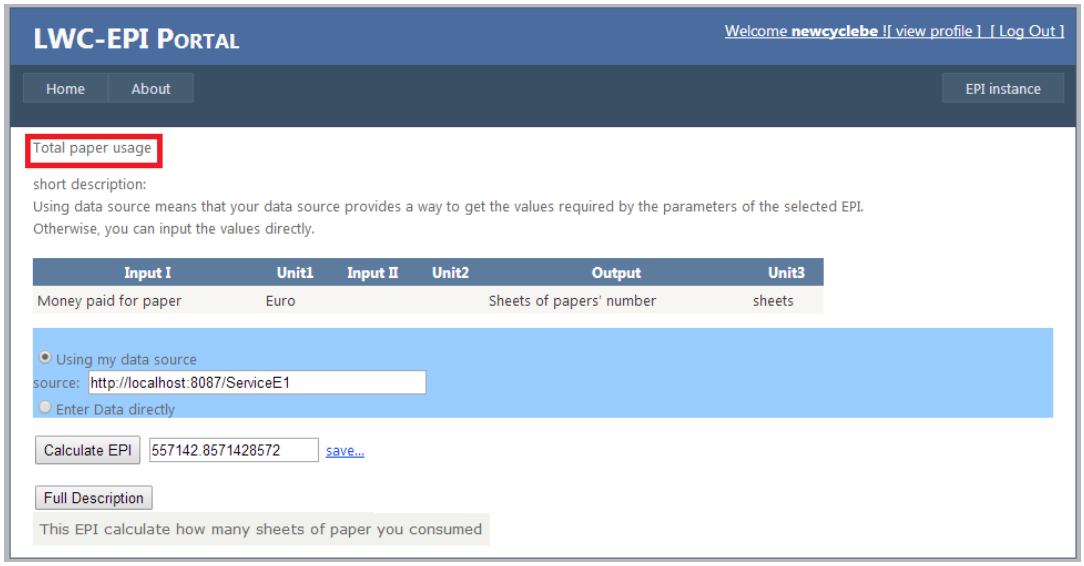


Figure 96: Calculating the "paper usage EPI" in newcycle

Generate the report

After saving the result, Mrs. Boeuf used the report's page to generate her report for the period from 01.01.2014 until 31.05.2014. She selected to include all the EPIs' values that she calculated during this period. Figure 97 represents the requested report by Mrs. Boeuf.

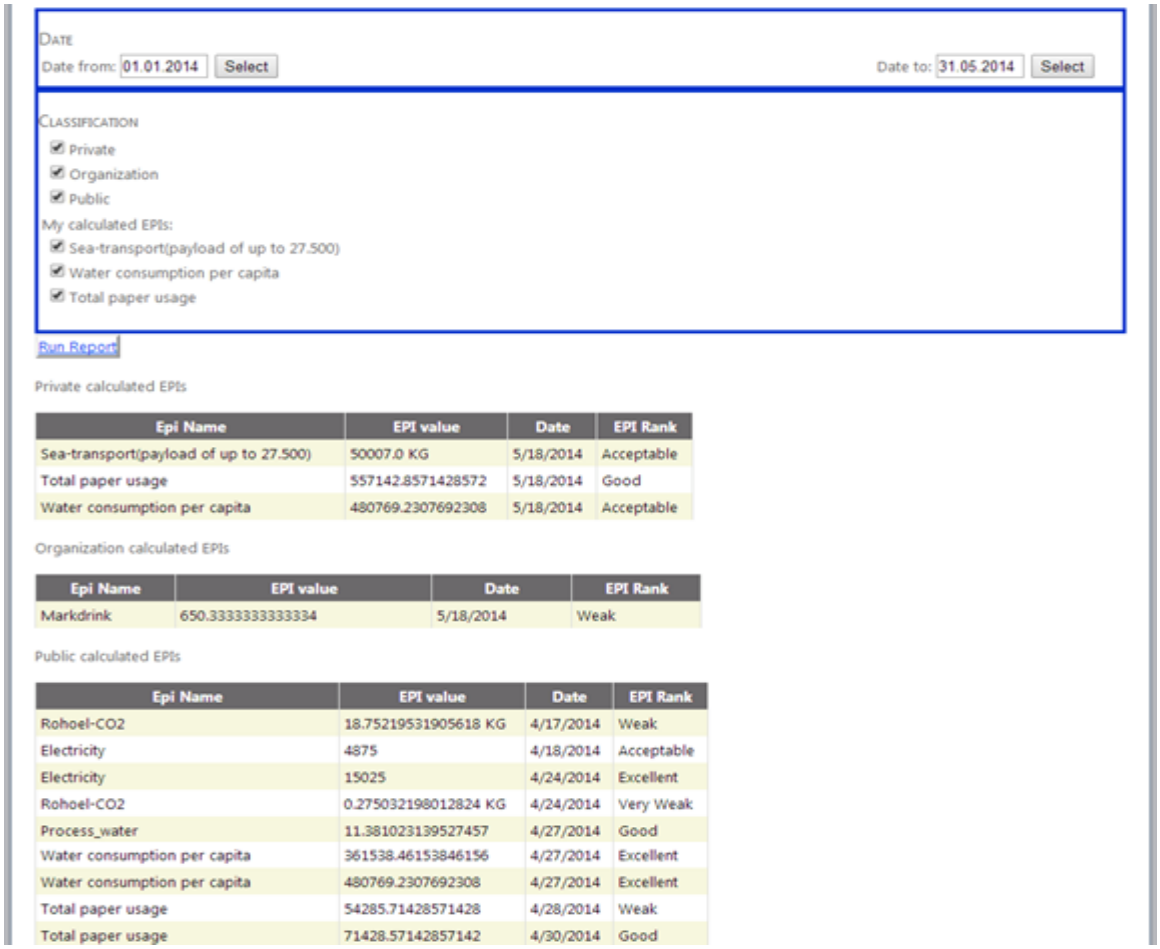
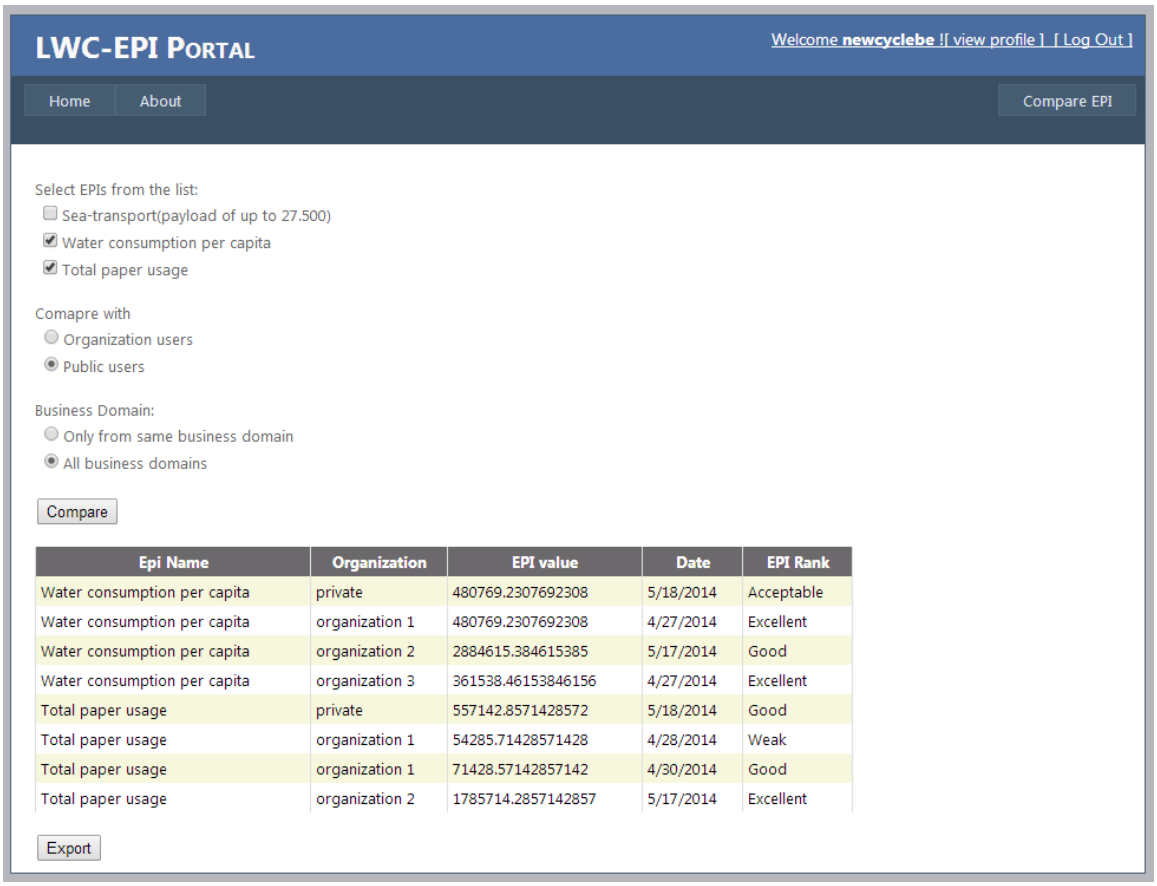


Figure 97: The newcyclebe's user report

Comparison report

As a registered organization, Mrs. Boeuf wanted to compare the performance of newcycle to the other registered organizations. After specifying the time frame as [from 01.01.2014 until 30.05.2014], and selecting to include two of her calculated EPIs, she ran the report to receive the result in Figure 98. As it can be seen in the report, newcycle should reduce its water consumption, while its paper usage indicator is close to the other competitors. To be able to use both of the last two generated reports (depicted in Figures 97 and 98), Mrs. Boeuf exported them to the MS Excel by clicking the "Export" button.



Epi Name	Organization	EPI value	Date	EPI Rank
Water consumption per capita	private	480769.2307692308	5/18/2014	Acceptable
Water consumption per capita	organization 1	480769.2307692308	4/27/2014	Excellent
Water consumption per capita	organization 2	2884615.384615385	5/17/2014	Good
Water consumption per capita	organization 3	361538.46153846156	4/27/2014	Excellent
Total paper usage	private	557142.8571428572	5/18/2014	Good
Total paper usage	organization 1	54285.71428571428	4/28/2014	Weak
Total paper usage	organization 1	71428.57142857142	4/30/2014	Good
Total paper usage	organization 2	1785714.2857142857	5/17/2014	Excellent

Figure 98: The comparison report provided by the LWC-EPI portal

The above mentioned user story has been presented to Mr. Osterroth as a potential business user. It demonstrated the LWC-EPI services in a non-IT driven manner, and he agreed that it could facilitate the company plan in starting to communicate its environmental performance with minimum investments (human, money, time, etc.) that would not affect his business activities. It should be noted that Mr. Osterroth stated some essential points that should be taken into consideration in the future plan. For example, it was important to know how the organizations could be convinced to register in this portal, and how they can assure their privacy. Another question was if the solution can support improving the work processes from environmental perspective. Moreover, it was recommended to integrate more communication channels for the user interface e.g. mobile applications. Mr. Osterroth commented saying: "Der Bericht entspricht der Vorgehensweise und hat uns bei der Beurteilung der Situation sehr geholfen. Danke, dass Du mit uns die Analyse durchgeführt hast." [The report corresponds to the explained procedure and has helped us assessing our situation. Thank you

that you have done this analysis with us]. Finally, this workshop concludes that the LWC-EPI prototype is a good starting point, and it has the potential to be used after some improvements.

6.5 Summary

This chapter focused on the implementation of the LWC-EPI prototype as a proof of concept for the LWC-EPI framework. It began by explaining the architectural design as well as identifying the technical specifications. The criteria named for the prototype were that the technologies must allow for the development of a web application and that they should be enterprise ready. As the prototype will be accessed as a web application, 13 tools of web applications' frameworks were compared, and it was decided to use Microsoft products to develop the prototype while also using C#, Java, and web service techniques. Furthermore, all technologies that were used in developing the prototype and in which layer they are a part of have been listed. The chapter continues by describing the LWC-EPI prototype. Section 2 and its subsections demonstrated how the LWC-EPI web application functioned.

The next step was to evaluate the prototype by using continuous code testing, functional black box testing, and white box testing, and continuous assessment activities. For an end user functionality test, potential end-users tested the functionalities, system performance, and ease of use. The ten participants were asked to complete 17 tasks where number of clicks, and time needed to complete the assignment was mentioned. It was found that most users were able to complete the tasks in less than fifteen minutes, and all were able to do so without assistance. Then, a business use case was presented showing how a non-expert user will use the LWC-EPI prototype to calculate EPIs, generate a report, and compare his organizations' performance to other registered organization. This latter evaluation step has been conducted in corporation with newcycle Kunststofftechnik GmbH as a potential end use. Final recommendations and open issues for future development determined from the workshop with the newcycle Kunststofftechnik GmbH management ended the chapter.

7 Conclusion and outlook

Chapter seven recaps all findings, concepts, and proposed ideas that have been discussed throughout this research. Moreover, it highlights some ideas as a roadmap for future steps that can be taken based on this work's results. The chapter starts with an outlook on the work. Afterward, the future research is discussed as a guideline for improvement steps that could be taken to enrich the LWC-EPI artefacts and contribution to the Information and Communication Technology (ICT) Environmental Sustainability research domain.

The LWC-EPI research aims to find a proper way to increase the use of EMIS by SMEs. Serving this aim, this dissertation contained seven chapters that comprise the full research cycle. It started with an exploratory chapter where the research idea was motivated, the main related issues were highlighted, and the LWC-EPI vision was defined as: ***Supporting SMEs to comply with environmental responsibility***. The second chapter highlights the research methodologies that have been followed. It explained how the seven guidelines of the Design Science in Information Systems Research method (Hevner, et al., 2004) were followed in this dissertation. Moreover, it explained the LWC-EPI process sequence as it has been adopted from the Design Science Research Method (DSRM) (Peffers, et al., 2007).

In the third chapter, a comprehensive literature review was provided. Related concepts, current EMIS solutions, open research issues, and significant related work have been defined, examined, and discussed. It has been found that even though the information technology adoption rate has been visibly increasing during the last decade, none of the available EMIS have been designed to fulfil the need of the small and midsize segments to integrate and communicate their environmental performance. The findings of this chapter have strengthened the research's necessity and novelty. Moreover, it provided vital ideas and guidance for the conception and design, as well as structuring the LWC-EPI framework. The chapter included a review of environmental standards, followed by and examination of Environmental Performance Indicators (EPIs). In addition, important reporting schemes and standards were presented. The chapter continues by introducing the concept of the EMIS. The most commonly accepted definitions and categorization of the EMIS were given and discussed. Correspondingly, it was noted that the proposed LWC-EPI framework would mainly be used for solutions that were categorized as sustainability reporting tools and environmental compliance management tools. In this regard, a study of such tools was conducted. As a next step, the problems and open research issues of the current EMIS and related work were examined. It was concluded that several related studies have been published, although none in particular presented an EMIS framework for environmental sustainability reporting and compliance management that specifically targeted SMEs.

Chapter 4 contained the conception and presentation of the LWC-EPI framework. It started with examining the barriers that the SMEs face when they decide to start their sustainable development. In this regard, barriers to SMEs in following an EMS and implementing an EMIS were inspected, and it was found that both applying an EMS and EMIS in SMEs share common barriers. To enhance those findings, a field study was conducted. Its results were analyzed, and they lead to the construction the ECET model as an assessment model that can guide SMEs on how to perform in order to maximize the benefit of using EMIS. The model's correctness has been mathematically confirmed using the Partial Least Squares method as a

confirmatory factor analysis. This method has been applied to the result of a second survey that has been extracted from the first field study survey results. As a final outcome, the ECET model has combined four dimensions that shaped a foundation for the successful implementation and use of an EMIS within an organization. After describing the ECET model as part of the LWC-EPI framework, a simple organization model was proposed in order to contain the information about the organization and its possible structure. Another significant model in the LWC-EPI framework was the EPI model. An in-depth study was conducted to formulize this central model. The study has proposed more than one important idea such as the comprehensive classification model of the EPIs in addition to the final proposed EPI model. The OEPI ontology and its knowledge have been used to enhance this model. Then, a data model was proposed containing three main components that can support the LWC-EPI framework concept in combining operational databases of enterprises with outsource-data. The final model that was discussed in this chapter was the report model, which was designed based on the common knowledge from IT-solutions. The chapter ended by demonstrating a holistic overview of the LWC-EPI framework and its five models showing how these models are connected. This framework was the main contribution to this dissertation.

Based on the LWC-EPI framework, Chapter 5 proposed a vision of an LWC-EPI structural design. Following SOA architecture, this conceptual solution consisted of three layers that are connected using web services: the database layer, the application layer, and the presentation layer. The chapter discussed new ideas for each layer and how they serve the research objectives. For example, on the database layer, the concept of a Virtual Shard Database (VSDB) was explained and discussed. It focused on how the database layer can enable the LWC-EPI's users to get the benefit of using other organizations' data without violating their privacy. Separating the three layers in design was important to enable physical separation in the implementation phase, which ensures flexibility. For example, a mediator can host the system platform and manage the system from a distance, whereas users' organizations use the system via different presentation channels such as web-based portals, mobile applications, service on cloud, etc. After demonstrating the LWC-EPI system architectural design, the LWC-EPI lifecycle of services were discussed, and the system business logic was studied and presented. The five services named were acquisition, preparation, transformation, integration/execution, and analysis and presentation. The services' presentation was accompanied with a business case scenario. Since the system acceptance by end-users is a major success factor, the chapter ends with a system use case scenario, illuminating the system from an end user's perspective. This has been done using UML activity diagrams of eight proposed activities (use cases), enhanced with detailed explanations of the interaction between the system's layers and the business processes in each step.

As proof of the LWC-EPI concept, Chapter 6 presented a prototypical implementation of the LWC-EPI system, highlighting how it was tested and evaluated and demonstrating a business use case accompanied with a detailed user story. The chapter started by illustrating the architectural design and identifying the system technical specifications. The prototype has been implemented as web-application using the appropriate Microsoft products such as the ASP.Net and Visual Studio, while C# and Java were used as the programming languages. Moreover, the web service technique was deployed to establish communication with external databases. The chapter continues by describing the LWC-EPI prototype, providing details on how each function of the LWC-EPI portal operates. This was enriched with snapshots from

the system presentation channel which was the LWC-EPI portal. The next step was to test and evaluate this prototype. Continuous code tests, functional black box tests, and white box tests, together with continuous assessment activities, were applied during and after the implementation phase. A user functionality test was conducted with potential end-users to test the system functionalities, performance, and ease of use. In addition, the system was evaluated and validated using a detailed business use case demonstrated and discussed with newcycle Kunststofftechnik GmbH. It showed how a non-expert user would use the LWC-EPI prototype to calculate EPIs, generate reports, and compare his organizations' performance to other registered organizations. The chapter closes with final recommendations, and open issues for future development.

Many research works, which were presented and discussed in specialized international conferences, have been conducted based on this thesis and then published in peer reviewed scholarly publications. The 2010 publication, titled "Proposed Light-Weight Composite Environmental Performance Indicators (LWC-EPI) Model", was the first publication where an elementary model was proposed and discussed in the venue of 24st International Conference on Informatics for Environmental Protection (EnviroInfo2010) (Jamous, et al., 2010-I). The concept of the LWC-EPI has been discussed in the (Jamous, et al., 2011-II) publication titled "Light-weight composite environmental performance indicators (LWC-EPI) concept". It clarified what "light-weight", and "composite" mean from the LWC-EPI perspective. The research semantic approach and deploying the OEPI ontology in the LWC-EPI was discussed in a specialized workshop in SOA, namely the BSOA 2011 through the (Jamous, et al., 2011-I) titled "Deploying OEPI ontology into the Light-Weight Composite Environmental Performance Indicators (LWC-EPI) system". The research question, initial architectural design, system requirements and expectation were communicated through the (Jamous, 2013) journal publication titled "Light-Weight Composite Environmental Performance Indicators (LWC-EPI): A New Approach for Environmental Management Information Systems (EMIS)". The (Jamous, et al., 2013-III) publication present the research approach as well as the field study and its results, deriving the ECET assessment model. This paper has been discussed in the 46th HICSS, Hawaii International Conference on System Sciences. In addition, students' team projects were developed based on the LWC-EPI concept, e.g. the prototypical implementation mentioned in Chapter 6 has been developed based on one of these projects.

In summary, the LWC-EPI research contributes to the EMIS community by providing new concepts and artifacts, such as:

- The LWC-EPI provides new framework that serves as a base for developing new EMIS, taking the SMEs requirements into consideration. This encourages the SMEs to be more engaged in the sustainability movement from an environmental perspective.
- Reusability: The framework consists of models, each that have their own added values. This ensures a high level of reusability, for example:
    - The ECET assessment model provides a seamless assessment model that guides the organization on how and what to improve in order to achieve more benefit from the use of the LWC-EPI solution. This model can be the base of standalone assessment solution.
    - In the course of building the EPI model, a new comprehensive EPI classification's model was proposed. This model can be used in research,

projects that seek better EPI standardization, or in order to improve the society knowledge about the EPIs.

- The LWC-EPI prototype demonstrates a validated way of data processing, extracted from different sources with the use of web services.
- The reporting model enables m:n relation instead of n:1 relation:
  - As is model: Input → Data processing → Output

  Same data in another representation form, e.g. report.

  - LWC-EPI model: Input → the LWC-EPI data processing → Output

  Provides new information using different data sources enhanced by additional expert knowledge (e.g. the ELCD), and then presents the processed data to the end-user in a different form.

- A new semantic approach: deploying the OEPI ontology knowledge to derive the EPI model. This has been shown in the "Creating EPI" functionality of the LWC-EPI prototype.
- Benchmarking: As for benchmarking, the reporting functionalities provided by the LWC-EPI prototype serves the intra-organizational and inter-organizational aspects of the LWC-EPI concept. This enables the user to compare his results with other colleagues' results, as well as with the results of other registered organizations.

As it can be seen, much supplementary research can be derived from this dissertation. For example, using the provided (parsing) java code after a small modification, the LWC-EPI can be enriched with more EPIs from different external database (e.g. ELCD, or A+). This step will ensure a varied of EPI collection to serve the registered organizations. As a complementary idea, a simple EPI game can be developed based on the EPI aggregation requirement model and the LWC-EPI's EPI model demonstrated in Chapter 5. Serving the social awareness aspect of this research, this game can support new users improving their knowledge about different EPIs, their classifications, equations, measurement units, etc.

The research pointed out many relevant open questions that need to be answered. One of these is the security pattern which was not covered in this thesis. Another is to develop an appropriate method that ensures more organizations that it is secure to share their data with the system. This method should take into consideration that the organization worries about its privacy as well as the quality of the provided and resulting data quality. Other research solution, for example ecoinvent,[54] examined the latter mentioned issue and provided new data quality guidelines to ensure coherent data acquisition and reporting. Specifying a suitable business model is one more challenging research question that needs to be addressed in future work. For now, a concept idea was developed as a student team project. The main aim was to integrate the LWC-EPI functionalities in one of the ready-to-use application system. For this,

[54] http://www.ecoinvent.org/

the AMEE[55] database was chosen to be linked dynamically to OpenERP®[56] using web service. The calculated data has been represented in the OpenERP/product module as a new tab named LWC-EPI.

Another way to bring the LWC-EPI to the market can be by providing it as a cloud based service. For example, a cloud service provider such as Ariba®[57] starts to offer the LWC-EPI service to its customers. This can ensure achieving the critical mass of participating organizations, which is important for a many-to-many platform like the LWC-EPI. Ariba® will get the benefit of providing a new service, and this service can support its environmental friendly image. As for the registered organizations, they will get new services that enable them to communicate their environmental performance, and they will not need to sign a new service level agreement (SLA) with the service provider. On top of that, this model can solve the privacy and trusting issues which have been mentioned.

The main focus of this dissertation was to provide a new EMIS framework named the LWC-EPI framework to encourage SMEs to start complying with their environmental sustainability responsibilities, as well as communicating their environmental performance. The LWC-EPI concept was proven by a prototypical implementation, and evaluated with an accompanying business use case that has been validated by a potential end user. It can be concluded that the LWC-EPI paved the way for using environmental data presented as EPIs on a large scale, and laid a foundation for the inclusion of SMEs in the sustainability movement.

[55] AMEE is a collection of environmental data sources that can be uniformly accessed by using the AMEE technology platform https://www.amee.com/

[56] https://www.openerp.com/

[57] http://www.ariba.com/

A. Appendix

A.1 The Fifth EC Environmental Action Programme "Towards Sustainability"

The needed instruments for the "Towards Sustainability" strategy: (EC-Environment, 1998)

- Legislation to set environmental standards;
- Economic instruments to encourage the production and use of environmentally friendly products and processes;
- Horizontal support measures (information, education, research);
- Financial support measures (funds).

The covered areas:

- Five 'Target Sectors'
  - Industry
  - Energy Sector
  - Transport
  - Agriculture
  - Tourism
- Seven 'Themes and Targets'
  - Climate change
  - Acidification and Air Quality
  - Urban Environment
  - Coastal Zones
  - Waste Management
  - Management of Water Resources
  - Protection of nature and Bio-Diversity
- Three areas of specific attention with respect to Risk Management
  - Industry-Related Risks
  - Nuclear Safety and Radiation Protection
  - Civil Protection and Environmental Emergencies
- Seven types of Policy Instruments
  - Improvement of environmental data
  - Scientific Research and Technological Development
  - Sectoral and Spatial Planning
  - The Economic Approach: getting the prices right
  - Public Information and Education
  - Professional Education and training
  - Financial Support Mechanisms

A.2 The key indicators defined by the sixth EC Environmental Action Programme "Thematic Strategies"

- Climate change and energy:
  - Global air temperature change
  - Natural disasters linked to climate change
  - Total Kyoto greenhouse gas emissions
  - Electricity produced from renewable energy
  - Combined heat and power generation
  - Energy intensity
  - Final energy consumption by transport
  - Average CO2 emissions from passenger cars
  - Cumulative spent fuel from nuclear power plants
- Nature and biodiversity:
  - Common birds
  - Landscape fragmentation
  - Freight transport
  - Area occupied by organic farming
  - Area under Agri-environmental commitment
  - Sufficiency of site designation under the Habitats Directive
  - Natura 2000 area (% terrestrial area)
- Environment and health:
  - Urban population exposure to air pollution by particles
  - Urban population exposure to air pollution by ozone
  - Emission projections for air pollutants
  - Air emissions of nitrogen oxides
  - Exposure of ecosystems to acidification
  - Exposure of ecosystems to eutrophication
  - Water exploitation index
  - Production of toxic chemicals
  - Pesticides residues in food
- Natural resources and waste:
  - Fish catches from stocks outside safe biological limits
  - Municipal waste generated
  - Recycling of packaging waste
- Environment and the economy:
  - Environmental taxes
- Implementation:
  - Infringements of EU environmental legislation

A.3 List of the reports studied for organizations use the GRI

- ABB Group Sustainability Performance 2009: http://www02.abb.com/global/seitp/seitp255.nsf/bf177942f19f4a98c1257148003b7a0a/93d1620e90704990c12576e100363c62/$FILE/ABB+Group+Sustainability+Performance+2009+GRI+indicators.pdf.
- ABB Group Sustainability Performance 2010: http://www05.abb.com/global/scot/scot266.nsf/veritydisplay/8cc06869495220de8325785b00570e86/$file/final_sustainability_2010.pdf
- Anheuser-Busch InBev Annual Report 2009: http://www.ab-inbev.com/pdf/AB_InBev_AR09.pdf
- Anheuser-Busch InBev Annual Report 2010: http://www.ab-inbev.com/pdf/AB_InBev_AR10.pdf
- Baxter Sustainability Priorities Report 2008: http://sustainability.baxter.com/documents/reports/2008/sustainability_report_2008.pdf
- Baxter Sustainability Priorities Report 2009 http://sustainability.baxter.com/documents/reports/2009/sustainability_report_2009.pdf
- Baxter Sustainability Priorities Report 2010: http://sustainability.baxter.com/documents/reports/2010/2010SustainabilityHighlights.pdf
- BHP Billiton Sustainability Summary Report 2009: http://www.bhpbilliton.com/home/investors/reports/Documents/2009/sustainabilitySummaryReport2009.pdf
- BHP Billiton Sustainability Summary Report 2010: http://www.bhpbilliton.com/home/aboutus/sustainability/reports/Documents/2010%20BHP%20Billiton%20Sustainability%20Report%20Supplementary%20Information%20and%20Framework.pdf
- Bridgestone Europe Environmental Commitment and Performance. December 2009: http://www.bridgestone.eu/filelibrary/English/Global/Corporate/Environment/Environmental_brochure_2009.pdf
- Crown van Gelder N.V. “CVG N.V” 2009: http://cvg.nl/pdf/2009/Annual%20Report%202009.pdf
- Crown van Gelder N.V. “CVG N.V” 2010: http://cvg.nl/pdf/2011/Annual%20Report%2020101.pdf
- Deutsche Post DHL Sustainability Report 2009: http://www.dp-dhl.com/SR2009/servicepages/downloads/files/entire_dp_csr09.pdf.
- Fuji Xerox Sustainability Report 2009: http://www.fujixerox.com/eng/company/sr/booklet/2009e.pdf.
- Fuji Xerox Sustainability Report 2010: http://www.fujixerox.com/eng/company/sr/booklet/2010e.pdf
- Fuji Xerox Sustainability Report 2011: http://www.fujixerox.com/eng/company/sr/booklet/2011e.pdf
- Heinz Corporate Social Responsibility Report 2008-2009: http://www.heinz.com/CSR2009/media/Heinz_2008_2009_CSR_Report.pdf
- Heinz Corporate Social Responsibility Report 2010-2011: http://www.heinz.com/CSR2011/media/Heinz_2010_2011_CSR_Report.pdf
- Henkel Sustainability Report, 2009:

http://www.henkel.com/com/content_data/172157_2010.02.25_2009_sustainabilityreport_en.pdf
- Henkel Sustainability Report 2010:
- http://www.henkel.com/com/content_data/208531_SR2010.pdf
- Henkel Sustainability Report 2011: http://www.henkel.com/com/content_data/258005_258005_2012.03.08_2011_sustainabilityreport_de.pdf
- ING Sustainability Reports, 2009, 2010, and 2011: are available under http://www.ing.com/investor-relations/annual-reports.htm
- NetBalance Sustainability Report 2009: http://www.netbalance.com/sites/all/themes/netbalance/reports/NBSR2009.pdf
- NetBalance Sustainability Report 2010: http://www.netbalance.com/sites/all/themes/netbalance/reports/NBSR2010.pdf
- NetBalance Sustainability Report 2011: http://www.netbalance.com/sites/all/themes/netbalance/reports/NBSR2011.pdf
- Nike Inc. Corporate Responsibility Report 2005-2006: http://ebookbrowse.com/nike-fy05-06-corporate-responsibility-report-pdf-d243396505
- Nike Inc. Corporate Responsibility Report 2007-2008-2009: http://www.nikebiz.com/crreport/content/pdf/documents/en-US/full-report.pdf
- Origin energy Sustainability Report 2009: http://www.originenergy.com.au/files/SustainabilityReport09.pdf
- Origin energy Sustainability Report 2010: http://www.originenergy.com.au/files/Origin_Sustainability_Report_2010.pdf
- Origin energy Sustainability Report 2011: http://reports.originenergy.com.au/2011/sustainability/gri/gri_index/
- Pacifichydro Sustainability Report 2009: http://www.pacifichydro.com.au/files/2011/09/sustainability-report-2009.pdf
- Pacifichydro Sustainability Report 2010: http://www.pacifichydro.com.au/files/2011/09/sustainability-report-2010.pdf
- Royal Dutch Shell PLC Sustainability Report 2009: http://sustainabilityreport.shell.com/2009/servicepages/downloads/files/all_shell_sr09.pdf.
- Royal Dutch Shell PLC Sustainability Report presentation 2010: http://s00.static-shell.com/content/dam/shell/static/investor/downloads/presentations/2011/shell-sri-goldmansachslondon14042011.pdf
- Royal Dutch Shell PLC Sustainability Report 2011: http://reports.shell.com/sustainability-report/2011/servicepages/downloads/files/entire_shell_sr11.pdf
- Volkswagen Sustainability Report 2009/2010: http://www.volkswagenag.com/content/vwcorp/info_center/en/publications/2009/09/sustainability_report0.-bin.acq/qual-BinaryStorageItem.Single.File/VW_Sustainability_Report_2009.pdf
- Volkswagen Sustainability Report 2010: http://www.volkswagenag.com/content/vwcorp/info_center/en/publications/2011/05/Report_2010.-bin.acq/qual-BinaryStorageItem.Single.File/VWAG_Nachhaltigkeitsbericht_online_e.pdf

A.4 Corporate Sustainability Assessment of SAM Research

Environmental performance (Eco-Efficiency):

- Total direct GHG emissions in Metric tons CO2 equivalent.
- Total energy consumption in GJ.
- Total water use in Cubic meters (m3).
- Total waste generation in Metric tons.

Environmental Reporting:

- Has your company adopted a corporate environmental policy?
- Please indicate whether your corporate environmental policy applies to: Company's own operations, Environmental impacts of products & services, Suppliers & service providers (e.g. contractors), other key business partners (e.g. non-managed operations, JV partners, etc.).
- Please indicate how your environmental management system is verified/audited/certified.
- Please indicate the percentage of total revenues verified/audited/certified according to these systems.

A.5 References Software Tools Studied

Credit360:
http://www.credit360.com
David.net:
http://www.2rsoftware.de/
Earthster:
http://earthster.org
ELCD database II:
http://lct.jrc.ec.europa.eu/assessment/data
Envis recycle and Envis waste:
http://www.tegos.de
Gabi 4:
http://lca.jrc.ec.europa.eu/lcainfohub/tool2.vm?tid=252
Intelex EMS:
http://www.intelex.com/Environmental_Management-150-1product.aspx
KCL Eco 4:
http://lca.jrc.ec.europa.eu/lcainfohub/tool2.vm?tid=209
OpenLCA:
http://www.openlca.org
SAP Carbon Impact:
http://www.sap.com/solutions/sustainability/offerings/carbon-impact/index.epx
SAP EHS Management:
http://www.sap.com/solutions/business-suite/erp/corporate_services/ehs/features-functions/environmental-compliance-software/index.epx
and
http://www.sap.com/solutions/business-suite/erp/corporate_services/ehs/features-functions/reach-software/index.epx
Silvanus 360:
www.silvanus360.com
SimaPro 7:
http://lca.jrc.ec.europa.eu/lcainfohub/tool2.vm?tid=216
SoFi:
http://www.sofi-software.com/
STORM:
http://storm.uni-oldenburg.de
Umberto 5.5:
http://lca.jrc.ec.europa.eu/lcainfohub/tool2.vm?tid=201
Wizard:
www.ecobilan.com/uk_wisard.php
WMS 2010, list of warehouse management systems:
http://www.warehouse-logistics.com/48/1/teilnehmer_und_systeme.html

A.6 Survey for SMEs requirements

General Information:

Name of the Company: _____

Country: _____

Nr. of Employees: ☐ Less than 10 ☐ 10 - 49 ☐ 50 - 99 ☐ 100 – 250

Sector: _____

Activities of your company: (please specify percentage of activities e.g. based on your revenue)

Manufacturing ____% Service provision ____% Warehouse ____% Logistics ____%

Are you motivated to make any environmental improvements within your company?

☐ Yes ☐ No

2. Awareness of current environmental legislation:

Are you aware of the current environmental legislation?

☐ Yes in detail ☐ General awareness ☐ Unaware

Does your company publish environmental/sustainable reports?

☐ Yes "how often?"____ No ☐ Planned ☐

Does your company have an Environmental Management System in place?

☐ Yes: EMAS ☐ Yes: ISO 14000 ☐ Yes:_____ ☐ No ☐ Planned

Does your company have environmental improvement programs in place?

☐ Yes: which topics ☐ No ☐ Planned

- ☐ Energy efficiency
- ☐ Design for Environment
- ☐ Resource efficiency
- ☐ Waste reduction
- ☐ Other: _____

How many environmental experts are employed in your company?

☐ Unit or department ☐ 3rd party: experts used on demand or on regular basis

☐ One Employee ☐ None

3. Environmental Management Information System (EMIS)

Do you use any Enterprise Information System "e.g.ERP"?

☐ Yes, which _____ ☐ No ☐ Planned

Do you use any Environmental Management Information System?

☐ Yes, which _____ ☐ No ☐ Planned

Please rank the importance of monitoring environmental data/ information on the following levels:

Enterprise level _____ Product level _____ Process & activity level _____

Please rank the importance of the following types of environmental data:

Static/statistical data _____

Dynamic data automatically updated _____

Real time data _____

How frequent do you check your environmental data/information:

☐ Daily ☐ Monthly ☐ Quarterly

☐ Semi yearly ☐ Yearly ☐ on Demand ☐ Non

Are you satisfied with your current situation on?

Environmental expertise:	☐ Yes	☐ No	Environmental monitoring:	☐ Yes	☐ No
Environmental reporting:	☐ Yes	☐ No	Timely response:	☐ Yes	☐ No
Data availability:	☐ Yes	☐ No	Data accuracy:	☐ Yes	☐ No
IT support:	☐ Yes	☐ No	Other: _____		

How would you prefer your EMIS? "more than one choice is possible"

☐ Integrated with my IS ☐ Stand alone system ☐ Webapplication based

☐ Designed for expert users ☐ Licensed software ☐ Open source system

☐ Designed for any end user ☐ Light weight (No need for extra hardware)

How much money do you invest into your IT structure on a yearly basis?

☐ No budget ☐ 1000 - 10.000 ☐ 10.000 – 100.000

☐ 100.000 - 500.000 ☐ 500.000 - 1 Million ☐ Over 1 Million

How much money do you spend for collecting, monitoring and reporting environmental data (People, HW, SW) on a yearly basis?

☐ No budget ☐ 1000 - 10.000 ☐ 10.000 – 100.000

☐ 100.000 - 500.000 ☐ 500.000 - 1 Million ☐ Over 1 Million

A.7 EMIS implementation success survey

The information in this survey will be used only for research purposes within the OVGU – ITI Dept. – Business Informatics 1 group.

Name of the Company: _____

Business sector: _____

Country: _____

Nr. of Employees: □ up to 10 □ 11 – 49 □ 50 – 99 □ 100 – 250 □ > 250

Building Block 1: Current Environmental Situation

1.1 The current information availability situation in your organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

1.2 The current information accuracy situation in your organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

1.3 The current response time of the IS in place affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

1.4 The current environmental sustainability reporting situation affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

1.5 The current environmental expertise in your organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

1.6 The current IT support situation affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

Building Block 2: environmental footprint expectation

2.1 The need of dynamic data/automatically updated affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

2.2 The need of static/statistical data affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

2.3 The need for enterprise level EPIs availability affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

2.4 The need for product level EPIs availability affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

2.5 The need for process and activities level EPIs availability affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

2.6 The preference of using an open source EMIS affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

Building Block 3: Environmental maturity level

3.1 The number of environmental experts employed by your organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

3.2 Having an EMS within your organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

3.3 The usage of a former EMIS within your organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

3.4 The motivation of improving the environmental sustainability within your organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

3.5 The experience rate of monitoring and checking environmental data / information within your organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

3.6 Having environmental improvement programs within your organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

3.7 The reserved budget for collecting, monitoring and reporting environmental data in your organization’s budget planning affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

3.8 The experience of publishing environmental/ sustainability reports within your

organization affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

Building Block 4: Technological Experience

4.1 A web based EMIS affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

4.2 An EMIS as light-weight solution affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

4.3 The expected level of integration of an EMIS affects the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

4.4 The country, society, laws, and regulations affect the success rate of an EMIS implementation in your organization.

□	□	□	□	□
Strongly agree	Agree	Uncertain	Disagree	Strongly disagree

A.8 ISO 14031 EPIs

- Management performance indicators (MPIs) are “a type of EPIs that provide information about management efforts to influence the environmental performance of the organization’s operations. MPIs relate to the policy, people, practices, procedures, decisions and actions at all levels of the organization”.
- Operational performance indicators (OPIs) are “a type of EPIs that provide information about environmental performance of the operations of the organization, and OPIs relate to:
    - Design, operation, and maintenance of the organization’s physical facilities and equipment;
    - Materials, energy, products, services, wastes, and emissions related to the organization’s physical facilities and equipment; and
    - Supply of materials, energy and services to, and the delivery of products, services and wastes from the organization’s physical facilities and equipment”.

Management EPI

- Implementation of policies and programs
- number of achieved objectives and targets
- number of organizational units achieving environmental objectives and targets
- degree of implementation of specified codes of management or operating practice
- number of levels of management with specific environmental responsibilities
- number of employees that have environmental requirements in their job descriptions
- number of employees participating in environmental programs (e.g. suggestion, recycle, clean-up initiatives, reward and recognition, or others)
- number of employees trained versus the number that need training
- number of environmental improvement suggestions from employees
- results of employee surveys on their knowledge of the organization’s environmental issues
- number of suppliers and contractors queried about environmental issues
- number of contracted service providers with an implemented or a certified environmental management system
- number of products with explicit “product stewardship” plans
- number of products designed for disassembly, recycling or reuse

Conformity

- degree of compliance with regulations
- number of non-compliances

- degree of compliance with regulations by contracted service providers
- time to respond to or correct environmental incidents
- numbers of resolved and unresolved corrective actions
- number of or costs attributable to fines and penalties
- number and frequency of specific activities (e.g.audits)
- number of audits completed versus planned
- number of audit findings per period
- frequency of review of operating procedures
- number of emergency drills conducted
- percentage of emergency preparedness and response drills demonstrating planned readiness

Financial performance

- costs (operational and capital) that are associated with a product's or process environmental aspects
- return on investment for environmental improvement projects
- savings achieved through reductions in resource usage, prevention of pollution or waste recycling
- sales revenue attributable to a new product or a byproduct designed to meet environmental performance or design objectives
- research and development funds applied to projects with environmental significance
- environmental liabilities that may have a material impact on the financial status of the organization

Community relation

- number of inquiries or comments about environmentally related matters
- number of press reports on the organization's environmental performance
- number of environmental educational programs or
- materials provided for the community
- resources applied to support of community environmental programs
- number of sites with environmental reports
- number of sites with wildlife programs
- number of local cleanup or recycling initiatives, sponsored or self-implemented
- favourability ratings from community surveys

A.9 EPI Quality: The five accounting and reporting principles (Jamous, et al., 2010-II)

The five accounting and reporting principles have been defined and used by several standards such as ISO14040, ISO 14025, or GHG protocol:

- **Relevance:** Refers to the closeness of the operational definition of the indicator to the environmental problem to be measured, the methodology chosen and the relevancy of the breakdown published and serves the decision-making needs of users – both internal and external to the company.
  Requirements derived:
  - Description of EPI shall include the link to the environmental aspects as well as describing the interactions between society and the environment using e.g. the DPSIR model, references to stakeholder interests as well as relevance of standards
- **Completeness:** Account for and report on all activities within the chosen inventory boundary. Disclose and justify any specific exclusion.
  Requirements derived:
  - Completeness check shall be conducted using the description of EPI coverage and exclusions.
  - Exclusions shall be justified e.g. by using screening results or analogies.
- **Consistency**: Use consistent methodologies to allow for meaningful comparisons of EPIs over time. Transparently document any changes to the data, inventory boundary, methods, or any other relevant factors in the time series. Comparability over time deals with the completeness of the time series and the consistency of methodology used over time. Comparability over space relates to the use of the same or similar methodologies by organizations, the geographical coverage and reliability of data within the organizations.
  Requirements derived:
  - Description of EPI value shall include the link to time series, inventory boundaries, geographical coverage , calculation method used
  - Consistency check is a prerequisite to calculate or process EPI values
- **Transparency**: Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.
  Requirements derived:
  - Description of EPI shall include the origin of EPI, the accounting method (financial or operational control) used, the calculation method used, the data source used (see hierarchy of data), age and geographical coverage of EPI value
- **Accuracy:** Ensure that the EPI value is systematically neither over nor under actual value, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users to make decisions with reasonable

assurance as to the integrity of the reported information. Overall accuracy represents issues such as comparability of data, reliability of data sources, coverage of the indicator, reliability of the methodology used and whether the results could be validated (e.g. sensitivity analysis; confirmation through other data or approaches, external verification or certification).

Requirements derived:

- Description of EPI shall include the data collection method
- Data collection method shall include whether the method is validated/certified externally
- Consistency and completeness checks shall be traceable
- Description of EPI value shall include whether the value is verified/certified internally or externally

A.10 EPI Data types (Jamous, et al., 2010-II)

As a general rule, companies should apply the following hierarchy of data types in collecting data of ***organizational accounting***:

- Primary Data: collected directly from the daily operations within the organization. These data have the following hierarchy:
  - Product-level data
  - Process-level data
  - Facility-level data
  - Business-unit data
  - Corporate-level data
- Secondary Data: collected indirectly from the daily operations within the organization.
- Extrapolated Data: primary or secondary data related to a similar input, process, or activity to the one in the inventory, which are adapted or customized to a new situation to make it more representative.
- Proxy Data: primary or secondary data related to a similar (but not representative) input, process, or activity to the one in the inventory, which are directly transferred or generalized to the input, process, or activity of interest without being adapted or customized to make more representative.

As for the data types collected for product lifecycle accounting, it has the following hierarchy:

- Primary data: data extracted directly from specific process of the organization's business process or another organization related to its supply chain.
- Secondary data: data extracted indirectly from specific process of the organization's business process or another organization related to its supply chain, e.g. environmentally extended input/output data.
- Process data: These are physical flow data relating to the individual process within the defined system boundary, and may consist of site specific primary data, generic/average secondary data, and secondary data from literature studies, expert estimates, and impact assessments.
- Input-Output data: Non-process data derived from an environmentally extended input-output analysis (IOA), which is the method of allocating GHG emissions (or other environmental impacts) associated with upstream production processes to groups of finished products by means of inter-industry transactions. The main data sources for IOA are sectoral economic and environmental accounts. Economic accounts are compiled by a survey of facilities on economic inputs and outputs and tax data from individual establishments. Environmental accounts are derived from (surveyed) fossil fuel consumption by industry and other GHG sources compiled in national emission inventories.
- Extrapolated data: Primary or secondary data related to a similar (but not representative) input, processor activity to the one in the inventory that are adapted or customized to a new situation to make it more representative. For example, using data from the same or a similar activity type and customizing the data to the relevant region, technology, process, temporal period and/or product.

- Proxy data: Primary or secondary data related to a similar (but not representative) input, process, or activity to the one in the inventory, which may be used in lieu of representative data if unavailable. These existing data are directly transferred or generalized to the input/process of interest without adaptation.

The common data quality indicators used to describe individual data are outlined in Table 36 and are applicable to product life cycle accounting and corporate accounting. All data quality indicators should be used to describe primary data, while technological, temporal and geographic representativeness are the most relevant for secondary data.

Data Quality Indicator	Explanation (corporate reporting)	Explanation (product life cycle reporting)
Technological representativeness	Degree to which the data set reflects the actual technology(ies) used	Degree to which the data set reflects the actual technology(ies) used in the processes within system boundary, including any background data sets used.
Temporal representativeness	Degree to which the data set reflects the actual time (e.g., year) or age of the activity or whether an appropriate time period is used (e.g., annual/seasonal averages may be appropriate to smooth out data variability due to factors such as weather conditions)	Degree to which the data set reflects the actual time (e.g., year) or age of the processes within the system boundary, including any background data sets used or whether an appropriate time period is used (e.g., for food products annual/seasonal averages or average of several seasons may be appropriate to smooth out data variability due to factors such as weather conditions).
Geographical representativeness	Degree to which the data set reflects actual geographic location of the activity e.g., country or site	Degree to which the data set reflects actual geographic location of the processes within the system boundary such as, e.g., country or site, including any background data sets used.
Completeness	The degree to which the data represents the relevant activity. The percentage of locations for which site specific or generic data are available and used out of the total number that relate to a specific activity. Generally, a percent target is	The degree to which the data represents the relevant process. The percentage of locations for which site specific or generic process data are available and used out of the total number that relate to a specific product or process. Generally, a percent

	identified for the number of sites from which data is collected for each process.	target is identified for the number of sites from which data is collected for each process.
Precision	Measure of the variability of the data points used to derive the GHG emissions from a process (e.g., low variance = high precision). Relates mostly to where direct measurements have been used.	Measure of the variability of the data points used to derive the GHG emissions from a process (e.g., low variance = high precision). Relates mostly to where direct measurements have been used.

Table 36: Data Quality Indicators

Secondary data are typically sourced from existing lifecycle databases. To identify the appropriate database(s) or data set to use, additional information should be sourced about and require an adequate description in defining EPIs and EPI values.

- How long has the database existed?
- How long has its developer/data service been in business?
- How extensively has the database been used?
- How frequently is the database updated?
- Are the data sources consistent with the scope, geography, product use and product manufacturing characteristics (e.g., processes) for the GHG account being performed?
- How current are the data sources used for developing the LCA emissions data in the database?
- Can uncertainties be estimated for the data and are the meta-data available?

A.11 The LWC-EPI Prototype Code

The configurations file of the LWC-EPI web application:

```
<?xml version="1.0" encoding="UTF-8"?>
<!--
  For more information on how to configure your ASP.NET application, please visit
  http://go.microsoft.com/fwlink/?LinkId=169433
  -->
<configuration>
  <appSettings>
    <add key="ChartImageHandler" value="storage=file;timeout=20;dir=c:\TempImageFiles\;" />
  </appSettings>
  <connectionStrings>
    <add   name="ApplicationServices"   connectionString="data   source=.\SQLEXPRESS;Integrated
Security=SSPI;AttachDBFilename=|DataDirectory|\aspnetdb.mdf;User                Instance=true"
providerName="System.Data.SqlClient" />
    <add name="LWCEPI" connectionString="Data Source=141.44.30.154,50000;Initial Catalog=LWC-
EPI;User ID=XXXX;Password=XXXX" providerName="System.Data.SqlClient" />
    <add                 name="LWC-EPIConnectionString"                connectionString="Data
Source=141.44.30.154,50000;Initial     Catalog=LWC-EPI;Persist     Security     Info=True;User
ID=XXXX;Password=XXXX" providerName="System.Data.SqlClient" />
  </connectionStrings>
  <system.web>
    <httpHandlers>
      <add                        path="ChartImg.axd"                        verb="GET,HEAD,POST"
type="System.Web.UI.DataVisualization.Charting.ChartHttpHandler, System.Web.DataVisualization,
Version=4.0.0.0, Culture=neutral, PublicKeyToken=31bf3856ad364e35" validate="false" />
    </httpHandlers>
    <pages>
      <controls>
        <add       tagPrefix="asp"       namespace="System.Web.UI.DataVisualization.Charting"
assembly="System.Web.DataVisualization,           Version=4.0.0.0,           Culture=neutral,
PublicKeyToken=31bf3856ad364e35" />
      </controls>
    </pages>
    <compilation debug="true" targetFramework="4.0" />
    <authentication mode="Forms">
      <forms loginUrl="~/Account/Login.aspx" timeout="2880" />
    </authentication>
    <membership defaultProvider="LWC">
      <providers>
        <clear />
        <add                                                  name="AspNetSqlMembershipProvider"
type="System.Web.Security.SqlMembershipProvider"    connectionStringName="ApplicationServices"
enablePasswordRetrieval="false"  enablePasswordReset="true"  requiresQuestionAndAnswer="false"
requiresUniqueEmail="false"    maxInvalidPasswordAttempts="5"    minRequiredPasswordLength="6"
minRequiredNonalphanumericCharacters="0" passwordAttemptWindow="10" applicationName="/" />
        <add            name="LWC"            type="System.Web.Security.SqlMembershipProvider"
connectionStringName="LWCEPI"    enablePasswordRetrieval="false"    enablePasswordReset="true"
requiresQuestionAndAnswer="false"     applicationName="LWCtest"     requiresUniqueEmail="true"
passwordFormat="Hashed"      maxInvalidPasswordAttempts="5"      minRequiredPasswordLength="7"
minRequiredNonalphanumericCharacters="1"                                passwordAttemptWindow="10"
passwordStrengthRegularExpression="" />
      </providers>
    </membership>
    <profile>
      <providers>
        <clear />
        <add    name="AspNetSqlProfileProvider"    type="System.Web.Profile.SqlProfileProvider"
connectionStringName="ApplicationServices" applicationName="/" />
      </providers>
    </profile>
    <roleManager enabled="false">
      <providers>
        <clear />
        <add      name="AspNetSqlRoleProvider"      type="System.Web.Security.SqlRoleProvider"
connectionStringName="ApplicationServices" applicationName="/" />
        <add                                                 name="AspNetWindowsTokenRoleProvider"
type="System.Web.Security.WindowsTokenRoleProvider" applicationName="/" />
      </providers>
    </roleManager>
        <identity impersonate="true" />
  </system.web>
  <system.webServer>
    <modules runAllManagedModulesForAllRequests="true" />
```

```
    <validation validateIntegratedModeConfiguration="false" />
    <handlers>
      <remove name="ChartImageHandler" />
      <add    name="ChartImageHandler"    preCondition="integratedMode"    verb="GET,HEAD,POST"
path="ChartImg.axd"           type="System.Web.UI.DataVisualization.Charting.ChartHttpHandler,
System.Web.DataVisualization,                Version=4.0.0.0,                Culture=neutral,
PublicKeyToken=31bf3856ad364e35" />
    </handlers>
  </system.webServer>
  <system.serviceModel>
    <bindings>
      <basicHttpBinding>
        <binding          name="BasicHttpBinding_IServiceE1"          closeTimeout="00:01:00"
openTimeout="00:01:00"  receiveTimeout="00:10:00"  sendTimeout="00:01:00"  allowCookies="false"
bypassProxyOnLocal="false"    hostNameComparisonMode="StrongWildcard"    maxBufferSize="65536"
maxBufferPoolSize="524288"        maxReceivedMessageSize="65536"        messageEncoding="Text"
textEncoding="utf-8" transferMode="Buffered" useDefaultWebProxy="true">
          <readerQuotas  maxDepth="32"  maxStringContentLength="8192"  maxArrayLength="16384"
maxBytesPerRead="4096" maxNameTableCharCount="16384" />
          <security mode="None">
            <transport clientCredentialType="None" proxyCredentialType="None" realm="" />
            <message clientCredentialType="UserName" algorithmSuite="Default" />
          </security>
        </binding>
      </basicHttpBinding>
      <wsHttpBinding>
        <binding           name="WSHttpBinding_IElecService"           closeTimeout="00:01:00"
openTimeout="00:01:00"            receiveTimeout="00:10:00"            sendTimeout="00:01:00"
bypassProxyOnLocal="false"   transactionFlow="false"   hostNameComparisonMode="StrongWildcard"
maxBufferPoolSize="524288"        maxReceivedMessageSize="65536"        messageEncoding="Text"
textEncoding="utf-8" useDefaultWebProxy="true" allowCookies="false">
          <readerQuotas  maxDepth="32"  maxStringContentLength="8192"  maxArrayLength="16384"
maxBytesPerRead="4096" maxNameTableCharCount="16384" />
          <reliableSession ordered="true" inactivityTimeout="00:10:00" enabled="false" />
          <security mode="Message">
            <transport clientCredentialType="Windows" proxyCredentialType="None" realm="" />
            <message     clientCredentialType="Windows"     negotiateServiceCredential="true"
algorithmSuite="Default" />
          </security>
        </binding>
        <binding          name="WSHttpBinding_IElecService1"          closeTimeout="00:01:00"
openTimeout="00:01:00"            receiveTimeout="00:10:00"            sendTimeout="00:01:00"
bypassProxyOnLocal="false"   transactionFlow="false"   hostNameComparisonMode="StrongWildcard"
maxBufferPoolSize="524288"        maxReceivedMessageSize="65536"        messageEncoding="Text"
textEncoding="utf-8" useDefaultWebProxy="true" allowCookies="false">
          <readerQuotas  maxDepth="32"  maxStringContentLength="8192"  maxArrayLength="16384"
maxBytesPerRead="4096" maxNameTableCharCount="16384" />
          <reliableSession ordered="true" inactivityTimeout="00:10:00" enabled="false" />
          <security mode="Message">
            <transport clientCredentialType="Windows" proxyCredentialType="None" realm="" />
            <message     clientCredentialType="Windows"     negotiateServiceCredential="true"
algorithmSuite="Default" />
          </security>
        </binding>
      </wsHttpBinding>
    </bindings>
    <client>
      <endpoint      address="http://localhost:1234/ElecService/"      binding="wsHttpBinding"
bindingConfiguration="WSHttpBinding_IElecService1"
contract="ElectricityServiceRefNew.IElecService" name="WSHttpBinding_IElecService1">
        <identity>
          <dns value="localhost" />
        </identity>
      </endpoint>
      <endpoint                      address=""                      binding="basicHttpBinding"
bindingConfiguration="BasicHttpBinding_IServiceE1"  contract="EnterpriseServiceRefn.IServiceE1"
name="BasicHttpBinding_IServiceE1" />
    </client>
  </system.serviceModel>
</configuration>
```

In contrast to traditional web-designing, ASP.NET separates the code (here c#) from the display (HTML) in order to keep your code clean and structured, the same method is applied in OOP. You can still use Jscript or VBScript alone, but because Jscript for example is a scripting language, you are forced to entwine the script in the HTML and likely end up messy

in case of large applications. In this way, every ASP.NET page has two files: Markup, and its code. Hereafter, these codes are presented without the Markup part.

Default home Page:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;
using DBLayerLibrary;
using System.Web.Security;

namespace WCF_EPI
{
    public partial class _Default : System.Web.UI.Page
    {
        private DBLayerLibrary.DBDataContext db = new DBLayerLibrary.DBDataContext();
        protected void Page_Load(object sender, EventArgs e)
        {
            ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text     =
"Home page";

((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].NavigateUrl          =
this.ResolveClientUrl("~/Default.aspx");

            if (Membership.GetUser() != null)
            {
                Guid user = (Guid)Membership.GetUser().ProviderUserKey;
                //check if the current user make ECET survey
                var ECET = (from q in db.Organizations
                            join   p   in   db.UserCompanies   on   q.OrganizationID   equals
p.OrganizationID
                            where p.UserId == user
                            select q.Survey).First();
                //if the user made survey => make the menu items enabled
                if (ECET.Value)
                {
                    ((Literal)HeadLoginView.FindControl("Literal1")).Text = "";
                    ((Menu)HeadLoginView.FindControl("menu1")).Items[1].Enabled = true;
                    ((Menu)HeadLoginView.FindControl("menu1")).Items[2].Enabled = true;
                    ((Menu)HeadLoginView.FindControl("menu1")).Items[3].Enabled = true;
                    ((Menu)HeadLoginView.FindControl("menu1")).Items[4].Enabled = true;
                }
                else
                    ((Literal)HeadLoginView.FindControl("Literal1")).Text  =  "Please  complete
the ECET questionnaire to use the system functionalities";
            }
        }
        //example using the service
       protected void HeadLoginView_ViewChanged(object sender, EventArgs e)
        {
        }     } }
```

Create EPI page:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;

using System.Web.Security;
using System.Diagnostics;
using DBLayerLibrary;
using System.Drawing;

namespace WCF_EPI
{
    public partial class CreateEPI : System.Web.UI.Page
    {
        private DBLayerLibrary.DBDataContext db = new DBLayerLibrary.DBDataContext();
        protected void Page_Load(object sender, EventArgs e)
        {          ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text
= "Create EPI";
      ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].NavigateUrl     =
```

```
this.ResolveClientUrl("~/CreateEPI.aspx");
            if (!Page.IsPostBack)
            {
            var EnviromentalAspect = from q in db.EnviromentalAspects
                                     select q.EnviromentalAspect1;
            EnviromentalAspectD.DataSource = EnviromentalAspect;
            EnviromentalAspectD.DataBind();
            EnviromentalAspectD.Items.Insert(0, new ListItem("", "0"));
            var BusinessField = from q in db.classifiers
                                select q.BusinessField;

            D_BusinessDomain.DataSource = BusinessField.Distinct();
            D_BusinessDomain.DataBind();
            D_BusinessDomain.Items.Insert(0, new ListItem("", "0"));
            var DpsirCategory = from q in db.DpsirCategories
                                select q.DpsirCategory1;
            DpsirCategoryD.DataSource = DpsirCategory;
            DpsirCategoryD.DataBind();
            DpsirCategoryD.Items.Insert(0, new ListItem("", "0"));
            var LevelAspect = from q in db.LevelAscpects
                              select q.LevelAspect;
            LevelAspectD.DataSource = LevelAspect;
            LevelAspectD.DataBind();
            LevelAspectD.Items.Insert(0, new ListItem("", "0"));
            var Impact = from q in db.Impacts
                         select q.Impact1;
            Impact1D.DataSource = Impact;
            Impact1D.DataBind();
            Impact1D.Items.Insert(0, new ListItem("", "0"));
            Impact2D.DataSource = Impact;
            Impact2D.DataBind();
            Impact2D.Items.Insert(0, new ListItem("", "0"));
            Impact3D.DataSource = Impact;
            Impact3D.DataBind();
            Impact3D.Items.Insert(0, new ListItem("", "0"));
            var Field = from q in db.BusinessFields
                        select q.Field;
            D_field1.DataSource = Field;
            D_field1.DataBind();
            D_field1.Items.Insert(0, new ListItem("", "0"));
            D_field2.DataSource = Field;
            D_field2.DataBind();
            D_field2.Items.Insert(0, new ListItem("", "0"));
            var Material = from q in db.Materials
                       select q.MaterialName;
            InputD.DataSource = Material;
            InputD.DataBind();
            InputD.Items.Add(new ListItem("Add new Material"));
            InputD.Items.Insert(0, new ListItem("", "0"));
            InputD0.DataSource = Material;
            InputD0.DataBind();
            InputD0.Items.Add(new ListItem("Add new Material"));
            InputD0.Items.Insert(0, new ListItem("", "0"));
            OutputD.DataSource = Material;
            OutputD.DataBind();
            OutputD.Items.Add(new ListItem("Add new Material"));
            OutputD.Items.Insert(0, new ListItem("", "0"));
            var Equivalence = from q in db.Equivalences
                              select q.Equivalence1;
            D_Equivalence.DataSource = Equivalence;
            D_Equivalence.DataBind();
            D_Equivalence.Items.Insert(0, new ListItem("", "0"));
            }
        }
        protected void EnviromentalAspectD_SelectedIndexChanged(object sender, EventArgs e)
        {
        }
        protected void Create_Click(object sender, EventArgs e)
        {
            var equation = from q in db.EPIs
                           where ( q.Equation == TB_Equation.Text && q.RefDoc == null )
                           select q.EpiName;
            if (equation.Count() == 0)
            {
                EPI epi = new EPI();
                epi.EpiName = TB_EPIName.Text;
                epi.Equation = TB_Equation.Text;
                epi.Reference = TB_Reference.Text;
```

```
                epi.Description = TB_Description.Text;
                epi.Creator = (Guid)Membership.GetUser().ProviderUserKey;
                //Input Material
                if (TB_MatName1.Enabled == false)
                {
                    var input = from q in db.Materials
                                where q.MaterialName == InputD.SelectedItem.Text
                                select q.MaterialID;
                    epi.Inputmat1 = input.FirstOrDefault();
                }
                else
                {
                    Material mat1 = new Material();
                    mat1.MaterialName = TB_MatName1.Text;
                    mat1.MaterialUnit = TB_Unit1.Text;
                    db.Materials.InsertOnSubmit(mat1);
                    epi.Material1 = mat1;
                }
                //Output Material
                if (TB_MatName2.Enabled == false)
                {
                    var output = from q in db.Materials
                                 where q.MaterialName == OutputD.SelectedItem.Text
                                 select q.MaterialID;
                    epi.Outputmat = output.FirstOrDefault();
                }
                else
                {
                    Material mat2 = new Material();
                    mat2.MaterialName = TB_MatName2.Text;
                    mat2.MaterialUnit = TB_Unit2.Text;
                    db.Materials.InsertOnSubmit(mat2);
                    epi.Material = mat2;
                }
                classifier c = new classifier();
                if ( EnviromentalAspectD.SelectedIndex != 0 )
                c.EnviromentalAspect = EnviromentalAspectD.SelectedItem.Text;
                if (D_BusinessDomain.SelectedIndex != 0)
                c.BusinessField = D_BusinessDomain.SelectedItem.Text;
                if (DpsirCategoryD.SelectedIndex != 0)
                c.DpsirCategory = DpsirCategoryD.SelectedItem.Text;
                if (LevelAspectD.SelectedIndex != 0)
                c.LevelAspect = LevelAspectD.SelectedItem.Text;
                if (Impact1D.SelectedIndex != 0)
                c.Impact1 = Impact1D.SelectedItem.Text;
                if (D_rel1.SelectedIndex != 0)
                c.ImpactRel1 = D_rel1.SelectedItem.Text;
                if (Impact2D.SelectedIndex != 0)
                c.Impact2 = Impact2D.SelectedItem.Text;
                if (D_rel2.SelectedIndex != 0)
                c.ImpactRel2 = D_rel2.SelectedItem.Text;
                if (Impact3D.SelectedIndex != 0)
                c.Impact3 = Impact3D.SelectedItem.Text;
                if (D_rel3.SelectedIndex != 0)
                c.ImpactRel3 = D_rel3.SelectedItem.Text;
                if (D_Equivalence.SelectedIndex != 0)
                c.Equivalence = D_Equivalence.SelectedItem.Text;
                db.classifiers.InsertOnSubmit(c);

              if (D_BusinessDomain.SelectedIndex != 0 && D_BusinessDomain.SelectedIndex != 1)
                {
                    ClassField cf1 = new ClassField();
                    cf1.Field = D_field1.SelectedItem.Text;
                    db.ClassFields.InsertOnSubmit(cf1);
                    cf1.classifier = c;
                }
                epi.classifier = c;
                //Insert the new object
                db.EPIs.InsertOnSubmit(epi);
                //Sumbit changes to the database
                db.SubmitChanges();
                //Page.Response.Redirect(Page.Request.Url.Crea);
                Message.ForeColor = Color.Green;
                Message.Text = "The EPI was successfully inserted";
            }
            else
            {
                Message.ForeColor = Color.Red;
```

```
                Message.Text = "This EPI ist already inserted in our Data Base " +
equation.First().ToString();
            }         }
        protected void InputD_SelectedIndexChanged(object sender, EventArgs e)
        {
            if (InputD.SelectedIndex == InputD.Items.Count - 1)
            {
                TB_MatName1.Enabled = true;
                TB_Unit1.Enabled = true;
            }
            else
            {
                TB_MatName1.Enabled = false;
                TB_Unit1.Enabled = false;
            }         }
        protected void InputD0_SelectedIndexChanged(object sender, EventArgs e)
        {
            if (InputD0.SelectedIndex == InputD.Items.Count - 1)
            {
                TB_MatName3.Enabled = true;
                TB_Unit3.Enabled = true;
            }
            else
            {
                TB_MatName3.Enabled = false;
                TB_Unit3.Enabled = false;
            }         }
        protected void OutputD_SelectedIndexChanged(object sender, EventArgs e)
        {
            if (OutputD.SelectedIndex == OutputD.Items.Count - 1)
            {
                TB_MatName2.Enabled = true;
                TB_Unit2.Enabled = true;
            }
            else
            {
                TB_MatName2.Enabled = false;
                TB_Unit2.Enabled = false;
            }         }
        protected void Add_Click(object sender, EventArgs e)
        {
            BusinessField BD = new BusinessField();
            BD.Field = TB_BusinessDomain.Text ;
            ////Insert the new object
            db.BusinessFields.InsertOnSubmit(BD);
            ////Sumbit changes to the database
            db.SubmitChanges();
            var Field = from q in db.BusinessFields
                        select q.Field;
            D_field1.DataSource = Field;
            D_field1.DataBind();
            D_field1.Items.Insert(0, new ListItem("", "0"));
            D_field2.DataSource = Field;
            D_field2.DataBind();
            D_field2.Items.Insert(0, new ListItem("", "0"));
        }
        protected void D_BusinessDomain_SelectedIndexChanged(object sender, EventArgs e)
        {
            if (D_BusinessDomain.SelectedValue == "Specific")
            {
                D_field1.Enabled = true;
                D_field2.Enabled = true;
            }
            else
            {
                D_field1.Enabled = false;
                D_field2.Enabled = false;
            }         }     }  }
```

Compare EPI page:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;
```

```
using System.Web.Security;
using System.Data;
using System.IO;

namespace WCF_EPI
{
    public partial class CompareEPI : System.Web.UI.Page
    {
        private DBLayerLibrary.DBDataContext db = new DBLayerLibrary.DBDataContext();

        protected void Page_Load(object sender, EventArgs ee)
        {
            if (Membership.GetUser() == null)
            {
                Page.Response.Redirect("Default.aspx");
                return;
            }
((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text = "Compare EPI";

((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].NavigateUrl          =
this.ResolveClientUrl("~/CompareEPI.aspx");
            if (!IsPostBack)
            {
                var x = from i in db.InstanceStatements
                        join e in db.EPIs
                        on i.EpiId equals e.EpiId
                        where i.privacyData == (Guid)Membership.GetUser().ProviderUserKey
                        select new { e.EpiName, e.EpiId };
                foreach (var i in x.Distinct())
                {
                    CheckBoxList1.Items.Add(new ListItem(i.EpiName, i.EpiId.ToString()));
                }
            }
        }
      protected void CheckBoxList1_SelectedIndexChanged(object sender, EventArgs e)
        {
        }
        protected void Button1_Click(object sender, EventArgs ee)
        {
            //chosen EPIs IDs
            List<int> L = new List<int>();
            foreach (ListItem i in CheckBoxList1.Items)
            {
                if (i.Selected)
                    L.Add(Convert.ToInt32(i.Value));
            }
            if (L.Count == 0)
            {
                Literal1.Text = "Please select at least one EPI for your report";
                return;
            }
            DataTable DT = new DataTable();
            DT.Columns.Add("Epi Name");
            DT.Columns.Add("Organization");
            DT.Columns.Add("EPI value");
            DT.Columns.Add("Date");
            DT.Columns.Add("EPI Rank");

            #region organization block
            if (RadioButtonList1.Items[0].Selected)
            {
                foreach (var m in L)
                {
                    //Orgainzation, all business domain
                    var y = (from i in db.InstanceStatements
                             join e in db.EPIs
                             on i.EpiId equals e.EpiId
                             where
                                  (i.privacyData                                                  ==
(Guid)Membership.GetUser().ProviderUserKey)
                             && i.EpiId == m
                             select  new  {  i.privacyData,  i.EPI.EpiName,  i.NumericDataItem,
i.ObtainTime, i.EPIRank }).OrderBy(c => c.privacyData);

                    var x = (from i in db.InstanceStatements
                             join e in db.EPIs
                             on i.EpiId equals e.EpiId
                             where
```

```
                                (from q in db.UserCompanies
                                 where q.UserId == (Guid)Membership.GetUser().ProviderUserKey
                                 select q.OrganizationID).Contains(i.privacyData)
                            && i.EpiId == m
                            select new { i.privacyData, i.EPI.EpiName, i.NumericDataItem,
i.ObtainTime, i.EPIRank }).OrderBy(c => c.privacyData);
                    foreach (var j in y)
                    {
                        DataRow DR = DT.NewRow();
                        DR["Organization"] = "private";// Membership.GetUser().UserName;
                        DR["Epi Name"] = j.EpiName;
                        DR["EPI value"] = j.NumericDataItem;
                        DR["Date"] = j.ObtainTime.Value.ToShortDateString();
                        switch (j.EPIRank)
                        {
                            case 1: DR["EPI Rank"] = "Excellent"; break;
                            case 2: DR["EPI Rank"] = "Good"; break;
                            case 3: DR["EPI Rank"] = "Acceptable"; break;
                            case 4: DR["EPI Rank"] = "Weak"; break;
                            case 5: DR["EPI Rank"] = "Very Weak"; break;
                        }
                        DT.Rows.Add(DR);
                    }
                    foreach (var i in x)
                    {
                        DataRow DR = DT.NewRow();
                        DR["Organization"] = "own organization";
                        DR["Epi Name"] = i.EpiName;
                        DR["EPI value"] = i.NumericDataItem;
                        DR["Date"] = i.ObtainTime.Value.ToShortDateString();
                        switch (i.EPIRank)
                        {
                            case 1: DR["EPI Rank"] = "Excellent"; break;
                            case 2: DR["EPI Rank"] = "Good"; break;
                            case 3: DR["EPI Rank"] = "Acceptable"; break;
                            case 4: DR["EPI Rank"] = "Weak"; break;
                            case 5: DR["EPI Rank"] = "Very Weak"; break;
                        }
                        DT.Rows.Add(DR);
                    }
                }
                GridView1.DataSource = DT;
                GridView1.DataBind();
            }
            #endregion

            #region public block
            else if (RadioButtonList1.Items[1].Selected)
            {
                var field = (from q in db.Organizations
                             join u in db.UserCompanies
                             on q.OrganizationID equals u.OrganizationID
                             where u.UserId == (Guid)Membership.GetUser().ProviderUserKey
                             select q.Field).First();
                foreach (var m in L)
                {
                    //public, all business domain
                    var x = (from i in db.InstanceStatements
                             join e in db.EPIs
                             on i.EpiId equals e.EpiId
                             where
                                (i.privacyData == (Guid)Membership.GetUser().ProviderUserKey)
                                 //&& L.Contains(i.EpiId)
                                && i.EpiId == m
                             select new { i.privacyData, i.EPI.EpiName, i.NumericDataItem,
i.ObtainTime, i.EPIRank }).OrderBy(c => c.privacyData);
                    var y = (from i in db.InstanceStatements
                             join e in db.EPIs
                             on i.EpiId equals e.EpiId
                             where
                                 ((from q in db.UserCompanies
                                   where                        q.UserId                        ==
(Guid)Membership.GetUser().ProviderUserKey
                                    select q.OrganizationID).Contains(i.privacyData)
                                 )
                             && i.EpiId == m
                             select new { i.privacyData, i.EPI.EpiName, i.NumericDataItem,
i.ObtainTime, i.EPIRank }).OrderBy(c => c.privacyData);
```

```
                    if (BDRadioButtonList.SelectedIndex == 0)//same business field
                    {
                        var z = (from i in db.InstanceStatements
                                 join e in db.EPIs
                                 on i.EpiId equals e.EpiId
                                 join g in db.UserCompanies
                                 on i.Owner equals g.UserId //into X
                                 join v in db.Organizations
                                 on g.OrganizationID equals v.OrganizationID
                                 where i.privacyData == null
                                     //&& L.Contains(i.EpiId)
                                 && v.Field == field && i.EpiId == m
                                 select new { i.EPI.EpiName, i.NumericDataItem, i.ObtainTime,
i.Owner, i.EPIRank }).OrderBy(c => c.Owner);
                        foreach (var j in x)
                        {
                            DataRow DR = DT.NewRow();
                            DR["Organization"] = "private";// Membership.GetUser().UserName;
                            DR["Epi Name"] = j.EpiName;
                            DR["EPI value"] = j.NumericDataItem;
                            DR["Date"] = j.ObtainTime.Value.ToShortDateString();
                            switch (j.EPIRank)
                            {
                                case 1: DR["EPI Rank"] = "Excellent"; break;
                                case 2: DR["EPI Rank"] = "Good"; break;
                                case 3: DR["EPI Rank"] = "Acceptable"; break;
                                case 4: DR["EPI Rank"] = "Weak"; break;
                                case 5: DR["EPI Rank"] = "Very Weak"; break;
                            }
                            DT.Rows.Add(DR);
                        }
                        foreach (var i in y)
                        {
                            DataRow DR = DT.NewRow();
                            DR["Organization"] = "own organization";
                            DR["Epi Name"] = i.EpiName;
                            DR["EPI value"] = i.NumericDataItem;
                            DR["Date"] = i.ObtainTime.Value.ToShortDateString();
                            switch (i.EPIRank)
                            {
                                case 1: DR["EPI Rank"] = "Excellent"; break;
                                case 2: DR["EPI Rank"] = "Good"; break;
                                case 3: DR["EPI Rank"] = "Acceptable"; break;
                                case 4: DR["EPI Rank"] = "Weak"; break;
                                case 5: DR["EPI Rank"] = "Very Weak"; break;
                            }
                            DT.Rows.Add(DR);
                        }
                        int count = 1;
                        Guid temp = new Guid();
                        if (z.Count() > 0)
                            temp = z.First().Owner.Value;
                        foreach (var i in z)
                        {
                            if (i.Owner.Value != temp)
                                count++;
                            DataRow DR = DT.NewRow();
                            DR["Organization"] = "organization " + count;
                            DR["Epi Name"] = i.EpiName;
                            DR["EPI value"] = i.NumericDataItem;
                            DR["Date"] = i.ObtainTime.Value.ToShortDateString();
                            switch (i.EPIRank)
                            {
                                case 1: DR["EPI Rank"] = "Excellent"; break;
                                case 2: DR["EPI Rank"] = "Good"; break;
                                case 3: DR["EPI Rank"] = "Acceptable"; break;
                                case 4: DR["EPI Rank"] = "Weak"; break;
                                case 5: DR["EPI Rank"] = "Very Weak"; break;
                            }
                            DT.Rows.Add(DR);
                        }
                    }
                    else
                    {
                        var z = (from i in db.InstanceStatements
                                 join e in db.EPIs
                                 on i.EpiId equals e.EpiId
                                 where i.privacyData == null
```

```
                                    //&& L.Contains(i.EpiId)
                                 && i.EpiId == m
                                 select new { i.EPI.EpiName, i.NumericDataItem, i.ObtainTime,
i.Owner, i.EPIRank }).OrderBy(c => c.Owner);
                        foreach (var j in x)
                        {
                            DataRow DR = DT.NewRow();
                            DR["Organization"] = "private";// Membership.GetUser().UserName;
                            DR["Epi Name"] = j.EpiName;
                            DR["EPI value"] = j.NumericDataItem;
                            DR["Date"] = j.ObtainTime.Value.ToShortDateString();
                            switch (j.EPIRank)
                            {
                                case 1: DR["EPI Rank"] = "Excellent"; break;
                                case 2: DR["EPI Rank"] = "Good"; break;
                                case 3: DR["EPI Rank"] = "Acceptable"; break;
                                case 4: DR["EPI Rank"] = "Weak"; break;
                                case 5: DR["EPI Rank"] = "Very Weak"; break;
                            }
                            DT.Rows.Add(DR);
                        }
                        foreach (var i in y)
                        {
                            DataRow DR = DT.NewRow();
                            DR["Organization"] = "own organization";
                            DR["Epi Name"] = i.EpiName;
                            DR["EPI value"] = i.NumericDataItem;
                            DR["Date"] = i.ObtainTime.Value.ToShortDateString();
                            switch (i.EPIRank)
                            {
                                case 1: DR["EPI Rank"] = "Excellent"; break;
                                case 2: DR["EPI Rank"] = "Good"; break;
                                case 3: DR["EPI Rank"] = "Acceptable"; break;
                                case 4: DR["EPI Rank"] = "Weak"; break;
                                case 5: DR["EPI Rank"] = "Very Weak"; break;
                            }
                            DT.Rows.Add(DR);
                        }
                        int count = 1;
                        Guid temp = new Guid();
                        if (z.Count() > 0)
                            temp = z.First().Owner.Value;
                        foreach (var i in z)
                        {
                            if (i.Owner.Value != temp)
                                count++;
                            DataRow DR = DT.NewRow();
                            DR["Organization"] = "organization " + count;
                            DR["Epi Name"] = i.EpiName;
                            DR["EPI value"] = i.NumericDataItem;
                            DR["Date"] = i.ObtainTime.Value.ToShortDateString();
                            switch (i.EPIRank)
                            {
                                case 1: DR["EPI Rank"] = "Excellent"; break;
                                case 2: DR["EPI Rank"] = "Good"; break;
                                case 3: DR["EPI Rank"] = "Acceptable"; break;
                                case 4: DR["EPI Rank"] = "Weak"; break;
                                case 5: DR["EPI Rank"] = "Very Weak"; break;
                            }
                            DT.Rows.Add(DR);
                        }
                    }
                }
                GridView1.DataSource = DT;
                GridView1.DataBind();
            }
            #endregion
        }
        protected void RadioButtonList1_SelectedIndexChanged(object sender, EventArgs e)
        {
            //select public comparsion
            if (RadioButtonList1.SelectedIndex == 1)
            {
                BDLabel.Visible = true;
                BDRadioButtonList.Visible = true;
            }
            else
            {
```

```
                BDLabel.Visible = false;
                BDRadioButtonList.Visible = false;
            }
        }
        protected void Button2_Click(object sender, EventArgs e)
        {
            Response.ClearContent();
            Response.Buffer = true;
            Response.AddHeader("content-disposition",               string.Format("attachment;
filename={0}", "EPIs.xls"));
            Response.ContentType = "application/ms-excel";
            StringWriter sw = new StringWriter();
            HtmlTextWriter htw = new HtmlTextWriter(sw);
            GridView1.AllowPaging = false;
            //Change the Header Row back to white color
            GridView1.HeaderRow.Style.Add("background-color", "#FFFFFF");
            //Applying stlye to gridview header cells
            for (int i = 0; i < GridView1.HeaderRow.Cells.Count; i++)
            {
                GridView1.HeaderRow.Cells[i].Style.Add("background-color", "#507CD1");
            }
            int j = 1;
            //Set alternate row color
            foreach (GridViewRow gvrow in GridView1.Rows)
            {
                gvrow.BackColor = System.Drawing.Color.White;
                if (j <= GridView1.Rows.Count)
                {
                    if (j % 2 != 0)
                    {
                        for (int k = 0; k < gvrow.Cells.Count; k++)
                        {
                          gvrow.Cells[k].Style.Add("background-color", "#EFF3FB");
                        }
                    }
                }
                j++;
            }
            GridView1.RenderControl(htw);
            Response.Write(sw.ToString());
            Response.End();
        }
        public override void VerifyRenderingInServerForm(Control control)
        {
            /* Verifies that the control is rendered */
        }
    }
}
```

SaveInstance page:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;

namespace WCF_EPI
{
    public partial class saveInstance : System.Web.UI.Page
    {
        private DBLayerLibrary.DBDataContext db = new DBLayerLibrary.DBDataContext();
        protected void Page_Load(object sender, EventArgs e)
        {          ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text
=                                        "Save                                                  EPI";
((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].NavigateUrl          =
this.ResolveClientUrl("~/saveInstance.aspx");
            if (Session["calcResult"] == null)
            {
                Server.Transfer("GetEPIGH.aspx");
                return;
            }
            if (!IsPostBack)
            {
                TextBoxResult.Text = Session["calcResult"].ToString();
            }
        }
```

```
        protected void Button1_Click(object sender, EventArgs e)
        {
            //LinqDataSource1.DataBind();
            var OrganizationID = from q in db.UserCompanies
                                 where q.UserId == (Guid)Session["userID"]
                                 select q.OrganizationID;
            if (DropDownListprivacyType.SelectedValue == "organization")
                ObjectDataSourceInsert.InsertParameters["privacyData"].DefaultValue          =
OrganizationID.First().ToString();
            else if (DropDownListprivacyType.SelectedValue == "private")
                ObjectDataSourceInsert.InsertParameters["privacyData"].DefaultValue          =
Session["userID"].ToString();
            ObjectDataSourceInsert.InsertParameters["ObtainTime"].DefaultValue               =
DateTime.Now.Date.ToString();
            ObjectDataSourceInsert.InsertParameters["EPIRank"].DefaultValue                  =
RadioButtonList1.SelectedItem.Value;
            try
            {ObjectDataSourceInsert.Insert();
                var     maxValue     =     db.InstanceStatements.Max(x     =>     x.InstanceId);
ObjectDataSourceInsertDataSource.InsertParameters["EpiInstanceID"].DefaultValue              =
(Convert.ToInt32(maxValue)).ToString();
                ObjectDataSourceInsertDataSource.Insert();
                //ObjectDataSourceOrga.Select();
                LabelSaving.Text = "Data saved successfully";
                Button1.Enabled = false;
            }
            catch (Exception ex)
            {
                LabelSaving.Text = "Error! " + ex.Message;
            }         }     } }
```

Get EPI-List page:

```
using System;
using System.Reflection;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;
using System.Web.Security;
using DBLayerLibrary;
using System.Configuration;
using System.Diagnostics;
using System.Collections;

namespace WCF_EPI
{
    public partial class GetEPIGH : System.Web.UI.Page
    {
        DBLayer                          db                          =                          new
DBLayer(ConfigurationManager.ConnectionStrings["LWCEPI"].ConnectionString);
        protected void Page_Load(object sender, EventArgs e)
        {
((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text    =    "Calculate
EPIs";
   ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].NavigateUrl       =
this.ResolveClientUrl("~/GetEPIGH.aspx");
            if (!IsPostBack)
            {
                try
                {
              Session["list"] = null;
              Guid userID = (Guid)Membership.GetUser().ProviderUserKey;//get userID
                    Session["userID"] = userID;//store it to weiter usage
                    db.openConnection();
                    TextBoxHost.Text = db.GetHostAddress(userID);
                    db.closeConnection();
                }
                catch
                {
                    Response.Redirect("~/Default.aspx");
                }
            }
        }
        protected void Button1_Click1(object sender, EventArgs e)
        {
            //DropDownListEPIs.DataSourceID = string.Empty;
```

```
            //change the data source
            //DropDownListEPIs.DataSource = ObjectDataSourceEPI_All;
            RadioButtonListEpi.DataSourceID = string.Empty;
            RadioButtonListEpi.DataSource = ObjectDataSourceEPI_All;
            RadioButtonListEpi.DataBind();
            //DropDownListEPIs.DataBind();
            CheckBoxListEpi.DataSourceID = string.Empty;
            CheckBoxListEpi.DataSource = ObjectDataSourceEPI_All;
            CheckBoxListEpi.DataBind();
        }
        protected void Buttoncalc_Click(object sender, EventArgs e)
        {
            int epiID;
            if (int.TryParse(RadioButtonListEpi.SelectedValue, out epiID))
                Session["EpiID"] = epiID;
            else
            {
                LabelTest.Text = "error! Please select an EPI!";
                return;
            }
            string EPI = RadioButtonListEpi.SelectedItem.Text;
            if (EPI == "Electricity")
            {
                double result;
                //Session["EpiID"] = int.Parse(RadioButtonListEpi.SelectedValue);
                if (RadioButtonDataSource.Checked)//data source
                {
                    Session["source"] = TextBoxHost.Text;
                    double billValue = 0; //Data1
                    string userElecProvider = string.Empty; //Data2
                    try
                    {
                        using    (EnterpriseServiceRefn.ServiceE1Client    sClient    =    new
EnterpriseServiceRefn.ServiceE1Client("BasicHttpBinding_IServiceE1", TextBoxHost.Text))
                        {
                            userElecProvider = sClient.get_ElecCompany();
                            billValue = double.Parse(sClient.get_ElecBillValue());
                        }
                    }
                    catch
                    {
                        LabelTest.Text = "Error! Your data source is not correct or does not
provide required EPI functionality";
                        return;
                    }
                    //external data
                    ElectricityServiceRefNew.KWPrices            kw            =            new
ElectricityServiceRefNew.KWPrices();
                    using    (ElectricityServiceRefNew.ElecServiceClient    eClient    =    new
ElectricityServiceRefNew.ElecServiceClient())
                    {
                        kw = eClient.get_KWPrices(userElecProvider);
                    }
    //transformation required:(hier, divide the data into 2 categories)
    //we already know the EPI-Equation
                    result = billValue / kw.Price1;
                    if (result > kw.KWTo1)
                        result = billValue / kw.Price2;
                }
                else //if(RadioButtonInputDirect.Checked)
                {
                    Session["source"] = "User Input";
                    double in1;
                    if (!double.TryParse(TextBoxIn1.Text, out in1))
                    {
                        TextBoxResult.Text = "invalid input!";
                        return;
                    }
                    string providerName = TextBoxIn2.Text;
                    if (string.IsNullOrEmpty(providerName))
                    {
                        LabelTest.Text = "Error! Please enter the name of your Electricity-
Provider";
                        return;
                    }
                    ElectricityServiceRefNew.KWPrices            kw            =            new
ElectricityServiceRefNew.KWPrices();
                    using    (ElectricityServiceRefNew.ElecServiceClient    eClient    =    new
```

```
ElectricityServiceRefNew.ElecServiceClient())
                    {
                        kw = eClient.get_KWPrices(TextBoxIn2.Text);//default!!!
                    }
                    //transformation  ..as above..
                    if (kw.Price1 == 0)
                    {
                        LabelTest.Text  =  "Error!  "  +  "Your  Electricity  provider  is  not
supported.";
                        return;
                    }
                    result = in1 / kw.Price1;
                    if (result > kw.KWTo1)
                        result = in1 / kw.Price2;
                }
                TextBoxResult.Text = result.ToString();
                Session["calcResult"] = result;
            }
            else//not Electricity..Do something Dynamic
            {
                db.openConnection();
                string Equation_ = db.GetEquation(epiID);
                string reference_ = db.GetRefDocument(epiID);
                string InputMatName_ = db.Get_InputMaterial_Name(epiID);
                string InputMatUnit_ = db.Get_InputMaterial_Unit(epiID);
                string OutputMatName_ = db.Get_OutputMaterial_Name(epiID);
                string OutputMatUnit_ = db.Get_OutputMaterial_Unit(epiID);
                db.closeConnection();
                string SomeInput_ = string.Empty; //!!!
        //get input for the Equation..1-from datasource or directly
                if (RadioButtonDataSource.Checked)
                {
                    Session["source"] = TextBoxHost.Text;
                    try
                    {
                        using    (EnterpriseServiceRefn.ServiceE1Client    sClient    =    new
EnterpriseServiceRefn.ServiceE1Client("BasicHttpBinding_IServiceE1", TextBoxHost.Text))
                        {
                            SomeInput_ = sClient.getDataOfmaterial(InputMatName_);
                        }
                    }
                    catch (Exception eee)
                    {
                        LabelTest.Text = "Error! Your data source is not correct or does not
provide required EPI functionality. " + eee.Message;
                        return;
                    }
                }
                else //if (RadioButtonInputDirect.Checked)
                {
                    ;//read from interface
                    Session["source"] = "User Input";
                    SomeInput_ = TextBoxIn1.Text;
                }
                // try to run java (elcd or A++):
                try
                {
                  //string javaFilePath = GetJavaFilePath();
                 string javaFilePath = @"C:\Program Files\Java\jre7\bin\java.exe";
                    ProcessStartInfo processInfo;
                    if (reference_ != "") //i.e. ELCD
                    {
                        processInfo     =     new     ProcessStartInfo(javaFilePath,     "-jar
calculateELCD.jar  "  +  reference_  +  "  "  +  InputMatName_  +  "  "  +  OutputMatName_  +  "  "  +
SomeInput_ + " " + InputMatUnit_ + " " + OutputMatUnit_)
                        //Referenz, Input, Output, Anzahl, InputUnit, OutputUnit
                        {
                            CreateNoWindow = true,
                            UseShellExecute = false,
                            RedirectStandardOutput = true,
                            //Arguments= parametrs,
                            WorkingDirectory = "C:\\ELCD"
                        };
                    }
                    else
                    {
                        processInfo = new ProcessStartInfo(javaFilePath, "-jar calculateEq.jar
\"" + Equation  + "\" " + SomeInput )
```

```
                        //Formel, Anzahl
                        {
                            CreateNoWindow = true,
                            UseShellExecute = false,
                            RedirectStandardOutput = true,
                            WorkingDirectory = "C:\\ELCD"
                        };
                    }
                    Process rProcess = Process.Start(processInfo);
                    string output = rProcess.StandardOutput.ReadToEnd();
                    rProcess.WaitForExit();
                    TextBoxResult.Text = output;
                    Session["calcResult"] = output;
                }
                catch (Exception ex)
                {
           LabelTest.Text = "Error communicating with ELCD Database:" + ex.Message;
                    return;
                }
            }
        }
        protected void ButtonShowDesc_Click(object sender, EventArgs e)
        {
            int EPIID = int.Parse(RadioButtonListEpi.SelectedValue);
            db.openConnection();
            string reference_ = db.GetRefDocument(EPIID);
            db.closeConnection();
            if (!string.IsNullOrEmpty(reference_))
            {
                try
                {
                    //javaFilePath
                    string javaFilePath = @"C:\Program Files\Java\jre7\bin\java.exe";
                    ProcessStartInfo processInfo = new ProcessStartInfo(javaFilePath, "-jar
getDescription.jar \"" + reference_)
                    {
                        CreateNoWindow = true,
                        UseShellExecute = false,
                        RedirectStandardOutput = true,
                        //Arguments= parametrs,
                        WorkingDirectory = "C:\\ELCD"
                    };
                    Process rProcess = Process.Start(processInfo);
                    string output = rProcess.StandardOutput.ReadToEnd();
                    rProcess.WaitForExit();
                    LabelDesc.Text = output;
                }
                catch (Exception ex)
                {
           LabelDesc.Text = "Error communicating with ELCD Database:" + ex.Message;
                }
            }
        }
        protected void RadioButtonListEpi_SelectedIndexChanged(object sender, EventArgs e)
        {
            //db.openConnection();
            LabelDesc.Text= db.GetDescription(int.Parse( RadioButtonListEpi.SelectedValue));
            //db.closeConnection();
        }
        protected void RadioButtonListEpi_DataBound(object sender, EventArgs e)
        {
            RadioButtonListEpi.SelectedIndex = 0;
        }
    protected void RadioButtonDataSource_CheckedChanged(object sender, EventArgs e)
        {
            if (RadioButtonDataSource.Checked)
            {
                TextBoxHost.Visible = true;
                LabelSource.Visible = true;
                Table1.Visible = false;
            }
            else
            {
                TextBoxHost.Visible = false;
                LabelSource.Visible = false;
            }
        }
        protected void RadioButtonInputDirect CheckedChanged(object sender, EventArgs e)
```

```
        {
            if (RadioButtonInputDirect.Checked)
            {
                Table1.Visible = true;
                TextBoxHost.Visible = false;
                LabelSource.Visible = false;
            }
            else
            {
                Table1.Visible = false;
            }
        }
        private string GetJavaFilePath()
        {
            //check environment... if not works-> check registery
            string filePath;
            try
            {
                string environmentPath = Environment.GetEnvironmentVariable("JAVA_HOME");
                if (!string.IsNullOrEmpty(environmentPath))
                {
                    filePath = System.IO.Path.Combine(environmentPath, "bin\\Java.exe");
                    return filePath;
                }
                //regedit:
                string     javaKey     =     "SOFTWARE\\Wow6432Node\\JavaSoft\\Java     Runtime
Environment\\";
                bool env = Environment.Is64BitOperatingSystem;
                Microsoft.Win32.RegistryKey rk;
                if (env)
                    rk                                                                    =
Microsoft.Win32.RegistryKey.OpenBaseKey(Microsoft.Win32.RegistryHive.LocalMachine,
Microsoft.Win32.RegistryView.Registry64);// .LocalMachine.OpenSubKey(javaKey))
                else
                    rk                                                                    =
Microsoft.Win32.RegistryKey.OpenBaseKey(Microsoft.Win32.RegistryHive.LocalMachine,
Microsoft.Win32.RegistryView.Registry32);// .LocalMachine.OpenSubKey(javaKey))
                rk.OpenSubKey(javaKey);
                string currentVersion = rk.GetValue("CurrentVersion").ToString();
                javaKey += currentVersion + "\\";
                Microsoft.Win32.RegistryKey rk2 = rk.OpenSubKey(javaKey);
                filePath     =     System.IO.Path.Combine(rk2.GetValue("JavaHome").ToString(),
"bin\\Java.exe");
                return filePath;
            }
            catch
            {
                throw new Exception("Java Error! Jave is not detected!");
            }
        }

        protected void Button2_Click(object sender, EventArgs e)
        {
            ArrayList EPIs = new ArrayList();
            foreach (ListItem i in CheckBoxListEpi.Items)
            {
                if (i.Selected)
                {
                    EPIs.Add(i.Value);
                }
            }
            if(EPIs.Capacity == 0)
                LabelTest.Text = "error! Please select an EPI!";
            else
            {
            Session["list"] = EPIs;
            Server.Transfer("InstanceEPIs.aspx");
            }
        }
    }
}
```

ECET-Result page:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
```

```
using System.Web.UI.WebControls;
using System.Web.Security;
using System.Web.UI.DataVisualization.Charting;
using System.Drawing;

namespace WCF_EPI
{
    public partial class EMSI_result : System.Web.UI.Page
    {
        private DBLayerLibrary.DBDataContext db = new DBLayerLibrary.DBDataContext();
        private static Guid g;
        protected void Page_Load(object sender, EventArgs e)
        {
            //check if user not login
            if (Membership.GetUser() == null)
            {
                Label1.Text = "Not login";
                return;
            }
            ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text     =
"Assessment Result";

((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].NavigateUrl          =
this.ResolveClientUrl("~/ECET_result.aspx");

            if (!IsPostBack)
            {
                //get user ID and organization ID
                Guid userID = (Guid)Membership.GetUser().ProviderUserKey;//get userID
                var organizationID = from q in db.UserCompanies
                                     where q.UserId == userID
                                     select q.OrganizationID;
                g = organizationID.First().Value;



                // select all the available ECET answers for the logged-in user
                var x = db.ECET_answers.Where(row => row.OrganizationID == g).Select(row =>
row.answer_date).Distinct();

                // fill the dropdown list with ECET answers' date
                foreach (DateTime d in x)
                {
                    DropDownList1.Items.Add(new                          ListItem(d.ToString(),
d.ToBinary().ToString()));
                }
                //show the first result
                string message = DisplaySelectedResult(g, x.First().ToBinary().ToString());
                Label2.Text = message;

            }
        }

        protected void DropDownList1_SelectedIndexChanged(object sender, EventArgs e)
        {

            Label2.Text = DisplaySelectedResult(g, DropDownList1.SelectedValue);
        }
        private string DisplaySelectedResult(Guid g, string d)
        {
            DateTime date = new DateTime(long.Parse(d));

            //get answer count and sum for each block
            var results = from q in db.ECET_answers
                          where q.OrganizationID == g && date == q.answer_date

                          group q by q.BlockID into w
                          select new
                          {
                              count = w.Count(),
                              sum = w.Sum(item => item.answer),
                              block = w.Key
                          };
            var answers = from q in db.ECET_answers
                          where q.OrganizationID == g && date == q.answer_date
                          select new { q.answer, q.BlockID, q.QuestionID };

            int[] yValues = new int[4]; // Here y values is related to display three month
```

```
values

            foreach (var i in results)
            {
                //covert to 100% (normalize)
                yValues[i.block - 1] = (100 * i.sum.Value) / (i.count * 4);
            }

            string[] xValues = { "Block one", "Block two", "Block three", "Block four" };
            Chart1.ChartAreas[0].AxisY.Maximum = 100;
            Chart1.Series["Series1"].Points.DataBindXY(xValues, yValues);
            Chart2.ChartAreas[0].AxisY.Maximum = 100;

            //            Chart1.Palette = ChartColorPalette.None;
            //              Chart1.PaletteCustomColors = new Color[] { Color.Red, Color.Blue,
Color.Yellow };

            Chart2.Series["Series1"].Points.DataBindXY(xValues, yValues);
            string    Name    =    db.Organizations.First(row    =>    row.OrganizationID    ==
g).OrganizationName;
            #region massage
            string result = "";
            //block1
            if (yValues[0] < 40)
            {
                result  +=  "current  environmental  performance  of  "  +  Name  +  "  is  below
average";
            }
            else if (yValues[0] < 70)
            {
                result += Name + "has an average environmental performance.";
            }
            else
            {
                result += "Currently, " + Name + " is preforming good from an environmental
perspective.";
            }
            result += "<br />";
            //block2
            if (yValues[1] < 40)
            {
                result += Name + "'s environmental maturity level is below average.";
            }
            else if (yValues[1] < 70)
            {
                result += Name + " has an average environmental maturity level.";
            }
            else
            {
                result += Name + " is environmentally mature, and ready to start communicating
its performance indicators.";
            }
            result += "<br />";

            //block3
            if (yValues[2] < 40)
            {
                result += Name + " lacks the required technological experience to successfully
use an Environmental Management Information System.";
            }
            else if (yValues[2] < 70)
            {
                result += Name + " has an average technological experience.";
            }
            else
            {
                result  +=  Name  +  "  has  a  good  technological  experience,  and  ready  to
successfully use an Environmental Management Information System.";
            }
            result += "<br />";
            int   xx   =   answers.First(row   =>   row.BlockID   ==   1   &&   row.QuestionID   ==
1).answer.Value;
            int acceptable = 2;
            if (answers.First(row => row.BlockID == 1 && row.QuestionID == 4).answer.Value <
acceptable ||
                answers.First(row => row.BlockID == 3 && row.QuestionID == 8).answer.Value <
acceptable)
                result += "Since " + Name + " lacks the required experience or the knowledge
```

```
to generate good sustainable reports, the LWC-EPI will guide you to start building your report
step by step. For this, the LWC-EPI team recommend you to";

            if (answers.First(row => row.BlockID == 1 && row.QuestionID == 1).answer.Value <
acceptable)
                result += " make sure that your data is saved and provided wen it is needed.";
            if (answers.First(row => row.BlockID == 1 && row.QuestionID == 2).answer.Value <
acceptable)
                result += " improve the data quality provided by your data provider (system or
human).";

            if (answers.First(row => row.BlockID == 1 && row.QuestionID == 5).answer.Value <
acceptable ||
    answers.First(row => row.BlockID == 3 && row.QuestionID == 1).answer.Value < acceptable ||
    answers.First(row => row.BlockID == 3 && row.QuestionID == 2).answer.Value < acceptable ||
    answers.First(row => row.BlockID == 3 && row.QuestionID == 3).answer.Value < acceptable ||
    answers.First(row => row.BlockID == 3 && row.QuestionID == 5).answer.Value < acceptable)
                result += "If it is possible, try to recruit environmental experts in your
team. Otherwise, please try to inform yourself more about the current environmental standards,
laws, and technologies by visiting the recommended pages mentioned on our homepage. In
addition, the LWC-EPI portal supports you with important hints using the tooltip technology.";

            result += "<br />";
            result += "\r\n Follow visit the recommended pages which you can find on the
“About” page.";
            #endregion
            return result;
        }
    }
}
```

ECET questionnaire page:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;
using System.Web.Security;

namespace WCF_EPI
{
    public partial class EMSI : System.Web.UI.Page
    {
        private DBLayerLibrary.DBDataContext db = new DBLayerLibrary.DBDataContext();
        protected void Page_Load(object sender, EventArgs e)
        {
            ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text     =
"Assessment Questionnaire";

((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].NavigateUrl          =
this.ResolveClientUrl("~/ECET.aspx");
            Guid g;
            if (Membership.GetUser() == null)
            {
                Label1.Text = "Not login";
                return;
            }
            else
            {
              Guid userID = (Guid)Membership.GetUser().ProviderUserKey;//get userID
                var organizationID = from q in db.UserCompanies
                                     where q.UserId == userID
                                     select q.OrganizationID;
                g = organizationID.First().Value;
                DBLayerLibrary.Organization o = db.Organizations.First(p => p.OrganizationID
== g);
                // if user have made the survey
                if (o.Survey == true)
                {
                    Label1.Text = "Already done";
                    HyperLink1.Visible = true;
                    LinkButton1.Visible = true;
                    DropDownList1.Visible = true;
                    var x = db.ECET_answers.Where(row => row.OrganizationID == g).Select(row
=> row.answer_date).Distinct();
                    foreach (DateTime d in x)
                    {
```

```
                        DropDownList1.Items.Add(new                         ListItem(d.ToString(),
d.ToBinary().ToString()));
                    }
                }
            }
            #region block1 question
            {               //get the first block questions
                var questions = from q in db.ECET_block1s
                                select q.QuestionText;

                //array of labels and radio button Lists
                Label[] l = new Label[questions.Count()];
                RadioButtonList[] r = new RadioButtonList[questions.Count()];
                //for (int i = 0; i < v.Count(); i++)
                int counter = 0;
                foreach (var i in questions)
                {
             //define question label
                    l[counter] = new Label();
                    l[counter].Text = i.ToString();
             //define the answer radio button
                    r[counter] = new RadioButtonList();
                    r[counter].RepeatDirection = RepeatDirection.Horizontal;
                    r[counter].ID = "RadioButtonList1" + counter;
                    r[counter].Items.Add("Very weak");
                    r[counter].Items.Add("Weak");
                    r[counter].Items.Add("Acceptable");
                    r[counter].Items.Add("Good");
                    r[counter].Items.Add("Excellent");
                    r[counter].SelectedIndex = 2;
                 l[counter].AssociatedControlID = r[counter].ID;
             //add the question & radion button to the panel
                    EMSIPanel.Controls.Add(l[counter]);
                    EMSIPanel.Controls.Add(new LiteralControl("<BR>"));
                    EMSIPanel.Controls.Add(r[counter]);
                    EMSIPanel.Controls.Add(new LiteralControl("<BR>"));
                    counter++;
                }
            }
            #endregion
            #region block2 question
            {
                //get the first block questions
                var questions = from q in db.ECET_block2s
                                select q.QuestionText;
                //array of labels and radio button Lists
                Label[] l = new Label[questions.Count()];
                RadioButtonList[] r = new RadioButtonList[questions.Count()];
                //for (int i = 0; i < v.Count(); i++)
                int counter = 0;
                foreach (var i in questions)
                {
                    //define question label
                    l[counter] = new Label();
                    l[counter].Text = i.ToString();
                    //define the answer radio button
                    r[counter] = new RadioButtonList();
                    r[counter].RepeatDirection = RepeatDirection.Horizontal;
                    r[counter].ID = "RadioButtonList2" + counter;
                    r[counter].Items.Add("Very weak");
                    r[counter].Items.Add("Weak");
                    r[counter].Items.Add("Acceptable");
                    r[counter].Items.Add("Good");
                    r[counter].Items.Add("Excellent");
                    r[counter].SelectedIndex = 2;
                    l[counter].AssociatedControlID = r[counter].ID;
                    //add the question & radion button to the panel
                    EMSIPanel.Controls.Add(l[counter]);
                    EMSIPanel.Controls.Add(new LiteralControl("<BR>"));
                    EMSIPanel.Controls.Add(r[counter]);
                    EMSIPanel.Controls.Add(new LiteralControl("<BR>"));
                    counter++;
                }
            }
            #endregion
            #region block3 question
            {
        //get the first block questions
```

```
            var questions = from q in db.ECET_block3s
                            select q.QuestionText;
        //array of labels and radio button Lists
            Label[] l = new Label[questions.Count()];
            RadioButtonList[] r = new RadioButtonList[questions.Count()];
        //for (int i = 0; i < v.Count(); i++)
            int counter = 0;
            foreach (var i in questions)
            {
         //define question label
                l[counter] = new Label();
                l[counter].Text = i.ToString();
         //define the answer radio button
                r[counter] = new RadioButtonList();
                r[counter].RepeatDirection = RepeatDirection.Horizontal;
                r[counter].ID = "RadioButtonList3" + counter;
                r[counter].Items.Add("Very weak");
                r[counter].Items.Add("Weak");
                r[counter].Items.Add("Acceptable");
                r[counter].Items.Add("Good");
                r[counter].Items.Add("Excellent");
                r[counter].SelectedIndex = 2;
                l[counter].AssociatedControlID = r[counter].ID;
                //add the question & radion button to the panel
                EMSIPanel.Controls.Add(l[counter]);
                EMSIPanel.Controls.Add(new LiteralControl("<BR>"));
                EMSIPanel.Controls.Add(r[counter]);
                EMSIPanel.Controls.Add(new LiteralControl("<BR>"));
                counter++;
            }
        }
        #endregion
        #region block4 question
        {
            //get the first block questions
            var questions = from q in db.ECET_block4s
                            select q.QuestionText;
            //array of labels and radio button Lists
            Label[] l = new Label[questions.Count()];
            RadioButtonList[] r = new RadioButtonList[questions.Count()];
        //for (int i = 0; i < v.Count(); i++)
            int counter = 0;
            foreach (var i in questions)
            {
       //define question label
                l[counter] = new Label();
                l[counter].Text = i.ToString();
         //define the answer radio button
                r[counter] = new RadioButtonList();
                r[counter].RepeatDirection = RepeatDirection.Horizontal;
                r[counter].ID = "RadioButtonList4" + counter;
                r[counter].Items.Add("Very weak");
                r[counter].Items.Add("Weak");
                r[counter].Items.Add("Acceptable");
                r[counter].Items.Add("Good");
                r[counter].Items.Add("Excellent");
                r[counter].SelectedIndex = 2;
             l[counter].AssociatedControlID = r[counter].ID;
         //add the question & radion button to the panel
                EMSIPanel.Controls.Add(l[counter]);
                EMSIPanel.Controls.Add(new LiteralControl("<BR>"));
                EMSIPanel.Controls.Add(r[counter]);
                EMSIPanel.Controls.Add(new LiteralControl("<BR>"));
                counter++;
            }
        }
        #endregion
    }
    private void DeleteOld(Guid g,DateTime Date)
    {
        var deletedAnswers =
            from q in db.ECET_answers
            where q.OrganizationID == g
            && q.answer_date == Date
            select q;
        foreach (var delete in deletedAnswers)
        {
            db.ECET answers.DeleteOnSubmit(delete);
```

```
            }
            db.SubmitChanges();
        }
        private void Submit(Guid g)
        {
            DateTime now = DateTime.Now;
            DBLayerLibrary.ECET_answer answer;
            #region block1 answers
            {
                var count = db.ECET_block1s.Count();
                for (int i = 0; i < count; i++)
                {
                    answer = new DBLayerLibrary.ECET_answer();
                    answer.OrganizationID = g;
                    answer.QuestionID = i + 1;
                    answer.BlockID = 1;
                    answer.answer_date = now;
                    answer.answer = ((RadioButtonList)EMSIPanel.FindControl("RadioButtonList1"
+ i)).SelectedIndex;
                    db.ECET_answers.InsertOnSubmit(answer);
            }    }
            #endregion
            #region block2 answers
            {
               var count = db.ECET_block2s.Count();
                for (int i = 0; i < count; i++)
                {
                    answer = new DBLayerLibrary.ECET_answer();
                    answer.OrganizationID = g;
                    answer.QuestionID = i + 1;
                    answer.BlockID = 2;
                    answer.answer_date = now;
                    answer.answer = ((RadioButtonList)EMSIPanel.FindControl("RadioButtonList2"
+ i)).SelectedIndex;
                    db.ECET_answers.InsertOnSubmit(answer);
                }
            }
            #endregion
            #region block3 answers
            {
                var count = db.ECET_block3s.Count();
                for (int i = 0; i < count; i++)
                {
                    answer = new DBLayerLibrary.ECET_answer();
                    answer.OrganizationID = g;
                    answer.QuestionID = i + 1;
                    answer.BlockID = 3;
                    answer.answer_date = now;
                    answer.answer = ((RadioButtonList)EMSIPanel.FindControl("RadioButtonList3"
+ i)).SelectedIndex;
                    db.ECET_answers.InsertOnSubmit(answer);
                }
            }
            #endregion
            #region block4 answers
            {
                var count = db.ECET_block4s.Count();
                for (int i = 0; i < count; i++)
                {
                    answer = new DBLayerLibrary.ECET_answer();
                    answer.OrganizationID = g;
                    answer.QuestionID = i + 1;
                    answer.BlockID = 4;
                    answer.answer_date = now;
                    answer.answer = ((RadioButtonList)EMSIPanel.FindControl("RadioButtonList4"
+ i)).SelectedIndex;
                    db.ECET_answers.InsertOnSubmit(answer);
                }
            }
            #endregion
            db.SubmitChanges();
       }
       protected void Button1_Click(object sender, EventArgs e)
        {
            if (Membership.GetUser() == null)
            {
                Label1.Text = "Not login";
                return;
```

```
            }
            else
            {
                Guid orgainzation_guid;
             Guid userID = (Guid)Membership.GetUser().ProviderUserKey;//get userID
                var organizationID = from q in db.UserCompanies
                                     where q.UserId == userID
                                     select q.OrganizationID;
                orgainzation_guid = organizationID.First().Value;
                DBLayerLibrary.Organization o = db.Organizations.First(p => p.OrganizationID
== orgainzation_guid);
                // if user have made the survey
                if (o.Survey == true)
                {
                    Label1.Text = "Already done";
                    HyperLink1.Visible = true;
                    DropDownList1.Visible = true;

                    LinkButton1.Visible = true;
                    return;
                }
                Submit(orgainzation_guid);
                //make survey true
                o.Survey = true;
                db.SubmitChanges();
            }
            Server.Transfer("ECET_result.aspx");
        }
        protected void LinkButton1_Click(object sender, EventArgs e)
        {
            //select the date of replacement
            Guid userID = (Guid)Membership.GetUser().ProviderUserKey;//get userID
            var organizationID = from q in db.UserCompanies
                                 where q.UserId == userID
                                 select q.OrganizationID;
            Guid g = organizationID.First().Value;
            var Date =
                from q in db.ECET_answers
                where q.OrganizationID == g
                select q.answer_date;

            DateTime date = new DateTime(long.Parse(DropDownList1.SelectedValue));
            DeleteOld(g,date);
            Submit(g);
            Server.Transfer("ECET_result.aspx");
        }
        protected void SaveLink_Click(object sender, EventArgs e)
        {
                Guid orgainzation_guid;
             Guid userID = (Guid)Membership.GetUser().ProviderUserKey;//get userID
                var organizationID = from q in db.UserCompanies
                                     where q.UserId == userID
                                     select q.OrganizationID;
                orgainzation_guid = organizationID.First().Value;
                DBLayerLibrary.Organization o = db.Organizations.First(p => p.OrganizationID
== orgainzation_guid);
                // if user have made the survey
                Submit(orgainzation_guid);
                //make survey true

                //db.SubmitChanges();
             Server.Transfer("ECET_result.aspx");
        }
    }
}
```

User registeration Page:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;
using System.Web.Security;
using System.Configuration;
using System.Data.SqlClient;
```

```
using DBLayerLibrary;
using System.Collections;
namespace WCF_EPI
{
    public partial class WebForm1 : System.Web.UI.Page
    {
        private DBLayerLibrary.DBDataContext db = new DBLayerLibrary.DBDataContext();
        //private static ArrayList units ;
        protected void Page_Load(object sender, EventArgs e)
        {          ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text
=                                                                                    "Registeration";
//((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].NavigateUrl        =
this.ResolveClientUrl("~/Account/Register.aspx");
            if (Session["units"] == null)
                Session["units"] = new ArrayList();
            if  (CreateUserWizard1.ActiveStep.ID  ==  "OrganizationStep")  //first  registration
step
            {
                if (!IsPostBack)
                {
                    //fill the drop down list with companies names
                    var companyName = from q in db.Organizations
                                      select q.OrganizationName;

                    DropDownList                                d                                =
((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList"));

((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList")).DataSourc
e = companyName;

((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList")).DataBind(
);
                    d.Items.Insert(0, new ListItem("Add new organizaton", "0"));
                }
            }
        }

        protected void CreateUserWizard1_CreatedUser(object sender, EventArgs e)
        {
            DBLayerLibrary.Organization o = new DBLayerLibrary.Organization();
            DBLayerLibrary.Unit u = new DBLayerLibrary.Unit();

            if
(((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList")).Selected
Index == 0)
            {
                o.OrganizationID = Guid.NewGuid();
                o.OrganizationName                                                               =
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("CompanyName")).Text.Trim();
                o.BusinessField                                                                  =
((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("Field")).SelectedValue.T
rim();
                o.Country                                                                        =
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("Country")).Text.Trim();
                o.City                                                                           =
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("City")).Text.Trim();
                o.Zip                                                                            =
Convert.ToInt32(((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("Zip")).Text.T
rim());
                o.Street                                                                         =
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("Street")).Text.Trim();
                o.EmployeeNr                                                                     =
Convert.ToInt32(((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("EmployeeNr"))
.Text.Trim());
                o.Survey = false;

                //Insert the new object
                db.Organizations.InsertOnSubmit(o);

                //Sumbit changes to the database
                db.SubmitChanges();
            }
            else
            {
                var OrganizationID = from q in db.Organizations
                                     where                 q.OrganizationName                ==
((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList")).SelectedI
tem.Text
```

```
                                    select q.OrganizationID;
                o.OrganizationID = OrganizationID.First();
            }
            bool NewUnit = false;
            //INSERT UNIT
            if
(((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitList")).SelectedIndex == 0)
            {
                NewUnit = true;
if(((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitName")).Text.Trim() != "")
                {
                u.UnitID = Guid.NewGuid();
                u.UnitName                                                                  =
((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitName")).Text.Trim();
                u.UnitDescription                                                           =
((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitDescription")).Text.Trim();
                u.UnitType                                                                  =
((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitTypeDropdownlist")).Selected
Value.Trim();
                u.OrganizationID = o.OrganizationID;

                //Insert the new object
                db.Units.InsertOnSubmit(u);
                }
                foreach (Unit unit in ((ArrayList)Session["units"]))
                {
                    u = new DBLayerLibrary.Unit();
                    u.UnitID = Guid.NewGuid();
                    u.UnitName = unit.Name;
                    u.UnitDescription = unit.Desc;
                    if (unit.t == type.Physical)
                        u.UnitType = "Physical";
                    else
                        u.UnitType = "Organizational";
                    u.OrganizationID = o.OrganizationID;
                    db.Units.InsertOnSubmit(u);
                }
           //Sumbit changes to the database
                db.SubmitChanges();
            }
            else
            {
                var UnitID = from q in db.Units
                             where                          q.UnitName                      ==
((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitList")).SelectedItem.Text
                             select q.UnitID;
                u.UnitID = UnitID.First();
            }
            // Get the UserId of the just-added user
            MembershipUser newUser = Membership.GetUser(CreateUserWizard1.UserName);
            Guid newUserId = (Guid)newUser.ProviderUserKey;
            //Get Profile Data Entered by user in CUW control
            String                                  HostAddress                             =
((TextBox)CreateUserWizardStep1.ContentTemplateContainer.FindControl("HostAddress")).Text.Trim
();
            UserCompany user = new UserCompany();
            user.UserId = newUserId;
            user.HostAddress = HostAddress;
            user.OrganizationID = o.OrganizationID;
            if (!NewUnit)
                user.UnitID = u.UnitID;
            else
            {
                user.UnitID = db.Units.Single(row => row.OrganizationID == o.OrganizationID &&
row.UnitName                                                                                ==
((DropDownList)CreateUserWizardStep1.ContentTemplateContainer.FindControl("DropDownList1")).Se
lectedValue).UnitID;
            }
            db.UserCompanies.InsertOnSubmit(user);
       //Sumbit changes to the database
            db.SubmitChanges();
        }
        protected void register()
        {
            // DBDataContext db = new DBDataContext();
            Organization o = new Organization();
            o.OrganizationID = Guid.NewGuid();
            o.OrganizationName                                                              =
```

```
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("CompanyName")).Text.Trim();
            o.BusinessField                                                                 =
((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("Field")).SelectedValue.T
rim();
            o.Country                                                                       =
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("Country")).Text.Trim();
            o.City                                                                          =
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("City")).Text.Trim();
            o.Zip                                                                           =
Convert.ToInt32(((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("Zip")).Text.T
rim());
            o.Street                                                                        =
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("Street")).Text.Trim();
            o.EmployeeNr                                                                    =
Convert.ToInt32(((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("EmployeeNr"))
.Text.Trim());

       //Insert the new object
            db.Organizations.InsertOnSubmit(o);
      //Sumbit changes to the database
            db.SubmitChanges();
            DBLayerLibrary.Unit u = new DBLayerLibrary.Unit();
            u.UnitID = Guid.NewGuid();
            u.UnitName                                                                      =
((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitName")).Text.Trim();
            u.UnitDescription                                                               =
((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitDescription")).Text.Trim();
            u.UnitType                                                                      =
((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitType")).SelectedValue.Trim()
;
            //Insert the new object
            db.Units.InsertOnSubmit(u);
            //Sumbit changes to the database
            db.SubmitChanges();
        }
      protected void DropDownList1_SelectedIndexChanged(object sender, EventArgs e)
        {
            DropDownList                                        d                           =
((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList"));
            Panel                                             p                             =
((Panel)OrganizationStep.ContentTemplateContainer.FindControl("CompanyPanel"));
            Panel                                           pID                             =
((Panel)OrganizationStep.ContentTemplateContainer.FindControl("Panel2"));
            if (d.SelectedIndex > 0)
            {
                p.Visible = false;
                pID.Visible = true;
            }
            else
            {
                p.Visible = true;
                pID.Visible = false;
            }
        }
        protected void UnitList_SelectedIndexChanged(object sender, EventArgs e)
        {
            DropDownList                                        d                           =
((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitList"));
            Panel p = ((Panel)UnitStep.ContentTemplateContainer.FindControl("UnitPanel"));
            if (d.SelectedIndex > 0)
            {
                p.Visible = false;
            }
            else
            {
                p.Visible = true;
            }
        }
     protected void CreateUserWizard1_ActiveStepChanged(object sender, EventArgs e)
        {
       if (CreateUserWizard1.ActiveStep.ID == "UnitStep") //second registation step
            {
                #region missing mandatory fields
                if
(((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList")).Selected
Index == 0
                    //check if not chose existing company
```

```
&&(((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("CompanyName")).Text.Trim()
== "" ||

((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("Country")).Text.Trim() == ""
||
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("City")).Text.Trim() == "" ||
((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("EmployeeNr")).Text.Trim() ==
""))
                {

((Literal)(OrganizationStep.ContentTemplateContainer.FindControl("ErrorMessage"))).Text      =
"missing mandetory field";
                    CreateUserWizard1.ActiveStepIndex = 0;
                    return;
                }
                #endregion

                #region to unit
                //if the user choose company from the list
                DropDownList                                    d                                   =
((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitList"));
                d.Items.Clear();
                if
(((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList")).Selected
Index > 0)
                {
                    d.Items.Clear();
                    if
(((TextBox)OrganizationStep.ContentTemplateContainer.FindControl("CompanyIdTextBox")).Text.Tri
m()         !=         db.Organizations.First(q         =>         q.OrganizationName         ==
((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList")).SelectedV
alue).OrganizationID.ToString())
                    {

((Label)OrganizationStep.ContentTemplateContainer.FindControl("WarningLabel")).Text  =  "wrong
identification";
                        CreateUserWizard1.MoveTo(OrganizationStep);
                        return;
                    }
                    else
                    {

((Label)OrganizationStep.ContentTemplateContainer.FindControl("WarningLabel")).Text = "";
                    }
                    string                              organizationName                            =
((DropDownList)OrganizationStep.ContentTemplateContainer.FindControl("CompanyList")).SelectedV
alue;
                    var UnitName = from q in db.Units
                                   where q.OrganizationID == (from p in db.Organizations where
p.OrganizationName == organizationName select p.OrganizationID).First()
                                   select q.UnitName;
((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitList")).DataSource =
UnitName;

((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitList")).DataBind();
                }
                d.Items.Insert(0, new ListItem("Add New Unit", "0"));
                #endregion
            }
            else if (CreateUserWizard1.ActiveStep.ID == "CreateUserWizardStep1")
            {
                #region missing mandatory fields
                if(((ArrayList)Session["units"]).Count == 0) //no unit add to the array
                //and no unit information fills at the form
                if
(((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitList")).SelectedIndex == 0
&&//check if chose existing unit
(((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitName")).Text.Trim() == "" ||
((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitDescription")).Text.Trim() ==
""))
                {
((Literal)(UnitStep.ContentTemplateContainer.FindControl("ErrorMessage"))).Text   =   "missing
mandetory field";
                    CreateUserWizard1.ActiveStepIndex = 1;
                    return;
                }
                #endregion
//((DropDownList)CreateUserWizardStep1.ContentTemplateContainer.FindControl("DropDownList1"))
```

```
                //final step, fill the unit drop down list
((DropDownList)CreateUserWizardStep1.ContentTemplateContainer.FindControl("DropDownList1")).It
ems.Clear();
     if(((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitName")).Text.Trim()     !=
"")

((DropDownList)CreateUserWizardStep1.ContentTemplateContainer.FindControl("DropDownList1")).It
ems.Add(((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitName")).Text.Trim());
                foreach (Unit u in ((ArrayList)Session["units"]))
                {
((DropDownList)CreateUserWizardStep1.ContentTemplateContainer.FindControl("DropDownList1")).It
ems.Add(u.Name);
                }
            }
        }
        protected void Button1_Click2(object sender, EventArgs e)
        {
            Unit unit = new Unit();
            unit.Name=
((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitName")).Text.Trim() ;
            unit.Desc                                                                    =
((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitDescription")).Text.Trim();
            if
(((DropDownList)UnitStep.ContentTemplateContainer.FindControl("UnitTypeDropdownlist")).Selecte
dIndex == 0)
                unit.t = type.Organizational;
            else
                unit.t = type.Physical;
            ArrayList units = ((ArrayList) Session["units"]);
            units.Add(unit);
 ((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitName")).Text = string.Empty;
 ((TextBox)UnitStep.ContentTemplateContainer.FindControl("UnitDescription")).Text            =
string.Empty;
        }
    }
    public enum type { Organizational, Physical }
    public class Unit
    {
        public string Name;
        public string Desc;
        public type t;
        public Unit() { }
        public Unit(string Name, string Desc, type t)
        {
            this.Name = Name;
            this.Desc = Desc;
            this.t = t;
        }
    }
}
```

User login Page:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;

namespace WCF_EPI.Account
{
    public partial class Login : System.Web.UI.Page
    {
        protected void Page_Load(object sender, EventArgs e)
        {
            RegisterHyperLink.NavigateUrl        =        "Register.aspx?ReturnUrl="        +
HttpUtility.UrlEncode(Request.QueryString["ReturnUrl"]);

            ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text     =
"Login";
        }
    }
}
```

View profile page:

```
using System;
```

```
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;
using System.Web.Security;
using System.Data;

namespace WCF_EPI
{
    public partial class ViewProfile : System.Web.UI.Page
    {
        private DBLayerLibrary.DBDataContext db;
        protected void Page_Load(object sender, EventArgs e)
        {
            ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text     =
"View Profile";
            if (!IsPostBack)
            {
                db = new DBLayerLibrary.DBDataContext();
                Session["userID"] = (Guid)Membership.GetUser().ProviderUserKey;
                var x = from u in db.Units
     join o in db.Organizations on u.OrganizationID equals o.OrganizationID
     join user in db.UserCompanies on o.OrganizationID equals user.OrganizationID
     join member in db.aspnet_Memberships on user.UserId equals member.UserId
 where user.UserId == (Guid)Membership.GetUser().ProviderUserKey && u.UnitID == user.UnitID
                        select new
                        {
                            o.OrganizationName,
                            o.BusinessField,
                            o.Country,
                            o.City,
                            o.Street,
                            o.Zip,
                            o.EmployeeNr,
                            u.UnitName,
                            u.UnitType,
                            user.HostAddress,
                            member.Email,
                            member.PasswordQuestion
                        };
                DataTable DT = new DataTable();
                DT.Columns.Add("Organization Name");
                DT.Columns.Add("Business Field");
                DT.Columns.Add("Number of Employees");
                DT.Columns.Add("Unit Name");
                DT.Columns.Add("Unit Type");
              DataRow DR = DT.NewRow();
                DR["Organization Name"] = x.First().OrganizationName;
                DR["Business Field"] = x.First().BusinessField;
                DR["Number of Employees"] = x.First().EmployeeNr;
                DR["Unit Name"] = x.First().UnitName;
                DR["Unit Type"] = x.First().UnitType;
              DT.Rows.Add(DR);
            GridView1.DataSource = DT;
                GridView1.DataBind();
             //Grid view2
                DT = new DataTable();
                DT.Columns.Add("Country");
                DT.Columns.Add("City");
                DT.Columns.Add("Street");
                DT.Columns.Add("Zip");
              DR = DT.NewRow();
                DR["Country"] = x.First().Country;
                DR["City"] = x.First().City;
                DR["Street"] = x.First().Street;
                DR["Zip"] = x.First().Zip;
              DT.Rows.Add(DR);
               GridView2.DataSource = DT;
                GridView2.DataBind();
            //Grid view3
                DT = new DataTable();
                DT.Columns.Add("User Name");
                DT.Columns.Add("Host Address");
                DT.Columns.Add("Email");
            DR = DT.NewRow();
                DR["User Name"] = Membership.GetUser().UserName;
                DR["Host Address"] = x.First().HostAddress;
```

```
                DR["Email"] = x.First().Email;
            DT.Rows.Add(DR);
                GridView3.DataSource = DT;
                GridView3.DataBind();
            }
        }
    }
}
```

Edit profile:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.UI;
using System.Web.UI.WebControls;
using System.Web.Security;

namespace WCF_EPI.Account
{
    public partial class Edit : System.Web.UI.Page
    {
        private DBLayerLibrary.DBDataContext db = new DBLayerLibrary.DBDataContext();
        protected void Page_Load(object sender, EventArgs e)
        {
            ((Menu)(Master.FindControl("Form1").FindControl("TitleMenu"))).Items[0].Text     =
"Edit Profile";

            if (Membership.GetUser() == null)
            {
                Page.Response.Redirect("Default.aspx");
                return;
            }
            else
            {
                if (!IsPostBack)
                {
                    Guid userID = (Guid)Membership.GetUser().ProviderUserKey;//get userID
                    Guid          g          =          db.UserCompanies.First(q          =>
q.UserId.Equals(userID)).OrganizationID.Value;

                    //select & fill the company ID
                    CompanyIdLabel.Text = "Company Identification: " + g.ToString();

                    //fill the business fields drop down list
                    DropDownList1.DataSource = db.BusinessFields.Select(row => row.Field);
                    DropDownList1.DataBind();
                    ListItem item = new ListItem(" ");
                    DropDownList1.Items.Add(item);
                    DropDownList1.SelectedIndex = DropDownList1.Items.Count - 1;

                    //fill the units drop down list
                    DropDownList2.DataSource  =  db.Units.Where(row  =>  row.OrganizationID  ==
g).Select(row => row.UnitName);
                    DropDownList2.DataBind();
                    DropDownList2.Items.Add(item);
                    DropDownList2.SelectedIndex = DropDownList2.Items.Count - 1;
                }
            }
        }
        protected void SaveButton_Click(object sender, EventArgs e)
        {
            bool changed = false;
            if (EmailTextBox.Text.Trim() != "")
            {
                var user = Membership.GetUser();
                user.Email = EmailTextBox.Text;
                Membership.UpdateUser(user);
                changed = true;
            }
            var userID = from y in db.aspnet_Users
          where y.UserName == Membership.GetUser().UserName
                                        select y.UserId;
            if (HostAddressTextBox.Text.Trim() != "")
            {
                var record =
                (
```

```
                    from x in db.UserCompanies
                    where x.UserId == userID.First()
                    select x
                ).Single();

                record.HostAddress = HostAddressTextBox.Text;
    //      record.DateUpdated = DateTime.Now;
                db.SubmitChanges();
                changed = true;
            }
            if(PasswordTextBox2.Text.Trim() != "")
            {
                bool result = Membership.GetUser().ChangePassword(PasswordTextBox1.Text,
PasswordTextBox2.Text);
                if (!result)
                    WarningLabel.Text = "Password did not change";
                else
                    changed = true;
            }
            //business field
            if (DropDownList1.SelectedIndex < DropDownList1.Items.Count - 1)
            {
                changed = true;
                var record =
                (
                    from x in db.Organizations
                    where x.OrganizationID == (from q in db.UserCompanies where q.UserId ==
userID.First() select q.OrganizationID).First()
                    select x
                ).Single();
                record.BusinessField = DropDownList1.SelectedValue;
                db.SubmitChanges();
            }
            //units
            if (DropDownList2.SelectedIndex < DropDownList2.Items.Count - 1)
            {
                changed = true;
                var record =
                (
                    from x in db.UserCompanies
                    where
                    x.UserId == userID.First()
                    select x
                ).Single();
                record.UnitID      =      db.Units.Where(row      =>      row.UnitName      ==
DropDownList2.SelectedValue).First().UnitID;
                db.SubmitChanges();
            }
            if (TextBox1.Text.Trim() != "")
            {
                var record =
                (
                    from x in db.Organizations
                    where x.OrganizationID == (from q in db.UserCompanies where q.UserId ==
userID.First() select q.OrganizationID).First()
                    select x
                ).Single();
                record.EmployeeNr = int.Parse(TextBox1.Text);
                db.SubmitChanges();
                changed = true;
            }
            if (Country.Text.Trim() != "")
            {
                var record =
                (
                    from x in db.Organizations
                    where x.OrganizationID == (from q in db.UserCompanies where q.UserId ==
userID.First() select q.OrganizationID).First()
                    select x
                ).Single();
                record.Country = Country.Text;
                db.SubmitChanges();
                changed = true;
            }
            if (City.Text.Trim() != "")
            {
                var record =
                (
```

```
                    from x in db.Organizations
                    where x.OrganizationID == (from q in db.UserCompanies where q.UserId ==
userID.First() select q.OrganizationID).First()
                    select x
                ).Single();
                record.City = City.Text;
                db.SubmitChanges();
                changed = true;
            }
            if (Zip.Text.Trim() != "")
            {
                var record =
                (
                    from x in db.Organizations
                    where x.OrganizationID == (from q in db.UserCompanies where q.UserId ==
userID.First() select q.OrganizationID).First()
                    select x
                ).Single();
                record.Zip = int.Parse(Zip.Text);
                db.SubmitChanges();
                changed = true;
            }
            if (Street.Text.Trim() != "")
            {
                var record =
                (
                    from x in db.Organizations
                    where x.OrganizationID == (from q in db.UserCompanies where q.UserId ==
userID.First() select q.OrganizationID).First()
                    select x
                ).Single();
                record.Street= Street.Text;
                db.SubmitChanges();
                changed = true;
            }
            if (changed)
            {
                resultLabel.Text = "upadate successfully";
            }
        }
    }
}
```

LINQ and ADO.NET are used to deal with the database.

- LINQ is used directly within pages, such a code can be seen in the section “code behind” of the site-pages.
- a small part of the database logic is programmed with ADO.NET in a separated file, which acts a s a layer between the application and the database:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Data.SqlClient;
using System.Data;
using System.Data.Sql;

namespace DBLayerLibrary
{
    /// <summary>
    //the logic to access the databese and then perform operations.
    /// </summary>
    public class DBLayer
    {
        private SqlConnection _conn;
        private SqlCommand _cmd;
        #region main logic: create,open and close a connection
        public DBLayer(string connectionString)//the caller (our webApplication) will pass the
value
        {
            _conn = new SqlConnection(connectionString);
            _cmd = new SqlCommand();
            _cmd.Connection = _conn;
        }
        public void openConnection()
        {
```

```
            try
            {
                _conn.Open();
            }
            catch (Exception e)
            {
                Exception ex = new Exception("Database Open Error", e);
                throw ex;
            }
        }
        public void closeConnection()
        {
            _conn.Close();
        }

        #endregion
        public string GetDescription(int EPIID)
        {
            string r = string.Format("select Description from EPI where EpiID={0}", EPIID);
            _cmd.CommandText = r;
            _cmd.CommandType = CommandType.Text;
            Object o = _cmd.ExecuteScalar();
            return o.ToString();
        }

        public string GetEquation(int EPIID)
        {
            string r = string.Format("select Equation from EPI where EpiID={0}", EPIID);
            _cmd.CommandText = r;
            _cmd.CommandType = CommandType.Text;
            Object o = _cmd.ExecuteScalar();
            return o.ToString();
        }
        public string GetHostAddress(Guid userID)
        {
            string r = string.Format("SELECT HostAddress FROM UserCompany WHERE UserId
='{0}'", userID);
            _cmd.CommandText = r;
            _cmd.CommandType = CommandType.Text;
            Object o = _cmd.ExecuteScalar();
            return o.ToString();
        }
        #region ELCD
        public string GetRefDocument(int EpiID)
        {
            string s = string.Format("SELECT RefDoc FROM EPI  where EpiID={0}", EpiID);
            _cmd.CommandText = s;
            _cmd.CommandType = CommandType.Text;
            Object o = _cmd.ExecuteScalar();
            return o.ToString();
        }
        public string Get_InputMaterial_Name(int EpiID)
        {
            string s = string.Format("SELECT MaterialName FROM EPI JOIN Material ON
EPI.Inputmat1 = Material.MaterialID WHERE EpiID={0}", EpiID);
            _cmd.CommandText = s;
            _cmd.CommandType = CommandType.Text;
            Object o = _cmd.ExecuteScalar();
            return o.ToString();
        }
        public string Get_OutputMaterial_Name(int EpiID)
        {
            string s = string.Format("SELECT MaterialName FROM EPI JOIN Material ON
EPI.Outputmat = Material.MaterialID WHERE EpiID={0}", EpiID);
            _cmd.CommandText = s;
            _cmd.CommandType = CommandType.Text;
            Object o = _cmd.ExecuteScalar();
            return o.ToString();
        }
        public string Get_InputMaterial_Unit(int EpiID)
        {
            string s = string.Format("SELECT MaterialUnit FROM EPI JOIN Material ON
EPI.Inputmat1 = Material.MaterialID WHERE EpiID={0}", EpiID);
            _cmd.CommandText = s;
            _cmd.CommandType = CommandType.Text;
            Object o = _cmd.ExecuteScalar();
            return o.ToString();
        }
```

```
        public string Get_OutputMaterial_Unit(int EpiID)
        {
            string s = string.Format("SELECT MaterialUnit FROM EPI JOIN Material ON
EPI.Outputmat = Material.MaterialID WHERE EpiID={0}", EpiID);
            _cmd.CommandText = s;
            _cmd.CommandType = CommandType.Text;
            Object o = _cmd.ExecuteScalar();
            return o.ToString();
        }
        //..end ELCD
        #endregion
    }
}
```

Elect Provider service:

This service is self-hosted, i.e using just one program. Here the program is Windows-Forms-application. The Service Interface:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Runtime.Serialization;
using System.ServiceModel;
using System.Text;

namespace ElecProvidersService
{
    // NOTE: You can use the "Rename" command on the "Refactor" menu to change the interface
name "IElecService" in both code and config file together.
    [ServiceContract]
    public interface IElecService
    {
        [OperationContract]
        KWPrices get_KWPrices(string yourProvider);

        /*
         * [OperationContract(IsOneWay = true)]
         void SetMessage(string msg);
         */
    }
    [DataContract]
    public class KWPrices
    {
        double _KWTo1;
        double _KWTo2;
        double _price1;
        double _price2;
        string stringValue = "Hello ";
        [DataMember]
        public double Price1
        {
            get { return _price1; }
            set { _price1 = value; }
        }
        [DataMember]
        public double Price2
        {
            get { return _price2; }
            set { _price2 = value; }
        }
        [DataMember]
        public double KWTo1
        {
            get { return _KWTo1; }
            set { _KWTo1 = value; }
        }
        [DataMember]
        public double KWTo2
        {
            get { return _KWTo2; }
            set { _KWTo2 = value; }
        }
    }
}
```

The sevice-implementation:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Runtime.Serialization;
using System.ServiceModel;
using System.Text;
using System.Data.SqlServerCe;
using System.Data;
using System.Data.Sql;

namespace ElecProvidersService
{
    [ServiceBehavior(InstanceContextMode = InstanceContextMode.PerSession)]
    public class ElecService : IElecService
    {
        string  _connstr  =  Properties.Settings.Default.Database1ConnectionString;  //@"Data
Source=|DataDirectory|\Database1.sdf";
        private SqlCeConnection _conn;
        public KWPrices get_KWPrices(string yourProvider)
        {
            //return "hi from service!";
            _conn.Open();
            KWPrices kw = new KWPrices();
            using (SqlCeCommand cmd = new SqlCeCommand("SELECT KFTo,Price FROM providers WHERE
(pName = @providername)", _conn))
            {
                cmd.Parameters.AddWithValue("@providername", yourProvider);
                SqlCeDataReader reader = cmd.ExecuteReader();
                if (reader.Read())
                {
                    kw.KWTo1 = Convert.ToDouble(reader[0]);
                    kw.Price1 = Convert.ToDouble(reader[1]);
                    reader.Read();
                    kw.KWTo2 = Convert.ToDouble(reader[0]);
                    kw.Price2 = Convert.ToDouble(reader[1]);
                }
            }
            _conn.Close();
            return kw;
        }
        public ElecService()
        {
            {
                _conn = new SqlCeConnection(_connstr);
            }      }     }  }
```

To run the service:

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;

using System.ServiceModel;

namespace ElecProvidersService
{
    public partial class Form1 : Form
    {
        //private ElecService service;
        private ServiceHost host;
        public Form1()
        {
            InitializeComponent();
        }
        //the concept of self-hosted service:
        //hosting the service in the load event (no second program for hosting)
        private void Form1_Load(object sender, EventArgs e)
        {

            //service = new ElecService();
            host = new ServiceHost(typeof(ElecService));
            host.Open();
            DisplayHostInfo(host);
```

```
        }
        void DisplayHostInfo(ServiceHost host)
        {

            listBox1.Items.Add("***** Host Info *****");

            listBox1.Items.Add("Port:");
            listBox1.Items.Add(host.BaseAddresses[0].Port);

            listBox1.Items.Add("Uri:");
            listBox1.Items.Add(host.BaseAddresses[0].AbsoluteUri);
            listBox1.Items.Add("Scheme:");
            listBox1.Items.Add(host.BaseAddresses[0].Scheme);

        }
        private void Form1_FormClosing(object sender, FormClosingEventArgs e)
        {
            host.Close();
        }
    }
}
```

The connection between the enterprises and the application (the web portal) is done using webservices. The enterprise take the following service-template, implement and host it. In practice, the LWC_EPI Portal communicates with this enterprise-host to get required enterprise-data. In the following, the service Interface (the template) and its implementation are packed in a library (dll file). This libraray is then used in the hosting-program.
The Web service template used in agent-side (enterprises or clients):

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.ServiceModel;// The key WCF namespace.
using System.Runtime.Serialization;

namespace WcfServiceLibraryE1
{
    [ServiceContract ]// the serviceContract represents the service operations

    public interface IServiceE1
    {
        [OperationContract]
        string get_ElecBillValue();

        [OperationContract]
        string get_ElecCompany();

        [OperationContract]
        CompositeType GetDataUsingDataContract(CompositeType composite);

        /// <summary>
        /// get the sum of amount for all materials or for a specific vewandtesMaterial
        /// </summary>
        /// <param name="vMaterial"> type "*" to consider all materials</param>
        /// <returns></returns>
        [OperationContract]
        string getDataOfmaterial(string Material);

        [OperationContract]
        double get_Amount(string vMaterial);

        [OperationContract]
        string get_Eiheit(string vMaterial);

        [OperationContract]
        double get_Destanz(string vMaterial);

        [OperationContract]
        double get_Gewicht(string vMaterial);

            [OperationContract]//op3
        string SomeFunction();
    // TODO: Add other service operations here//
    }
```

```
    // Use a data contract as below to add composite types to service operations
    [DataContract]
    public class CompositeType
    {
        bool boolValue = true;
        string stringValue = "Hello ";

        [DataMember]
        public bool BoolValue
        {
            get { return boolValue; }
            set { boolValue = value; }
        }
        [DataMember]
        public string StringValue
        {
            get { return stringValue; }
            set { stringValue = value; }
        }     }   }
```

Example of implementation:
The enterprise is responsible of coding its service functions, Here the enterprise has a SQL-database (Compact Edition) as an example, and has to code the connection logic to its database. Every client (enterprise) can implement the service in the way it wants. For example, providing the data directly if no database exists!

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Runtime.Serialization;
using System.ServiceModel;
using System.Text;
using System.Data.SqlServerCe;
using System.Data;
using System.Data.Sql;

namespace WcfServiceLibraryE1
{
    [ServiceBehavior(InstanceContextMode = InstanceContextMode.Single)]
    public class ServiceE1 : IServiceE1
    {
         private SqlCeConnection _conn;
       // EnterpriseDAL db;
        public ServiceE1(string strConn)
        {
            _conn = new SqlCeConnection(strConn);
        }
        public string get_ElecCompany()
        {
            _conn.Open();
            string r = string.Empty;
                using (SqlCeCommand cmd = new SqlCeCommand("select Name from ElecCompany",
_conn))
                {
                    object o = cmd.ExecuteScalar();
                    r = o.ToString();
                }
               _conn.Close();
               return r;
            }
        public string get_ElecBillValue()
        {
            _conn.Open();
            string r = string.Empty;

            using (SqlCeCommand cmd = new SqlCeCommand("select sum(bvalue) from ElecBills
where bYear=2013", _conn))
            {

                object o = cmd.ExecuteScalar();
                r = o.ToString();
            };
            _conn.Close();
            return r;
        }
        public string getDataOfmaterial(string Material)
```

```
        {
            _conn.Open();
            string r = string.Empty;

            using (SqlCeCommand cmd = new SqlCeCommand("select amount from materials1 where
VerwendetesMaterial=@vMaterial", _conn))
            {
                cmd.Parameters.AddWithValue("@vMaterial", Material);
                object o = cmd.ExecuteScalar();
                r = o.ToString();
            }
            _conn.Close();
            return r;
        }
        public double get_Amount(string vMaterial)
        {
            double r;
            _conn.Open();
            if (vMaterial == "*")
                using (SqlCeCommand cmd = new SqlCeCommand("select sum(amount) from
Materials1", _conn))
                {
                    object o = cmd.ExecuteScalar();
                    r = Convert.ToDouble(o);
                }
            else
                using (SqlCeCommand cmd = new SqlCeCommand("select sum(amount) from Materials1
where VerwendetesMaterial=@vMaterial", _conn))
                {
                    cmd.Parameters.AddWithValue("@vMaterial", vMaterial);

                    object o = cmd.ExecuteScalar();
                    r = Convert.ToDouble(o);
                }
            _conn.Close();
            return r;
            /*
            db.openConnection();

            if (vMaterial == "*")
                r = db.getAmount();
            else
            {
                r = db.getAmount(vMaterial);
            }
            db.closeConnection();
            return r;*/
        }

        public string get_Eiheit(string vMaterial)
        {
            string r=string.Empty;
            _conn.Open();
            using (SqlCeCommand cmd = new SqlCeCommand("select unit from materials1 where
VerwendetesMaterial=@vMaterial", _conn))
            {
                cmd.Parameters.AddWithValue("@vMaterial", vMaterial);
                object o = cmd.ExecuteScalar();
                r = o.ToString();
            }
            _conn.Close();
            return r;
        }
        public double get_Destanz(string vMaterial)
        {
            double r;
            _conn.Open();
            if (vMaterial == "*")
            using (SqlCeCommand cmd = new SqlCeCommand("select sum(TransportierteDistanz) from
materials1", _conn))
            {
                object o = cmd.ExecuteScalar();
                r = Convert.ToDouble(o);
            }
            else
                using (SqlCeCommand cmd = new SqlCeCommand("select sum(TransportierteDistanz)
from materials1 where VerwendetesMaterial=@vMaterial", _conn))
                {
```

```
                    cmd.Parameters.AddWithValue("@vMaterial", vMaterial);

                    object o = cmd.ExecuteScalar();
                    r = Convert.ToDouble(o);
                }
            _conn.Close();
            return r;
        }
        public double get_Gewicht(string vMaterial)
        {
            double r;
            _conn.Open();
            using (SqlCeCommand cmd = new SqlCeCommand("select sum(gewicht) from Materials1
where VerwendetesMaterial=@vMaterial", _conn))
            {
                cmd.Parameters.AddWithValue("@vMaterial", vMaterial);

                object o = cmd.ExecuteScalar();
                r = Convert.ToDouble(o);
            }
            _conn.Close();
            return r;
        }
        public string SomeFunction()
        {
            string[] answers = { "Future Uncertain", "Yes", "No","Hazy", "Ask again later",
"Definitely" };
            // Return a random response.
            Random r = new Random();
            return          string.Format("random          string          from          list:
{0}",answers[r.Next(answers.Length)]);
        }
        public CompositeType GetDataUsingDataContract(CompositeType composite)
        {
            if (composite == null)
            {
                throw new ArgumentNullException("composite");
            }
            if (composite.BoolValue)
            {
                composite.StringValue += "Suffix";
            }
            return composite;
        }     }  }
```

After that, the client has to host the service (the host here is a console application):

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.ServiceModel;
using WcfServiceLibraryE1;

//running this application,the host is alive in memory, ready to take
//incoming requests from remote clients
namespace ConsoleApplicationE1_ServiceHost
{
    class Program
    {
        static void Main(string[] args)
        {
            string strconn = Properties.Settings.Default.Database1ConnectionString;
            Console.WriteLine("***** Console Based WCF Host *****");
            Console.WriteLine("***** Starting ServiceE1 *****");

            using (ServiceHost serviceHost = new ServiceHost(new ServiceE1(strconn)))
            {
                // Open the host and start listening for incoming messages.
                serviceHost.Open();
                DisplayHostInfo(serviceHost);
                // Keep the service running until the Enter key is pressed.
                Console.WriteLine("The service is ready.");
                Console.WriteLine("Press the Enter key to terminate service.");
                Console.ReadLine();
            }
        }
        static void DisplayHostInfo(ServiceHost host)
```

```
        {
            Console.WriteLine();
            Console.WriteLine("***** Host Info *****");
            //Console.WriteLine("Name: {0}",
            //host.Description.ConfigurationName);
            Console.WriteLine("Port: {0}",
            host.BaseAddresses[0].Port);
            //Console.WriteLine("LocalPath: {0}",
            //host.BaseAddresses[0].LocalPath);
            Console.WriteLine("Uri: {0}",
            host.BaseAddresses[0].AbsoluteUri);
            Console.WriteLine("Scheme: {0}",
            host.BaseAddresses[0].Scheme);
            Console.WriteLine("**********************");
            Console.WriteLine();
        }     }   }
```

Calculate EPI (java code)

```
package calculateEpi;
import java.util.List;
import java.io.BufferedWriter;
import java.io.File;
import java.io.FileWriter;
import java.io.IOException;
import java.util.ArrayList;

import javax.xml.parsers.DocumentBuilderFactory;
import javax.xml.parsers.DocumentBuilder;
import javax.xml.parsers.ParserConfigurationException;

import org.w3c.dom.Document;
import org.w3c.dom.Element;
import org.w3c.dom.Node;
import org.w3c.dom.NodeList;
import org.xml.sax.SAXException;

public class calculateEpi {

        static String dir = "C:/ELCDIII/ILCD/processes/";
        static String dir2 = "C:/ELCDIII/ILCD/flows/";
        static String inputRef = "unknown";
        static String outputRef = "unknown";

        public static void main(String[] args) {

                //0a1b40db-5645-4db8-a887-eb09300b7b74 input output amount unit

                if(args.length == 0){
                        System.out.println("missing reference argument");
                }
                else if(args.length == 1){
                        System.out.println("missing input argument");
                }
                else if(args.length == 2){
                        System.out.println("missing output argument");
                }
                else if(args.length == 3){
                        System.out.println("missing amount argument");
                }
                else if(args.length == 4){
                        System.out.println("missing iunit argument");
                }
                else if(args.length == 4){
                        System.out.println("missing ounit argument");
                }
                else{
                        String uuid = args[0];
                        String input = args[1];
                        String output = args[2];
                        String amount = args[3];
                        String iunit = args[4];
                        String ounit = args[5];
                File xml = new File(dir+"/"+uuid+".xml");
                double inputAmount = findInputAmount(xml, input);
                //System.out.println(inputAmount);
                //System.out.println(inputRef);

                double outputAmount = findOutputAmount(xml, output);
```

```
                //System.out.println(outputAmount);
                //System.out.println(outputRef);
                String inputUnit = "unknown";
                String outputUnit = "unknown";
                outputUnit = findInputUnit(dir2 + outputRef + ".xml");
                inputUnit = findInputUnit(dir2 + inputRef + ".xml");

                //System.out.println(inputUnit);
                //System.out.println(outputUnit);

                if(inputUnit.compareTo("Mass") == 0) { inputUnit = "KG"; }
                if(inputUnit.compareTo("Energy") == 0) { inputUnit = "MJ"; }
                if(inputUnit.compareTo("Materials") == 0) { inputUnit = "KG"; }
                if(inputUnit.compareTo("Net calorific value") == 0) { inputUnit = "MJ"; }
                if(inputUnit.compareTo("Standard volume") == 0) { inputUnit = "M^3"; }


                if(outputUnit.compareTo("Mass") == 0) { outputUnit = "KG"; }
                if(outputUnit.compareTo("Energy") == 0) { outputUnit = "MJ"; }
                if(outputUnit.compareTo("Materials") == 0) { outputUnit = "KG"; }
                if(outputUnit.compareTo("Net calorific value") == 0) { outputUnit = "MJ"; }
                if(outputUnit.compareTo("Standard volume") == 0) { outputUnit = "M^3"; }

                if((iunit.compareTo(inputUnit)==0) || (ounit.compareTo(outputUnit)==0) ){
                        double amountDouble = Double.parseDouble(amount);
                        double value = amountDouble / inputAmount;
                        value = value * outputAmount;
                        System.out.println(value + " " + outputUnit);
                }
                else{
                        System.out.println("wroung Unit");
                }
                } // end if no parameter
        } // end main
private static String findInputUnit(String outputRef) {
        String outputUnit1 = "unknown";
        try {
                DocumentBuilderFactory dbFactory = DocumentBuilderFactory.newInstance();
                DocumentBuilder dBuilder = dbFactory.newDocumentBuilder();
                Document doc = dBuilder.parse(outputRef);

                NodeList nList = doc.getElementsByTagName("flowProperties");

                for(int i = 0; i< nList.getLength(); i++){

                        Node nNode1 = nList.item(i);
                        Element eElement = (Element) nNode1;
                        outputUnit1 =
eElement.getElementsByTagName("common:shortDescription").item(0).getTextContent();
                }
        } catch (Exception e) {
                e.printStackTrace();
    }
        return outputUnit1;
        }
private static double findInputAmount(File xml, String input) {
        String inputAmountString = "0";
                        try {
                DocumentBuilderFactory dbFactory = DocumentBuilderFactory.newInstance();
                        DocumentBuilder dBuilder = dbFactory.newDocumentBuilder();
                        Document doc = dBuilder.parse(xml);

                        NodeList nList = doc.getElementsByTagName("exchange");
                        NodeList nList2 = doc.getElementsByTagName("referenceToFlowDataSet");

                        for(int i = 0; i< nList.getLength(); i++){
                        Node nNode1 = nList.item(i);
                                Element eElement = (Element) nNode1;

                                String exchangeDirection =
eElement.getElementsByTagName("exchangeDirection").item(0).getTextContent();

                                if(exchangeDirection.compareTo("Input") == 0){

                                        String shortDescription =
eElement.getElementsByTagName("common:shortDescription").item(0).getTextContent();
                                        shortDescription = shortDescription.replaceAll(" ","_");
```

```
                                    if(shortDescription.compareTo(input)==0){

                                            inputAmountString =
eElement.getElementsByTagName("meanAmount").item(0).getTextContent();

                                            Node nNode2 = nList2.item(i);
                                            Element eElement2 = (Element) nNode2;
                                            inputRef =
(eElement2.getAttribute("refObjectId"));
                                    }       }       }
                } catch (Exception e) {
                        e.printStackTrace();
            }
                //System.out.println(productName);
                double inputAmountDouble = Double.parseDouble(inputAmountString);
                return inputAmountDouble;
        }
private static double findOutputAmount(File xml, String output) {

        String inputAmountString = "0";
        try {
                DocumentBuilderFactory dbFactory = DocumentBuilderFactory.newInstance();
                DocumentBuilder dBuilder = dbFactory.newDocumentBuilder();
                Document doc = dBuilder.parse(xml);

                NodeList nList = doc.getElementsByTagName("exchange");
                NodeList nList2 = doc.getElementsByTagName("referenceToFlowDataSet");

                for(int i = 0; i< nList.getLength(); i++){

                        Node nNode1 = nList.item(i);
                        Element eElement = (Element) nNode1;

                        String exchangeDirection =
eElement.getElementsByTagName("exchangeDirection").item(0).getTextContent();

                        if(exchangeDirection.compareTo("Output") == 0){

                                String shortDescription =
eElement.getElementsByTagName("common:shortDescription").item(0).getTextContent();
                                shortDescription = shortDescription.replaceAll(" ","_");

                                if(shortDescription.compareTo(output)==0){

                                        inputAmountString =
eElement.getElementsByTagName("meanAmount").item(0).getTextContent();

                                        Node nNode2 = nList2.item(i);
                                        Element eElement2 = (Element) nNode2;
                                        outputRef = (eElement2.getAttribute("refObjectId"));
                                }       }       }
        } catch (Exception e) {
                e.printStackTrace();
    }
        double inputAmountDouble = Double.parseDouble(inputAmountString);
        return inputAmountDouble;
} }//end class
```

Get the EPI description (java code)

```
import java.io.File;
import javax.xml.parsers.DocumentBuilder;
import javax.xml.parsers.DocumentBuilderFactory;
import org.w3c.dom.Document;
import org.w3c.dom.Element;
import org.w3c.dom.Node;
import org.w3c.dom.NodeList;

public class getDescription {

        static String dir = "C:/ELCDIII/ILCD/processes/";
        public static void main(String[] args) {
                if(args.length == 0){
                        System.out.println("missing reference argument");
                }
                else{

                        String desc ="no Description found";
```

```
		try{
			File xml = new File(dir+args[0]+".xml");
			DocumentBuilderFactory dbFactory = DocumentBuilderFactory.newInstance();
			DocumentBuilder dBuilder = dbFactory.newDocumentBuilder();
			Document doc = dBuilder.parse(xml);
			NodeList nList =
doc.getElementsByTagName("technologyDescriptionAndIncludedProcesses");
			if(nList.getLength() != 0){
				Node nNode = nList.item(0);
				Element eElement = (Element) nNode;
				desc = eElement.getTextContent();
				desc = desc.replaceAll("\n"," ");
				desc = desc.replaceAll("  "," ");
				desc = desc.replaceAll("  "," ");
				desc = desc.replaceAll("  "," ");
				desc = desc.replaceAll("  "," ");
			}
			else{
				desc = "no Description found";
			}

			System.out.println(desc);

		} catch (Exception e) {
			e.printStackTrace();
	    }   }          }    }
```

Parse the EPI equation (java code)

```
public class main {
	/**
	 * @param args
	 */
	public static void main(String[] args) {
		String Klammern = "(" + args[0] + ")";
		String klammererg = "0";
		String Teil = "";
		int Start = 0;
		int End = 0;
		while(Klammern.contains("(")){
			for(int i = 0; i< Klammern.length();i++){
				if(Klammern.charAt(i) == '('){
					Start = i;
				}
				if(Klammern.charAt(i) == ')'){
					End = i;
					break;
				}
				//System.out.println(Start + " - " + End);
			}
			Teil = Klammern.substring(Start+1, End);
			//System.out.println("Teil=" + Teil);

			klammererg = calcKlammer2(Teil, args);
			//System.out.println(klammererg);
			Teil = "("+Teil+")";
			Klammern = Klammern.replace(Teil, klammererg);
			//System.out.println("String=" + Klammern);
		}
		System.out.println(klammererg);
	}
	private static String calcKlammer2(String teil, String[] args) {
		teil = teil.replaceAll("G", args[1]);
		teil = teil.replaceAll(" ","");
		String[] sarray = new String[20];
		int counter = 0;
		//System.out.println("asd=" + teil);
		String zahl = "";
	for(int i = 0; i< teil.length();i++){
			if(teil.charAt(i) == '*'){

				sarray[counter] = zahl;
				counter++;
				zahl = "";
				sarray[counter] = "*";
				counter++;

			}
			else if(teil.charAt(i) == '/'){
```

```
                                sarray[counter] = zahl;
                                counter++;
                                zahl = "";
                                sarray[counter] = "/";
                                counter++;
                        }
                        else{
                                zahl = zahl+ teil.charAt(i);
                        }
                }
                sarray[counter] = zahl;
                double erg = Double.parseDouble(sarray[0]);
                if(sarray[2] != null){
                        if(sarray[1] == "*"){
                                erg = erg * Double.parseDouble(sarray[2]);
                        }
                        if(sarray[1] == "/"){
                                erg = erg / Double.parseDouble(sarray[2]);
                        }
                }
        if(sarray[4] != null){
                        if(sarray[3] == "*"){
                                erg = erg * Double.parseDouble(sarray[4]);
                        }
                        if(sarray[3] == "/"){
                                erg = erg / Double.parseDouble(sarray[4]);
                        }
                }
        if(sarray[6] != null){
                if(sarray[5] == "*"){
                        erg = erg * Double.parseDouble(sarray[6]);
                }
                if(sarray[5] == "/"){
                        erg = erg / Double.parseDouble(sarray[6]);
                }
        }
if(sarray[8] != null){
                if(sarray[7] == "*"){
                        erg = erg * Double.parseDouble(sarray[8]);
                }
                if(sarray[7] == "/"){
                        erg = erg / Double.parseDouble(sarray[8]);
                }
        }
                return ""+erg;
        }
        private static String calcKlammer(String klammern, String[] args) {
                String split[] = new String[50];
                String teil = "";
                char[] chararray= (klammern.toCharArray());
                int counter = 0;
                for(int i = 0; i < klammern.length();i++){
        //System.out.println(chararray[i]);
                        if(chararray[i] == '*' || chararray[i] == '/') {
                                split[counter] = teil.replaceAll(" ", "");
                                counter++;
                                teil = "";
                                if(chararray[i] == '*'){
                                        split[counter] = "*";
                                        counter++;

                                }
                                if(chararray[i] == '/'){
                                        split[counter] = "/";
                                        counter++;
                                }
                        }
                        else{
                                teil = teil + chararray[i];
                        }
                }
                split[counter] = teil.replaceAll(" ", "");
                String erg[] = new String[10];
                int counter2 = 0;
                double wert1 = 0;
                double  wert2 = 0;
                boolean geteilt = true;
                for(int h = 0; h < counter; h++){
```

```
                        if(split[h] == "*"){
                                if(geteilt == true){
                                        if(isNumeric(split[h-1])){
                                                wert1 = Double.parseDouble(split[h-1]);
                                        }
                                        else{
                                                wert1 = Double.parseDouble(args[1]);
                                        }
                                        if(isNumeric(split[h+1])){
                                                wert2 = Double.parseDouble(split[h+1]);
                                        }
                                        else{
                                                wert2 = Double.parseDouble(args[1]);
                                        }
                                }
                                if(geteilt == false){
                                        wert1 = Double.parseDouble(erg[counter2-1]);
                                        if(isNumeric(split[h+1])){
                                                wert2 = Double.parseDouble(split[h+1]);
                                        }
                                        else{
                                                wert2 = Double.parseDouble(args[1]);
                                        }
                                }
                                        erg[counter2] = "" + wert1 * wert2;
                                        counter2++;
                                        geteilt = false;
                        }
                        if(split[h] == "/"){
                                erg[counter2] = "/";
                                counter2++;
                                geteilt = true;
                        }               }
        double erg2 =  0;
        if(erg.length > 0){
                erg2 =  Double.parseDouble(erg[0]);
        }
        boolean containdiv = false;
        if(counter2 == 0){
                erg2 = Double.parseDouble(split[0]);
        }
        for(int u = 0; u < erg.length; u++){
                if(erg[u] == "/"){
                        containdiv = true;
                }       }
        if(containdiv){
        if(counter2 == 1 && erg[0] == "/"){
                erg2 = Double.parseDouble(split[0]) / Double.parseDouble (split[2]);
        }
        if(counter2 == 1 && erg[0] != "/"){
                erg2 = Double.parseDouble(erg[0]);
        }
        if(counter2 == 2 && erg[0] == "/"){
                erg2 = Double.parseDouble(split[0]) / Double.parseDouble (erg[1]);
        }
        if(counter2 == 2 && erg[0] != "/"){

                erg2 = Double.parseDouble(erg[0]) / Double.parseDouble (split[split.length-1]);

        }
        if(counter2 == 3){

                erg2 = Double.parseDouble(erg[0]) / Double.parseDouble (erg[2]);
        }
        if(erg[1] == "/"){
                erg2 = Double.parseDouble(erg[0]) / Double.parseDouble (erg[2]);
        }
        }
        else{
        }
                return ""+erg2;
        }
        public static boolean isNumeric(String str)
        {
          return str.matches("-?\\d+(\\.\\d+)?");
        }   }
```

A.12 The list of the user's tasks used for the user-test

- Please visite the LWC-EPI web page using the following link

  http:141.44.30.154/LWC-EPI/
- After reading the general information, please complete the following tasks mentioned in the next table
- Important notes:
  - Please count the number of clicks you needed for each task.
  - Please indicate the time you needed to complete each task.
  - Please add your remark if you have any on the last column in the table

Nr.	Task	Nr. of clicks	Time needed in sec.	Note
1	What is the first step you have to do in order to start using the system functionalities			
2	Please complete the registration step			
3	Log out and try to login with your user name and wrong password			
4	Please log in with the right data			
5	Try to calculate an EPI			
6	Complete the ECET assessment model and check the result			
7	Try to change 3 of your answers and save the new result			
8	Calculate three EPIs using the webservice you offered, and save the results with different privacy			
9	Try to define new EPI			
10	Try to calculate the new created EPI using manual data entry			
11	Try to generate a report with wrong dates			
12	Try the same with the right date, and select all of the options			
13	Can you see all of your correct results?			
14	Try to export the report and save it on your computer			
15	Try to generate a comparison report with the right date, and select all of options wrong dates			
16	Can you see all of your correct results?			
17	Try to export the report and save it on your computer			

References

1. **Ahmed, M. Daud; and Sundaram, David:** Sustainable Business Transformation [Conference] // (AMCIS), Association for Information Systems Conference. - Detroit, Michigan : [s.n.], 2011. - p. 356.
2. **Aier, Stephan; Gleichauf, Bettina; and Winter, Robert:** Understanding Enterprise Architecture Management Design – An Empirical Analysis [Conference] // The 10th International Conference on Wirtschaftsinformatik WI 2011. - Zurich : WI, 2011. - p. 645.
3. **Allam, Nabil; Junker, Horst: and Christel, Manuel:** Classification of CEMIS Standard Software available on the German Market [Book Section] // Information Technologies in Environmental Engineering, New Trends and Challenges / book auth. Golinska Paulina and Fertsch Marek / ed. Marx Gómez Jorge.. - Heidlburg : Springer, 2011. - Vol. 3. - ISBN: 978-3-642-19535-8.
4. **Amberg, Michael; and Pantiz, Johannes C.:** Towards a Compliance Reporting using a Balanced Scorecard [Journal] // World Academy of Science, Engineering and Technology. - [s.l.] : WASET, 2009. - 9 : Vol. 3. - p. 1923.
5. **Ammenberg, Jonas; and Hjelm, Olof:** Tracing business and environmental effects of environmental management systems—a study of networking small and medium-sized enterprises using a joint environmental management system. [Journal] // Business Strategy and the Environment. - [s.l.] : Wiley, 2003. - 3 : Vol. 12. - pp. 163-174. - ISSN 0964-4733.
6. **Antoni-komar, Irene; Beermann, Marina; and Schattke, Hedda:** Additional Challenges for CEMIS due to impacts caused by climate change [Book Section] // Corporate Environmental Management Information Systems, Advancements and Trend / book auth. Teuteberg Frank and Gómez Jorge.M. - [s.l.] : IGI Global, 2010.
7. **Archer, Leonard. B.:** Systematic method for designers [Book Section] // Developments in Design Methodology / book auth. Cross Nigel. - London : John Wiley, 1984.
8. **Arndt, Hans-Knud:** Betriebliche Umweltinformationssysteme (BUIS): Gestaltung und Implementirung eines BUIS - Kernsystems [Book]. - [s.l.] : Gabler, 1997. - ISBN 3409128352.
9. **Arndt, Hans-Knud:** Wissenmanagement, Konzepte und Anwendunqen aus dem Umweltmanagement [Book]. - Magdeburg : Shaker Verlag, 2012. - ISBN 9783844016178.
10. **Aruvian's Research:** Analyzing the Carbon Emissions Trading in Europe - The EU ETS Scheme [Online] // researchandmarkets.com. - November 2010. - http://www.researchandmarkets.com/reportinfo.asp?report_id=681603&t=d&cat_id=.
11. **Asfoura, Evan; Jamous, Naoum; Kassem, Gamal; Dumke, Reiner:** FERP Mall Role in FERP Web Services Marketing [Conference] // The International Conference on Information Society (i-Society 2010). - London : [s.n.], 2010. - pp. 156-161. - ISBN 978-0-9564263-3-8.

12. **Baars, Henning; and Kemper, Hans-Georg:** From data warehouses to transformation hubs - A conceptual architecture [Conference] // The 17en European Conference on Information Systems (ECIS). - Verona, Italy : [s.n.], 2009. - p. 397.
13. **Bartolomeo, Matteo:** Environmental performance indicators in industry. [Journal] // Nota di Lavoro. - Milan : Fondazione Eni Enrico Matei, 1995. - Vol. 41.
14. **Beaulac, Michael; Blakeslee, Mary; Burling, Dennis; Crawford, Tim; Garvey; Hisel-McCoy, Sarah; Kempson, David; Lamberson, Tom; Murphy, Dennis; Calvillo, Sarah; Jeng, Tony; Liu, Sara; Pagella, Cheryl; Palis, Mell; Su, Sony; Sweeny, Louis:** CORE Reference model for Environmental Information Exchange Network [Report]. - Lawrenceville, New Jersey : [s.n.], 2003.
15. **Bengtsson, Magnus:** Weighting in Practice:Implications for the Use of Life-Cycle Assessment in Decision Making [Journal] // Journal of Industrial Ecology. - 2000. - Vol. 4. - pp. 47-60.
16. **Bennett, Martin; and James, P.:** Environment under the spotlight: current practice and future trends in environment-related performance measurement for business [Report]. - London : Association of Chartered Certified Accountants (ACCA), 1998. - Research report 55.
17. **Bennett, Martin: and James P.:** Environmental performance measurement in business: current practice and future trends [Journal] // International Journal of Business Performance Management. - 2000. - 1/2/3 : Vol. 2. - pp. 109-123.
18. **Bernroider, Edward:** IT governance for enterprise resource planning supported by the DeLone–McLean model of information systems success [Journal] // Information & Management. - [s.l.] : Elsevier, 2008. - 5 : Vol. 45. - p. 257.
19. **Bi, Xinhua; and Yu, Cuiling:** A Research on Synergic and Spiral-Propulsion Mechanism of Enterprise Information Systems Growth [Journal] // IFIP Advances in Information and Communication Technology / ed. Xu Li D., Tjoa A. Min and Chaudhry Sohail S.. - [s.l.] : Springer, 2008. - Vol. 254. - pp. 798-802.
20. **Bischof, Sandro; and Bauer-Messmer, Bettina:** Semantic Enhancement of Environmental Metadata [Conference] // EnviroInfo 2008, Environmental Informatics and Industrial Ecology / ed. Möller A Page B, Schreiber M (eds). - Lüneburg : Shaker, 2008. - pp. 123-131. - ISBN: 978-3-8322-7313-2.
21. **BMU/UBA:** Leitfaden Betriebliche Umweltkennzahlen. [Report]. - Berlin : Bundesumweltministerium and Umweltbundesamt., 1997.
22. **Braun, Christian; and Winter, Robert:** A Comprehensive Enterprise Architecture Metamodel and Its Implementation Using a Metamodeling Platform [Conference] // Enterprise Modelling and Information Systems Architectures 2005 / ed. Desel Joerg and Frank Urlich. - Klagenfurt : EMISA, 2005. - p. 66.
23. **Bronstein, I.N.; and Semendjaew, Konstantin A.:** Taschenbuch Der Mathematik [Book]. - Frankfurt/Main : Verlag Harri Deutsch, 1991. - Vol. 1 : pp. 688 - 693. - ISBN: 3-87144-492-8.

24. **BS-8555:** Environmental Management System: Guide to the phased implementation of an environmental management system including the use of environmental performance evaluation. [Report]. - [s.l.] : BSI, 2003.
25. **Bullinger, Hans-Jörg; and Eversheim, Walter:** Auftragsabwicklung optimieren nach Umwelt- und Kostenzielen [Book] / ed. Haasis Hans-Dietrich. - Berlin : Springer, 2000. - ISBN: 978-3-642-64114-.
26. **Carlsson, Sven.A.; Henningsson, Stefan; Hrastinski, Stefan; Keller, Christina:** Socio-technical IS design science research: developing design theory for IS integration management [Journal] // Information Systems and e-Business Management. - [s.l.] : Springer, March 2011. - 1 : Vol. 9. - pp. 109-131. - Print ISSN 1617-9846.
27. **Cheesman, John; and Daniels, John:** UML Components A Simple Process for Specifying Component-Based Software [Book]. - MA. USA : Addison-Wesley, 2000. - ISBN 0-201-70851-5.
28. **Chen, Bo:** ISO 14001, EMAS, OR BS 8555: AN ASSESSMENT OF THE ENVIRONMENTAL MANAGEMENT SYSTEMS FOR UK BUSINESSES [Report] : Master thesis / School of Environmental Sciences ; University of East Anglia. - Norwich : [s.n.], 2004.
29. **Child, Dennis;** The Essentials of Factor Analysis [Book]. - GB : MPG Books Ltd., Bodmin, Cornwall, 2006. - 3rd.. - ISBN 0-8264-8000-4.
30. **Child, John:** Organizational Structure, Environment and Performance: The Role of Strategic Choice [Journal] // Sociology. - January 1972. - 1 : Vol. 6. - pp. 2-3.
31. **Clausen, Jens:** Umsteuern od Neugründen? Die Realisierung ökologischer Produktpolitik im Unternehmen. [Report] / Bremen, Univ., Diss.. - [s.l.] : Jens Clausen, Hannover, 2004. - pp. 97-99. - ISBN 3-8334-1545-2.
32. **Coelli, Timothy J.; Roa, Dodla Sai Prasada; O'Donnell, Christopher J.; Battese, George Edward:** An Introduction to Efficiency and Productivity Analysis [Book]. - New York : Springer, 2005. - 2ed. - ISBN: 9780387242651.
33. **Commission, European:** The new SME definition: user guide and model declaration [Book] / ed. Commission EU. - Luxembourg : Office for Official Publications of the European Communities, 2005.
34. **Cooper, Maureen:** Environmental Management Systems (EMS) and learning in small and medium size establishments (SME) : a case study from the beverage industry [Report] / Environmental Applied Science and Management ; Ryerson University. - Toronto : [s.n.], 2011.
35. **Credit 360:** what we do [Online] // Credit 360. - 2011. - 2011. - https://www.credit360.com/credit/site/what_we_do.acds.
36. **Curran, Mary Ann:** Life Cycle Assessment: Principles and Practice [Report] / office of research and development ; National Risk Management Research Laboratory. - Ohio : The U.S. Environmental Protection Agency, 2006.

37. **Dada, Ali:** The case for a New EPI Management Solution [Book Section] // Organizations' Environmental Performance Indicators: Measuring, Monitoring, and Management / ed. Dada Ali, Stanoevska Katarina and Gómez Jorge M.. - [s.l.] : Springer, 2013. - Vol. 1.
38. **Dao, Viet; Langella, Ian; and Carbo, Jerry:** From green to sustainability: Information Technology and an integrated sustainability framework [Journal] // The Journal of Strategic Information Systems. - [s.l.] : Elsevier, 2011. - 1 : Vol. 20. - pp. 75-76.
39. **Darnall, Nicole: Jolley, G. Jason; and Handfield, Robert:** Environmental management systems and green supply chain management: complements for sustainability? [Journal] // Business Strategy and the Environment. - [s.l.] : John Wiley & Sons, Ltd., 2008. - 1 : Vol. 17. - pp. 30-45.
40. **DEFRA:** Environmental Key Performance Indicators - Reporting Guidelines for UK Business [Report]. - [s.l.] : © Queen's Printer and Controller 2006, 2006. - Product code PB 11321.
41. **Dietz, Thomas; Rosa, Eugene A.; and York, Richard:** Driving the human ecological footprint [Journal] // Frontiers in Ecology and the Environment. - [s.l.] : The Ecological Society of America, 2007. - 1 : Vol. 5. - pp. 15-17.
42. **Dixona, Robert; Mousaa, Gehan A.; and Woodheada, Anne:** The Role of Environmental Initiatives in Encouraging Companies to Engage in Environmental Reporting [Journal] // European Management Journal. - [s.l.] : Elsevier, 2005. - 6 : Vol. 23. - pp. 702 - 716.
43. **DJSI:** Dow Jones Sustainability World Index Guidebook [Report]. - [s.l.] : Dow Jones Indexes and SAM research, 2010. - http://www.sustainability-index.com/djsi_pdf/publications/Guidebooks/DJSI_World_Guidebook_11_4.pdf.
44. **DJSI:** sustainability-indexes - DJSI [Online] // sustainability-indexes. - CME group company, 2002. - 2011. - http://www.sustainability-indexes.com/07_htmle/indexes/djsi.html.
45. **EC-Environment:** European Commission for Environment [Online] // European Commission. - October 1998. - 2009. - http://ec.europa.eu/environment/archives/actionpr.htm. - can be accessed under http://www.3mfuture.com/articles_sd/EUROPA%20-%20Environment%20-%20Title%20The%205th%20Environmental%20Action%20programme.htm.
46. **Eco92, UNConf:** The United Nations Conference on Environment and Development (Eco92) [Online] // The United Nations. - Department of Public Information, May 23, 1997. - January 15, 2009. - http://www.un.org/geninfo/bp/enviro.html.
47. **EIA:** International Energy Outlook 2010 [Online] // U.S. Energy Information Administration. - July 2010. - http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2010).pdf. - Office of Integrated Analysis and Forecasting U.S. Department of Energy, Washington, DC 20585..
48. **Ellerman, A. Denny; and Buchner, K.Barbara:** The European Union Emissions Trading System: Origins, Allocation, and Early Results [Journal] // Review of Environmental Economics and Policy. - Santa Barbara, CA : Association of Environmental and Resource Economists,

2007. - 1 : Vol. 1. - pp. 66-87. - URL: http://reep.oxfordjournals.org/cgi/content/full/1/1/66. - 1750-6816.

49. **Elliot, Steve:** Transdisciplinary Perspectives on Environmental Sustainability: A Resource Base and Framework for IT-Enabled Business Transformation [Journal] // Management Information Systems Quarterly. - March 2011. - 1 : Vol. 35. - pp. 197-236.
50. **EMAS:** http://ec.europa.eu/environment/emas/index_en.htm [Online] // The EU Eco-Management and Audit Scheme (EMAS). - 2012. - 01 2012.
51. **EMAS-Easy:** Case 10: EMAS Easy Hungary, EMAS-Easy project implementation in Hungary. [Online] // ec.europa.eu. - 2006. - April 2009. - http://ec.europa.eu/environment/sme/pdf/emas_easy_en.pdf..
52. **ENDS 340:** Management Systems for SMEs, Report 340. [Report]. - [s.l.] : ENDS, 2003. - URL: www.endsreport.com.
53. **Epstein, Marc; and Roy, Marie Josée:** Managing Corporate Environmental Performance: A Multinational Perspective [Journal] // European Management Journal. - [s.l.] : Elsevier, 1998. - 3 : Vol. 16. - pp. 284 - 296.
54. **EU-ETS:** Questions and Answers on the Commission's proposal to revise the EU Emissions Trading System [Online] // Europa.eu. - January 23, 2008. - October 12, 2009. - http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/08/35&format=HTML&aged=0&language=EN&guiLanguage=en. - Reference:MEMO/08/35 ; Brussels 23/01/2008.
55. **Fiksel, Joseph R.:** Design for environment: Creating eco-efficient products and processes [Book]. - [s.l.] : McGraw-Hill, 1996. - ISBN 0070209723.
56. **Filho, Fernando Castor; Asterio de C. Guerra, Paulo; Asta Pagano, Vinicius; Rubira, Cecília Mary F.:** A systematic approach for structuring exception handling in robust component-based software [Journal] // Journal of the Brazilian Computer Society . - [s.l.] : Springer-Verlag, 2004. - 3 : Vol. 10. - pp. 3-17.
57. **Fisher, Dana R.; and Freudenburg, William R.:** Postindustrialization and Environmental Quality: An Empirical Analysis of the Environmental State. [Journal] // Social Forces. - [s.l.] : Oxford Open, 2004. - 1 : Vol. 83. - pp. 178-180.
58. **Freundlieb, Michael; and Teuteberg, Michael:** Towards a Reference Model of an Environmental Management [Conference] // Environmental Informatics and Industrial Environmental Protection: Concepts, Methods and Tools. EnviroInfo(2009). - Berlin : Shaker Verlag, 2009. - page 129-138. - ISBN: 978-3-8322-8397-1.
59. **Funk, Burkhardt; Möller, Andreas; and Niemeyer, Peter:** Integration of Risk-oriented Environmental Management Information Systems and Resource Planning Systems [Conference] // EnviroInfo 2007: Environmental Informatics and Systems Research / ed. O. Hryniewicz and J. Studzinski. - Warschau : Shaker, 2007. - pp. 271-277. - ISBN: 978-3-8322-6397-3.

60. **Funk, Burkhardt; Möller, Andreas; and Niemeyer, Peter:** The Prospects of Product Carbon Footprints in ERP Systems [Conference] // EnviroInfo 2008: Environmental Informatics and Industrial Ecology / ed. A. Möller, B. Page and M. Schreiber. - Lüneburg : shaker, 2008. - pp. 534-540. - ISBN: 978-3-8322-7313-2.
61. **Gagliardi, D.; Muller, P.; Glossop, E.; Caliandro, C.; Fritsch, M; Brtkova, G.; Bohn, N.; Klitou, D.; Avigdor, G.; Marzocchi, C.; Ramlogan, R.** ANNUAL REPORT ON EUROPEAN SMEs 2012/2013 [Report]. - [s.l.] : EC-E&I, 2013.
62. **Gandhi, N. Mohan; Das, Selladurai V.; and Santhi, P.:** Unsustainable development to sustainable development: a conceptual model. [Journal] // Management of Environmental Quality: An International Journal. - [s.l.] : Emerald, 2006. - 6 : Vol. 17. - pp. 663-669.
63. **Gefen, David; Straub, Detmar.W.; and Boudreau, Marie-Claude:** Structural Equation Modeling and Regression: Guidelines for Research Practice [Journal] // Communications of the AIS. - August 2000. - 7 : Vol. 4. - pp. 1-70.
64. **Goeken, Matthias; and Knackstedt, Ralf:** Referenzmodellgestütztes Compliance Reporting am Beispiel der EU-Finanzmarktrichtlinie MiFID [Journal] // HMD Praxis der Wirtschaftsinformatik. - [s.l.] : HMD, 2008. - Vols. 263, 45 . - pp. 47-57. - ISSN 1436-3011.
65. **Gómez, Jorge Marx:** Automatisierung der Umwelt-berichterstattung mit Stostrommanagementsystemen [Book]. - Magdeburg : [s.n.], 2004. - PhD thesis, Fakultt fur Informatik der Otto-von-Guericke-Universitt Magdeburg, Habilitationsschrift.
66. **Gómez, Jorge Marx:** Betriebliches Umweltinformationssystem. - Oldenburg : Carl von Ossietzky Universität Oldenburg, Abt. Wirtschaftsinformatik I / VLBA, Department für Informatik, 2009. - enzyklopaedie der wirtschaftsinformatik. Last edited: 23.08.2012 21:08.
67. **Gómez, Jorge Marx:** Corporate Environmental Management Information Systems – CEMIS 2.0 [Book Section] // ICT Innovations 2009 / book auth. Davcev Danco and Gómez Jorge Marx / ed. Davcev Danco and Gómez Jorge Marx. - [s.l.] : Springer Berlin Heidelberg, 2010. - ISBN: 978-3-642-10780-1.
68. **González, P.; Sarkis, J.; and Adenso-Díaz, B.:** Environmental management system certification and its influence on corporate practices: Evidence from the automotive industry [Journal] // nternational Journal of Operations & Production Management. - [s.l.] : Emerald Group Publishing Limited, 2008. - 11 : Vol. 28. - pp. 1021 - 1041.
69. **Gray, Steven A.; Gray, Stefan; Cox, Linda J.; Henly-Shepard, Sara A.:** Mental Modeler: A Fuzzy-Logic Cognitive Mapping Modeling Tool for Adaptive Environmental Management [Conference] // The 46th Hawaii International Conference on System Sciences. - Maui : IEEE computer society, 2013. - pp. 965-973.
70. **Green 500:** Green500 [Online] // www.green500.co.uk. - 2009. - 2009. - http://www.green500.co.uk/cms/.

71. **GRI** G3: online guidlines [Online] // global reporting initiative. - 2007. - 2011. - https://www.globalreporting.org/reporting/guidelines-online/G3Online/StandardDisclosures/Environmental/Pages/default.aspx.
72. **GRI:** RG Sustainability Reporting Guidelines [Report]. - [s.l.] : GRI, 2011. - © 2000-2011 Global Reporting Initiative. Version 3.1.
73. **GRI** RG: Sustainability Reporting Guidelines [Report] : E-report. - [s.l.] : © 2000-2006 GRI, 2006. - Version 3.0.
74. **Grüninger, Michael; and Fox, Mark S.:** Methodology for the design and evaluation of ontologies [Conference] // The 1995 International Joint Conference on AI (IJCAI95).. - Montreal : [s.n.], 1995. - Workshop on Basic Ontological Issues in Knowledge Sharing.
75. **Grünwald, Christian; and Gómez, Jorge M.:** Conception of a System for Waste Management as Integral Part of an Environmental System Scenario – a Case Study. [Conference] // ITEE 2005, Second International ICSC Symposium on Information Technologies in Environmental Engineering / ed. WL Filho, JM Gómez and (eds) Rautenstrauch C. - Magdeburg : Shaker, 2005. - pp. 506-514.
76. **Günther, Oliver:** Environmental Information Systems [Book]. - Berlin : Springer, 1998. - ISBN: 3-540-60926-1.
77. **HABITAT:** Building an Environmental Management Information System (EMIS) [Book]. - [s.l.] : United Nations Human Settlements Programme (UN-HABITAT), 2008.
78. **Habitat:** Community-based Environmental Management Information System (CEMIS) Module No.4 [Book]. - Nairobi : United Nation Center for Human Settelments, 1995. - ISBN 92-1-131287-6.
79. **Hart, Stuart L.:** Beyond Greening: Strategies for a Sustainable World. [Journal] // Harvard Business Review 75. - [s.l.] : Harvard college, 1997. - Vol. 1. - pp. 66-76.
80. **Henri, Jean-Francois; and Journeault, Marc:** Environmental performance indicators: An empirical study of Canadian manufacturing firms [Journal] // Journal of Environmental Management. - [s.l.] : Elsevier, 2008. - Vol. 87. - pp. 165-176.
81. **Hevner, Alan R.; March, Salvatore T.; and Park, Jinsoo:** Design Science in Information System Research [Journal] // Management Information Systems Quarterly. - March 2004. - 1 : Vol. 28. - pp. 75-105.
82. **Hey, Christian:** EU Environmental Policies: A short history of the policies strategies [Book Section] // EU Environmental Policy Handbook; A Critical Analysis of EU Environmental Legislation. / book auth. Scheuer Stefan. - Brussels : EUROPEAN ENVIRONMENTAL BUREAU (EEB), 2005. - Link: http://www.eeb.org/?LinkServID=3E1E422E-AAB4-A68D-221A63343325A81B&showMeta=0.
83. **Hey, Christian:** SRU publication [Online] // German Advisory Council on the Environment (SRU). - March 4, 2010. -

http://www.umweltrat.de/SharedDocs/Downloads/DE/06_Hintergrundinformationen/2010_04_Towards_a_7th_EAP.pdf?__blob=publicationFile. - Presentation in the EEB Workshop 2010.

84. **Hillary, Ruth:** Developments in Environmental Auditing [Journal] // Managerial Auditing Journal. - [s.l.] : Emerald, 1995. - 8 : Vol. 10. - pp. 34 -39.
85. **Hillary, Ruth:** Environmental management systems and the smaller enterprise [Journal]. - Journal of Cleaner Production : Elsevier, 2004. - 6 : Vol. 12. - pp. 561-569.
86. **Hilty, Lorenz M.; and Rautenstrauch, Claus:** Environmental Information Systems for Production and Recycling [Conference] // 2nd International Symposium on Environmental Software Systems (ISESS), Whistler (Canada) / ed. Schimak D Wayne and R Denzer and G. - New York : Chapman & Hall, 1997. - pp. 21 - 29.
87. **Hilty, Lorenz Manuel:** Umweltbezogene Informationsverarbeitung. Beiträge der Informatik zu einer Nachhaltigen Entwicklung (Habilitationsschrift) [Book]. - Hamburg : Universität Hamburg, 1997. - korrigierte Auflage Oktober 2006.
88. **Hitchens, David:** Small and medium sized companies in Europe. Environmental performance, competitiveness and management; international EU case studies. [Book]. - Berlin : Springer-Verlag, 2003. - ISBN 3540401474.
89. **Honkasalo, Antero:** The EMAS scheme: a management tool and instrument of environmental policy [Journal] // Journal of Cleaner Production. - [s.l.] : Elsevier, 1998. - 2 : Vol. 6. - pp. 119 - 128.
90. **Houghton, J.T.; Ding, Y.; Griggs, D.J.; Noguer, M.; Van der Linden, P.J.; Dai, X.; Maskell, K.; Johanson, C.A. J.T.:** CLIMATE CHANGE 2001: The Scientific Basis [Book]. - Cambridge : The Press Syndicate Of The University Of Cambridge, 2001. - ISBN 0521 80767 0.
91. **Humphreysa, P.K.; Wongb, Y.K.; and Chan, F.T.S.:** Integrating environmental criteria into the supplier selection process [Journal] // Journal of Materials Processing Technology. - [s.l.] : Elsevier Science, 2003. - Vol. 138.
92. **IEEE:** IEEE Recommended Practice for Architectural Description of Software-Intensive Systems [Report]. - NY, USA : the Institute of Electrical and Electronics Engineers, Inc., 2000. - p. 9. - ISBN 0-7381-2519-9 SS94869.
93. **IEMA:** Institute of Environmental Management and Assessment ‘IEMA’ [Online] // IEMA. - 2009. - http://www.iema.net/ems/emas..
94. **IFM-bann:** Studien [Online] // IFM-bann.org. - 2002. - 2011. - http://www.ifm-bonn.org/index.php?id=89.
95. **ISO:** Information technology -- Process assessment -- Part 8: An exemplar process assessment model for IT service management [Report] / Software and systems engineering ; ISO. - 2012. - TC/SC: ISO/IEC JTC 1/SC 7.
96. **ISO:** ISO 14001 Environmental Management Systems: Specification with Guidance for Use [Report]. - Geneva : International Organisation of Standardisation, 1996.

97. **ISO/IEC:** ISO/IEC Directives, Part 1 [Report]. - [s.l.] : ISO/IEC, 2012.
98. **ISO14031:** International Standard ISO14031: environmental management- environmental performance evaluation. [Report] / Technical Committee 207. ; International Standards Organization (ISO).. - Geneva : [s.n.], 1996.
99. **Jamous, Naoum; Kramer, Frederik; Kassem, Gamal; Löschner, Elke; Mätäsniemi, Teemu:** Deploying OEPI ontology into the Light-Weight Composite Environmental Performance Indicators "LWC-EPI" system. [Conference] // BSOA. - [s.l.] : Shaker, **2011-I.** - pp. 101 -108. - ISBN 9783844005305.
100. **Jamous, Naoum; Kramer, Frederik; Kassem, Gamal; Gómez, Jorge Marx; Dumke, Reiner** Light-weight composite environmental performance indicators (LWC-EPI) concept. [Book Section] // Information Technologies in Environmental Engineering, New Trends and Challenges / book auth. Golinska P.; and Fertsch, M./ ed. Gómez, J.M. - Berlin : Springer, **2011-II**. - Vol. 3. - http://www.springerlink.com/content/j86665463452kt25/. - ISBN 978-3-642-19535-8.
101. **Jamous, Naoum; Kassem, Gamal; Gómez, Jorge M.; Dumke, Reiner :** Proposed Light-Weight Composite Environmental Performance Indicators (LWC-EPI) Model [Conference] // the 24st International Conference on Informatics for Environmental Protection (EnviroInfo2010). - Bonn & Cologne : shaker Verlag, **2010-I**. - pp. 222-231. - http://www.shaker.de/Online-Gesamtkatalog-Download/2011.01.20-19.39.57-141.44.30.154-rad5B823.tmp/3-8322-9458-9_INH.PDF. - ISBN 978-3-8322-9458-8.
102. **Jamous, Naoum; and Alwafaie, Rami; Albadawi D., Miguel:** Corporate Environmental Management Information Systems (CEMIS) - Sustainability Reporting Tools for SMEs [Conference] // EnviroInfo2012. Light up the ideas of Environmental Informatics; part 2: open data and industrial ecological management. - Dessau : Shaker, 2012. - Vol. 2. - pp. 657-664. - ISBN: 978-3-8440-1248-4.
103. **Jamous, Naoum; and Müller, Katrin:** Environmental Performence Indicators [Book Section] // Organizations' Environmental Performance Indicators: Measuring, Monitoring, and Management / ed. Dada Ali Stanoevska Katarina and Gómez Jorge M.. - Berlin : Springer, **2013-I.**
104. **Jamous, Naoum; and Müller, Katrin:** OEPI Deliverable D1.1: State-of-the-art for EPIs [Report]. - **2010-II**.
105. **Jamous, Naoum:** Light-Weight Composite Environmental Performance Indicators (LWC-EPI): A New Approach for Environmental Management Information Systems (EMIS) [Journal] // International Journal of Information Technologies and Systems Approach (IJITSA). - [s.l.] : IGI Global, 2013. - 1 : Vol. 6. - pp. 20-38.
106. **Jamous, Naoum; Kramer, Frederik; and Kassem, Gamal:** Evaluation categorizes, technologies decision for a Composite Environmental Performance Indicators (LWC-EPI)

solution [Conference] // Innovations in sharing environmental observations and information; (EnviroInfo2011). - Ispra : Shaker Verlag, **2011-III**. - Vol. 2. - pp. 669-683. - ISBN 978-3-8440-0451-9.

107. **Jamous, Naoum; Kramer, Frederik; and Schrödl, Holger;** Eine Light-Weight Composite Environmental Performance Indicators (LWC-EPI) Lösung - Eine systematische Entwicklung von EMIS, deren Anforderungen und Hindernisse aus Anwender-; KMU-Perspektive, Experten- und [Book Section] // IT-gestütztes Ressourcen- und Energiemanagement / ed. Gómez Jorge Marx, Lang Corinna and Wohlgemuth Volker. - [s.l.] : Springer Berlin Heidelberg, **2013-II**. - Vol. 3.
108. **Jamous, Naoum; Schrödl, Holger; and Turowski, Klaus:** Light-Weight Composite Environmental Performance Indicators (LWC-EPI) Solution: A Systematic Approach towards Users Requirements [Conference] // HICSS-46. - Maui : [s.n.], **2013-III**.
109. **Jasch, Christine;** Environmental Performance Evaluation and Indicators [Journal] // Journal of Cleaner Production. - London : Elsevier, 2000. - Vol. 8. - pp. 79-88.
110. **Jolliet, Olivier; Margni, Manuele; Charles, Raphaël; Humbert, Sébastien; Payet, Jérôme; Rebitzer, Gerald; Rosenbaum, Ralph:** IMPACT 2002+: A new life cycle impact assessment methodology [Journal] // the International Journal of Life Cycle Assessment. - 2003. - 6 : Vol. 8. - pp. 324-330. - DOI: 10.1007/BF02978505.
111. **Kerschberg, Larry; and Weishar, Doyle:** Conceptual Models and Architectures for Advanced Information Systems [Journal] // Applied Intelligence. - [s.l.] : Springer, Sept. 2000. - 2 : Vol. 13. - pp. 149-164.
112. **Kieser, Alfred; and Walgenbach, Peter:** Organisation [Book]. - Stuttgart : Schäffer-Poeschel, 2010. - 6 : p. 21. - ISBN 978-3-7910-2926-9.
113. **Kraemer, R. Andreas;** Results of the "Cardiff-Processes" – Assessing the State of Development And Charting the Way Ahead [Report] : Report to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. - Berlin : [s.n.], 2001.
114. **Král, Jaroslav; and Žemlička, Michal:** Service orientation in environmental information systems [Conference] // EnviroInfo 2005; Networking Environmental Information / ed. Hřebíček J Racek J (eds). - Brno : [s.n.], 2005. - pp. 12-23. - ISBN: 80-210-3780-6.
115. **Kramer, Johanes:** Erfahrungen mit der Entwicklung Betrieblicher Umweltinformationssysteme [Book Section] // Öko-Audit und Öko-Controlling, gemäß ISO 14000 ff und EG-Verordnung Nr.1836/93 / book auth. Schimmelpfeng Lutz and Machmer Dietrich. - Taunusstein : Blottner, 1996. - ISBN: 3-89367-059-9.
116. **Krcmar, Helmut; Dold, Georg; Fischer, Hartmut; Strobel, Markus; Seifert, Eberhard K.H:** Informationssysteme für das Umweltmanagement: Das Referenzmodell ECO-Integral [Book]. - Oldenbourg : Oldenbourg Wissenschaftsverlag, 2000. - ISBN-10: 3486254200.

117. **Kristensen, Peter:** The DPSIR Framework [Online] // http://enviro.lclark.edu. - 2004. - http://enviro.lclark.edu:8002/rid=1145949501662_742777852_522/DPSIR%20Overview.pdf.
118. **Kuik, Onno; and Verbruggen, Harmen:** In search of indicators for sustainable development. [Report]. - Dordrecht : kluwer academic publishers, 1991. - p. 27.
119. **Lang, Corinna:** Konzeption eines Referenzmodells für betriebliche Umweltinformationssysteme im Bereich der innerbetrieblichen Logistik [Book]. - Magdeburg : Shaker Verlag, 2007. - Dissertation . - ISBN-10: 3832257837.
120. **Lang-Koetz, Claus:** Ein Vorgehensmodell zur Einführung eines integrativen Umweltcontrollings auf Basis eines ERP-Systems [Report] : PHD report / Fakultät Maschinenbau, Uni Stuttgart . - Stuttgart : Jost-Jetter, 2006.
121. **Laudon, Kenneth C.; and Laudon, Jane P.:** Management Information System [Book]. - NY : Macmillan, 1994. - 3ed : pp. 08-46.
122. **Lee, Choong Kwon; Lee, Hong-Hee; and Kang, Moonsik:** Successful implementation of ERP systems in small businesses: a case study in Korea. [Journal] // Service Business. - [s.l.] : Springer-Verlag, Nov. 2008. - 4 : Vol. 2. - p. 276.
123. **Lee, Gwanhoo; and Xia, Weidong:** Development of a Measure to Assess the Complexity of Information Systems Development Projects. [Conference] // The International Conference on Information Systems (ICIS 2002). - Barcelona : ICIS 2002, 2002. - p. paper 8.
124. **Liberatore, Angela:** The integration of sustainable development objectives into EU policy-making: Barriers and prospects [Book Section] // The Politics of Sustainable Development: Theory, Policy and Practice Within the EU / ed. Baker Susan [et al.]. - [s.l.] : Routledge, 1997. - ISBN 0415138736.
125. **Liu, Chang; and Arnett, Kirk P.:** Exploring the factors associated with Web site success in the context of electronic commerce [Journal] // Information & Management. - [s.l.] : Elsevier, 2000. - Vol. 38. - pp. 23-33.
126. **Liu, Jian; Bastani, Farokh B.; and Yen, I-Ling:** Glue Code Synthesis for Distributed Software Programming [Book Section] // Advances in Systems, Computing Sciences and Software Engineering. - [s.l.] : Springer Netherlands, 2006.
127. **Loew, Thomas; and Kottmann, Heinz:** Kennzahlen im Umweltmanagement [Journal] // Oekologisches Wirtschaften. - München : [s.n.], 1996. - Vol. 2. - pp. 10–12.
128. **Loiseau Eléonore [et al.]** Adapting the LCA framework to environmental assessment in land planning [Journal] // Int. Journal Life Cycle Assessment. - Berlin : Springer-Verlag, May 16, 2013. - Vol. 18. - p. 1533.
129. **Löschner, Elke; and Mätäsniemi, Teemu:** OEPI Deliverable D1.3: Reference Ontology for EPIs –Requirements and Design [Report]. - 2011.

130. **Löschner, Elke:** Oepi Ontology [Book Section] // Organizations' Environmental Performance Indicators: Measuring, Monitoring, and Management / ed. Dada Ali, Stanoevska Katarina and Gómez Jorge M.. - Berlin : Springer, 2013.
131. **Mahmoud, Tariq:** Lightweight Semantic-enabled Enterprise Service-Oriented Architecture [Report] : PHD Dissertation / Department für Informatik ; Carl von Ossietzky University of Oldenburg. - Achen 2013 : Shaker Verlag, 2013. - p. 43. - ISBN: 978-3-8440-2122-6.
132. **Mann, Tejinder:** An Evaluation Perspective on Environmental Management Information Systems Software Selection using a Principle Agency Framework [Report] : Master's projects. - [s.l.] : Nicholas School of the Environment , 2012.
133. **Martin, Reiner; Mauterer, Heiko; and Gemünden, Hans-Georg:** Systematisierung des Nutzens von ERP-Systemen in der Fertigungsindustrie [Journal] // Wirtschaftsinformatik. - [s.l.] : Springer, April 2002. - 2 : Vol. 44. - pp. 110-111.
134. **Mas, Antonia; and L. Mesquida, Antoni:** A Software Tool to Support the Integrated Management of Software Projects in Mature SMEs. [Conference] // 18th European Conference, EuroSPI 2011, Roskilde, Denmark, June 27-29, 2011. Proceedings / ed. O'Connor .Rory V., Pries-Heje J. and Messnarz R.. - Roskilde, Denmark : Springer, 2011. - Vol. 1. - pp. 236-237.
135. **Matthews, Deanna H.:** Environmental management systems for internal corporate environmental benchmarking [Journal] // Benchmarking: An International Journal. - [s.l.] : MCB UP Ltd, 2003. - 2 : Vol. 10. - pp. 95-106. - ISSN: 1463-5771.
136. **Matute, Juan:** Methods for Modeling GHG Emissions from Transportation [Report]. - [s.l.] : UCLA, 2010. - Measuring Progress Symposium, March 05, 2010 .
137. **Meadows, Donella H.; Meadows, Dennis L.; Randers, Jørgen; Behrens, William W.:** The Limits to Growth [Book]. - [s.l.] : Universe Books, 1972. - ISBN-13: 978-0451057679.
138. **Meinshausen, Malte; Meinshausen, Nicolai; Hare, William; Raper, Sarah C. B.; Frieler, Katja; Knutti, Reto; Frame, David J.; Allen, Myles R.:** Greenhouse-gas emission targets for limiting global warming to 2 °C [Journal] // Nature. - [s.l.] : npg, 2009. - Vol. 458. - pp. 1158-1162. - ISSN: 0028-0836.
139. **Melville, Nigel P.:** Information systems innovation for environmental sustainability [Journal] // Management Information Systems Quarterly. - March 2010. - 1 : Vol. 34. - pp. 1-21.
140. **Mendelsohn, Robert; Nordhaus, William D.; and Shaw, Daigee:** The Impact of Global Warming on Agriculture: A Ricardian Analysis [Journal] // The American Economic Review. - [s.l.] : American Economic Association, 1994. - 4 : Vol. 84. - pp. 753-771.
141. **MEPI:** Measuring the Environmental Performance of Industry (MEPI) [Report] : Research Theme 4 / Human Dimensions of Environmental Change ; EC Environment and Climate Research Programme. - 2001. - Contract No.:ENV4-CT97-0655.

142. **Möller, Andreas; and Schaltegger, Stefan:** The Sustainability Balanced Scorecard as a Framework for Eco-efficiency Analysis [Journal] // Journal of Industrial Ecology. - 2005. - 4 : Vol. 9. - pp. 73-83.
143. **Möller, Andreas:** Efficiency : A Guiding Principle of Corporate Environmental Management Information Systems [Book Section] // Corporate Environmental Management Information Systems: Advancements and Trends / book auth. Teuteberg Frank and Marx Gómez Jorge. - New York : IGI Global, 2010. - ISBN13: 9781615209811.
144. **Molloy, Ian:** Environmental Management Systems and Information Management – Strategic-Systematical Integration of Green Value Added [Conference] // ITEE 2007; Information Technologies in Environmental Engineering. / ed. Gomez JM Sonnenschein M, Müller M, Welsch H, Rautenstrauch C. - [s.l.] : Springer, 2007. - pp. 251-260.
145. **Monecke, Armin; and Leisch, Friedrich:** semPLS: Structural Equation Modeling Using Partial Least Squares [Journal] // Journal of Statistical Software. - [s.l.] : the American Statistical Association, 2012. - 3 : Vol. 48. - p. 1. - ISSN: 1548-7660.
146. **Morrow, David; and Rondinelli, Dennis:** Adopting Corporate Environmental Management Systems: Motivations and Results of ISO 14001 and EMAS Certification [Journal] // European Management Journal. - [s.l.] : Elsevier Science Ltd., 2002. - 2 : Vol. 20. - pp. 159–171.
147. **MSDN:** The Microsoft Developer Network, library [Online]. - 2010. - 2010. - http://msdn.microsoft.com/en-us/library/ee658081.aspx.
148. **Mueller, John Paul:** Microsoft IIS 7 Implementation and Administration [Book]. - [s.l.] : John Wiley & Sons, 2008. - ISBN: 9780470178935.
149. **Müller, Katrin:** Design for Environment [Book Section] // Organizations' Environmental Performance Indicators: Measuring, Monitoring, and Management / book auth. Dada Ali, Stanoevska Katarina and Gómez Jorge M.. - [s.l.] : Springer, 2013.
150. **Nawrocka, Dagmara; Brorson, Torbjörn; and Lindhqvist, Thomas:** ISO 14001 in environmental supply chain practices. [Journal] // Journal of Cleaner Production. - [s.l.] : Elsevier Ltd., 2009. - 16 : Vol. 17. - pp. 1441-1442.
151. **Nee, Goh Yen; and Abdul Wahid, Nabsiah:** The Effect of ISO 14001 Environmental Management System Implementation on SMEs Performance: An Empirical Study in Malaysia [Journal] // Journal of Sustainable Development. 2010. 2 : Vol. 3.- pp. 215- 220.
152. **Noy, Natalya; and McGuinness, Deborah L.:** Ontology Development 101: A Guide to Creating Your First Ontology [Report] / Knowledge Systems Laboratory. - Stanford : Stanford University, 2000. - Technical Report KSL-01-05.
153. **NRTEE:** Measuring eco-efficiency in business: backgrounder [Report] / National Round Table on the Environment and the Economy (NRTEE). - Ottowa : [s.n.], 1997. - Available at www.nrtee-trnee.can.

154. **Ntoskas, Ioannis:** Identifying Environmental Performance Indicators for Non-manufacturing Companies: The case of Gardline Marine Sciences Group [Report] : Master of Science Thesis / School of Environmental Sciences ; University of East Anglia. - 2006.
155. **Nunnally, Jim: C.** Psychometric theory [Book]. - NY : McGraw-Hill, 1978. - 2.
156. **OEPI:** http://www.oepi-project.eu/ [Online]. - March 2010.
157. **Olsthoor, Xander; Tyteca, Daniel; Wehrmeyer, Walter; Wagner, Marcus Xander:** The EMAS scheme: a management tool and instrument of environmental policy [Journal] // Journal of Cleaner Production. - [s.l.] : Elsevier, 2001. - 5 : Vol. 9. - pp. 119 - 128. - URL: http://www.sciencedirect.com/science/article/pii/S0959652601000051.
158. **Österle, H.; Becker, J.; Frank, U.; Hess, T.; Karagiannis, D.; Krcmar, H.; Loos, P.; Mertens, P.; Oberweis, A.; Sinz, E.J. H.:** Memorandum on design-oriented information systems research [Journal] // European Journal of Information Systems. 2010. 1 : Vol. 20.
159. **Pandaya, Kaushik V.:** Sustainability for SMEs [Book Section] // Small and Medium Enterprises: Concepts, Methodologies, Tools, and Applications / book auth. Johnston Lindsay and Gamon Joel / ed. Association Information Resources Management. - [s.l.] : IGI, 2013. - ISBN 978-1-14666-3887-7.
160. **Papazoglou, Mike P.; and Van den Heuvel, Willem-Jan:** Service oriented architectures: approaches, technologies and research issues [Journal] // The VLDB Journal. - [s.l.] : Springer-Verlag, 2007. - 3 : Vol. 16. - p. 389.
161. **Peffers, Ken; Tuunanen, Tuure; Rothenberger, Marcus; Chatterjee, Samir;** A Design Science Research Methodology for Information Systems Research [Journal] // Journal of Management Information Systems. - NY : M. E. Sharpe, Inc., 2007. - 3 : Vol. 24. - pp. 45-77.
162. **Porter, Michael.E.; and Kramer, Mark R.;** Strategy and Society: The Link between Competitive Advantage and Corporate Responsibility [Journal] // Harvard Business Review 84. - [s.l.] : Harvard college, 2006. - Vol. 12. - pp. 77-92.
163. **Posch, Alfred;** A Management Information System (MIS) for Sustainability Networks [Conference] // Environmental Communica-tion in the Information Society / ed. W. Pillmann and Tochtermann K.. - Vienna : [s.n.], 2002. - pp. 502-509.
164. **Pride, William M.; Hughes, Robert J.; and Kapoor, Jack R.;** Business [Book]. - 2011. - 11 : p. 504. - accessed through the Boundless alternative, URL: https://www.boundless.com/business/organizational-structure/model-of-organization-structure/matrix-structire/CC-BY-SA. - ISAN: 978-0538478083.
165. **Ramayah, T.; Omar, Azizah; Mohamad, Osman; Mrimuth, Malliga; Yeap Ai Leen, Jasmine;** Green Manufacturing Practices and Performence among SMEs: Evidence from a Developing Nation [Book Section] // Small and Medium Enterprises: Concepts, Methodologies, Tools, and Applications / book auth. Johnston Lindsay and Gamon Joel / ed. Association Information Resources Management. - [s.l.] : IGI, 2013. - ISBN 978-1-14666-3887-7.

166. **Rautenstrauch, Claus:** Fachkonzept für ein integriertes Produktionssystem, Recyclingplanungssystem und Steuerungssystem (PRPS-System) [Book]. - Berlin : Walter de Gruyter, 1997. - ISBN 3-11-015446-3.
167. **Rautenstrauch, Claus:** Betriebliche Umweltinformationssysteme : Grundlagen, Konzepte und Systeme [Book]. - [s.l.] : Springer, 1999. - ISBN: 3-540-66183-2..
168. **Rennen, Ward; and Martens, Pim:** The Globalisation timeline [Journal] // Integrated Assessment. - London : Taylor & Francis, 2003. - 3 : Vol. 4. - pp. 137-144. - http://www.informaworld.com/smpp/content~db=all~content=a725291091~frm=titlelink. - 1389-5176.
169. **Rizzoli, Andrea E.; Athanasiadis, Ioannis N.; and Villa, Ferdinando:** Delivering Environmental Knowledge: a Semantic Approach [Conference] // EnviroInfo 2007; / ed. O Hryniewicz and J. Studzinski. - Warschau : Shaker, 2007. - Vol. 2. - pp. 43-50. - ISBN: 978-3-8322-6397-3.
170. **RobecoSAM:** DJSI 2013 Review Results. - [s.l.] : A cooperation of S&P Dow Jones Indices and RobecoSAM , 2013.
171. **RobecoSAM-AG:** Dow Jones Sustainability Australia Index Guide [Report]. - [s.l.] : RobecoSAM AG, 2013. - Version 6.3.
172. **Rohloff, Michael:** Advances in business process management implementation based on a maturity assessment and best practice exchange. [Journal] // Information Systems and e-Business Management. - [s.l.] : Springer, 2011. - 3 : Vol. 9. - pp. 392-402.
173. **Sackmann, Stefan:** Automatisierung von Compliance [Journal] // HMD, Praxis der Wirtschaftsinformatik. - [s.l.] : dpunkt.verlag, Oct. 2008. - 45 : Vol. 263. - pp. pages 39-46.. - ISSN: 1436-3011.
174. **SAI-Global:** AS3806-2006 Compliance programs [Report] / The Standards Australia Committe QR-014. - Sydney : SAI Global, 2006. - ISBN 073377296X.
175. **SAM:** www.sam-group.com - indexes [Online] // www.sam-group.com. - SAM, 1999. - 2011. - http://www.sam-group.com/en/indexes/index.jsp.
176. **Santos, Azulla: C.G.** Using life cycle assessment (LCA) methodology to develop eco-labels for construction and building materials [Book Section] // Eco-efficient Construction and Building Materials: Life Cycle Assessment (LCA), eco-labelling and case studies / ed. Fernando Pacheco-Torgal Luisa F. Cabeza, João Labrincha, , Aldo Giuntini de Magalhaes. - [s.l.] : Woodhead PL, 2014.
177. **SAP:** Sap Carbon Impact [Online] // SAP. - 2011. - 2011. - http://www.sapcarbonimpact.com.
178. **Schaltegger Stefan, Burritt Roger and Petersen Holger** An Introduction to Corporate Environmental Management – Striving for Sustainability [Book]. - Sheffield, UK : Greenleaf Publishing, 2003. - ISBN-13: 978-1874719656.

179. **Schmidt, M.; Lambrecht, H.; and Möller, A.:** Optimisation Approaches in Material Flow Models of Manufacturing Systems. [Conference] // EnviroInfo2007, Environmental informatics and systems research / ed. In: Hryniewicz O Studzinski J (eds). - Warsaw : Shaker, 2007. - Vol. 1. - pp. 545-552.
180. **Schroll, Hennin; and Kjærgård, Bente:** Sustainable Development and TES. [Journal] // Journal for Transdisciplinary Environmental Studies. - 2006. - 1-2 : Vol. 5. - pp. 1-3. - ISSN: 1602-2297.
181. **Schulz, Werner F.; and Burschel, C.:** Lexikon Nachhaltiges Wirtschaften [Book]. - München : Oldenburg Verlag, 2001.
182. **Schulze, Lothar:** Basics planning of logistical systems [Report] : online module / Global campus 21 ; Deutsche Gesellschaft für Internationale zusammenarbeit (GIZ) GMBH. - [s.l.] : GIZ, 2006.
183. **Schumacker, Randall E.; and Lomax, Richard G.:** A beginner's guide to structural equation modeling [Book]. - New Jersey : Lawrence Erlbaum Ass., Inc., 2004. - 2 : pp. 01 - 10. - 0805840176.
184. **Scipioni, Antonio; Mastrobuonob, Michele; Mazzi, Anna; Manzardo, Alessandro:** Voluntary GHG management using a life cycle approach. A case study [Journal] // Journal of Cleaner Production. - [s.l.] : Elsevier Ltd., 2010. - 4 : Vol. 18. - pp. 299-300.
185. **SD-CSR Enablon:** Enablon SD-CSR [Online] // Enablon. - 2011. - http://enablon.com.
186. **Seuring, Stefan; Müller, Martin; Westhaus, Magnus; Morana, Romy** Conducting a Literature Review - The Example of Sustainability in Supply Chains [Book Section] // Research Methodologies in Supply Chain Management. - [s.l.] : Springer, 2005. - ISBN: 978-3-7908-1583-2.
187. **Siegenthaler, Marcel; and Schmid, Cyrill:** ERP für KMU. Praxisleitfaden: richtig evaluieren & einführen. [Book]. - Rheinfelden/Schweiz : BPX-Edition, 2005. - pp. 8-39. - ISBN: 390541371X.
188. **Silver, Mark S.; Markus M., Lynne; and Beath, Cynthia Mathis:** The Information Technology Interaction Model: A Foundation for the MBA Core Course [Journal] // MIS Quarterly. - [s.l.] : Management Information Systems Research Center, University of Minnesota, 1995. - 3 : Vol. 19. - pp. 361-390.
189. **Skillius, Åsa; and Wennberg, Ulrika;** Continuity, Credibility and Comparability; Key challenges for corporate environmental performance measurement and communication [Online] // http://www.ertc.deqp.go.th. - March 20, 1998. - April 2008. - http://www.ertc.deqp.go.th/ertc/images/stories/user/ct/ct1/cp/cp_accounting_and_financial_analysis/eea_corp_env_reptg.pdf.
190. **Smith, Ann; Kemp, Robert; and Duff, Charles;** Small firms and the environment: factors that influence small and medium-sized enterprises' environmental behaviour [Book Section] // Small and Medium-Sized Enterprises and the Environment: Business Imperatives / book auth. Hillary Ruth. - New York : Greenleaf Publishing, 2000. - http://www.greenleaf-publishing.com/productdetail.kmod?productid=19. - 978-1-874719-22-9.

191. **SoFi:** Sofi Software [Online] // SoFi Sofware. - 2011. - 2011. - www.sofi-software.com/deutsch/index/.
192. **SRU:** Environmental Report 2002 [Online] // The German Advisory Council on the Environment. - 2002. - http://www.umweltrat.de/DE/Publikationen/publikationen_node.html. - http://www.umweltrat.de/SharedDocs/Downloads/EN/01_Environmental_Reports/2002_Environmental_Report_summary.pdf?__blob=publicationFile.
193. **Staab, Steffen; Schnurr, H P; Studer, Rudi; Sure, York V.:** Knowledge processes and ontologies [Journal] // Intelligent Systems, IEEE. - [s.l.] : IEEE, 2001. Vol.16., pp. 26-34.
194. **Steger, Ulrich:** Environmental Management Systems:Empirical Evidence and Further Perspectives [Journal] // European Management Journal. - UK : Elsevier Science Ltd., 2000. - 1 : Vol. 18. - pp. 23–37. - http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6V9T-3YF4490-5-1&_cdi=5907&_user=1908389&_pii=S0263237399000663&_origin=search&_coverDate=02/29/2000&_sk=999819998&view=c&wchp=dGLbVzb-zSkWb&md5=44e444d63cc1460ea071aee6ffb5c0e8&ie=/sdarticle.pdf.
195. **Sun, Albert Y.T.; Yazdani, Abe; and Overend, John D.:** Achievement assessment for enterprise resource planning (ERP) system implementations based on critical success factors (CSFs) [Journal] // International Journal of Production Economics. - [s.l.] : Elsevier, 2005. - Vol. 98. - pp. 189-203.
196. **Süpke, Daniel; Allam, Nabil; and Gómez, Jorge M.;** Solving Environmental Management and Public Relation Issues by Combining Industrial Environmental Information Systems with Automated Environmental Reporting [Conference] // Environmental informatics and industrial ecology, / ed. Möller A Page B, Schreiber M (eds). - Lüneburg : Shaker, 2008. - pp. 28-31. - Proceedings of the 22nd International Conference Environmental Informatics - Informatics for Environmental Protection, Sustainable Development and Risk Management.
197. **Supply-Chain-Council:** SCOR 9.0 Model Reference [Online] // www.supply-chain.org. - 2008.
198. **Tabachnick, Barbara G.; and Fidell, Linda S.:** Using Multivariate Statistics [Book] / ed. 5. - [s.l.] : Pearson, 2006. - ISBN-10: 0205459382.
199. **Taylor, Frederick W.:** The Principles of Scientific Management [Book]. - New York : Harper & Brothers Publications, 1911.
200. **Teuteberg, Frank; and Gómez, Jorge Marx:** Green Computing & Sustainability - Status quo und Herausforderungen für BUIS der nächsten Generation [Journal] // HMD. - August **2010-II**. - 47 : Vol. 274. - pp. 6-17. - ISSN 1436-3011.
201. **Teuteberg, Frank; and Gómez, Jorge M.:** Corporate Environmental Management Information Systems: Advancements and Trends [Book]. - [s.l.] : IGI Global, **2010-I**. - ISBN 978-1-61520-981-1.

202. **Teuteberg, Frank; and Gómez, Jorge M.:** Tawords the next generation of Corporate Environmental Management Information Systems: What is there and what is missing? [Book Section] // Corporate Environmental Management Information Systems: Advancements and Trends. - NY : IGI Global, 2010-III. - Vol. 1. - ISBN 978-1-61520-981-1.
203. **Teuteberg, Frank; and Straßenburg, Jan:** State of the art and future research in Environmental Management Information Systems - a systematic literature review [Book Section] // Information Technologies in Environmental Engineering / book auth. Athanasiadis Ioannis. N. [et al.]. - Berlin Heidelberg : Springer, 2009. - ISBN-13: 978-3540883500.
204. **Thies, Hans; and Stanoevska-Slabeva, Katarina:** Environmental Reporting [Book Section] // Organizations' Environmental Performance Indicators. - [s.l.] : Springer Berlin Heidelberg, 2013.
205. **Tinsley, Stefen; and Pillai, Illona:** Environmental Management Systems: Understanding Organizational Drivers and Barriers [Book]. - London : Earthscan, 2006. - ISBN: 1853839361.
206. **Tsoulfas, Giannis T.; and Pappis, Costas P.:** A model for supply chains environmental performance analysis and decision making [Journal] // Journal of Cleaner Production. - [s.l.] : Elsevier Ltd, 2008. - Vol. 16.
207. **UNAIDS:** Glossary of M&E Terms [Report]. - 2008. - Prepared by the Evaluation Technical Working Group of the Joint United Nations Programme on HIV/AIDS (UNAIDS), Monitoring and Evaluation Reference Group..
208. **UNEP:** The UNEP Corporate Reporting Guide, Companies and Analysts Measure Corporate Performance. [Report]. - New York : UNDP, 1994.
209. **Uschold, Mike; and King, M. Martin:** Towards a Methodology for Building Ontologies [Conference] // The 1995 International Joint Conference on AI (IJCAI95). - Monterial : [s.n.], 1995. - Workshop on Basic Ontological Issues in Knowledge Sharing.
210. **US-EPA:** Environmental Indicators Gateway [Online] // U.S. Environmental Protaction Agency. - July 2010. - http://www.epa.gov/igateway/whatIndicator.html.
211. **Vasilenko, Laura; and Arbačiauskas, Valdas:** Obstacles and Drivers for Sustainable Innovation Development and Implementation in Small and Medium Sized Enterprises [Journal] // Environmental Research, Engineering and Management. - June 2012. - 2 : Vol. 60. - pp. 58-66. - ISSN: 1392-1649 .
212. **Viere, Tobias; and Möller, Andreas:** Pleased Accountants – Happy Environmentalists: Challenges of Environmental Management Accounting for Management Information Systems and Tools [Conference] // EnviroInfo 2006: Managing Environmental Knowledge / ed. K. Tochtermann and A. Scharl. - Graz : Shaker, 2006. - pp. 307-310. - ISBN: 978-3-8322-5321-9.
213. **Waldron, Christina D.; Harnisch, Jochen; Lucon, Oswaldo; Mckibbon, R. Scott; Saile, Sharon B.;** Mobile Combustion [Book Section] // IPCC Guidelines for National Greenhouse Gas Inventories. - [s.l.] : IPCC, 2010. - Vol. 2.

214. **Waters, Jean S.:** Environmental Management Systems [Report] / Health and Environment ; University of Kansas. - 1998. - prepared for the Small Business Leadership Training Program, 1998.

215. **Watson, Richard T.; Boudreau, MMarie-Claude; Chen, Adela J.; H., Sepúlveda Héctor:** Green projects: An information drives analysis of four cases [Journal] // The Journal of Strategic Information Systems. - [s.l.] : Elsevier, March 2011. - 1 : Vol. 20. - pp. 59-61.

216. **WCED:** Report of the World Commission on Environment and Development (WCED): Our Common Future. [Report]. - [s.l.] : Oxford University Press, 1987.

217. **Webster, Jane; and Watson, Richard T.:** Analyzing the Past to Prepare for the Future: Writing a Literature Review [Journal] // MIS Quarterly. - [s.l.] : MISQ, June 2002. - 2 : Vol. 26. - pp. xiii–xxiii.. - Guest Editorial.

218. **Welford, Richard:** Corporate Environmental Management: systems and strategies [Book]. - London : Earthscan Pub, 1996.

219. **White, Gwendolen B.:** Sustainability Reporting: Managing for Wealth and Corporate Health [Book]. - NY : Business Expert Press, 2009. - ISBN-10: 1606490788.

220. **Winter, Robert; and Joachim, Schelp:** Dienstorientierung im Business Engineering [Journal] // HMD- Praxis Der Wirtschaftsinformatik. - Feb. 2005. - 42 : Vol. 241. - pp. 45-54.

221. **Wymenga, Paul; Spanikova, Vera; Barker, Anthony; Konings, Joep; Canton, Erik:** EU SMEs in 2012: at the crossroads, Annual report on small and medium-sized enterprises in the EU, 2011/12 [Report] / Ecorys and Cambridge Econometrics. - Rotterdam : EU commission, 2012.

222. **Yap, CS; CPP, Soh.; and Raman, KS:** Information Systems Success Factors in Small Business [Journal] // Int. J. of Mgmt Sci. - [s.l.] : Pergamon Press Ltd, 1992. - 5/6 : Vol. 20. - pp. 579-609.

223. **Zachman, John A.:** A Framework for Information Systems Architecture [Journal] // IBM Systems Journal. - [s.l.] : IBM, 1987. - 3 : Vol. 26. - p. 277.

224. **Zhang, Zhihui; Wu, Xing; Yang, Xiaomin; Zhu, Yimin**: BEPAS—a life cycle building environmental performance assessment model [Journal] // Building and Environment. - [s.l.] : Elsevier, 2006. - Vol. 41. - p. 669.

225. **Zoellick, Bill; and Frank, Ted:** Governance, Risk Management, and Compliance: An Operational Approach [Report]. - [s.l.] : Gilbane Report, 2005.

226. **Zorpas, Antonis:** Environmental management systems as sustainable tools in the way of life for the SMEs and VSMEs [Journal] // Bioresource Technology. - [s.l.] : Elsevier, March 2010. - 6 : Vol. 101. - pp. 1544-1557.