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METHODOLOGY FOR ENERGY EFFICIENCY ASSESSMENT

Master of Science thesis

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Examiner and topic approved by the Faculty Council of the Faculty of
6th May 2015

ABSTRACT

MARIA FERNANDA MANTILLA RAMOS: Methodology for Energy Efficiency Assessment
Master of Science Thesis, 72 pages, 23 Appendix pages
April 2015
Master's Degree Program in Machine Automation
Major: Factory Automation
Examiner: Professor Dr. Jose L. Martinez Lastra

Keywords: Smart Cities, Energy Efficiency, Key Performance Indicators, parameters, methodology.

The rapid urbanization processes and increasing populations pose issues to cities, especially in the area of energy requirements. Smart City strategy has been used for many cities to overcome those issues by implementing energy efficient projects and handle the systematically more complex nature of the city, through interconnected frameworks, and the use of Information and Communication Technology (ICT). However the absence of a common methodology for monitoring and evaluation those energy efficiency projects produce misleading in their final impact.

This thesis explores the energy efficient projects and the methodologies around their evaluation, to finally propose a methodology for energy efficient assessments for Smart Cities. As the number of systems that form a city is considerable high, this thesis consider two sectors, Transport Sector (TrS) and Industrial sector (IndS), this last one on the point of view of the current standardizations on Energy Management System (EMS). The methodology is applied to three smart cities, and feedback from cities authorities is integrated to refine the methodology as well as its implementation process. Finally a generic application is designed to support the methodology implementation process, and use in one of the smart cities.

PREFACE

This document is the result of long hours work share with friend and colleagues. I want to thank Professor Jose L. Martinez Lastra to give me the opportunity to work in an interesting project, as well as all the members of FAST laboratory. In addition, to my dear friends Anisha, Veeru, and Maya for their support and good food when I needed, and Behar for all those weekends working with me.

I dedicate this work to my mother, my hero and inspiration, and family for their constant encouragement.

Le dedico este trabajo a mi madre, mi héroe e inspiración, y a mi familia por su constante apoyo.

22 of June of 2015

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

ALM	Alternative Modes
API	Application Programming Interface
ASME	American Society of Mechanical Engineers
CO2	Carbon Dioxide
CVS	Cleaner Vehicles Strategies
EC	Energy Consumption
EE	Energy Efficiency
EMS	Energy Management System
GUI	Graphical User Interface
ICT	Information and communications technology
ID	Identification
IEA	International Energy Agency
IEE	Intelligent Energy Europe
IIASA	International Institute for Applied Systems Analysis
IndS	Industry Sector
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
MEEP	Measures of industrial Energy Efficiency Performance
MMS	Mobility Management Strategies ()
MOST-MET	Monitoring & Evaluation Toolkit
MVC	Model View Controller
OPTIMUS	OPTIMising the energy USe in cities with smart decision support systems
OR	On Road routes
PHP	PHP Hypertext Pre-processor
PT	Public Transport
PTP	Personal Travel Planning
PV	Private Vehicles
R&D	Research and Development
REST	REpresentational State Transfer
SEAF	Smart City Energy Assessment Framework
SME	Small and Medium sized Enterprises
SRA	Swedish Road Administration
SUMO	System for Evaluation of Mobility Projects
TF	Traffic free road
TMC	Transport Mode of Choice
TrS	Transport Sector
TUT	Tampere University of Technology
URL	Uniform Resource Locator

pkm	passengers per km
pp	number of users

1. INTRODUCTION

Over the past years authorities around the world had to face a rising demand of energy, especially in main cities. The demand of energy is increasing in hand with the growing population. By 2020 it is expected that 75% of the world population will be in the cities, and 50% of those cities will be over 10 million people. In Europe, the percentage is higher with 80% of inhabitants living and working in cities. Data from the international energy agency shows that by 2035, the global energy demand will rise 1/3, mainly from demand of transportation, industry and housing [1][2].

Cities have to face multiple consequences of having large populations, W. J. Mitchell (2007) compile some of those consequences like increase need of resource management, air pollution, traffic congestion, etc. [3]. According to the models for 2050 from the EU energy agency, the growing tendency of the transportation Energy Consumption (EC) will stay until 2030. The increase is caused by freight transport, following by passenger transport, where road is the main component of this last one representing 32.6%. Road transportation had continuously transformed the landscape of entire countries, especially in areas where the landscape had been designed for vehicles, not for people. Vehicles made easy to commute longer distances and as the prices went down during the 20th century, vehicles positioned as the principal mode of transportation in several countries such as USA, Australia, Canada, and some countries in Europe [2][4].

The increased number of vehicles and suburbanization made mobility needs scale up in distance and participants having result in several consequences apart to the energy use. A report of the European Commission compile those consequences in one concept, the external cost of transport, which is mainly compose by the congestion, accidents, air pollution, noise, climate change and marginal infrastructure. Other studies add the olfactory and visual contamination, social and urban fragmentation, as well as the public health deterioration. Even though the transport external cost is considerable high is generally not include by the users and hence not taken into account at the time of taking a transport decision, thus the side effects of the decisions is imposed into the society [1][5].

The Industry sector (IndS) use about 30% of the global energy, most of it is required in emerging countries like China and India. However the energy intensity in different countries had been decline, the reason might be found in energy (especially fuels) price rises that force industries to improve their energy efficiency. Despite the reduced energy use, there is a potential in energy savings of 10% to 30% that can be achieve either by process integration, such as heat pumps and cogeneration, or by replacing old technology like motors [1]. Another report from the European commission found that there is a potential of 50% in emissions reductions just by reaching better energy efficiency. The reduction in the transport sector can be found in current use of inefficient technologies (such as old cars), and consumerist habits (changing from needs to desires[1]). The 2050 energy strategy also concluded that EE has a relation between energy efficient technologies and changes in citizen behaviour, additional to the use of several alternative fuels which is expected will replace conventional fuels [6].

This rapid urban population growth increases the need of finding smarter ways to manage resources (energy, fuel etc.) and smart city is the strategy to mitigate the problems generated by this rising population and rapid urbanization. Figure 1 illustrates the holistic approach of a Smart City with emphasis in sustainable EC combined with the Smart City concept. These cities are defined in the Europe 2020 Initiative from the European Commission as the place where:

"digital technologies translate into better public services for citizens, better use of resources and less impact on the environment."[7]

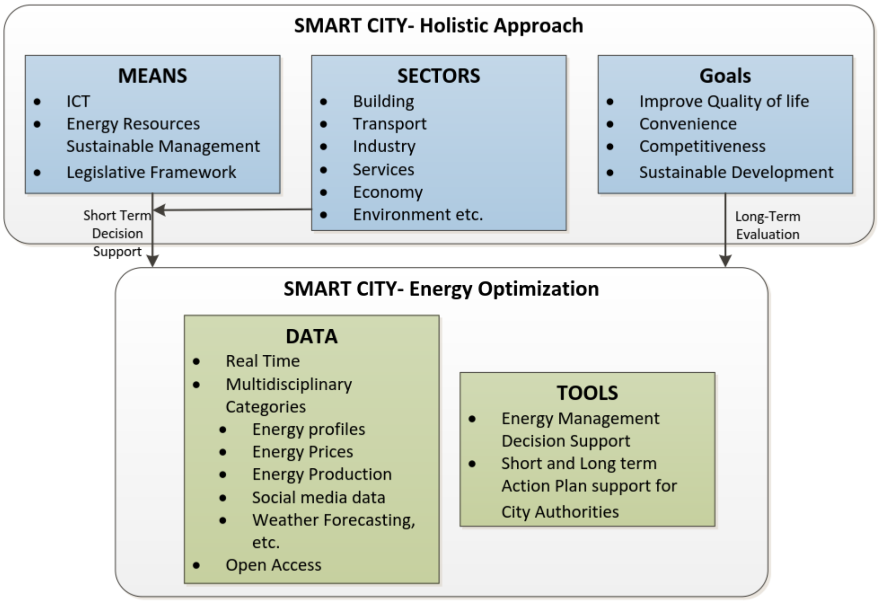

Figure 1. *Smart City holistic and energy optimization approach from [8].*

Several countries had been developing policies and strategies to engage the EE, as an illustration, the energy efficiency plan 2020 for Europe describes how EE can be a considerable source of energy. This efficiency is supported by several strategies including the implementation of advanced traffic management systems, infrastructure that will develop a Single European Transport Area to promote multimodal transport. On the IndS, industrial low carbon roadmaps are the principal measure for energy reduction, however introduction of new cooperative models, eco-industrial parks and new energy

[1] An example is mobility preferences, e.g. USA citizens are least likely to use public transportation than private vehicles, even though both fulfil the need of mobility.

sources like biomass had been also implemented. Additionally, investments in smart pricing technologies (for PT and Private Vehicles (PV)), ICTs (Information and communications technology) and higher regulations in efficiency standards for vehicles, and production lines are other measures.

On the side of citizens' behaviour, the European commission included actions to make more attractive public transport (PT) or politics that restrict the number of cars in determinate areas of the city, additional infrastructure for multimodal connections as well as facilities for alternative modes (walking and cycling), among other strategies. However a widely accepted methodology to perform monitoring and evaluation of those strategies in terms of energy at the level of the cities' transport systems is still missing [2][9].

Stablish the central role of the EE in the reduction of EC and as a source of energy, city authorities will require tools to follow and evaluate the performance of cities' systems (TrS, IndS, etc.). Therefore, defining appropriate methodologies to perform monitoring and evaluation energy assessments at the level of city's system is a key element in order to design future policies that pursuit sustainable systems.

1.1 Problem Definition

Difficulties in the monitoring and evaluation process of projects that attempt to increase the city's EE are partly due the complex nature of the systems. The complex term is assign to a system that has several components that interact between them in several ways, which might be or non-linear. One of the characteristics of this kind of system is that are difficult to predict [10]. As a consequence, the evaluation of TrS and IndS constitutes a challenge for cities' authorities around the word.

Some studies attribute the complexity of the system to a variety of interconnected problems. In the case of TrS, the combination of the external cost of transport with the components that generate those costs are the source of the complexity. As an example, the vehicles generate noise, carbon dioxide and represent status. At the same time, the noise has negative impact in city's residents, carbon dioxide impact health and increases greenhouse effect (no-only in the city but globally), and the last one, status emphasize the income inequality that can also represent social problems [11]. Users (citizens) constitute a considerable portion of the complexity of the system. According to the Organisation for Economic Cooperation and Development (OECD), millions of citizen's daily action have a great impact into the system, so in order to reduce the impact, it will require to understand how each of the individuals make a travel decision and what motivates them to choose one mode over the others [12].

The IndS complexity comes from the diversity of the industry (primary, secondary and tertiary) as well as their internal processes (Manufacturing, services, extraction, etc.)

that can include diverse number of components that might be unique or standard. Despite the complexity of the system the need of measuring its performance is a permanent issue for most of the authorities, but in order to measure and increase the EE of the city they shall handle the complexity of the systems first.

Strategies to reduce complexity for performing monitoring and evaluation processes are already implemented in the IndS. Effective Energy Management System (EMS) had been use as the base for presenting energy information in form of Key Performance Indicators (KPIs) to improve EE in the production floor. Several studies have proposed KPIs for various aspects of the industry, implementations focused in functional layers of the system had been performed, as well as information relevance classifications [13][14][15].

In light of these sources of increasing expend of energy in IndS, TrS and others, complexity of the system and absence of a common framework for monitoring and evaluating projects in the energy domain, it is important to devise a coherent objective methodology in order to assist the monitoring and evaluation processes. This methodology will provide a structure, in order to guarantee the quality and comparability of the energy assessment.

1.2 Work description

The aim of this work is to develop a methodology for energy assessments for smart cities, which has as a purpose, to give clarity in issues related to the monitoring and evaluation processes of EE projects. The method here explained is a guideline that might be complemented by authorities' experience and knowledge of their own cities system in order to achieve energy savings, higher energy efficiency, lower carbon footprint, etc.

The methodology here developed is supported by a list of performance indicators. The performance indicators might be pursued to overcome or manage in a more simple way the complexity of the system, as it is currently applied to other complex systems. The project includes the methods for calculating each of the indicators, as well as recommendations for future ICT applications.

1.2.1 Objectives

The main objective of the thesis, as it is mentioned before, is to develop a methodology for energy assessment in the TrS, IndS, etc. for smart cities. In order to achieve the main objective, the thesis is divided in sub objectives that are presented below:

1. Develop a methodology that is supported by objectives 2 and 3.
2. Identify a set of relevant KPIs for TrS in energy.
3. Identify a set of energy KPIs for IndS in energy.
4. Implement the methodology in some European cities.

5. Design and implement a web based methodology management system that provides guidance on the methodology to be used for the monitoring and evaluation process of energy projects mainly in TrS and IndS.

1.2.2 Methodology

A literature review was used to structure a methodology for energy assessments. Through the methodology approach, exploration of KPIs for the TrS and Ind was performing based on the needs and concept of Smart City.

The research is dividing in the following phases:

- Phase1: a literature review on projects related with EE in TrS and IndS, KPIs and their role in energy monitoring and evaluation, and methodologies for energy assessments. During this phase key aspect of the thesis were identified.
- Phase 2: the development of a methodology for energy efficiency assessment was conducted. A design of an application was perform in order to support authorities in the application of the methodology.
- Phase 3: the implementation of the methodology in TrS for three smart cities. However the designed tool for methodology support only was used in one smart city (Tampere, Finland).

1.2.3 Assumption and limitation

The thesis is done under the following assumptions and limitations:

- The information provided by the smart cities is assumed to be correct and reliable.
- The KPIs cover the most relevant components of the system in terms of their impact in overall energy efficiency.
- The methodology is not static and rigid; in consequence, it can be modified to fulfil the requirement of the application.

1.3 Outline

This document is structured as follows. Chapter 2 present the background, including the EE projects, the KPIs related with the transport domain, the EE scale up/down parameters, and the KPIs for EMS energy information. Chapter 3 introduces the developed energy efficiency methodology. Chapter 4 describe the application of the methodology in three European cities. Chapter 5 gives an overview of the web based methodology management system used in this thesis and its application on Tampere, Finland TrS. Finally chapter 6 concludes and present future work.

2. BACKGROUND

This chapter presents an overview of the background behind the methodology application done in this thesis project. First, some projects that aim to increase the energy performance of the TrS and IndS around the word are described. Then a background on mobility projects and policies are used to develop a list of KPI in transport sector, for the IndS a review of KPIs in MES energy management systems is include. Finally some of the existing methodologies for evaluate mobility projects and EE standards are studied.

2.1 Energy efficiency Projects

As the cities energy requirements increase constantly in a time of limited quantity of resources left, governments have as a challenge to increase the efficiency of their systems, in other words to do more with less. Several projects have been already implemented and others are on the way to be, but government are not the only source of those projects, applications from the private sector are joining the tendency to reduce the energy use. This chapter outline some of those projects that aim to reduce the EC in different areas of the TrS and IndS.

2.1.1 Projects in the TrS

Countries and organizations across the world have implement ambition solutions to increase their EE and corresponding reduction of CO2 emissions and energy (fuel) consumption. Those solutions can be classified in six areas depending of their focus area: *consumption information, sustainable PT, switching modes in passenger transport, navigation systems, intermodal transport, and alternative fuels*.

- Consumption information

Consumption information has several applications, one of them is to persuade car owner or future owners to use the most efficient vehicle (use less fuel). Strategies such as ***Fuel economy label*** from EPA, rank vehicles with a label with multiple data related with energy, so at the end, the user can identify its car with the label and simple information about the greenhouse gas emissions (GHG) and their effect on the environment reinforcing the choice [16]. Similar, ***Energywise*** from New Zeeland shows the consumption of fuel in money, so the user can go for the cheapest option that fulfil his/her needs without over size the vehicle [17].

Australian government in a simpler format gives the consumption of the vehicles through a ***Green Vehicle Guide*** support by multiple applications [18]. Another data base from UK is ***Car Fuel Economy and Emissions: Find the Best*** gives similar information as the previous projects mentioned [19]. Also from UK ***Fuel Good*** mobile application not only uses the technical information of the car, but tracks the user activity in real time, with the information suggests fuel-efficient driving habits [20]. Comparatively, ***GreenMeter*** mobile application shows consumption, as same as, savings in fuel [21].

- Sustainable PT

To reach a sustainable PT system is one of the priorities for achieving efficient transport systems. Sustainable PT are obtained by impacting different areas, the most use is by increasing its market share in the TrS, other way is by reducing the emissions of the vehicles (Bus, trains, ships etc.) or its infrastructure (stations, stops, etc.). New electro-mobility solutions aim to make infrastructures more energy efficient by managing energy. In Madrid, ***Train2car*** project uses energy regenerations installed in the Metro to get energy is use to charge stations for electric vehicles [22]. Similar projects had been deploying by ***Clean Fleets*** from Intelligent Energy Europe (IEE) program, which assist cities in implementing energy-efficiency vehicles for PT, same as ***CIVITAS*** [23][24]**.**

- Switching modes in passenger transport

These projects promote changes in users' daily travel behaviors, specifically on their transport mode choices (TMCs). ***PTP-Cycle*** from IEE uses Personal Travel Planning (PTP) methods to promote shifting from PV to ALM [25]. Other project from IEE is ***MOBI***, which encourage companies to establish their own mobility projects, focus on sustainable transport modes (such ALM) for their commute and business travel journeys [26]. Similarly, websites like ***carpoolingnetwork.com*** and ***Carpooling.com*** App and website, point to car users, but in this case they attempt to increase occupancy of PV by offering a platform for carpooling and information about the CO2 saved, rather than change their TMC.

Other initiatives promote the use of ALM by giving journey options and personalize information. Some examples are ***Walkit.com, Sustrans***, ***and cyclesheme.co.uk*** websites, where journey planners give information in ALM, as well as extra simulations such as calories that have been burned, Carbon Dioxide equivalent emissions (CO2) saved or/and money saved by using ALM [27][28][29].

- Navigation systems

In order to make the system more efficient, reduction of congestion and effective routes are key measures. Nevertheless those measures require high accuracy navigation systems. Projects like ***GALILLEO*** from the European Space Agency, will provide highly accurate global positioning service, ***SESAR*** is the pillar of ***Single European Sky*** project that aims to make an efficient use of European airspace by develop a unified air traffic management system [30][31]. Other projects like ***FREILOT*** from ***eCoMove*** and ***DRIVE C2X*** impact directly on optimizing the vehicles speed and traffic light phase in cities [32][33].

- Intermodal transport

Intermodality opens multiple possibilities to perform a more sustainable journey to/into/and in the cities by interconnecting transport modes. Projects like ***Kombiverkehr*** and ***Oy Langh Ship*** aim to facilitate intermodal transport in Europe by creating new infrastructure and ICT. ITS Niedersachsen is an extended group of industries in the transport sector that aims to develop intermodal and sustainable mobility services through several projects, especially in the ICT area [34].

Others examples are ***Wattmobile***, which offers electric scooters and bicycles outside of the rail station, so passengers can use them to get to their final destination. ***Personal Travel Assistant*** from CISCO is an application that calculates best itineraries by taking the CO2 emissions in consideration and multimodal transportation, with additional functionalities ***MoveUs*** project also integrates multimodal journeys and EC [35][36][37].

- Alternative fuels

Another way to achieve higher EE is by introducing alternative fuels, not only they guaranty a new source of energy, but also decreases cities fuel dependency. ***ALTER-MOTIVE*** project aims to find new alternative fuels and corresponding technologies in vehicles to create new sustainable PV and PT systems. Information about these technologies is available in tools like ***Alternative Fuel Data Center (AFDC)*** from U.S. Department of energy (38)(39).

2.1.2 Projects in the IndS

The industrial sector account for around 28% of the energy consumption of the global consumption, where 26% is loss [1]. However, better practices in different countries have shown declines in that waste and rises in EE. Practices like the implementation of the energy management standard ISO 50001 (ISO: International Organization for Standardization, ISO 50001: Energy management), the replacement of old motor system for new and more EE systems, heat recovery, waist control, etc. had been applied to different sectors of the IndS. Examples of industries that adopted those practices had achieved savings between 10 to 30% in the average operational cost.

Even though practices such as energy management programs had been implemented in Denmark, Sweden, Ireland, South Korea, Spain, Thailand, and USA, there is still a concern about the rising energy need in developing countries like china or India. Data from the IIASA (International Institute for Applied Systems Analysis) revels that the average EE is 30% globally, this mean that new processes and technologies should be implement in order to achieve greatest EE. Some of the improvements can be through Research and Development (R&D), especially in whole processes instead of individual components. At the same time, more countries should encourage the application of energy management standards like ISO 50001, and promote system assessment standards for systems, such as ASME (American Society of Mechanical Engineers) standard for motors and steam systems. Finally, authorities in all countries and industry partnerships should stablish an environment to incentive EE learning between companies by sharing and documenting best practices, so in that way opportunities to increase EE will widespread through all the IndS [1][40][41].

The link between the EE need and policy design is essential, not only because guarantee best use of energy, but to ensure resources for the future. Thus government and industry have been applying projects in different areas of the industry and processes, as well as in different sectors. A systematic view of an industrial process in Figure 2 show the different components in which some of the projects that are mention in this section have focus.

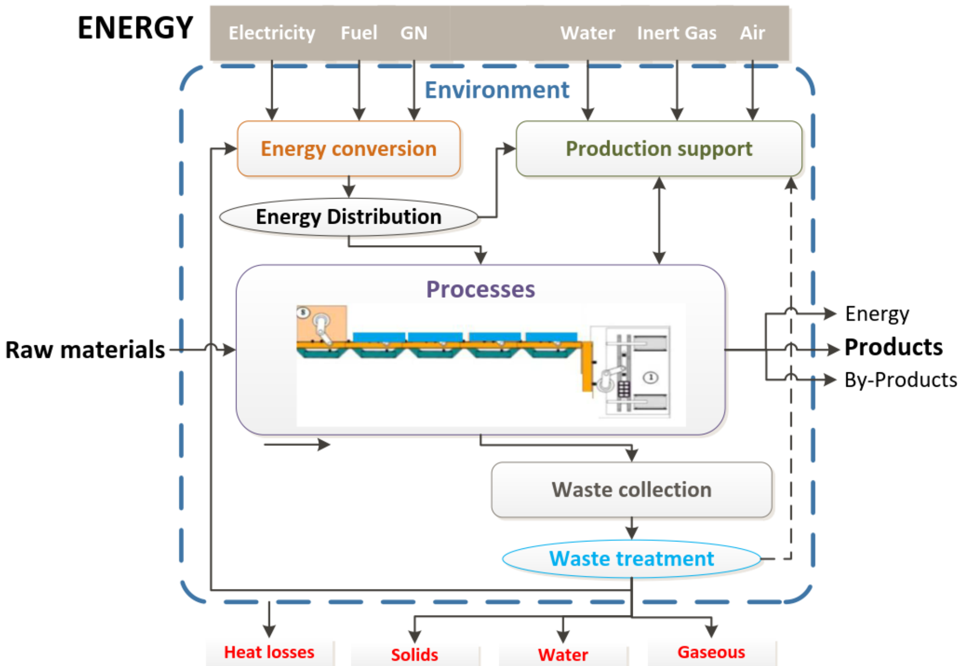

Figure 2. *The systematic vision of an industrial process [1].*

Projects in EE target several areas of the industrial processes (see Figure 2), from the energy to the waste. In the energy side, application of new energy sources such as renewables and new fuels are some examples. On the raw materials, the application of preprocesses that decrease the energy requirements during processing and more efficient use of them during the manufacturing process are complemented by reuse of other companies waste. On the environment component, projects target the operation conditions that can lead in optimized processes. More efficient processes have been achieved through several strategies, such as replacement of old components (e.g. motors) for new ones, or a redesign of new more efficient processes. Finally, waste collection and waste treatment can be an input for other companies (raw materials), or can be use in combined systems, such as power production and heating [42].

- Public awareness and energy state studies

EE improvements in the IndS need to consider the potentials of the sector, however technical and lack of knowledge in its real capacities hold the implementation of EE projects. On the side of public awareness, ***EUREMPLUS*** offers energy management training programs for knowledge exchange [43], other similar projects are ***EFFI*** that aims to introduce an independent organization for energy services (like training) and ***REGCEP*** that provides energy planning systems for regional authorities [44][45].

Other project focused in specific sectors includes ***EEMUSIC*** that targets information, training in energy management for music industry events [46]. On the chemical sector, two projects aim to recognize the sector potential of EE, ***CARE+*** and ***SPiCE*** which is also a platform for ISO 50001 certification [47][48]. For surface finishing and printing circuit manufacturing industry sector ***SURFENERGY*** offers support of EE measures [49]. Similar projects in textile (***EMS-TEXTILE***), tourism (***HES***) and ceramics (***CERAMIN***) sector have been implemented in Europe [50][51].

- Energy

Energy sources can represent a high portion of the production cost, with prices rise in the conventional sources; the application of new sources seams a good solution to solve those issues. Programs like ***EECA BUSINESS*** from New Zeeland provides information and resources to implement new sources of energy, as an example, wood energy knowledge centre is a tool that give information about wood residue and its use as a renewable energy source [52]. Projects in Small and Medium-sized Businesses (SMEs) like ***AIM 4SMES*** provide appliance of monitoring energy systems and better practices of energy use [53]. Another project that tries to target lower EC is ***CHANGE***, which aims to optimize SMEs energy use by developing a European network of Intelligent Energy advisors at Chambers of Commerce and Industry [54].

- Raw Materials

The scarce raw materials and processing cost affect the final products' price, which represent a cost and a decreasing competiveness of companies. To respond to those problems project and policies, focus in two main measures is done: pre-processing (waste) materials and target more efficient use of raw materials. On the pre-processing of raw materials projects in several sectors have been deployed, as an example ***CSI*** project aims to reduce the energy use and raw materials in the cement sector by applying pre-processing processes of wastes for thermal recovery and replacement of raw materials [55]. ***TOP-REF*** project aims to improve the energy efficiency of the chemical, agro-chemical and petrochemical industry sector by promoting better raw material consumption.

- Environment

The environment refers to the operating conditions that make the process optimal, so the production will work in a point of high EE. However process operation in today's complex industries is an intersection of multiple variables, which presents a challenge that, can lead many times in inefficiencies. In order to target optimal operational points, different groups (companies, authorities, organizations etc.) have apply real- time optimization technologies as well as advance process control that has resulted in average 3% reduction of the EC. As an illustration, a chemical European producer DSM, implemented a utility system that manages a large complex site that optimizes their EC. Other strategies address the conditions of the building where the production is carried out, reducing the EC in areas such as lighting, heating, ventilation and cooling, one example from US is the Sustainable Buildings Industry Council ***SBIC*** which has multiple projects in this area [56].

- Processes

Application of technologies represents a considerable percentage of the potential EE in the IndS. Technologies like speed drive in motor systems, high efficient motors and compress systems, and more efficient processes are being applied across IndS. Programs like ***technology demonstration support*** in New Zealand encourage the implementation of technologies that improve the energy performance of the industry [57]. Projects like ***PINE*** and ***GO ECO*** aims to increase the energy efficiency in business parks and SMEs through implementation of customized EE technologies in Europe [58][59].

Some projects focus in specific processes, such as ***COOL-SAVE*** that aims to reduce EC in cooling installations for the food and drinking sector and ***FOUNDRYBENCH*** for foundries in the metal casting sector [60][61]. Other examples focus in different IndSs like ***EEEI*** for EE in graphic Media Industry [62], ***ECOINFLOW*** in European sawmilling industry [63], ***IND-ECO*** for leather production industry [64], and ***GREENFOODS*** from the European food and beverage industry [65].

- Waste

Through a systematical analysis of the processes that are in the system, by application of mass and energy balances, authorities can guaranty that not useful products, goods or services leave the system as waste in solid, liquid or gaseous form. One way to guaranty no waste is by integrating processes such as recycling of materials and energy, which reuse materials to convert them into products or useful energy. One example is the GEL BOLU solid waste disposal plant, which uses some of the waste in agricultural purposes (growing vegetables) and energy generation that it is use by the plant [66].

Other integrating processes are heat recovery systems that use heat from hot streams to heat up cold streams. Polygeneration production systems that convert fuels into several products like heat, electricity or mechanical power. Waste heat utilization system use heat to produce mechanical power, and waste heat upgrade systems that transfer heat directly to the final use, e.g. building calefaction [1]. Projects in Europe like ***SUMMERHEAT*** that promotes the heat production by cogeneration during summer, and ***OPTIPOLYGEN*** that incentives the application of technologies to transform multiple primary energy sources to multiple energy outputs for the European food industry [67][68].

2.2 KPIs

Organizations around the world are implementing performance measures in order to quantify their performance, currently there are three types of performance indicator: first type is Key Result Indicators (KRIs) measure performance in a perspective, second type is Performance Indicators (PIs) that gives a view of what to do, and finally KPIs that shows what to do to increase performance considerable. KPIs are a measurable metric to qualify and evaluate systems' performance against targets and goals [69][13]. This section presents a selection KPIs for monitoring and evaluation of EE projects in for TrS and IndS.

2.2.1 KPIs in TrS

Cities today face common increasing EC and implement similar solutions. However, in the absence of common accepted performance measure indicators, it is difficult for the authorities to assess the effects of those solutions (policies, technologies, services etc.) and learnt from them and from other cities. The aim of this section is to introduce a set of KPI for common evaluations of the cities transport performance. The KPI were identifying from policies and projects around the globe.

In order to avoid the negative effects of TrS, authorities had apply different strategies that can be classify in *cleaner vehicles strategies* (CVS) and *mobility management strategies* (MMS). Clear vehicles strategies aims to reduce vehicles consumption per unit travel, some examples are extra fees on inefficient vehicles, fleet management and driving training, fuel quality control, fuel taxes, etc. Additionally these strategies are associated with rebound effects, which mean that vehicle travel units increase as a consequence of the increased fuel efficiency. On the other hand mobility management strategies contrary to the clear vehicles strategies aims to reduce the total vehicle travel, some examples are areas with vehicle restrictions, road pricing, distance-based vehicles insurance, etc. [12][70][71][72].

MMS are usually reinforced with projects that promote collective transport (especially PT) like special road lines and zoning [72][73]. On average, cars require four times more energy to transport one passenger per km than PT (rail transport and buses), and five times more energy than rail transport alone (trains, metros and tramways) [74]. On the freight transport's specific consumption for a lorry is around 15 times higher than using a railway[72]. Additional impact comes from the infrastructure that vehicles required such as, parking places, roads, bridges, etc. from the manufacturing process and the indirect impacts like health, climate impact, etc. [75][76][77].

Others target transport options like walking and cycling, which result in more diverse areas in terms of mobility [70][71]. Demographic knowledge is crucial in order to apply these strategies, studies have shown that data such the number of vehicles per 1000 habitants and the average income can determinate whether or not the citizens use private car. Other demographic data such percentage of workers, families and students can define the frequency of transportation as well as the distance traveled [73][78].

CVS are more like policies that reinforce the change of vehicles, one example is the adoption of diesel engines (consider more efficient). other strategies target more environmental friendly technologies like electric vehicles or bio fuels engines [79][78]. Projects like eco-driving courses, fuel saving information available on internet and speed limits are some examples of strategies that target the behavior of the driver in order to get the maximum efficiency of the vehicle [16][17].

For additional information this section was extracted from the project MoveUs (ICT Cloud-Based Platform And Mobility Services Available, Universal And Safe For All Users), European Union's Seventh Framework Program for research, technological development and demonstration under grant agreement number 608885 Deliverable 4.1. The appendix A contains a list of performance indicators mentioned in this chapter.

2.2.2 KPIs in IndS

The pressure of increasing EE in the IndS partly comes from the increasing cost of energy. A report from the International Energy Agency (IEA) exposes the results of efficiency gains and CO2 emissions reductions in manufacturing industries in the last decade. The results establish a potential of energy saving between 7-12% of global CO2 emissions, just by adopting advance technologies and systematic improvements in industry processes. Another important finding of this study is that IndS is almost independent on the climate and consumer behaviour, opposite to TrS, which is significantly sensitive to users behaviour [41].

The KPIs in IndS are a statistical tool that measure energy use based on physical production. These indicators give a vision of current energy use, past trends, and improvement potentials. However, there are not commonly implemented KPIs due to the number and the complexity of physical industrial production, that complexity is illustrated in Figure 3. In general the indicators had been generated by particular industries in particular countries. In this thesis, the listed indicators are from heterogeneous sources of manufacturing industries and international agencies.

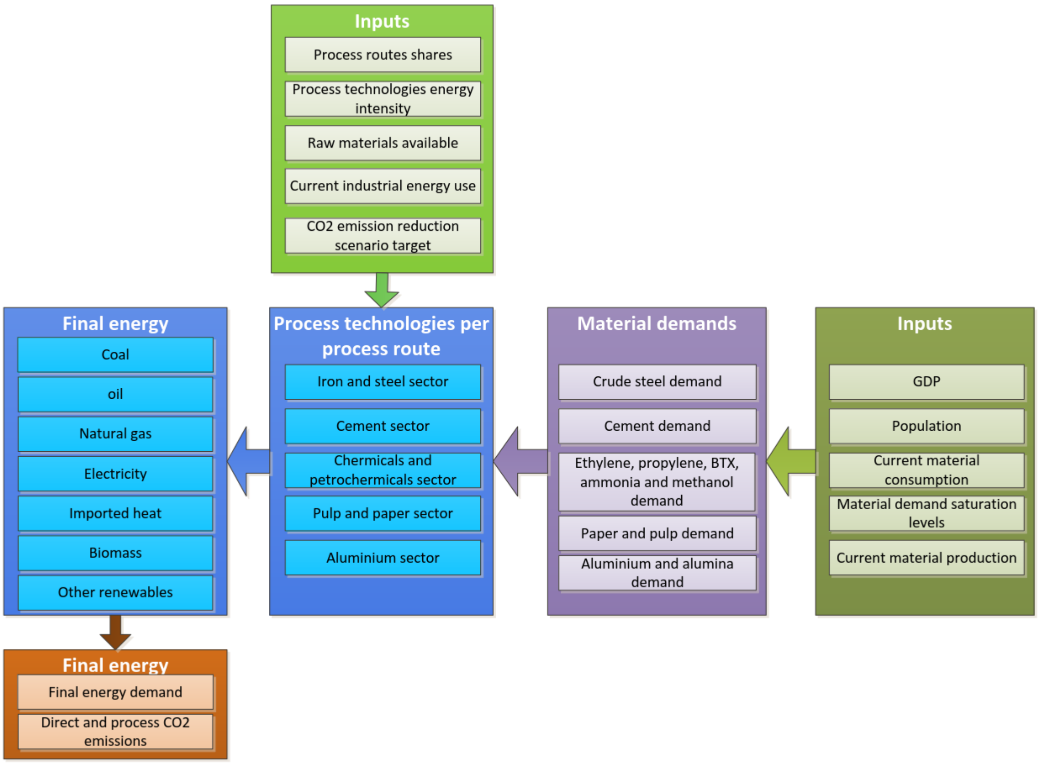

Figure 3. *Final energy in the Industry Sector from [41].*

When considering measuring the EE of IndS it is important to include the level in which measurement has to be done. To simplify there are three levels: world, country and production. Production scope is limited to the EMS, in other words the measurement of EE only concern the production to disposal of completed products (Figure 4). Country involve energy input and output of the companies by sector, which can be also classify by sub-regions, this measurements are usually use as support for country policies. Last, world scope includes multinational industry and their performance by sector worldwide (Figure 5) [40].

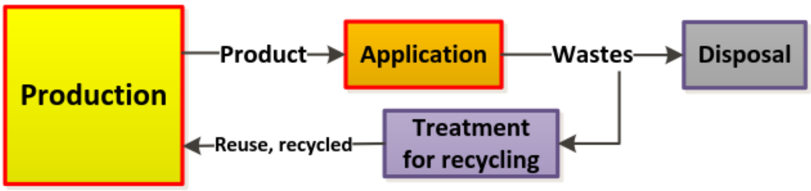

Figure 4. Scheme of stages from production to disposal of products [40].

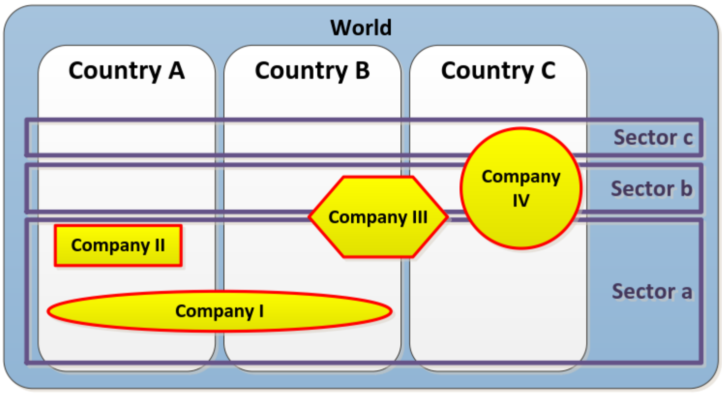

Figure 5. Schematic view of the levels in Industrial System [40].

On the level of production, the research of Leena Sivill (2012) presents some of the measures and indices used for EE performance that were classified in three categories: the EE of energy production and consumption, the sources of energy used for manufacturing products, and the value added in the activities related to the previous two. Additionally the research describe some of the ways to improve EE that are: deploy more efficient technology, improve operations and improve process integration (80).

Zhang Bin et al. (2012) propose a set of KPIs that cover multiple manufacturing assets including energy [13], another study from Anna Florea propose an energy management system in medium enterprises [81]. Energy use parameters are describe in [82] as a result of the project AmI-MoSES, which focused on assisting manufacturing companies with energy awareness by applying energy services. Studies in specific sectors of the industry such as paper machine production [83] and automotive companies [84] also offer a list of KPI or performance indicators in energy for increase EE in production process.

To resume EC in production (manufacturing industry) is composed by two elements as can be see it in the Figure 6. EC in production, are at the same time can be divided into EC in process and EC by supporting utilities. EC in process refers to the energy used by the production elements that are involve in the transforming stages of the production such as robots, controllers, conveyors etc. EC by support utilities, as the name suggest, is the energy used in production supporting elements like compressed air flow, heating, etc. The second element is the EC in facilities, which is the energy used in office equipments that are part of management facilities, such as air conditioning, lighting, heating, etc. [15].

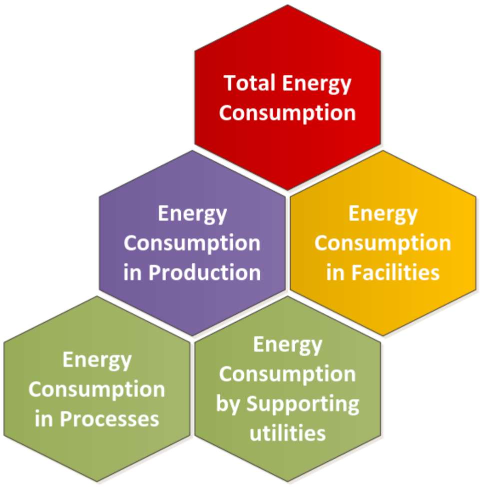

Figure 6. *Energy Consumption in Production.*

For measurements in IndS in world level, studies from IEA explore the measures of energy efficiency and performance in IndS. They classify Measures of industrial Energy Efficiency Performance (MEEP) in: absolute EC, energy intensity, diffusion of specific energy-saving technology and thermal efficiency. The absolute EC refers to the end EC level from the industry. Energy intensity expresses a relation between the energy input and output, this indicator measures energy use based on physical production of industrial products and even countries. The diffusion of specific energy-saving technology measures reflects the level of introduction of new energy efficient technologies (see Figure 7). Finally, thermal efficiency as same as the absolute EC shows the relation between the energy input and output, however this measure only is applied to end-use technology and energy conversion technology [40].

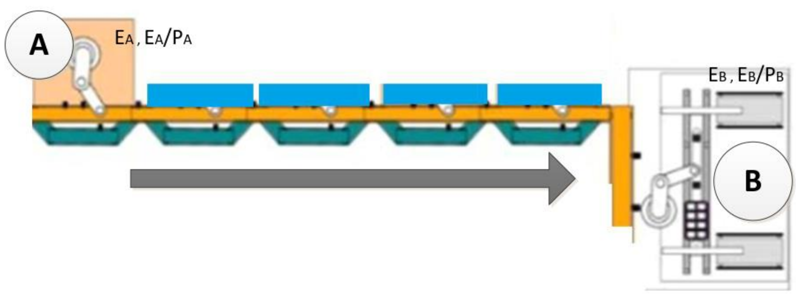

Figure 7*. Comparison of energy efficiency between two components in production [40].*

Several measures have been discussed and applied to the IndS in literature in order to define KPIs or performance indicators in different levels (production, country, and world) the appendix B contains a list of performance indicators mentioned in this chapter.

2.3 Methodologies for evaluation of energy projects

Energy Assessments are the processes of analysing a system energy usage to get a baseline and reduce its overall usage. With climbing energy costs, this area of reduction is becoming more and more essential for smart cities. Different types of systems have different requirements in energy consumption. Thus, there is a need for performing analysis, monitoring and evaluation of systems (TrS and IndS). This section describes some of the methodologies and international standards used to define the methodology describe in the next chapter and is one of the main contributions of this work.

2.3.1 MOST MET

Mobility management can be defined as soft measures to influence a journey before it begins. MOST-MET was set up as part of the EU project MOST (MObility management STrategies for the next decades) that ran between 2000 and 2002. MET takes a collection of input data in order to examine the impact of mobility management projects, the evaluation come after with the interpretation of the input data for finally give an assessment of the process by combining the evaluation and monitoring into an overall examination of the impacts. MOST-MET structure is resume in Figure 8 [84].

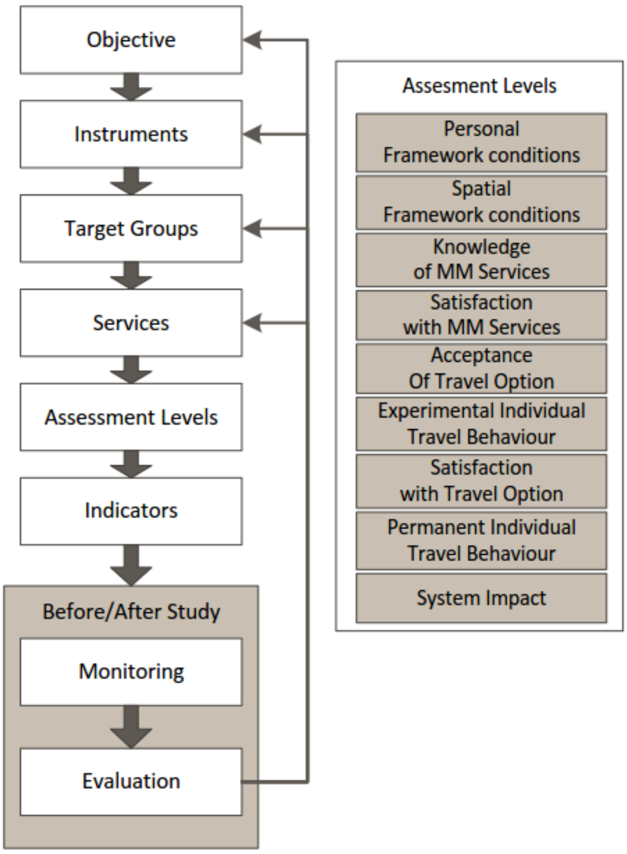

Figure 8. *The MOST Monitoring and Evaluation approach (MET) Schema [84].*

2.3.2 SUMO

A methodology based in MOST-MET and from Swedish Road Administration (SRA), System for Evaluation of Mobility Projects toolkit (SUMO) aims to monitor and evaluate mobility projects, especially in the area of soft measures (ICTs). SUMO consists in a set of different levels, which contain target values, indicators and results. SUMO valuation process is illustrated in Figure 9. The levels makes possible to measure the effects of mobility projects from early stages to the end results. The number of levels applicable depends of the type of project and its specific areas of impact [85].

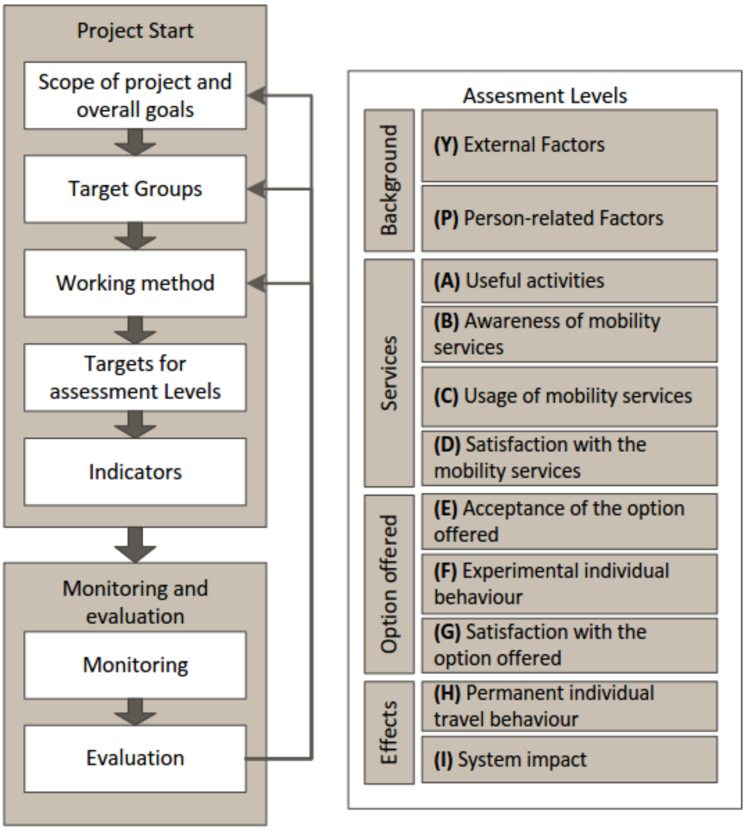

Figure 9. *System for Evaluation of Mobility project, SUMO process schema [85].*

2.3.3 OPTIMUS

OPTIMUS stand for OPTIMising the energy Use in cities with smart decision support systems (OPTIMUS). The aim of OPTIMUS is to design a ICT platform for collecting and structuring open data from: weather conditions, social mining, building's energy profile, energy prices and energy production, in order to show energy saving potentials available in public buildings [86]. The platform is based on a developed Smart City Energy Assessment Framework (SEAF) for conducting energy efficiency assessments of public buildings. SEAF is composed by three axes illustrated in the Figure 10, where each axis include a number of indicators, which are used for the evaluation process.

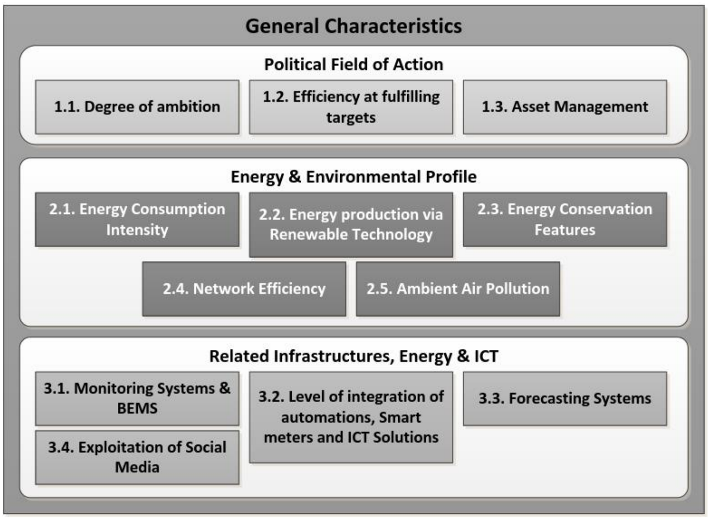

Figure 10. *OPTIMUS of City level and Municipal Building Level Schema [86].*

2.3.4 ISO 5001

The international standard ISO 50001 is a tool that stablishes systematic procedures to achieve EC reductions. The norm is also well known as the plan-do-check-act cycle that support organisations in different areas to improve their energy performance by constant improvements. Figure 11 illustrates the process, which includes measurements, documentation and reports. Implementation and operation have the design and procurement practise for EC by equipment, system and processes. Checking process, the variables previously defined in the implementation are used for monitoring and evaluation processes [87].

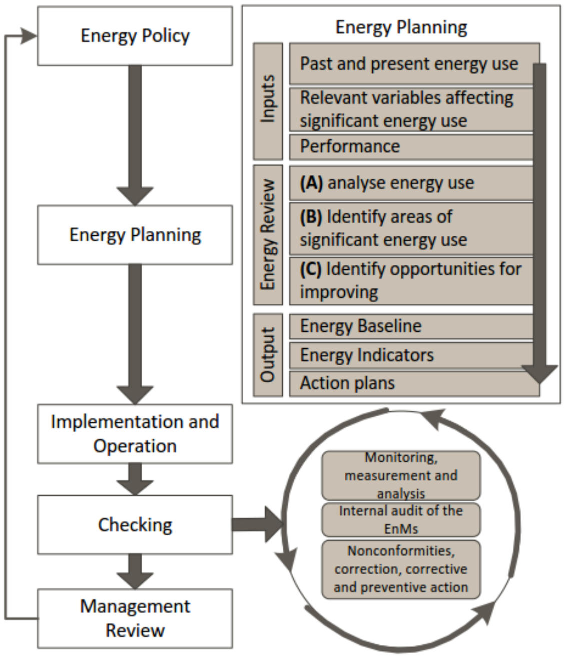

Figure 11. *ISO 50001 Standardized Energy Saving Support [87].*

3. METHODOLOGY FOR ENERGY ASSESSMENTS IN SMART CITIES

This chapter describes the methodology that was developed for getting a better understanding of the impact of EE projects in different Smart Cities' sectors. This methodology uses a multi-step strategy to systematically assess monitoring and evaluation processes. A satisfactory monitoring and evaluation processes of EE projects will allow authorities to target initiatives and resources more efficiently, not only saving resources but gradually making their cities more sustainable. Additionally, the methodology pretends to be a long-term tool or common frame for these processes (monitoring and evaluation). As a result, in the future, authorities all around the world would be able to share experiences on EE projects by spreading information as the methodology steps establishes what will help others to learn and apply successful strategies to their own cities.

The methodology for energy assessments in smart cities (see Figure 12) must be implemented at the start of an EE project by defining the goals, objectives, target groups and variables. The method then describes how the energy evaluation has to be performed, giving as a result a list of performance indicators and base lines. Finally, the methodology describes how to use the previous steps to monitory and evaluate EE projects. Feedback from some steps let authorities to go to backward steps for making improvements in EE projects in progress or EE starting projects (in the Figure 12 are represented as feedback arrows).

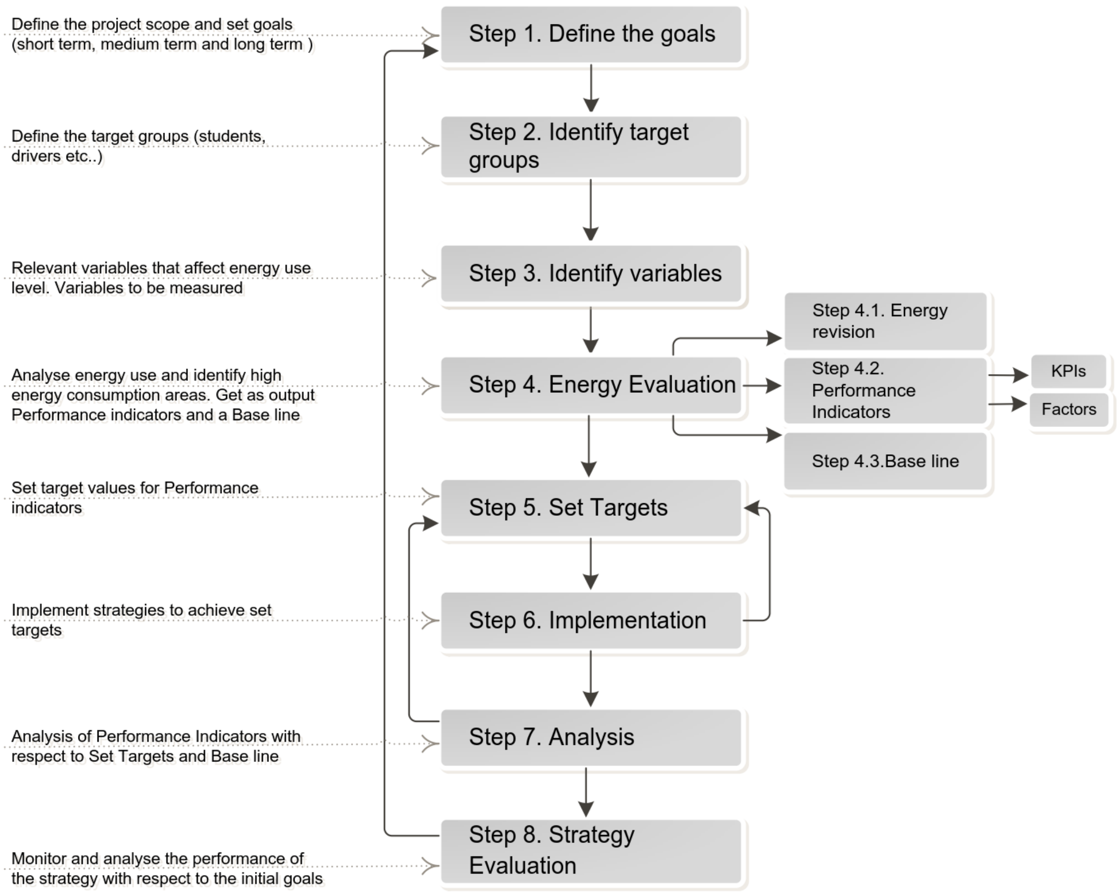

Figure 12. *Methodology for energy efficiency assessments schema.*

3.1 Define the goals

The goals are a representation of what the cities expect to achieve at the end of an EE project. First, the authorities should define goals that should be reached through the implementation of EE strategies. After establishing the goal(s), it is necessary to divide them into small objectives that should be always defined under a time-span (short, long term, days, months, etc.). The defined objectives can be describe by using the SMART (Specific, Measurable, Achievable, Relevant and Time framed) method developed by Doran (1981) (89)].

Specific objectives can be developed by answering the following questions: who is involved? what does the city wants to accomplish?, where?, when? and why? *Measurable objectives* refer to a characteristic of the objective. In order to identify if an objective is measurable its definition should respond to how much? and/or how many? *Achievable objectives* are the ones that can be accomplish, but in this stage of the methodology is more like questioning if the goal is important or not for the city, also cities can know that their objectives are *relevant* too. Finally it is important to settle a time frame, this will help authorities to prioritize actions in the direction of achieve the main goal(s) (89)].

3.2 Identify Target Groups

A target group is understood as a group of citizens that have similar or same travel needs; however, their travel choices might be different, in the case of the transportation sector. It is important to describe and understand the target group in this early stage as authorities can focus their strategies on the right citizens, so in that way cities can save resources that might be used in implementing other strategies.

There are several ways cities can identify their target groups, coming from management in this chapter two advices are going to be given. 1) Consult your goals: goals and objectives defined in the previous step will give a clue of what it is the target group, as an example, if one of the objectives is to reduce use of PV, some target group might be numbers of car owners. 2) develop a profile of the target group: this is an in-depth description of who your target group, going further with the previous example, car owners are citizens between 25 to 58 with families living mainly in suburban areas with an average income of £1520, etc. As much information it is in the profile of the target group, much easier will be the identification of strategies for change their habits.

3.3 Identify variables

After identifying the target group, the energy sources should be also determinate. The number of energy sources identified depends on the goals and objectives previously described, meaning that not all the energy sources that the city has should describe only the ones that are according with the main goal and objectives (step1). This identification will decrease the complexity of the variables that can measure the EE of the system. Additionally, the mapping of sources will help in the next step because they will be the units for identifying significant energy uses in the system.

Next part in this step is to identify the variables that describe the objectives of the cities. The main idea is to identify a set of regularly generated, well-documented, easily obtainable variables that can explain the variability of energy use/carbon emission levels in the system. A good practice in this step is to look for cities authorities' experiences and knowledge, or similar projects that already measure and which results are also sources of useful information.

3.4 Energy evaluation

The energy evaluation includes an inventory of all EC activities. It is a process to determine the energy performance of the system based on data or real time measurement, which lead to authorities to identify opportunities for EE improvements. This step has as an output a set of KPIs and a base line.

3.4.1 Energy revision

The energy revision is a compilation of the energy use according with the city's goals and objectives. This step will give enough information to identify components of the system with high EC. To conduct a revision, the authorities shall establish with enough detail all the components of the system area that the objectives make reference.

During the implementation of this step, some items should be noticed: components with significant EC should be described as its main output, energy source, location, etc. any necessary information that can describe them should be used. Determinate if there is a measure installation for those components, or if there is some way authorities can monitor and record the EC. If there is not an available measurement of the actual consumption, estimation might be necessary in order to get an approximation of the EC, however, justification and any other assumption used in the estimation should be clearly explained. Finally, the energy revision should be updated as often as necessary, especially in situations when some of the components of the system are replaced for more EE element. At the end of this step the authorities will have an energy profile of the system, which allow them to have a detailed view of the EC status of the system.

3.4.2 Performance Indicators

After establishing the energy profile of the system, authorities should identify a set of performance indicators to monitor and evaluate the energy state of the system. In the case of the city's systems (TrS and IndS) a set of KPIs is available and describe in previous sections, Appendix A and B. Each city should select and determinate suitable performance indicator based on their cities' behaviour and their environment. Additionally they should match with the objectives and target groups defined in previous steps.

The first step in selecting the KPIs for reducing the energy use (opportunity) is to define the boundary across which the energy flows. The boundary will vary depending on the complexity of the system, which is why authorities can stablish boundaries by site, specific equipment level or process. For example in the case of a manufacturing company, one set of KPIs could be established for the entire company or for specifically production line or for a specific machine (see Figure 13).

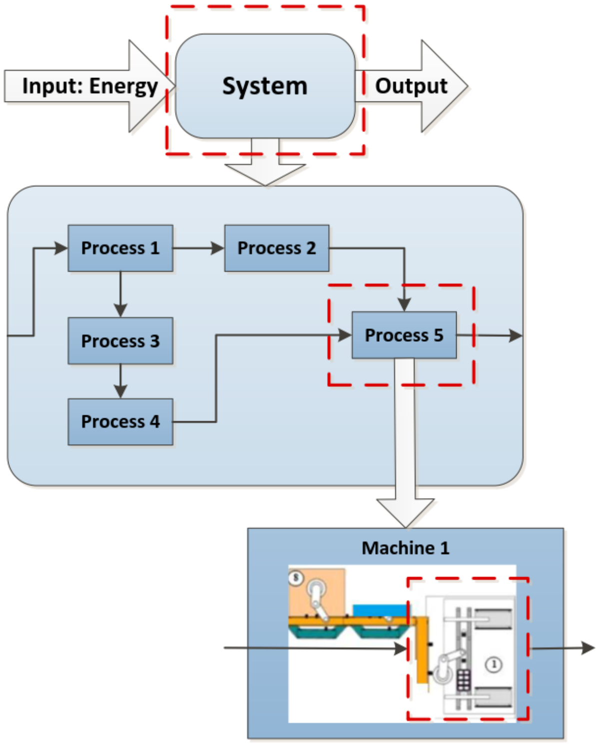

Figure 13. *Divided system for analysis, red boxes represents boundaries.*

In case none of the KPIs described fit in the city's needs, authorities should define a new KPI. This new KPI should be defined as accurate as possible, in line with international standards in order to use in future comparisons, to see more information about the format go to Appendix A. Performance indicators should be updated when the activities of the system or baselines change and they are not more relevant for the evaluation of the EE project.

3.4.3 Baseline

The baselines are defined in ISO 50001 as "quantitative references providing a basis for comparison of performance" that applies to a specific period of time, and as the description suggest, provide a reference value for comparison before and after apply strategies to improve the EC. The baseline is defined with the information from the energy revision and the performance indicators in an appropriate period of time. Developing an accurate energy baseline is crucial to get an equally accurate energy savings measurements. The standard suggest three methods in order to stablish an energy baseline: 1) regression analysis, 2) modelling or/and simulation, 3) short-term metering [87].

A regression analysis determinates the relationship between a dependent variable (can be EC) and an independent variable (like time, weather etc.). The KPIs described in the previous section already set those relations. After collecting the data of both variables, then is analysed to get an equation, which describes the relation. The relation should be found by setting a regression, whether it is a simple linear or a high degree polynomial.

The second method is using modelling or/and simulation, in this method a model of the system needs to be develop, which should include the variables that affect the energy consumption. Then the model can provide the information for calculate de KPIs, the inputs can be changed in order to simulate different energy scenarios. Due to the complexity of most of cities systems (TrS, IndS, etc.) it is difficult to create simple models with ordinary computational tools, so the use of specific analysis software is required. However, measures through simulations can be costly (resources like experts are required) and time expending, in consequence should be implemented only in cases where authorities can prove that it is a cost effective situation. Examples like PTV Visum (Figure 14) is used for simulate city's traffic or Tecnomatix Plant Simulation from Siemens for plant simulations (Figure 15).

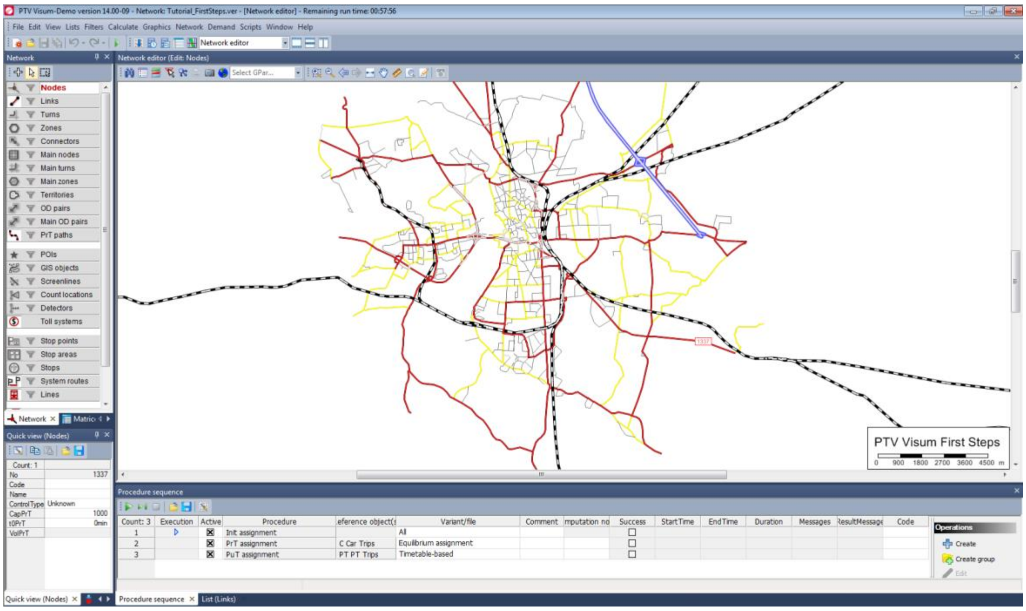

Figure 14. *PTV Visum for cities' traffic simulations [89].*

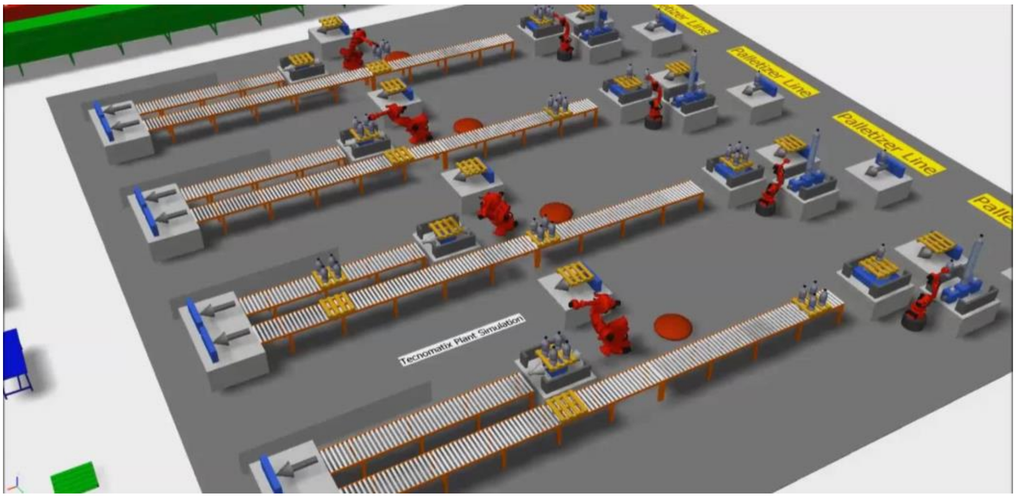

Figure 15. *Tecnomatix Plant Simulation from Siemens [90].*

The last method is the metering and it is the simplest method due to the stability of EC of a component or the whole system. As the nature of the system is constant, a provisional measure system can be used, or a simple monitoring station might be required in order to evaluate the performance of the component of the system. As an illustration, the power requirement of an electrical motor is constant during a process, which requires the motor for a consistent period of time, so in this case the EC of the motor is known and it is steady until the process change.

In order to set a target, a forecasting of the baseline is required. It is necessary also for comparing the saving after and during the implementation step. The forecast energy baseline is a future scenario of the system or component before the strategies to reduce the EC are implemented. It is calculated by extending the period of times on the previous described methods (Figure 14).

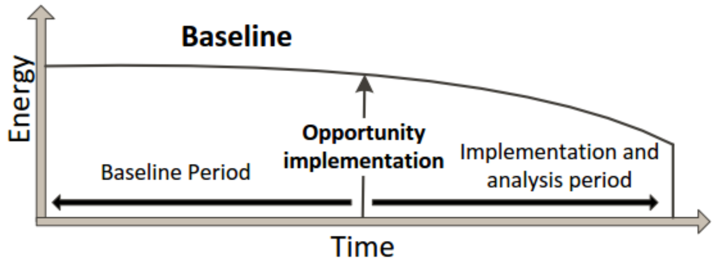

Figure 16. *Baseline behavior.*

3.5 Set Targets

In this step the target values are defined. Targets values as the name suggest are expected performance values that can be compared with the current system performance (Figure 17). They are mainly used to define if the performance is satisfactory or not during and after the implementation step. The target should be set based on the previous base line, and the desire of improve. To demonstrate, a target for a whole system could be to reduce EC by 4% after the implementing period.

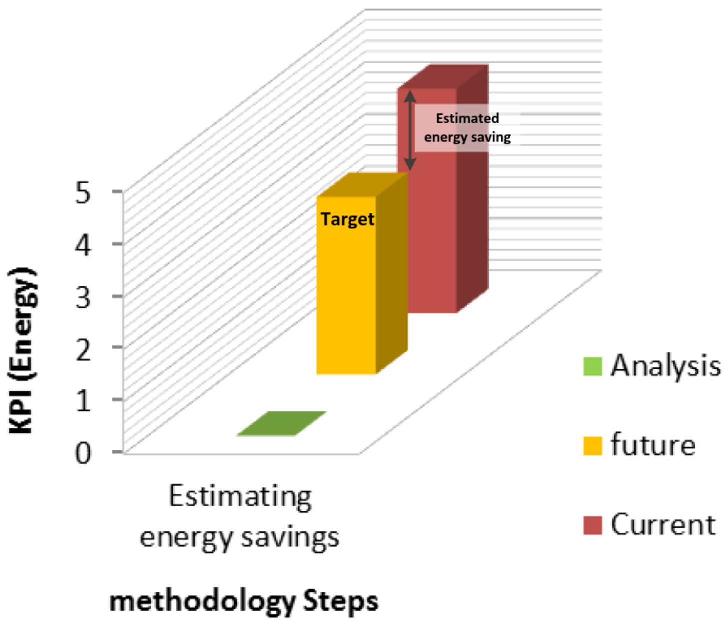

Figure 17. *Current energy value and target value.*

The accuracy and correspondence with the system capacities of targets is important. An incorrect target will mislead and in consequence overshadow improvements that maybe be not be reflected during the monitoring and evaluation processes (step 6, 7 and 8). On the other side poor targets reflect lower confidence and possible a failure to achieve the goals (defined in step 1).

3.6 Implementation

There are several solutions that come out when authorities want to improve their systems' EC or EE. In this step authorities should implement strategies (solutions) in order to achieve the goals previously defined in the step 1. During this step the authorities should focus on the development the desired outcome of the system, supported by control procedures that guaranty the satisfaction of strategies implementation. Additionally if the authorities perceive that the set targets overcome the city's capacity, a redefinition of the targets should be performed.

3.7 Analysis

The improvements in EC or /and EE cannot be measure directly, however they can be calculated by comparing the values before the implementation (base line and Target) and after the implementation performance. No matter which strategy was implemented, the authorities should monitor the current energy performance and identify the tendency of the system, whether it is an EC reduction or an increased. The below Figure 18 is a continuation of the previous Figure 17, the measure energy saving is the main purpose of this step represented by the green column. In the case final savings are not similar to the Target, it is important to analyse the cause of this, if the capacity of the city is limited and that caused the failure, a redefinition of the target value is required.

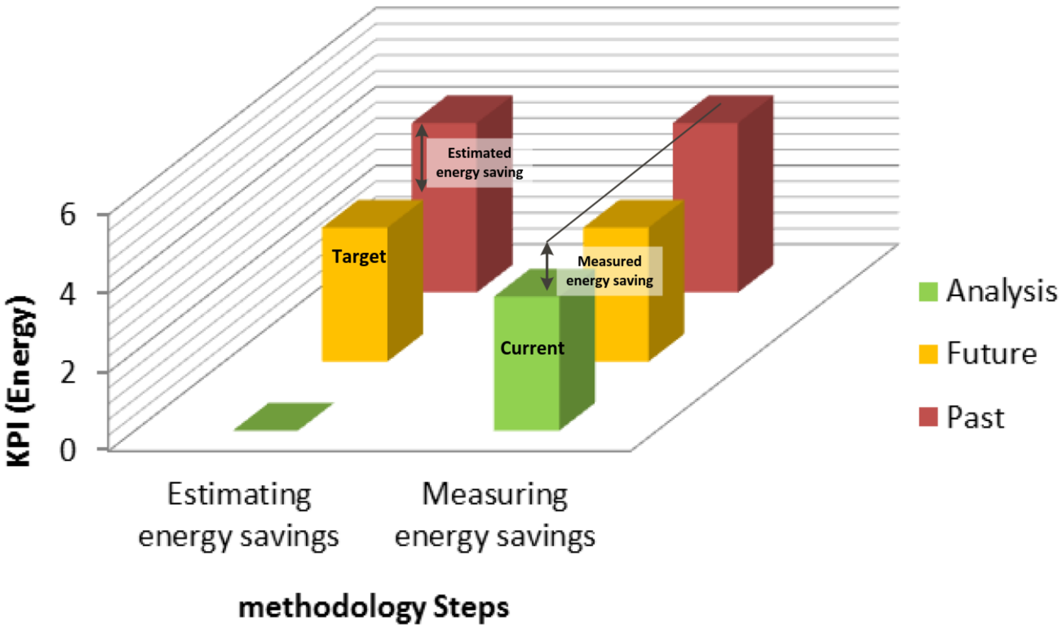

Figure 18. *Calculation of the energy savings.*

3.8 Strategy evaluation

As it is defined in the step 1, the goals and corresponded objectives have a time-span in which should be achieved. After that time, a strategy evaluation must be performed, in this step the implemented strategies results (Evaluation step) are compared with the goals and objectives set in the beginning. In the case the goals have not been achieved, the authorities have to make improvements by applying corrective actions.

Corrective actions should be supported by the capability of the city to identify and fix the problems, as well as, eliminate or mitigate the cause of the falling achievement. This process should include an analysis of the causes, identification and implementation of corrective actions, as same as, preventive measurements. In some cases it is necessary to run studies on the system in order to find the causes of the failing achievements. Finally, if the goals were achieve, meaning that the strategy evaluation give satisfactory results, new goals need to be defined for further improvements.

4. IMPLEMENTATION OF THE METHODOLOGY IN SMART CITIES

The methodology was use as a tool for evaluating and monitoring MoveUs project in three European cities. These cities represent the variety of TrS that can prove the versatility of the methodology. This chapter introduces the three European cities and their particularities. The methodology implementation in one of the cities is used as an illustration and finally, some considerations about the methodology process are presented at the end of the chapter.

4.1 Introduction to the three European smart cities

4.1.1 Madrid, Spain: larger size city

Madrid is the biggest city as well as the capital of Spain. It has a population around 4 million only in the city centre, additional 3 million people come from the metropolitan area and visitors, additionally by 2013 more than 1 million cars were register. The increasing share of commuters and the amount of private vehicles causes considerable congestion and air quality problems, during peak hours around 35% of the trips are done by car, 34% by PT and 31% by ALM [91]. Transport sector consumes 1/3 of the city's energy.

Currently, the city authorities are putting all efforts on increasing the share in ALM and PT, and optimizing the use of this last one by improving time of travel, cost and real time information. Multimodal real-time information and well as priority road lanes for PT and high occupancy vehicles are part of the actions to reach the PT optimizations. For ALM users, services like smart routing for pedestrians/cyclists and smart crossing are under development. Additional efforts in enhance a better mobility in city centre for visitors through personalizing multiple mobility services.

4.1.2 Genoa, Italy: middle size city

Genoa has the main Italian port and is the capital of the Lingurian Region. The city location between the cost and Apennines Mountains combines an increasing population of 603.560 inhabitants with a limited space of land of approximately 257.39 square kilometres. The historical centre area concentrates 50% of the population. The tight space left and the reduced options of mobility have produce high air pollution levels, which 91% are coming from private and commercial sources, 7% by PT and 2% by municipal fleet. By 2010 the city established a "Strategy Energy Action Plan" for 2020, which looks for a reduction of emission of 23%. At the same time, "Urban Mobility Plan" is used by authorities as planning tool for developing cost and energy effective urban mobility.

4.1.3 Tampere, Finland: small size city

Tampere is the third biggest city in the middle of Finland, with 220.000 inhabitants. Being part of Finland, Tampere is not apart to have a considerable amount of lakes, two of them (Näsijärvi and Pyhäjärvi) surround the city centre, that limits the possibilities to go from east to west. Additionally the number of private cars is higher that the European average with 90,906 of registered cars. As a result, the modal share for cars is 49% and only 19% for PT and 32% for ATM.

The city had been implementing actions to develop a smart mobility by several services such as mobility, traffic, and telematics management services. However the city is looking to increase the share of ALM and PT by creating new bus routes and bicycle/walking parking places promoted by open traffic data and real time applications.

4.2 Implementation of the methodology for energy assessments in Tampere city, Finland

4.2.1 Step1: Define the goals

Main goal

The main goal of Tampere pilot is to contribute to Tampere's sustainable mobility goals by increasing the share of walking, cycling and public transport.

Objectives

1. Reduce the use of private car
2. Increase the modal share percentage for alternative modes cycling and walking
3. Increase the use of public transport
4. Increase public transport service awareness in the Tampere area

Table 1. *Objective definition.*

Question	Objectives			
	1	**2**	**3**	**4**
Who	Tampere city Public Transport Department	Tampere city Public Transport Department	Tampere city Public Transport Department	Tampere city Public Transport Department
What	Reduce the use	Increase modal	Increase modal	Increase public

	of private car	share of alternative modes	share of Public transport	transport awareness
Where	In city urban area	In city urban area	In city urban area	In city urban area
When	Long term	Long term	Long term	Short term
Why	- Increase the energy efficiency and reduce carbon emissions. - Less pollution=air quality - Less congestion and traffic jams due to reduced number of cars	- Increase inhabitants health - Environmental protection (no pollution, no noise) - Maintenance of a safe and lively urban area - No emissions of greenhouse gases - Health	- Makes more energy efficient the system - Reduced noise - Larger green areas and a lower number of/ less need for car parks and parking lots - Faster and more reliable public transport	- Increase public transport modal share - Increase knowledge about energy efficiency - Increase the access to Public transport system

The objectives were defined in three time periods: short (0-1 year), medium (2-5 year) and long (6-15 years) term. The city urban area is the zone 1 of public transport as can be seen it in the map below.

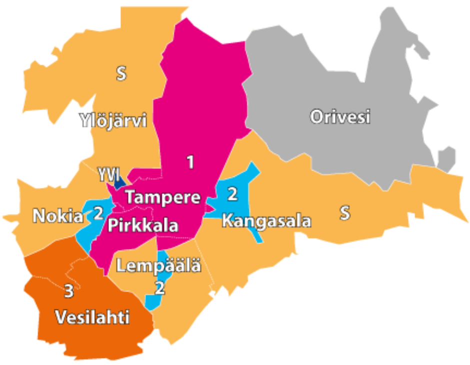

Figure 19. *Tampere public transport zones [92].*

4.2.2 Step2: Identify Target Groups

There are three main target groups in Tampere city: private car users, commuters, and Tampere city inhabitants. Direct target groups are private car users and commuters. Tampere city inhabitants is a target group, however they are classified by multiple target groups like the ones mentioned before.

Tampere had 220,446 inhabitants by 31 December of 2012, which represents a population density of 410 inhabitants per square kilometre. The number of private cars registered in Tampere is 90,906; and in this case, Tampere will assume that one private car is equivalent to one user.

4.2.3 Step3: Identify variables

The variables identified are related with the objectives described in the step1. For example, Energy consumption per vehicle is related with objective 1, because the consumption directly measures the reduction of private cars. It has also relation with objective 3 due to the modal shift, meaning that reductions in car can lead to increases in PT. finally the variable has relation with Objective 4 because the consumption can be used to promote modal shift.

Table 2. *Identified variables.*

Variable	Objective
Energy consumption per vehicle	1,3,4
Fuel consumption per vehicle	1,3,4
Calories consumption in alternative modes	1,2
Modal share percent in each mode	1,2,3,4
Number of public transport passengers	3,4
Number of cyclists	2

4.2.4 Step4: Energy evaluation

1. Energy revision

Energy sources:

Tampere has available all conventional fuels and electricity. The conventional fuels have a percentage of Biofuels call Bio-share, for 2014 constitutes 8% in both gasoline and diesel. Transportation has an important percentage on Tampere's greenhouse gas emissions; fortunately, it has been decreasing in the last four years as shown in Figure 20.

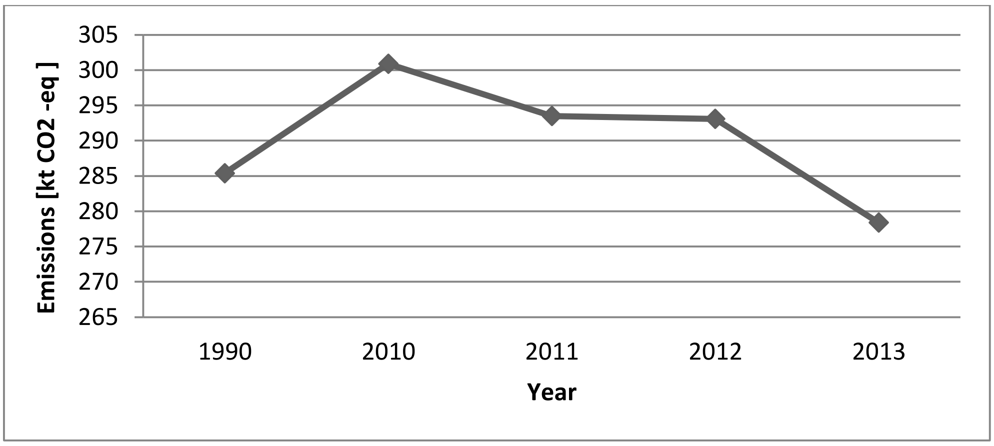

Figure 20. *Transport sector emissions in Tampere.*

Tampere current car ownership is 90,906 vehicles, which has been increasing by 4% per year, in average there are 425 cars per thousand inhabitants. Additionally, a pilot project has 20 electrical vehicles, which are being tested by the Tampere Adult Education Centre.

The modal share distribution in Figure 21 shows the evolution of Tampere's modal split and its goals for 2016. The percentage on PT has increased with respect to 2005 and it will continue growing for 2016. In ATM, from 2005 to 2012 there was a small decrease but for 2016 is expected a higher percentage.

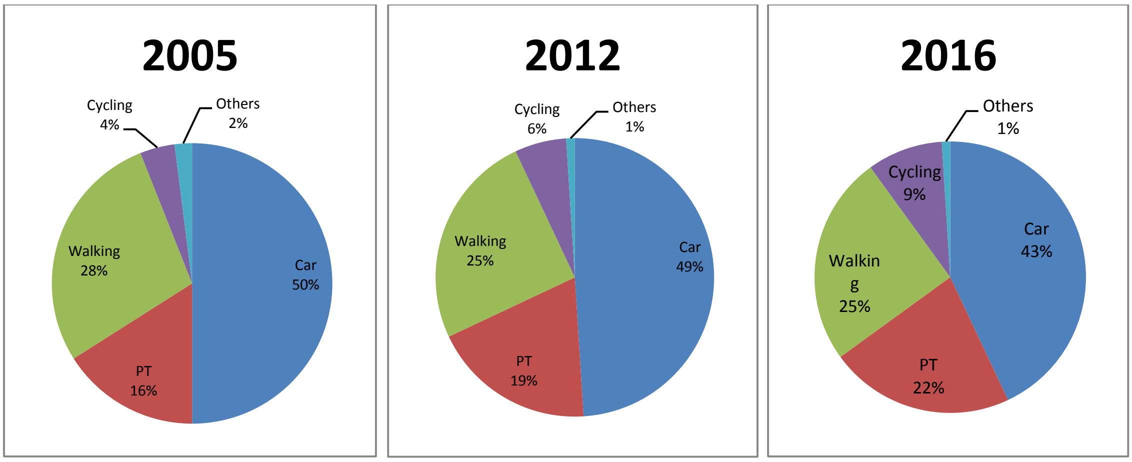

Figure 21. *Transport modal share, 2005-2012-2016.*

PT is mainly constituted by bus traffic; however there are some taxis and in the future a modern city tramline. Since 2006 the city has been implementing different strategies such as extending bus services, lanes and traffic light priorities in order to promote the use of PT, as a result, this has grown from 2006 to 2012 (Figure 22). In addition, the city is expected to have its first tramline by 2020.

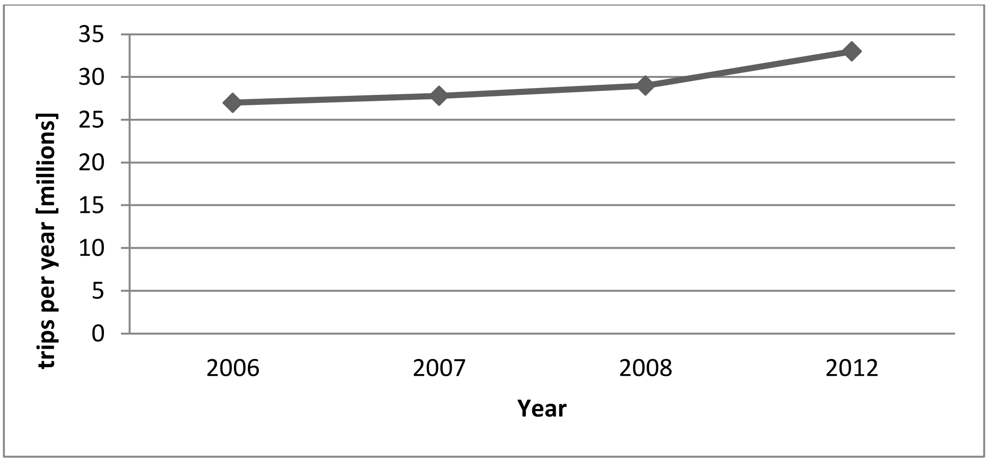

Figure 22. *Commuters per year in public transport in Tampere city.*

ALM has also grown, mostly in the cycling volume and especially during winter season. A constant growing of the bicycle path network length can be the reason behind the cycling increment, by 2011 the extension of the paths were 602 km (Figure 23). Some other measures to promote the use of bicycles are: improvements in the roads such as new tunnels and bridges, and campaigns like Minä poljen in 2012.

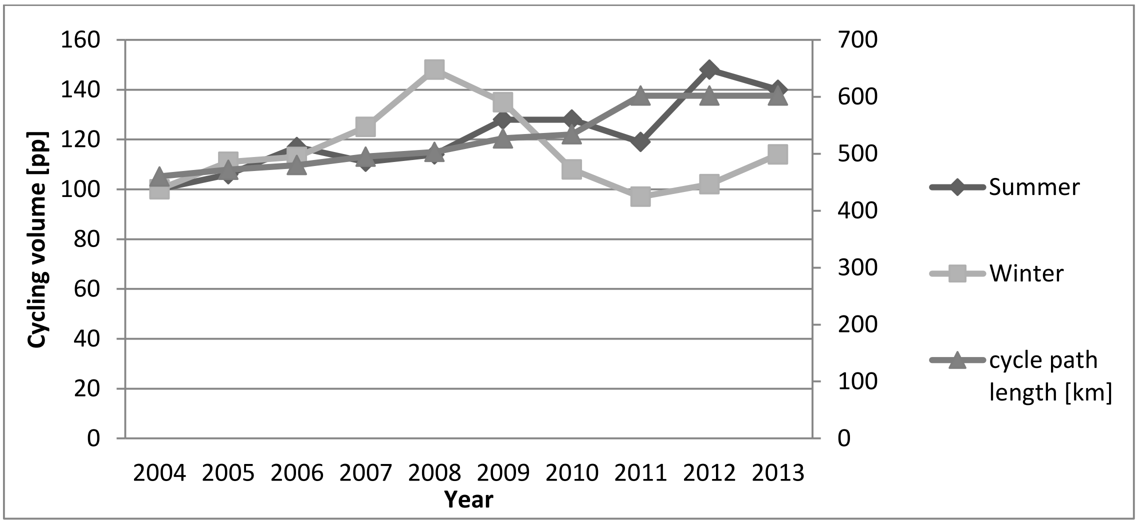

Figure 23. *Cycling volumes developed during winter and summer and cycle path length.*

The city has several projects in the alternative modes, some of them are Walking and cycling communication plan, incl. Example. HEAT calculations (2014), Commuting walking- and cycling potential, UKK Institute (2014-2016), ARTICLE II: Commuter cycling potential and walking the streets (2014), Walking and cycling computations (2014), an urban walking and cycling follow-up model (2014), Waterway and bike parking information in the open window of data (2013).

The PT service awareness has used maps that contain buses routes and books with more detail information about times and stops for each bus line [92]. Recently Tampere made available a web site where users can consult PT information. This web site also includes a journey planner call REPA, which contains the Timetables, Journey planner, Transit map, Cycle route planner and Traffic monitoring. The Timetables are disposed in an interactive way where users can choose the bus line and access for each of its stops, the next three departures and timetables per day (Monday-Friday, Saturday and Sunday) see Figure 24.

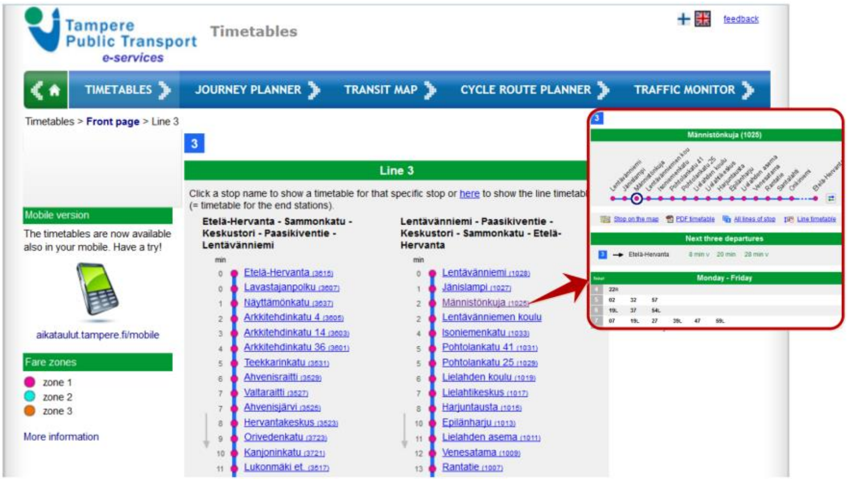

__Figure 24.__ Tampere public transport REPA time table [92].

The journey planner consists in a route search that allows users to enter the departure and destination as well as the time and date of arrival or beginning of the trip. With the user request the system calculates the route and gives different options, which include the bus number, time in departure and destination place, and the walking distance to the final destination. This information is complemented by a map that shows the suggested route. Other way to access PT information is through the Transit map, it shows the bus lines information over the map, and so by choosing the line, the users access all the stops and can select the stop which location is displayed in the map.

Cycle route planner, as well as the journey planner, users enter the starting and destination point, it is also possible to choose a prefer cycle path. The suggested route is displayed in the map with information about the maximum altitude and length of the route. Additionally users can modify displacement speed, so in that way the route planner calculates the journey time in a more accurate way (see Figure 25).

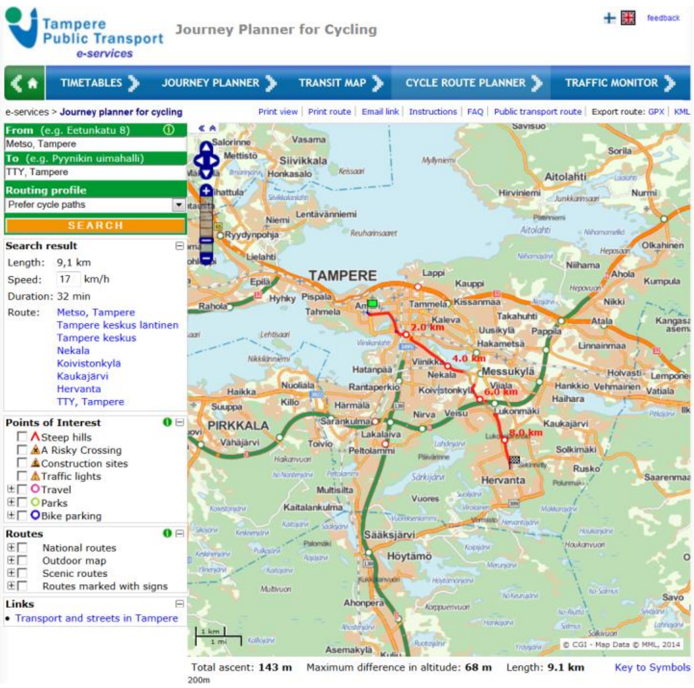

__Figure 25.__ Public transport REPA Cycle Route Planner [92].

Finally, the traffic monitoring shows in real time the buses that are covering a specific route. The users from the menu on the top could select the route, also it is possible to enter the stop name so the system will show only the buses that stop in that station (see Figure 26).

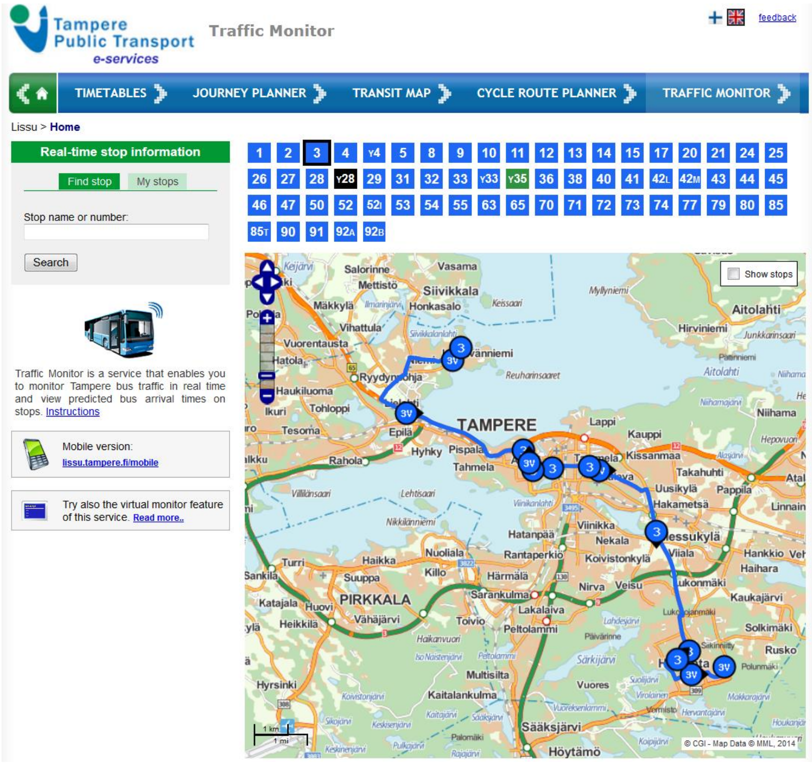

Figure 26. Public transport REPA Traffic Monitor [92].

2. Performance Indicators

Based on the energy revision, the goal and objectives (step1) that the city has defined, a number of KPIs that reflect the performance of the system were selected (Table 3), for further information about the KPIs go to Appendix A and paper [93].

***Table 3.** List of KPIs*

ID	Name
KP4	Density of passenger transport
KP5	Number of passenger transported by fuel unit
KP6	Number of fuel units per passenger
KP8	Total CO_2 emissions for travel (multiple modes) passengers
KP10	Private vehicles density rate
KP13	Share of public transport in total passenger traffic
KP16	Presence of alternative fuels vehicles
KP18	Traffic-free (TF) and on-road (OR) routes
KP19	Annual usage estimation in alternative modes

KP23	KPI's change per time unit
KP24	KPI's percentage of change

The following figures show the behavior of the city's TrS.

- KP4: Density of passenger transport

Figure 27 Figure 27. KP4 Density of passenger transport. Shows the density of passengers in public transport in Tampere city, which after a considerable increase has decline in the last year to 2.39 passengers per kilometer.

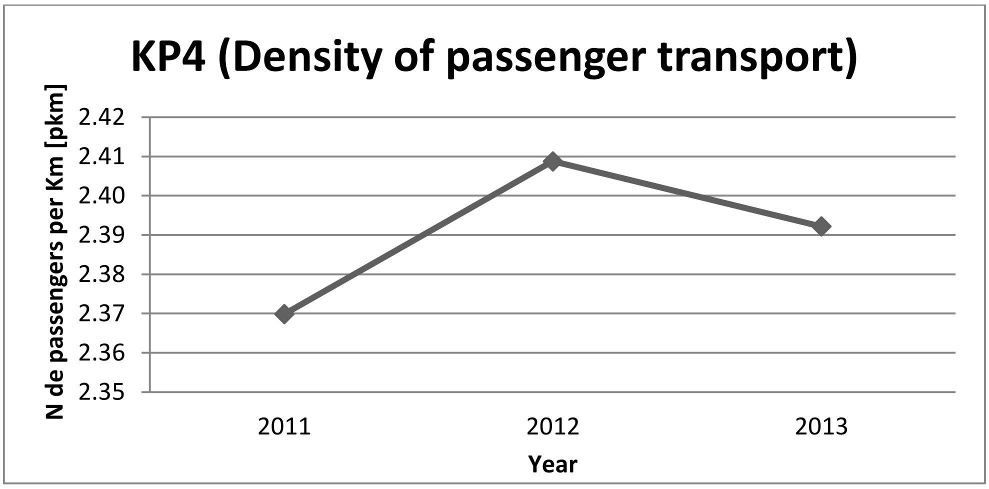

Figure 27. *KP4 Density of passenger transport.*

- KP5 Number of passengers transported by fuel unit and KP6 Number of fuel units per passenger

In contrast with KP4, the KP5 shows that the number of passengers per fuel unit has been growing. There are two causes for this behavior, one is that the density of passenger has also grown as it is represented in KP4, however the grown is mainly cause for the buses consumption, which is more efficient (Figure 28). As KP6 is a reflection of KP5, it has similar behavior, showing that the fuel units per passenger are less in 2013 compared with previous years (see Figure 29).

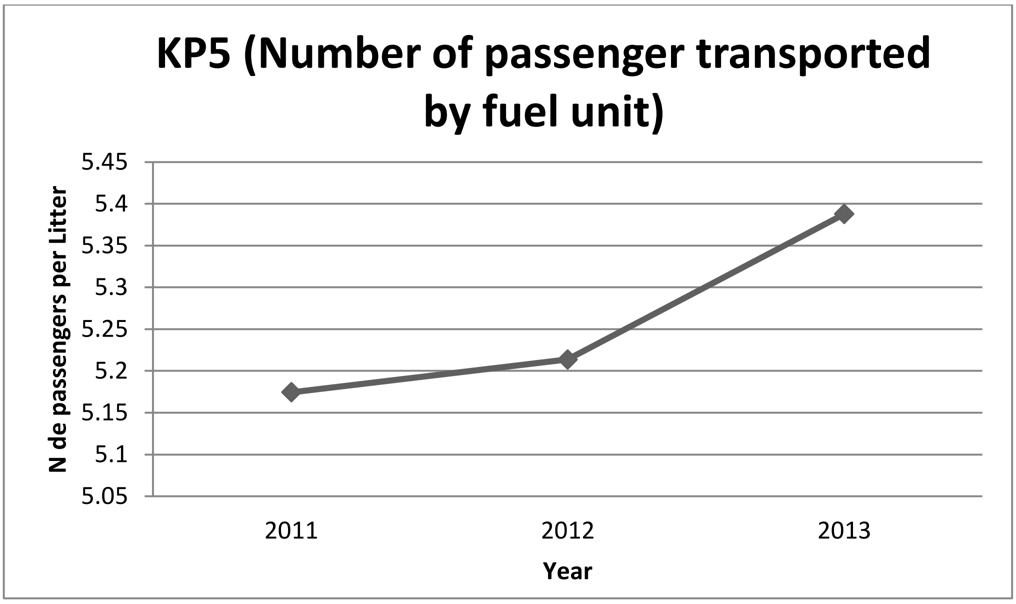

Figure 28. *KP5 Number of passenger transported by fuel unit.*

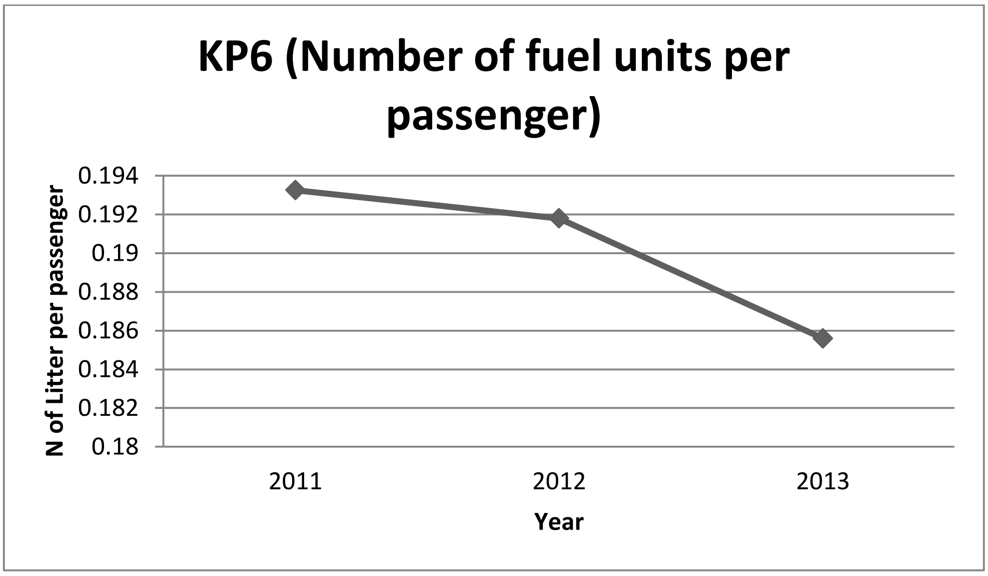

Figure 29. *KP6 Number of fuel units per passenger.*

- KP8 Total CO2 emissions for travel (multiple modes) passengers

KP8 shows the composition of the emissions in the transport sector, as it can be seen in the following figure, Tampere has a high modal share percentage for private car over the years (2005 to 2012), next is PT, and ALM are understood as a negative emissions, however the use of those modes had been decreasing.

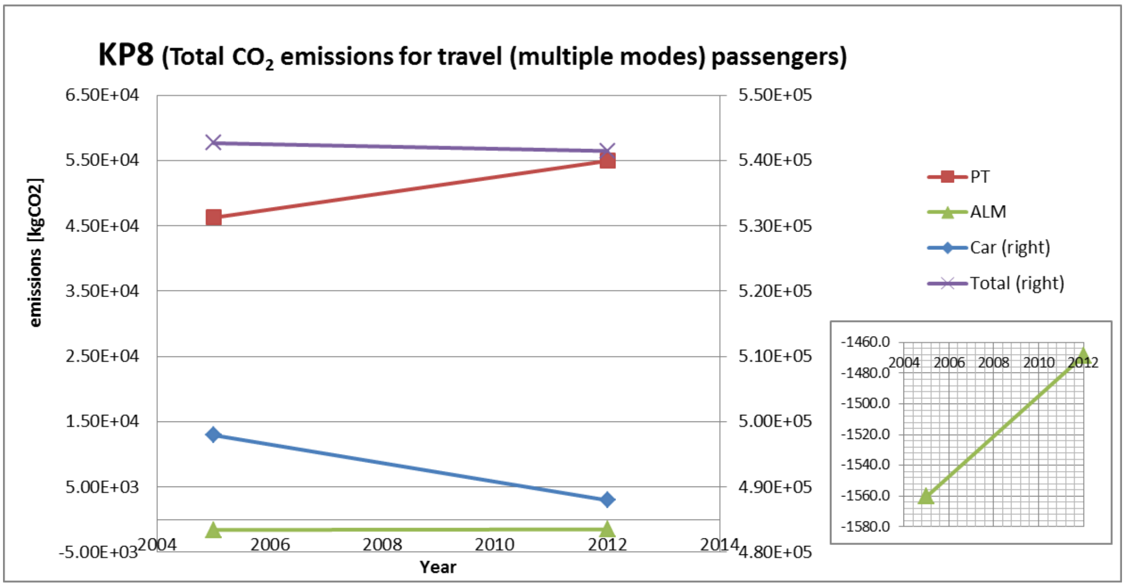

Figure 30. *KP8 Total CO_2 emissions for travel (multiple modes) passengers by mode.*

Figure 31 shows in more detail the total CO2 emissions for an average Finn per year, which had decreased from 2005 to 2012 as it is observed in the figure. This change is a consequence of the decline in the share percentage for private car and the rise of the PT percentage.

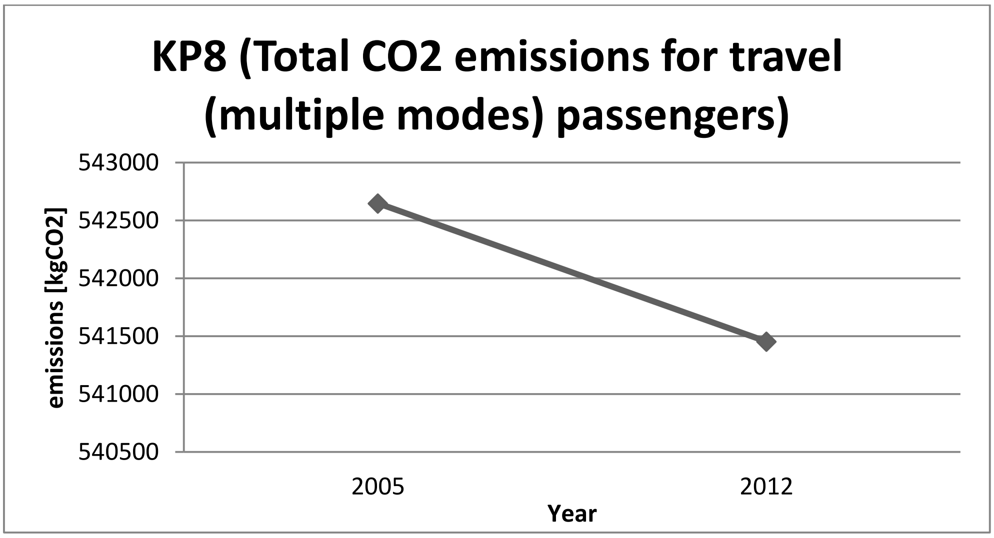

Figure 31. *KP8 Total CO_2 emissions for travel (multiple modes) passengers.*

- KP10 Private vehicles density rate

The Figure 32 shows that the number of vehicles per 1000 habitants has drop from 2012 to 2013, meaning that the car availability is less and as a result less people is willing to choose to drive over PT or ALM.

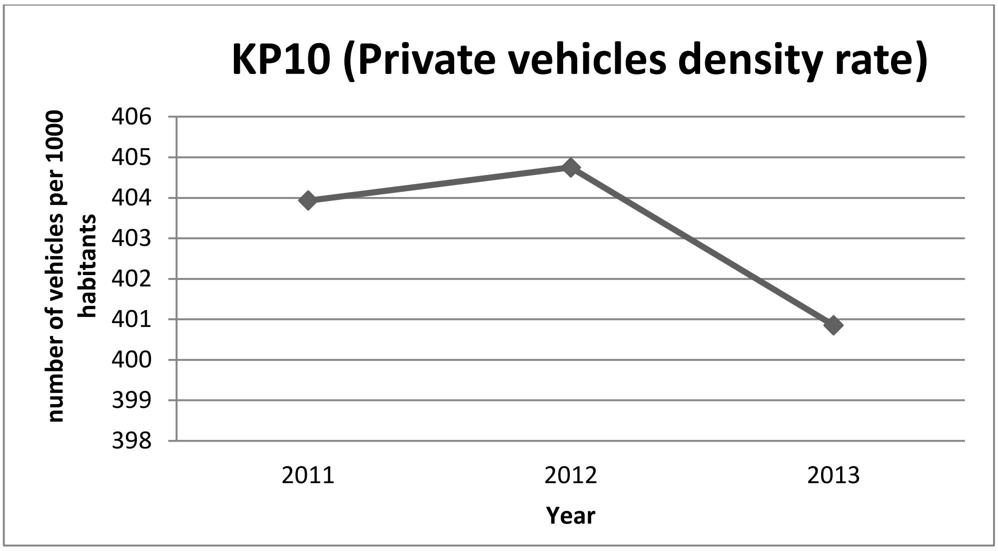

Figure 32. *KP10 Private Vehicle's density rate.*

- KP13 Share of public transport in total passenger traffic

This car availability affects the other transport modes. As can be seen in the Figure 33, the KP13 shows that the share of public transport has increased from 16% to 19% in 2005 to 2012 respectively.

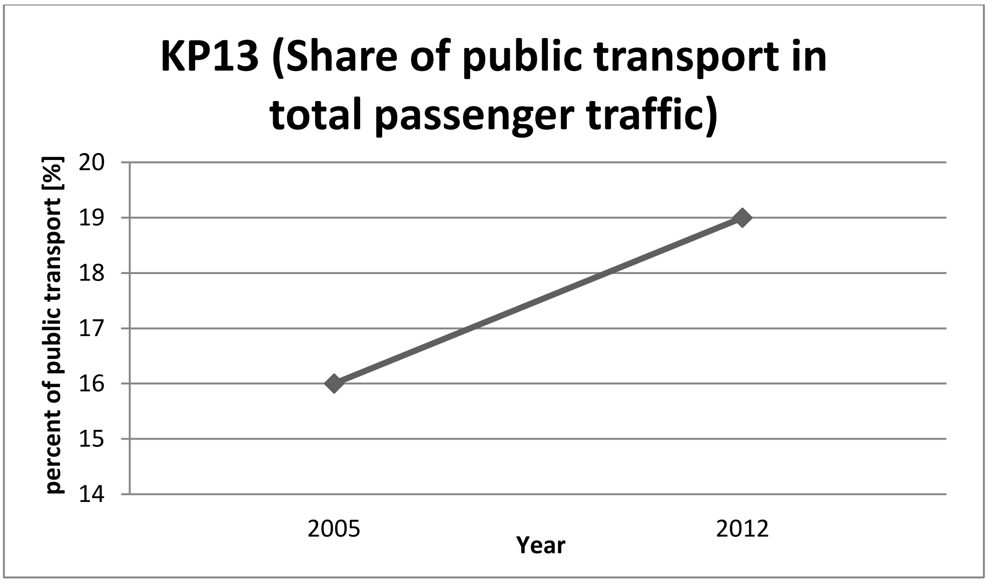

Figure 33. *KP13 Share of public transport in total passenger traffic.*

- KP16 Presence of alternative fuels vehicles

The Figure 34 shows how a new plug-in electric cars and hybrids have been added to the Finnish vehicle fleet from 2011 to 2014, we assume that similar growing has been happening in Tampere; however, the technology is in a testing stage.

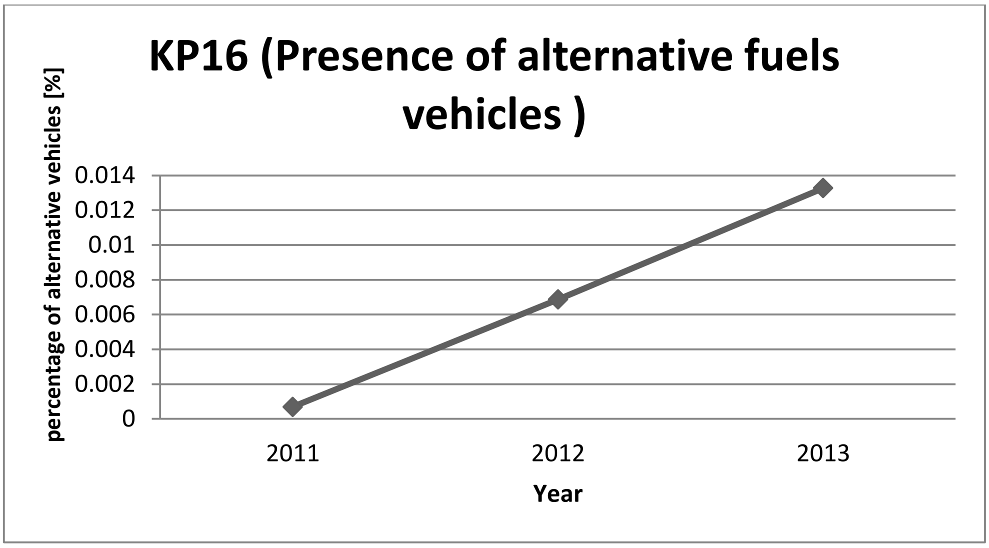

Figure 34. *KP16 Presence of alternative fuels vehicles.*

- KP18 Traffic-free (TF) and on-road (OR) routes

Figure 35 shows the ALM modes by the kilometers of Traffic free (TF) and On Road (OR) routes, which have been constantly growing from 2004 to 2011 (Figure 35).

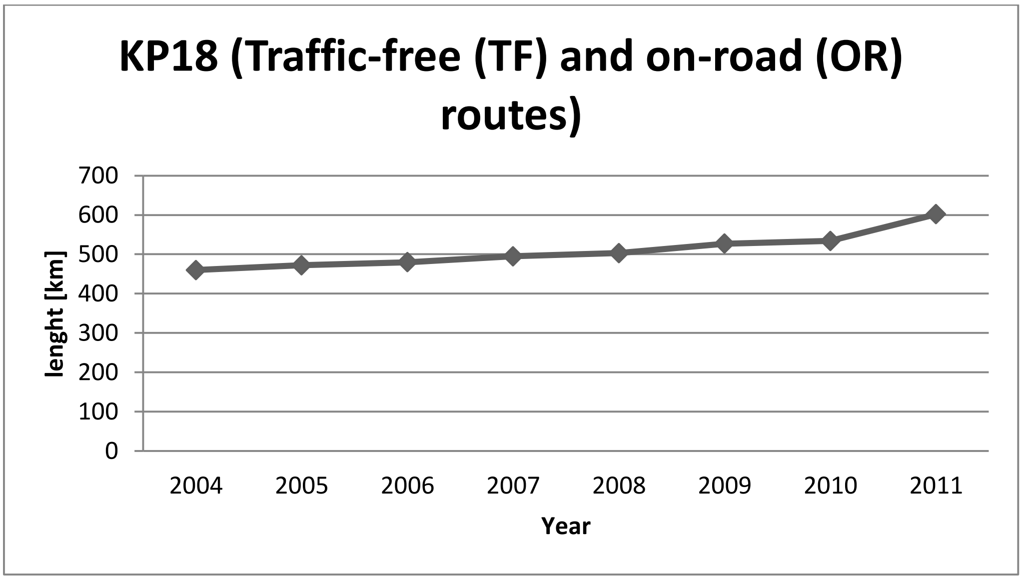

***Figure 35**. KP18 TF and OR routes.*

- KP19 Annual usage estimation in alternative modes

However the number of users has declined from 2005 to 2012. Figure 36 shows the users in a couple of points in the Tampere city (specific locations) and are cyclist, so in consequence the number of user is quite low compared with the whole Tampere population, however for the purpose of knowing the performance of usability, this number is used as a reference.

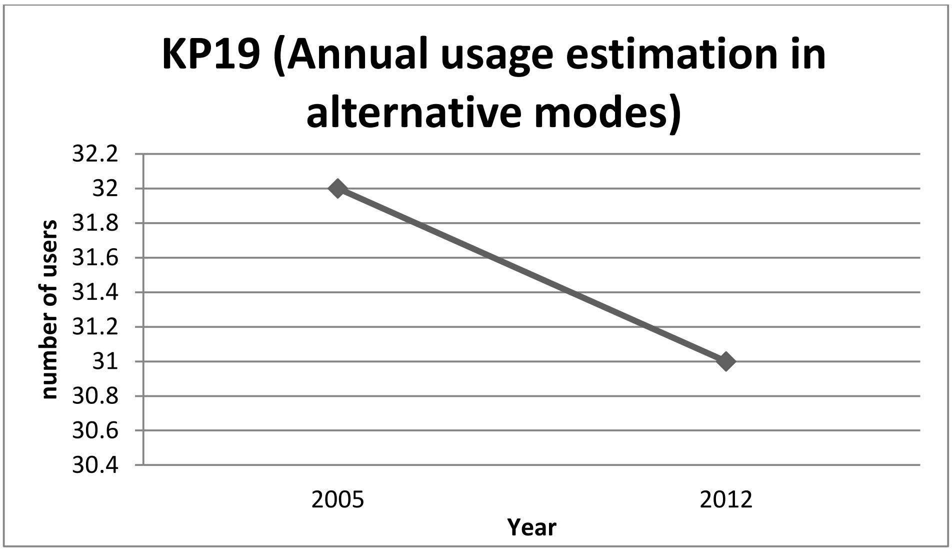

Figure 36. *KP19 Annual usage estimation in alternative modes.*

3. Baseline and step5: set Targets

As it was explained before, the implementation of the methodology is part of the monitoring and evaluation of the project MoveUs. As consequence, further mathematical operations to the KPIs were added, and the base lines, as well as the set Targets were defined based on those values. Details of those operations can be found in Appendix C. in order to illustrate the base line and set Target, one KPI will be use, for the other KPIs consult MoveUs Documents, Deliverable 4.1.

The KP19 is transform to KP19s that represent the emission saved by the ALM users per year. As Tampere wants to increment the usability of those TF and OR paths, the base line for 2016 is 4.33 $kgCO_2$, so the Target value for 2016 is 4.84 $kgCO_2$ (Figure 37).

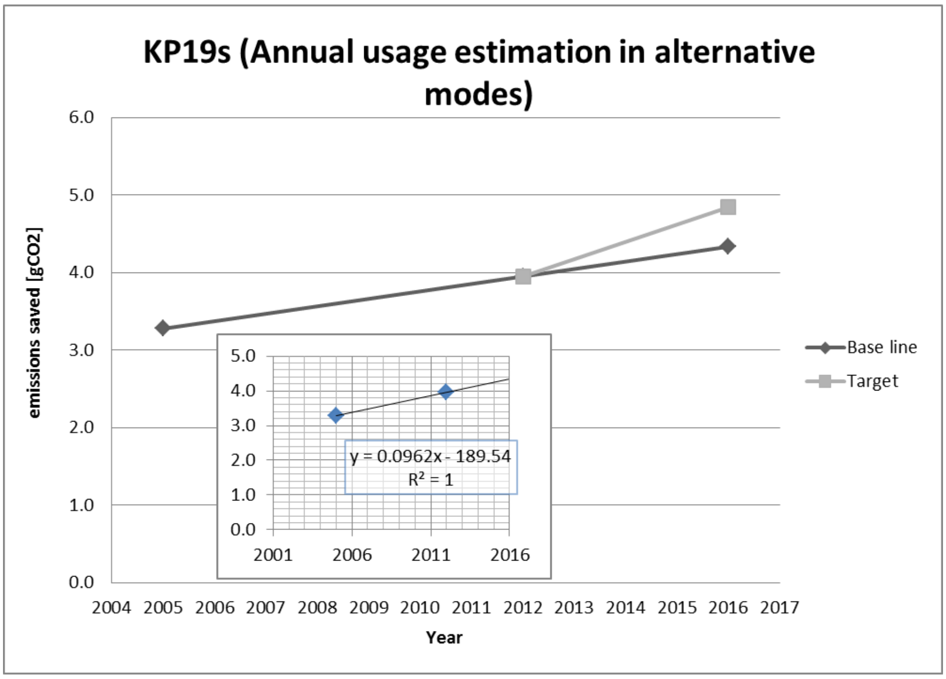

Figure 37. *KP19 Annual usage estimation in alternative modes.*

At the date of release of this thesis work (spring 2015), MoveUs project is at implementation stage and therefore it is too early to implement the last three steps of the methodology.

4.3 Feedback

The following section describes the evaluation of the methodology from some of the individual partners who apply the methodology in order to evaluate the MoveUs project. The evaluation data was obtained through a survey that was send to the partners. The survey document can be seen in Appendix D.

The methodology was describe as easy and logic to implement however all the partners agreed that it was difficult the calculation in steps 4 and 5. These steps were not the only difficulty for the first time users of the methodology; the collection process of data for calculations was unclear. However the methodology does not include the process to collect data, the reason is that data collection is a unique process for authorities and particular systems. Due to the difficulties, the partners found that applying the methodology is a time consuming process, mostly taking many days to complete the previously explained steps.

Additionally, it is important to clarify that most of the data for the implementation described previously (MoveUs project) came from external sources such as: department of transport, municipalities, private companies, etc. For some of the partners the cooperation with those external actors was difficult. Although the process was described as difficult and time consuming, as the partners when through the methodology steps they found it useful. Finally, all the partners coincide that they would like to implement the methodology in other projects.

5. WEB BASED METHODOLOGY MANAGEMENT SYSTEM

Based on the feedback described in the previous section and in order to make more accessible the information and facilitate the interaction between authorities and the implementation of the methodology, a web application was developed. The demands and requirements for the system come from the methodology definitions. This section contains the description of the application as it is shown in the Figure 38.

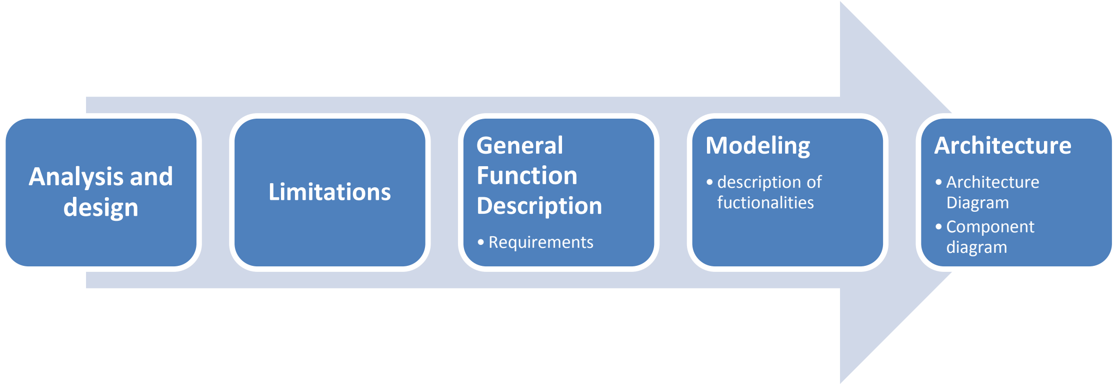

Figure 38. *Structure of the web Application.*

5.1 Analysis and design

The web based methodology management system was written in PHP (PHP Hypertext Pre-processor) programming language, and has some JavaScript and HTML inside. The demands and requirements for the system come from the structure of the methodology previously describe. PHP integrates all the components of the application. It was selected because of it is widely used in many web operating systems and platforms; additionally it is available as an open source, deployed mostly on web servers.

The web based methodology management system was design to improve collaboration between the authorities working on energy efficiency projects, helping to ensure that the methodology application is correct. The design procedure was done in two stages: preliminary design, where the features of the application were specified. Second stage is the detailed design (structure), which results in a design application that correctly and completely implements the requirements expressed in previous stage. For the preliminary phase, the main goal was to describe how the web-based application management system will perform the functions specified in the requirements, within the defined interfaces, and the environment.

5.2 Limitations

The program functionalities should remind easy and basic so the path through the methodology is smooth for the users. Even though the web-based application is designed for helping authorities to implement the methodology, the data entered through the application can be only accessed during the section, and database (PHP session) is accessed with the session ID. This is the first version of the application, in consequence further modification and additional functionalities may or not be necessary to add or develop.

5.3 General function description

To determine the requirements for the development of the web application, the steps of the methodology were analyzed. Each step requires information and specific processes. The Functional Requirements are the operations and/or services that the program should provide to the user, detail information can be found in appendix E. The functional requirements that were identified are:

- R1 Enter the information for Step 1: Main Goal
- R2 Enter the information for Step 1: Objectives
- R3 Enter the information for Step 2
- R4 Enter the information for Step 3
- R5 Enter the information for Step 4- Energy revision 4.1
- R6 Enter the information for Step 4- Performance Indicators 4.2
- R7 Enter the information for Step 4- Performance Indicators 4.2 variables
- R8 Calculate for Step 4- Performance Indicators 4.2
- R9 Update the information for Step 4- Performance Indicators 4.2 variables
- R10 Calculate mathematical regression of step 4- Performance Indicators 4.2
- R11 Calculate further values of PI of step 4- Baseline 4.3
- R12 Enter the information for Step 5
- R13 Enter the information for Step 6
- R14 Enter the information for Step 7
- R15 Enter the information for Step 8

Additional Non-functional requirements were identified; these are related with the interaction of the user and visualization of the information. Detailed information can be found in appendix E.

- NR1 show the methodology diagram
- NR2 user can go to previous steps
- NR3 inform step
- NR4 inform previous and next step

5.4 Modeling

In this section, there is a description of the functionality of the web application. The following UML diagrams represent a graphical overview of the functionality provided by the application. The main purpose of a use case diagram is to show what system functions are performed for which actor. Roles of the actors in the system can be depicted, however this application only has one actor, which it is the direct user of the application. On Figure 39 is shown the functionalities of the application that were described previously.

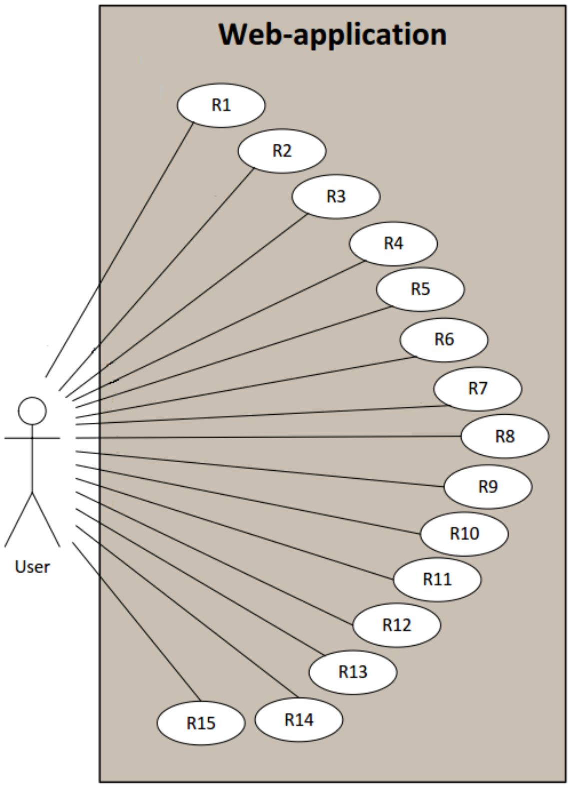

Figure 39. *Functionality of the web application.*

A sequence diagram in Unified Modeling Language (UML) is a kind of interaction diagram that shows how processes operate with one another and in what order. In the appendix F the sequence diagram represents the flow of information between the user and the application. First, user goes to main page where he/she gets an introduction page. After pressing a button for the next step the user is able to add the data required for step 1, as soon as the input is added to the page, user can save the information and a link will lead him/her to the next part of the step1 (description of objectives). In the description of objectives, the user can add the data, and request a new column for another objective if it is need. Another link lead to the step2, in there, user can add the data and go to the next step through a link.

In the step3, the data can be added and save, additional, spaces for new variables can be added by the user if it is needed. The step4 is divided in three parts: step 4.a, 4.b and 4.c. the step 4.a require user to select the energy sources and the data of the energy revision, after save through a link user can go to next section. Step 4.b shows the KPIs available in the database and allows user to enter the data from each of the KPI's variables. Step 4.c display the KPIs data entered by the user (selected), and calculates a regression line (baseline) so the user can give the year input to obtain the baseline value.

Step5 shows the data added by the user from the step 4.b until the baseline (4.c) and allow user to input the target value, as soon as the user save the value, the visualization updates with the new value. Step6, 7 and 8 allow user to input the data and save. Finally a report is printed to the screen with all the data added in the session.

5.4.1 The web application user Interface

The implemented interfaces as well as the identification of the functionalities are introduced in this section.

The first step of the application is an introductory page where users can see the schema of the methodology as well a description (Figure 40).

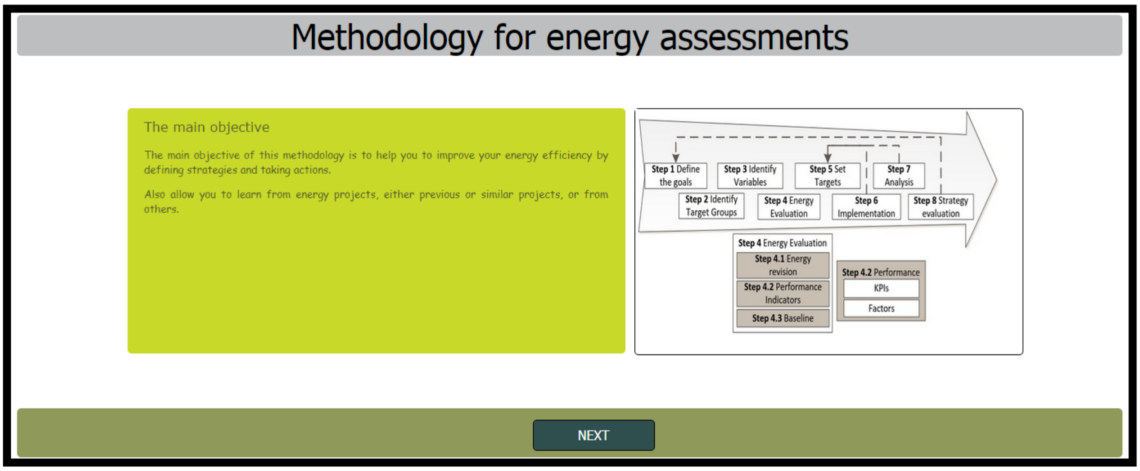

Figure 40. *Introduction visualization.*

The next page is the step 1 interface in where a small description of the step and a text area are shown. In the text are the user can add the main goal, and go to the next stage of the step 1 (Figure 41). The next stage is the objectives description, which is composed by a column, constitute by several text areas in which user can add the input, in case there is more than one objective, the user can request as much columns as is necessary by pressing the button ADD NEW OBJECTIVE (Figure 42).

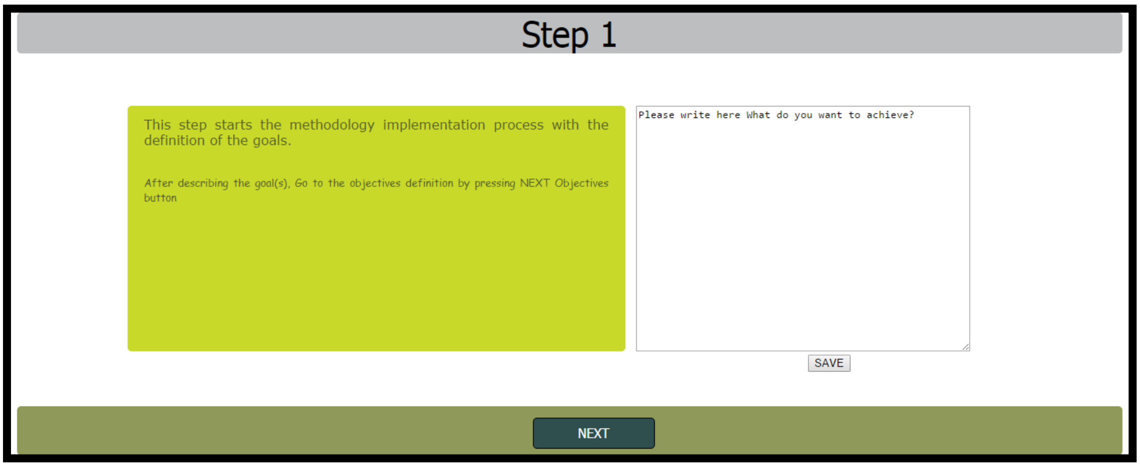

Figure 41. *First visualization Step 1*

Figure 42. *Second visualization Step 1*

After saving the objectives user can go to the next step. The step2 is also an informative description of the step and a text area where users can save their input (Figure 43).

Figure 43. *Visualization Step2.*

Step 3 is represented by two text areas, one representing the variable and the other the objectives that are related with that variable. By pressing the button ADD NEW OBJECTIVE a new row of text areas is added (Figure 44), and as well as the previous step user should save the data before go to the next step.

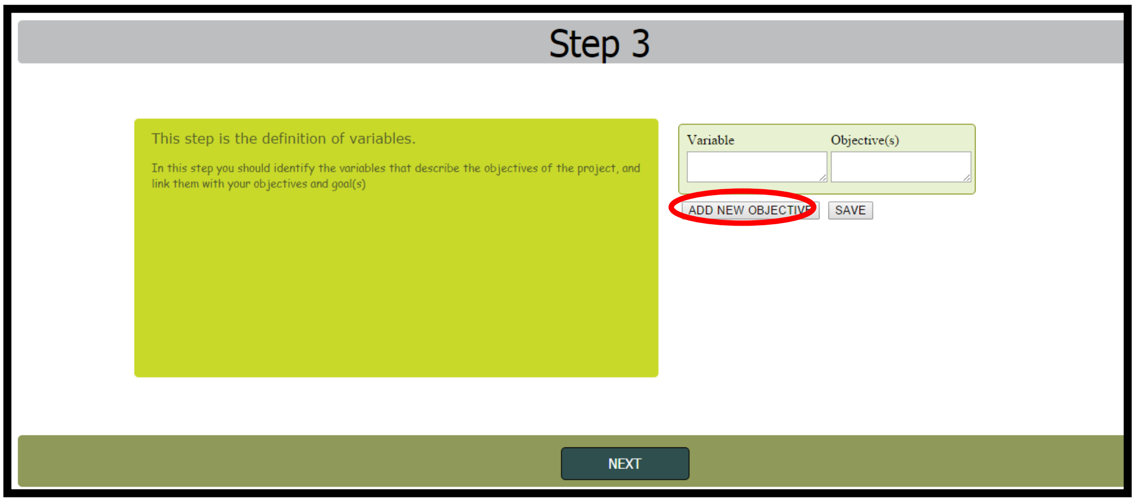

Figure 44. *Visualization Step3.*

Page 4 introduces the step four and at the same time shows the sub steps as buttons (Figure 45). By pressing the button "energy revision", the user goes to the energy revision in where can select the energy sources and add the description of the system into the text area (Figure 46). After finish the user can save and return to the page Step4.

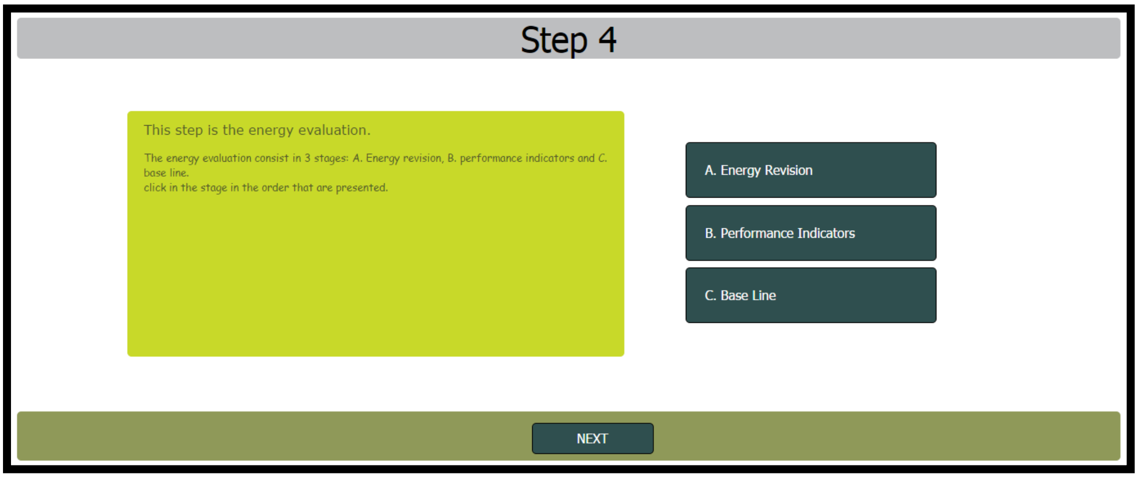

Figure 45. *Introduction visualization Step4.*

Figure 46. *Visualization Step 4.a*

The performance indicators and baseline are calculated in the same visualization. The visualization consist in a dynamic list of KPIs (Figure 47), by pressing a KPI a subarea is display with a description of the KPI included the variables (Figure 48). At the time, user adds values to the KPI's variables; a line graph is displayed (Figure 49). The user can add as much values as necessary, so the regression is calculated with those values and displayed in the same graph. In the same visualization, users can add the year for the baseline and set the target value (Figure 50). Finally a pdf and print options are available for each of the graphs.

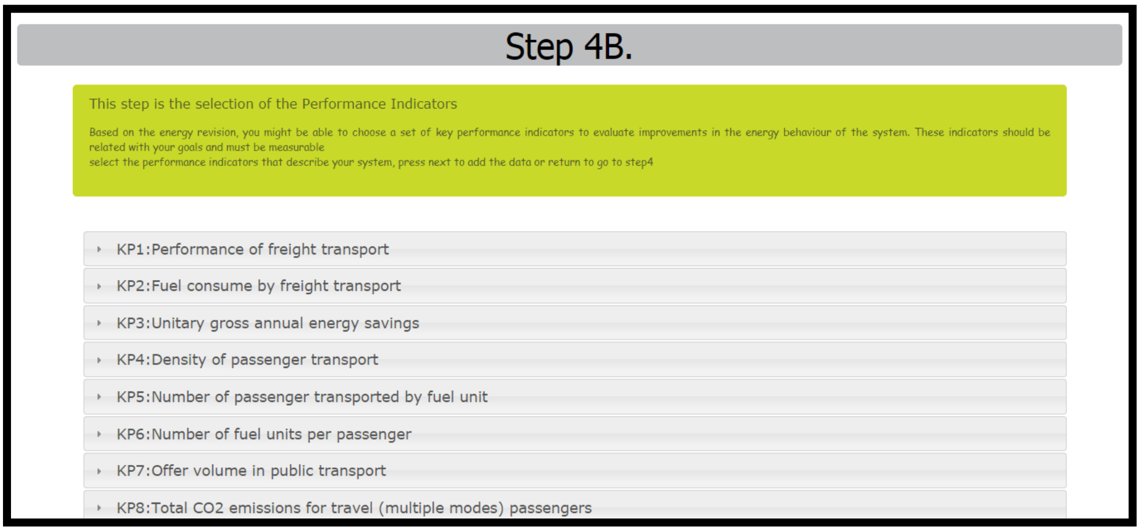

Figure 47. *Initial visualization of KPIs in Step 4.*

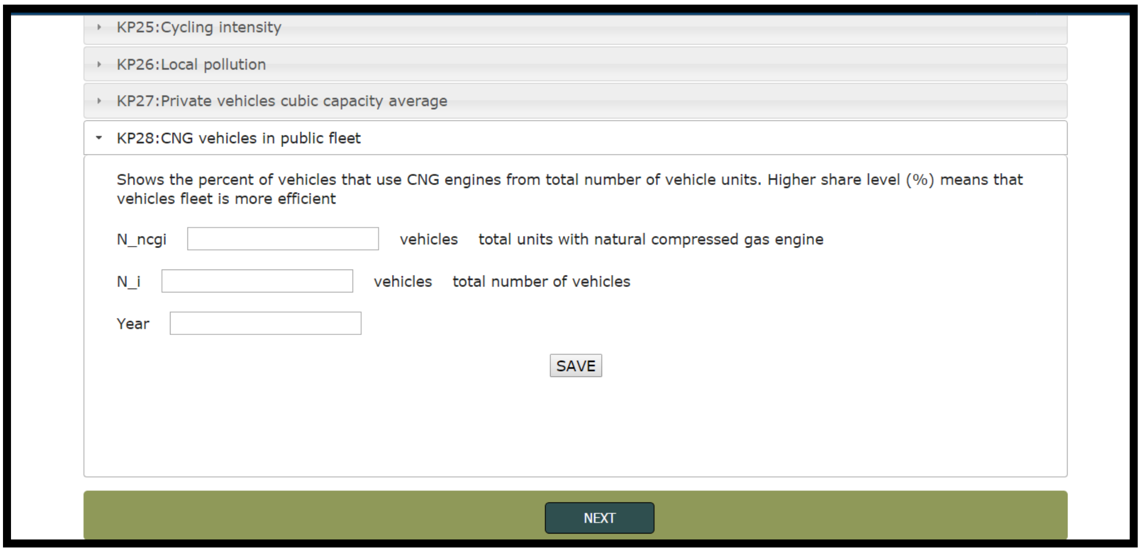

Figure 48. *KPI individual visualization in Step 4.*

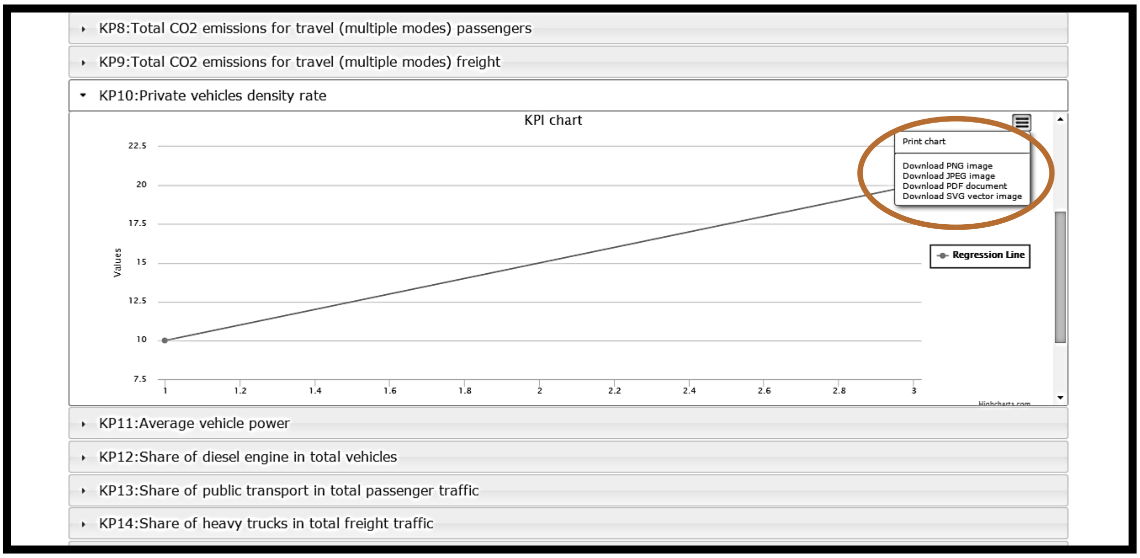

Figure 49. *KPI's graph.*

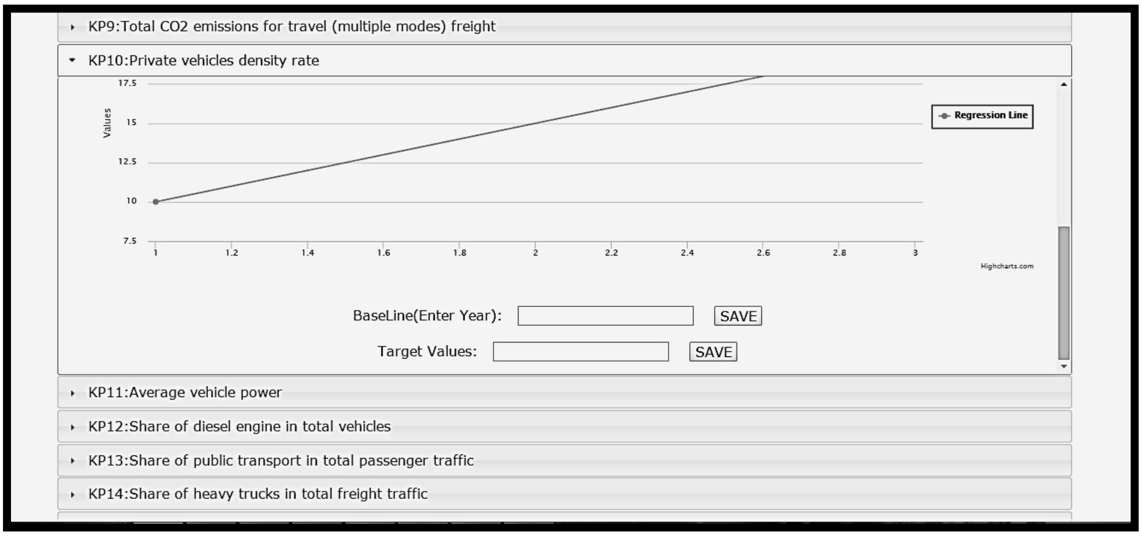

Figure 50. *Base line (Step 4) and Target value (Step5).*

For the step 6, 7 and 8 a text area is available for user input, as well as, their respective descriptions. All the steps can be seeing it in the following Figure 51, Figure 52, and Figure 53. In all the visualization the user should save the values and press next to go to the following step. Finally the user have available a pdf download option of the steps inputs.

Figure 51. *Visualization Step 6.*

Figure 52. *Visualization Step 7.*

Figure 53. *Visualization Step 8.*

5.5 Architecture

In this section, the architecture is described. The architecture of the web application is shown on Figure 54; it has a MVC (Model-View-Controller) pattern, meaning that the application development was separate in three main pieces.

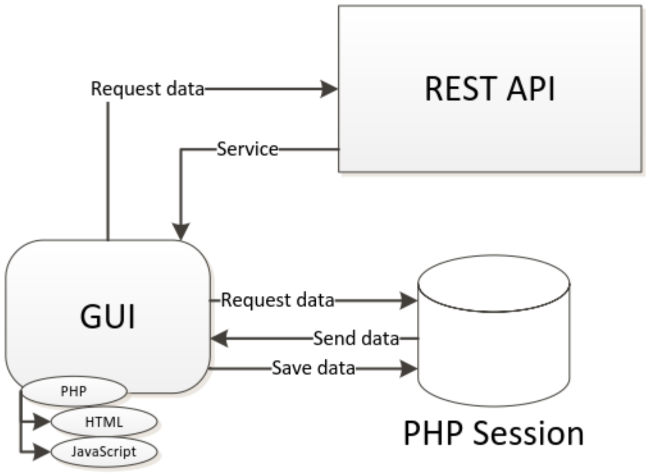

Figure 54. Web application Architecture.

The controller is basically the traffic controller of the application, in this case was develop in PHP that is a widely-used general –purpose scripting language. The PHP contains all of the application logics as well as the view, meaning that integrates the HTML (Hyper Text Markup Language) and JavaScript content. The visible interface that the user interacts with is defined in HTML, which is called by the controller and interacts with the model that is done in JavaScript and PHP.

The REST (Representational state transfer) API (Application Programming Interface) also integrates the model; this is used to make the necessary calculations for the steps 4 and 5 of the methodology. It communicates with the server and, as a resource, has the values given by the users in form of JSON (JavaScript Object Notation). It gets the result of the calculations from the service and stores them in PHP session and creates the graphs to post them in the GUI. As can be seen in the figure the system utilizes PHP session as a database to store information. In order to deploy the application, a web server called WampServer was used. The server is a windows web development environment.

Finally, it is possible to use this application for other sectors, by changing or adding a new list of performance indicators into the JSON file that is call KPI_DATA.json.

6. CONCLUSIONS

The methodology for energy assessment aims to encourage more authorities to implement EE projects in their expertise areas. The methodology offers a great help for project planning and managing, especially in the first steps (1 to 3). Additionally, the methodology is a common frame that allows comparisons of different EE projects. Comparisons can be done between projects with different targets, or locations, and also learn from the result and collect data for future research and analysis on how the system (TrS or IndS) behaves in terms of energy.

Other step that has great impact in the implementation process of the methodology is the Step 4 (energy evaluation). It provide the opportunity to have a perspective on how is the current energy state of the system and shows how the authorities can use those performance measurements for the next steps of the methodology. The identified set of performance indicators simplifies the complexity of the system, which partners from MoveUs project found useful. In the next step, authorities can establish their target values and proceed with the implementation, monitoring and final analysis of the project results. However in the application shown in this thesis, the last steps (6 to 8) have not been applied due to the duration of MoveUs project.

Additionally, the emphasis on the target group depends of the project, in the case of MoveUs a well-defined target group, so authorities can find what motivates that target group to change, and in that way apply strategies that will influence people's behavior, and made success the project.

On the other hand, current access to technology makes essential the use of tools, especially for monitor and support authorities' actions (decisions) towards EE for reaching sustainable systems. The present web-based application can be considered as a useful tool for decision support. It provides a friendly interface in which authorities can follow the designed methodology, in a fast way no matter the location (because is web).

One of its advantages is its visualization and self-contained computation (mathematical processes). The visualization helps users to easily perceive how the tendency of the performance indicators is and track if the behavior is going toward their target. The self-contained computation help users to go through the steps 4 and 5 without worrying about the mathematical procedure, which in more of the cases were considered difficult.

As a future work, the pilot cities of MoveUs project will implement the last steps of the methodology (step 6 to 8) in order to evaluate their EE project, so in that way all the methodology will be validated. At the end, it is expected to get conclusions about its usefulness and applicability.

Additionally, there is a significant potential of this methodology to be implemented in different sectors. The next stage to probe the flexibility of the methodology is to apply it in other domains, as it was explained before the Industrial sector is consider as a complex system, which has a great potential for energy saving through the application of EE projects. In the long term the methodology can be apply to all the industry different levels as was explain in the background, which will give a more clear understanding of the industrial sector energy state.

The designed tool can be use in other projects and domains, however needs improvements, especially in the introduction of new KPI and its requirements that can be done in a more user friendly way. Others improvements should be done in the database, which at the moment is artificially created into the browser session, meaning that it is needed to create a permanent database for user to be able to access the data after the session is closed. Also a user identification system may be useful, because at the moment the application does not require identification. Finally, KPIs variables data can be done automatically in cases where the data is available in a digital form.

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APPENDIX A: KPI IN TrS LIST

- **ID**: each KPI includes an identifier to facilitate tracing through subsequent phases. The identifier is formed by two letters and a number; in case of a pilot city specific KPI there is an additional letter at the end, **T** for Tampere, **M** for Madrid and **G** for Genoa.
- **Title**
- **Mathematical expression**: mathematical formulation indicating which variables are included in the KPI and how they are related to each other. It also gives an idea of the dimension of the indicator (dimensionless, percentage, etc.)
- **Description**: explanation of what the indicator shows, and how the variables are related to each other.
- **Goal**
- **Comment**

ID KP1	**Title: Performance of freight transport**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{\sum W_i}{ADT}$ $[Kg\ per\ Km]$
Description	W_i = Annual total weight of goods transported by a unit [Kg] ADT= Annual distance travelled of the unit [Km]
Goal	Aims to improving vehicle energy efficiency, by showing the relation between distance and weigh. The transport system is more efficient if the quantity of goods is higher than the distance.
Comment	This KPI can be use also to find the total gross annual energy savings by multiple with N°: number of units The indicator can be implemented by mode and by type of fuel

ID KP2	**Title: Fuel consume by freight transport**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{\sum W_i}{ADT} * C_i\ [Kg\ per\ Litre]$
Description	W_i = Annual total weight of goods transported by a unit [Kg] ADT= Annual distance travelled of the unit [Km] C_i= unit of fuel consumption in [Km/litre]
Goal	Aims to improving vehicle energy efficiency, by show-

	ing the relation between total fuels consume and weight. The transport system is more efficient if the quantity of goods is higher than the consumed fuel.
Comment	This KPI can be used also to find the total gross annual energy savings by multiple with N°: number of units The indicator can be implemented by mode and by type of fuel

ID KP3	**Title: Unitary gross annual energy savings**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\left(En_{inef\ fveh} - En_{ef\ fveh}\right) * ADT\ \ [gCO_2\ per\ Km]$
Description	En_{*} = Energy consumption of a certain transport mode. Distinguee between efficient and inefficient modes ADT= Annual distance travelled of the unit
Goal	Aims to improving vehicle energy efficiency, to prevent a number of consumers to buy inefficient vehicles. This indicator helps to create a baseline. Additionally the baseline can be used as a base for new target in vehicles efficiency
Comment	This KPI can be used also to find the total gross annual energy savings by multiple with N°: number of units The indicator can be implemented by mode and by type of fuel

ID KP4	**Title: Density of passenger transport**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{\sum P_i}{ADT}\ \ [N\ passengers\ per\ Km\ (pkm)]$
Description	P_i = Annual total passengers transported by a unit ADT= Annual distance travelled of the unit [Km]
Goal	Aims to improve vehicle's energy efficiency by showing the relation between distance and passengers. The transport system is more efficient if the number of passengers is higher than the distance.
Comment	This KPI can be also used to find the total gross annual density of passengers by multiple with N°: number of units

ID KP5	Title: Number of passenger transported by fuel unit
KPI category	Energy efficiency, vehicles
Mathematical expression	$$\frac{\sum P_i}{ADT * C_i} \ [N\ passengers\ per\ Litre]$$
Description	P_i = Annual total passengers transported by a unit ADT= Annual distance travelled of the unit [Km] C_i= unit consume in [litre/km]
Goal	Aims to improve vehicle's energy efficiency. The indicator shows the number of passengers transported by a unit of fuel (litre). The transport system is more efficient if the quantity of passengers is high per unit of fuel.
Comment	This KPI can be use also to find the units of fuel per passenger The indicator can be implemented by mode and by type of fuel

ID KP6	Title: Number of fuel units per passenger
KPI category	Energy efficiency, vehicles
Mathematical expression	$$\frac{ADT * C_i}{\sum P_i} \ [N\ Litre\ per\ passenger]$$
Description	P_i = Annual total passengers transported by a unit ADT= Annual distance travelled of the unit [Km] C_i= unit consume in [litre/km]
Goal	Aims to improve vehicle energy efficiency. The indicator shows the number of fuel units per passenger. The transport system is more efficient if the quantity of units is low.
Comment	The indicator can be implemented by mode and by type of fuel

ID KP7	Title: Offer volume in public transport
KPI category	Energy efficiency
Mathematical expression	$$\frac{ADT}{A} \ [km\ per\ \text{km^2}]$$
Description	ADT= Annual distance travelled by the unit [Km] A= area where the unit travels [km^2]
Goal	Aims to improve vehicle energy efficiency. The indica-

	tor shows the volume of public transport offer.
Comment	This indicator can be implemented by mode

ID KP8	**Title: Total CO_2 emissions for travel (multiple modes) passengers**
KPI category	Energy efficiency, modes
Mathematical expression	$$\frac{\sum P_i}{ADT} * S * ADT * En_* \; [gCO2\; per\; pkm]$$
Description	$\frac{\sum P_i}{ADT}$ = density of passenger transport [N passengers per Km (pkm)] S = Modal shares in total activity. [%] En_* = Energy consumption of a certain transport mode [gCO_2] ADT= Annual distance travelled of the unit [Km]
Goal	Shows the energy use for passengers transportation using several transport modes, and the energy intensities of each mode.
Comment	The KPI can be used to identify energy efficient combination of modes to transport passengers

ID KP9	**Title: Total CO_2 emissions for travel (multiple modes) freight**
KPI category	Energy efficiency
Mathematical expression	$$\frac{\sum W_i}{ADT} * S * ADT * En_* \; [gCO2\; per\; km]$$
Description	$\frac{\sum W_i}{ADT}$= performance of freight transport [Kg per Km]. S = Modal shares in total activity. [%] En_* = Energy consumption of a certain transport mode [gCO_2] ADT= Annual distance travelled of the unit [Km]
Goal	Shows the energy use for freight transportation using several transport modes, and the energy intensities of each mode.
Comment	The KPI can be used to identify energy efficient combination of modes to transport goods

ID KP10	**Title: Private vehicles density rate**
KPI category	Energy efficiency, vehicles

Mathematical expression	$\frac{V_{pi}}{H} * 1000 \; [vehicles\ per\ 1000\ inhabitants]$
Description	H= total number of inhabitants [inhabitants] V_{pi} = number of private vehicles [vehicles]
Goal	Shows the number of private vehicles per inhabitants, lower number of private vehicles, less emissions
Comment	The KPI can be used to identify the levels of private vehicles ownership.

ID KP11	**Title: Average vehicle power**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{\sum V_{hpi}}{N_i} \; [hp]$
Description	N_i= total number of vehicles [vehicles] V_{hpi} = unit total horse power [hp]
Goal	Shows the average vehicle power, more power is related with higher average specific consumption of the vehicles fleet.
Comment	The KPI can be used to identify the average power in vehicles

ID KP12	**Title: Share of diesel engine in total vehicles**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{N_{Di}}{N_i} * 100 \; [\%]$
Description	N_i= total number of vehicles [vehicles] N_{Di} = total units with diesel engine [number of units]
Goal	Shows the percent of vehicles that use diesel engines from total number of unit vehicles. Higher share level (%) means that vehicles fleet is more efficient.
Comment	The KPI can be used only in cases where vehicles fleet has gasoline and diesel engines, example cars.

ID KP13	**Title: Share of public transport in total passenger traffic**
KPI category	Energy efficiency
Mathematical expression	

	$$\frac{P_{pi}}{P_i} * 100\ [\%]$$
Description	P_i= Annual total passengers transported by a unit P_{pi} = Annual total passengers transported by a unit of public transport
Goal	Shows the percent of share of public transport in total passenger traffic. Higher share means more energy efficient
Comment	The KPI can be used per type of unit vehicle or as a total vehicle fleet

ID KP14	**Title: Share of heavy trucks in total freight traffic**
KPI category	Energy efficiency
Mathematical expression	$$\frac{V_{ht}}{V_{ft}} * 100\ [\%]$$
Description	V_{ht}= total heavy trucks V_{ft} = vehicle use for freight transport
Goal	Shows the percent of share of heavy trucks (>16 tons) in total freight traffic. Higher share means more energy efficient
Comment	The KPI can be used only in road transportation. Vehicles use for freight transport for this KPI means transportation in roads.

ID KP15	**Title: Share of new units in vehicles fleet**
KPI category	Energy efficiency, vehicles
Mathematical expression	$$\frac{V_{yi}}{V_i} * 100\%\ [\%]$$
Description	V_i= Total vehicles V_{yi} = Total vehicles with new technology
Goal	Aims to show the share of new vehicle units with cleaner technologies (more efficient or less emissions)
Comment	The KPI can be used with different types of vehicles The y refers to the reference year, e.g. y=2010 so vehicles newer than 2010 are consider more efficient

ID KP16	**Title: Presence of alternative fuels vehicles**
KPI category	Energy efficiency, vehicles

Mathematical expression	$$\frac{V_{Ai}}{V_i} * 100\% \ [\%]$$
Description	V_i= Total vehicles V_{Ai} = Total vehicles with new technology that use alternative fuels
Goal	Aims to show the share of new vehicle units, which use alternative fuels
Comment	The KPI can be use with different types of vehicles and with different types of alternative fuels (electricity, ethanol etc.)

ID KP17	**Title: Presence of alternative fuels vehicles offering**
KPI category	Energy efficiency, vehicles
Mathematical expression	$$\frac{V_{Aoi}}{V_{oi}} * 100\% \ [\%]$$
Description	V_{oi}= Total vehicles model offering V_{Aoi} = Total vehicles with new technology that use alternative fuels offering
Goal	Aims to show the availability of vehicle model that use alternative fuels
Comment	The KPI can be used with different types of vehicles and with different types of alternative fuels (electricity, ethanol etc.)

ID KP18	**Title: Traffic-free (TF) and on-road (OR) routes**
KPI category	Energy efficiency, facilities for alternative modes (walking and cycling)
Mathematical expression	$$\sum A_r \quad [Km]$$
Description	A_r= Total traffic-free (TF) and on-road (OR) routes in km
Goal	Aims to show the availability of TF and OR routes
Comment	The KPI can be used for walking and cycling modes

ID KP19	**Title: Annual usage estimation in alternative modes**
KPI category	Energy efficiency, alternative modes
Mathematical expression	

	$\sum A_u$ $[number\ of\ users]$
Description	A_u= Total number of cyclists and pedestrians that use the TF and OR routes
Goal	Aims to show the usability of TF and OR routes
Comment	The KPI can be used for walking and cycling modes It can be used by age range and other population classification e.g. students and workers Alternatively, can be used by journey type such as displacement to work or school or as a leisure trip.

ID KP20	**Title: Facilities density in alternative modes**
KPI category	Energy efficiency, facilities for alternative modes (walking and cycling)
Mathematical expression	$\frac{\sum A_f}{\sum A_r}$ $[facilities\ per\ Km]$
Description	A_r= Total traffic-free (TF) and on-road (OR) routes [km] A_f = Total alternative modes facilities
Goal	Aims to show the availability of facilities per km of TF and OR routes
Comment	The KPI can be used for walking and cycling modes Facilities should be directly related with the activity (walking or cycling) e.g. safe parking places for bicycles or Safe drinking water in parks

ID KP21	**Title: Density of links in multimodal**
KPI category	Energy efficiency, multimodal transportation
Mathematical expression	$\frac{\sum L_{im} P_S}{A}$ $[Links\ per\ Km^2]$
Description	L_{im}= Total links between modes A= area in where the units travel $[Km^2]$ P_S = importance of the link
Goal	Aims to show the density of links between different transport modes in multimodal transportation
Comment	The KPI can be used all the modes and can be differentiate by the type of mode and service (public, private, passengers or freight etc.)

	Links should be calculated according to seasonal importance. The weight of a link (P_S) should be reflecting its changing importance during the year.

ID KP22	**Title: link's Length in multimodal**
KPI category	Energy efficiency, multimodal transportation
Mathematical expression	$$\frac{1}{n}\sum L_{ilm}P_S \quad [Km]$$
Description	L_{ilm}= link's length between modes [Km] n= number of links between modes. P_S = importance of the link
Goal	Aims to show the average link length between different transport modes in multimodal transportation
Comment	The KPI can be used all the modes and can be differentiate by the type of mode and service (public, private, passengers or freight etc.) Links should be calculated according to seasonal importance. The weight of a link (P_S) should be reflecting its changing importance during the year.

ID KP23	**Title: KPI's change per time unit**
KPI category	General all KPIs
Mathematical expression	$$KPI_i - KPI_{i-1}\ [KPI's\ unit]$$
Description	KPI_i= KPI in time unit i and KPI_{i-1} = KPI in a time unit $i-1$
Goal	Aims to follow the performance of each KPI in a unit of time
Comment	The unit of time can be hours, months, years etc. but it must be the same unit for both values. E.g. number of fuel units per passengers in year 2014 – number of fuel units per passengers in year 2015

ID KP24	**Title: KPI's percentage of change**
KPI category	General all KPIs
Mathematical expression	$$\frac{KPI_i - KPI_{i-1}}{KPI_{i-1}} * 100\%\ [\%]$$
Description	KPI_i= KPI in time unit i and KPI_{i-1} = KPI in a time

	unit $i-1$
Goal	Aims to follow the performance of each KPI in a unit of time and observe respect with previous data (positive or negative) changes
Comment	The unit of time can be hours, months, years etc. but it must be the same unit for both values. E.g. number of fuel units per passengers in year 2014 – number of fuel units per passengers in year 2015

APPENDIX B: KPI IN IndS LIST

This list of KPIs comes from the previous implementations and studies described in the background, and also form Mohammad Mahmud Hossain master thesis (15).

ID EMS001	**Title: Apparent Electrical Power**
KPI category	General all KPIs
Mathematical expression	$R_{NY} = I * V$
Description	I = Electrical current V= voltage Apparent Power is multiplication Voltage and Ampere in the System.
Goal	It is necessary to monitor Apparent Power also as it is an element of creating power factor.

ID EMS002	**Title: Reactive Electrical Power**
KPI category	General all KPIs
Mathematical expression	$Q_{NY} = I * V * \sin\varphi$
Description	I = Electrical current V= voltage Reactive Power is the angle between the current and voltage.
Goal	It is necessary to monitor Reactive Power also as most often it causes extra charge in electric bill.

ID EMS003	**Title: Reactive Electrical Power**
KPI category	General all KPIs
Mathematical expression	$V_{rms} = V_p / \sqrt{2}$
Description	Vp= peak voltage RMS (root mean square) voltage is the equivalent DC voltage.
Goal	This KPI helps to monitor harmony of voltage supply. As most of renewable energy comes in form of DC voltage this value would also help Managers to consider the needed amount of renewable energy resource units.

ID EMS004	Title: Root mean square Current
KPI category	General all KPIs
Mathematical expression	$$I = I_p/_{\sqrt{2}}$$
Description	Ip = Peak electrical current RMS (root mean square) of Current is the equivalent to steady DC.
Goal	This Kpi helps to monitor harmony of Current supply. Value denotes heat (Thermal Energy) created by the component itself. It can warn the monitoring system to avoid damage in advance.

ID EMS005	Title: Power Factor This Month for complete System
KPI category	General all KPIs
Mathematical expression	$$cos\varphi = \frac{\sum AcPCbyCELL[i]}{\sum ApPCbyCELL[i]}$$
Description	AcPCbyCELL: Average Active Power Consumption This Month by complete production System ApPCbyCELL: Average Apparent Power Consumption This Month by complete production System Power Factor is ratio of active power and apparent power in percentage.
Goal	Power Factor improvement is the significant fragment for energy savings. Since true power consumption depends upon this factor. A cost effective Power factor is greater than 0.95

ID EMS006	Title: Total Active Electrical Energy Consumption for complete Production Line
KPI category	General all KPIs
Mathematical expression	$$W_{TAEC} = \left[\sum_{n=0}^{N} W_{TMAEC}\right]_{t_1}^{t_2}$$
Description	W_{TAEC} [KWh]: total Active Energy Consumption W_{TMAEC} [KWh]: Measured Energy Consumption value Total active energy consumption is summation of measured active electric consumption of components,

	actively involved in production system at FASTORY. More specifically, Cells and bypass Conveyors.
Goal	This KPI gives figure about overall active energy consumption of production system in processes. Cost can be calculated directly with this KPI.

ID EMS007	**Title: Total Reactive Electrical Energy Consumption for complete Production Line**
KPI category	General all KPIs
Mathematical expression	$$W_{TREC} = \left[\sum_{n=0}^{N} W_{TMREC}\right]_{t_1}^{t_2};$$
Description	W_{TREC} [KWh]: total Reactive Energy Consumption W_{TMREC} [KWh]: Measured Energy Consumption value Total active energy consumption is summation of measured active electric consumption of components, actively involved in production system at FASTORY. More specifically, Cells and bypass Conveyors.
Goal	This KPI gives figure about overall active energy consumption of production system in processes. Cost can be calculated directly with this KPI.

ID EMS008	**Title: Peak Load**
KPI category	General all KPIs
Mathematical expression	$$P_p = MAX\left(\sum p_{xny}\right)$$
Description	p_{xny} [WATT]: Active Power $Maximum\ load\ of\ the\ manufacturing\ system$
Goal	Overloading of Manufacturing system can cause damage, It also has penalty in Energy Bill. So it is necessary to identify Peak Load events.

ID EMS009	**Title: Energy Consumption Per Complete Product**
KPI category	General all KPIs
Mathematical expression	

	$$ECP_r = \frac{W_{TAEC}}{PrU}$$
Description	Average Energy Consumption Per Complete Product
Goal	This KPI helps to find Average Energy Consumption per product that can be displayed to show overall energy cost per product in manufacturing system.

ID EMS010	**Title: Energy Consumption Per Complete Product**
KPI category	General all KPIs
Mathematical expression	$$TPsU = \left[\sum TCPs\right]_{t_1}^{t_2}$$
Description	TPsU: Total Completed Process Units TCPs: Total Completed Processes by whole system Total Process Units produced by all cells.
Goal	This KPI helps to compare with produced complete product to monitor quality rate.

ID EMS011	**Title: Energy Drain Coefficient**
KPI category	General all KPIs
Mathematical expression	$$ED = \left(\frac{TIP}{TEnFastory}\right) * 100$$
Description	ED: Energy Drain Coefficient in percentage TEnFastory: Total Energy consumption at Fastory TIP: Total Energy consumption when all Production
Goal	It takes the Energy Consumption during IPC Stop status and Total Energy consumption to calculate the percentage of energy consumed in stop status.

APPENDIX C: KPIS CONVERSIONS

In order to derive the corresponding overall energy use/CFP, or to be able to perform mathematical operation with selected KPIs, in MoveUs project, the data was combined with the following conversion factors.

To acquire overall CFP, the factor for conversion is the average carbon emission per unit of energy (crten) $\left[\frac{gCO_2}{kWh}\right]$[2] that is, the emission factor. Greenhouse gas emissions from fuels are expressed in terms of grams of CO_2 equivalent per fuel kilogram. The value changes from fuel to fuel and factors as fuel quality varies from country to country. Carbon Conversion Factor for private car (CCF_{car}) depend on technical information about the vehicle$\left[\frac{gCO_2}{km}\right]$. Carbon Conversion Factor for PT (CCF_{PT}) is calculated by dividing the amount of emissions per kilometer by the average number of passengers $\left[\frac{gCO_2}{pkm}\right]$.

Other units like Kilometers of TF and OR routes can be turned into energy saved or emission units by proposing a reference scenario, which is the worst scenario. For example for KP18, the worst reference scenario is a private car with low occupancy level, and high energy consume per km, energy/km x KP18[3]= Total energy saved.

The forward table shows the conversions used in the project MoveUs for each KPI.

ID: each KPI includes an identifier to facilitate tracing through subsequent phases. The identifier is formed by two letters (KP), one small letter below the text baseline (e=emissions and s=saving). **Title**. **Conversion to gCO$_2$:** mathematical formulation indicating the conversion of the KPI unit to gCO$_2$. **Description**: explanation of what the indicator shows, and what is the reference scenario.

ID	Title	Conversion to gCO$_2$	Description
KP1	Conversion is not required		
KP2$_e$	Emissions produce by freight transport $[kg/\mathrm{gCO_2}]$	$\mathrm{KP2}\left[\frac{\mathrm{kg}}{\mathrm{litre}}\right] * conv\left[\frac{\mathrm{litre}}{\mathrm{gCO_2}}\right]$	Use conversion Litre to emissions, depends of the fuel type.
KP3	The unit of this KPI is already gCO$_2$ do not require a conversion		
KP4$_e$	Emissions per km of	$\mathrm{KP4[pkm]} * \mathrm{CCF}_{PT}\left[\frac{\mathrm{gCO_2}}{\mathrm{pkm}}\right]$	Carbon emissions of

2 Grams of Carbon dioxide
3 KP18 unit is km

	passengers $[gCO_2]$		total passenger transported by a PT unit
KP4s	Emission saved by passengers in public transport $[gCO_2]$	$KP4[pkm] * CCF_{car}\left[\frac{gCO_2}{km}\right] - KP4e$	Carbon emission saved in 1km from total passenger transported by PT. Use of reference scenario of private car with low occupancy
KP5e	Number of passengers per fuel emissions $\left[\frac{P}{gCO_2}\right]$	$\frac{KP5\left[\frac{p}{fuel\ litre}\right]}{conv\ fuel\ \left[\frac{gCO_2}{fuel\ litre}\right]}$	Use the conventional conversion fuel to emissions
KP6e	Total emissions per passenger $\left[\frac{gCO_2}{P}\right]$	$KP6\left[\frac{fuel\ kg}{p}\right] * conv\ fuel\ \left[\frac{gCO_2}{kg\ fuel}\right]$	Use the conventional conversion fuel to emissions
KP7e	Emission volume in PT $\left[\frac{gCO_2}{Km^2}\right]$	$KP7\left[\frac{km}{Km^2}\right] * CCF_{PT}\left[\frac{gCO_2}{pkm}\right]$	Use the PT carbon conversion factor
KP7s	Emission volume saved by PT $\left[\frac{gCO_2}{Km^2}\right]$	$KP7\left[\frac{km}{Km^2}\right] * CCF_{car}\left[\frac{gCO_2}{km}\right] - KP7e$	Use of reference scenario of private car with low occupancy.
KP8	The unit of this KPI is already gCO_2 do not require a conversion		
KP9	The unit of this KPI is already gCO_2 do not require a conversion		
KP10e	Private vehicle emissions density rate $[gCO_2\ per\ 1000\ inhabitants]$	$KP10\left[VpI^4\right] * CCF_{car}\left[\frac{gCO_2}{km}\right] * ADT[km]$	Use the car carbon conversion factor and annual average distance (ADT)
KP11e	Average emission equivalent from average vehicle power$[gCO2]$	$\frac{KP11[hp]}{1{,}34\left[\frac{hp}{kWh}\right]} * crten\left[\frac{gCO_2}{kWh}\right]$	Use of Horsepower conversion to Kilowatt-hour and conversion of average carbon emission per unit of

[4] VpI is vehicles per 1000 inhabitants

			energy (crten)
KP12s	Share of diesel engine in total vehicles emissions savings $[gCO_2]$	$(CCF_{car} - CCF_{carDiesel})\left[\frac{gCO_2}{km}\right] * N_i * KP12 * ADT$	Carbon emissions save by diesel vehicles use CCF_{car} is car carbon conversion factor for gasoline and $CCF_{carDiesel}$ is car carbon conversion factor for diesel fuel. Use of reference scenario of private car with low occupancy
KP13s	Share of PT in total passengers traffic emissions savings $[gCO_2]$	$(CCF_{car} - CCF_{PT})\left[\frac{gCO_2}{km}\right] * P_i * KP13 * ADT$	Carbon emissions savings. Use of reference scenario of private car with low occupancy
KP14s	Share of heavy trucks in total freight traffic emissions savings $[gCO_2]$	$(CCF_{fta} - CCF_{fth})\left[\frac{gO_2}{km}\right] * V_{ft} * KP14 * ADT$	Carbon emissions savings, average freight truck carbon conversion factor for all the vehicle fleet (CCF_{fta}) and heavy vehicles(CCF_{fth}). Use of reference scenario of full capacity truck
KP15s	Share of new units in total vehicles emissions savings $[gCO_2]$	$(CCF_{car} - CCF_{carN})\left[\frac{gCO_2}{km}\right] * V_i * KP15 * ADT$	Carbon emissions savings, average car carbon conversion factor for all the vehicle fleet and new vehicles. Use of reference scenario of private car with low occupancy
KP16s	Presence of alternative fuels vehicles emissions savings	$CCF_{car}\left[\frac{gCO_2}{km}\right] * V_i * KP16 * ADT$	Carbon emissions savings, assuming that the alternative fuel

	$[gCO_2]$		vehicles are zero emission, if that is not the case, it is necessary to considerate their emissions. Use of reference scenario of private car with low occupancy
KP17	Conversion is not required		
KP18s	Emission saved in TF and OR routes $[gCO_2]$	$KP18\ [km] * CCF_{car} \left[\frac{gCO_2}{km}\right]$	Use of reference scenario of private car with low occupancy
KP19s	Savings from TF and OR usability $[gCO_2]$	$KP19\ [users] * CCF_{car} \left[\frac{gCO_2}{km}\right] * KP18[km]$	Use of reference scenario of private car with low occupancy
KP20	Conversion is not required		
KP21	Conversion is not required		
KP22	Conversion is not required		
KP23	Conversion is not required		
KP24	Conversion is not required		

APPENDIX D: FEEDBACK SURVEY

Using the methodology for energy efficiency assessments in the early stages of MoveUs project allows cities to have a tool for evaluate their energy use during the course of this project. We would like to report the feedback on how the individual authorities use the methodology for the energy evaluation of their cities and which difficulties they faced during the process. Although it is a methodology base on well know methodologies and standards that had been implemented in other projects, it is for MoveUs partners relatively new, so it is important to know the partners evaluation of the methodology, what they found that can be improve and their experiences.

- Please select from which of the following living labs (cities) are you?
  - ☐ Tampere
  - ☐ Genoa
  - ☐ Madrid
- How would you describe the methodology process?
  - ☐ Easy
  - ☐ Easy, but time consuming
  - ☐ Difficult to follow, why?____
  - ☐ Other , which?____

- Which of the following words describe the methodology process? (multiple choice)
  - ☐ Clear
  - ☐ Paper work
  - ☐ Logic
  - ☐ Unnecessary
  - ☐ Helpful
  - ☐ Other, which?_________________________________

- Based on the previous answers, would you like to implement this methodology in other mobility project?
  - ☐ Yes
  - ☐ No, why?____

- How much time did you spend in collecting the information for the first steps of methodology?
  - ☐ A couple of hours
  - ☐ Many days
  - ☐ Months
  - ☐ Don’t apply
  - ☐ Other, _________________

- During the collecting process. Did you got the information from other departments or organizations, e.g. Department of transport, Department for Culture etc.?
    - ☐ yes
    - ☐ No
- If the response of the previous question was yes. Which of the following words describe the cooperation process? (multiple choice)
    - ☐ easy
    - ☐ difficult
    - ☐ effective
    - ☐ New
    - ☐ unclear
    - ☐ Other(s), which?________________________________
- What difficulties did you face during the process of the methodology implementation?

  ____
  ____
  ____
  ____
  ____

- Do you think that additional training in the methodology process would prevent having those difficulties?

  ☐ Yes
  ☐ No, why?
  ☐ Other,____

- In overall from 1 to 5, being 5 totally agree and 1 totally disagree :

	1	2	3	4	5
The methodology process gives a clarity and direction to the project					
It was a useful methodology					
The methodology help to achieve the goals set out in the project					

APPENDIX E: WEB BASED METHODOLOGY MANAGEMENT SYSTEM REQUIREMENTS

ID R1	Name: Enter the information for Step 1: Main Goal
Description	It is required to receive the information of the organization main goal. The information is compose by a text describing the main goal
Inputs	Description of the main goal
Outputs	The Main Goal information had been accepted

ID R2	Name: Enter the information for Step 1: Objectives
Description	It is required to receive the information of the organization objectives. The information is composed by answering to 5 questions
Inputs	number of the Objective name of who is involved what where: location when: time frame Why
Outputs	The objectives information had been accepted

ID R3	Name: Enter the information for Step 2
Description	It is required to receive the information of the organization target group. The information is compose by a text with the target group description
Inputs	Description of the Target Groups
Outputs	The target group information had been accepted

ID R4	Name: Enter the information for Step 3
Description	It is required to receive the information of the organization variables. The information is composed by a text with the variable description and the numbers of the objectives related
Inputs	Description of the variables
Outputs	The variables information had been accepted

ID R5	Name: Enter the information for Step 4- Energy revision 4.1
Description	It is required to receive the information of the organization energy revision. The information is composed by a text with the revision
Inputs	Energy sources selection energy revision
Outputs	The energy revision information had been accepted

ID R6	Name: Enter the information for Step 4- Performance Indicators 4.2

Description	It is required to receive the information of the organization performance Indicators (PI). The information is composed by a set of PI
Inputs	Key Performance Indicators selection
Outputs	The PI information had been accepted

ID R7	**Name: Enter the information for Step 4- Performance Indicators 4.2 variables**
Description	It is required to receive the information of the organization performance Indicators (PI) variables values. The information is composed by a set of numbers for calculate KPIs
Inputs	Key Performance Indicators variables values
Outputs	The PI variables information had been accepted

ID R8	**Name: calculate for Step 4- Performance Indicators 4.2**
Description	calculate the PI and inform the value
Inputs	Key Performance Indicators variables values
Outputs	PI calculated value

ID R9	**Name: update the information for Step 4- Performance Indicators 4.2 variables**
Description	Allow update the variables values for PI calculation
Inputs	New Performance Indicators variables values
Outputs	The PI variables information had been accepted new PI calculated value

ID R10	**Name: calculate mathematical regression of step 4- Performance Indicators 4.2**
Description	calculate the mathematical regression of the PI
Inputs	PI values
Outputs	The PI mathematical regression

ID R11	**Name: calculate further values of PI of step 4- Baseline 4.3**
Description	calculate the values of PI in the future for base line
Inputs	PI mathematical regression
Outputs	The PI baseline

ID R12	**Name: Enter the information for Step 5**
Description	It is required to receive the information of the organization target value. The information is compose by a number
Inputs	The Target value for each PI
Outputs	The Target value information had been accepted

ID R13	Name: Enter the information for Step 6
Description	It is required to receive the information of the organization strategies that are being or going to be implemented
Inputs	description of the implementation
Outputs	The strategies implemented information had been accepted

ID R14	Name: Enter the information for Step 7
Description	It is required to receive the information of the analysis
Inputs	description of the analysis
Outputs	The analysis information had been accepted

ID R15	Name: Enter the information for Step 8
Description	It is required to receive the information of the strategy evaluation
Inputs	description of the strategy evaluation
Outputs	The strategy evaluation information had been accepted

Non-Functional requirements

ID NR1	Name: show the methodology diagram
Description	show the user all the steps of the methodology with a briefly description
Inputs	user accepts to start the methodology process
Outputs	The schema of the methodology

ID NR2	Name: user can go to previous steps
Description	user can go to previous steps
Inputs	the step that wants to go
Outputs	the step selected by the user

ID NR3	Name: Inform current step
Description	shows the user current step
Inputs	
Outputs	

ID NR4	Name: Inform previous and next step
Description	shows the user previous and next steps
Inputs	user step
Outputs	user next and previous step

APPENDIX F: SEQUENCE DIAGRAM

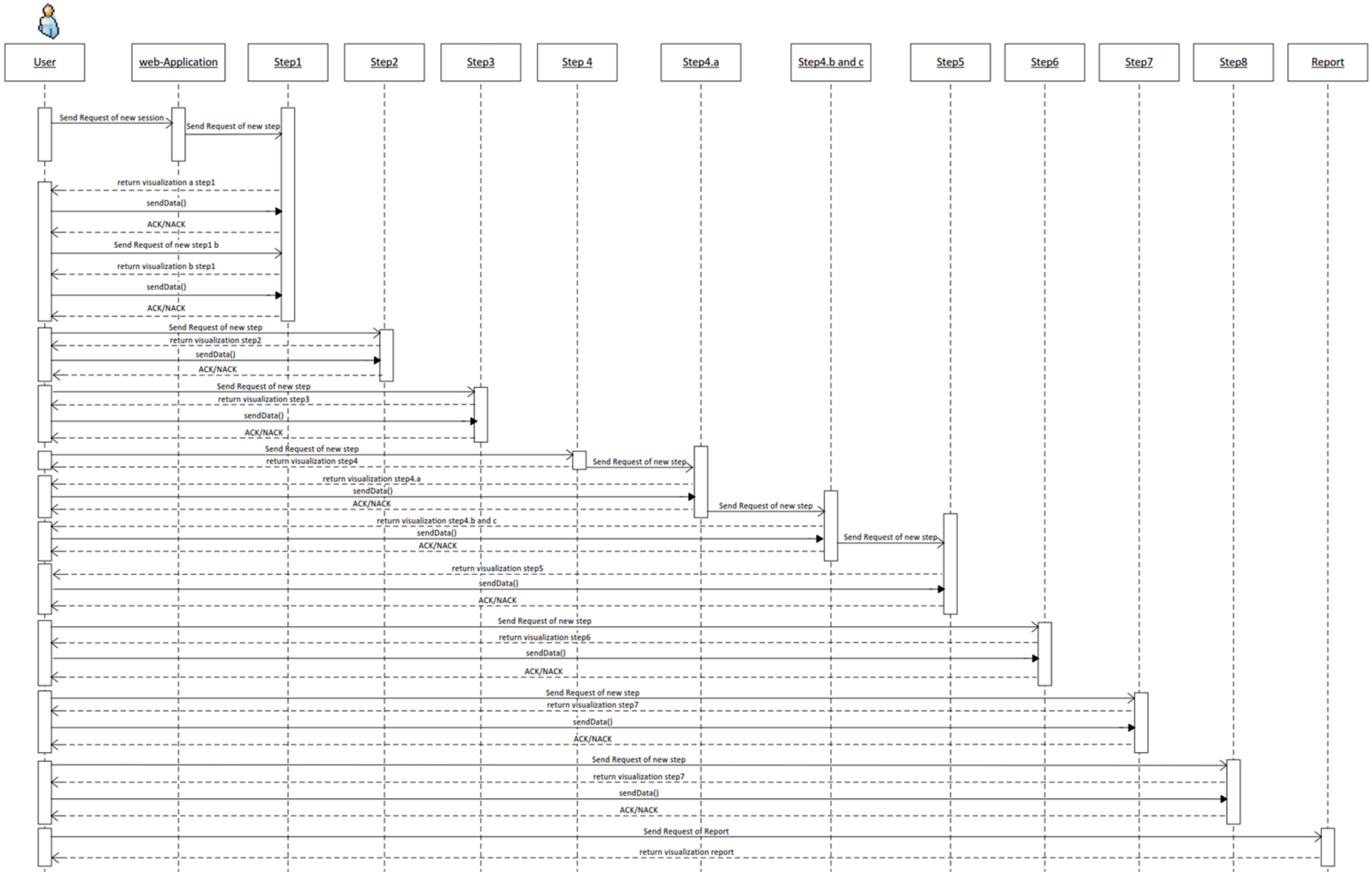

Figure F1. *Sequence Diagram*