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CitInES Project – Tool for the Sustainable Energy Action Plan for Cities

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1 ABSTRACT

Sustainable Energy Action Plan (SEAP) is the key document in which outlines how it intends to reach its CO_2 reduction target by 2020. It defines the activities and measures set up to achieve the targets, together with time frames and assigned responsibilities. However to orient cities toward a low carbon society, longer lasting investment decisions and organisational changes will be necessary.

In this conttext, the overall objective of CitInES European project is to design and demonstrate a multi-scale multi-energy decision-making tool to optimise the energy efficiency of cities to support the cities for the developemnt and monitoring of their SEAP. To achieve this goal, innovative energy system modelling and optimization algorithms were designed to allow end-users to optimize and monitor their energy strategy through detailed simulations of local energy production, storage, transport, distribution and consumption, including demand side management and coordination functionalities enabled by smart grid technologies.

This paper presents the study case of the municipality of Cesena. This municipality, as a partner of the project, has implemented its SEAP under the tool to assess the impact of the measures taken under several scenarios and monitor its activities to validate the developed software. The different measure adopted to reduce the CO_2 emissions and energy consumption together with an increase of the energy efficiency and use of renewables are such as increase of the green areas, increase of the use of cogeneration, renovation of the building or the promotion the use of PV and thermal solar panels.

2 INTRODUCTION

In March 2007, the European Union (EU) endorsed an integrated approach to climate and energy policy that aims to combat climate change and increase the EU’s energy security while strengthening its competitiveness. The policy committed Europe to transforming itself into a highly energy-efficient and low carbon economy. To kick-start this process, the EU set a series of climate change and energy targets to be met by 2020, namely the so-called 20-20-20 target: at least 20% reduction of greenhouse gas emissions below 1990 levels, 20% energy consumption to come from renewable resources and 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency [1].

In this context, the key challenges for Smart Cities and Communities are to significantly increase the overall energy efficiency of cities, to exploit better the local resource both in terms of energy supply as well as through the demand side measures. This will imply the use of energy efficiency measures optimising at the level of districts, the use of renewables, the sustainability of urban transport and the needed drastic reduction of greenhouse gas emissions in urban areas – within economically acceptable conditions - while ensuring for citizens better life conditions: lower energy bills, swifter transport, job creation and as a consequence a higher degree of resilience to climate impacts (e.g. urban heat islands effects) etc.

Local governments manage or oversee all city activities and city development, they play a central role in determining the energy and carbon emissions picture of their cities. They also have direct access to their citizens and are best placed to know their needs and to influence their behaviour. Sustainable Energy Action Plan (SEAP) is the key document in which outlines how it intends to reach its CO2 reduction target by 2020. It defines the activities and measures set up to achieve the targets, together with time frames and assigned responsibilities [2].

Over the past decade a variety of attempts have been made at developing a holistic decision-making tool that will assist cities in developing urban energy strategies by helping them to assess how well they are currently performing (in terms of energy security and affordability and greenhouse gas emissions) and allowing them to evaluate energy strategies - bundles of energy demand reduction measures energy efficiency and supply measures – with respect to tcheir impacts in terms of increase in energy security, reduction in carbon emissions and their capital and operational costs, their cost savings and the ownership of those costs and savings as well as the payback periods of the concepts. Each development has originated from a particular discipline and has typically been an extension to the urban energy system as a whole of tools specific to that discipline [3-5].

The software tool developed within CitInES will consider the urban energy system as a whole. It will provide its user with the possibility to assess the financial risk and environmental impacts of a broad spectrum of measures ranging from the reduction of energy demand, the production and transformation of energy, its distribution and storage as well as the optimization of the whole energy system thanks to the communication of its sub-components.

3 METHODOLOGY

CitInES methodology is driven by supply-demand balance methodologies used by Transmission Systems Operators and has been adapted to a more local context [6-7]. It can be divided into the following steps:

3.1 Characterization of the energy demand by usage and type of consumer

The first step is to characterize the consumers by type (old/new apartment buildings, offices, hotels...) and by usage (space heating, water heating, lighting…). Thus, following data should be collected:

- Urban planning: number of buildings of a given type, mean number of inhabitants by building, specific industries description…
- Transport: description of public transport, statistics on mobility…
- Energy use measurement (at city or district level, if possible by type of contract and with a hourly time step)

The details of the useful data are given in the database definition. Then, using CitInES energy demand profile data base, demand curves are to be provided by usage and type of end-user. It is indeed important to split the demand curves by usage and type of consumer in order to be able to build energy demand projections using macroeconomic scenarios.

3.2 Choice of macroeconomic scenarios for long-term energy demand and price evolution

In this step, energy demand scenarios (typically for 2020, 2030 and 2050) will be constructed based on assumptions about long-term evolution scenarios of energy demand by usage and consumers type.

- World macroeconomic models (for instance World Energy Outlook from IEA or scenarios from European Climate Foundation, see www.tsp-data-portal.org for a detailed inventory), which also generate correlated energy prices
- Local context evolution: urban planning, evolution of GDP by sector, forecast of population growth…

These scenarios give typically the annual energy consumption for a given type of consumer and usage, over a period of 40 years.

3.3 Definition of studied energy strategies and characterization of energy generation mix and transmission networks

Once the energy demand scenarios are built, the next step is to define a set of energy strategies to study. Following data have to be specified for each energy strategy:

- the forecast energy mix for each usage and type of consumer i.e. the proportion of each energy carrier (electricity, gas, heat, wood, fuel…) used for a given usage
- local energy generation and storage system: PV cells, waste-to-energy, cogeneration, geothermal energy, heat from industry process…
- transmission and distribution networks (electric, gas, heat, cold)
- demand side management : building insulation, energy efficiency or smart grids
- public transport policies : for instance electrical vehicles introduction

3.4 Definition of uncertainty scenarios (temperature, wind, solar radiation, outages, power market prices…)

The evaluation of energy strategy depends on long-term energy price and demand scenarios, but also on short-term uncertainties scenarios (temperature, wind, solar radiation, outages, power market prices…).

Test cases with a hourly granularity over a year will be built, crossing local historical data (for instance for weather) with CitInES data base. Typically, 10 to 100 test cases (yearly time series with an hourly granularity) will be used for strategy evaluation.

3.5 Scenario simulation

To assess an energy strategy, CAPEX is computed by optimizing local generation and storage capacity to face the demand but also includes required energy network CAPEX costs, while OPEX and fuel costs evaluation is obtained by minimizing costs to match production and demand, taking into account technical and operational energy system constraints. Optimization takes also into account existing and potential energy generation from renewable energy sources. Finally, pollutant emissions are evaluated including direct emissions generated from local energy systems and indirect emissions generated from grid energy supply.

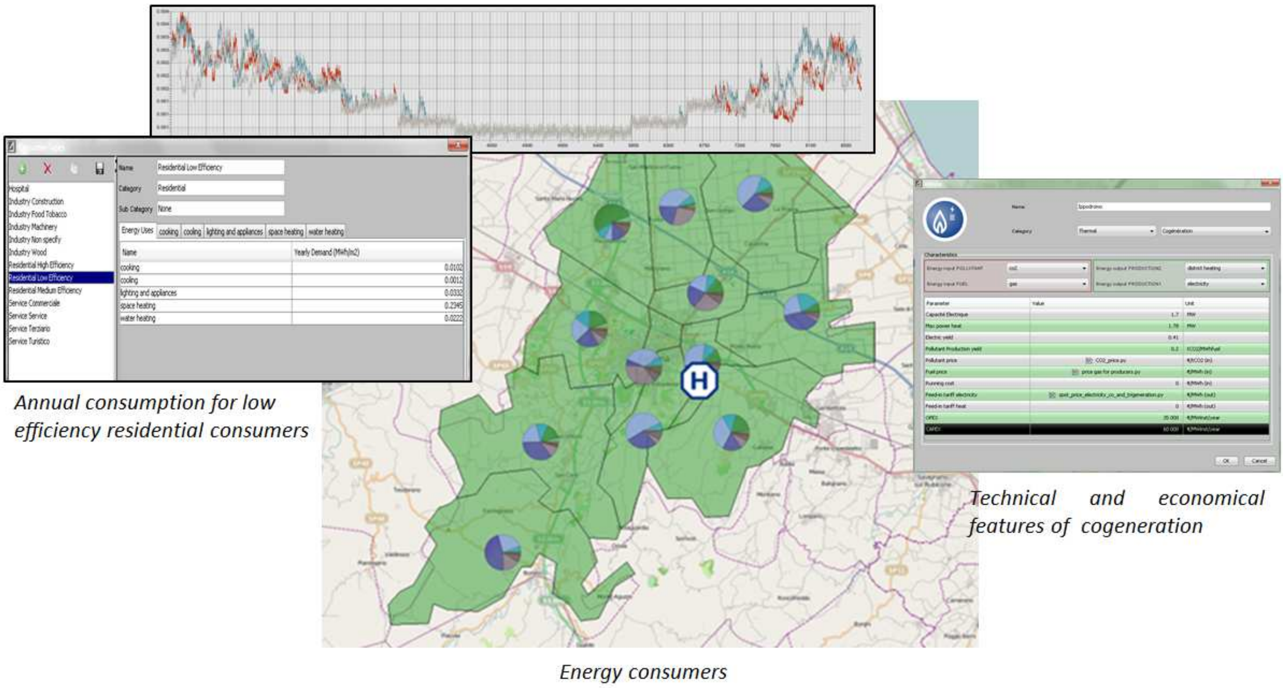

Fig. 1: CitInES software overview – Cesena study case

4 CESENA – STUDY CASE

Cesena belongs to the Emilia-Romagna region of the northern Italy and is situated ca. 15 km away from the Adriatic coast. Together with Forlì, Cesena is the capital of the Forlì-Cesena province that contains ca. 378.000 inhabitants and 30 Municipalities. Cesena itself has a population of ca. 97.500 inhabitants (31st December 2011).

Due to its proximity to many important towns (such as Bologna, Rimini, Firenze and Ancona), Cesena has an important role as a transport hub and is a strategically significant logistical point in Italy (Bologna airport and railway station, harbours of Ravenna and Ancona). In addition, some strategic national routes pass by Cesena.

Cesena has a long established tradition as a centre of manufacturing, specialized in the agro-industrial sector. In comparison to other manufacturing fields, this sector has grown considerably over the last decade. The industrial and demographic pressures require a new kind of approach to the challenge of energy efficiency and environmental impact. There are wide margins for improvement in terms of a sustainable approach to energy consumption and efficiency.

ISBN: 978-3-9503110-6-8 (CD-ROM); ISBN: 978-3-9503110-7-5 (Print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI

4.1 Energy networks

Electric grid: Cesena has an extensive medium voltage electric network supplying the residential, service and industrial sector with a total energy consumption of around 490 GWh [8]. Specific information about the high and medium voltage is available together with the location for the electric substations for high-medium and medium-low voltage. The total length of the electric network at high and medium voltage is around 596 Km of electric lines where 14 Km are high voltage [9]

Natural gas grid: To the municipality of Cesena belongs an extensive grid for the distribution of natural gas supplying the residential, service and industrial sector which supplies around 920 GWh of energy [8]. The total length of the gas distribution network piping is around 750 km. Specific information about the material of the pipeline, diameter, length and type together with connection points to the buildings and distribution for each pipeline is available for the Municipality of Cesena [10]

Heating and cooling grid: In the municipality of Cesena are existing six district heating networks delivering heat to residential and service buildings. Specific information about the distribution of the pipelines, connection points to the buildings and the installed capacity is available. The total length of the district heating network is 11 Km of pipelines. Base load is provided by the CHP plants located in the parts of the town called “Ippodromo” and “Buffalini” (inaugurated in 2012). An absorption machine is connected to the CHP installed at Buffalini providing cooling for the hospital “Ospedale Murizio Buffalini”. The remaining district heating grids are micro-grids driven by gas boilers which are connected to 19 gas boilers with a thermal capacity of 21.7 MWt with an annual thermal energy production of around 15529 MWht [11-12].

4.2 Building sector

Technical information about the characteristics, location and activities developed for the residential, service and industrial buildings of the Municipality of Cesena is.

Residential Sector (RS): The residential sector with a total surface of 2.73 km2 represents around the 54% of the total built surface of the municipality. For each residential building the year of construction, the location and if it is use also use for additional purposes (part of the building is use for commercial activities) is available [13]. Around 11% of residential buildings are classified as High Efficiency buildings with energy consumption less than 50 KWh/m2/a, around the 33% are Medium Efficiency buildings with energy consumption between 50 - 200 KWh/m2/a and around 54% as Low Efficiency building with energy consumption higher than 200 KWh/m2/a [14-15]. The Municipality of Cesena does not have specific information related to the share of the electricity and heat consumption by end use. However, statistics at national level were considered as assumptions for the calculations [16].

Service Sector (SS): The service sector with a total surface of 1.197 km2 represents around 24% of the total built surface of the Municipality [13]. Each building is classified according to its main activity in four categories: commercial, tertiary, service and touristic. Commercial buildings include activities such as shops, tertiary cover office building, service comprise all the public activities such as school and touristic covers restaurants and hotels. Most of the buildings are oriented to commercial activities representing around 65%. Service activities, related with the public activities such as school, accounts with around one 23%. Finally, the rest of the surface is designated for service and tourist activities.The Municipality of Cesena does have specific information related to the energy consumption by end use for the service sector. However, national statistics are available about this issue [17].

Industrial Sector (IS): The industrial sector with a total surface of 1.09 km2 represents around the 22% of the total built surface of the Municipality [13]. Each building is classified according to its main activity according Eurostat classification following the ATECO code which is register for each industry of the Municipality of Cesena. The main economic activities are oriented to wholesale, retail and repair of vehicles and motorbikes or manufacture of metal product (Except machinery and equipment) and represent around 86%. Agriculture sector and the production machinery and transport equipment for it which suppose around the 8% of the total. Construction sector represents also relative high share with around the 2.5%. The Municipality of Cesena accounts only with aggregate statistics about the energy consumption by fuel in the overall industrial sector [8]. However, national statistics are available about the share for the fuel consumption for each industrial activity [18].

4.3 Local energy production and green areas

Photovoltaic panels: The Municipality of Cesena accounts with several photovoltaic installations for electricity production. For each installation the location, surface, power capacity together with the year of the connection to the grid is available. The total installed capacity is around 40 MWp with an average efficiency of 14% [19].

Wind Turbines: The Municipality of Cesena accounts with a group of wind turbines installed in the Parco Educativo Sperimentale delle Energia Alternative (PESEA). The installed power capacity is 40 kW which an estimated energy production of 50 MWh considering 1250 hours of operation per year [20].

Hydropower plant: The Municipality of Cesena accounts with a small hydropower plant with a production capacity of 0.3 MW and a nominal production of 0,9 GWh of electric energy [21].

Biogas: The Municipality of Cesena produce biogas in the waste which treated in the in the composting plant in Busca and the local water treatment plant which later is use for the electricity production. The electric installed capacity for the plant is respectively 1200 kW and 330 kW [22].

Green areas: Municipality of Cesena accounts with detail information about the location and surface of its green areas. Its total surface is a round 4162 Ha where are almost the totality are forest, around the 96%, and rest are Park and Gardens

4.4 Indicator

The Municipality of Cesena has defined several indicators to monitor its energy strategy action plan. This action plan has three main pillars: reduction of CO2 emissions, increase of the use of renewable energy sources and increase of the energy efficiency. Following these objectives, five main key performance indicators (KPIs) has been selected to measure the impact of the:

- CO_2 Emissions (kton)
- Reduction of CO_2 emissions (%)
- Primary energy consumption (ktep)
- Energy efficiency improvement (reduction of primary energy consumption) (%)
- Share of locally produced renewable energy (%)

5 SCENARIOS

Several scenario states of the local energy system in Cesena have been study. They are used to assess and compare the pollutant emissions, renewable energy production and energy efficiency of the city, in line with the 20-20-20 objectives, in the past, current or projected situation of the territory.

5.1 2020 SEAP Scenario - Reference Scenario

This scenario is based on the current state of the energy sector in Cesena and the goals collected in the SEAP of the city. This configuration was composed of three parts:

- "2010 real": snapshot of the city's situation in 2010. This node consists in the reference situation for SEAP.
- "2012 real": snapshot of the city's situation in 2012.
- "2020 SEAP": situation in 2020 if target is reached for all SEAP actions.

5.2 2020 Projected Scenario

The monitoring process aimed at collecting data about the current situation of the city regarding SEAP actions advancement. This data was used to create a projected situation of the territory in 2020 if SEAP implementation keeps a constant pace.

In this scenario, except for SEAP actions implementation, it was considered that everything in the local energy system has stayed the same as in 2010 and 2012 represents a "theoretical" current situation of the territory which is in line with the covenant of mayor's guideline.

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Based on this representation of the current situation, the projection of the situation in 2020 if the rhythm of action implementation stays the same was assessed. To create 2020 Projected scenario, the following projecting rules were used:

- A linear projection is used, assuming that the completion rate of the action is linear between 2010 and 2020: If 10% of the action has been reached in 2012, 50% will be reach in 2020
- If the rate exceeds 100% in 2012, the 2012 rate is kept for 2020; it is therefore assumed that the level reached in 2012 is also reached in 2020 (the advancement of action does not decrease), but that the advancement of the actions stops in 2012.
- If the projected rate exceeds 100% in 2020, the 100% rate is kept for 2020; it is therefore assumed that unless the SEAP is reviewed, the targets of actions are not exceeded.

5.3 2020 Alternative Scenario

Based on the analysis of actions effectiveness regarding the cost of the ton of CO_2 emission avoided and on the assessment of potential new actions, an alternative 2020 scenario is built up. This scenario aims at reducing Cesena global costs while keeping the same reduction of CO_2 emissions in 2020 as the ones targeted in the SEAP, to make this objective easier to reach.

The actions effectiveness is mainly assessed using the indicator of the cost of the ton of CO_2 emission avoided, including subsidies for the city such as feed-in tariffs. Fig. 2 shows the application of this methodology to measures adopted in the SEAP together with some additional more.

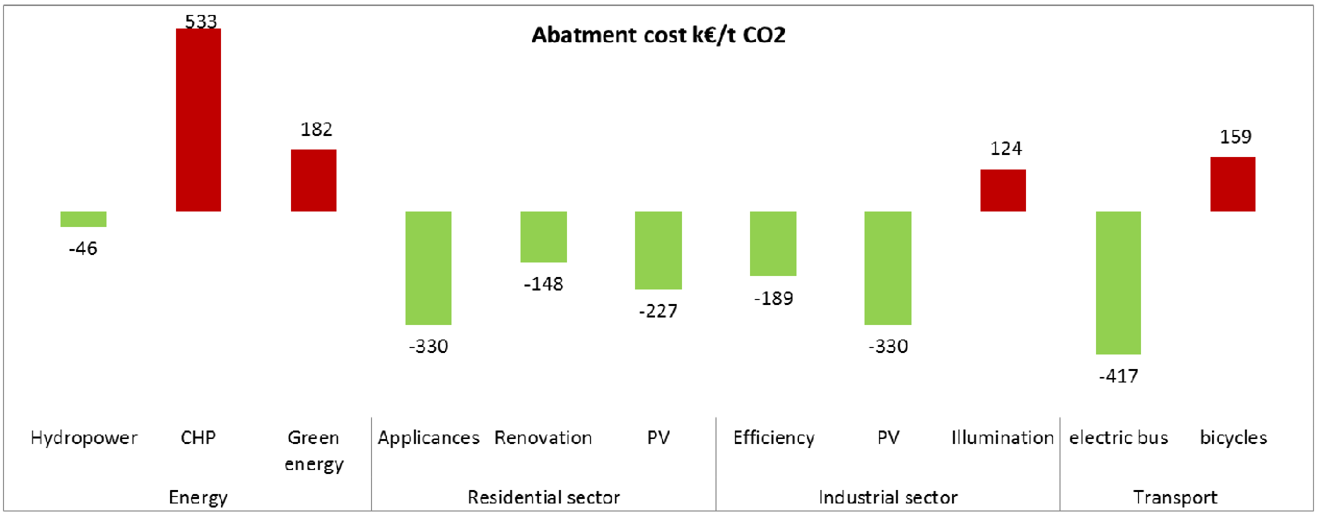

Fig. 2: Abatement cost for several measures

Based on these results shows in Fig. 2, the following modifications were included in the 2020 Alternative scenario (compared to the current SEAP scenario):

- Reduction of the cogeneration implementation rhythm (50% of the SEAP target)
- Keep the importation of Green Energy at the 2012 level (3.6 GWh)
- Increase in the installation of solar panels (double SEAP target)
- For all other actions, the targets of the SEAP were kept unchanged.

Furthermore, three new additional measures has been identified and included in this alternative scenario:

- Replacement of diesel and gasoline buses by electric ones
- Installation of public bikes that reduces the use of private cars
- Increase in hydro power plant production

5.4 Summary of the Scenario

Table 1 summarizes the different actions taken in each of the analyzed scenarios: 2020 SEAP Scenario, 2020 Projected scenario and 2020 Alternative scenario.

	2020 SEAP	2020 projected	2020 alternative
Green areas	Inc. in 160 ha	Inc. in 164.75 ha	Inc. in 164.75 ha
Red. of lighting & appliances comp. in residential sector	Red. of 11 GWh	Red. of 11 GWh	Red. of 11 GWh
Cogeneration	146 GWht + 102 GWhe	110 GWht + 21 GWhe	73 GWht + 61 GWhe
Renovation of the buildings	18% Residential sector		18% Residential sector
PV Panels	61 MWp installed	61 MWp installed	102 MWp installed
Red. of public illumination	Dec. of comp. in 50%		Dec. of comp. in 50%
Red. of electric comp. in the Industrial Sector	Inc. of the eff. in 6%	Inc. of the eff. in 3%	Inc. of the eff. in 6%
Green Energy	Purchase 22 Gwhe	Purchase 18 Gwhe	Purchase 3.6 Gwhe
Buses replacement			50% of diesel and gasoline buses
Public bikes			Red. of 3% of private cars use
Hydro power plant			Inc. in 50% of the production

Sceanrios for the energy sector of Cesena up to 2020

6 RESULTS AND DISCUSSION

6.1 Energy and environmental impacts

Table 2 shows the impact in terms of energy consumption and CO_2 emissions of the measure in each of the proposed scenarios.

	2010	2020 SEAP	2020 Projected	2020 Alternative
CO_2 Emissions (kton)	435	361	398	351
Reduction of CO_2 emissions (%)		17%	9%	19%
Primary energy consumption (ktep)	217	168	193	163
Energy efficiency improvement (%)		8%	4%	14%
Share of local renewable energy (%)	2,6%	8%	7,4%	12%

Table 2: Enegy and CO_2 emission impact for the scenarios

In all the scenarios proposed, there is an improvement in terms of energy performance, use of renewable and reduction of CO_2 emissions. In fact the 2020 projected scenarios, the less ambitious scenario which considers that the rhythm of action implementation stays the same was assessed, achieves a reduction of 9% and 11% in the in the CO_2 emissions and the primary energy consumption compared to 2010. Especially interesting is the increase of the share of the local renewable energy which grows from a 2.6% in 2010 to 7.4% in 2020 mainly due to increase of the installed capacity of PV panels.

The additional measures including in the 2020 SEAP scenario produces an improvement of all the indicators compared with the 2020 projected scenario. Although, the share of renewables is only slight better between both scenario, an important improve in the energy efficiency produce in 2020 SEAP scenario a significant decrease of the CO_2 emissions and the primary energy consumption. These represent 17% and 22% respectively compared with 2010 and double of the improvements compared with the 2020 projected scenario.

Finally, the 2020 Alternative scenario gets the better impact in terms of energy efficiency and CO_2 emissions. In this scenario the improvements in terms in CO_2 emissions are slightly better than for the 2020 SEAP scenario. This is because the increase of the installed capacity of PV panels which compensate the impact of other measures which could produce an increase of the CO_2 emissions such as the reduction of the cogeneration in 50% or the reduction of the green energy purchase to the grid. This measure not only has impact in terms of CO_2 emissions also explain the improvement in the indicator related to the energy consumption and efficiency.

6.2 Economic impacts

The analysis of economic impacts is based on three indicators:

- Investments are considered annualized, with an actualization rate of 7.25%. They were obtained from the study of similar actions lead in Europe and give an order of magnitude of the necessary investments.
- Annual energy savings cost refer to the total energy costs saved within the city (producers, consumers and imports costs), including subsidies.
- The global net value represents the total savings of the city, adding annualized investments and annual energy savings.

Table 3 shows the economic impact for the scenarios. In all the scenarios the adopted measures represent a decrease of the annuals energy savings cost within the city. Nevertheless, in spite of 2020 SEAP and 2020 Projected scenarios have lower investment cost compared to the 2020 Alternative scenario, this scenario is the only one where the global net value is profitable from the economic point of view.

	2010	**2020 SEAP**	**2020 Projected**	**2020 Alternative**
Investments (M€)		27	18	38
Annual energy savings cost (M€)		-20	-10	-41
Global net value (M€)		7	8	-3

Table 3: Ecomical impact for the scenarios

It is important to note that the evaluation of action investment costs has been done with general data using examples of already executed projects, those costs may thus differ from local costs that Cesena should benefit.

7 CONCLUSIONS

This paper presents the study case of the municipality of Cesena. This municipality, as a partner of the project, has implemented its SEAP under the tool to assess the impact of the measures taken under several scenarios and monitor its activities to validate the developed software. The different measure adopted to reduce the CO_2 emissions and energy consumption together with an increase of the energy efficiency and use of renewables. The methodology employed is driven by supply-demand balance methodologies used by Transmission Systems Operators and has been adapted to a more local context.

Several scenarios have been presented and analysed in which different measures are adopted focus in the following objectives: increase the use of renewable energy sources, the energy efficiency and reduce of CO_2 emissions. The 2020 SEAP scenario represents the current state of the energy sector in Cesena and the goals collected in the SEAP of the city. Based on the current situation of the city, the 2020 projected scenario reflects the projection of the situation in 2020 if the rhythm of action implementation stays the same was assessed. Finally, the 2020 Alternative scenarios is built on focus on the analysis of actions effectiveness regarding the cost of the ton of CO_2 emission avoided and on the assessment of potential new actions.

In all the scenarios proposed there is an improvement in terms of energy performance, use of renewable and reduction of CO_2 emissions. In fact the 2020 projected scenarios the less ambitious scenario achieves a reduction of 9% and 11% in the in the CO_2 emissions and the primary energy consumption compared to 2010. In the 2020 SEAP scenario only a slight improvement in the share of renewable is achieve compared to the 2020 Projected scenario. In this scenario the decrease of the CO_2 emissions and the primary energy consumption is 17% and 22% compared with 2010 and the double of the improvements compared with the 2020 projected scenario. Finally, the 2020 Alternative scenario gets the better impact in terms of energy efficiency and CO_2 emissions which is mainly due to higher capacity installed of PV panels compared with the rest of scenarios. Additionally, this scenario was the only one where the global net value is profitable.

The future work will be oriented to assess the impact of additional measures such as the integration of new measures such as the increase of micro-wind turbines and the development of new scenarios.

8 ACKNOWLEDGEMENT

This work has been supported by the FP7 Framework Programme for Research and Technology development under project "CitInES - Design of a decision support tool for sustainable, reliable and cost-effective energy strategies in cities and industrial complexes" (Grant agreement no: 288295).

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