Supporting cities' efforts towards a highly efficient and sustainable resource-efficient future: the RE-SEEties integrated toolkit

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Abstract

Supporting cities' efforts towards a highly efficient and sustainable resource-efficient future requires a detailed description of the present energy and waste management systems and a comprehensive evaluation of alternative pathways. The development of a reliable baseline is also a prerequisite for the application of efficient forecasting methodologies. Starting from a careful examination of data, methods and tools currently used by municipalities in their planning activities, an extensive research was carried out on internationally recognized methods and tools to support decision-making on local energy planning and waste management. This research was carried out in the framework of the on-going RE-SEEties project "Towards resource-efficient urban communities in SEE" funded by the South East Europe programme. First, this paper focuses on the integrated toolkit, which is a key component of the overall RE-SEEties methodology. Second, some exemplifying results obtained in two partner cities are discussed in terms of energy forecasting and quantification of the ecological footprint of the waste management system.

Keywords: GHG emissions inventory, energy forecasting, waste management, ecological footprint, ICLEI tool.

1 Introduction

Trends of energy consumption (EIA [1]) and waste generation (Hoornweg and Bhada-Tata [2]) are expected to increase steadily in the future. Most of activities related to production and consumption of goods and services is concentrated in

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cities, contributing to about 80% of global greenhouse gas emissions (Whiteman *et al.* [3]).

At the same time, municipalities are the level of government closest to citizens and represent the most appropriate channel to understand their concerns and meet their needs. Local authorities play an important role in achieving national and European energy and climate targets but, as outlined by the Green Paper on a 2030 Framework for climate and energy policies [4], they need political, legislative and incentive framework to play a bigger role in the climate and energy 2030 strategy. In this respect, many initiative have arisen in the recent years focusing on cities and sustainable urban development, among which: the *Covenant of Mayors* [5] where local and regional authorities voluntarily commit themselves to meet and exceed the European Union 20% CO_2 reduction objective by 2020, *Energy Cities* [6], *CONCERTO* [7]. Moreover, several, Smart City initiatives (e.g. [8]) have arisen Europe-wide to help cities to start planning their future in a new way: adopting a comprehensive multi-sector approach and accelerating innovation to become more sustainable and resilient. These initiatives aim to demonstrate that the citizens' quality of life and local economies can be improved through innovation towards energy efficiency and reduction of carbon emissions.

On the other hand, the European institutions are funding cooperation projects involving local authorities, academia and research institutions to make the team and increase the attractiveness of cities, making them more resource-efficient and transforming them in places of progress and socio-economic development. Funded by the South East Europe Transnational Cooperation Programme, the RE-SEEties project "Towards resource-efficient urban communities in SEE" aims to address the problem of inefficient resource use in cities. The main goal is to help municipalities develop integrated waste and energy solutions, in order to move towards more resource-efficient urban communities. The core transnational outcome of RE-SEEties deals with the implementation of an integrated methodological toolkit aimed at providing valuable strategic and adaptable guidance for all SEE municipalities on how to improve resource efficiency by applying smart strategic measures in urban energy planning and waste management.

This paper focuses on the integrated toolkit, which is a key component of the overall RE-SEEties methodology. The methodological aspects as well as the main results obtained by city partners are described in the following chapters.

2 Methodology

Supporting the cities' efforts towards a highly efficient and sustainable resource-efficient future requires an in-depth knowledge of the present energy and waste management systems. This is essential to find out suited pathways towards more sustainable configurations of the local systems demonstrating the benefits of the proposed policies to decision makers. The first step dealt with a careful examination of data, methods and tools currently used by RE-SEEties' city partners in their planning activities. The outcomes of this investigation pointed out that most of the municipalities involved in the project do not make use of tools/models in their regular planning and decision-making activities. In the second step, an extensive research was carried out on internationally recognized methods and tools delivered by previous projects of research and cooperation. The main idea was to take benefit from previous experiences and techniques selecting those tools suitable for the project in terms of objectives and average expertise of the partnership on engineering models and technical issues. In the latest decades, waste management and energy system analysis have become increasingly important in policy definition and planning and this is reflected in the wide range of tools to support decision-making currently available based on different mathematical approaches (e.g. Keirstead *et al.* [9], Pires *et al.* [10]). These tools generally require a medium-high level of expertise, which is not frequently available in local public administrations. What is more, energy forecasting is a quite complex issue where easy-to-use models or tools are not available in scientific literature.

To fulfil to this request of user-friendly decision support methods for municipalities an integrated toolkit was set-up (Figure 1). The main components are described in the following paragraphs.

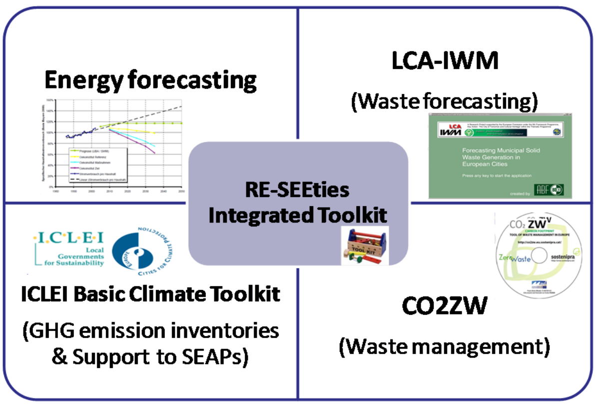

Figure 1: Overview of the RE-SEEties integrated toolkit.

2.1 The ICLEI tool

One of the main aim of this work was to support city partners in adhering or renovating their commitments to the Covenant of Mayors, which is also a common need for many municipalities all around Europe. To this end, the ICLEI Europe's Basic Climate Toolkit [11] (indicated in the following as the "ICLEI tool") was selected to collect and systematise all energy data as well as to provide GHG emission inventories. These inventories can help local governments to understand where emissions are released and which are the key priority areas and the achievements obtained by reduction actions. In more detail, the ICLEI tool is based on Excel spreadsheets which are filled in with two categories of input data: Local Government Operations and Community Inventory. The first category takes into account energy consumption of municipal buildings, vehicle fleet, public lighting, water and sewage, waste and local energy production, the other considers the energy consumption in Residential, Commercial, Industry, Transport, Community Waste and Agriculture sectors. As an output the tool produces a Baseline Emissions Inventory (BEI) which is a GHG inventory for the reference year in different formats among which the Covenant of Mayors/SEAP format.

A possible limitation of the ICLEI tool, from the RE-SEEties point of view, but also from a more general perspective, is that it does not address forecasting issues as well as planning issues, i.e. calculation of efficiency and emissions after certain investments or actions. This limitation does not affect modelling tools capable of representing the dynamics of energy consumption at city level but need higher resources and expertise from municipal technical officers which is not always available, especially in the SEE area.

Another key issue is that local administrations quite often lack the appropriate data to conduct simple calculations mainly due to the absence of dedicate officers which monitor and register energy consumption flows throughout the city. This makes particularly difficult for municipalities estimating the energy consumption reported in the Community spreadsheets. For this reason it has been adopted a back-up strategy developing an additional calculation tool, consisting of a set of spreadsheets, what we called the ICLEI "add-in" tool. This tools facilitates calculation of the input parameters of the ICLEI tool based on primary information and using proxy variables where no data exist and is also a fundamental input to any forecasting method. Proxy variables can be derived either from national or regional databases (e.g. ODYSSEE-MURE database [12]) and are distinguished between "calculation proxy variables", directly used to make the calculations, and "verification proxy variables" used as comparative indicators. These indicators originate from various public databases and are provided at a national level of detail. Thus, in case municipalities fail to collect the required data due to their unavailability they could easily base the data computation on the basis of national values and either adopt or better adjust their estimations. This approach can also provide a measure of comparison with other cities and constitutes also a tool to control data reliability. The ICLEI "add-in" tool developed in RE-SEEties constitutes an intermediate step between the ICLEI tool and municipal energy modelling, which extends the typical calculations of the Baseline Emissions Inventory to an improved level of analysis typical of energy models (e.g. TIMES [13]). In the following sections the proposed methodology is fully described by sector.

2.1.1 Residential

The main data required by the ICLEI tool to describe Residential deal with a detailed fuel breakdown of energy consumption. This is often unavailable at municipal level therefore it was implemented a supporting methodology based on energy consumption per fuel and per household as proxy variables. In order to assess the data input municipalities have to provide additional data on population, total number of households as well as technology breakdown. The calculation of the fuel consumption per household is completed giving the specific consumption per household and per energy end-uses (Space heating, Space cooling, Water heating, Cooking, Fridges and Freezers, Cloth washing and Other). Once the calculation proxy variable is obtained it can be used to derive the input required by the ICLEI tool, multiplying it by the number of households. Moreover, verification proxies such as Energy consumption per capita allow to assess comparatively the estimations obtained.

2.1.2 Commercial

Similarly to Residential also for the commercial sector, the ICLEI tool requires a detailed fuel breakdown of the energy consumption. In this case additional data are related with sector floor areas, number of the employees and number of establishments, which are needed to assess the data input with indicators such as energy/CO_2 emissions per 1000 m^2 or per employee or per establishment. For a more detailed analysis of the commercial sector the following subsectors were singled out in the "add-in" tool: Hotels, Hospitals, Commerce, Education, Private Offices, Athletic, Airports and Other. These subsectors are commonly used in national energy modelling because they present very different consumption patterns. If detailed data are available at subsector level than the baseline could be build up very accurately, providing a reliable initial point to proceed with necessary forecasting calculations. If not, which is often the case, the "add-in" tool we developed allows to deriving the missing data using the energy consumed per fuel/subsector/end use as calculation proxy variable. To this end, two main set of data should be provided: Technology breakdown (%) per fuel and commercial subsector, and Energy breakdown (%) per fuel and energy end use and subsector. Finally, verification proxies such as Energy consumption per employee can be used to assess comparatively the results from the applied methodology.

2.1.3 Transport

As concern the Transport sector, the ICLEI tool offers two ways to calculate CO_2 emissions based on Fuels Sales data or Vehicle kilometres travelled (VTK) by all vehicles registered within local government area (motorcycles, cars, light truck, heavy truck, bus, trams). If municipalities cannot find fuels data, CO_2 emissions can be evaluated starting from Vehicle Kilometres Travelled (VKT) because vehicle registration databases are commonly available in most countries. In such a case, users have to input the Total Annual Vehicle Kilometres Travelled in Municipality filling in two tables: percentage breakdown of VKT by vehicle type and fuel, and Vehicle Efficiency for different fuels (default values are provided which can be further improved with national data). In order to simplify these calculations, the ICLEI add-in tool allows to calculate automatically the Total Annual Vehicle Kilometres Travelled and the percentage breakdown of VKT. Municipalities have to enter only the number of vehicles at municipal level by type and fuel and, if possible, they can modify the annual average (Km year) with national data. The results obtained in this table can be fed in the ICLEI tool.

2.1.4 Industry

As concern the industrial sector, the Guidelines of the Covenant of Mayors [14] report that Industries involved in the EU Emissions Trading System (EU ETS) and process emissions from all industrial plants have not be considered in the Baseline Emission Inventory. On the other hand, Combustion Emissions from Industries not involved in the EU ETS can be considered if the SEAP includes some measures for their reductions. The ICLEI tool automatically calculates total CO_2 emissions starting from energy consumption of 14 commodities: Electricity, Natural gas, District Heating, District Cooling, Fuel Oil, Diesel, Petrol, Propane, Sub-Bituminous Coal, Lignite (Brown Coal), Coke, LPG, Methane/Biogas/ Landfill Gas and Wood. To help those municipalities which cannot rely on industrial energy consumption data it can be referred to the Eurostat database [15] which provide national energy consumption data for each subsector. In order to simplify the calculation of the industrial energy consumption, the number of workers for each subsector was used as proxy variable in the ICLEI add-in tool. Based on national energy consumption for each subsector (Eurostat database) and the number of workers for each subsector (national statistics) there were derived the Fuel energy consumptions per number of workers for each industrial subsector. Municipalities can obtain energy consumption for each industrial subsector entering the number of workers for each subsector at municipal level and multiplying them for the energy consumption per number of workers (national data). If there are some industries involved the EU ETS then starting from the number of workers the energy consumption can be computed but the obtained values have to be subtracted from the previous energy consumption for relative industrial subsector. Finally, the sum of values obtained for all the 13 subsectors and each energy commodity have to be entered into the ICLEI tool.

2.1.5 Agriculture

The inclusion of this sector in the Baseline Emission Inventory (BEI) is not compulsory according to the Covenant of Mayors Guidelines but a worksheet to calculate GHG emissions from the Agriculture Sector is available in the ICLEI tool. This sheet can be useful to city partners interested in developing a GHG emissions balance or a mitigation plan, which have to take into account also the contribution from Agriculture. In such a case, entering the number of various domestic livestock (proxy variable) the ICLEI tool automatically calculates the Total Animal Enteric Emissions (kton CO_2eq). In particular, to obtain the total agriculture emissions, the ICLEI tool considers the share of GHG emissions by enteric fermentation reported by the ITALY 2009 National Inventory Report of UNFCCC [11]. The ICLEI tool assumes also that the ratio of animal enteric emissions to total agriculture emissions for this area is the same ratio as for the whole of Italy. To improve this assumption the add-in tool gathered national specific data (based on the UNFCCC Greenhouse Gas Inventory [16]) on the share of emissions by enteric fermentation for eight countries (corresponding to those involved by the RE-SEEties partner) in the years 1990–2010.

2.2 Energy forecasting

In the latest decades, energy analysis and forecasting have become increasingly important as planning and policy tool. The following sections provide a brief overview on how this complex issue was dealt with in RE-SEEties.

2.2.1 Residential

In order to obtain the energy forecasting for residential sector, municipalities have to provide the average efficiency per energy fuel and energy end-use. This table is required to calculate useful energy, which is the base of the forecasting calculations. Considering a standard elasticity per energy use the evolution of the energy demand can be calculated as reported in equation (1):

$$ED_{eu,y} = ED_{y-1,eu} * (1 + RoGDP_y * El_y) \quad (1)$$

where “ED” is the useful energy demand, “eu” is the energy use, “y” is the index of the current year, “RoGDP” is the annual rate of GDP change, and “El” is the elasticity of useful energy demand in relation with GDP.

Once the forecasting of the useful energy demand is obtained, an estimation of the Final Energy can be derived on the basis of the evolution of the average efficiency on the analysed time the horizon provided by the users.

2.2.2 Commercial

Forecasting demand in commercial sector follows the same methodology utilised for Residential. However, in the majority of the cities examined it was quite difficult to find data with the requested level of detail on the commercial subsectors. Typically the only data available are the energy consumption per fuel in the base year and the number of employees in the whole sector. Therefore it was necessary to introduce some simplifications in the forecasting methodology for Commercial: two main ratios calculated with national data (fuel consumption/ employee and employee/capita) were therefore multiplied to the municipal population to obtain an estimate of the number of employees in the commercial sector at city level. An evolution of the numbers of employees was then assumed, allowing to obtain an estimate of fuel consumption till 2020 and the evolution of the useful energy demand through an average sector efficiency. Eventually, an elasticity of energy demand can be assumed in relation with the GDP as done in the residential sector.

2.2.3 Transport

Forecasting demand in Transport deals with the calculation of the vehicle kilometres of five types of vehicles adopted in the analysis: Motor Cycles, Cars, Light Trucks, Heavy Trucks and Buses. The projection of the vehicle kilometres will be the basis for estimating the Final Energy in the whole sector. Users provide the stock of the vehicles for the base year and its evolution in time respectively. If the evolution cannot be obtained then an elasticity of the stock is made increasing in relation with the basic macroeconomic index. The evolution of the stock per vehicle type is then multiplied with the evolution of the Average Annual Distance per vehicle type to obtain the forecasting of the vehicle kilometres. Users also provide the Average Annual Distance in the base year and its evolution on time. If this evolution cannot be obtained then an elasticity related to the fuel increase and an elasticity linked to the basic macroeconomic index have to be assumed. While the simplest assumption regarding the transport demand forecasting considers unitary elasticity in relation with the basic macroeconomic index, here it was adopted a more elaborated calculation that can be proved intuitive for the users of the tool, especially for the better understanding of the transport sector dynamics by the municipalities. Finally the breakdown of the vehicle kilometres per vehicle type and fuel is used in combination with the fuel efficiency per vehicle type in order to obtain an estimation of the Final Energy in the transport sector.

2.3 Waste

Waste management is a crucial issue and municipalities needs to be supported in their strategic choices which should be aimed to shift away from the simple disposal towards a more integrated waste management systems.

In this study the CO2ZW software [17] was utilised to assess the ecological footprint of municipal waste management in terms of greenhouse gas (GHG) emissions (in carbon dioxide equivalents) and providing values of generated and avoided emissions. The tool is an Excel-based calculator which receive as an input data on municipality-specific waste (waste composition, waste flows, characteristics of waste treatment plants, etc.). It is possible to include also GHG emissions from waste transportation inserting data related to urban waste collection and inter-urban waste transportation (expressed in tkm).

Another key issue which affect municipalities in dealing with waste management regard forecasting municipal solid waste (MSW) generation. This is often a challenging task due to the lack of data and selection of a suitable forecasting method (Rimaityte *et al.* [18]). Unfortunately, no simple waste prognosis tool is currently available particularly if the focus is on South East Europe countries. As far as we know, the only exception is represented by the LCA-IWM waste prognosis model (Den Boer *et al.* [19]) developed under the FP5 LCA-IWM project. LCA-IWM is freely available and presents a very user friendly interface. This prognostic model was used as a reference for waste forecasting at municipal scale although it is based on outdated socio-economic forecasts (base year: 2005).

3 Results

Two case studies were chosen for the application of the integrated toolkit. The first is related to energy forecasting in the city of Ivanic Grad (Croatia). The second concerns the application of the CO2ZW software to evaluate the ecological footprint of municipal waste in the Municipality of Potenza (Italy).

3.1 Energy forecasting in the city of Ivanic Grad (Croatia)

The case study of energy forecasting focuses on the City of Ivanic Grad in Croatia. Energy consumption for the base year was calculated using the ICLEI “add-in” tool. As concerns Residential, as described in paragraph 2.2.1, starting from the energy demand of each energy end-use in the base year and using standard elasticity based on national values (Table 1) it was derived the evolution of the final energy consumption on the time horizon (Table 2).

Table 1: Forecasting of the macroeconomic index (GDP) in Croatia.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GDP variation (%)	-0.8	-0.8	-0.8	-0.8	2.4	2.4	2.4	2.4	2.4	1.9

Table 2: Forecasting of the final energy (MWh) in Residential.

	2011	2014	2017	2020
Space Heating	49143	48488	50465	52389
Space Cooling	1533	1513	1574	1635
Water Heating	1168	1152	1199	1245
Lighting	1533	1513	1574	1635
Cooking	3288	3244	3376	3505
Refrigeration	2788	2751	2863	2972
Cloth Washing	836	825	859	892
Cloth Drying	0	0	0	0
Dish Washing	279	275	286	297
Other Electric Uses	3345	3301	3435	3566
Total (GWh)	63.91	63.06	65.63	68.13

Concerning Commercial, the detailed data available for this city made an in depth analysis of the commercial subsectors possible, applying the methodology to each of these subsectors (results represented in Table 3). The breakdown of the energy with the respect to energy uses is shown in Table 4.

Table 3: Forecasting of the final energy in Commercial.

	2011		2014		2017		2020	
	MWh	%	MWh	%	MWh	%	MWh	%
Hotels	2041	1.86	2010	1.85	2062	1.87	2159	1.89
Hospitals	3331	3.04	3312	3.05	3344	3.03	3403	2.98
Commerce	64299	58.65	63384	58.45	64896	58.78	67739	59.37
Education	3178	2.90	3161	2.92	3190	2.89	3242	2.84
Private offices	35722	32.58	35515	32.75	35858	32.48	36488	31.98
Athletic	304	0.28	304	0.28	304	0.27	304	0.27
Other	754	0.69	750	0.69	756	0.69	768	0.67
Total	109.63		108.44		110.41		114.10	

Table 4: Forecasting of the final energy per energy use in Commercial.

(MWh)	2011	2014	2017	2020
Space Heating	42871	42261	43269	45165
Space Cooling	5249	5174	5297	5529
Water Heating	433	427	437	456
Lighting	3149	3104	3178	3318
Cooking	0	0	0	0
Refrigeration	4199	4139	4238	4424
Other Electric Uses	8398	8278	8476	8847
Total (GWh)	64.30	63.38	64.90	67.74

The evolution of Transport demand (Table 5) was assessed on the basis of the evolution of the stock per vehicle type (in 1000s of vehicles) and the average annual distance (km), considering an annual rate of increase of crude oil [20].

Table 5: Evolution of Transport demand.

(thousand vehicle-km)	2011	2014	2017	2020
Motor Cycles	4819	4721	5023	5255
Cars	93264	91264	97435	101284
Light Truck	10326	10023	10960	11795
Heavy Truck	5400	5217	5782	6315
Bus	1250	1233	1283	1343

Assuming both the percentage breakdown of vkm per fuel and vehicle type and fuel efficiency per vehicle type in litres of fuel per 100 km constant on the time horizon, it was possible to obtain the estimation of final energy consumption in Transport sector (1000s litres of fuel). In Table 6 the forecast estimate of the final energy consumption in 2020 is reported.

Table 6: Forecast estimate of the final energy in Transport for 2020.

(1000s litres of fuel)	Motor Cycles	Cars	Light Truck	Heavy Truck	Bus
Petrol	52.549	5704.296	237.660	221.674	
Diesel	0.000	1922.769	1195.967	2263.984	429.802
Liquid Gas (LPG)		226.065			

3.2 Ecological footprint of waste management in Potenza (Italy)

Potenza is a city localized in Southern Italy. The main data were provided by the Local Waste Management Agency (ACTA). Waste collection is carried out using bins for both sorted and unsorted collection. To date, the collection of organic material has not started yet. In 2012 with a population of 66,698 inhabitants, the total amount of municipal waste was 28,657 ton, of which only 4,180 ton (24%) were source-separated materials, as reported in Table 7.

Table 7: Amount of source-separated materials (City of Potenza).

Source separated collected materials	ton
Glass	623
Plastic packaging	395
Metals	162
Paper and cardboard	1,508
Organic matter	0
Other waste materials (wood, textile, drugs, etc.)	4,180

Using the average recycling efficiency of Italian plants, the typical composition of the MSW waste and quantifying the credit of GHG emissions due to the recovery and recycling of products (through the default values) and disregarding the carbon footprint linked to transportation of waste there were obtained the results shown in Table 8. In brief, the carbon footprint of waste management in Potenza is 14,876 ton CO_2eq/year (223 kg CO_2eq/inhabitant and 519 kg CO_2eq/ton) whereas the avoided emissions are -3,352 ton CO_2eq (-50 kg CO_2eq/inhabitant and -117 kg CO_2eq/ton).

Table 8: Results of CO_2ZW application to municipality of Potenza.

		Results expressed in t CO_2eq			
	Quantity of waste (t/year)	Direct Impact (A)	Indirect Impact (B)	Avoided Impact (C)	(A+B+C)
Recycling of Paper and Cardboard, Plastics, Glass and Metals	2,688	5	33	-1,762	-1,724
Total waste to landfill	22,069	14,612	226	-1,590	13,248
Total		14,618	258	-3,352	11,524

4 Conclusions

Resource efficiency needs to deal with energy and waste in an integrated and comprehensive way. Municipalities play a crucial role in the achievement of national and international targets on energy and climate. However, cities lack of a depth knowledge of the baseline situation (data collection and management) and in most of the cases are not supported by tools in their strategic choices, which require a medium-long term vision and should be built upon a transectoral vision of urban planning. This research had a two-fold objective. First, it promoted the use of decision support tools among local authorities in managing energy and waste strategic planning. Second, it focused on the full application of these tools among municipal actors which were enabled at collecting and using their own data. Moreover a calculation tool was implemented to deal with lack of data at municipal level, allowing to estimate very detailed sectorial energy consumptions by using as input projections and estimates of primary parameters. The energy consumption figures are then fed into the ICLEI tool in order to calculate GHG emissions and derive the Baseline Emissions Inventory on which every Sustainable Energy Action Plan (SEAP) is based. The proposed set of tools constitute the technical component of the RE-SEEties integrated toolkit and can be generally applied across European cities to support cities in adhering or renovating their commitments to the Covenant of Mayors as well as to implement sustainable energy and waste management strategies with a long term perspective.

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