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Sustainable energy action plans of medium-sized municipalities in north Greece

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Abstract. The covenant of Mayors initiative includes the commitment of the municipalities-signatories to reduce voluntarily the greenhouse gas emissions over 20% by 2020 within their boundaries and obligates them to develop and submit an energy consumption analysis and a sustainable energy action plan within a year from the adhesion. The present paper discusses the energy profile of three medium-sized north-eastern Greek Municipalities (Kavala-MoK, Alexandroupolis-MoA, Drama-MoD) through the analysis of their municipal energy balance. The results of the total final energy consumption per capita include 14.10MWh/capita, 14.24MWh/capita and 12.91MWh/capita for MoK, MoA and MoD respectively. The analysis highlighted the increased energy consumption of the private sectors, namely residential and tertiary buildings and private transport. The assessment of the municipalities' energy profiles along with examination of national regulations and action plans and investigation of best available practices within the Covenant of Mayors shaped the development of the sustainable energy action plans of the examined municipalities that is presented in this paper. The proposed pathway towards low-carbon municipalities can be considered a representative case study and a starting point for other municipalities with similar characteristics.

Keywords: municipal energy planning; energy consumption analysis; policy development

1. Introduction

Within the European Union (EU), more than 75% of the population lives in urban areas, which corresponds to approximately 390 million of people (Eurostat 2014a). Additionally, approximately 70% of the total primary energy is consumed within cities (IEA 2008). It is therefore apparent that mobilizing local authorities of urban regions to take action towards energy consumption and CO_2 emissions reduction is crucial for the future of EU climate and energy policy. Energy planning at municipal level is also significant for sustainable development since municipalities constitute the closest authority to the final consumer. The strategic role of municipalities in the energy-planning process has been extensively assessed (Brandoni *et al*. 2012).

The energy profile of cities or municipalities constitute an important subject for researchers and

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policy-makers in order to assess possible sustainable energy action plans towards a low-carbon energy future (Morlet *et al*. 2013). However, the energy profile of each city within a country and across countries is different, due to economic structure, climate and energy markets. The examination of the energy profile is necessary in order to develop an efficient sustainable energy action plan. The analysis of energy consumption from particular sectors of municipalities' energy balance, as well as from the total municipal energy system has been investigated providing with insights regarding the sectors in general and the municipal facilities in comparison with increased energy consumption (Oliver-Sola *et al*. 2013, Fiaschi *et al*. 2012, Brandoni *et al*. 2012). Sperling *et al*. (2011) underline more specifically the importance of municipalities, as local energy planning authorities, to contribute to the achievement of Denmarks' national target of 100% renewable energy sources (RES) and highlights the necessity for simultaneously centralised and decentralised approaches within a strategic energy planning system. Rogero Pitt (2010) pinpoints that energy planning results in successful climate mitigation policies when the municipalities engage communities and neighbourhoods in their decision-making processes.

In this paper the energy profile of three north-eastern medium-sized Greek municipalities is assessed and is extensively examined. The objective is to analyse the energy profile of these municipalities and compare the findings between them and among other Greek and/or European municipalities with similar characteristics (building stock, climate, etc.). The understanding of the energy profile requires an appreciation of the differences in the energy system of each municipality. The detailed analysis of energy profiles of more than one municipalities and the comparison with other municipalities is expected to provide valuable insights regarding the methodological approaches adopted for the development of the energy profiles, as well as the development of actions to reduce final energy consumption within the municipal energy system.

Recognising the importance of local energy planning, many studies have investigated possible energy policies to reduce the final energy consumption within the boundaries of a municipality or a region from all public and private sectors responsible for energy consumption (Comodi *et al*. 2011, Chwieduk 2003). Several municipal energy plans have been developed (Brandoni *et al*. 2011, Hou *et al*. 2011). Fiaschi *et al*. (2012) presents an action plan to reduce energy consumption and integrate renewable energy sources in buildings and utilities of a small Italian city. Additionally, several studies have pinpointed the importance of local authorities to promote and develop renewable energy sources locally (Sperling *et al*. 2011, Economou 2010). Tozer (2013) discusses the success and the barriers of the implementation of community energy plans in five Canadian cities. Roosa (2009) concludes that energy conservation and energy efficiency techniques can lead to sustainable urban development.

Since the importance of local energy planning has broadly being accepted, several initiatives within Europe have been launched in an attempt to promote the development of energy plans from local and regional authorities (MangEnergy 2014, Smart Cities 2014, ICLEI 2014). One of the most successful initiatives in Europe regarding the development of sustainable energy action plans is the Covenant of Mayors (CoM). The participating municipalities, usually called "signatories", are voluntarily committed to increase energy efficiency and renewable energy production within their jurisdiction above the European targets by 2020 (CoM 2014a). The "signatories" are obligated to submit to the Covenant of Mayors office within 12 months from the adhesion, a Sustainable Energy action Plan (SEAP). The development of SEAPs of municipalities within the Covenant of Mayors constitutes a planning tool to promote strategies towards reduction of energy consumption and CO_2 emissions and increase of renewable energy production. The number of SEAPs currently submitted accounts for 3,619, of which 2,083 were accepted by the Joint

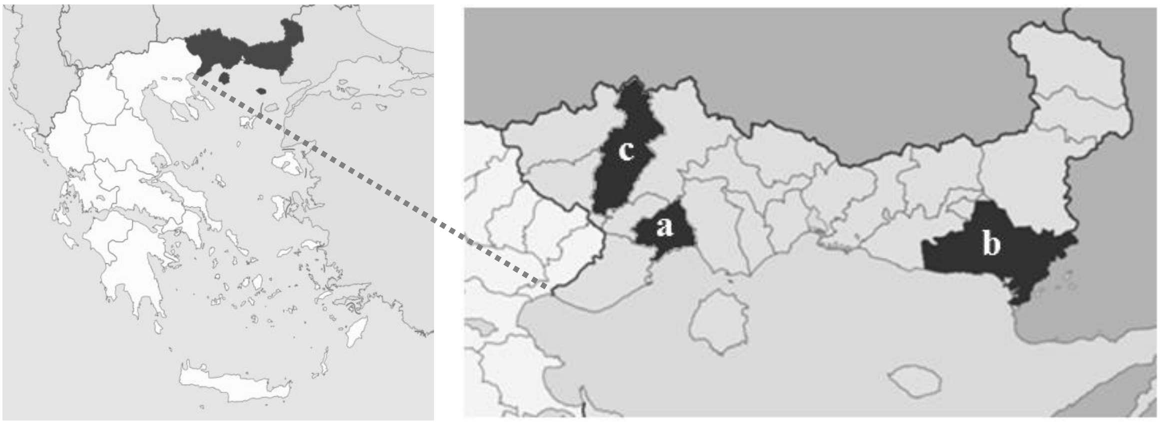

Fig. 1 The region of Eastern Macedonia and Thrace (a: municipality of Kavala, b: municipality of Alexandroupoli, c: Municipality of Drama)

Research Centre (JRC) of European Commission (CoM 2014b). In contrast with other European countries, such as Italy, which has legislated the obligation of municipalities with a population of greater than 50,000 inhabitants to develop a Municipal Energy Plan (Fiaschi *et al*. 2012), Greece relies only on volunteering initiatives of the local authorities to develop their own local energy action plans. In that context, 92 municipalities from Greece have signed the Covenant of Mayors, 65 of which have submitted their SEAP and 25 of them were accepted by the JRC (CoM 2014b).

The development of the sustainable action plan of three medium-sized Greek municipalities within the Covenant of Mayors initiative has been performed within this study. The analysis of these SEAPs and of the proposed pathway towards low-carbon future, which could be representative for other Greek and European municipalities with similar characteristics, constitutes the objective of this study. The specific study is expected to be useful for local authorities, public agents, decision-makers and stakeholders interested in the assessment and improvement of energy consumption and energy planning related aspects in municipal level.

2. Methodology

2.1 Municipalities profile

The municipalities under analysis and under investigation comprise the Municipality of Kavala (MoK), Municipality of Alexandroupolis (MoA) and Municipality of Drama (MoD). All three municipalities were examined in terms of their energy profile and their Sustainable Energy Action Plan (SEAP). They are located in the region of Eastern Macedonia and Thrace, Northeastern Greece (Fig. 1). East Macedonia and Thrace region constitutes one of the thirteen administrative regions of Greece, comprising the eastern part of the region of Macedonia along with the region of Thrace and the islands of Thasos and Samothrace. The total covered area of Eastern Macedonia and Thrace is approximately 14,160 km^2 with population of about 610,000 residents. Key figures regarding the profile of the municipalities are summarized in Table 1. It is worth mentioning that the percentage of population that lives in the urban areas of the municipalities is approximately

Table 1 Main characteristics of the municipalities of Kavala, Alexandroupolis and Drama

Characteristic	Unit	MoK	MoA	MoD
Population (2011 census revised)	inhabitants	70,501	72,959	58,944
Population density	inhabitants/km^2	238.7	59.2	70.8
Population in urban area	%	79.9	79.7	77.7
Temperature range (monthly average)	^{o}C	6.8 – 26.5	5 – 26	1.3 – 27.4
Humidity range (monthly average)	%	64.9 – 68.8	53.9 – 76.7	n/a
Annual precipitation	mm	403	557	635
Residential building stock	m^2	2.958.607	3.406.631	3.224.475
Households	number	28.765	28.975	22.540

equal. Moreover, important is the fact that these municipalities account for approximately 33% of the total population and 17% of the total area of the region of Eastern Macedonia and Thrace. The specific characteristics are representative for most medium-sized Greek municipalities (in between 50,000 and 100,000 population).

As far as local climate is concerned, MoK, MoA and MoD include Mediterranean climate, moderately continental with mild winters and hot summers, without particularly extreme temperatures. In terms of demographic development, a population reduction is observed during the last years whereas most of their population (>60%) is occupied in tertiary sector.

2.2 Development of the energy balance

The development of the energy balance of a system requires the selection of a baseline year, the selection of the boundaries of the system and the collection of the energy consumption data for the baseline year. Although, Covenant of Mayor’s guidelines suggest 1990 as a baseline year, in order to ensure that the energy balance calculation is based on reliable energy consumption data, the selection of a recent baseline year was the only solution for the development of MoK’s, MoA’s and MoD’s energy balance. Thus, for both municipalities of Kavala and Alexandroupoli, the year of 2011 was selected for baseline year. As far as MoD is concerned, the year 2012 was selected for baseline year, since limitations on the available energy consumption data of year 2011 were encountered.

The energy balance of the system includes all sectors presented in Table 2. The methodology followed regarding the collection of the energy data related to the previous sectors for all three municipalities included both top-down and bottom-up approaches. More specifically, top-down approach was followed for the energy consumption calculation of the residential and tertiary sector, as well as the public and private transport and the local energy production. On the contrary, bottom-up approach was utilised respectively for the municipal buildings, facilities, fleet and public lighting. Due to lack of national databases containing detailed information on municipal scale, part of the energy consumption data were estimated using proportional share of regional or national consumption based on number of households of each municipality.

Particular effort was made in order to accurately calculate the energy consumption of municipal buildings, facilities and lighting, which is necessary to propose and evaluate energy saving measures that would efficiently lead to energy consumption and cost reductions. Each of the three municipalities examined, possesses and/or manages a significant number of buildings that are used for the provision of various municipal services. The absence of any database regarding the energy

Table 2 Sectors included into the energy balance development

Sector	Energy Type						
	Electricity	Heating Oil	Gasoline	Diesel	Natural Gas	Wood	RES*
Energy/Fuel consumption							
Municipal** Buildings	√	√			√		
Municipal Facilities	√	√					
Municipal Lighting	√						
Residential Buildings	√	√				√	
Tertiary Buildings	√	√					
Public Transport			√	√			
Private Transport			√	√			
Energy Production	√						√

*Renewable Energy Systems (in this case solar, wind and hydroelectric energy).
** Municipal refers to buildings and facilities that are owned and/or managed by municipal authorities.

consumption of the municipal buildings and facilities in combination with the increased number of buildings resulted in particular difficulty in calculating both the electrical and thermal energy consumption.

The methodology used in the SEAPs of MoK and MoA to calculate the energy consumption of residential sector included the use of proportional share of national energy consumption data provided by the National Information System for Energy and based on number of households of each municipality. However, this methodology resulted in very conservative energy consumption calculations. Therefore, another approach was adopted for the calculation of the residential energy consumption of MoD, which was also used for the re-calculation of the residential energy consumption of MoK and MoA for the purpose of this study. For comparative reasons, the methodological approach used in MoK's and MoA's SEAP was utilised for the calculation of the residential energy consumption of MoD.

In more detail, the total residential building stock within the boundaries of each municipality was estimated and the respective energy consumption was calculated using average energy consumption per m^2 data derived from literature (Balaras *et al*. 2007) for the particular climatic zone of each municipality. The estimation of the total residential building stock of the municipalities was performed using the national census provided from the Hellenic Statistic Authority (El.Stat.) (El.Stat 2000, El.Stat 2001a - El.Stat. 2012b). The main assumption adopted was that the end-use of new buildings (2002-2012) is similar to end-use of the existing buildings. Moreover, since the number new buildings constructed after 2010, when the new national regulation on energy performance in the building sector (KENAK) was put into force (Ministerial Decision D6/B/5825), is relatively small, it was assumed that the thermal and electrical energy consumption per m^2 is similar to the buildings constructed between 2002 and 2010. An important assumption adopted in the calculation of thermal energy consumption of the residential sector includes the consideration of the fuel (or energy) poverty phenomenon, which is enhanced in regions of increased thermal comfort needs and in regions that encounter economic issues. Thus, according to Santamouris *et al*. (2013), the energy consumption of Greek households during the winter 2011-2012 was 37% less than expected, which indicates that the actual energy consumption is significantly lower than the theoretically calculated.

Partial information gathered mainly from the technical department of each municipality was

Table 3 Sources of data collection

Building/Facilities	Electricity, Heating oil, Wood
Municipal buildings/facilities	Building energy audits, data from municipal authorities, PPC (public power corporation), Municipal Water Supply and Drainage Company.
Residential buildings	The total building stock area was estimated using available data from the Hellenic Statistical Authority and the respective energy consumption was calculated using average energy consumption per m^2 derived from literature.
Tertiary buildings	Data were estimated based on national annual consumptions acquired from national information system for energy and the number of households in municipalities.
Municipal public lighting	Estimations from municipal technical services and field observations.
Transportation	Diesel/Gasoline
Municipal fleet	Data from municipal technical service department.
Public transport	Local transportation cooperative i.e. KTEL, and estimations based on total km traveled.
Private transport	Statistical data from Egnatia Odos S.A., and Hellenic Statistical Authority, and estimations based on total km traveled.

used in order to estimate the electricity consumption of public lighting. On the contrary the collection of energy consumption of the municipal fleet was not time-consuming, since all three municipalities had database containing all the information required. As far as the local energy production is concerned, the energy balance of the municipalities includes the energy generated from units under 20MW of either thermal of electrical power. This is based on the assumption that the energy generated from small units is locally consumed, in contrast with the energy generated from larger units that is consumed elsewhere in the country. This assumption is included in SEAP guidelines published by the office of the Covenant of Mayors (EC 2010). Table 3 summarises the sources of data collection for the development of the energy balance of each municipality.

In general, the development of an energy balance of a medium-sized northern Greek Municipality is a relatively challenging and time-consuming task, mainly due to lack of any particular local energy consumption database, as far as the energy consumption that is subject to municipality’s management is concerned, and due to lack of national energy consumption database on municipal scale, as far as the residential and tertiary sector is concerned. Data collection required approximately two (2) to five (5) months for each municipality depending mainly on the available staff and the response time of various agents.

3. Results and discussion

3.1 Energy profile of the examined municipalities

According to the energy consumption analysis developed within the sustainable energy action plans of the examined municipalities, as submitted to the Covenant of Mayors office (MoK SEAP 2013, MoA SEAP 2013, MoD SEAP 2013), the total final energy consumption was estimated at 972,814 MWh for MoK, 926,490 MWh for MoA and 719,372 MWh for MoD. The corresponding values expressed in MWh per capita include 13,80 MWh/capita for MoK, 12,70 MW/capita for

Table 4 Final energy consumption breakdown per source of energy and per sector according to SEAP of each municipality (blue for MoK, red for MoA, green for MoD)

	Consumption [in MWh]						
Sector	Electricity	Heating oil	Diesel	Gasoline	Wood	Total	%
Buildings/Facilities							
Municipal buildings/facilities	16,886 5,463 12,430	7,779 6,623 7,566	-	-	8	24,665 12,094 20,347*	3% 1% 3%
Tertiary buildings	130,606 108,913 91,671	17,802 14,845 12,045	-	-	-	148,408 123,758 103,716	15% 13% 14%
Residential buildings	131,534 138,323 96,109	161,317 134,523 261,926	-	-	50,369 42,003 60,927	343,220 314,849 419,002	35% 34% 58%
Municipal public lighting	10,059 3,209 12,263	-	-	-	-	10,059 3,209 12,263	1% <1% <1%
Transport							
Municipal fleet	-	-	2,672 3,465 1,159	236 213 256	-	2,908 3,678 1,415	<1% <1% <1%
Public transport	-	-	6,711 6,880 3,975	-	-	6,711 6,880 3,975	<1% <1% <1%
Private transport	-	-	233,160 258,878 90,089	203,683 203,144 68,565	-	436,843 462,022 158,654	45% 50% 22%
Total (%)	30% 28% 30%	19% 17% 39%	25% 29% 13%	21% 22% 10%	5% 4% 8%	972,814 926,490 719,372	100% 100% 100%

*351MWh due to natural gas consumption were also included in the analysis
Subtotal values may vary a little due to approximations

MoA and 12,20 MWh/capita for MoD. The breakdown of the total final energy consumption of each municipality, as calculated in their SEAP is presented in Table 4.

The energy consumption that is subject to municipality's management (i.e., buildings, fleet, public lighting) constitutes a relatively low percentage (2-6%) of the total energy consumption for all the examined municipalities. Nevertheless, it is significant in absolute units and presents a substantial potential for energy saving measures, which could be used as exemplar and vehicle to raise awareness of residents of MoK, MoA and MoD. The consumption of heating oil of the municipal buildings and facilities is similar for all three municipalities. On the contrary, the electricity consumption significantly differs among the municipalities. In particular, MoK presents increased electricity consumption mainly due to the relatively significant altitudinal differences and land slopes of MoK, which result in increased electrical needs for the operation of the water supply and sewerage network. Moreover, the water supply network of MoD encounters significant losses that result in increased electricity consumption (more water pumped to cover the losses). Additionally, differences between the energy consumption of municipal public lighting are observed, mainly, as a result of the different estimations undertaken by the technical departments of each municipality regarding the number and type of the lamps installed. The energy consumption originating from the municipal fleet is very similar for MoK and MoA and relatively smaller for MoD, as a result of the less municipal vehicles that MoD possesses. A significant fact that regards the energy consumption of the transport sector is related with the presence of part of the Egnatia highway within the boundaries of both MoK and MoA. More specifically, the consumption of diesel and gasoline is significantly higher for MoK and MoA as compared to MoD, due to the increased private transport originating from the Egnatia highway. As shown in Table 4 the energy profile of MoD is considerably altered as compared to MoK and MoA, as a result of the smaller energy consumption of the private transport sector.

As far as the energy consumption from the residential buildings is concerned, MoK and MoA present similar results due to the fact that the consumption is calculated using proportional share of relevant national consumption based on number of households, which is similar for these two medium-sized Greek municipalities. However, the residential buildings' heating oil consumption of MoD is significantly higher, since a different methodology based on the calculation of the total municipal building stock area is used. According to the latest data of the Hellenic Statistical Authority (El.Stat. 2013), the average annual thermal energy consumption per Greek household is 10,244 kWh, of which 85.9% is for heating, 4.4% is for domestic hot water and 9.7% is for cooking. The fuel type that is mostly used for thermal energy is heating oil (60.3%), followed by wood (23.8%). Thus, the thermal energy consumption per household of MoK (7,964.2 kWh) and MoA (7,964.1 kWh) was calculated below the national average per Greek household (8,799.6 kWh), despite the fact that the examined municipalities are located in north-eastern Greece. On the contrary, the thermal energy consumption per household of MoD (14,325.3 kWh) calculated in municipality's SEAP is approximately 40% higher as the one estimated by El.Stat., which is most likely the case due to the fact that MoD is located in climatic zone D of Greece that involves the highest thermal needs during winter. Regarding, the wood consumption for thermal energy production within the boundaries of MoD, the results indicate similar consumptions between the one calculated and the one estimated by El.Stat., as a consequence of the methodology utilised that takes into account previous data of the national energy mixture for heating of households and particularly before the rise of heating oil prices that resulted in rapid growth of wood consumption for heating.

It is obvious that the methodology applied for the thermal energy calculation of the residential buildings of MoD, as presented in paragraph 2.2, delivers more representative results regarding the energy profile of the municipality. Thus, when applying the same methodology for the calculation of the thermal energy consumption of residential buildings of MoK and MoA the results comprise 277,674 MWh and 320,739 MWh, respectively. In an attempt of comparison between the three Greek medium-sized north-eastern municipalities, the corresponding thermal energy consumption per m^2 of the residential buildings of MoK and MoA is 93.85 kWh/m^2 and 99.47 kWh/m^2, respectively and lower than the thermal energy consumption of residential buildings of MoD (105.32 kWh/m^2), which is expected as MoK and MoA belong to climatic zone C and MoD belongs to climatic zone D. The thermal energy consumption of residential buildings per household of MoK and MoA is now 9,653.2 kWh and 11,069.5 kWh respectively, higher than the national Greek average, as expected. The utilisation of the same methodology of calculation of the thermal energy consumption of residential buildings, namely the estimation of the existing total building stock area, for the calculation of the electricity consumption, resulted in 87,117 MWh for MoK, 106,348 MWh for MoA and 101,859 MWh for MoD. The corresponding electricity consumption per m^2 of the buildings is 29.45 kWh/m^2 for MoK, 32.98 kWhm^2 for MoA and 29.90 kWh/m^2 for MoD.

As mentioned, the methodology followed mainly for the calculation of the energy consumption of the residential sector resulted in misleading picture of the energy profile of the municipalities. Therefore, Table 5 presents the final energy consumption per source of energy and per sector that includes the methodological approach used for MoD, corrected with the latest available data in terms of energy mixture for heating of Greek households.

The energy profile of the municipalities also includes local energy production and particularly, electricity generation from Renewable Energy Sources, that significantly enhances the profile of the municipalities since it reduces the electrical energy coefficient for CO_2 emission. More specifically, MoA included in 2011 30,299 MWh of electricity production, of which 3,026 MWh originates from photovoltaic (PV) stations and 26,214 MWh from wind parks. MoK presented in 2011 very low electricity generation from PV stations and it was therefore

Table 5 Final energy consumption per source of energy and per sector for MoK (blue), MoA (red) and MoD (green)

	Consumption [in MWh]						
Sector	Electricity	Heating oil	Diesel	Gasoline	Wood	Total	%
Buildings/Facilities							
Municipal buildings/facilities	16,886 5,463 12,430	7,779 6,623 7,566	-	-	8	24,665 12,094 20,347**	2% 1% 3%
Tertiary buildings	130,606 108,913 91,671	17,802 14,845 12,045	-	-	-	148,408 123,758 103,716	15% 12% 14%
Residential buildings	87,117 106,348 101,859	181,876 210,084 254,627	-	-	72,743 83,713 93,648	364,791* 427,087* 460,662*	37% 41% 61%
Municipal public lighting	10,059 3,209 12,263	-	-	-	-	10,059 3,209 12,263	1% <1% 2%
Transport							
Municipal fleet	-	-	2,672 3,465 1,159	236 213 256	-	2,908 3,678 1,415	<1% <1% <1%
Public transport	-	-	6,711 6,880 3,975	-	-	6,711 6,880 3,975	1% 1% 1%
Private transport	-	-	233,160 258,878 90,089	203,683 203,144 68,565	-	436,843 462,022 158,654	44% 44% 23%
Total (%)	25% 28% 30%	21% 17% 39%	24% 29% 13%	21% 22% 10%	7% 4% 8%	994,385 1,038,728 761,032	100% 100% 100%

*Includes the total thermal energy consumption besides from heating oil and wood, namely liquid gas, solar thermal, district heating, etc.
**351MWh due to natural gas consumption were also included in the analysis
Subtotal values may vary a little due to approximations

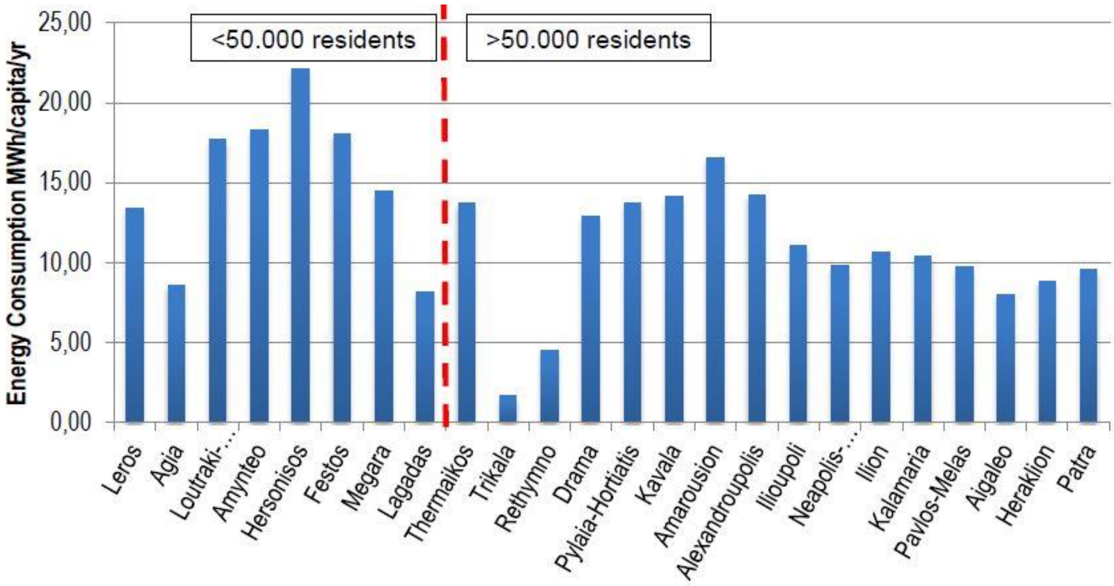

Fig. 2 Final energy consumption of Greek municipalities according to their SEAP submitted to CoM and approved by JRC

neglected. MoD presented 20,818 MWh of electricity production in 2012, of which 17,040 MWh from PV stations and 3,778 MWh from a small hydroelectric power plant. As shown, the baseline year of the energy profile calculations significantly influences the electricity generation since PV station installations radically increased during 2011 and 2012 in all three municipalities and generally in Greece.

3.2 Comparison with other municipalities

According to a sample of 1,287 SEAPs that have been accepted by the Joint Research Centre (JRC) of the European Commission before the 11th of June 2013 (JRC 2013), the average final energy consumption per capita in signatory municipalities is 25 MWh/capita, which is higher than the final energy consumption per capita of MoK, MoA and MoD (14.10 MWh/capita, 14.24 MWh/capita and 12.91 MWh/capita, respectively). According to Eurostat, the final energy consumption per capita is 25.50 MWh/capita for EU-28, 21.61 MWh/capita for Spain, 23.92 MWh/capita for Italy and 19.78 MWh/capita for Greece (Eurostat 2014b). Thus, the final energy consumption per capita of the three municipalities examined is below the Greek national average, as well as the national average of other Mediterranean countries. If energy consumption from other sources (i.e., industrial/agricultural activities) were additionally taken into account for the calculation of municipalities' final energy consumption, results would be much closer to the national average of Greece.

In Fig. 2 the final energy consumption per capita of all Greek municipalities that have submitted a SEAP and has been accepted by the JRC is presented. In total 25 SEAPs been approved by JRC until 31th of March 2014 of which 24 were available online (SEAP 2014). As far as MoK, MoA and MoD is concerned, Fig. 2 includes the final energy consumption calculated in this study (Table 5). The per capita indicators provide useful information for the energy

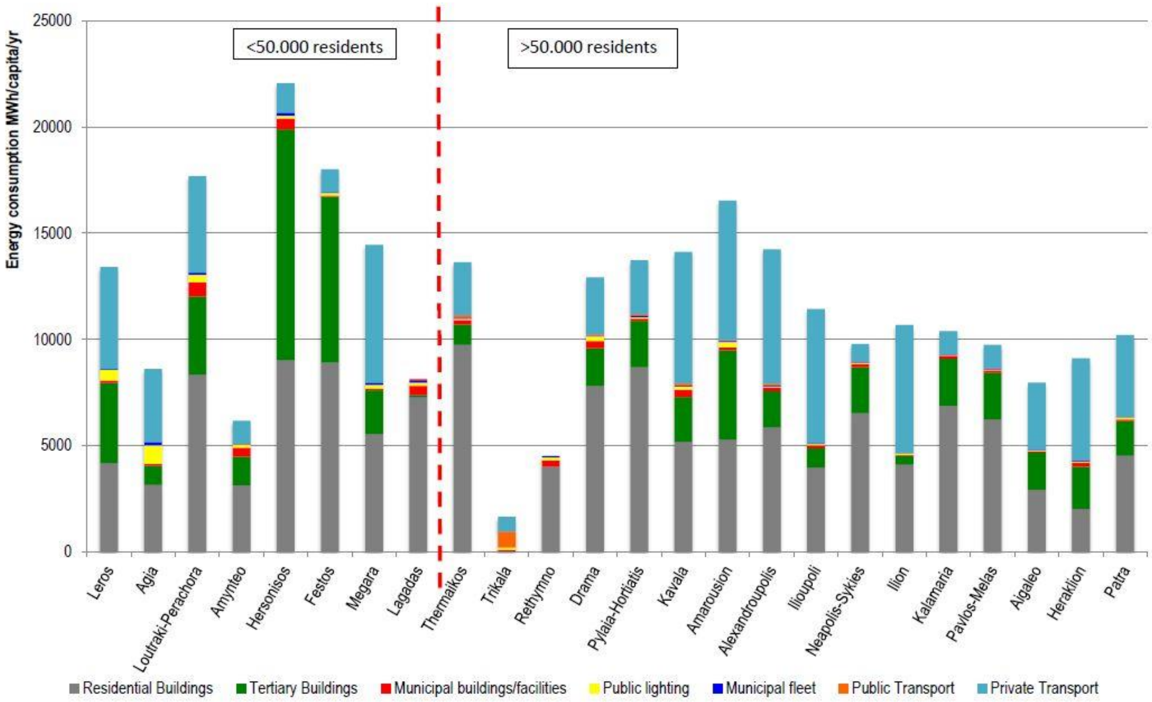

Fig. 3 Final energy consumption breakdown per sector of Greek municipalities according to their SEAP submitted to CoM and approved by JRC (presented in alphabetical order)

profile of the municipalities. For instance, municipality of Hersonisos presents the highest per capita energy consumption due to the increased seasonality of energy consumption as a result of the increased tourists visiting the area. Fig. 2 also shows that smaller, in terms of population municipalities, present (with exceptions) higher energy consumption per capita as compared to larger municipalities. Other medium-sized municipalities, such as Amarousion, Pilea-Hortiatis and Ilioupoli present similar final energy consumption per capita with the examined municipalities of Kavala, Alexandroupolis and Drama.

Fig. 3 shows final energy consumption breakdown per sector per capita, as included in municipalities' SEAP and according to the energy consumption calculations for MoK, MoA and MoD, presented in this paper. As shown, the energy profile of the Greek local authorities varies from one to another. However, comparisons between energy consumption data entail increased levels of uncertainty as they depend on different methodological approaches, cut-off criteria and allocation procedures. As shown, urban municipalities such as Patra, Heraklion, Aigaleo and Amarousion present similar energy profile, which however is different from other urban municipalities such as Ilion and Ilioupoli due to dissimilar methodological approaches. Nevertheless, if similar methodology for the development of the energy balance of municipalities is followed, the results indicate a reasonable proportionality to population, as shown by the comparison of MoK, MoA and MoD.

In general, final energy consumption in residential buildings represents significant part of the energy consumed in all the municipalities presented in Fig. 3. Proportionality to municipalities' population is reasonably applicable to the energy consumption of the residential sector. However,

Table 6 Final energy consumption per capita per annual average temperature (^{o}C)

Municipality	Final energy consumption per capita (MWh/capita/avg temp)	Municipality	Final energy consumption per capita (MWh/capita/avg temp)
Region of Attiki		Region of Crete	
Aigaleo	0.45	Festos	0.95
Amarousion	1.01	Heraklion	0.46
Ilion	0.61	Hersonisos	1.18
Ilioupoli	0.60	Rethymno	0.23
Loutraki-Perachora	0.97	Region of East Macedonia-Thrace	
Megara	0.80	Alexandroupolis	0.95
Region of Central Macedonia		Drama	0.86
Amynteo	1.41	Kavala	0.93
Kalamaria	0.66	Region of South Aegean	
Lagadas	0.52	Leros	0.71
Neapolis-Sykies	0.63	Region of Thessaly	
Pavlos-Melas	0.62	Agia	0.55
Pylaia-Hortiatis	1.05	Trikala	0.10
Thermaikos	0.87	Region of Western Greece	
		Patra	0.53

the residential sector' energy consumption is highly influenced by the methodological approach utilised, as shown in this study. The comparison of the energy consumption from municipal buildings and facilities of the municipalities indicates variations, even between municipalities with similar population, which is mainly a result of the differences between the energy consumption of their facilities such as the water supply and sewerage networks, as concluded from the comparison of MoK, MoA and MoD. Relatively reasonable proportionality to population is observed also in the final energy consumption from the municipal fleet. Private transport accounts for a significant portion of total energy consumption in all municipalities; however there is no proportionality to population since it is highly influenced by the parts of national highways that are within the municipalities' boundaries (example of MoK and MoA).

According to data presented in Table 6 it is evident that the final energy consumption of the municipalities partly follows the climatic conditions of the specific regions. However, as already mentioned, the final energy consumption is highly influenced by the methodologies, the cut-off criteria and the allocation procedures. Moreover, not all the sectors included in the final energy consumption are influenced from the climatic conditions. For instance, MoD presents low energy consumption per capita per annual average temperature from MoK and MoA in contrast with the lower annual average temperature, which mainly depends on the increased energy consumption resulting from the private transport sector. When comparing the energy consumption of the residential sector per capita per average temperature of each municipality, the results indicate that the lower the average temperature the higher the energy consumption for the residential buildings, which is expected since the thermal energy consumption per area of residential buildings in north climatic zones (with lower average temperature) is higher (Balaras *et al*. 2007).

3.4 Action plans to improve the energy profile

The ability to study best available practices applied by municipalities in European level to reduce their energy consumption, constitutes one of the main advantages of the development of the "community" within the Covenant of Mayors initiative. In addition, the exchange of experiences can deliver knowledge in terms of solving potential issues that may arise from the implementation of action/measures to reduce the energy consumption of a municipality.

This section describes an assessment of the actions to reduce energy consumption and improve the energy profile of the MoK, MoA and MoD. The analysis of the energy profile of the municipalities highlighted the points of potential interventions to reduce the final energy consumption. The SEAP of each municipality was developed in accordance with the guidelines published by JRC (2010) and in collaboration with the municipal authorities and stakeholders. The selection of the proposed measures and actions was based on the results of the energy consumption analysis, municipal and national regulations, the national energy efficiency action plan (YPEKA 2011, YPEKA 2013) and prevailing trends resulting from a study of the best available practices within CoM of municipalities with similar characteristics to MoK, MoA and MoD. The selection and assessment of the proposed measures and actions in terms of energy conservation and cost of implementation follows the "projection" approach. Namely, the measures and actions are selected to ensure compliance with the target of CoM (20% reduction in CO_2 emission by 2020) on the basis of what is considered viable given current conditions and available technology.

Table 7 presents the calculated energy savings per sector of each the examined municipalities, as planned in their SEAP, in order to achieve the goal of 20% reduction of CO_2 emission by 2020. As expected, the highest contribution to energy savings comes from the residential/tertiary building and transport sectors. The percentage of energy consumption reduction per sector that is achieved through the implementation of the proposed actions included in each SEAP is presented also in Table 7. As shown, the municipal public lighting presents a significant potential for energy conservation.

The energy profile analysis showed that in general the size and the number and consequently the energy consumption of buildings (not facilities) managed by the municipalities examined are approximately similar, indicating that they are representative for medium-sized Greek municipalities. This conclusion is similar to other European municipalities (Fiaschi *et al*. 2012). In particular, the proposed measures for energy renovating municipal buildings include similar actions for all three municipalities examined. The proposed actions consist of energy saving measures in municipal buildings/building complexes and facilities that present the highest energy

Table 7 Energy savings and percentage of energy savings from the proposed actions of each sector for MoK (blue), MoA (red) and MoD (green)

Sector	Municipal buildings/ facilities	Residential/ Tertiary buildings	Municipal public lighting	Municipal fleet	Private & Public transport
Energy savings (MWh)	1,033 400 2,172	81,202 85,702 94,310	5,029 2,288 5,070	705 818 503	82,173 85,626 43,942
Percentage of energy savings (%)	24.25 22.23 35.52	17.32 17.16 18.60	50.00 71.30 41.34	4.19 3.30 10.68	18.53 18.26 27.02

consumption in combination with increased energy saving intervention potential. It is worth noticing that only five (5) buildings account for 51% of the total energy consumption of the municipal buildings of MoK. The respective figure for MoA is 30% and for MoD is 40%. Besides energy consumption and intervention potential, the selection of buildings and facilities that have been proposed to be firstly addressed in terms of energy renovation includes factors such the number daily visitors and users of the buildings/facilities in order to enhance the exemplary role of the measures' implementation. The selection of the energy saving measures and the quantification of the respective energy consumption reduction for each building/facility was accomplished using available data in literature regarding the best practice in energy retrofitting of public buildings (Gaglia *et al*. 2007, Balaras *et al*. 2007).

Although, the energy consumption reduction from the municipal buildings/facilities sector is relatively small, their implementation will result in increase of the awareness of the residents about the advantages of energy saving measures in buildings and help the transition to low-carbon municipalities. MoD includes a highest target for energy savings from the municipal buildings/facilities (Table 7), as compared to MoK and MoA due the fact that at the time of development of its SEAP, the local authority had managed to secure the funding for energy saving measures in six municipal buildings, as well as for energy efficiency improvement of the municipality's water supply network. It is therefore clear that the local energy planning is strongly related with the national and regional energy planning. The implementation of energy saving measures at municipal buildings or facilities is considered as capital intensive, since approximately 2,500.00 € per MWh of energy consumption reduction is required. Hence, funding instruments other than the local authorities' own resources are considered necessary for the implementation of such actions. Selecting buildings and facilities to implement energy savings measures (e.g., schools) in accordance with the national prioritisation of energy efficiency targets (YPEKA 2011 and YPEKA 2013), results in securing national funding, as the example of MoD presents.

Regarding the proposed measures to reduce the energy consumption of the municipal public lighting, the replacement of the existing old technology with LED lamps consist an undoubtedly efficient solution (Fiaschi *et al*. 2012). The potential for energy savings and the respective target set in each SEAP, depends on the existing type of technology used in each municipal public lighting network. Similarly, to the municipal building and facilities sector, the implementation of replacement of public lighting with low energy consumption LED lamps is capital intensive (from 200.00 to 500.00 € per MWh of energy conservation). However, these types of actions are considered as "bankable", making them attractive to innovative financing schemes, such as Energy Service Companies (ESCOs). Another measure proposed in all three municipalities' SEAP includes the development of a study in order estimate the lighting level of all outdoor public traffic areas according to the European Standard EN 13201. It is often the case that main streets are over-illuminated resulting in increased electricity consumption and light pollution issues. It goes without saying that energy efficiency measures in the public lighting sector are feasible and result in energy savings, as well as reduction in direct and indirect costs for the municipalities (Radulovic *et al*. 2011).

The condition of the existing building stock of the municipalities presents significant energy savings potential. In more detail, as calculated, more than 50% of the residential building stock in all three examined municipalities is constructed before 1980, that is to say before Thermal Insulation Regulation was enacted. As stated by Balaras *et al*. (2007), simply the installation of thermal insulation to external walls of pre-1980 buildings results in 33-60% of energy savings for space heating. The cost effectiveness of energy saving measures for heating in Hellenic residential buildings has also been investigated (Droutsa *et al*. 2014). The potential energy savings from the non-residential building stock of Greece has been discussed in detail (Gaglia *et al*. 2007). Thus, although the potential for energy savings from residential and tertiary building sector of the municipalities is relatively high, the actions that the local authorities could take towards this direction are limited to information and awareness raising campaigns. Such an action that already brings positive results has been implemented in MoA and refers to the establishment of a particular information point where residents of Alexandroupolis can be informed about the potential energy saving measures of their dwellings as well as about the on-going national supporting schemes (i.e., program "Energy Saving at home", YPEKA 2014). The energy savings target from the residential and tertiary buildings of the examined municipalities is similar and approximately 18% of the total final energy consumption of the respective sectors. Although the number is considered as conservative compared to the potential for interventions, there is high level of uncertainty since the recent economic crisis significantly reduced the financial ability of Greek households to afford capital intensive expenditure of energy saving measures in their dwellings. Nevertheless, the adoption of actions from the local authorities to raise awareness and provide information of the advantages of energy conservation in residential buildings requires a relatively low capital (from 1.50 to 3.00 € per MWh of energy conservation) and therefore should be highly prioritised. Additionally, since the adoption of energy saving measures from inhabitants of the municipalities requires their behavioural energy chance, the positive results of the energy efficiency measures implemented in the municipal buildings should be made broadly public in order to actually succeed the required chance, as also mentioned by Vidmar (2012).

Similarly to the residential and tertiary building sector, the private and public transport sector constitutes an important energy consumer within the boundaries of the municipalities, which is not controlled by the local authorities. Therefore, the sustainable energy action plans of the municipalities includes information and awareness raising campaigns in order to inform and aware the residents about the use of alternative fuels, hybrid or electric vehicles and about eco-driving and reduction of use of private vehicles for short distance within the city. The study of the best practices in the transportation sector illustrates that the innovative and pioneering adoption of actions, such as the installation of electric vehicle (EV) charging stations (Sabadell 2014), results in successful reduction in final energy consumption. The profile of the examined municipalities shows that there is limited use of public transportation and increased use of private vehicles, which is very common in medium-sized Greek cities. Therefore, the measures for energy consumption reduction should be focused on limiting the use of private vehicles. As far as the MoD is concerned, the examination of its energy profile suggests that a reasonable target approximately of 27% of reduction in energy consumption of the private and public transport sector is achievable. On the contrary, municipalities such MoK and MoA, that include in their geographic boundaries parts of the Egnatia highway, should adopt a more conservative target, since the energy consumption that comes from the highway cannot be reduced by measures and actions taken in local level.

As far as the municipal fleet is concerned, the proposed actions are related with the age and technology of the possessed vehicles. All three municipalities have examined present significant energy consumption from their garbage trucks. Therefore, the proposed actions include the conversion of diesel-powered vehicles to high level biodiesel blends and the replacement of old diesel powered vehicles with new natural gas powered ones. Since, these actions have similarly to the municipal buildings sector, an exemplary nature, the replacement of gasoline-powered vehicles with hybrid or electric cars is proposed. Similarly to the municipal buildings sector, the implementation of these actions requires increased expenditure as compared to the energy consumption reduction that they offer (from 1,400.00 to 2,000.00 € per MWh of energy conservation).

Although the promotion of renewable energy production and the respective action plans follows a centralised national approach, it is well established that it should also be part of the local energy action plans (Sperling *et al*. 2011). Therefore, assessing the potential of renewable energy sources (RES) installations within the boundaries of the examined municipalities and in accordance with the national RES legislation, several actions have been included in the municipalities' SEAPs. Besides the conventional actions proposed, such as the installation rooftop PV stations, the SEAPs include innovative proposals such small wind turbines installations for the purpose of acting as exemplary to the inhabitants of the municipalities. Finally, the particular RES potential available in each municipality should be highly investigated since it may offer distinguished possibilities for increased RES deployment, as the example of MoA shows. In more detail, within the boundaries of MoA, there is a low-enthalpy geothermal field that according to the national legislation is available for long-term lease and exploitation. Currently, MoA has already secured the lease and exploitation of this geothermal field and plans to district heat eleven (11) public buildings and more than 20,000 m^2 of private greenhouses (MoA 2014). In the long-term the municipality plans to district heat all the near villages (more than 6,000 households), resulting in increased exploitation of the main local available renewable energy source (MoA SEAP 2013). Therefore, the selection of measures for the local RES production promotion requires the assessment of the particular RES potential of each municipality within its boundaries.

4. Conclusions

The specific study presents an analytical examination and assessment of the energy profile and the sustainable energy action plan of three medium-sized north-eastern Greek municipalities, namely Municipality of Kavala (MoK), Municipality of Alexandroupolis (MoA) and Municipality of Drama (MoA).

The urban way of life seems to be both part of the energy consumption problem and part of the possible solution to reduce CO_2 emissions. Realising the potential of energy consumption reduction within the boundaries of a municipality will boost the implementation of actions towards low-carbon future. It goes without saying that cities play a central role in mitigating the greatest challenge, the climate change. Developing an analytical and reliable energy balance of a Greek municipality is considered as an important challenge that requires significant effort. A bottom-up approach for the collection of energy consumption data, definitely results in representative energy profile of the municipality. However, the utilisation of the bottom-up approach in all sectors of a municipality's energy balance requires the engagement of all stakeholders and constitutes a great challenge for the local authorities.

The methodological approach for the development of the energy balance used in this study results in representative figures of the final energy consumption of the examined municipalities. Due to limitations and other factors the utilisation of bottom-up approach for the calculation of all sector's final energy consumption was not possible. Therefore, both bottom-up and top-down approaches were combined for the estimation of the final energy consumption of the three municipalities. The results of the total final energy consumption comprise 994,385 MWh for MoK, 1,038,728 MWh for MoA and 761,032 MWh for MoD. The corresponding values expressed in energy per capita are 14.10 MWh/capita for MoK, 14,24 MWh/capita for MoA and 12,9 1MWh/capita for MoD. The examination of the energy profile of the three municipalities and its comparison with other Greek and European municipalities resulted in the following main conclusions:

• The energy profiles of the examined municipalities present extensive similarities and they can be considered representative for other medium-sized Greek and European municipalities. However, some special characteristics, such as the presence of part of national highway within the boundaries of a municipality, may significantly alter the energy profile. The development and examination of specific energy profile for each municipality is crucial and provides with insights for the potential energy consumption reduction.

• Since the methodological approach for the development of a municipality's energy balance can significantly vary, the comparisons between energy consumption data entail increased levels of uncertainty. The need for guidelines for the development of energy balances of Greek municipalities is present.

• The development of analytical energy balance for a municipality and its comparison with other energy balances of municipalities with similar characteristics results in highlighting sectors and points of interest with increased energy consumption, assuming that similar methodological approach has been followed for the development of the energy balance.

• Municipal activities (buildings, facilities, fleet, public lighting) contributed to a small percentage to the total final energy consumption (<4%, <3% and <6% for MoK, MoA and MoD respectively). However, municipalities should target in planning and implementing exemplar energy conservation actions, in order to raise awareness and provide motivations.

• Although energy consumption from municipal buildings and fleet presents proportionality to population, meaning that their energy condition is similar for all three municipalities, the municipal facilities' energy consumption is strongly related with particular characteristics such as the altitudinal differences of MoK.

The development of the SEAP of a medium-sized Greek municipality can be an effective energy planning tool towards low-carbon future. The opportunity for low-carbon future lies in the decisions and actions of municipalities to promote sustainable energy actions. The proposed pathway, as presented in this study for the municipalities of Kavala, Alexandroupolis and Drama, can be considered as a representative case study and a starting point for other Greek of European countries with similar characteristics. As shown, a successful pathway towards low-carbon societies involves increased energy consumption reduction from the private sector (residential and tertiary). Local authorities can seriously reduce energy consumption and improve their energy profile only by increasing the environmental awareness of local citizens and stakeholders and helping them to implement energy conservation actions, especially in the building sector. In that context, the analysis of buildings and facilities in the municipality's management should play a central role in a SEAP, in order local authorities to play a demonstrative role for the private sector to accelerate improvement of energy efficiency and renewable energy production. Moreover, the implementation of energy saving measures in municipal buildings/facilities results in significant cost reduction that is vital for the local authorities' financial survival. As far as Greek municipalities are concerned, the examination of the SEAPs in this study highlights the necessity for consistency between different levels of energy planning, namely municipal, regional and national planning, in order to secure the successful implementation of the proposed measures/actions.

The specific study is expected to be useful for local authorities, public agents, decision-makers and stakeholders interested in the assessment and improvement of energy consumption and energy planning related aspects in municipal level.

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