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Financial Crisis in Greece, Economical Evaluation of Replacement of Heating Diesel Oil with a Heat Pump System

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In October 2009 the Greek government realized that the previous governments had been understating their public debt for years. Just two months later Fitch downgraded Greece's debt to BBB+, the lowest credit rating in Europe. The Greek government tries to resolve this historical "problem" with a loan from a troika (European Union, European Central Bank and the International Monetary Fund), which requires the country to implement a wide array of austerity measures, from spending cuts and public sector lay-offs to tax rises and the privatization of public assets. But the three-year crisis has left deep scars on the body of society, leaving thousands out of work and plunging them into poverty. According to the official data from the Greek ELSTAT statistic agency reports, unemployment in Greece hit a new record in October 2012 reaching 26,8 %, compared with 2008, when economic decline started in Greece, unemployment has more than tripled. In addition, according to study by ADEDY and GSEE labor unions, approximately one in two Greeks earns less than 4,871 € a year and lives below the poverty line, defined as the minimum income a family of four needs to eat, dress, use transportation, go to school, and pay the rent.

Based on the data from the ministry of environment, energy and climate change the Greek government knows that the greatest problem of the Greek fuels market is fuel smuggling, adulteration and cheating, which lead to distortions in the market. In order to solve this problem the government decides to equalize the price of heating oil with petrol pump prices. However, this decision pushes the price of a litre of heating oil to around 1,3 €, about 45 % higher than one year ago. With petrol out of the question for the many, attention has turned to alternative forms of heating. On the other hand, collusion among producers in Greece and a thorough lack of competition that allows a favored few to extract economically unjustified profits have as a result the price of natural gas, wood and pellet to climb.

The main goal of this work is to estimate the feasibility of a heat pump system as an alternative solution to the common heating diesel which is used in Greece. Based on the long-term meteorological data from 66 stations, the financial feasibility of a heat pump heating system at each site in Greece was estimated. The RETScreen Clean Energy Project Analysis software was used in order to carry out the feasibility analysis and the green house gas (GHG) emissions reductions. Generally Greece has a typical Mediterranean climate which means hot, dry summers and mild rainy winters with snow mainly at higher elevations. The facts that there aren't areas in Greece which are more than 140 kilometers away from water and nearly 80 % of country is mountainous give varying weather patterns across to the country. According to the heating degree-days, Greece can be divided into 4 climatic zones. Sensitivity analysis was realized for four cities, namely Rhodes, Athens/Filadelpeia, Kavala and Kastoria, which are located in the first, second, third and fourth zone respectively. In accordance with the financial results in the first climatic zone where heating demand is really low, the replacement of heating oil systems with heat pump systems is not very profitable investment.

In zone A, based on the results from the RETScreen, the payback period varies between 7–10,5 years, while for the poorest of citizens owing to government subsidy of 0,28€/l the payback period is between 9,8–14,5 years. In the second zone there are several financial benefits from using heat pump system instead of heating oil, the payback period fluctuates from 5,1 up to 6,9 years (without government grant) or from 7,3 up to 9,8 years (with government grant). In the climatic zone C, heat pump system seems provides considerable economic benefits, the relevant results showed that the payback period varies between 4,2–5 or 6–7,1 years without and with government subsidy. In the fourth climatic zone where the climate is similar with that in central Europe, heat pump system is a sound financial investment and the payback period is really short (3,2–4,2 years without government grant or 4,6–6,0 years with government grant). Last but not least, except from financial benefits, there are environmental benefits as well. Based on the RETScreen environmental analysis, the gross annual GHG emissions reduction was estimated to be 1,5 up to 5 tCO_2.

Keywords: *Financial crisis, Greece, RETScreen, heat pump, heating system, GHG emissions.*

Introduction

There's no doubt that the effects of the financial crisis in Greece are stronger than the ones at any other European country. According to the Greek statistics authority (ELSTAT) reports, unemployment in Greece in October 2012 was 26,8 % (Ekathimerini, 2012a). Compared with January 2008 when economic decline started in Greece, unemployment has more than tripled (26,8 % Vs 7,8 %) (ELSTAT, 2012). In December 2012 ELSTAT stated that the country's economy shrunk contracted by 6,9 per cent this year (2012) and the Bank of Greece forecasted a further 4-4,5 per cent contraction next year (Kaplanoglou and Rapanos, 2012) Greece's economy has shrunk by nearly 25 percent since its recession started in 2008. In accordance with a research by the Labour Institute GSEE-ADEDY, the Greeks' purchasing power decreased by 50 % during the last 2 years, the same survey showed that in 2011, at least 28,4 percent of the Greeks were lacking of means to cover basic goods and services, such as house rent, heating oil, meat or fish twice a week, electrical appliances. One in two Greek is on the verge of poverty, with annual income less than 4,871 € (GSEE, 2012; ADEDY, 2012). Austerity is a central tenet in order to solve this crisis and to restore competiveness and perspective for economic growth (Matsaganis, 2012; Mencinger & Aristovnik, 2013).

As a result, households have dramatically curtailed their spending. Until last spring, heating diesel was sold at much lower price than diesel fuel; however, the government decided to equalize the prices because, according to the General Chemical State Laboratory, 17 % of diesel fuel was found to contain adulterated fuel (GCSL, 2012). The most common way of tampering fuel was to mix heating diesel, with diesel fuel. Today (December 2012) 1 liter of diesel costs about 1,31 €. On comparison, last October a liter of heating oil cost 0,90 €, while two years ago it was around 0,65 € (European Commission, 2012). For these reasons Greek households started seeking for alternative heating methods.

The objective of this study is to estimate the feasibility of heat pump system as an alternative solution to the common heating diesel which is used in Greece and compare energy savings to the conventional system (based on heating diesel). Because heat pump systems are eco-friendly alternative for a heating system, the green house gas emissions (GHG) reductions were also calculated. RETScreen International Clean Energy Project Analysis Software was used to evaluate the overall performance of the investigated GSHP (ground source heat pump) system.

RETScreen software

RETScreen is clean energy project analysis software created and distributed by Natural Resources Canada. RETScreen is user friendly, free of charge and can be used world-wide for free commercial and research purposes to evaluate the life-cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies. The software provides monthly results using average monthly data based on Microsoft Excel spreadsheet file composed of a series of worksheets that allow users to enter the majority of the required variables needed to model a particular system (CEPA, 2005; RETScreen, 2011).

RETScreen uses heating degree-days (DD) to calculate the building heating requirements. According to this method, energy consumption required for heating can be easily calculated. The method assumes that the energy needs for a building are proportional to the difference between the mean daily temperature (the outdoor temperature) and a base temperature. When the outdoor temperature is below the base temperature, the heating system needs to provide heat. Heating degree-day values are estimated using the following expression:

$$DD_i = \sum_{k=1}^{N_i} T_{set} - T_{a,k} \quad (1)$$

where DD_i is the monthly degree-days for month i, N_i is the number of days in month i, T_{set} is the base temperature (in this study it is equal to 18°C), and $T_{a,k}$ is the average outside daily temperature for day k of month i. The annual degree-days, DD, can be calculated by adding the monthly degree days (Fantidis *et al.,* 2012b).

RETScreen software allows the user to include domestic hot water as part of the energy demand met by the heating system and it is calculated by the equation below.

$$DD_{DHW} = \frac{d}{1-d} DD \quad (2)$$

where DD_{DHW} is the equivalent degree-days for domestic hot water demand and is expressed as a fraction d of the annual total demand (in this study it is set to 20 %) (Büyükalaca *et al.,* 2001; Matzarakis and Balafoutis, 2004); Papakostas *et al.,* 2005).

Case study: Greece

New financial data in Greece

As a corollary of the acute financial crisis in Greece there is a very high taxation level with new taxes appearing every month. Based on the official data from the Hellenic Minister of development (YPEKA, 2012) in the last 8 years the heating diesel price was rising more than 300 % (Figure 1). At the time of writing this article (December 2012), the heating diesel fuel costs about 1,31 € compared to 95 cents a year ago. For these reasons many Greek households unable to afford heating oil, are increasingly seeking for alternative heating methods such as pellets, woods, natural gas or electrical heating systems.

As Greek families try to cut down their expenses due to salary cuts and a wave of taxes imposed by the government to address a severe debt crisis, wood stoves or fireplace, have become a popular alternative and are making a comeback after decades. However, wide wood consumption seems to have collateral damage on the environment. By now the effects can be seen in large cities with atmospheric pollution on the rise. The high demand for wood has led to a massive increase in illegal logging in mountainous regions of the country, where forests are being depleted, along with a rise in illegal sales. Last but not least, the price of the wood (and wood products) was rising more than 150 % in the last five years. Wood

heating systems are not the choice for the citizens which inhabit in cities because they require huge storage space. Wood pellet fuel is not so bulky, burns cleaner, and is much more convenient than firewood, however it is bulkier than oil and of course a little less convenient than oil and gas. Detailed information for wood heating pellets systems in Greece is available from the previous works by Fantidis et al. (Fantidis *et al.,* 2012a).

In Greece a heating with gas is available only in 6 cities namely Athens, Thessaloniki, Larisa, Karditsa, Trikala and Volos (DEPA, 2012) for heating price increased last year too, reaching the levels that Greeks can hardly afford this year. During the years of 2007–2012 the natural gas price was increasing more than 52 %. During the same period the electricity cost was nearly stable, although the Public Power Corporation (PPC, 2012) announces an increment of 9 percent from 1 January 2013. Comparing the alternative fuels, it's obviously from the Table 1, that the increment in the electricity cost is by the far the minimum. Although the implementation of austerity, Greece's tax rates have fluctuated and only increased, the electricity price has by far the minor increment in price. The reason for these is probably the fact that the Greek governments, during the depression, strive to not deprive the electricity from the struggling citizens. The main power corporation (which effectively holds a monopoly in electricity supply) in Greece is public and the Public Power Corporation is cutting the electricity supply to 30,000 homes and businesses each month due to unpaid bills. In the contrary, all the other alternatives fuels such as wood, pellet or natural gas, which are being administered by privates, owing to the lack of competition in Greece's fuel market, are costing hundreds of millions of Euros for Greek consumers (Ekathimerini, 2012b).

Climatic data

Greece is situated at the most southeastern part of Europe and has Mediterranean climate which means that the rainy season is limited to autumn and springtime, dry sunny summers and mild winters. Average temperature in Greece is 18.3°C, however due to the country's unique geographical location (there is no area in Greece further more than 140 kilometers from water) and landscape (nearly 80 % of Greece territory is mountainous), there are many areas with considerable local variations. Based on the heating degree-days (DD), Greece can be divided into 4 climatic zones (Figure 2) (TOTEE, 2010).

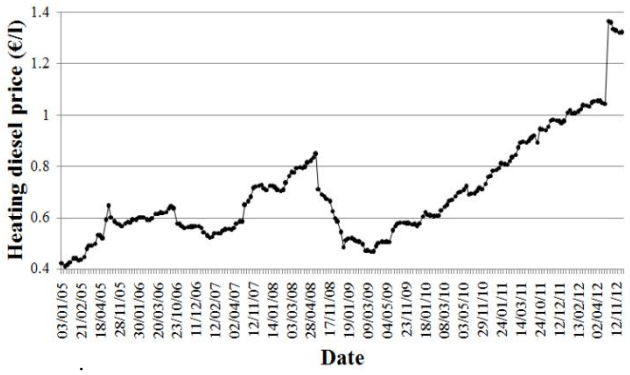

Figure 1. Heating diesel price in Greece in the last 8 years.

Table 1

Fluctuation of fuel prices in Greece (2007 - 2012)

Fuel	Price in 2007	Price in 2012	Increment
Wood	60€/t	150€/t	150 %
Pellet	135€/t	270€/t	100 %
Heating	0,526€/l	1,31€/l (1,03€/l)**	151% (98
Natural gas*	0,04121 €/kWh	0,06272 €/kWh***	52 %
Electricity	0,0984€/kWh	0,13 €/kWh****	32 %

*February 2007 and November 2012
** With governments subsidy
*** Price on the 1st November 2012
****Price on the 1st January 2013

The areas with lower DD (up to 1100) belong to the first climatic zone. In the climatic zone A, the climate is characterized by mild winters and hot, dry summers with average temperature for the year of 18,5 – 19°C. In the zone B, the summers are very hot, with mild and wet winters and any snow that falls does not last too long. The zone C (northern Greece) has a much more continental European climate to the rest of Greece. The summers are still hot but wet_{ter} than in southern Greece, winters are a lot colder and wetter and sometimes snowy. In the zone D, the climate and weather are much more Alpine than Greek. These mountainous regions are cooler than the rest of Greece, with abundant frost and heavy snowfall during the winter, with short, warm, and dry summers (Fantidis *et al.,* 2012c).

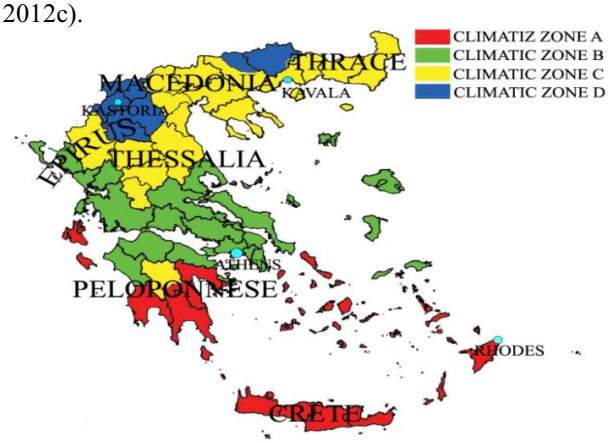

Figure 2. Climatic zones in Greece

The necessary accurate and reliable weather data were taken from the TCG-TEE (Technical Chamber of Greece) (TOTEE, 2010) and the Hellenic National Meteorological Service (HNMS, 2011). Based on these long-term (1955–1997) meteorological parameters, the heating needs for 66 Greek cities were estimated using RETScreen software. The geography in terms of latitude, longitude, elevation and climatic zone are given in Table 2. The building was also considered to have the same constructional characteristics in the four climatic zones in order to enable the direct comparison of results. The parameters of the investigated systems are listed in Table 3. The highest value of DD (2537) is recorded in the mountainous city of Florina, located in northwest Greece. This value is almost 5 times higher than the corresponding value of 573 DD observed on the Ierapetra, where the minimal thermal requirements of the country are observed.

Having intention to examine closely the financial viability of heat pump system in Greece, four cities

(Rhodes, Athens/Filadelpeia, Kavala and Kastoria) were selected as representative samples from each climatic zone. Rhodes is the largest of the Dodecanese islands in terms of both land area and population (119,640). The city of Rhodes (located in climatic zone A) is located in the north-east tip of the island and has a population of approximately 70,000. Rhodes is one of the sunniest parts of Greece. Its climate is mild Mediterranean characterized by sunny and dry summers and mild winters. The climate of Rhodes is warm and pleasant all through the year, with the summer weather arriving as early as April and not beginning to cool down until November. During the summer, the temperature rarely drops below 20°C even at night. Winters in Rhodes are mild but wet.

Table 2

Long-term degree-days values for 66 locations in Greece

N.	City	Latitude	Longitude	Elevation	Heating degree-days per month							
1	Agchialos	39° 13’	22° 48’	15,3	353	288	248	111	0	31	177	307
2	Agrinio	38° 37’	21° 23’	25	301	246	202	84	0	0	144	260
3	Alexandroupolis	40° 51’	25° 56’	3,5	403	339	301	144	0	71	216	341
4	Aliartos	38° 23’	23° 06’	110	338	274	229	84	0	34	180	291
5	Andravida	37° 55’	21° 17’	15,1	267	227	192	96	0	0	117	220
6	Araxos	38° 09’	21° 25’	11,5	242	210	180	84	0	0	99	198
7	Argos/Pirgela	37° 36’	22° 47’	11,2	307	269	229	99	0	6	153	264
8	Argostoli	38° 11’	20° 29’	22	205	182	161	81	0	0	66	161
9	Arta	37° 47’	20° 54’	7,9	310	252	202	102	0	6	165	276
10	Athens/Filadelfia	38° 03’	23° 40’	138	328	284	223	68	0	0	148	288
11	Athens/Hellenkion	37° 54’	23° 45’	15	251	230	195	84	0	0	102	211
12	Chalkida	38° 28’	23° 36’	5	276	249	192	57	0	0	123	233
13	Chania	35° 29’	24° 07’	150	198	174	149	51	0	0	57	152
14	Chios	38° 28’	26° 08’	5	260	232	198	87	0	0	132	214
15	Chrysopouli	40° 54’	24° 36’	5,4	388	330	288	129	0	74	228	353
16	Drama	41° 09’	24° 09’	104	412	322	248	99	0	50	243	372
17	Edessa	40° 58’	22° 03’	30	419	330	260	138	0	74	258	378
18	Elefsina	38° 10’	23° 60’	31	276	252	214	87	0	0	120	139
19	Florina	40° 48’	21° 26’	617	543	428	350	192	37	167	330	490
20	Ierapetra	35° 00’	25° 44’	10	158	143	118	30	0	0	15	109
21	Ioannina	39° 42’	20° 49’	484	412	336	285	168	16	93	249	378
22	Iraklion	35° 20’	25° 11’	39,3	183	162	140	45	0	0	39	133
23	Kalamata	37° 04’	22° 00’	11.1	242	207	177	84	0	0	96	198
24	Karditsa	39° 22’	20° 48’	111.1	419	311	236	123	0	59	237	425
25	Karistos	38° 01’	24° 25’	10	236	216	174	69	0	0	93	195
26	Karpenisi	38° 54’	21° 47’	1001	440	417	391	222	102	174	336	409
27	Kastoria	40° 27’	21° 17’	660,9	490	409	344	195	50	143	324	465
28	Kavala	40° 90’	24° 40’	51	406	350	289	127	0	43	221	372
29	Kerkira	39° 37’	19° 55’	4	257	216	186	90	0	0	111	214
30	Kithira	36° 17’	23° 10’	316,6	220	199	189	102	0	0	66	164
31	Komotini	40° 18’	21° 47’	30	409	330	291	147	0	87	216	341
32	Konitsa	40° 03’	20° 45’	542	397	322	264	174	25	81	246	360
33	Korinthos/Velo	40° 03’	20° 45’	30	285	244	202	78	0	0	138	245
34	Kos	36° 47’	27° 04’	129	217	210	183	78	0	0	90	174
35	Kozani	40° 18’	21° 47’	625	487	400	344	192	37	140	300	437
36	Lamia	38° 51’	22° 24’	11,5	338	277	226	90	0	31	183	304
37	Larisa	39° 39’	22° 27’	7,3	397	314	264	120	0	53	213	357
38	Leukada	38° 50’	20° 43’	34,5	242	207	164	84	0	0	102	202
39	Limnos	39° 55’	25° 14’	72	329	286	257	126	0	37	171	279
40	Methoni	36° 50’	21° 42’	115.6	208	182	158	78	0	0	60	158
41	Milos	36° 43’	24° 27’	17.9	226	202	189	90	0	0	81	174
42	Mitilini	39° 04’	26° 36’	151.6	264	227	198	72	0	0	111	208
43	Naxos	37° 06’	25° 23’	9.8	183	162	146	57	0	0	51	136
44	Paros	37° 01’	25° 08’	33.5	211	190	158	54	0	0	84	177
45	Patra	38° 15’	21° 44’	1	248	207	171	72	0	0	105	205
46	Pirgos	37° 40’	21° 18’	12	260	221	180	84	0	0	117	217
47	Poligiros	40° 23’	23° 26’	545	406	372	288	168	53	90	219	347
48	Preveza	39° 00’	20° 80’	4	267	232	195	102	0	0	111	226
49	Rethimno	35° 21’	24° 31’	7	161	143	118	27	0	0	21	109
50	Rhodes	36° 24’	28° 07’	11,5	186	162	133	42	0	0	39	140
51	Samos	37° 42’	26° 55’	7,3	236	218	180	57	0	0	99	186
52	Serres	41° 05’	23° 34’	34,5	434	328	257	108	0	71	258	409
53	Siros	37° 25’	24° 57’	72	192	174	152	48	0	0	63	161
54	Sitia	35° 12’	26° 06’	115,6	180	160	136	42	0	0	36	130
55	Skiros	38° 54’	24° 33’	17,9	251	218	202	90	0	0	102	198
56	Souda	35° 33’	24° 07’	151,6	220	196	167	66	0	0	72	167
57	Sparti	37° 04’	22° 25’	212	264	221	177	72	0	0	120	226
58	Tanagra	38° 19’	23° 33’	140,1	326	274	242	105	0	25	156	267
59	Thessaloniki	40° 31’	22° 58’	4.8	394	314	254	111	0	53	207	344
60	Thira	36° 25’	25° 24’	10	161	162	144	63	0	0	37	123
61	Trikala Imathias	39° 33’	21° 46’	114	412	333	260	108	0	68	249	388
62	Trikala Thessalias	40° 36’	22° 33’	0,8	391	311	229	90	0	50	234	360
63	Tripoli	37° 32’	22° 24’	650,9	400	342	313	189	31	105	237	350
64	Tymbakion	35° 00’	24° 46’	6,7	195	174	143	48	0	0	48	149
65	Xanthi	41° 08’	24° 53’	43	384	314	260	111	0	47	210	344
66	Zakinthos	39° 10’	21° 00’	7,9	233	210	192	96	0	0	96	195

Athens, the city with the most glorious history in the world, is located in the second climatic zone and is the capital of Greece. With population of 3,074,160 (in 2011) Athens is one of the largest cities in the Europe. Athens enjoys a typical Mediterranean climate, and can be summed up as having hot dry summers and mild wet winters. The summers are very hot, and heatwaves are common during July and August often reaching over 40ºC. Winters are mild although frost can occur and nights can be cold while snowstorms are infrequent.

Kavala is the second largest city in northern Greece (63,293 habitants) and is positioned in the third climatic zone. Kavala has a humid subtropical climate characterized by hot, humid summers and generally mild to cool winters. Summers are warm; during the warmest part of the day temperatures rise above 30°C; however, the nights are comfortable with cool, crisp mountain air blowing through the region. The winter is the wettest period of the year; snowfalls are sporadic, but happen more or less every year although usually the snow does not stay for more than 2 days.

Kastoria is located in the northwestern side of the Western Macedonia region of Greece. The city of Kastoria unfolds amphitheatrically 620 meters above the sea level and has more than 22,000 inhabitants. The landscape is mountainous and the climate is continental, with cold winters and hot summers. The temperature presents great variations between winter and summer, and during winter it is often below zero and brings heavy snow.

Heat pump system

Heat pump is a device that takes heat from a low temperature heat source and releases it into a high temperature heat sink. Heat does not naturally flow in this direction so heat pumps need an energy input to complete the process. From an energy and environmental consciousness perspective, the heat pump system is considered one of the most energy efficient and low GHG emitting systems available. It not only consumes less electricity but also has no direct GHG emitting parts. The name of the heat pump derives by analogy from the operation of the hydraulic pump that lifts water from a lower level to a higher altitude, thus opposing the natural flow originated by the force of gravity. Heat pump heating system is one alternative system that is interesting because it uses about one third of the energy use for the same heating capacity.

The operating principle is based on the phase change of refrigerant fluid along the thermodynamic cycle that it does. The cooling is obtained by evaporating of the refrigerant at temperatures and pressures which are the lowest in the entire cycle. Temperature and pressure are then increased by the intervention of a compressor which generates mechanical compression of the refrigerant fluid that after this process is at the state of superheated steam with values that are maximal in the cycle. The heating is obtained through reverse overheating of the refrigerant and its subsequent condensation. The cycle ends with the mechanical expansion of the fluid through a particular valve until it repeats the cycle of evaporation (Ochsner, 2008; Goumas and Haldezos, 2012; Minonne *et al.,* 2012). Last but not least, heat pump system can be used not only for heating demands but also for cooling.

Table 3

Input parameters for RETScreen software

Parameter	Value
Heated floor area for a building	90 m²
Heating load for a building	90 W/m²
Domestic hot water heating base demand	20 %
Capacity	10.0kW
Seasonal efficiency (heat pump system)	300 %
Inflation rate	3,0 %
Project life	20 yr
Total initial cost for heat pump system	6,500€
Total initial cost for natural gas system	1,800€
Total initial cost for pellet system	3,300€
Seasonal efficiency (diesel system)	90 %
Seasonal efficiency (natural gas system)	85 %
Seasonal efficiency (pellet system)	85 %

Results and discussion

According to the heating DD requirements, RETScreen software is able to calculate the necessary annual fuel consumption for the heating system based on diesel oil or in electricity (heat pump system). The quantity of heating diesel fuel that would be used from the central heating of diesel boilers for each of the 66 investigated cities is given in Table 4. In the first climatic zone, the annual required quantity of diesel is 624–950 l. The corresponding values for the zones B, C and D are 955–1364 l, 1502–1693 l, and 1698–2188 l respectively. The average cost of heating diesel in Greece is about 1.31 €. However, based on the location, income and property of each taxpayer, the Greek government offer 28 cents for every liter of heating oil to the unemployed and those living below the poverty line (GSIS, 2012).

Due to rising oil prices and taxation on oil, Greek households, whose incomes have already taken a big hit from years of recession, started seeking for alternative heating methods. It is realistic that amongst other alternatives, the heat pump based systems can result in drastic reduction of the buildings energy consumption for heating. According to the simulation from RETScreen for a 90 m^2 building with a medium insulation, the energy consumption for heating is given in Table 4 (ASHRAE, 1995). For the areas located in climatic zone A, the necessary annual energy requirements fluctuate from 2108 up to 3208 kWh. The cities located in the zone B require 3223–4600 kWh. Higher consumption of energy (5069–5715 kWh) is observed in the areas which cover the climatic zone C. The highest energy requirements for heating (5731–7165) are observed over all western Macedonia, in the mountain range of Pindos, and to a smaller extent in the centre of the Peloponnese (climatic zone D).

In order to further evaluate the commercial viability of heat pump system in Greece, the same systems were applied for a city for each zone, namely, Rhodes for Zone A, Athens/Filadelpeia for Zone B, Kavala for Zone C and Kastoria for Zone D.

Using RETScreen it is possible to calculate several financial feasibility indicators such as internal rate of

Table 4

Annual fuel consumption and electricity requirements for 66 locations in Greece

Location	Annual fuel consumption (l)	Annual electricity demands (KWh)
Ierapetra	624	2108
Rethimno	642	2169
Thira	691	2331
Iraklion	715	2415
Sitia	727	2454
Naxos	729	2462
Rhodes	742	2508
Chania	758	2592
Tymbakion	772	2608
Siros	809	2731
Methoni	828	2792
Argostoli	836	2823
Paros	844	2846
Souda	866	2923
Milos	914	3085
Kos	921	3108
Samos	927	3131
Kithira	928	3131
Karistos	932	3146
Kalamata	950	3208
Patra	955	3223
Araxos	957	3231
Leukada	973	3285
Zakunthos	985	3323
Athens/Hellenkion	1,004	3392
Pirgos	1,012	3415
Mitilini	1,015	3423
Sparti	1,015	3423
Elefsina	1,021	3446
Skiros	1,033	3485
Kerkira	1,042	3515
Andravida	1,044	3523
Chios	1,046	3531
Chalkida	1,059	3577
Preveza	1,092	3685
Korinthos/Velo	1,123	3792
Agrinio	1,145	3862
Agchialos	1,187	4008
Arta	1,203	4062
Argos/Pirgela	1,214	4100
Athens/Filadelfeia	1,233	4162
Tanagra	1,269	4285
Lamia	1,339	4523
Aliartos	1,347	4546
Limnos	1,364	4600
Thessaloniki	1,502	5069
Trikala Thessalias	1,514	5115
Larisa	1,559	5262
Drama	1,561	5269
Alexandroupoli	1,608	5431
Xanthi	1,610	5438
Karditsa	1,614	5446
Chrysopouli	1,631	5508
Trikala/Imathias	1,637	5523
Kavala	1,642	5546
Konitsa	1,643	5546
Edessa	1,644	5554
Komotini	1,646	5554
Serres	1,693	5715
Poligiros	1,698	5731
Ioannina	1,700	5738
Tripoli	1,717	5792
Kozani	2,021	6823
Kastoria	2,087	7046
Karpenisi	2,118	7154
Florina	2,122	7165

return (IRR), simple and equity payback periods. The three parameters were calculated for every area for 2 cases, with and without 28 cents subsidy for every diesel liter, and the results are displayed in Table 5. The cumulative cash flow analysis result, produced by RETScreen for the 4 cities are plotted in Figures 3–6. Even though that there aren't government subsidies or incentives for the installation of heat pump systems and despite the high installation cost, payback can be within 7 – 10,5 years (without government grant) or 9,8 – 14,5 years (with government grant) in zone A, 5,1 – 6,9 years or 7,3 – 9,8 years in zone B, 4,2 – 5 or 6 – 7,1 years in zone C and 3,2 – 4,2 or 4.6 – 6 years in zone D.

With intention to give a general overview of the situation, sensitivity analysis of the effect of diesel and electricity prices on the equity payback period were also conducted. In the present study, eleven discrete values for heating diesel price (1,00, 1,05, 1,10, 1,15, 1,20, 1,25, 1,30, 1,35, 1,40, 1,45, and 1.50 €/L) and eleven discrete values for electricity price (0,08, 0,09, 0,10, 0,11, 0,12, 0,13, 0,14, 0,15, 0,16, 0,17 and 0,18 €/kWh) were used in the sensitivity analysis (Figures 7-10).

RETScreen allows a comparative analysis with other alternatives fuels such as pellet and natural gas. For comparison purposes, the internal rate of return and the equity payback periods were also calculated for the four cities for diesel oil, electricity (heat pump), pellet and natural gas. The results are given in Table 6. In all circumstances the system based on heating diesel has considerable higher cost. Both natural gas and pellet offer more financial benefits, but natural gas is available only in some areas in Greece and the pellet heating systems are considerable less convenient than oil and gas (bagged wood pellets must be loaded weekly or more often if not delivered in bulk, wood pellet boilers need to have the heat exchanger brushed clean very often during the heating season and ash bins must be emptied often etc).

Table 5

Internal rate of return, simple and equity payback periods for Rhodes, Athens/ Filadelpeia, Kavala and Kastoria (in the bracket the values with 28 cents subsidy)

Parameter	Area			
	Rhodes	Athens/ Filadelpeia	Kavala	Kastoria
IRR	10,2 % (5,6 %)	15,5 % (9,8 %)	24,7 % (16,9 %)	32,5 % (22,2 %)
Simple payback period	10,6 yr (15,6 yr)	7,4 yr (10,9 yr)	4,6 yr (6,8 yr)	3,5 yr (5,2 yr)
Equity payback period	9,1 yr (12,7 yr)	6,6 yr (9,4 yr)	4,3 yr (6,1 yr)	3,3 yr (4,8 yr)

Table 6

Internal rate of return and equity payback periods for Rhodes, Athens/Filadelpeia, Kavala and Kastoria for heating systems based on electricity, natural gas or pellet

Area	Heating system		
	Heat pump	Natural gas	Pellet
Rhodes	10,2 % (9,1 yr)		19,6 % (5,3 yr)
Athens	15,5 % (6,6 yr)	45,6 % (2,3 yr)	33,5 % (3,2 yr)
Kavala	24,7 % (4,3 yr)		42,9 % (2,4 yr)
Kastoria	32,5 % (3,3 yr)		54,8 % (1,9 yr)

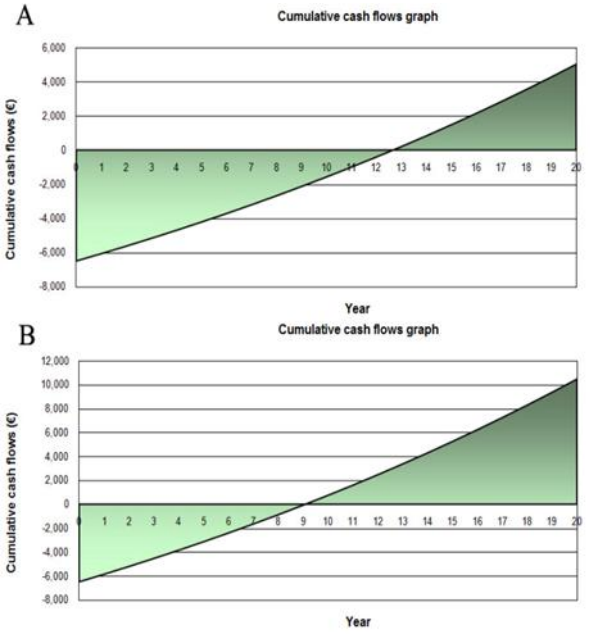

Figure 3. Cash flow analysis results for Rhodes (a) With subsidy Scenario, (b) Without subsidy

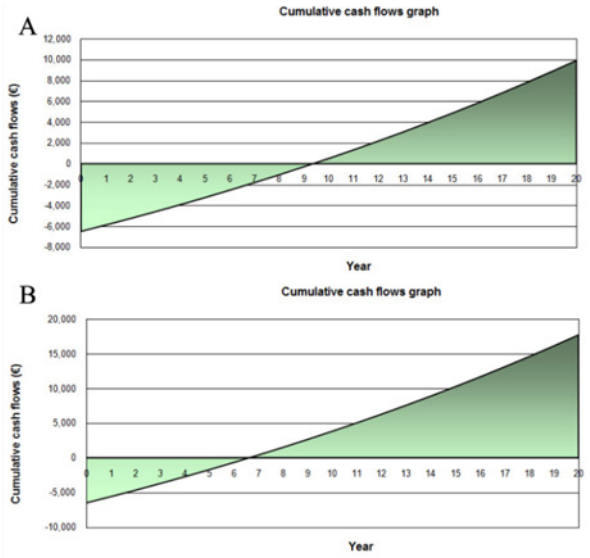

Figure 4. Cash flow analysis results for Athens/Filadelpeia (a) With subsidy Scenario, (b) Without subsidy

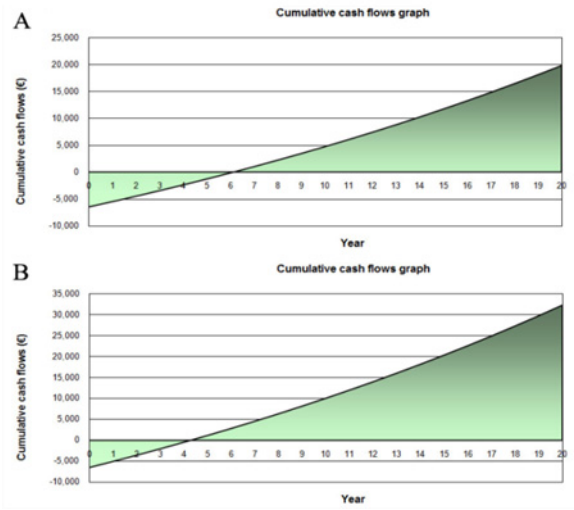

Figure 5. Cash flow analysis results for Kavala (a) With subsidy Scenario, (b) Without subsidy

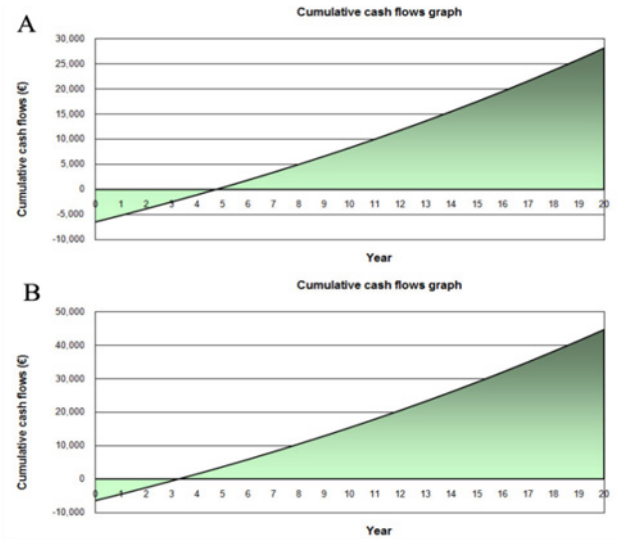

Figure 6. Cash flow analysis results for Kastoria (a) With subsidy Scenario, (b) Without subsidy

Based on the results for Rhodes it is obviously that the regions located in climatic zone A have really small heating demands so the installation of heat pump system is just profitable investment. In the zone B, according to the results from Athens/Filadelpeia, with the new data after the acute financial crisis, heat pump system is an interesting alternative solution. In the zone C, the replacement of heating diesel systems with heat pump systems is a financial interest. In the fourth climatic zone D, where the heating requirements are similar with those of many areas from the central Europe, heat pump is financially sound.

Replacing of conventional oil-fired heating system with a system based on heat pump could provide further benefits to Greece in the form of reduced GHG emissions. The amount of GHG reduction (tCO_2) for the 66 locations is calculated using RETScreen software. The results are presented in Figure 11. Based on Figure 11, the highest GHG emissions mitigation of 5.0 tons/year was observed in Florina and Karpenisi, while the lowest reduction was observed in Ierapetra and Rethimno with a value of 1.5 tons/year.

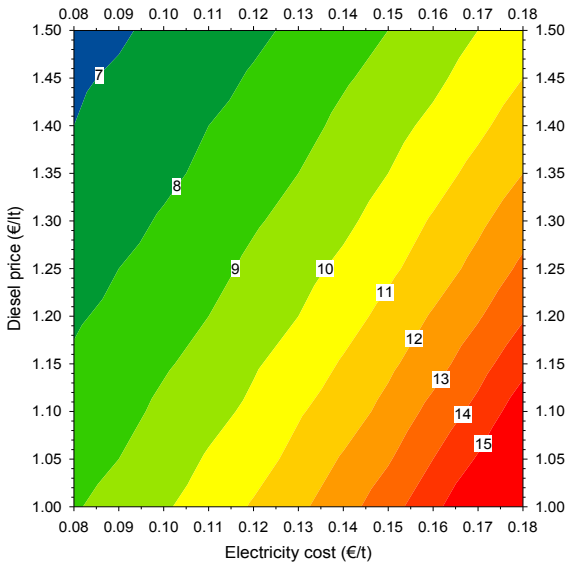

Figure 7. Sensitivity analysis of diesel price to electricity cost for Rhodes

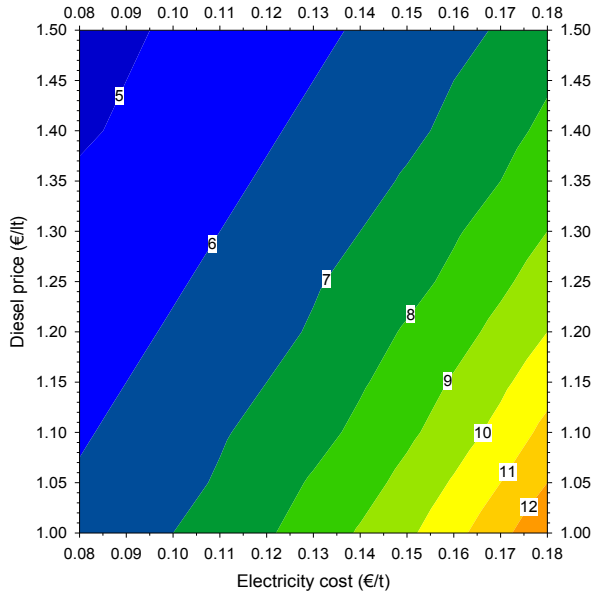

Figure 8. Sensitivity analysis of diesel price to electricity cost for Athens/Filadelpeia

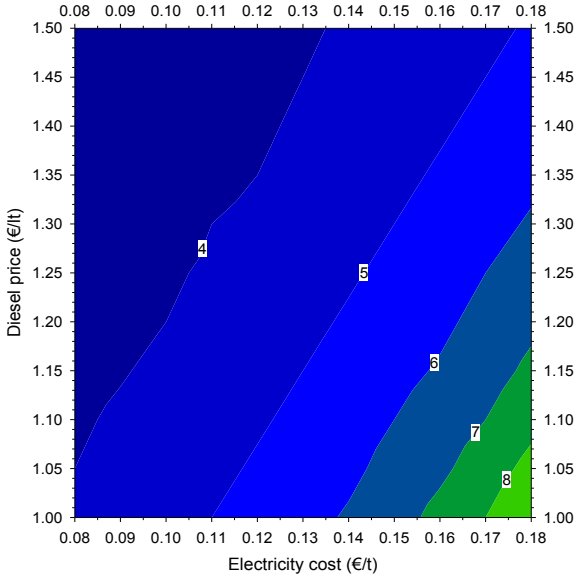

Figure 9. Sensitivity analysis of diesel price to electricity cost for Kavala

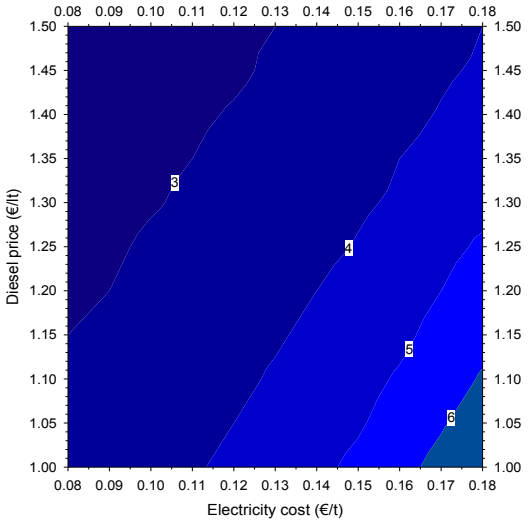

Figure 10. Sensitivity analysis of diesel price to electricity cost for Kastoria

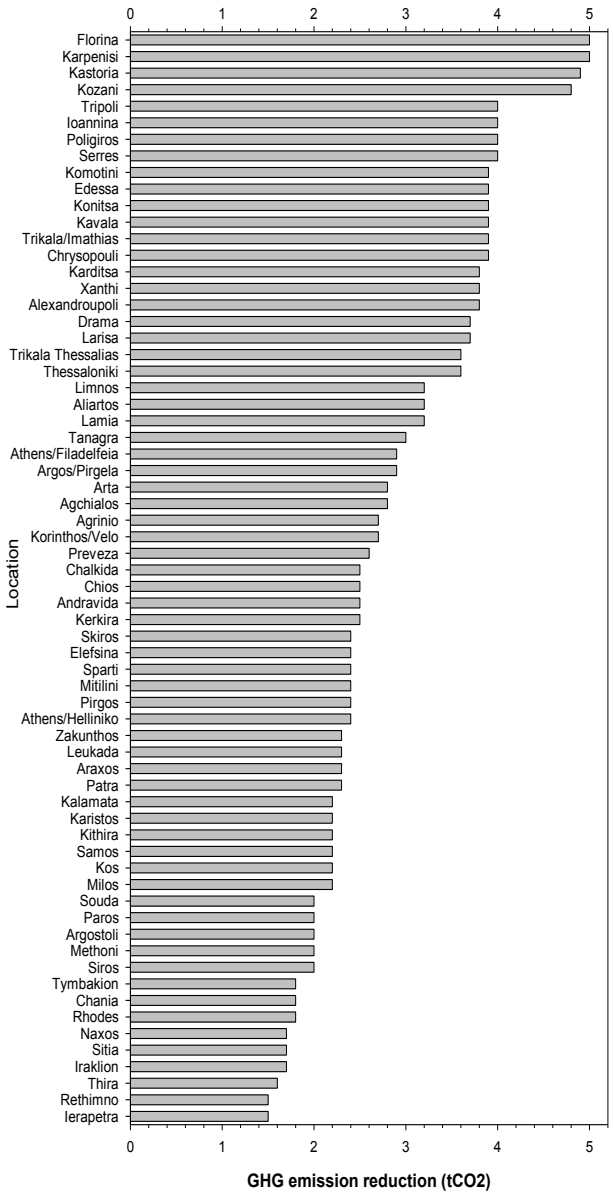

Figure 11. Green house gases reduction due to usage of heat pump systems for 66 locations in Greece

Conclusions

Greece is the biggest casualty of the European financial crisis. Since the financial crisis at the end of 2009, Greece has been dependent on international rescue loans as its economy continues to falter. In order to solve the situation, Greeks governments have introduced many rounds of austerity measures, leaving thousands out of work and plunging them into poverty. During the same period, the purchasing power associated with the average wage in Greece has halved.

The increase in international oil prices, the European Union embargo on Iranian oil and the equalization of prices between diesel and central heating oil in order the government to control the huge quantities of adulterated fuels resulted in the increase of cost of heating oil almost 35 percent. With oil-based fuels now out of the question for many citizens, attention has turned to alternative forms

of heating such as wood, pellet, natural gas or electrical based systems.

Heating systems based on wood are unsuitable for people who live in cities, because they require huge storage space and need to be manually fed several times a day. Wood pellet fuel is not so bulky; however the wood pellet heating systems require also high maintenance. Finally natural gas in Greece has really short network.

Owing to the lack of competition in Greek market which is managed by few privates, all fuels prices (wood, pellet, natural gas etc) except from the electricity, during the last five years increased at least to 50 %. In this study, heat pump system has been simulated as alternative solution using RETScreen software. Another significant benefit for citizens who live or stay in Greece with high temperatures during the summer is the fact that heat pumps can also be used to effectively cool a space. According to the financial results the conclusions, which arise from the present study can be summarized as follows:

- In climatic zone A owing to low heating demand, heat pump based heating system is just marginal profitable investment; the payback period varies between 7–10,5 years or 9,8–14,5 years, without and with government subsidy, respectively.
- In climatic zone B with the new fuel prices, heating pump seems is a good choice. According to the results obtained, the heat pump systems have relevant short payback period (5,1–6,9 years without government grant or 7,3–9,8 years with government grant.
- In climatic zone C, heat pump system is by far more cost-saver than the existent diesel oil heating systems, the relevant results showed that the payback period varies between 4,2–5 years or 6–7,1 years without and with government subsidy
- In climatic zone D, heat pump system is a sound financial investment and the payback period is really short (3,2 – 4,2 years without government grant or 4.6 – 6 years with government grant).

Last but not least, except from economic profit to the Greek inhabitant, the presence of heat pumps will offer and environmental benefits in Greece.

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Finansinė krizė Graikijoje, šildymo dyzeliniu kuru pakeitimo šilumos pumpavimo sistema ekonominis įvertinimas

Santrauka

2009 metų spalio mėnesį Graikijos vyriausybė suprato, kad vyriausybė metų metais menkino savo valstybines skolas. Vos dviem mėnesiais vėliau agentūra Fitch pažemino Graikijos skolos įvertinimą iki BBB+, žemiausio kredito įvertinimo Europoje. Graikijos vyriausybė bando išspręsti šią istorinę "problemą" panaudodama paskolą, gautą iš Europos Sąjungos, Europos Centrinio Banko ir Tarptautinio Valiutos Fondo, kurie reikalauja, kad šalis įdiegtų daugybę griežtos ekonomijos priemonių, nuo išlaidų sumažinimo ir priverstinio nedarbo viešajame sektoriuje iki mokesčių didinimo ir visuomeninio turto privatizavimo. Tačiau trijų metų krizė paliko gilius randus visuomenėje, palikdama tūkstančius žmonių be darbo ir įstumdama juos į skurdą. Oficialūs Graikijos ELSTAT statistikos agentūros duomenys rodo, kad nedarbas Graikijoje spalio mėnesį pasiekė naują rekordą, pasiekdamas 26,8 %. Lyginant su 2008 metais, kai Graikijoje prasidėjo ekonominis nuosmukis, nedarbas padidėjo daugiau nei tris kartus. Be to, kaip rodo graikų profsąjungų ADEDY ir GSEE atliktas tyrimas, maždaug pusė graikų uždirba mažiau nei 4,871 € per metus ir gyvena žemiau skurdo linijos, kurią apibūdina kaip minimalias pajamas keturių žmonių šeimai, skirtas valgiui, apsirengimui, transportui, mokslams ir nuomai.

Remdamasi aplinkos, energijos ir klimato kaitos ministerijos duomenimis, Graikijos vyriausybė žino, kad didžiausi Graikijos kuro rinkos problema yra kuro kontrabanda, maišymas ir sukčiavimas, kurie iškraipo rinką. Norėdama išspręsti šią problemą, vyriausybė nusprendė suvienodinti skysto kuro kainą su benzino kolonėlės kainomis. Tačiau šis sprendimas pakėlė skysto kuro litro kainą iki maždaug 1,3 €, maždaug 45 % daugiau nei prieš metus. Kadangi daugeliui žmonių apie benziną negali būti nė kalbos, dėmesys buvo atkreiptas į alternatyvias šildymo formas, todėl medžiu kaitinamos krosnys ar židiniai tapo populiaria alternatyva ir po dešimtmečių grįžo į namus. Tačiau, atrodo, platus medienos suvartojimas kartu daro žalą aplinkai. Iki dabar galima matyti jo įtaką dideliuose miestuose, kur didėja atmosferinė tarša. Didelis medienos poreikis masiškai padidino nelegalius miškų kirtimus šalies kalnuotuose regionuose, kur yra išeikvojami miškai, kartu su padidino nelegalius pardavimus. Paskutinis, bet ne mažiau svarbus dalykas yra medienos (medienos gaminių) kainos padidėjimas daugiau nei 150 % per paskutiniuosius penkerius metus.

Graikijoje šildymas dujomis įmanomas tik kai kuriuose miestuose, nes gamtinių dujų tinklas yra labai ribotas, o taip pat paskutiniaisiais metais mokesčiai už gamtines dujas šildymui padidėjo, pasiekdami tokį lygį, kad graikai vargiai gali sau tai leisti. Akivaizdu, kad Graikijos gamintojų sąmokslas ir visiškas konkurencijos nebuvimas leido keliems išrinktiesiems gauti ekonomiškai nepateisintus pelnus, ir tai sukėlė gamtinių dujų, medienos ir granulių kainas. Priešingai, nors ir įdiegta griežta ekonomija, Graikijos mokesčių normos svyravo ir tik didėjo, o elektros kainos padidėjimas yra mažiausias iki šiol.

Šio darbo tikslas yra įvertinti šilumos pumpavimo sistemos, kaip alternatyvaus įprastam šildymui dyzeliniu kuru, kuris naudojamas Graikijoje, sprendimo tinkamumą ir palyginti jos energijos taupymą su įprastine sistema (pagrįsta šildymu dyzeliniu kuru). Graikijos klimatas visų pirma yra viduržemiškas, su ilgomis sausomis vasaromis ir drėgnomis švelniomis žiemomis. Vidutinė metinė temperatūra Graikijoje svyruoja nuo +10 iki +19,7°C.

Remiantis iš 66 stočių gautais ilgalaikiais meteorologiniais duomenimis, buvo įvertintas šilumos siurblių šildymo sistemos finansinis pagrindimas kiekvienoje Graikijos vietoje. Norint atlikti tinkamumo ir šiltnamio efektą sukeliančių dujų (ŠESD) išskyrimo sumažinimo analizę buvo panaudota RETScreen Švarios Energijos Projekto Analizės programinė įranga. RETScreen yra švarios energijos projekto analizės programinė įranga, kurią sukūrė ir platina Kanados Gamtinių Resursų ministerija. RETScreen yra patogi naudoti, nemokama ir gali būti laisvai naudojama visame pasaulyje komerciniams bei tyrimų tikslams, norint įvertinti gyvavimo ciklo kaštus ir ŠESD išskyrimo sumažinimą įvairiems efektyvios energijos ir atnaujinamos energijos technologijų tipams. Ši programinė įranga pateikia mėnesinius rezultatus, panaudodama vidutinius mėnesinius duomenis, pagrįstus Microsoft Excel skaičiuoklės failu, sudarytu iš lentelių serijos, kuris leidžia vartotojams įvesti daugumą reikalingų kintamųjų, reikalingų norint sumodeliuoti tam tikrą sistemą. RETScreen panaudoja šildymo laipsnio-dienas, kad apskaičiuotų pastato šildymo poreikius. Laipsnio-dienų vertė yra matmuo, naudojamas, norint parodyti koks yra energijos poreikis pastatų šildymui arba vėsinimui. Metodas daro prielaidą, kad energijos poreikis pastatui yra proporcingas skirtumui tarp vidutinės dienos temperatūros ir bazinės temperatūros. Bazinė temperatūra yra temperatūra lauke, žemiau arba aukščiau kurios reikia šildymo arba vėsinimo.

Remdamasi šildymo laipsnio-dienų poreikiais, RETScreen programinė įranga gali apskaičiuoti būtiną metinį kuro sunaudojimą šildymo sistemai, varomai dyzeliniu kuru arba elektra (šilumos pumpavimo sistema). Pagal šildymo laipsnio-dienas Graikiją galima suskirstyti į 4 klimato zonas. Buvo laikomasi prielaidos, kad tirti pastatai turi vienodas konstrukcines savybes visose keturiose klimato zonose, kad būtų galima tiesioginį palyginti rezultatus. Pirmojoje klimato zonoje reikalingas metinis dyzelio kiekis yra 624 - 950 litrų. Zonose B, C ir D atitinkami kiekiai yra 955 - 1364 l, 1502 - 1693 l, ir 1698 - 2188 l. Vidutinė šildymo dyzeliu kaina Graikijoje yra maždaug 1,31 €. Tačiau, remdamasi kiekvieno mokesčių mokėtojo buvimo vieta, pajamomis ir nuosavybe, Graikijos vyriausybė siūlo 28 centus už kiekvieną skysto kuro litrą bedarbiams ir gyvenantiems žemiau skurdo ribos.

Realistiška, kad tarp kitų alternatyvų šilumos pumpavimu pagrįstos sistemos gali drastiškai sumažinti pastatų energijos suvartojimą šildymui. Anot RETScreen atlikto modeliavimo 90 m^2 pastatui turinčiam vidutinę izoliaciją, energijos suvartojimas šildymui yra žymai mažesnis. Teritorijoms, kurios yra klimato zonoje A, būtinas metinis energijos poreikis svyruoja nuo 2108 iki 3208 kWh. Zonoje B esantiems miestams reikia 3223 - 4600 kWh. Didesnis energijos suvartojimas (5069 –5715 kWh) pastebėtas teritorijose, kurias apima klimato zona C. Didžiausias energijos šildymui poreikis (5731 – 7165 kWh) pastebėtas visoje vakarų Makedonijoje, Pindo kalnuose ir mažesniu mastu Peloponeso centre (klimato zona D). Nors tai, kad šilumos pumpavimo sistemų įrengimui nėra vyriausybės subsidijų arba iniciatyvų ir nepaisant aukštų montavimo kaštų, atsipirkimo laikas gali būti 7–10,5 metų (be vyriausybės dotacijų) arba 9,8–14,5 metai (turint vyriausybės dotaciją) zonoje A, 5,1–6,9 arba 7,3–9,8 metai zonoje B, 4,2–5 arba 6–7,1 metai zonoje C ir 3,2–4,2 arba 4,6-6 metai zonoje D. Jautrumo analizė buvo atlikta keturiuose miestuose, Rode, Atėnuose (priemiestyje Filadelfeia), Kavaloje ir Kastorijoje, kurie yra atitinkamai pirmojoje, antrojoje, trečiojoje ir ketvirtojoje zonose. Tiems patiems miestams taip pat buvo atliktas dyzelinių šildymo

sistemų palyginimas su sistemomis, varomomis elektra (šilumos pumpavimas), gamtinėmis dujomis ir granulėmis. Visose aplinkybėse dyzeliu varomos sistemos šildymo kaina buvo žymiai aukštesnė. Nors gamtinių dujų ir granulių naudojimas siūlo didesnę finansinę naudą, tai nėra geri alternatyvūs sprendimai. Gamtinių dujų tinklas Graikijoje yra ypatingai ribotas (yra tik 6 miestuose!), o granulėmis varomoms šildymo sistemoms reikia daug priežiūros ir didelių saugojimo vietų. Mediena varomos šildymo sistemos tinka tik tiems žmonėms, kurie gyvena kaime, nes jos reikalauja daugybės vietos saugojimui, ir tiems, kurie gali kelis kartu per dieną rankomis papildyti sistemą.

Remiantis finansiniais rezultatais pirmojoje klimato zonoje, kur šildymo poreikis yra tikrai žemas, šildymo skystu kuru sistemų pakeitimas šilumos pumpavimo sistemomis nėra labai pelninga investicija. Antrojoje zonoje yra šiek tiek finansinės naudos iš šilumos pumpavimo sistemos naudojimo vietoj šildymo skystu kuru. Klimato zonoje C šilumos pumpavimo sistema, atrodo, duoda žymią ekonominę naudą. Ketvirtojoje klimato zonoje, kur klimatas yra panašus į centrinės Europos klimatą, šilumos pumpavimo sistema yra patikima finansinė investicija. Įprastinės šildymo skystu kuru sistemos pakeitimas į sistemą, pagrįstą šilumos pumpavimu, galu duoti tolesnę naudą Graikijai, sumažindama ŠESD išskyrimą. Šiltnamio efektą sukeliančių dujų (tCO_2) sumažinimas 66 vietovėms yra apskaičiuojamas naudojant RETScreen programinę įrangą. Remiantis RETScreen aplinkos analize, didžiausias ŠESD išskyrimo sumažinimas, 5.0 tonos per metus, buvo pastebėtas Florinoje ir Karpenisi, o mažiausias sumažėjimas buvo pastebėtas Ierapetroje ir Retimne, 1.5 tonų per metus. Faktas, kad šilumos siurbliai taip pat gali būti efektyviai naudojami erdvės vėsinimui vasarą, gali duoti papildomą finansinę ir aplinkosauginę naudą.

Raktažodžiai: *finansinė krizė, Graikija, RETScreen, šilumos siurblys, šildymo sistema, šildymo ŠESD išskyrimas.*

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