TRANSITION TOWARDS A SUSTAINABLE HEATING AND COOLING SECTOR - CASE STUDY OF SOUTHEAST EUROPEAN COUNTRIES

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Many traditional heating systems which are based on fossils face challenges such as lack of investment or unfavorable price regulations, low technical performance, environmental impacts and negative consumer perceptions. The CoolHeating project which is, funded by the EU's Horizon 2020 programme and presented in this paper promotes the implementation of small modular renewable heating and cooling grids for communities in South-Eastern Europe. Core project activities bincluded measures to stimulate the interest of communities and citizens to set-up renewable district heating systems in 5 target communities in Slovenia, Croatia, Bosnia and Herzegovina, Serbia and Macedonia up to the investment stage.

Single criteria and multi-criteria assessment approaches, considering economic, environmental and social indicators of the targeted projects, have been applied in this work in order to investigate opportunities for the sustainable transition of the heating and cooling sectors of the target communities of Southeast Europe. Both approaches confirm the feasibilities of the transition from traditional to renewable energy-based heating systems for each target community in the countries of South-Eastern Europe. After simulation and replication of the results, the sustainability analysis

indicatively shows that the transitions from traditional fossil-based, poor-maintained and difficult-to-manage heating systems towards renewable district heating and cooling (DHC) systems in Southeast Europe are sustainable solutions. Having in mind the modularity of such systems, those solutions can be replicated in other Southeast European cities and other countries.
Key words: *Heating, District heating systems, Modular renewable heating grids, Sustainability assessment*

1. Introduction

The heating and cooling sector is only slowly becoming cleaner, as heat supply from fossil fuels is still very high, both in the world (90%) and in the European Union (70%). This is due to the fact that fossil fuels are still the main energy source for both CHP and boiler plants, [1]. In Europe, the heating and cooling demand accounts for around 50% of the EU's final energy consumption. In order to reduce carbon dioxide emissions in the heating/cooling sector, new non-fossil heat sources must replace the current fossil-based plants. District heating (DH) as an efficient solution for heat supply and distribution can play a major part in meeting decarbonization targets. According to the EU Strategy on Heating and Cooling (2016), the contribution of DH in the EU accounts for 9% and is mainly driven by fossil fuels such as gas and coal, [2]. District and cooling heating networks present a high potential for the transition of the heat/cooling sector, both technically and organizationally, [3]. They allow the integration of renewable energies and thus can improve the overall energy efficiency and facilitate sector coupling (coupling between heating, electricity and mobility), [4,5]. In order to use this potential, many DH networks must first upgrade the existing distribution system, including the substations and consumer connections: reaching lower leakage rates and heat losses, reducing operation temperatures, adapting piping dimensions and hydraulics, introducing modern IT-based management systems and options for user control. This makes the heat distribution more efficient, but also improves the efficiency of the heat generation, hence, saving the primary energy. Moreover, it allows the integration of renewable energies and waste heat. In a further step, efficiency measures can be implemented on the generation side and the share of renewable and waste heat can be introduced and increased gradually. This must go hand-in-hand with predictions of future heat demand as well as with efficiency measures on the end use of heat, [6].

Small modular district heating and cooling (DHC) grids have several benefits. They can contribute to increase the local economy due to local value chains of local biomass supply. Local employment can be enhanced as well as security of supply. The comfort for the connected household can be increased as only the heat exchanger is needed in the basement of the buildings and no fuel purchase has to be organized. Small modular DHC grids can be fed by different heat sources, including from solar collectors, biomass systems, heat pumps and from surplus heat sources (e.g. heat that is not yet used from industrial processes or biogas plants). Especially the combination of solar heating and biomass heating (*Figure 1*) is a very promising strategy for smaller rural communities due to its contribution to security of supply, price stability, local economic development, local employment, etc., [7-9]. On the one hand, solar heating requires no fuel and on the other hand biomass heating can store energy and release it during winter when there is less solar heat available. Thereby, heat storage (buffer tanks for short-term storage and seasonal tanks/basins for long-term storage) needs to be integrated. With increasing shares of fluctuating renewable electricity production (PV, wind), the Power-to-Heat conversion through heat pumps can furthermore help to balance the power grid. If the planning process is done in a sustainable way, small modular DHC grids have the advantage, that at the beginning only part of the system can be realized, and additional heat sources and consumers can be added later. This modularity requires well planning and appropriate dimensioning of the equipment (e.g. pipes). It reduces the initial demand for investment and can grow steadily, [7-9].

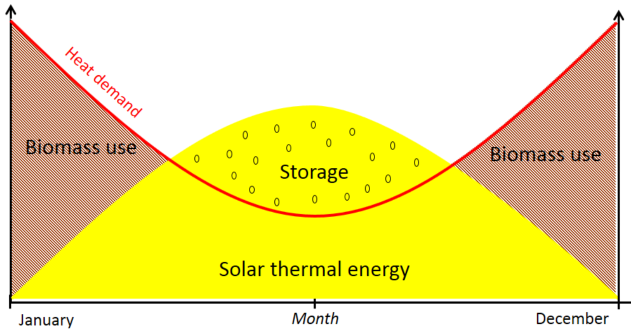

Figure 1. Scheme of the annual heat demand and the synergetic combination of solar thermal and biomass for DH, [8, 9]

1.1. State of the Art

Key issue concerning DH nowadays is the integration of renewables and to show that such district systems are feasible and sustainable solutions. Some of the recent studies focus on solar assisted DH systems, for example a study of cost-efficient solutions for integrating solar heating in an existing local DH system in Finland, reported in [10]. Therein centralized and distributed solar collectors and the effects of reducing supply temperature were investigated. It was found that centralized collector systems can provide cost savings from 7 to 21%. Some other investigations involving solar heating and cooling are reported in [11] and [12] with focus on the integration and optimization of solar thermal system in existing co-generation-based DH systems. On the other hand, biomass DH systems are a promising way to increase thermal efficiency in rural areas and some recent research showed such systems. In [13], authors reported on possible implementing biomass DH facilities in 499 rural municipalities with a population above 1,500 inhabitants in the continental region of Spain. Results show a potential for 154 biomass DH systems with an internal rate of return above 5%, and 31 systems above 10%. On the other hand, only three DH systems are classified as non-profitable. The massive implementation of these systems in the region under study reduce CO_2 emissions from fossil fuels in 5.4 million tons per year and would imply and important impulse to local economy. In [14], the development of a biomass combined heat and power station by smart energy system in Jelgava is reported. The scenarios were compared via technological, economic and bioeconomic indicators and evaluated for their restrictions for limiting long-term sustainable development. It is concluded that bioeconomic development scenarios can support sustainability of the DH systems. The cold deliveries from district cooling systems are much smaller than heat deliveries from DH systems, [1]. Some recent studies on cooling concentrate on system simulation and parametric study of the demonstration aiming to reduce electricity consumption, improve thermal COP's and capacity of the system, as reported in [15]. In [16] DH systems in Lithuania have been analyzed through a sustainable energy development promoting tool for the eco-labelling scheme of

DH and cooling systems. This was based on measured energy and environmental performance data of the DH and cooling system. Finally, in [17], various heat generation technologies were examined in a multi-criteria sustainability assessment frame of seven attributes which were evaluated based on a choice experiment (CE) survey.

However, it was found that none of these studies dealt with a sustainability assessment for the transition of the heating and cooling sector, only selected assessments were done. For example, several studies [10, 11, 12] deal with the costs savings of specific heating applications, while work [13] estimated total CO_2 emission savings for the considered group of projects in Spain. Work [14] defined indicators and analyzed/discussed them in context of sustainability improvements, and other studies mainly focused on overcoming technical difficulties and limitations. While [16] deal with DH sector in Lithuania through a sustainable energy development promoting tool, [17] performed a multicriteria sustainability assessment of different heat generation technologies in general. So, there is no sustainability assessment applied in the field of transition of heating-cooling sector nor reliable information about sustainability of the sector transition reported in literature so far.

1.2. Objectives

This paper investigates the sustainability of the transition of heating and cooling sectors from traditional fossil-based solutions to renewable heating-cooling solutions. It provides a methodology for such an assessment. This is applied to 5 target communities in the south-eastern Europe region: Slovenia, Croatia, Bosnia and Herzegovina, Serbia, and Macedonia. Space heating in the cold season and hot water is dominated on the European level and especially in south-eastern Europe with its strong winters and hot summers, by the use of fossil fuels (heating oil, natural gas, coal), wood, and grey electricity. Heating systems, either as individual boilers and systems, or as DH systems, are often old, inefficient and with high emissions. On the other hand, efficient and renewable heating-cooling technologies are commercially available and used in many cases, but with a very small market share compared to the traditional systems as described above. This applies especially to South Eastern European countries. The hypothesis is that this situation is due to the following reasons:

- South-eastern Europe is economically weaker than central Europe. Consumers have less money available to pay for the generally higher initial investment costs of clean and modern heating technologies.
- Low prices of fossil fuels and electricity due to subsidies make renewable heating and cooling less attractive than in central Europe.
- The political support to change the current situation is very limited.
- Low regulatory requirements (emission standards) on air polluting installations.

These challenges are addressed by the coherent and consistent methodology of the paper by which the heating sectors of traditional fossil based and low-economy regions, such as South-Eastern Europe, can be transferred into a more sustainable one. For the large market penetration, the above listed barriers need to be reduced. Several tools and methods were used to epistemologically analyze the requirements for the implementation of renewable heating and cooling systems as a function of the sustainable heating sector transition.

2. Materials and methods

The scope of the paper is the concept development for renewable DH system in selected municipalities of South Eastern Europe as well as the sustainability assessment of the transition from traditional fossil-based concepts to renewable concepts in the heating sector.

2.1. System under consideration – heating and cooling sector of Southeast Europe

In southeastern European countries, DH has not been seen as the technology to rely on. Many existing buildings have been heated by heating oil, gas or coal and accordingly not been furnished with water based central heating systems. The introduction of DH is not just a conversion of the heat source, but also requires a significant investment to be carried by the homeowners. The public perception of DH as a common, public utility also pays a role. The willingness to rely on a public utility for heating may be quite different from how the systems are perceived in the western and northern European countries and in the southern parts of Europe. The main technical characteristics and difficulties of DH systems in southeastern Europe are:

- Pipes are often poorly insulated steel pipes in concrete ducts, whereas renovated areas are often equipped with pre-insulated pipes.
- Systems were often designed for a fixed flow and for the use of ejector pumps. The original design may have been for 150/70 °C, but modern systems could be operated at much lower temperatures. The systems often struggle with thermal and hydraulic imbalances, fouling of heat exchangers and water leakages.
- New DH in areas without a long tradition of DH often use industrial surplus heat (waste heat). Here, systems are similar to the ones of central Europe, but with less focus on energy efficiency.
- Several new DH systems are installed in various countries of southeastern Europe which are mainly based on renewable energies (e.g. solar thermal or biomass). A new approach for some of these systems is to facilitate sector coupling (heat, power, transport). Many of the renewable-energy-based DH systems are smaller scale systems.

Renewable energy policies in most the an countries mainly focus on the electricity market, whereas policies for renewable heating and cooling are usually much weaker. Therefore, it is important to support and promote renewable heating and cooling concepts. Heating, cooling and electricity systems can support each other to realize the energy transition and to decarbonize in southeastern Europe.

2.2. Concept of modular DH and cooling projects in Southeast Europe

Within the CoolHeating project, concepts for seven projects in the five target countries were developed in order to supply them in total with 202 GWh/a heat and cold from renewable energies and to supply them only in selected cases by fossil peak load boilers. Core activities, besides techno-economical assessments, included measures to stimulate the interest of communities and citizens to set-up renewable DH systems as well as the capacity building about financing and business models. This initiated several new small renewable DH and cooling grids in the 5 target countries (**Error! Reference source not found.** up to the investment stage. In order to develop the concepts, surveys about the heat demand were made and options were discussed with the local stakeholders. The following chapters briefly summarize the concepts developed within the CoolHeating project, see website (www.coolheating.eu).

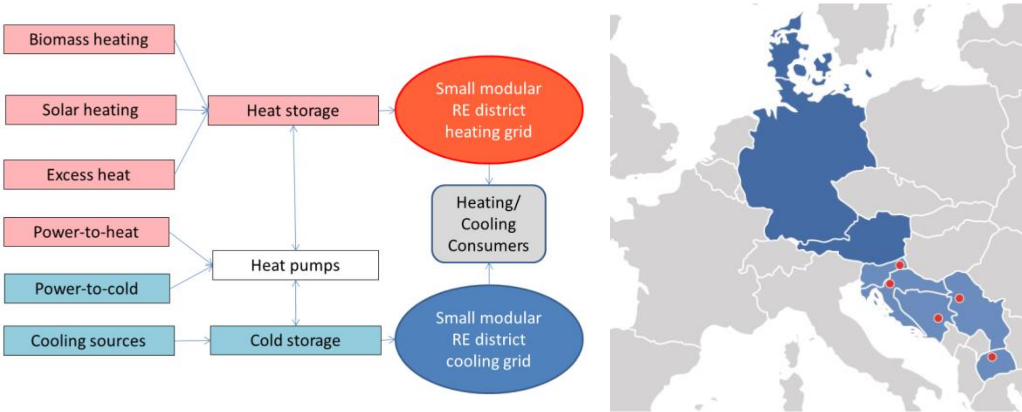

Figure 2. Concept of small modular renewable heating & cooling grids (left) in 5 target cities of Souteast Europe (right: light blue, red points), [2, 3, 4]

2.3. Modelling and optimization

A demand forecast was made, the capacities of the production units were determined, and the optimization of the operating mode was analyzed for each of the seven projects by the specialized software EnergyPRO, as shown in Figure 3. It is a modelling software used primarily in relation to DH projects. It was used to carry out an integrated detailed technical and financial analysis of both existing and new energy projects. The software was used to plan the optimal production for the energy plant for a whole year. The period for the optimization was calculated per hour throughout the year with a detailed production plan. Inputs for the optimization were typically parameters such as content of stored energy at the beginning of the optimization period, expected energy demands within the period as well as all operating expenses. Calculations and optimization of the capacities (type and installed power in MW) and production (heat energy generation in MWh) were based on inputs for all units, climate conditions, connection rates for private and collective housing facilities, prices of all energy sources, energy efficiency performances of the facilities, temperature levels of DH systems, heat loss assumptions in the grid, operating times and so on. The software can optimize the operation every hour based on operational costs such as maintenance costs, fuel costs, electricity prices, taxes, subsidies, etc. The objective was to analyze the cheapest solutions for heat supply. When the operating costs are calculated for a scenario, investments and capital costs can be calculated so that the economically optimal solution can be found.

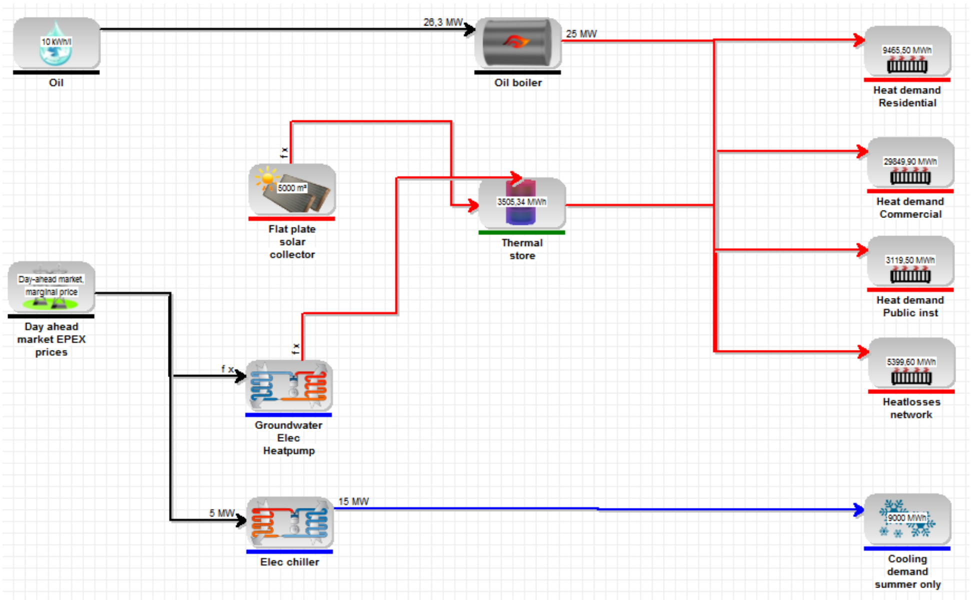

Figure 3. Scheme of heating and cooling production units and consumers calculated in EnergyPRO, example of CoolHeating project Karposh

2.4. Sustainability assessment methods used

Sustainability assessment can be used for analyzing the feasibility and sustainability of RES scenarios (options) and has been applied in [18], [19] and [20] to support the power plant selection between considered options as function of the highest general index of sustainability. A power utility generation portfolio optimization model in terms of its sustainability as function of specific targets on RES share in 2030, including comparative analyses between Single criteria analysis (SCA) and Multicriteria sustainability assessment (MSA), has been recently proposed in [21].

A similar approach of combined SCA and MSA is used in this paper. Therefore, a set of economic and environmental indicators were defined as shown below.

- Investment (capital expenditure) – EcCAPEX (EUR/MWh)
- Fuel costs (operation expenditure) – EcOPEX (EUR/MWh).
- CO_2 indicator (tonnes of CO2 emitted per MWh of produced heat energy) – EnCO2 (tCO2/MWh)
- SO_2 indicator (tonnes of SO2 emitted per MWh of produced heat energy) – EnSO2 (tSO2/MWh)
- NO_x indicator (tonnes of NOx emitted per MWh of produced heat energy) – EnNOx (tNOx/MWh)
- PM indicator ((tonnes of particle matter emitted per MWh of produced heat energy) – EnPM (tPM/MWh)

Selected economic and environmental indicators are typically used when considering a heating system, due to their high-effecting influence on sustainability of such a system. The most important economic indicators for this analysis, besides the *Investment indicator* (EcCAPEX), is the *Indicator of fuel costs* (EcOPEX). This is taking into account that fuel costs are the most influencing factor by far, among the fixed and variable O&M costs. The social aspect is analyzed by non-valuable indicators, i.e. *Increase in employment*, *Local income generation*, or *Region development*. Social indicators are evaluated for two considered cases of each target community in order to support sustainability analysis based on environmental and economic indicators.

Economic and Environmental Sustainability Indicators (SI) are calculated for two options of each target community on a real-base quantification of parameters (costs, emissions) within a period of 20 years (estimated Life Time of the project), divided by heat production in MWh in the life time of 20 years:

- Option 1 – Reference case – business as usual (doing nothing).
- Option 2 – CoolHeating concept – new case (renewable DH grid).

For each case study, a simple comparison of the indicators of Option 1 and Option 2 was made. This approach is based on SCA. Then, all indicators are normalized and aggregated into a General index of sustainability, by assigning weighting factors to each indicator. Weighting factors (rate of influence) of each sustainability indicator are given by the authors as experts in the field, based on their research and professional experience. Then preference of sustainability is determined by simple comparison of the General index of sustainability for two options (scenarios) of each target communities. In that way MSA is applied.

3. Results and discussion

Within this chapter, the main characteristics of the conceptualized seven DHC systems considered throughout the CoolHeating project in the five target countries are presented. Results are presented and discussed and integrated into a sustainability assessment.

3.1. Technical concepts and parameters of the projects

An overview of the technical concepts, optimized by EnergyPro, is given in Table 1.

The rural settlement of **Cven in Slovenia** has 226 households and a few larger public buildings. All public buildings should be connected to the DH grid, as well as 90% of the households. The technical concept considers a small biomass CHP (combined heat and power) unit with 112 kW_{el} for the baseload, an 800 kW_{th} biomass boiler and a 2.2 MW_{th} natural gas peak load boiler. A buffer storage tank could decrease the peaks after night setback time in the morning, when most households start heating again. Biomass (e.g. wood chips) is available in this region.

The municipality of **Ljutomer in Slovenia** selected the industrial zone for developing a DHC project. A biomass CHP with 448 kW_{el}, a 2 MW_{th} biomass boiler, a 4 MW_{th} natural gas peak load boiler, a 90 m^3 buffer storage tank and a 1.2 MW_{th} biomass steam boiler is considered. This scenario also covers the cooling needs from a dairy with an absorption chiller, operated with the DH grid.

The technical concept for the city of **Ozalj in Croatia** includes a 25 MW_{th} biomass boiler, 30,000 m^2 flat plate solar collectors and a fuel oil peak load boiler. The solar collectors are in combination with a 40,000 m^3 seasonal thermal storage, the biomass boiler with a 300 m^3 thermal storage.

Air quality during the heating season is quite bad in **Visoko in Bosnia and Herzegovina** due to heavy use of coal for heating. Existing heating systems are mainly individual ones and currently dominated by coal as the cheapest energy source on the market. Therefore, the concept plans a new DH grid using a 6.3 MW_{th} heat pump (from the river) as well as 5,000 m^2 solar thermal collectors in combination with a 13,500 m³ seasonal storage, plus a natural gas peak load boiler. About 150 private houses, 30 collective housing facilities and 6 public buildings are planned to be connected.

The concept for **Letnjikovac in Šabac (Serbia)** includes a biomass boiler with 1.5 MW_{th} and a 3.5 MW_{th} fuel oil boiler to connect public buildings and about 248 households. The feasibility study shown that the DH grid is economically valuable, due to the low grid density.

Šabac in Serbia has an existing DH system, using natural gas boilers. The concept for the implementation of renewable energy in the DH grid Šabac includes three biomass boilers with 4.5 MW_{th} nominal capacity each. This leads to about 61% coverage of the annual heat demand with renewable energy.

The new area Zajcev Rid in **Karposh (Macedonia)** could be connected to a DH grid, using a 15 MW_{th} ground water heat pump, 5,000 m² solar thermal collectors, in combination with a 55,000 m³ seasonal storage, plus a fuel oil peak load boiler. Using the DH grid for cooling in summer (15 MW_{th} electr. chiller) is an option for the cooling.

Table 1. Technical data of the 7 technical DHC concepts in the CoolHeating target municipalities

	Cven (Slovenia)	Ljutomer (Slovenia)	Ozalj (Croatia)	Visoko (BiH)	Letnjikovac (Serbia)	Šabac (Serbia)	Karposh (Macedonia)
DH grid length incl. consumer connections [m]	3,400	4,175	16,586	5,500	7,656	existing	9,500
Grid density [kWh/m/a]	934	3,524	3,873	3,482	462		4,467
Annual heat losses of the DH grid [%]	19	6	5	6	17		11
Annual heat losses of the DH grid [MWh/a]	745	915	3,029	1,129	738		5,400
Consumer needs heat [GWh/a]	2.24	10.94		17	3.54		42.44
Heat for wood drying for CHP operation [GWh/a]	0.94	3.77					
Total heat for DH grid incl. losses [GWh/a]	3.93	15.63	66.41	18.13	4.28	37.69 from biomass	47.84
Temperature level for DH grid, flow/return [°C]	90/65	100/70	90/65	80/60	90/65	110/60	70/40
DH grid operation in summertime	yes	yes	yes	no	no	no	cooling
CHP gross electr. production [kW_P / MWh/a]	112 / 918	448 / 3,673					
Share of total heat for DH from CHP [%]	48	48					
Share of total heat for DH from biomass boiler [%]	49	51	72		91	61	

Share of total heat for DH from solar thermal [%]			24	16			11
Share of total heat for DH from heat pump [%]				79			88
Share of total heat for DH from fossil peak boiler [%]	3	2	4	5	9	39	1
Thermal storage [m³]	50	90	40,000	13,500	60	200	55,000

3.2. Calculation of the Indicators

Information and data on investments and fuel costs were collected and calculated for all target projects, considering specific circumstances of each municipality. For the calculation of environmental indicators, emissions factors have been used from European Environment Agency, EMEP/EEA air pollutant emission inventory guidebook (https://www.eea.europa.eu//publications/emep-eea-guidebook-2016, [22]. The focus was on four environmental indicators namely: CO_2, NOx, SO_2 and PM (PM2.5 and PM10) and two economic indicators namely investment and O&M (incl. fuel) costs. The considered life time was 20 years. A realistic heat demand for each target community was assumed, the same for the reference case (existing solution) and the new case (CoolHeating project) for sake of comparison. For electricity, grid emission factors have been used taking into account the mixed production portfolio of power supplier (so called net emission factors). For the calculation of investment and fuel costs, real market prices were used. In estimation of investment costs for the reference case (existing solution), one replacement of all equipment and facilities in the predicted life time of 20 years was supposed.

Table sheets of all sub-indicators were formed for each target community, and then economic and environmental sub-indicators were summarized for all projects in table 2 and table 3, respectively.

As it can be seen from Table 2, for four of five target community under consideration, namely for the Municipality of Visoko in Bosnia and Herzegovina, for the Municipality of Cven in Slovenia, for the Municipality of Ozalj in Croatia, and for the Municipality of Karposh in Macedonia, the CAPEX indicators are higher for the CoolHeating option then for the reference cases. However, the life-time fuel costs of the reference cases were by far higher for all target communities, giving a ground for preference of the CoolHeating option.

Table 2. Economic indicators

	Investment (€/a)	*Fuel cost (€/a)*	*CAPEX (€/MWh)*	*OPEX (€/MWh)*
Municipality of Visoko, Bosnia and Herzegovina, Heat demand of 20,000.00 MWh/a				
Reference situation (Business as usual):	1,033,830.0	16,390,843.6	51.7	40.98
CoolHeating project:	5,000,000.0	6,443,544.7	250.0	16.11
Savings in Life time of 20 years	-3,966,170.0	9,947,298.9		
Municipality of Cven, Slovenia, Heat demand: 5,732.00 MWh/a				
Reference situation (Business as usual):	1,536,000.0	6,427,938.8	268.0	56.07
CoolHeating project:	1,995,000.0	2,201,163.0	348.0	19.20

Savings in Life time of 20 years	- 459,000.0	4,226,775.5		
Municipality of Letnjikovac, Serbia, Heat demand: 4,274.00 MWh/a				
Reference situation (Business as usual):	250,000.0	4,987,369.7	58.5	58.3
CoolHeating project:	100,000.0	2,223,274.7	23.4	26.0
Savings in Life time of 20 years	150,000.0	2,764,094.7		
Municipality of Ozalj, Croatia, Heat demand: 59,366.3 MWh/a				
Reference situation (Business as usual):	856,147.88	61,220,964.3	14.42	51.56
CoolHeating project:	21,614,400.0	20,166,373.4	364.09	16.98
Savings in Life time of 20 years	-20,758,252.12	41,054,590.9		
Municipality of Karposh, Macedonia, Heat demand: 47,560.1 MWh/a				
Reference situation (Business as usual):	3,480,000.0	2,467,165.6	73.17	51.87
CoolHeating project:	5,407,000.0	881,378.7	113.69	18.53
Savings in Life time of 20 years	- 1,927,000.0	1,585,786.9		
TOTAL for 5 target comminities of SouthEast Europe				
Reference situation (Business as usual):	7,155,977.88	91,494,282.0	52.26	50.52
CoolHeating project:	34,116,400.0	31,915,734.5	249.15	17.77
Savings in Life time of 20 years	-26,960,422.12	59,578,547.5		

Thus, if the CoolHeating projects are implemented, total fuel cost savings would be 59,578,547.5 EUR for the communities in a period of 20 years. This is 2.2 times more than the total investment in all CoolHeating projects.

Table 3 summarizes the environmental indicators for all five communities. Considerable savings in emissions, namely CO_2, SO_2, NO_x and PM10 and PM2.5 are achieved in the CoolHeating option for all 5 target communities. So, from the environmental aspect, the CoolHeating concept indisputably prevail over the option of reference case.

Table 3. Environmental indicators

	Emission CO_2 (t)	Emission SOx (t)	Emission NOx (t)	Emission PM10 (t)	Emission PM2.5 (t)	EnCO_2 (t/MWh)
Municipality of Visoko, Bosnia and Herzegovina, Heat demand of 20,000.00 MWh/a						
Reference situation (Business as usual):	131,871.0	238.27	1,728.21	635.48	632.87	0.330
CoolHeating project:	67,406.44	120.12	1,166.58	9.15	9.15	0.169
Savings in Life time of 20 years	64,464.6	118.1	561.6	626.3	623.7	
Municipality of Cven, Slovenia, Heat demand: 5,732.00 MWh/a						
Reference situation (Business as usual):	2,803,957.0	131,651.8	458,816.9	23,606.9	18,138.3	24.5

CoolHeating project:	3,635.4	32.15	8.45	293.35	293.35	0.032
Savings in Life time of 20 years	2,800,322.5	131,619.7	458,808.5	23,313.6	17,845.0	
Municipality of Letnjikovac, Serbia, Heat demand: 4,274.00 MWh/a						
Reference situation (Business as usual):	1,326.31	71.73	26.29	649.13	649.04	0.016
CoolHeating project:	3,002.35	26.89	23.13	205.62	205.41	0.035
Savings in Life time of 20 years	-1,676.0	44.8	3.2	443.5	443.6	
Municipality of Ozalj, Croatia, Heat demand: 59,366.30 MWh/a						
Reference situation (Business as usual):	214,023.2	504.61	793.95	2,300.22	2,291.54	0.180
CoolHeating project:	10,649.45	9.92	0.09	0.09	0.09	0.009
Savings in Life time of 20 years	203,373.8	494.7	793.9	2,300.1	2,291.5	
Municipality of Karposh, Macedonia, Heat demand: 47,560.10 MWh/a						
Reference situation (Business as usual):	465,676.6	770.88	6,955.89	755.69	755.69	0.489
CoolHeating project:	225,110.3	354.48	3,787.24	29.40	29.40	0.236
Savings in Life time of 20 years	240,566.3	416.40	3,168.60	726.30	726.30	
TOTAL 5 target comminities of SouthEast Europe						
Reference situation (Business as usual):	3,616,854.1	133,237.3	468,321.24	27,947.4	22,467.4	1.32
CoolHeating project:	309,803.94	543.56	4,985.49	537.61	537.40	0.11
Savings in Life time of 20 years	3,307,050.1	132,693.7	463,335.75	27,409.8	21,930.0	

3.3. Single Criteria Analysis – discussion of the results

Sustainability indicators have been calculated and then summarized for all 5 case studies as shown inTable 4.

Table 4. Results of Environmental and Economic indicators – summary of all 5 target communities

RES Scenario		OPTION 1	OPTION 2
SI	*Units*	Business as usual case	CoolHeating scenario
$EnCO_2$	kg/MWh	1322.35	113.22
$EnSO_2$	kg/MWh	48.65	0.198
$EnNO_x$	kg/MWh	171.01	1.82
EnPM	kg/MWh	10.21	0.196
EcCAPEX	EUR/MWh	52.26	249.15
EcOPEX	EUR/MWh	50.52	17.77

When SCA is applied by simple comparison of indicators of two options under consideration, namely the reference business-as-usual case and the CoolHeating concept scenario, it can be noted that, from the environmental aspect – i.e. considering environmental indicators of emissions, CoolHeating option has an advantage over the reference case (traditional heating option), no matter which emission indicator is considered. However, the EcCAPEX in the CoolHeating option is not a preferable. When life-time fuel costs are considered (EcOPEX), the CoolHeating option is again preferable over the reference case by far. The presented examples show that, within SCA, the selection of the optimal option for the power system depends exclusively on selected criteria. Notwithstanding of that, it is worth to note that five of six single criteria give an advantage to CoolHeating option, while only one single criterion gives advantage to the reference case i.e. the business as usual case "doing nothing".

3.4. Multicriteria sustainability assessment – discussion of the results

Under MSA, all set criteria are considered at the same time. Different economic and environmental criteria are adopted by respective weighting factors, to measure the influence of each effecting factor. Then, indicators adopted by weighting factors are agglomerated into a general index of sustainability. General indices are formed through the following procedure, [15-18]:

- Formation of vectors $x = (x_1.....x_m)$ of all input parameters (characteristics of system) which are necessary for full quality evaluation of the system; in the work, these characteristics are expressed by two criteria i.e. two groups of sustainability indicators, EnI (Environmental Indicators) and EcI (Economic Indicators).
- Formation of vectors of specific criteria $q = (q_1,........,q_m)$, by which input parameters $x_1,..., x_m$ are evaluated (in this case it is costs in EUR or emissions in tonnes divided by heat production in MWh in life time of 20 years) and then normalized (i.e. divided by maximum xi value).
- Introduction of weighting factors $w = (w_1.....w_m),\ \ w_i \geq 0,\ \ \ w_1 + ...w_m = 1$, by which sustainability rate of the considered cases is expressed by means of additive aggregate function, or synthesized function (general index) given by relation:

$$Q_+(q;w) = \Sigma\ w_i\ q_i \quad (1)$$

As final result of the MSA procedure, a priority list of the considered options is obtained. The general index of sustainability is derived in this work under the reference case (doing nothing) and the CoolHeating concept option, for a wide range of different combination of weighting factors. Which combinations of weighting factors are applied depend on the nature of the system under consideration, environment and economic issues of the area, as well as on the specific situation of the area. Generally, experts and decision makers together define values of specific weighting factors, to provide a realistic and reliable sustainability rating of the options under consideration. As a starting point in the analysis i this work, the authors have assigned equal weighting factors for the air quality in southeastern European communities, and the economic situation (i.e. economic power of consumers and GDP).

Following the procedure described above, values of weighting factors and vectors of specific criteria (normalized sustainability indicators values), and general indices with final ranking of the options are given in Table 5.

Table 5. Weighting factors (w), specific criteria vectors (q) and general indices (Q)

RES Scenario		REFERENCE CASE	COOLHEATING CASE
SI	w_i	q_i	q_i
$EnCO_2$	0.125	1	0.0856
$EnSO_2$	0.125	1	0.0041
$EnNO_x$	0.125	1	0.0106
EnPM	0.125	1	0,0192
EcCAPEX	0.250	0.2098	1
EcOPEX	0.250	1	0.3517
Q		0.8025	0.3529
Ranking		2	1

Generally, obtained results clearly confirm that CoolHeating scenario is preferable over the reference case. It is worth to mention that a wide range of values of weighting factors against the basic (equal) weighting factors distribution have been investigated, as a part of the MSA sensitivity analysis. If any reasonable combination of weighting factors is applied, the CoolHeating option is the preferable, i.e. more sustainable scenario. The performed sensitivity analysis points to the stability of the CoolHeating scenario option as well. The analysis has shown that if any advantage was given to Environmental criteria, the CoolHeating project becomes even more preferable compared to the situation when equal distribution of weighting factors to economic and environmental criteria is applied. Furthermore, when an advantage is given to economic criteria over environmental criteria, CoolHeating project is still preferable in a wide range of weighting factors applied. After considering which weight factors change the ranking of the options, it can be concluded that the CoolHeating scenario is preferable over the reference (doing nothing) scenario until economic indicators are weighted by 94% and environmental indicators by 6%, whereby assigning equal importance to the Economic group of indicators (+47% each) while the Environmental indicators weight only at 1.5% each. Special attention must be given to the $EnCO_2$ indicator under current and future climate change mitigation policy which is much better for the CoolHeating project during the whole life time.

In addition, the effects to the increase in employment, local income generation and rural development have been considered. Evaluating those social indicators as non-valuable characteristics, CoolHeating option is shown to be preferable option from the social aspect.

4. Conclusions

In this work, SCA and MSA were combined to investigate the sustainability of the heating sector transition in southeastern European countries from traditional fossil-based towards new modular renewable-based heating and cooling systems. Sets of economic and environmental indicators were first defined, while social aspect were analyzed by non-valuable indicators to support the sustainability analysis. Forecasts of the demands and determination of the capacities of the heat production units, as well as optimizations of the operating modes itself, were performed by the specialized software EnergyPRO.

The indicative results presented here show that the CAPEX for four of five target community under consideration, namely Municipality of Visoko in Bosnia and Herzegovina, Municipality of Cven in Slovenia, Municipality of Ozalj in Croatia and Municipality of Karposh in Macedonia is higher for the CoolHeating option than for the reference case. The total lite-time fuel costs are by far higher for all target communities in the option of the reference case (business as usual - doing nothing), giving a ground for preference to an option of the CoolHeating concept. Thus, if CoolHeating projects are implemented, total 20 years life-time savings in fuel costs would be 59,578,547.5 EUR for the 5 communities, which is 2.2 times larger than the total investment costs in CoolHeating projects in all 5 communities. Furthermore, considerable savings in emissions, namely CO_2, SO_2, NO_x and PM10 and PM2.5 are achieved in the CoolHeating scenarios for all 5 target communities. Total savings in CO_2 emissions in lifetime of 5 target communities are over 3,300,000 tonnes. So, from the environmental aspect, the CoolHeating concept indisputably prevail over the option of reference case.

Obtained results of multicriteria sustainability assessment improve and strengthen SCA results while clearly confirming that the CoolHeating scenario is preferable over the Reference case. It is worth to mention that a wide range of values of weighting factors against the basic weighting factors distribution have been investigated, as a part of sensitivity analysis. If any reasonable combination of weighting factors is applied, the CoolHeating option is the preferable i.e. more sustainable scenario.

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Nomenclature

EcCAPEX, EUR/MWh – investment indicator
EcOPEX, EUR/MWh – O&M indicator
EnCO2, kg/MWh – CO2 indicator
EnSO2, kg/MWh – SO2 indicator
EnNOx, kg/MWh – NOx indicator
EnPM, kg/MWh – PM indicator
q – specific indicator
Q – Sustainability index
x – weighting factor

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