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Support for Decision-Making in Prioritizing Boiler Rooms for Decommissioning

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Abstract

Environmentally harmful boiler rooms fueled by coal or liquid fuels (heavy fuel oil and heating oil) still exist in cities as part of centralized systems or standalone installations. Despite their undoubtedly negative impacts on the environment, they are not being decommissioned, mainly because the financial parameters of the feasibility studies for their decommissioning are unfavorable. Unlike greenhouse gases, for which there is a monetary equivalent thanks to emissions trading schemes and which can be taken into account in feasibility studies, there is no generally recognized method for taking local pollution into account when assessing the financial viability of investments.

Therefore, this paper proposes a fuzzy decision-making model for the integral consideration of financial, climate, and environmental indicators for decommissioning projects. It is structured to analyze the available options for fuel switching, including integration with a centralized system, and to evaluate the reduction of pollutant emissions in flue gases. Based on the analyses carried out, environmental efficiency indicators are proposed. These indicators measure the emission reduction per the heat power of the boiler rooms and compare the necessary investments with the emission reduction. Together with the typical indicator of project feasibility (payback period but including the cost of avoided greenhouse gas emissions), these indicators are presented as fuzzy linguistic variables, and the max-min composition is used as a tool for the overall assessment of the project.

To demonstrate the application of the proposed fuzzy decision-making model in the prioritization of decommissioning projects, the case study is presented, which includes 28 boiler rooms fueled by coal, heavy fuel oil, or heating oil in 6 Serbian cities (Belgrade, Niš, Užice, Valjevo, Novi Pazar, Smederevo). The emissions of pollutants (SO_2, NOx, and particulate matter) and greenhouse gases are calculated and presented. For each of the boiler rooms, a solution for the decommissioning of the existing boiler rooms was proposed. The projects were evaluated and categorized based on financial and environmental indicators using a fuzzy decision-making model. The analysis of the results shows that environmental indicators should be taken into account as they promote environmentally very significant projects that would otherwise be neglected due to their financial inadequacies.

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Presentation Content

- INTRODUCTION
- METHODOLOGICAL FRAMEWORK
- CASE STUDY
- CONCLUSION

Introduction

- Obsolete coal- and fuel oil-fueled boiler rooms located in cities are among the most significant sources of local air pollution, including NOx, SO_2, particulates (PM2.5, PM5, PM10), CO, and soot.

- Solutions for decommissioning:
  - Connecting consumers to a district heating system
  - Building a new boiler room that will use locally available RES (biomass, thermal solar, ambient heat, waste heat) with natural gas for peak demand

- Problem in project prioritization when the information about projects is limited

Introduction

- A relatively simple methodology based on for evaluating and ranking different project proposals is proposed
- The fuzzy decision-making model integrally considers financial, climate, and environmental indicators of decommissioning projects
- Case study: 28 boiler rooms fuelled by coal, heavy fuel, or heating oil in six Serbian cities (Belgrade, Niš, Užice, Valjevo, Novi Pazar, Smederevo)

Methodological framework

- I phase: Engineering approach in the determination of project solutions

  - Description and analysis of the current situation - Baseline Data Collection

<table>
<tr><th colspan="2">Collected</th><th colspan="2">Calculated</th></tr>
<tr><td rowspan="7">Basic technical and operation characteristics</td><td>Total heat power (kW)</td><td rowspan="2">Production and efficiency</td><td>Energy production (kWh)</td></tr>
<tr><td>Heat power of single boiler units (kW)</td><td>Efficiency of consumption (kWh/m^2/year, kWh/m^2/HDD)</td></tr>
<tr><td>Operation regime (^{o}C/^{o}C)</td><td rowspan="5">Emission of GHG (kg)</td><td>CO_2</td></tr>
<tr><td>Efficiency of boilers</td><td>CH_4</td></tr>
<tr><td>Operation period (h/year)</td><td>N_2O</td></tr>
<tr><td>Type of fuel (Coal, Heavy fuel oil, Heating oil, Natural gas)</td><td>CO_2eq.</td></tr>
<tr><td>Annual fuel consumption</td></tr>
<tr><td rowspan="4">Consumers characteristics</td><td rowspan="3">Area of heated residential space (m²)</td><td rowspan="4">Pollutants emissions (kg)</td><td>NOx</td></tr>
<tr><td>SO_2</td></tr>
<tr><td>Area of heated commercial space (m²)</td><td>CO</td></tr>
<tr><td>Heating Degree Days</td><td>PM</td></tr>
<tr><td colspan="4">Cost of energy production (EUR/kWh)</td></tr>
</table>

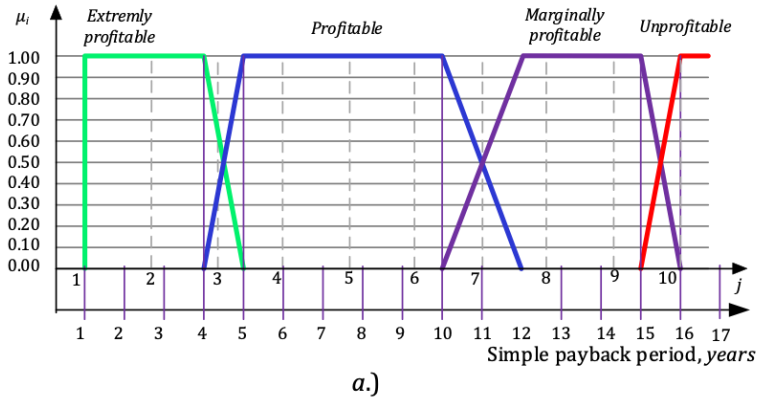
  - Identification and assessment of available energy inputs
  - Technical concepts/options for the new heating source

Methodological framework

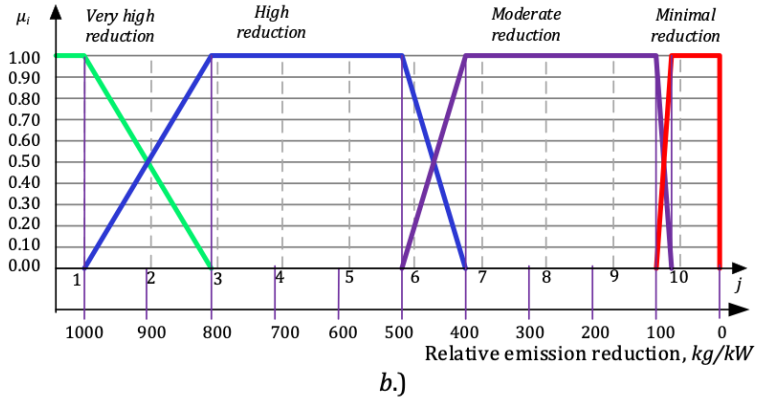
- Assessment of Environmental Benefits
- Financial Analysis of Proposed Concepts
- Calculation of indicators
  - Simple payback period - SP (year)
  - Relative emission reduction – RE (kg/MW)
  - Costs of emission reduction – CR (EUR/t (SO2+NOx+PM+CO) reduction)

Methodological framework

- II phase: Fuzzy decision-making model (FDM)
  - FDM utilizes a fuzzy inference engine to transform input indicators and compose them into a single overall indicator
  - In the initial phase of project consideration, most of the figures concerning project financial and further operational parameters are relatively uncertain



a.)



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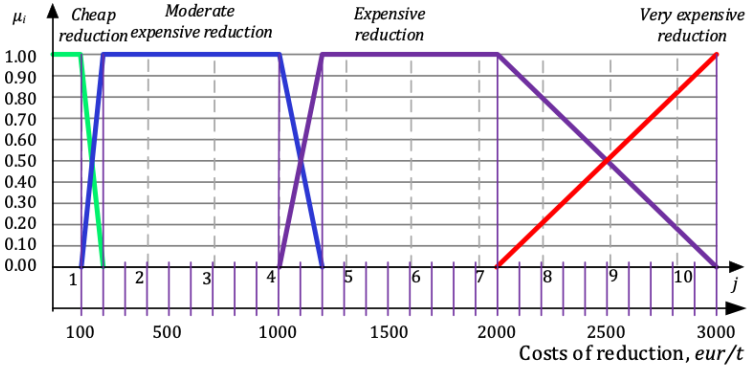

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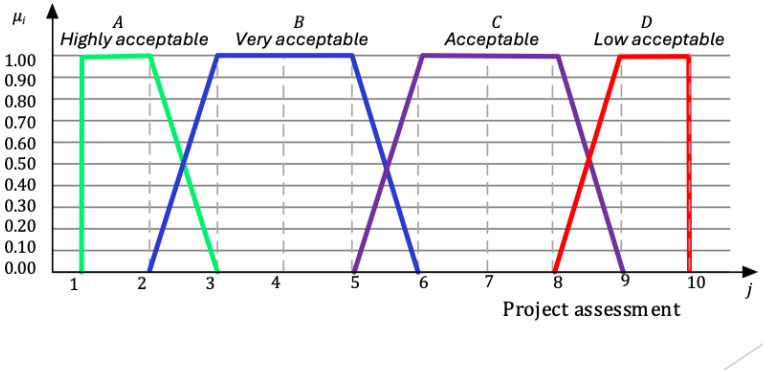


d.)

Fuzzy sets, linguistic variables, and mapping rules for:
a. – simple payback period,
b, - relative emission reduction,
c – cost of reduction,
d - project assessment

Max-min fuzzy composition

$$PA = SP \circ RE \circ CR$$

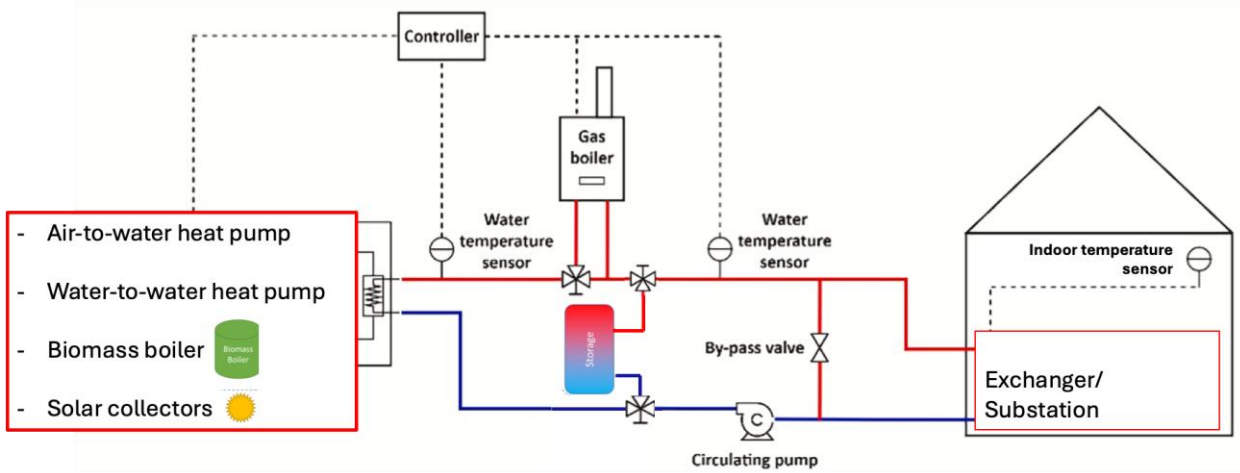
Case study

- 28 boiler rooms in 6 Serbian cities (Belgrade-BG, Niš-NI, Užice-UE, Valjevo-VA, Novi Pazar-NP, and Smederevo-SM) that are sources of significant pollution are considered
- The total heat power is 241.7 MW.
- The average annual consumption: 13,450.2 t of heavy fuel oil, 2,567 t of coal, and 452,66 t of heating oil.
- 990 thousand sq. meters of residential, public (schools, kindergartens, hospitals, etc.), and commercial buildings
- 121.3 kWh/m^2 (1:8) or 0.053 kWh/m^2/HDD (1:10)
- 47,392.67 t of CO_2eqv.
- 65 t NOx, 58 t SO_2, 3,2 t CO, and 6,1 t PM
- 0.093 EUR/kWh

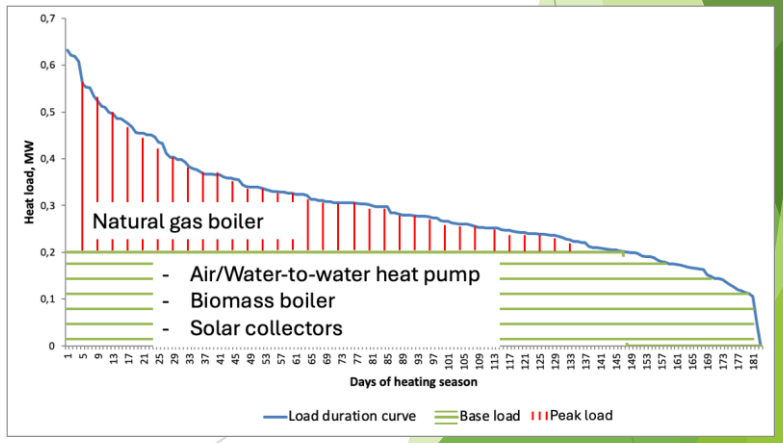
Case study

- Connection to the DH system
- RES utilization

Layout of the existing DH network, connecting pipeline



General scheme of RES utilization for boiler house decommissioning



Load duration curve

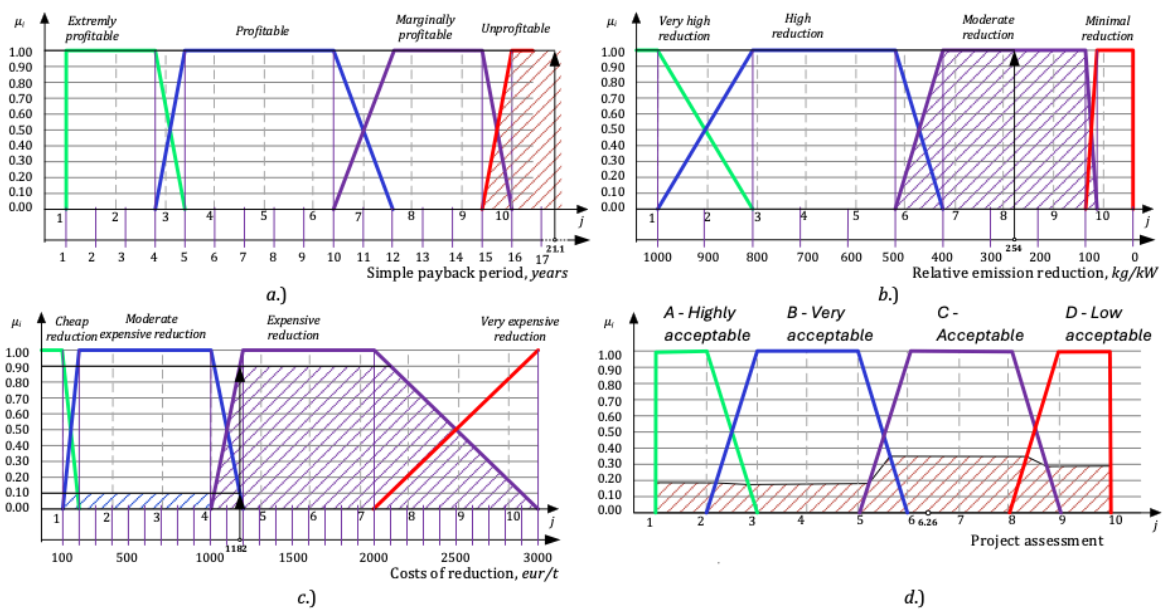
Case study

Boiler room code	Total heat power (MW)	Fuel	Average annual fuel consumption (t)	Consumers	Heated space (m^2)
NP2	0.6	Heating oil	21.00	Public buildings	2,711
NP3	1	Coal/Firewood	100.00	School	4,350

Boiler room code	Efficiency of consumption		Annual emissions					Costs of energy production
	kWh/m^2/year	kWh/m^2/HDD/year	t CO_2eq	kg NOx	kg SO2	kg CO	kg PM	eur/kWh
NP2	73	0.024	66.2	41.6	12.4	1.2	0.75	0.074
NP3	102.5	0.033	153.9	189.2	192.7	41.2	4	0.049

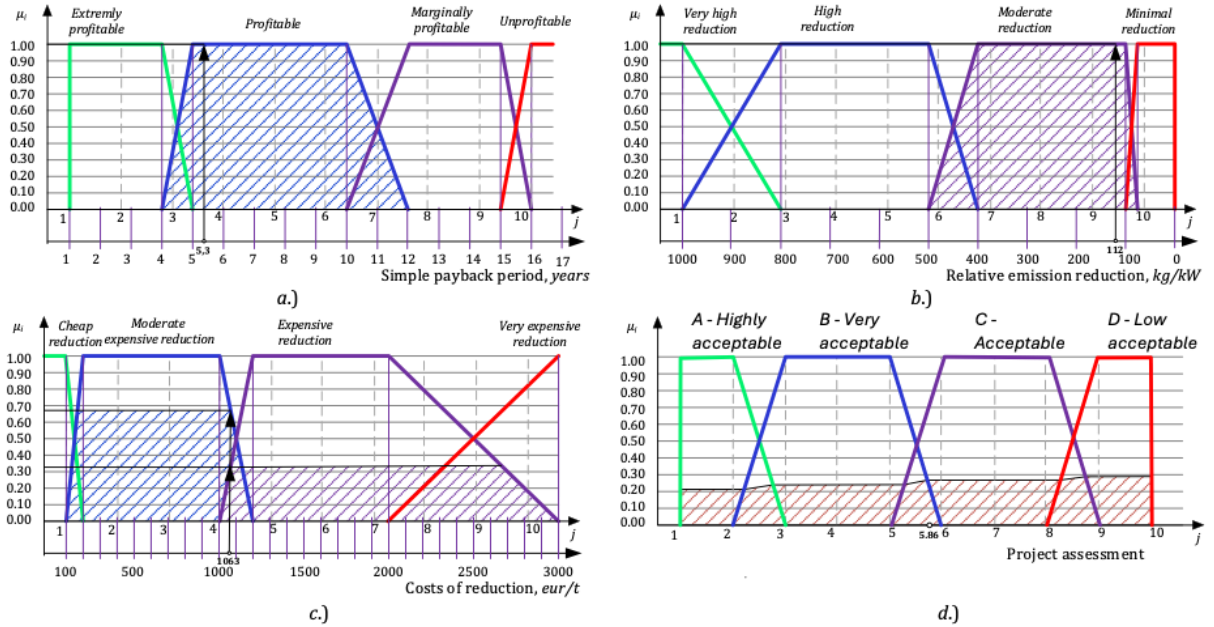
Boiler room code	Costs of energy production (eur/kWh)	Annual emissions reduction				
		t CO_2eq	kg NOx	kg SO2	kg CO	kg PM
NP2	0,056	64,1	10,6	1,18	0,61	0,073
NP3	0,046	150,5	52,8	180,4	14,6	2,5

Project code	Project Solutions	Payback Period (year)	Relative Emission Reduction (kg/kW)	Costs of Emission Reduction (eur/t)
NP2	Connection to DH system	5,3	112	1063
NP3	Pellet boiler (2 x 0.6 MW)	21,1	254	1182



Indicators' fuzzy sets and project assessment for NP2 boiler room

Case study



Indicators' fuzzy sets and project assessment for NP3 boiler room

Conclusion

- The effects of all 28 projects' realization would be 55% emissions reduction of GHGs (CO_2eqv.), 88% emissions reduction of NOx, 99% emissions reduction of SO2, 74% emissions reduction of CO, and 93% emissions reduction of PM compared to the present state.
- The Fuzzy Decision-Making model is proposed for ranking projects according to the overall score. It takes into consideration both environmental benefits and financial parameters of project realization, helping decision makers in prioritization of project realization.
- The obtained results show that most of the project solutions (20) belong to the "Very Acceptable" fuzzy set. Just one project has even better characteristics and belongs to the "Highly Acceptable" fuzzy set, while seven project solutions are evaluated as "Acceptable" only.
- The feedback from project evaluation can be used for the optimization of project solutions in the following phases of project development.

THANK YOU!

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