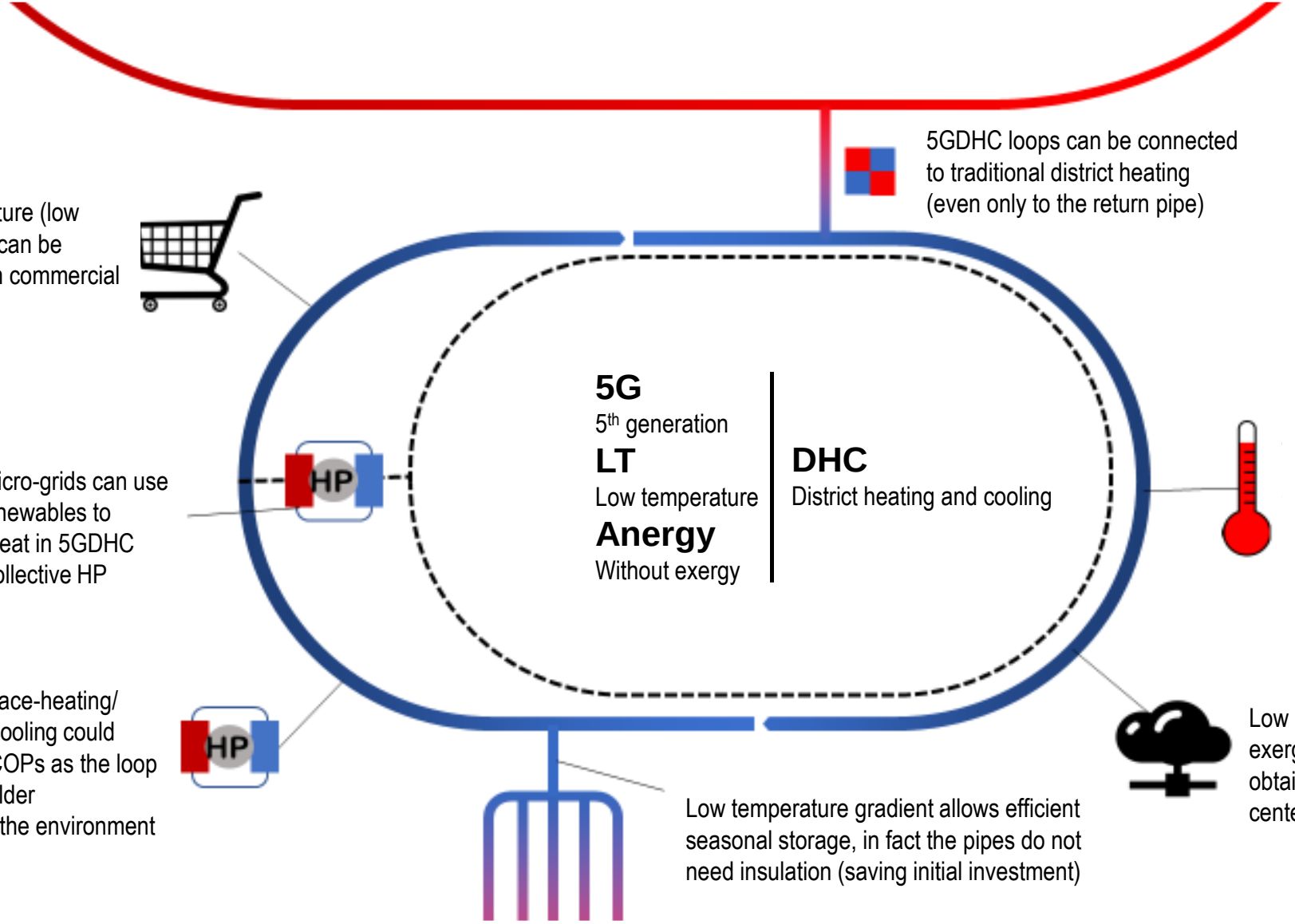
TECHNO-ECONOMIC PERFORMANCE AND FEASIBILITY STUDY OF THE 5GDHC TECHNOLOGY USING AGENT BASED MODELLING AND GIS

prof. Anna Volkova, Tallinn University of Technology

Department of Energy Technology

Nordic Energy Research

5TH GENERATION DISTRICT HEATING AND COOLING



PARTNERS

- Tallinn University of Technology, Estonia
- Dalarna University, Sweden
- Riga Technical University, Latvia
- Lithuanian Energy Institute, Lithuania

MEETINGS

- ~25 online meetings
- 2 meetings in person, bilateral meetings

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PAPERS AND PRESENTATIONS

- Presentations during international scientific conferences
  - PRESENTED: (CONECT 2022 (Riga), SES Conference (Aalborg)
  - PLANNED: SDEWES 2022 (Paphos), IAQVEC 2023 (Tokyo)

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Large-scale heat pumps for district heating systems in the Baltics: Potential and impact

A. Volkova [a,*], H. Koduvere [b], H. Pieper [c]

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Research paper

5th generation district heating and cooling (5GDHC) implementation potential in urban areas with existing district heating systems

Anna Volkova [a,*], Ieva Pakere [b], Lina Murauskaite [c], Pei Huang [d], Kertu Lepiksaar [a], Xinxing Zhang [d]

[a] Tallinn University of Technology, Estonia
[b] Riga Technical University, Latvia
[c] Lithuanian Energy Institute, Lithuania
[d] Dalarna University, Sweden

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ABSTRACT

The 5th Generation District Heating and Cooling (5GDHC) network has great advantages in terms of integration of low-temperature resources, bi-directional operation, decentralised energy flows, and possible energy sharing. One way to develop the idea and concept of 5GDHC is to identify potential agents, including residential buildings, office buildings, shopping malls, data centres, electrical transformers, and so on, in 5GDHC in each target context. The prospects for 5GDHC have been assessed in light of the conditions in the Baltics. The multi-criteria analysis method was used to quantify the main identified barriers and drivers behind the implementation of 5GDHC systems. It should be noted that new urban areas in the Baltic states are being actively developed with low-energy buildings, so 5GDHS can be integrated to supply heat to these areas. The highest score in the multi-criteria assessment was achieved by Lithuania due to support availability and open heating market conditions. When all applied criteria are weighted equally, Estonia has the most favourable conditions for 5GDHC systems due to widespread use of heat pumps and greater excess heat potential.

1. Introduction

District heating and cooling (DHC) technology has been widely recognised as a promising solution to reduce both primary energy consumption and local emissions (Rezaie and Rosen, 2012; International Energy Agency, 2014). The 5th generation district heating and cooling (5GDHC) network is the latest district heating/cooling concept, which is characterised by low temperature supply (i.e. close to ground temperature), bi-directional operation (i.e. it can provide heating and cooling simultaneously), decentralised energy flows (i.e. it allows multiple heat sources and heat sinks in the network), and heat sharing (i.e. it can recover waste heat and share it with different users) (Buffa et al., 2019). Unlike the 4th generation district heating (4GDH) technology, the 5GDHC technology is geared towards the consumer/prosumer. It only needs one thermal grid, but it serves multiple purposes for both heating and cooling distribution, including heat and cold storage, and thus provides flexibility in adopting local renewable energy and waste heat resources. As pointed out in Revesz et al. (2020), by integrating the low-grade heat with photovoltaic arrays, batteries, and vehicle-to-grid applications, 5GDHC systems also support the electrification of both the building and transportation sectors towards the broader concept of 'fifth generation smart energy networks'.

The distinction between 5GDHC and 4GDH has been studied in the past. For instance, Lund et al. (2021) performed a systematic comparison of 5GDHC and 4GDH in terms of goals and capabilities. According to their findings, 5GDHC has five of the same core capabilities as 4GDH: (i) the ability to supply different types of buildings, (ii) the ability to distribute heat with small grid losses, (iii) the ability to recycle heat from low-grade sources, (iv) the ability to be integrated into large smart energy systems, and (v) the ability to ensure proper planning and cost-effective investment. The main differences in 5GDHC are the strong emphasis on combined heating and cooling, as well as the use of a collective network close to ground temperature as a common heat source or sink for heat pumps (HP). After reviewing various literature, they also concluded that 5GDHC can be viewed as a technology with its own merits. It does not have to replace other 4GDH technologies. Instead, it can coexist with other 4GDH technologies. Ref. Gudmundsson et al. (2021) compared the levelised costs of heat from both 4GDH and 5GDHC in Denmark and the UK. The results of this study showed that, under current cost scenarios, 4GDH is more cost-effective compared to 5GDHC in both of these countries. This is due to three key factors: (1) economy of scale of central

* Corresponding author.
E-mail address: anna.volkova@taltech.ee (A. Volkova).

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- A.Volkova, H.Koduvere, H.Pieper Large-scale heat pumps for district heating systems in the Baltics: Potential and impact, *Renewable and Sustainable Energy Reviews*, Volume 167, October 2022, 112749, https://doi.org/10.1016/j.rser.2022.112749
- I.Pakere, M.Kacare, L.Murauskaite, P.Huang, A.Volkova Can suitable business models promote 5GDHC implementation? Environmental and Climate Technologies (In Press), 2022

PLANNED

- P.Kumar, P.Hauang, A.Volkova, X.Zhang Techno economic analysis of 5th generation DH system in heating-dominated climates: Simulation and parametric analysis

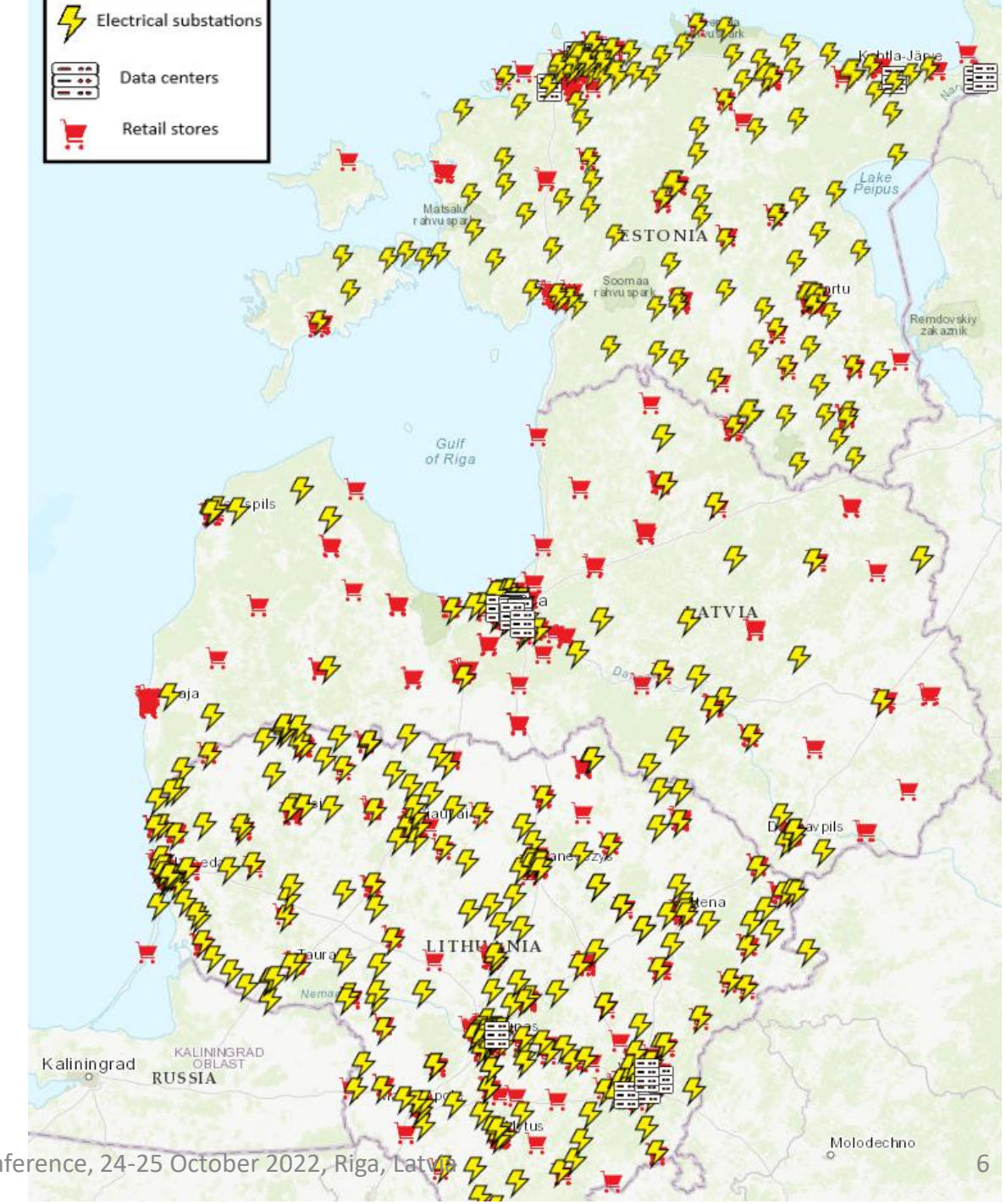
PROJECT AGENT-GIS-5GDHC

- **Duration:** 01.12.2020-30.11.2022.
- **The project addresses** the following areas of key interest for the Baltic-Nordic Energy Research Programme:
  - Energy efficiency in buildings and industry
  - Energy system analysis
  - Challenges and opportunities for regional electricity grids
- **Work packages**
  - 5GDHC database development (TalTech)
  - Technical performance analysis of the 5GDHC in representative Baltic and Nordic regions (HDa)
  - Business models for 5GDHC (RTU)
  - 5GDHC implementation and replication barriers and drivers (LEI)

OUTCOMES: DATABASE GIS MAP

- Updating the map, developed within project JBNER «Heat pump potential in the Baltic states»
- From previous project: district heating regions, sea, lakes, rivers.
- Added non-conventional heat sources:
  - Electric transformers
  - Retail stores
  - Data centres

LINK



OUTCOMES: BARRIERS AND DRIVERS

BARRIERS	DRIVERS
• Dependence on the electricity system • High initial costs • New infrastructure is needed • Increase in the price of electricity • Financial sources • Awareness • Institutional/administrative barriers • Lack of public acceptance • Regulatory and policy barriers • Pipes for heating and cooling • Centralised energy production/ limiting network expansion area • Dwelling spatial impact and dwelling noise • Existing RES based DH	• Climate change targets • Geopolitical implications of using imported natural gas • Ambitious energy transition targets of the country • Reduced price volatility • Strengthening energy security • Creating local economic value and jobs • Increased access to affordable, reliable, and sustainable energy for heating and cooling • Ability to reuse waste heat

MULTI-CRITERIA ANALYSIS

- Average final price of electricity
- Share of RES energy
- Share of heat supplied via HPs
- CO2 emission factor for electricity
- Future CO2 emission factor for electricity
- Maximum/minimum heat tariff
- DH tax rates
- Available support measures
- Possibility for new business models
- Specific building heat consumption
- Share of new buildings
- Excess heat source potential from shopping malls/transformers/data centres

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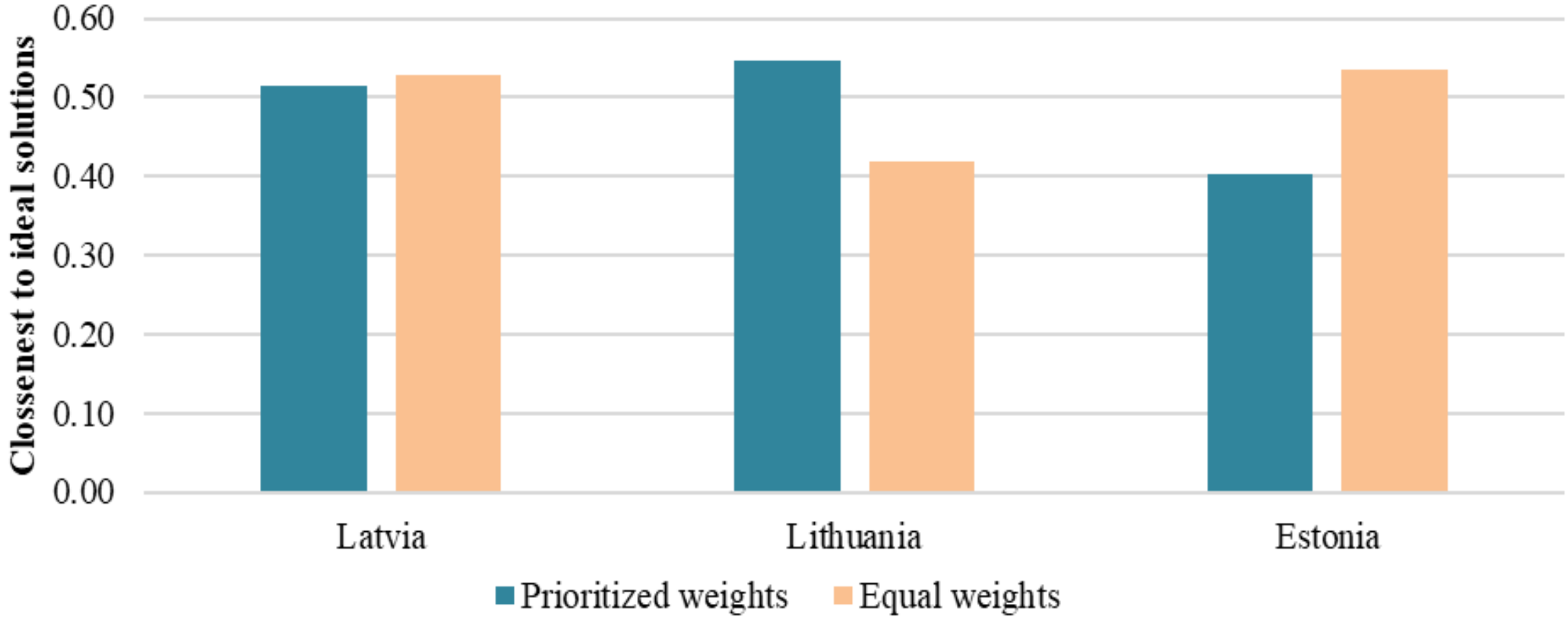
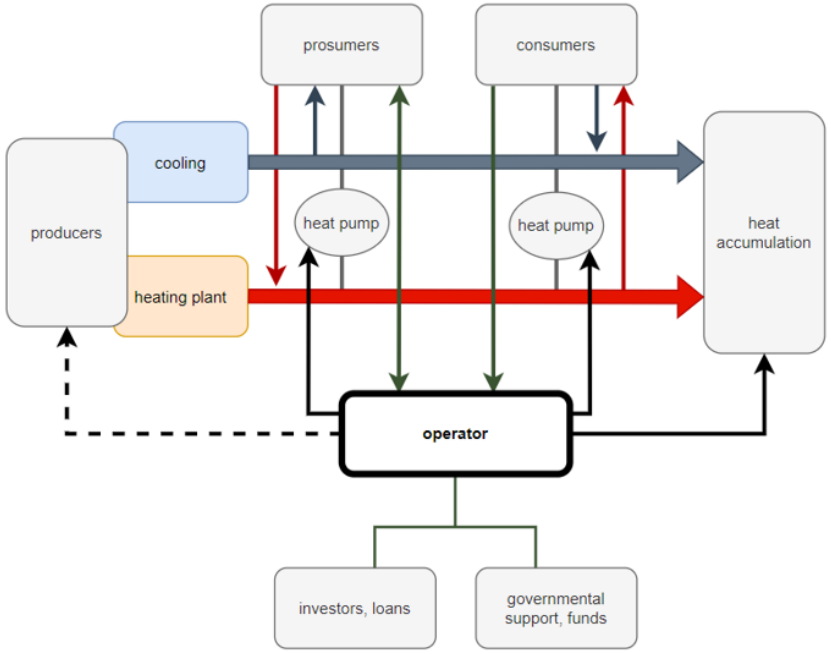
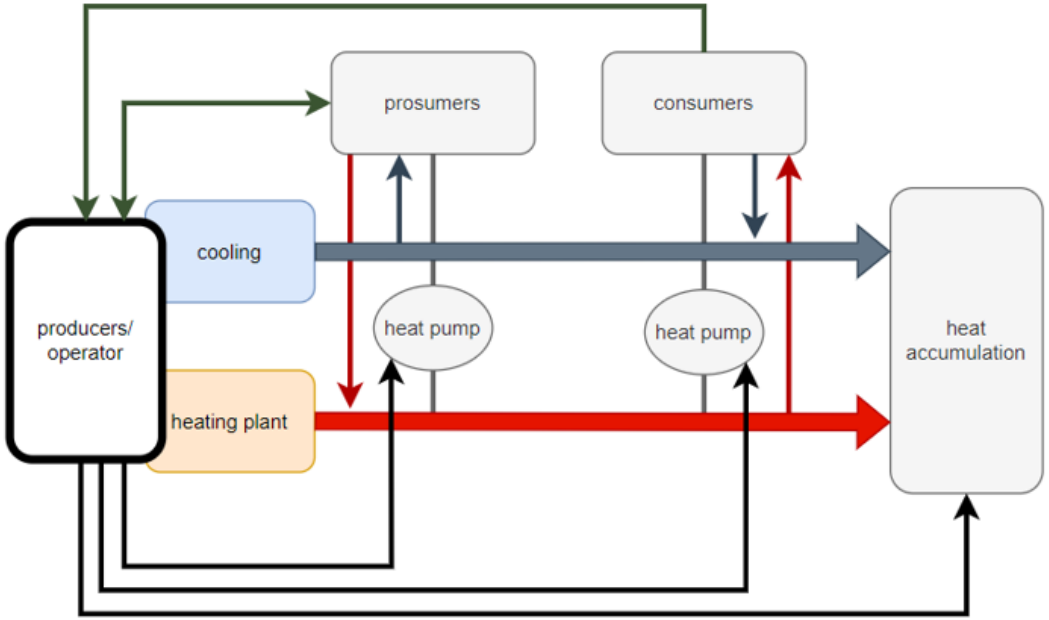
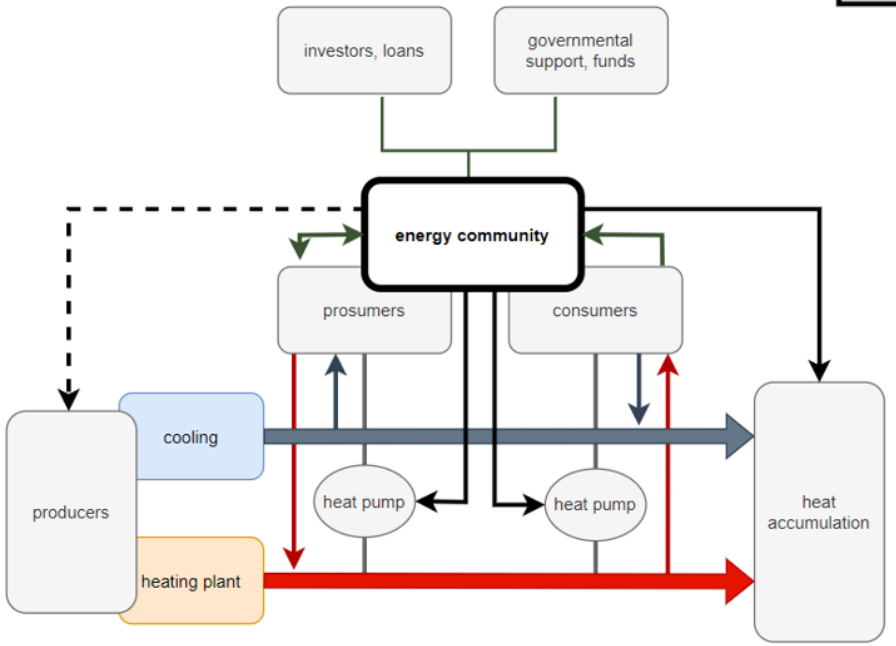
OUTCOMES: POTENTIAL FOR IMPLEMENTATION OF 5GDHC



OUTCOMES: BUISNESS MODELS BY GAME THEORY







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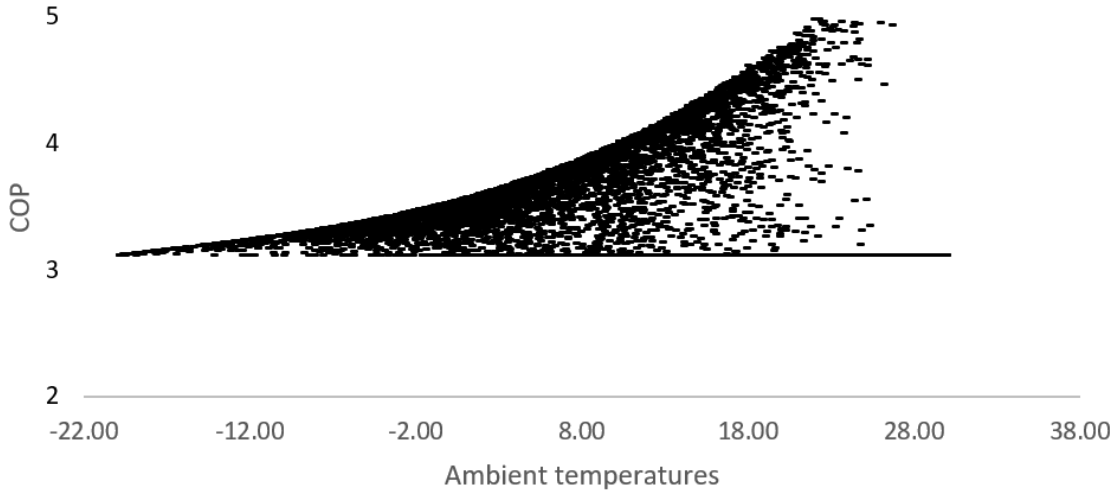
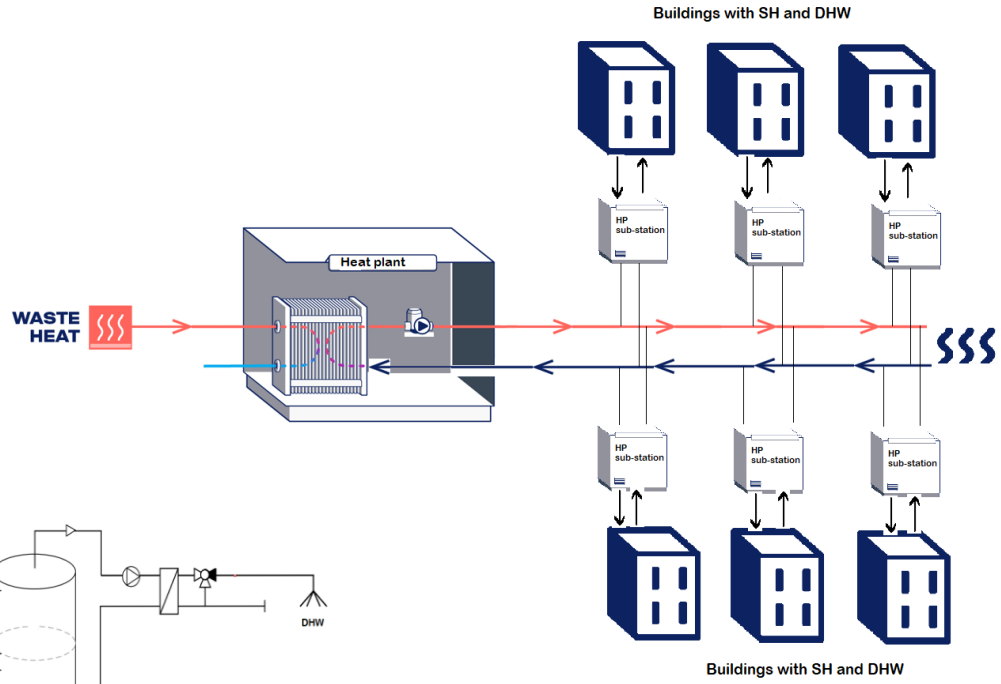
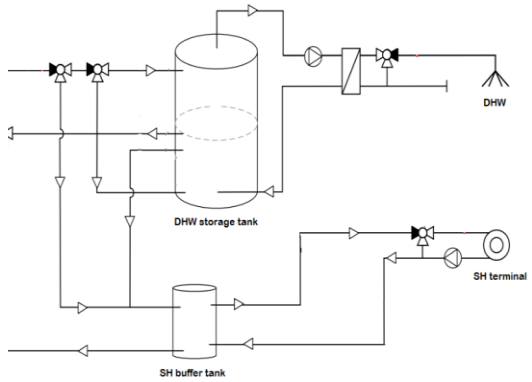
TECHNO ECONOMIC ANALYSIS OF 5TH GENERATION DH SYSTEM

- detailed thermo-hydraulic model for a small district
- TRNSYS model of substation (for 5GDHC)
- Network model in Fluid it







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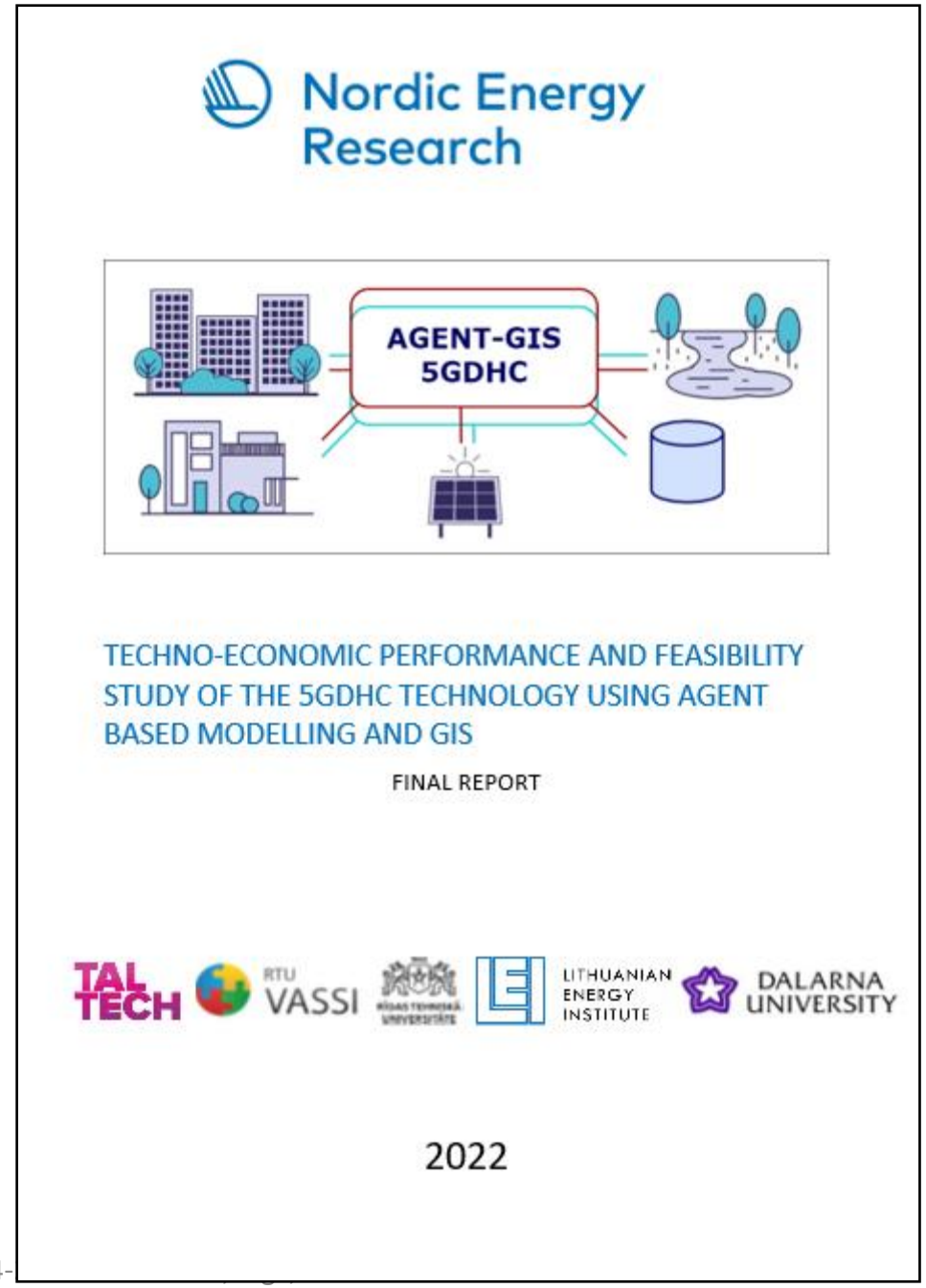
IN PROGRESS

- **Final project report**
- **Recommendations**
- **Factsheet published**
- **Final workshop**



Please contact

Anna Volkova anna.volkova@taltech.ee

https://www.linkedin.com/in/anna-volkova-8562b143/

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