The role of district heating in decarbonization:

insights from the case study on Helsinki region, Kaunas and Warsaw

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REEEM

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691739.

District heat (DH) can support the energy system transition

- Use of local biomass & waste fuels in heating
- Provide balancing to the system when wind power and solar power are increasing
    - Heat storages
    - Use of either heat pumps or CHP plants, depending on the electricity market situation
- In all these cities, DH is very energy efficient and an essential part of the energy system

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REEEM work in district heating

- Energy system models were used:
  - MESSAGE for Kaunas modelling (LEI)
  - EnergyPRO for modelling of Helsinki region (Helsinki, Espoo and Vantaa) and Warsaw (Aalto)

- TIMES Pan-EU results were interpreted to city-level
  - TIMES Pan-EU (Stuttgart University) produces cost-optimal solutions at country-level to meet the specified CO_2 emission targets by 2050
  - These scenario results were combined with the actual existing city-level targets and policies

- Also changes in heat demand due to climate change were included, modelled by DTU/Denmark.

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Case Kaunas

- Second-largest DH system in Lithuania (approx. 1.4 TWh per year)

- Dominated by biomass (90% in 2017*)

- High penetration of independent heat producers**
  - Number of independent heat producers: 9 (+2 in Kaunas region)
  - Heat generation capacity at independent heat producers: 1409.69 MW
  - Average heat generation capacity demand in the system: 151.2 MW
  - Average heat capacity supply of independent heat producers: 108.3 MW

- A new waste to energy CHP (24 MW_e and 70 MW_{th}) is being built

* Data source: http://lsta.digiart.lt/wp-content/uploads/2019/01/2017-WEB_Final.pdf
** Data source: https://www.regula.lt/SiteAssets/naujienu-medziaga/2019/NSG_apzvalga_2018_metai.pdf

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Studied DH scenarios in Kaunas

- BAU
  - No emission limitation
- C-Free
  - Linear decrease of CO_2 emissions from current level to zero in 2050

- In both scenarios:
  - Optimal investment decisions and operation scheduling is allowed
  - Operation of all existing technologies is allowed during their technical life time.
  - Rebuilding of existing technologies after end of their technical life time, extension of their capacities, construction of a new Waste-to-Energy CHP, electrical and steam-driven absorption heat pumps, solar collectors, heat storages are considered among new candidate heat producing technologies.

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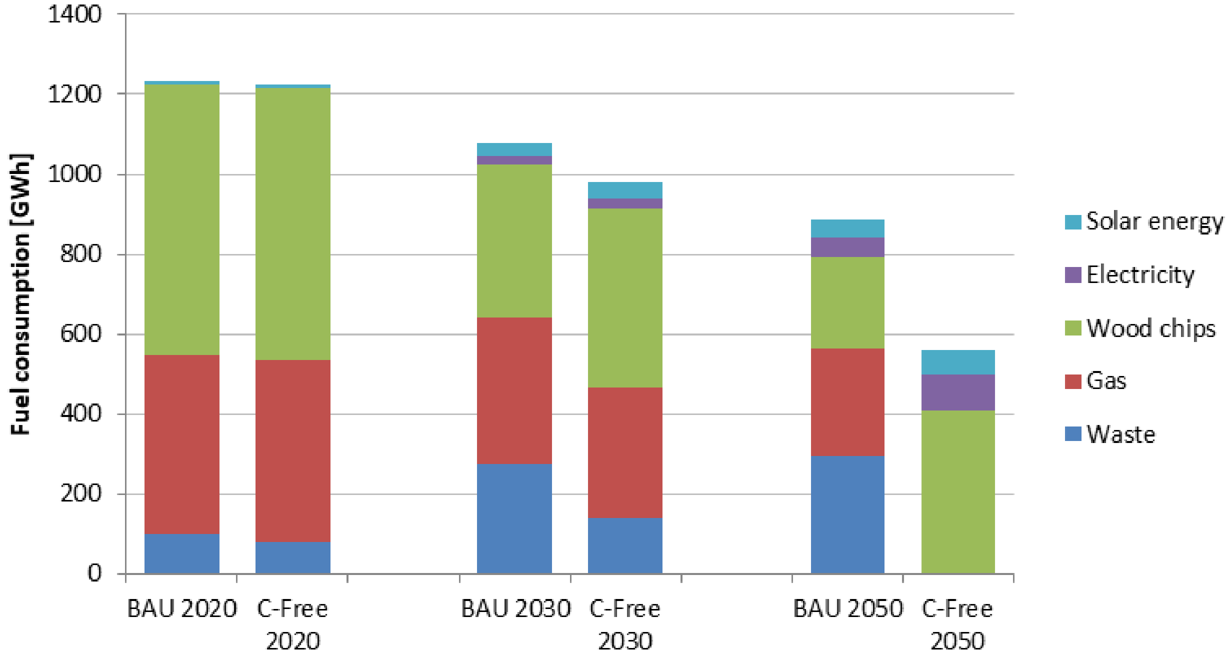
Modelling results for Kaunas



- In C-free scenario, natural gas is abandoned and replaced by mainly wood chips. Also heat pumps and solar heat become more common.

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Kaunas results and findings

- The common trend for both scenarios is the decommissioning of excess (mainly natural gas) capacities:
    - expected decrease of energy demands due to efficiency improvements (deep renovation of buildings)
    - the development of heat storages might allow for peak shaving and decreasing needs for investment in peaking capacities.
- The new investments in the Kaunas DH scenarios analyzed are made mainly to replace part of existing capacities after the end of their lifetime.
- In both scenarios, investments are put to biomass heat only boilers, but there is also a considerable capacity of new gas-fired boilers installed (in C-Free scenario they are used for reservation only). Solar collectors receive some investment, but their share in the capacity structure remains modest.
- The capacity of waste-to-energy CHP is lower than expected (up to 60 MW_{th} in BAU and 34 MW_{th} in the C-Free scenario) due to relatively low heat demand during summer. In the case of C-Free scenario, accounting of GHG emissions decreases the attractiveness of waste as an energy resource.
- The main difference between the modelled scenarios is a high penetration of steam-driven absorption heat pumps in C-Free scenario (65 MW_{th} of total installed capacity in C-Free scenario in 2050 compared to 15 MW_{th} in BAU in the same year).

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Case Helsinki metropolitan area

- Market share of DH is > 90 % in Finnish cities

- In Helsinki, CHP is important:
  - Salmisaari coal-fired CHP plant 160/300 MWe/MWth
  - Hanasaari coal-fired CHP plant 220/420 MWe/MWth, *to be closed in 2024*
  - Vuosaari natural-gas fired CHP plant 650/600 MWe/MWth
  - In addition, heat-only boilers (mainly gas), large heat pump in Katri Vala 170 MW_{heat} / 70 MW_{cool} and cold-water storages for district cooling use.

- Similar DH structures in Espoo and Vantaa. In Vantaa, also a modern waste-CHP plant exists, 920 GWh heat and 600 GWh electricity (natural gas as support fuel) .

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Studied DH scenarios for Helsinki region

2030

- Finland has recently introduced law which requires abandoning coal use in energy generation by 2029.
- We assume that coal is replaced by wood (50%) and natural gas (50%).
- A new waste CHP plant is built (heat output 140 MW, electricity output 75 MW).
- Use of waste heat is increased to 15%.

2050

- Natural gas and oil replaced by wood (60%) and heat pumps (40%).
- Geothermal energy unit built in Helsinki (heat output 40 MW).
- Capacity of solar thermal increased to 270 MW.
- Utilization of waste heat increased to 20% of heat demand.

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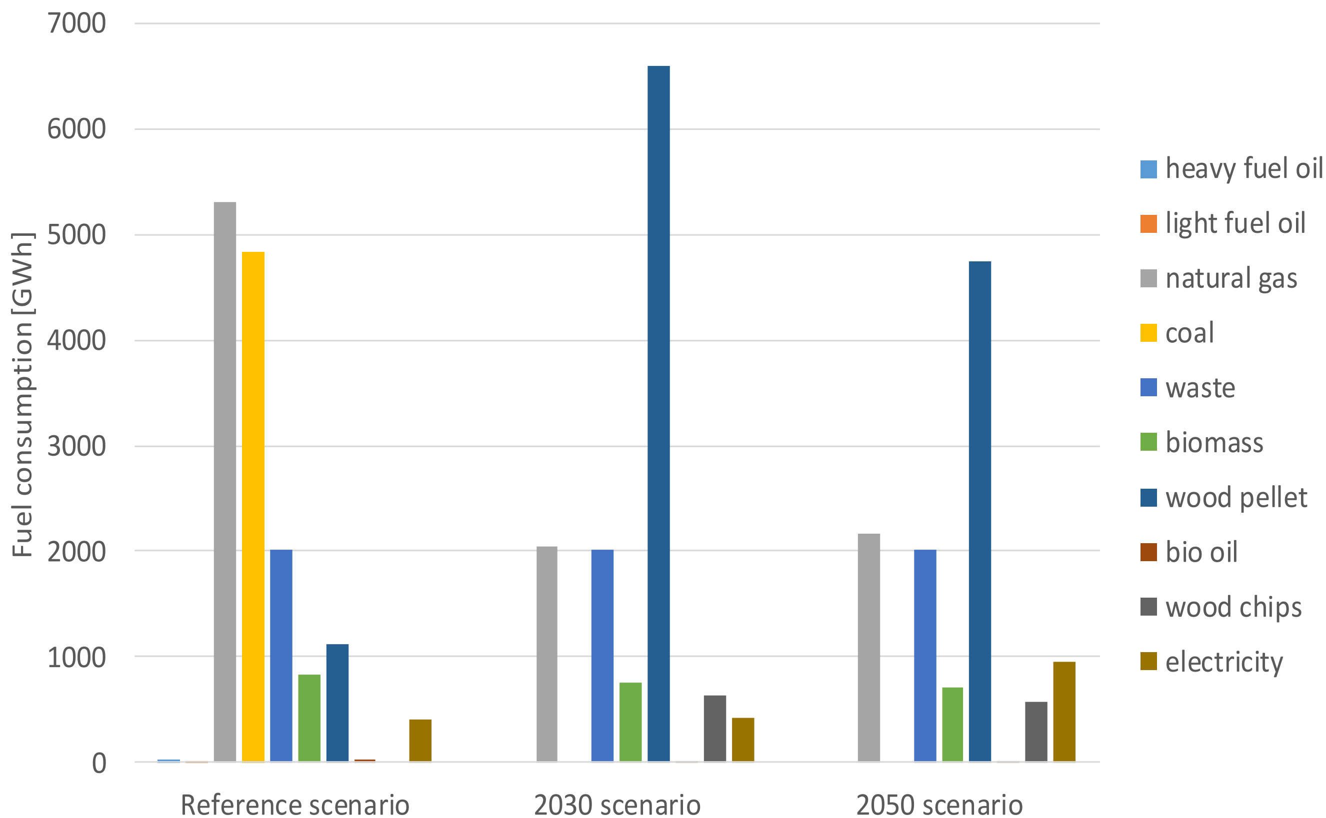
Modelling results for Helsinki region



- Waste and wood fuels and geothermal heat become important by 2050.
- With stringent climate targets, natural gas with CCS will be used as well.

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Findings on Helsinki scenarios

- According to modelling results, DH production costs would only increase modestly in ambitious low-carbon scenarios compared to already presently agreed city-level and national policies. Average heat production cost in 2050 is 58 €/MWh compared to 50 €/MWh in Reference scenario.

- In Finnish electricity market area, electricity prices will be more volatile in future due to strongly increasing wind power in Sweden and Finland

  => Heat storages are especially suitable: use of either heat pumps or CHP according to electricity market situation limits DH price increases. Heat storages are rather cheap.

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Case Warsaw

- The share of district heating is about 80% in Warsaw.

- Warsaw and whole Poland are using extensively domestic coal in electricity and heat production. Presently in Warsaw there are for example Zeran 386/1580 MWe/MWth and Siekierki 620/2078 MWe/MWth coal-fired CHP plants.

- At present, co-firing of biomass is being prepared for Zeran and Siekierki. There are also plans for a new waste-to-energy plant and to replace aging boilers by natural gas.

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Studied DH scenarios for Warsaw

2030 DH scenario

- Oil replaced by gas-fired CHP.
- Solar thermal capacity increased to 190 MW.

2050 DH scenario

- Coal use is abandoned.
- Heat capacity of gas-fired plants equipped with CCS is increased to 480 MW, electrical capacity to 240 MW.
- Increased utilization of geothermal heat (heat output 810 MW).
- Heat capacity of biomass-fired CHP plants increased to 1800 MW, electrical capacity to 770 MW.
- Heat capacity of biomass-fired HOBs increased to 1000 MW.
- Heat capacity of waste-fired CHP plants increased to 280 MW, electrical capacity to 70 MW.
- Capacity of heat pumps increased to 150 MW.
- Solar thermal capacity increased to 430 MW.

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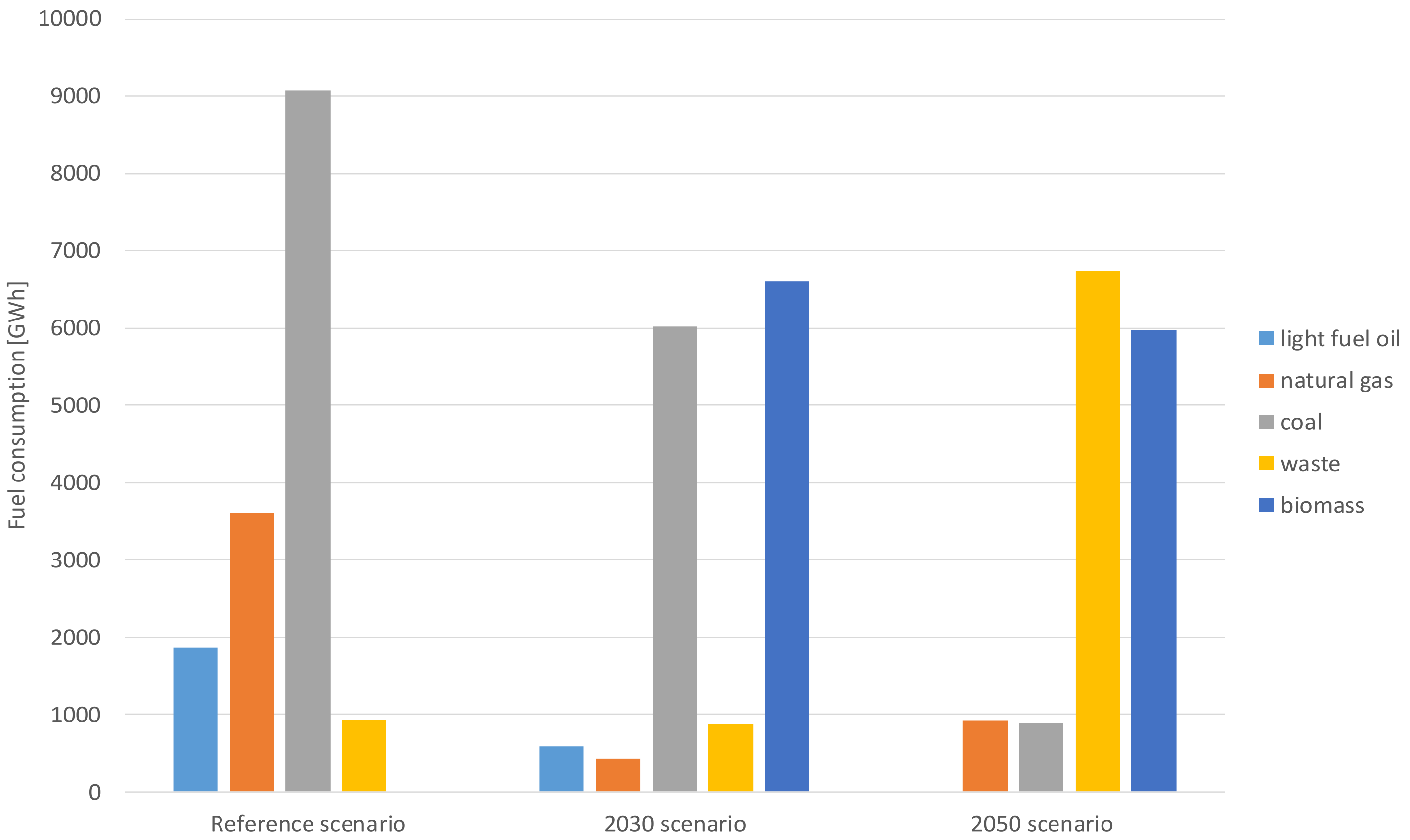
Modelling results for Warsaw



- Coal is used extensively in Warsaw. In low-CO2 scenarios, coal is mostly replaced by waste and biomass fuels.

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Specific issues in Warsaw

- Warsaw and whole Poland are using extensively domestic coal in electricity and heat production.

⇒Transition to low-carbon district heating increases costs especially in Warsaw. In low-carbon scenario, heat production cost could be about 90 €/MWh, compared to 66 €/MWh in Reference scenario.

- This can have significant adverse impacts as increasing energy poverty.

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Key findings from city-level modelling

- In Helsinki region emissions could be cut by 90% by 2050 and the average heat production costs increased only by 16%.
- In Warsaw emissions were cut by 75% by 2050 and the average heat production costs increased by 40%.
- In Kaunas emissions could be cut from 0.102 MtCO_2 to 0.087 MtCO_2 with cost increase of 29% and to zero with cost increase of 55%.

- In Helsinki region, heat production with wood and waste fuels as well as utilization of geothermal and waste heat become important by 2050.
- In Warsaw, heat pumps were profitable in 2030 and 2050 scenarios in traditional electricity price scenario.
- In Warsaw, heat production with biomass, waste and electricity increases by 2050.
- Heat storages were profitable investments in almost all cases, bringing system cost saving of about 3-6%.

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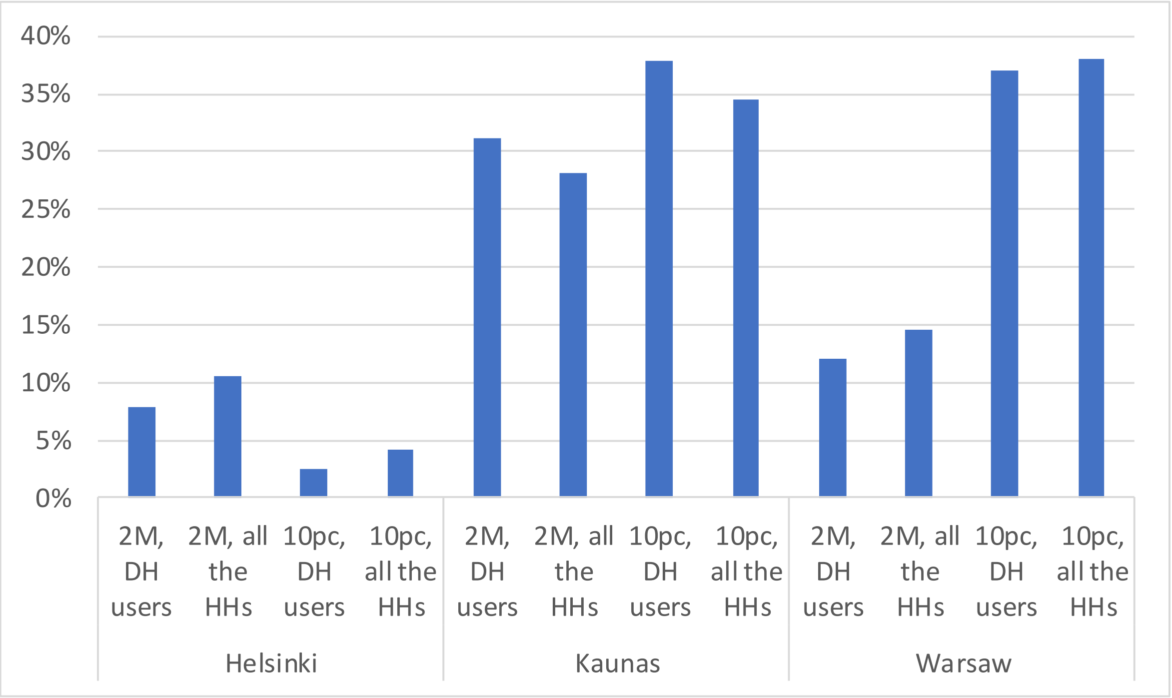
Energy poverty indicator: situation currently



- In Helsinki region, only 4% of households spend > 10% of income on energy.
- Already at present, in Kaunas 34% and in Warsaw 38% spend > 10% of income on energy.
- Energy poverty may increase significantly with ambitious emission reduction measures in DH systems.

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Publications

- Joint conference paper (Aalto, LEI) published in SDEWES conference in 2017: Hast, Aira; Syri, Sanna; Lekavičius, Vidas; Galinis, Arvydas, District heating in cities as a part of low-carbon energy system.
- Extended to Journal article: Hast, Aira; Syri, Sanna; Lekavičius, Vidas; Galinis, Arvydas, Energy 2018. **District heating in cities as a part of low-carbon energy system.**
- Conference paper (Aalto, USTUTT, DTU) in EEM conference in Lodz, Poland 2017: Hast, A., Syri, S., Welsch, J., Korkmaz, P. & Balyk, O., 2018, 15th International Conference on the European Energy Market (EEM). **Transition to carbon neutral energy systems – implications to district heating in cities**.

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Thank you for your attention!

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