Summary: 100MW of AI-driven district heating in Espoo

In Finland, there is no future for the fossil-based fuels and the district heating companies are seeking the most feasible ways to replace the fossil-fired units. Since there is no single "silver bullet" technology to cover the absence of the fossil-fired units, the replacements come from a variety of new innovations.

In Espoo, the second largest city in Finland with over 280,000 inhabitants, Fortum have a roadmap to decarbonize the city's district heating system during the 2020's. The most viable technologies seem to be heat pumps that utilize excess heat from the data centers, sewage water or industrial processes. Fortum will also utilize geothermal heat and pilot some air-to-water heat pumps. All of these new production methods make the 1,474 MW district heating network really complex and difficult to operate. At the same time, our 200,000 end-users in Espoo are expecting district heating to be affordable also in the future. They also want even better living conditions with stable temperature.

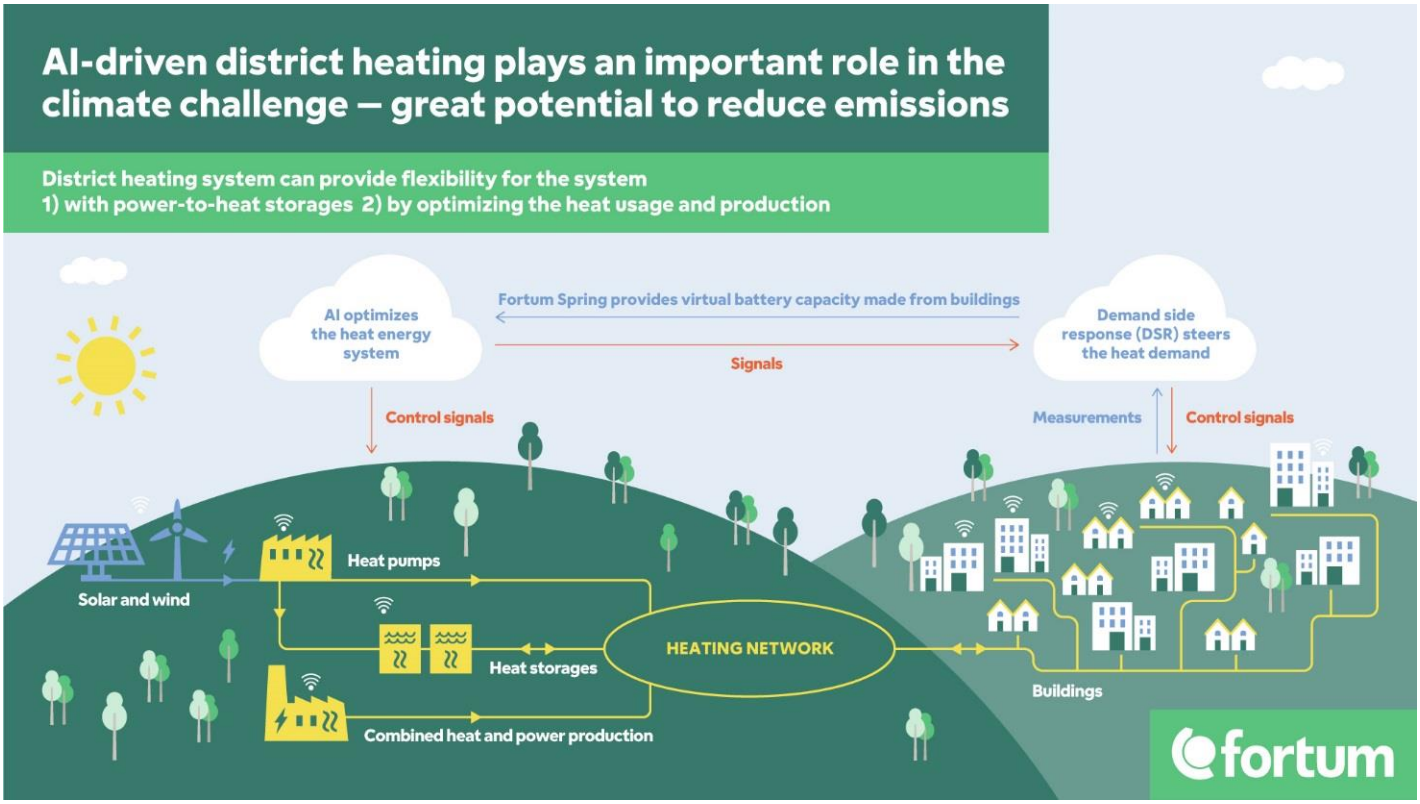
How to solve these important issues? Our answer is artificial intelligence and the smart digital steering system. We are implementing a AI-driven smart steering and end-to-end optimization system for 100MW amount of customer buildings during 2019 in Espoo and we're aiming to scale it up after that. Our target is to cover up to 80% ordered power in the system level. This may be the largest implementation in the world.

The benefits of the system for the customer are: more stable temperature and humidity in the apartment and cost savings by reduced peak power need. For the society the benefit is cleaner heat production and for the operator better profitability through data-optimized production. Over time, established data connectivity also enables better control over ever-increasing complexity of the network. Our system's operation is based on 1) system level optimization 2) building level optimization and 3) apartment-specific optimization.

Building level optimization: by establishing the two-way data connectivity to the buildings connected to the district heating network, we are able to steer the heat demand in the buildings in a flexible way. The building level optimization system controls the heating volume of the connected buildings by optimizing the energy usage in entire building. The end-user won't notice any difference in their living conditions. This also saves energy and costs for the customer. In a pilot project, the energy savings has been around 7-10% and the cost savings around 10-15%. The system is being used e.g. in Espoon Asunnot housing company and in several other housing companies in Espoo. Connected buildings can be further integrated into system level optimization offering flexibility potential to the whole district heating network.

System level optimization: The flexibility potential offered by the buildings can be used in the demand side response (DSR). With DSR we are able to reduce peaks in heat consumption as all the buildings are not heated in maximum volume at the same time. When the consumption peaks are lowered, there is no need to use peak load production units which reduces the amount of fossil fuels in heat production and therefore emissions. Calculated theoretical CO2 emission reductions for the 100MW connectivity are 417 tons. The established data connectivity also serves for future purposes and for the optimization of the system which is more and more scattered and complex. Most importantly, it helps to choose the optimal merit order of all assets in the system including DSR by taking into account for example weather conditions, commodity prices and electricity prices.

Apartment-specific optimization: The system enables better living comfort and energy efficiency in the building. Apartment-specific sensors are sending data to the substation which controls the apartment's temperature and humidity. The system also enables digital customer feedback channel and notifications about moisture and temperature deviations through the dedicated mobile app.



In the district heating system, energy recycling means the utilisation of a mix of electrical heat pumps, waste heat, ground heat and geothermal production instead of traditional combustion-based heat production. This kind of district heating system supports carbon neutral energy system which is based on the clean electricity.

As combustion-based heat production decreases and heating becomes electrified, heat production will be scattered here and there. Instead of a few large primary production plants, there will be many smaller production units that will supply heat for the district heating network, each in its own way. This will lead to a complex district heating system.

The district heating network also provides an irreplaceable flexibility element for the new energy system. The increase of wind and solar power will also affect the future electricity market. However, because the wind is not always blowing and the sun is not always shining, the future electricity system will require flexibility, i.e. ways to store the energy. The district heating system will enable this.

Heat can be produced from electricity and heat can be stored. On a daily basis, heat can be stored in district heating networks, heat accumulators and in buildings. In the future, heat can be even stored in longer-term seasonal storages. District heating also significantly differs from other heating options by enabling energy recycling through the district heating network. For example, it can recycle the excess heat of buildings, industrial processes, data centres and sewage water and utilize it in cost-efficient way.

Smart and sustainable district heating holds great potential to reduce emissions. However, maximising this potential will require residential buildings, commercial buildings and other counterparties to actively connect to the district heating networks. The only way to recycle the energy is inside the network. Individual heat pumps and other similar stand-alone solutions cannot transfer heat between consumers. This needs to be kept in mind when considering the actions we in society want to take to resolve the climate challenge.

How can buildings provide flexibility for the system?

Heat demand varies by season, week day, time of day, temperature etc. Traditionally, demand peaks have been covered by increasing heat production. Usually this has meant producing extra heat at heat plants, often by using fossil fuels.

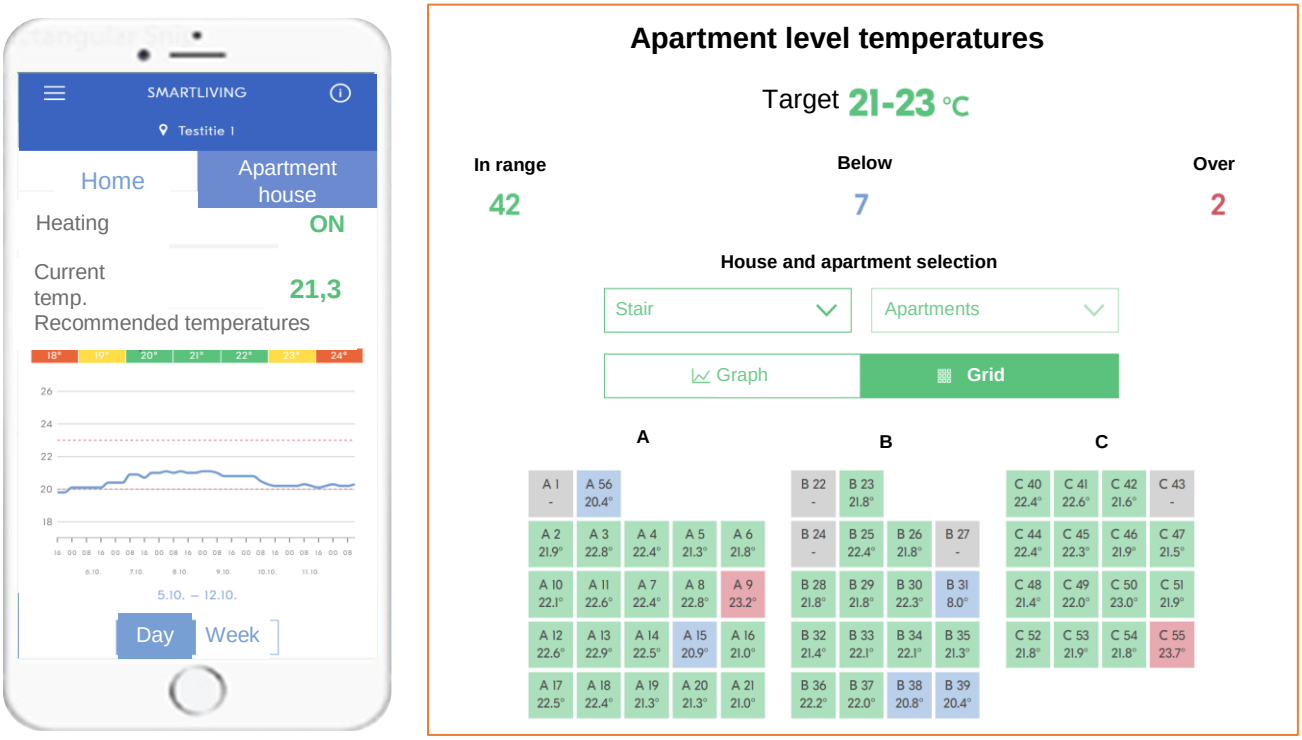
In the future, demand and supply in a smart district heating system can be optimised and controlled automatically in order to bring flexibility to the system. Buildings are used for different purposes and at different times. Everything does not have to be heated simultaneously. For example, when spaces are not being used, heating and ventilation could be reduced. Or, for example, to avoid peak loads, heating could be reduced while hot water is being used. Consumers wouldn't notice these kinds of short interruptions.

Fortum cooperates with several different actors in different countries to provide energy savings at the real-estate level. However, just the real-estate level is not enough – a demand side response is needed at the entire district heating system level. Centralized demand side response is a kind of virtual battery, which enables real-estate level steering from the district heating system's point of view. Fortum has started the development in cooperation with the City of Espoo in Finland.

Piloting of Demand Side Response with Espoon Asunnot started already in 2015. The pilot covered fan apartment house where temperature sensors were implemented. Based on a pilot results the algorithms to forecast the heating demand, optimize indoor conditions and decrease the overheating were developed further. In the piloted apartment house the heating demand has decreased by 10 per cent.

During autumn 2018 the DSR system and temperature and humidity sensors were installed to almost all of the buildings owned and maintained by Espoon Asunnot, a company providing rental apartments in Espoo. The implementation of DSR was the largest in the Nordics at the time.

The service is enhancing the living conditions, decreasing the heating demand and increasing the efficiency in the district heating system. The indoor temperature in the apartment flats are more stable, there are less overheated apartments, less apartments where temperature should be higher and number of alarms has decreased. A separate App was created to give a chance for property managers to follow-up the indoor temperatures in every apartment. Residents were given their own view to see their indoor temperature in real-time and give feedback on the conditions through the App.



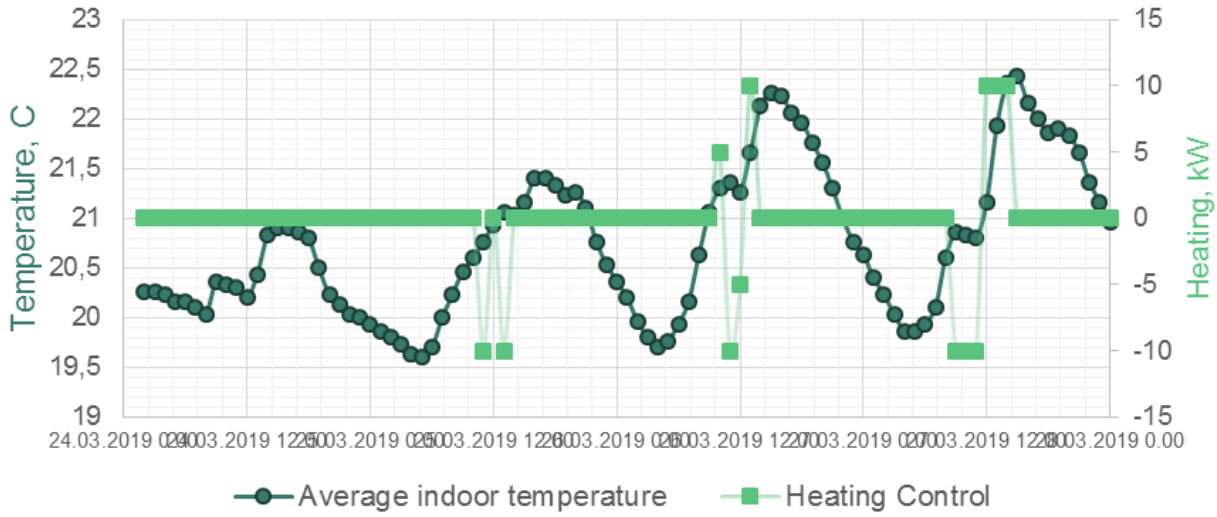
Picture 1: App for property managers and residents for monitoring the building and individual apartments

Artificial intelligence (AI) to optimise the entire district heating system

Fortum has developed artificial intelligence to optimise the district heating system and its operations; this will enable the flexible district heating system of the future. AI predicts the heat demand of our customers, steers the usage of storages and guides the control room in the optimal utilisation of assets. In practice, already now, this often also means the prioritisation of carbon-neutral production. AI has already been implemented in Fortum's district heating systems in Finland, the Baltic countries, Poland and Norway.

Building of the system level optimization started with the building level optimization in 2015. The pilot implemented a system which optimizes the heat demand in an apartment building with temperature and humidity sensors in every apartment. In 2018, the system was expanded into 300 buildings. In 2019 both the district heating system level optimization and building level optimization were integrated into a system level AI-driven smart steering enabling the utilization of the heat capacity in the buildings to be used as a virtual heat storage - in 2019 this will be scaled up to 600 apartment buildings and two largest shopping centers in Espoo creating a 100MW virtual storage.

System level optimization was tested in 5 schools and kindergartens in Espoo in the beginning of 2019. Indoor temperature sensors were installed to follow how changers in heat controller were affecting the indoor temperatures. The pilot showed that moderate commands for Demand Side Response (DSR) delayed or accelerated changes in indoor temperatures but did not have a noticeable impact.



Picture 2: Pilot in schools and kindergartens showcased how controlling the heating by increasing or decreasing the heating power affected the indoor temperatures

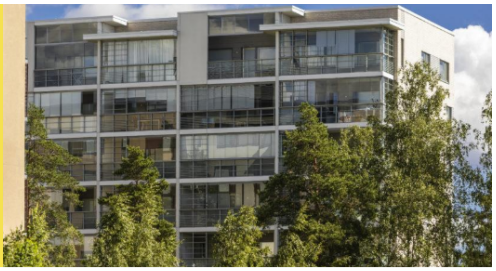
Two largest shopping centers in Espoo joined the DSR programme in spring 2019. The systems are based on cloud-to-cloud connections where Fortum's AI is sending request for DSR and local automation is implementing that within the acceptable limits without compromising the heating nor the air quality indoors.

Picture 3: Two largest shopping malls in Espoo, Sello and Iso Omena, joined the DSR programme in spring 2019.

AI development work and integration into operations continues. Artificial intelligence will enable automation of district heating when electrification increases the amount of controllable units as the energy system becomes more complex. This way, the district heating system becomes an enabler of flexibility for the electricity system. It can provide mechanisms for the frequency market and cost-efficiently decrease investment needs for the electricity distribution network.

CUSTOMER STORY

Espoon Kilonhovi housing association saved up to 13% in district heating expenses in one year



2003
Building year

79
Apartments

up to 13%
Savings in heating expenses

USED SERVICES

Heating optimization

Discover a new, smarter way to heat your building - with living comfort always in mind

Read more →

Espoon Kilonhovi is a 79-apartment housing association in located in Espoo Finland. They have faced various issues with high annual heating costs and uneven temperature in apartments. To fix these problems, they started using the Fortum SmartLiving heating optimization service in December 2017. The SmartLiving heating optimization service continuously measures temperature and humidity from each apartment and based on this information adjusts the right amount of heating energy for that instant, also taking the outdoor weather forecast into consideration.

"The best thing about SmartLiving is that the heating costs for our building have decreased by 13% in less than a year."

Satu Lind
Espoon Kilonhovi Housing association

"After hearing about the SmartLiving service through one of our board members, we begun to research what kind of benefits and extra costs the service could bring to our housing association. After weighing the benefits and the price, we wanted to give the service a go – as the benefits seemed so substantial.", says Kilonhovi's chairman of the board **Satu Lind.**

Smart heating control system brought long wanted savings

According to Satu Lind, the two major causes for high heating costs were the significant differences in apartment indoor temperatures and large lobby spaces, that have always been kept too warm. Attempts to adjust the heating system manually to lower temperatures in stairwells did not produce desired results. The new smart heating system came as a saving grace.

""The best thing about the service is that the district heating costs for our building have decreased by 13% in less than a year", Satu Lind points out. The monthly email report also receives praises. "As the chair of the board, the report keeps me up to date whether or not apartment temperatures and humidity meet the recommended level. I can also check up on resident feedback regarding these."

Residents are satisfied with even temperatures

In addition to savings Satu Lind has also received thanks from residents due to considerably more even temperatures in their homes. Before the association started using the optimization service were differences in temperatures significant – during winter the coldest apartments only had temperatures of approximately 18 to 20 degrees, whereas the hottest ones had measurements of over 26 degrees. "At first our residents were worried that we as the board had made an investment in something completely useless. But after getting results very quickly we started receiving praises and thanks. After the initial learning period residents of apartments that were previously too hot or cold have been satisfied."

Source: https://www.fortumsmartliving.com/customer-story/espoon-kilonhovi/

Other links:

Fortum SmartLiving: https://www.fortumsmartliving.com/

SmartLiving pilot: https://leanheat.com/2017/05/23/fortums-new-service-reduces-district-heating-costs-artificial-intelligence/

Fortum Spring: https://www.fortum.com/products-and-services/smart-energy-solutions/virtual-battery-spring

Emission-free district heating is under construction in Espoo: https://www.espoo.fi/en-US/Housing_and_environment/Sustainable_development/Energy_solutions/Emissionfree_district_heating_is_under_c(128317)

The City of Espoo and Fortum introduce solutions for an emission-free city: Carbon-free district heat and smart heating solutions: https://www.fortum.com/media/2018/01/city-espoo-and-fortum-introduce-solutions-emission-free-city-carbon-free-district-heat-and-smart-heating-solutions

From Smart Homes to Cities and Back – How Smartness Shapes Residential Buildings. White paper. https://www.demoshelsinki.fi/wp-content/uploads/2017/12/how-smartness-shapes-residential-buildings.pdf

Artificial intelligence holds a substantial promise for the power industry: https://www.tekoalyaika.fi/en/2018/11/artificial-intelligence-holds-a-substantial-promise-for-the-power-industry/