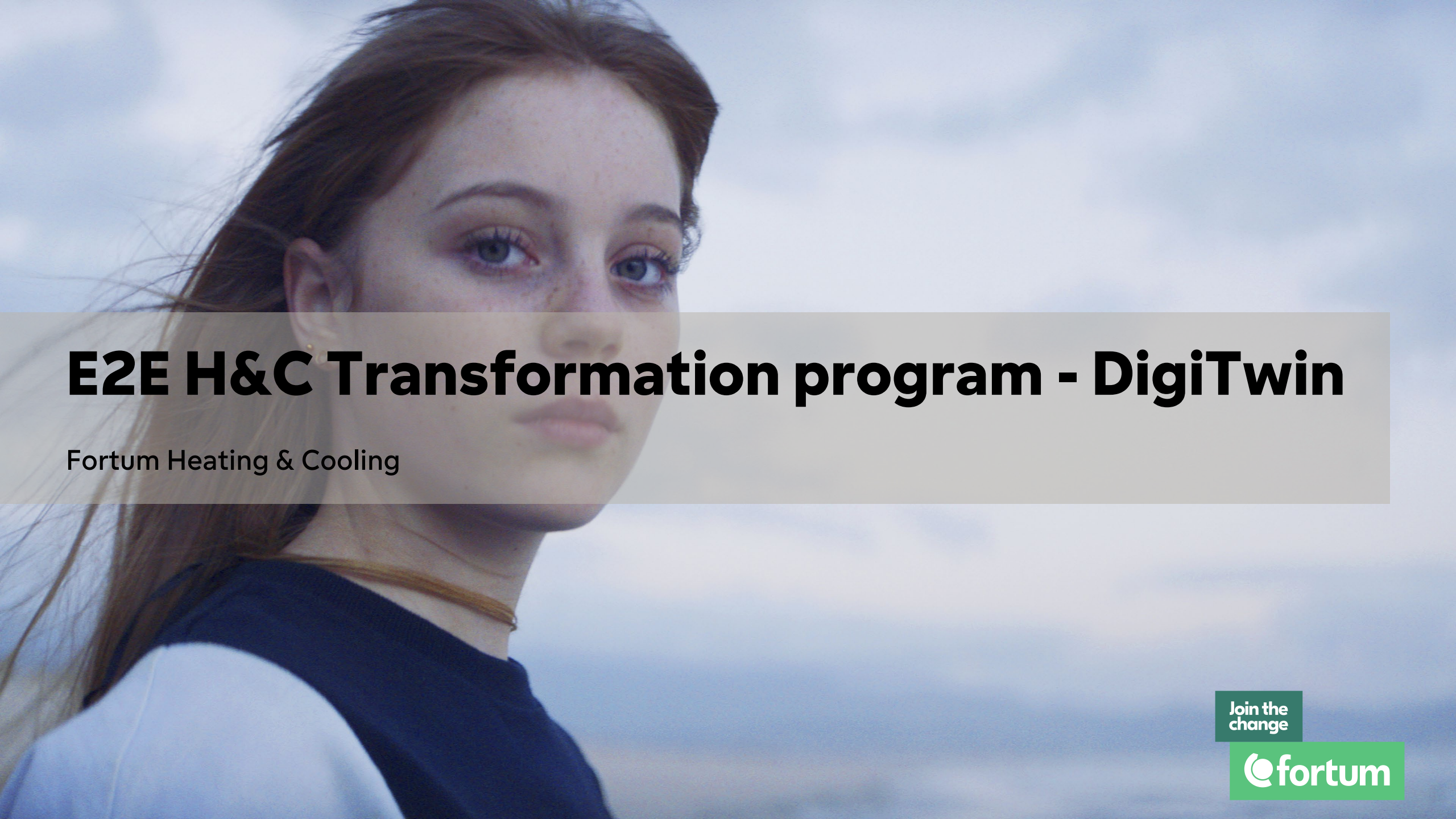

E2E H&C Transformation program - DigiTwin

Fortum Heating & Cooling

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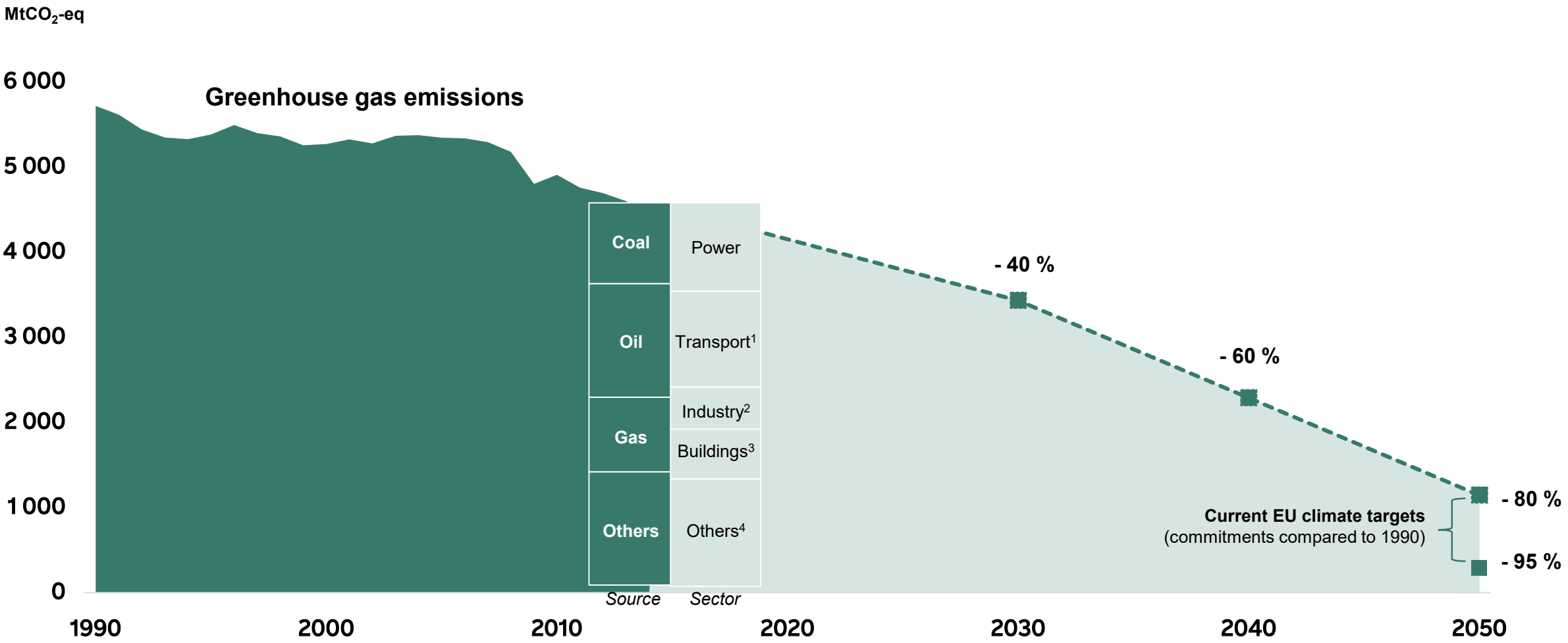
Europe needs to eliminate CO2 emissions to reach climate goals – actions required from all sectors



Sources: European Environmental Agency (total emissions), IEA World Energy Outlook 2018 (fuel emissions), EURELECTRIC (sector emissions), Fortum Industrial Intelligence

[1] including international aviation and marine

[2] iron & steel and chemicals are among the biggest contributors

[3] residential and commercial heating & cooling

[4] non-energy related emissions: industrial processes and product use, waste management, agriculture, fugitive emissions

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Heating & Cooling has its own role in the climate challenge

1

Reduce heating emissions by electrifying production and utilizing waste heat

2

Enabling flexibility to the electricity market helps to reduce overall emissions from the electricity system

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District heating changing

District heating today

- Large centralized production units
- Fossil base production
- Peak production units ensures heat supply at momentary peak consumption
- The heating sector is also a producer of electricity
- CHP[1] production as a base production
- Generated heat is delivered to customers through the district heating network

District heating in the future

- Distributed heat sources
- Carbon neutral and non-combustion base production
- Demand side response offsets peak consumption and reduces the use of peak production units
- The heat sector will become an electricity consumer
- The role of CHP[1] will change to security of supply
- District heating network enables recycling of waste heat → The need for primary energy is reduced

1 Combined heat and power

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Case Espoo – the 2nd largest city in Finland

- 280,000 residents
- Awarded as the Most Sustainable City in Europe
- Carbon-neutral Espoo in 2030
- District heating accounts for over 50% of the CO2-emissions at the moment
- 900 km of district heating network including also the municipalities of Kirkkonummi and Kauniainen
  - Total 250,000 end users
- Heat production capacity 1380 MW
- Total annual heat production 2,200 GWh, power generation nearly 600 GWh
- 230 MW of coal-fired heat units in base load use, accounting for 50% of production

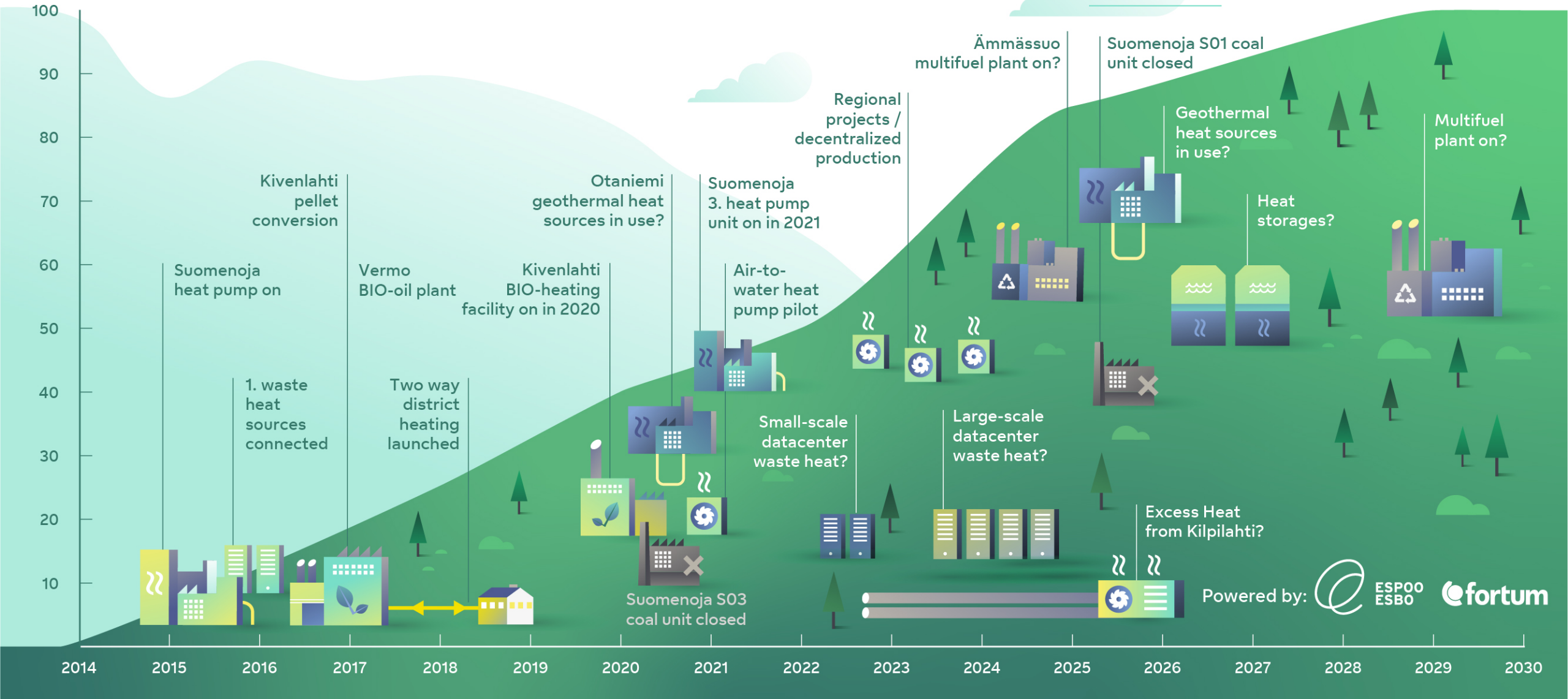
Espoo district heating transformation journey 2014–2029

Illustrative

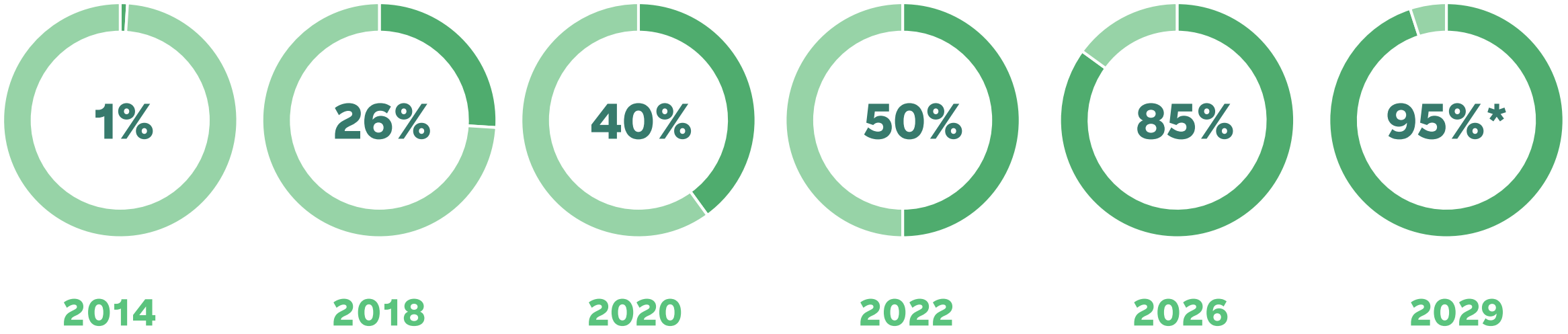
Espoo Clean Heat

% CO_2 emissions in relation to 2014 level

% share of carbon neutral production



Amount of carbon neutral district heating in Espoo (forecast)



* Due to security of supply, a certain proportion of natural gas remains in capacity. This proportion will be compensated

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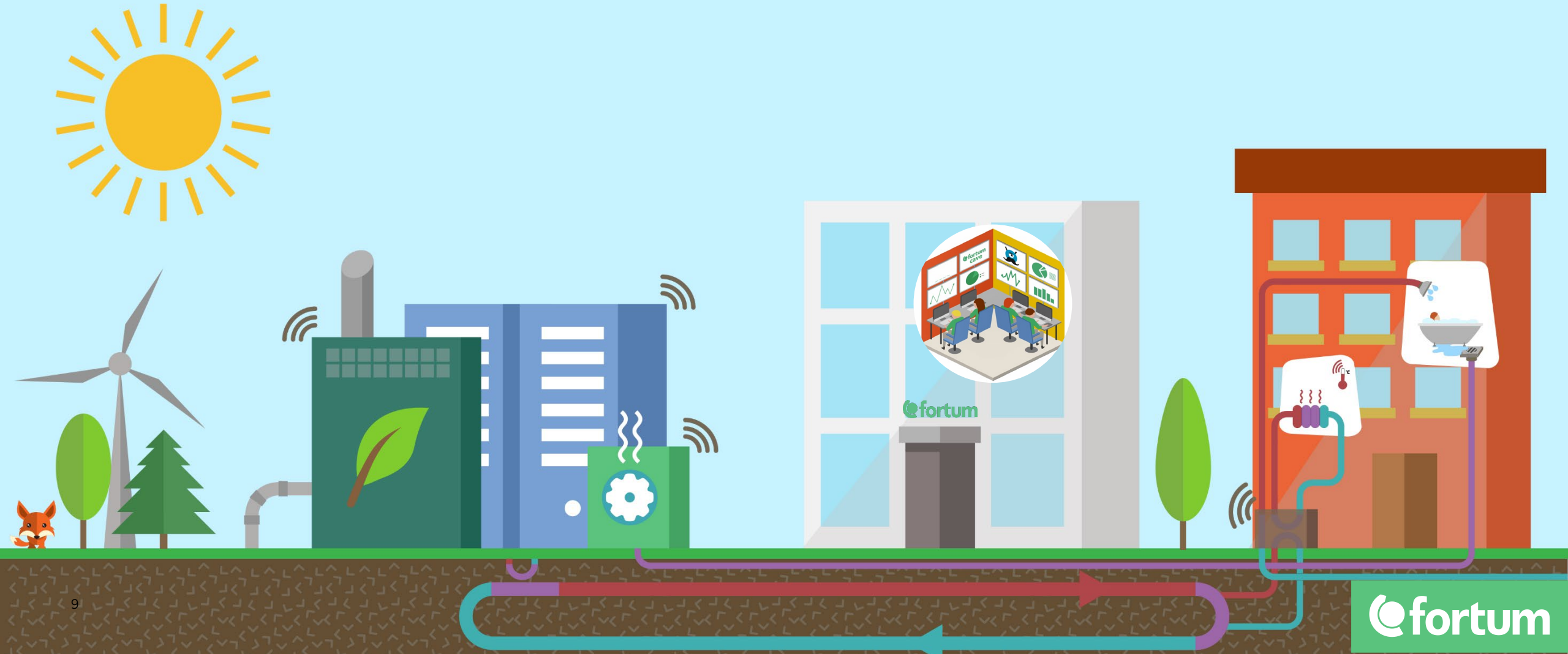
AI-driven district heating plays an important role in the climate challenge – E2E H&C transformation in key role

Three major changes

1. Increasing complexity requires automation of operations
2. System optimization ensures efficient operation and provides flexibility for the electricity market
3. New customer services enables energy efficient properties and helps reducing local emissions



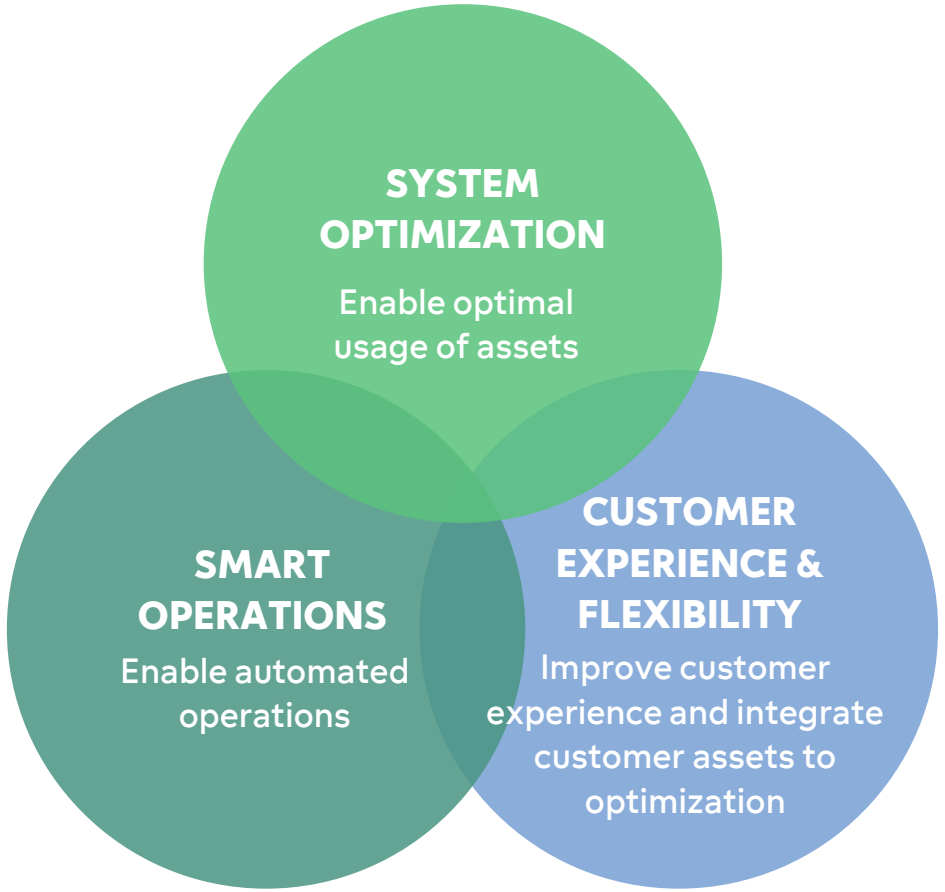
End-to-end transformation program in Heating and Cooling

Decarbonization in Heating and Cooling is mainly driven by electrification, transforming the business from centralized power producer towards de-centralized power consumer. Increasing complexity requires automation and sector coupling opens opportunities for value creation through system optimization.

1. **Smart operations**
   Automated steering of operations and centralized asset dispatch and trading in single control room lower operating cost and ensure reliability and responsiveness for E2E optimization
2. **System optimization and sector coupling**
   With electrification and demand-side response, heat system can provide flexibility for the power system, adding a dimension to the E2E power and heat systems optimization.
3. **Customer experience and flexibility**
   Improved digital customer experience, value adding services and modern pricing models retain customers and enable demand-side response.

Identified benefits:

- Improve heat supply costs
- Reduce fixed costs
- Optimize capital expenditure
- Enable decarbonization
- Improve customer experience



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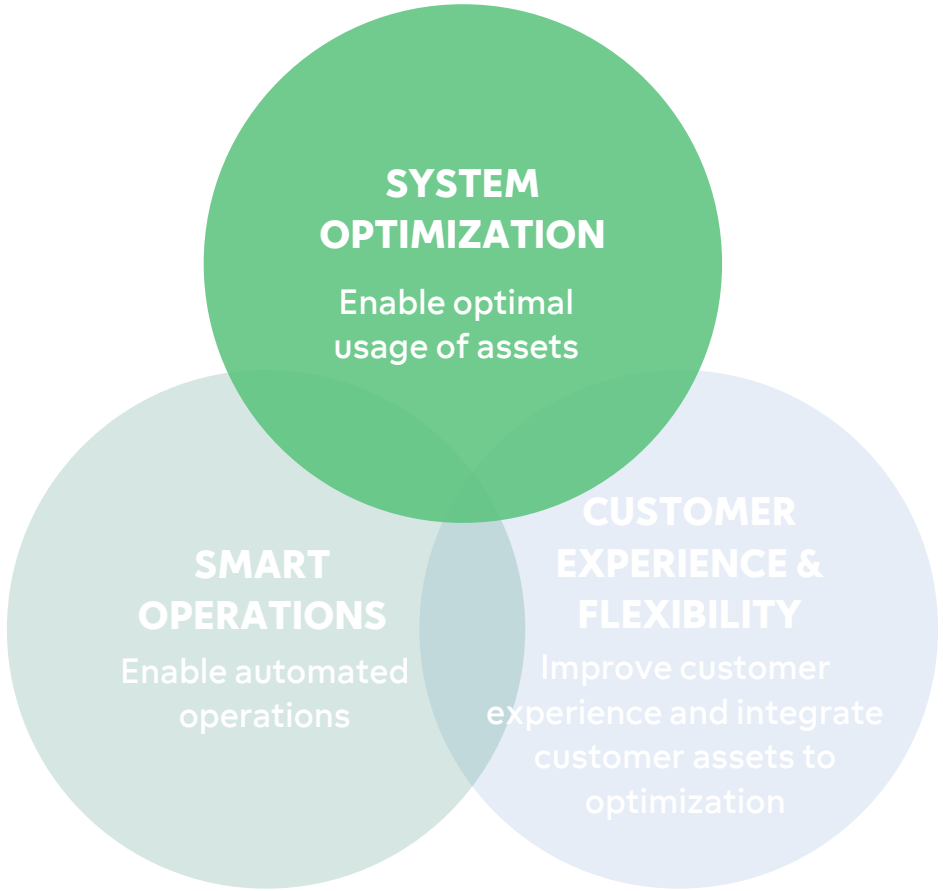
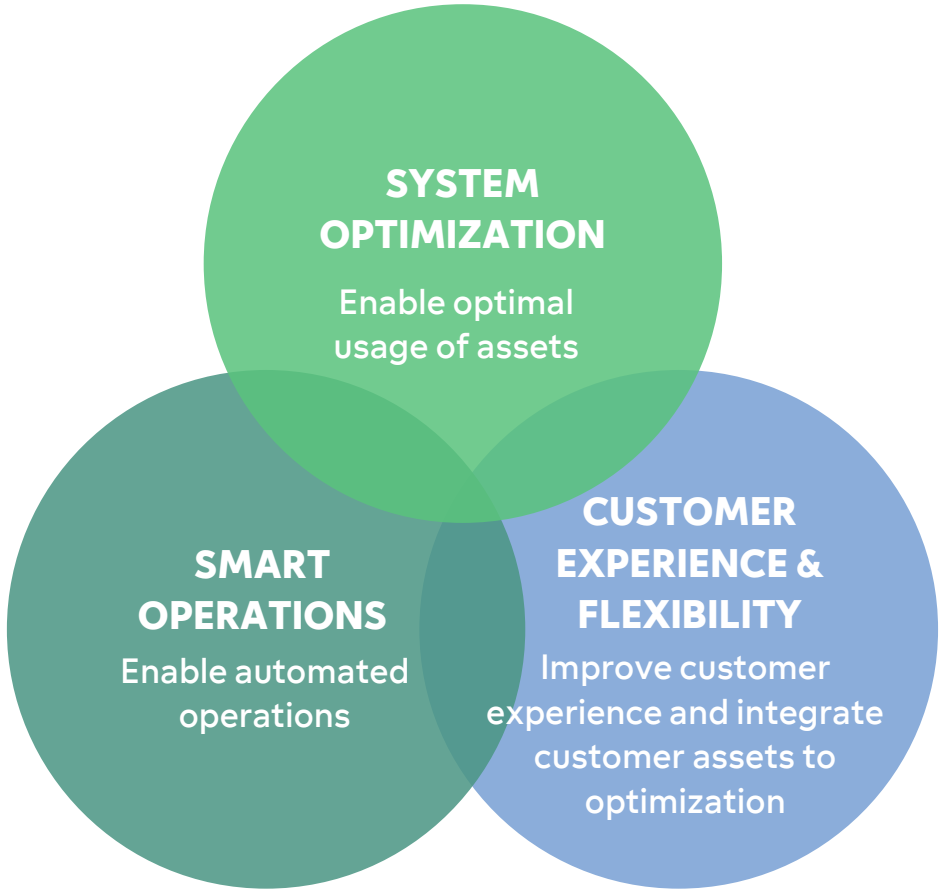


System Optimization Digital Twin



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Digital Twin in System Optimization

Optimization

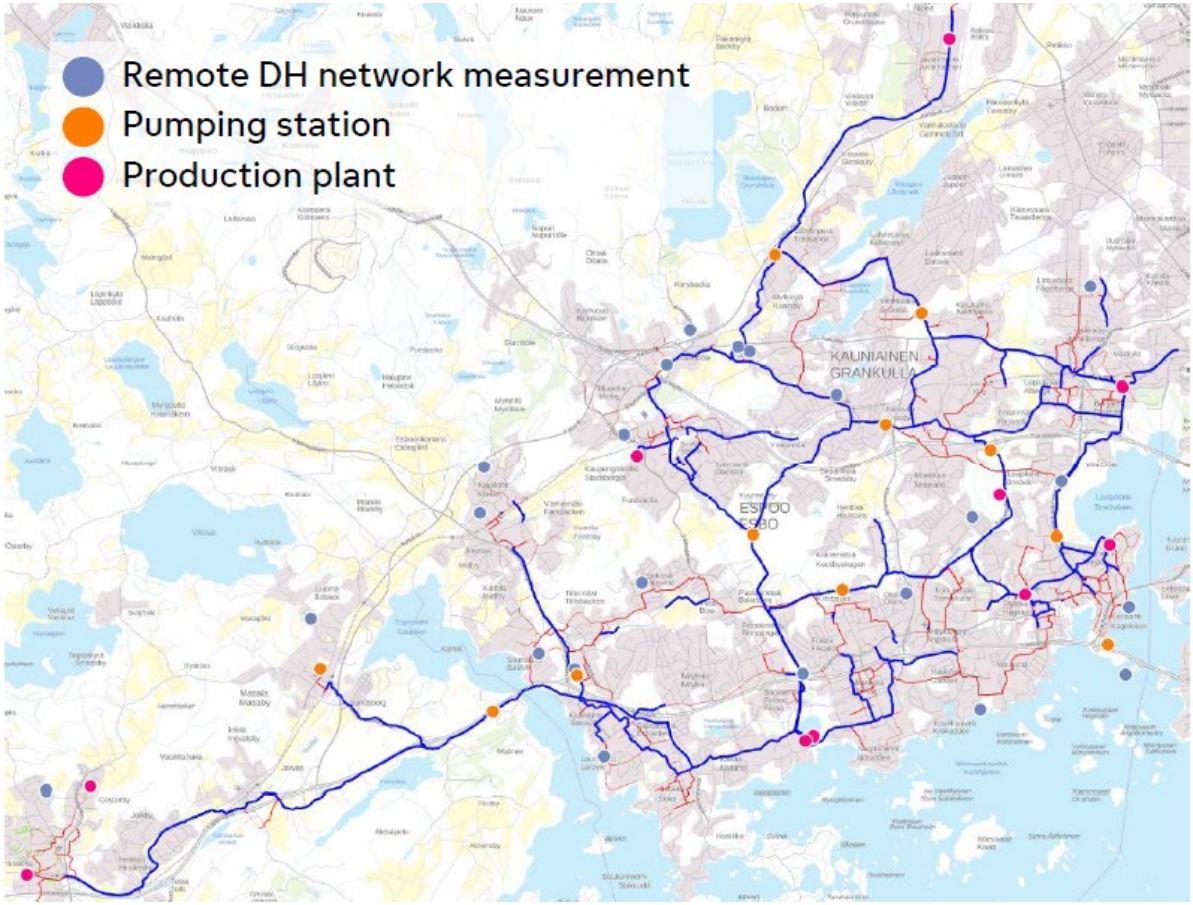
- System Optimization – 48 h optimized plan for production, transfer and demand side response (DSR)
- Optimized output of production plans, accumulators and DSR
- Production heat power, supply temperature and dispatch of production plants

Operation

- Realtime online dynamic Espoo district heating network model continuously up-to-date with real network
- Virtual measurements for operator decision support to provide up-to-date detailed situation of network

Design

- General and long-term strategic design based on up-to-date dynamic network model



Digital Twin Core – Apros®

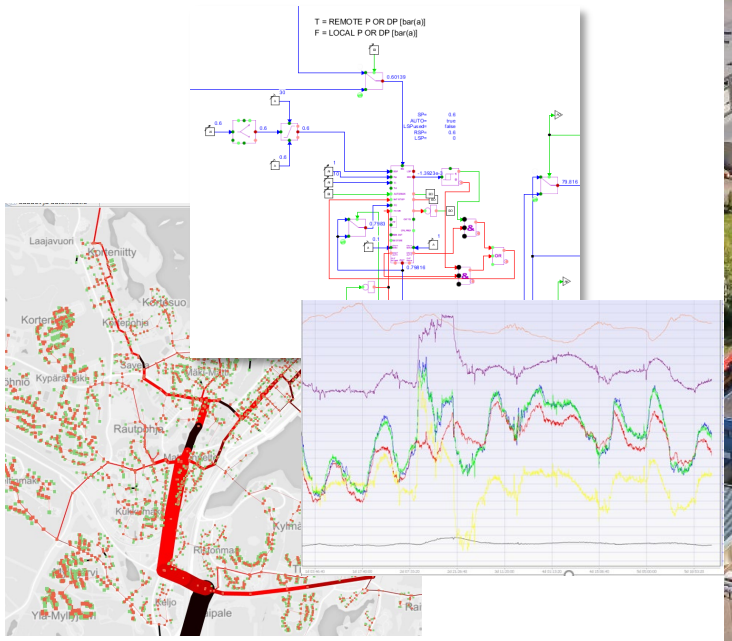
Detailed first-principles Apros ® dynamic software

- Production fleet
- Distribution network
- Consumers
- Control logics

Simulation-based digital replica of Espoo district heating network

Digital Twin utilization

- Optimization
- Decision support
- Design



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