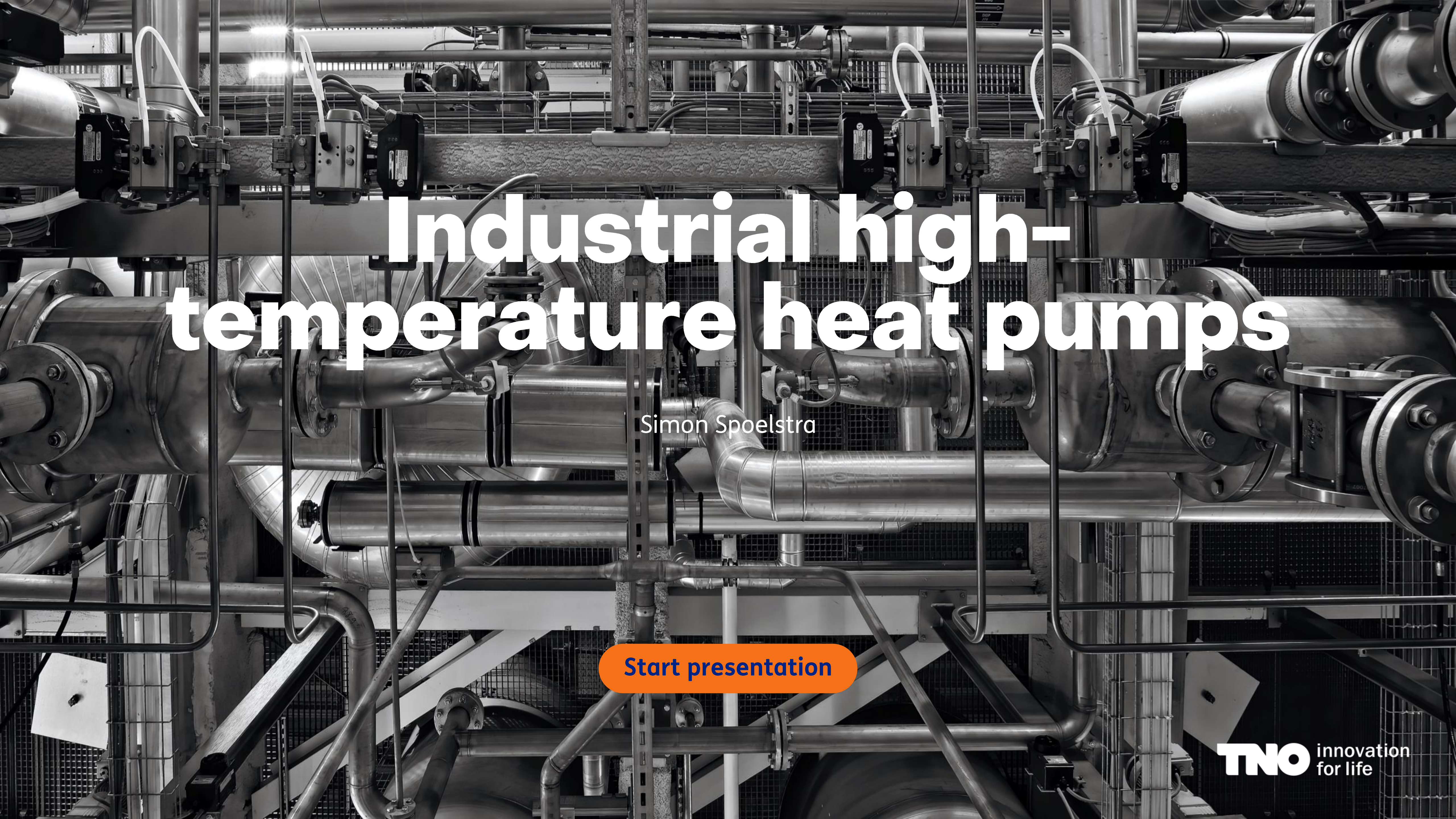


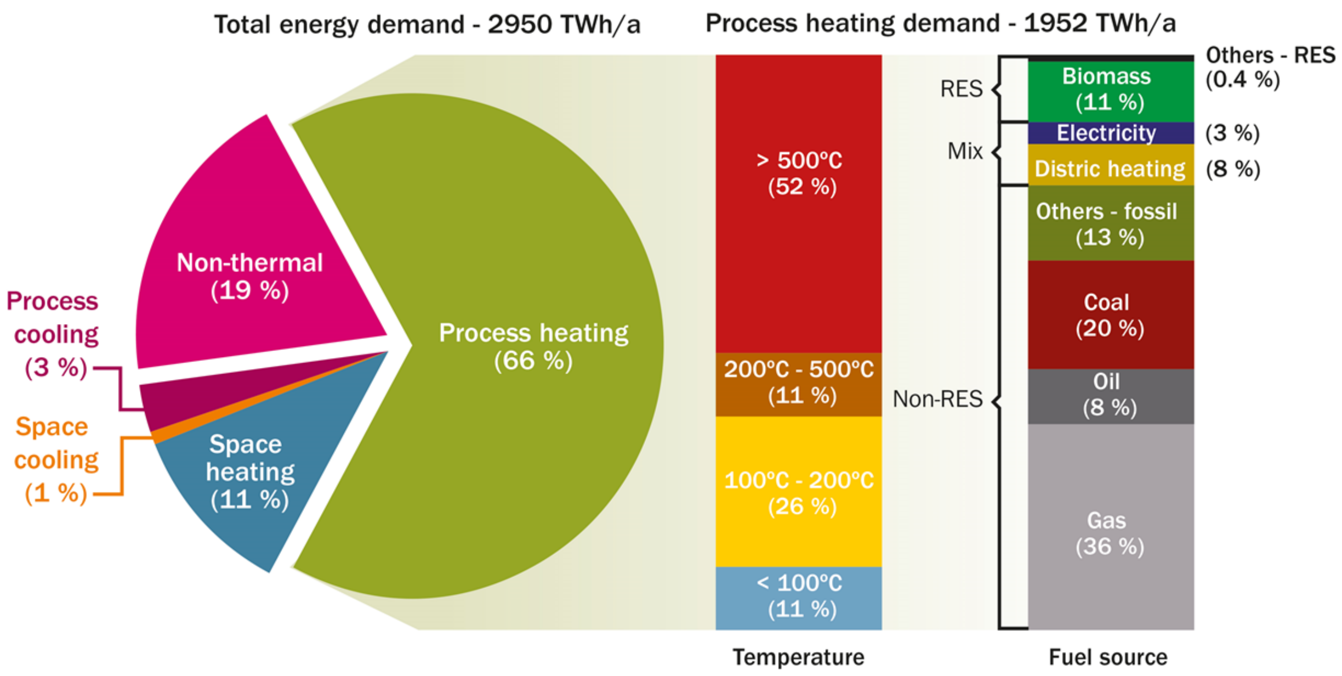
Industrial high-temperature heat pumps

Simon Spoelstra

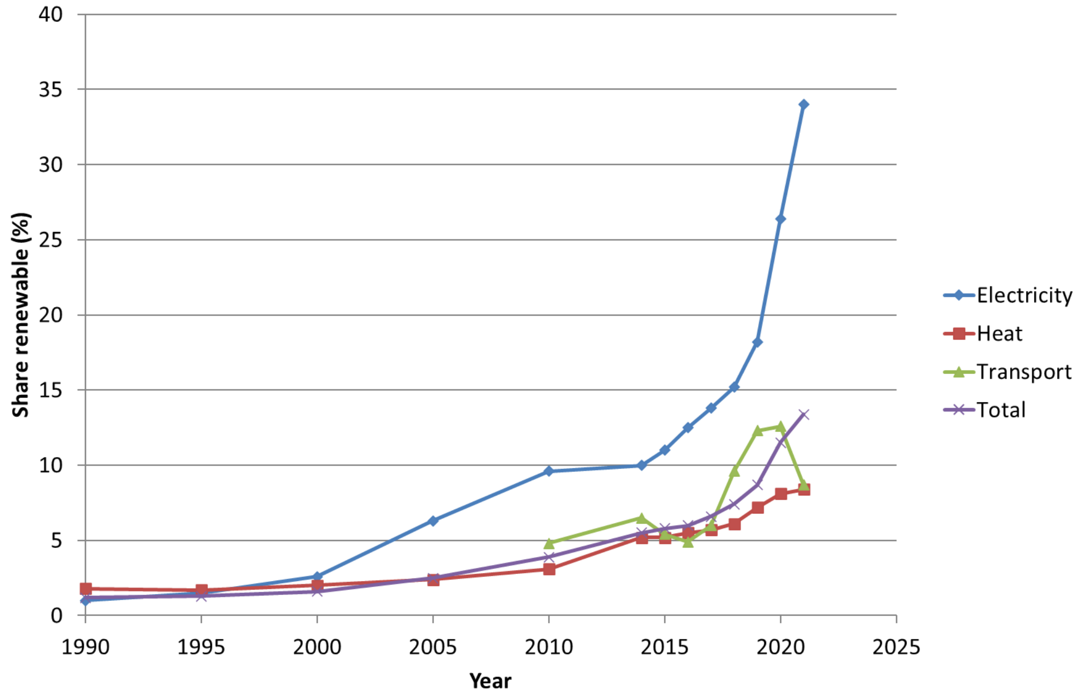
Start presentation

TNO innovation for life

R&D program Sustainable Industrial Heat System

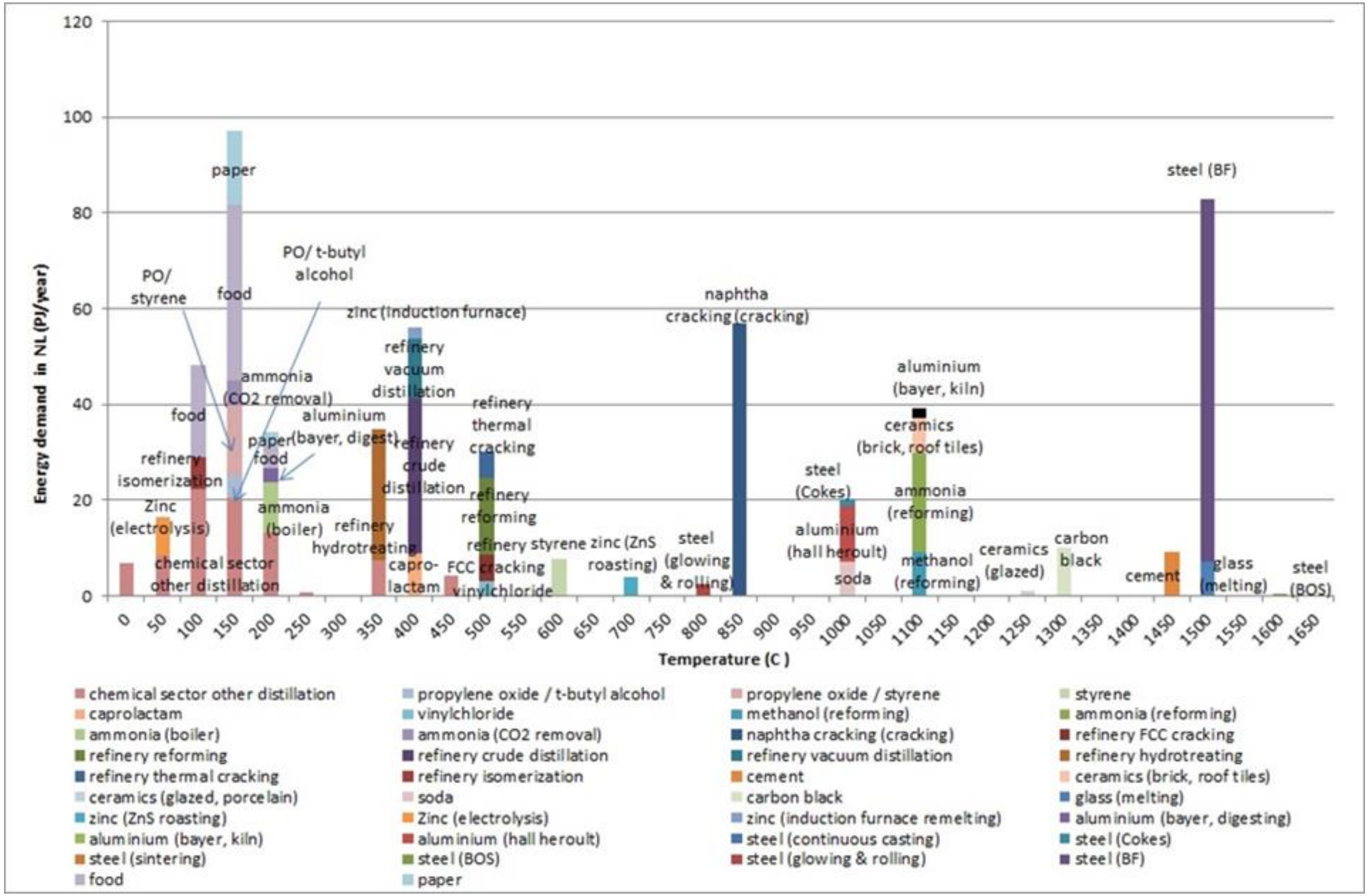


EU - Industrial energy use



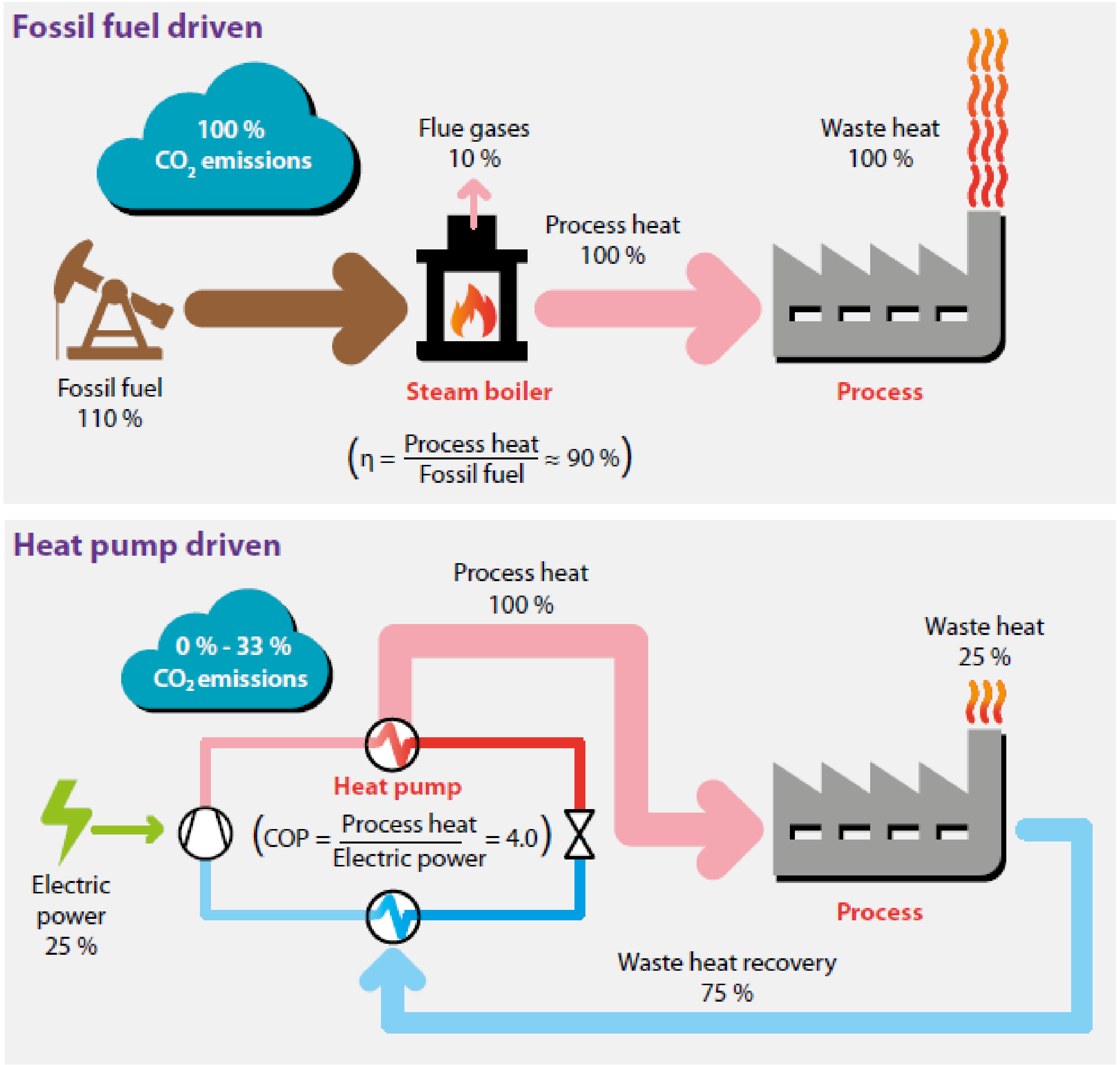
NL – share of renewables

Industrial heat demand – NL



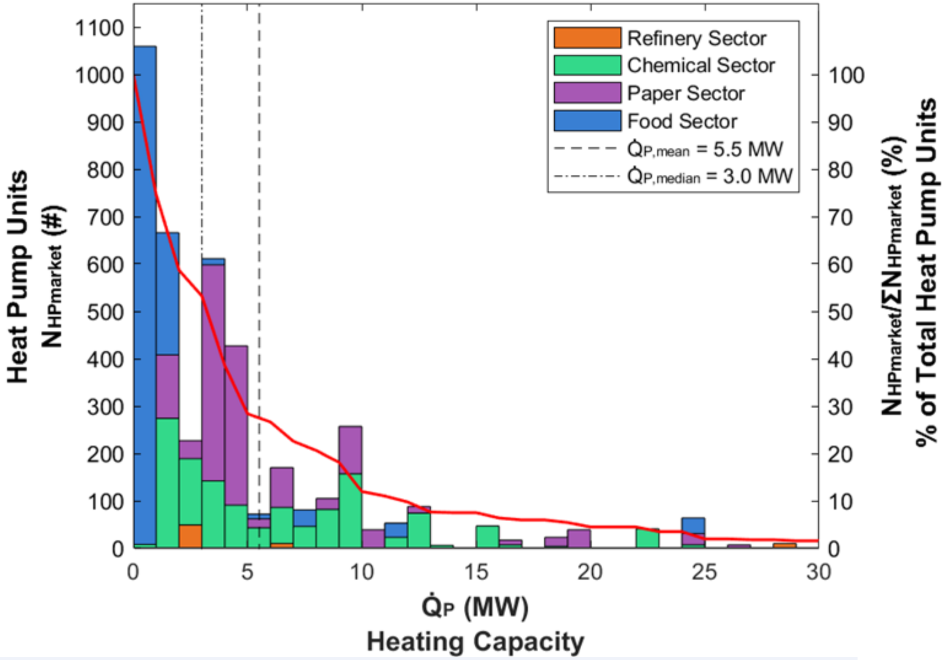
Transition to circular heat

- Structure of the existing energy system based around cheap and readily available fossil fuels
  - Heat is cascaded once through the process
  - Low temperature heat released to environment
- Lacking knowledge on heat pump integration
  - Efficient, & flexible operation, contingency, etc.
- Technology availability is limited
  - Commercial availability to temperatures 90°C → 120°C
- Economic constraints (CAPEX and OPEX)
  - OPEX: Gas/Electricity price ratio, CO_2 tax
  - CAPEX: Heat pump, integration costs (1-10x heat pump)
- Limited confidence in the technology



IHP potential market – EU28

- Heating/cooling profiles per production process
- Distillation column database (chemicals + refining)
- Paper industry
- Food (brewery, milk, potato processing, sugar)
- Typical plant capacities used to calculate typical heat pump capacities
- Production statistics from Eurostat
- Savings, current electricity system or all renewables
  - Avoided fossil fuel use 371 – 724 PJ/a
  - CO_2-emission reduction 37 – 53 Mton/a
- Market paper can be found here



	Thermal power (GW)	# units	Process heat (PJ/a)
Refining	0.5	69	14
(Petro)chemical	9.1	1291	283
Food	5.5	1463	98
Paper	7.9	1351	245
Total	**23.0**	**4174**	**641**

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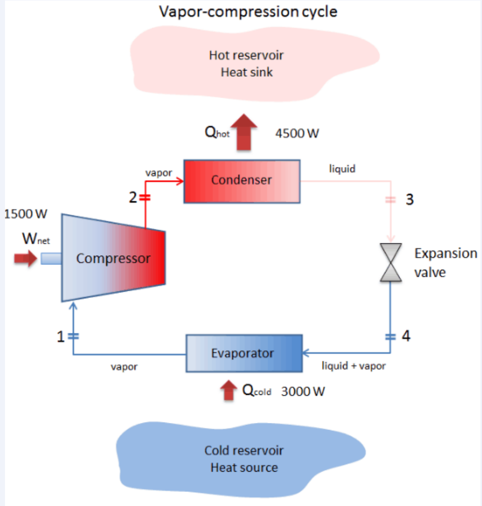
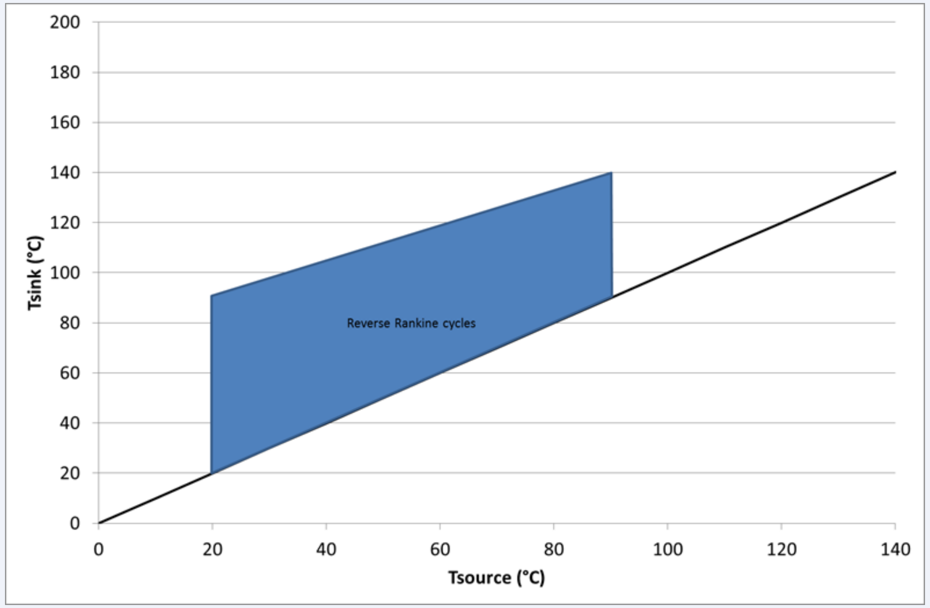
Heat pump development goals

- Temperature window
  - Waste heat < 100°C
  - Process heat > 100°C , up to 200°C
- Performance targets
  - COP > 50% of maximum (Lorenz/Carnot) efficiency
- Unit size
  - Standard sizes of 1, 2 and 5 MW
- Cost targets
  - < 500 €/kW_{th} (heat pump skid)

Reverse Rankine cycle

- Technology originating from refrigeration
- Operating range determined by working medium
- Multistage compression for high temperature lifts
- Refrigerants subdivided into synthetic and natural (CO_2, NH_3, hydrocarbons)
- Commercially available for sink temperatures up to 120 - 140°C
- Under development for sink temperatures > 140°C,
  using either hydrocarbons or newly developed synthetic refrigerants

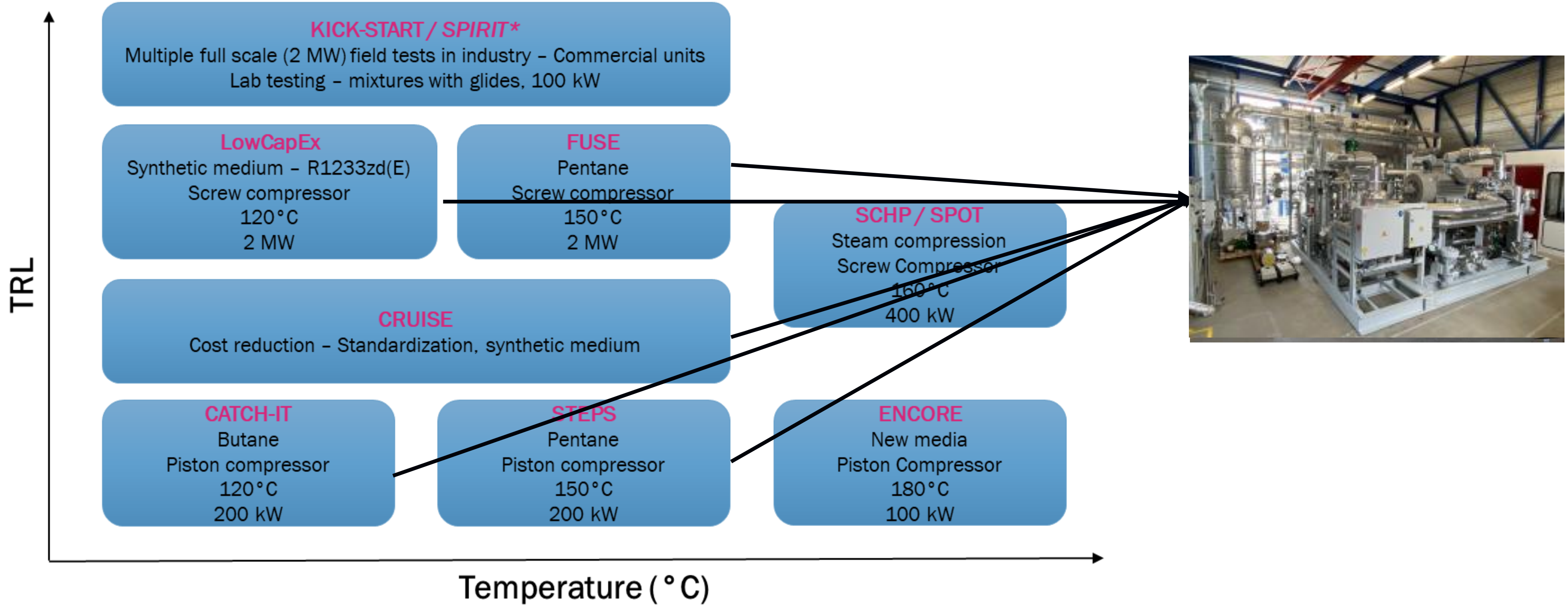




Development areas

- Increase delivery temperatures to 200°C
  - Compressor, Oil lubrication, Working media
- Efficiency
  - Cycle configurations, Reduce heat losses in oil lubrication system
  - Improve compressor efficiency/oil free compressor
  - Heat exchanger design, Expansion work recovery
- Integration
  - Dynamics – control strategies, combination with heat storage
  - Brown field vs green field design
- Cost reduction
  - Standardization

TNO development roadmap compression heat pump



SPIRIT – HEU project

- Current situation
  - Annual production of 5000 mt prawns
  - Steam at 145°C used for cooking, produced by propane boiler
  - 9000 MWh/year
  - 2600 ton CO2/year

- Demonstration
  - Cascade heat pump (NH_3, pentane)
  - Waste heat from refrigeration plant at 21°C
  - Process heat 700 kW at 145°C

Funded by the European Union

From concept to realization

Final remarks

- Large energy and CO_2-emission reduction potential for industrial heat pumps
- Wide range of operating temperatures already commercially available in the market, however
  - A temperature match does not necessarily indicate a match in capacity
  - Technically feasible does not mean economically feasible (investment, efficiency)
  - Individual companies may impose specific requirements with respect to working media on their sites
- Heat pumps fit in electrification trend and is a robust choice towards the future
- Large market in NL and EU (23 GW * 1000 €/kW = 23 G€)

Innovation for life

Thank you for your attention

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