Industrial Heat Recovery & Fuel Switching

25th Feb 2021

CATCH

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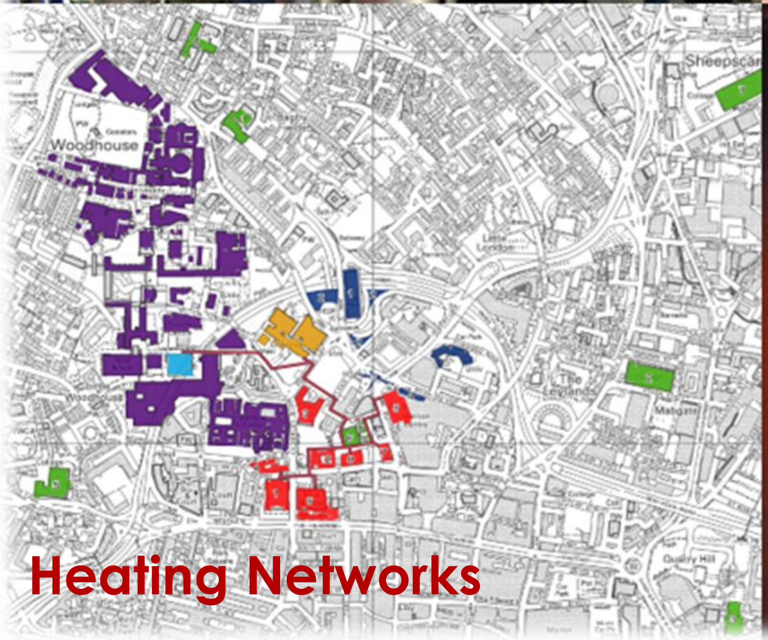


Content

1. Introduction - Industrial Heat

- Emissions from heat are the single biggest contributor to UK emissions, with industrial processes contributing ~66 $MtCO_2$/pa[1]
- For the UK to meet its climate change obligations, it must simulate the success had with electricity decarbonisation
- Decarbonisation of heat is recognised as one of the biggest challenges we face in meeting our climate targets

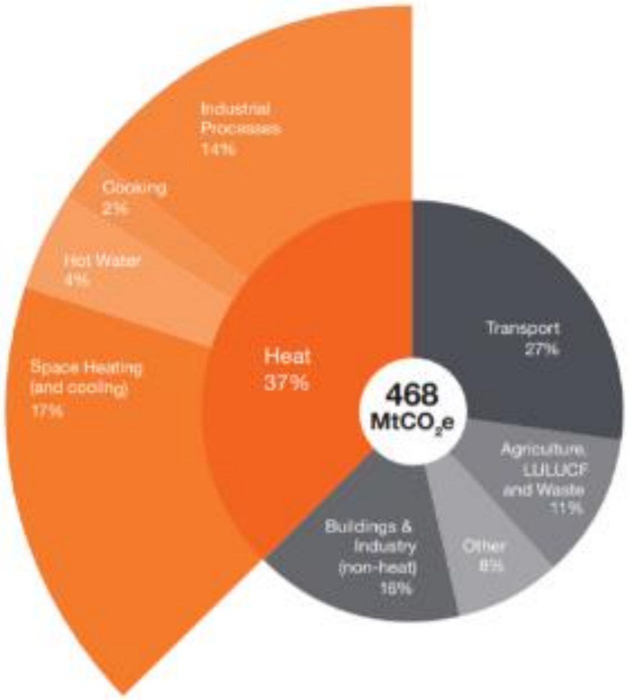
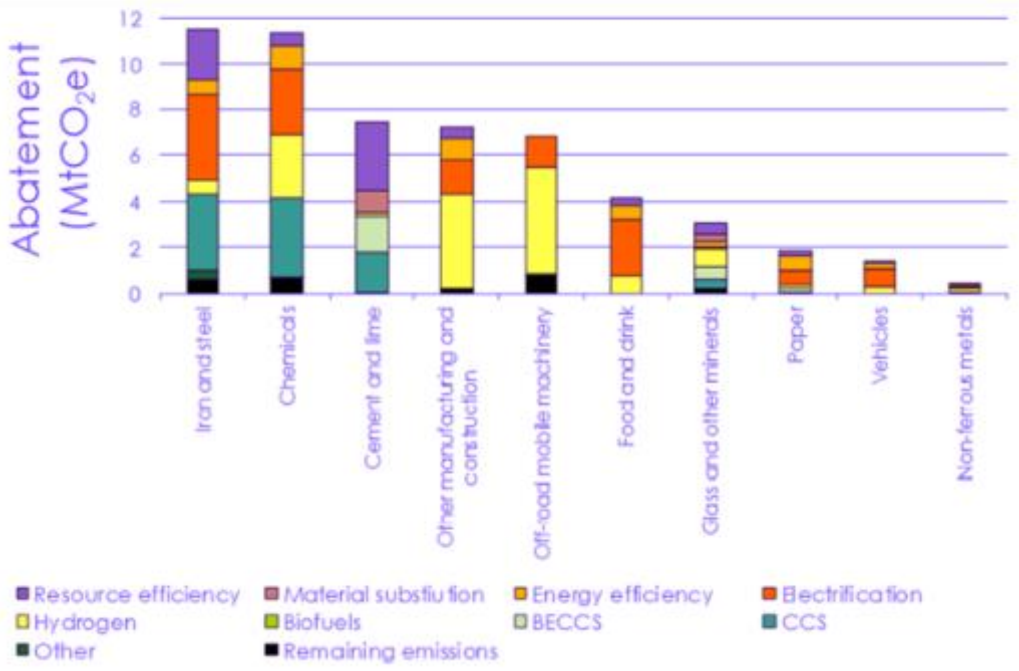


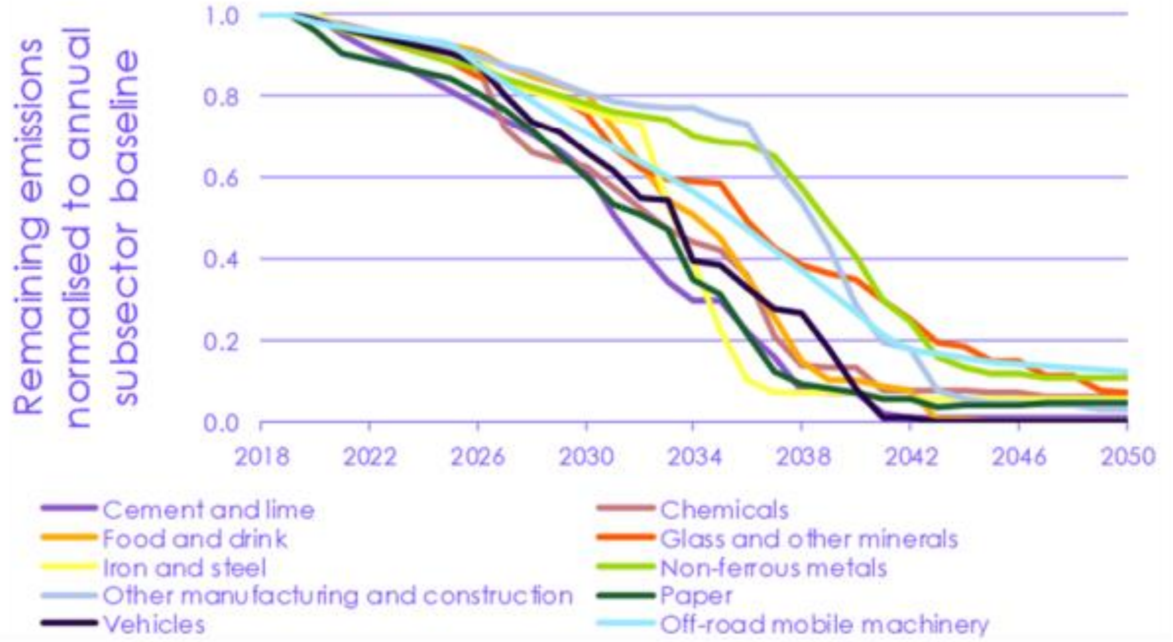
Figure 2.1 UK emissions in 2016 across different sectors[4]

[1]Source: BEIS Clean Growth - Transforming Heating (2018)

1. Introduction - Net Zero

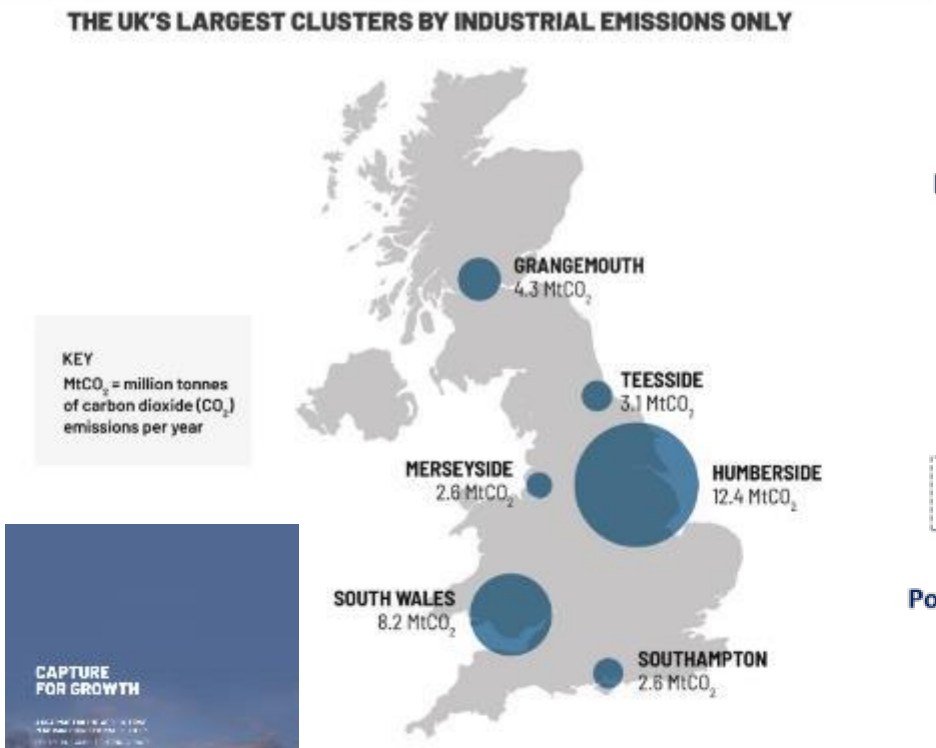
- CCC 6th UK Carbon Budget (Manufacturing & Construction Subsectors 2050)
- Resource and energy efficiency is the first stepping stone in industrial decarbonisation

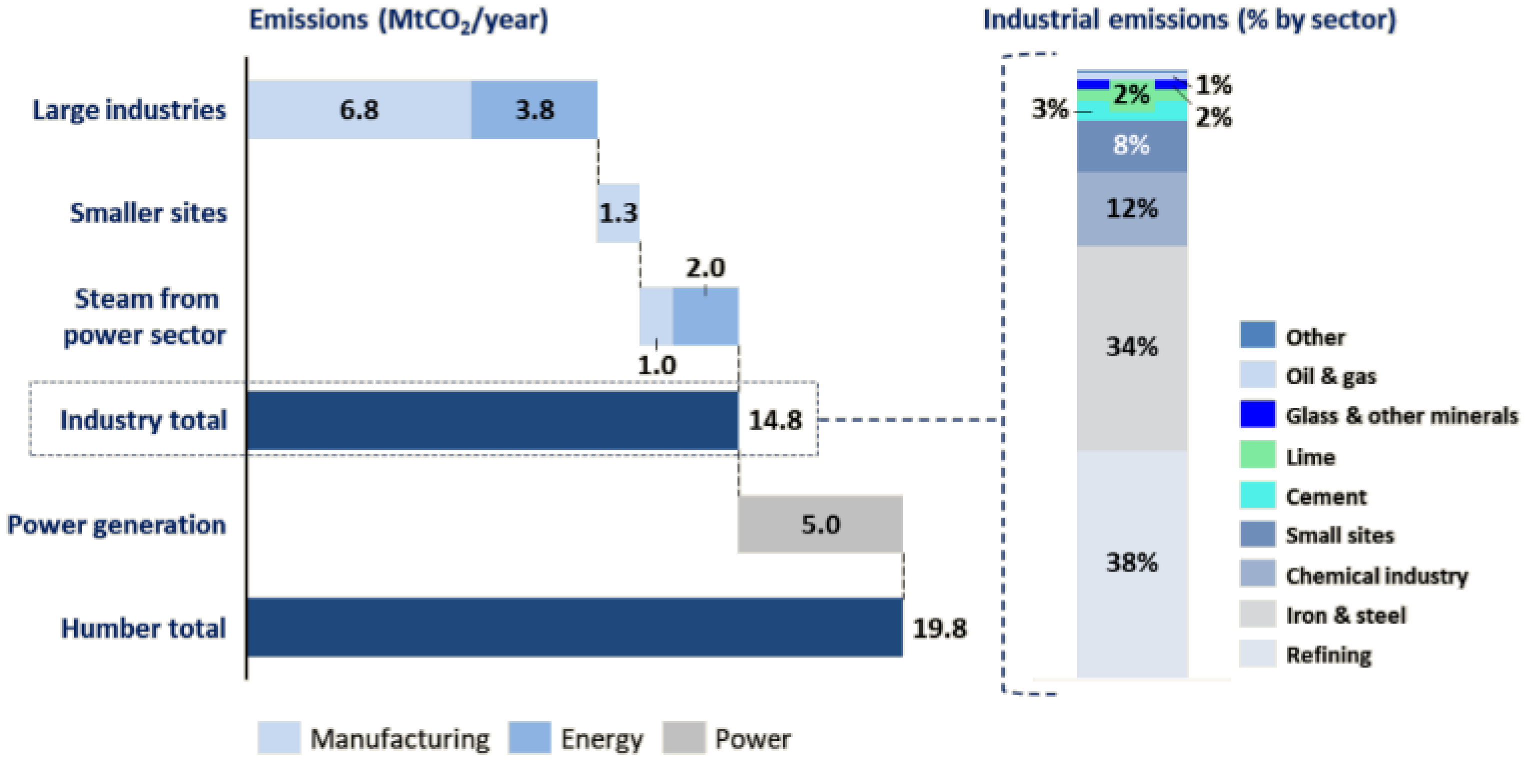




- Energy efficiency improvements achieve emissions reductions of 4 $MtCO_2e$ per year by 2050
- Heat recovery opportunity defined as 0.5 $MtCO_2e$ per year
- Energy costs typically 40% of operating costs, efficiency improvements = global competitiveness

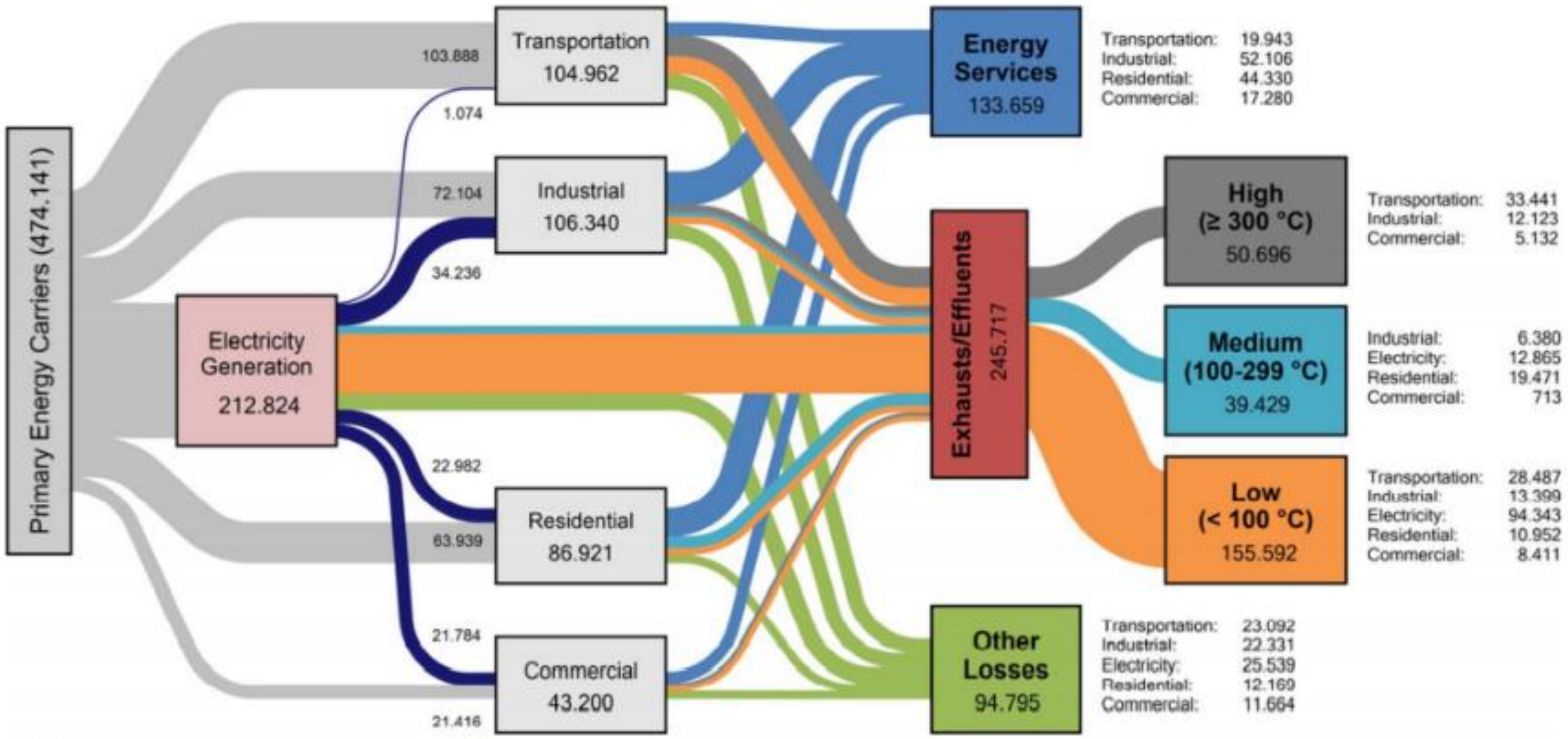
1. Introduction - Humber CO_2 Emissions



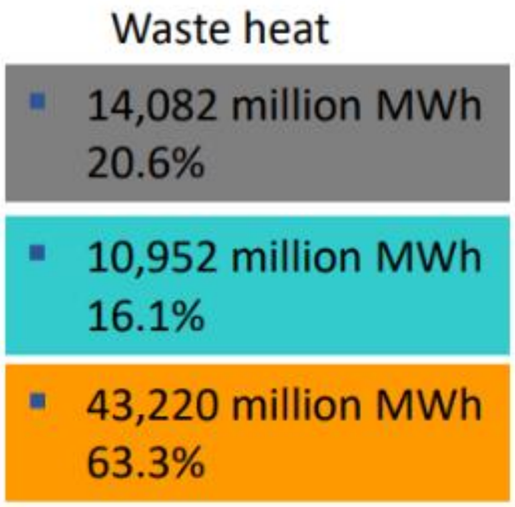


Source: Beacontech Ltd

1. Introduction - Global Waste Heat



Source: Estimating the global waste heat potential, Renewable and Sustainable Energy Reviews, 2016



- 72% of the global primary energy consumption is lost after conversion
- Waste heat - Electricity 43.6%, Transport 25.2%, Buildings 18.2%, Industrial 13.0%,
- 63% of the considered waste heat streams arise at a temperature below 100 °C

1. Introduction - Industrial Process Heat / Humber CO_2

Direct Heating Processes

Sector	Process[17]	Cross-sectoral process	Process requirements
Steel finishing	Rolling	Direct - High Temperature	240-2,000°C
Primary iron production	Melting	Direct - High Temperature (Blast furnace)	240-2,000°C
Primary iron production	Sintering	Direct - High Temperature (Sinter plant)	240-2,000°C
Cement	Kiln firing	Direct - High Temperature (Mixed kiln)	240-2,000°C
Vehicles	"High temperature process"	Direct - High temperature	240-2,000°C
Vehicles	"Low temperature process"	Direct - Low temperature	80-240°C
Glass	Melting	Direct - High Temperature	240-2,000°C
Ceramics	Kiln firing	Direct - High Temperature (kiln)	240-2,000°C
Non-ferrous metal	Melting and other high temperature processes	Direct - High Temperature	240-2,000°C
Non-metallic mineral	Kiln firing and other high temperature processes	Direct - High Temperature	240-2,000°C
Non-metallic mineral	Drying	Direct - Low temperature	80-240°C
Other industry	"High temperature process"	Direct - High Temperature	240-2,000°C
Other industry	Drying / Separation	Direct - Low temperature	80-240°C

34% CO_2 (Primary iron production: Melting, Sintering)

Indirect Heating Processes

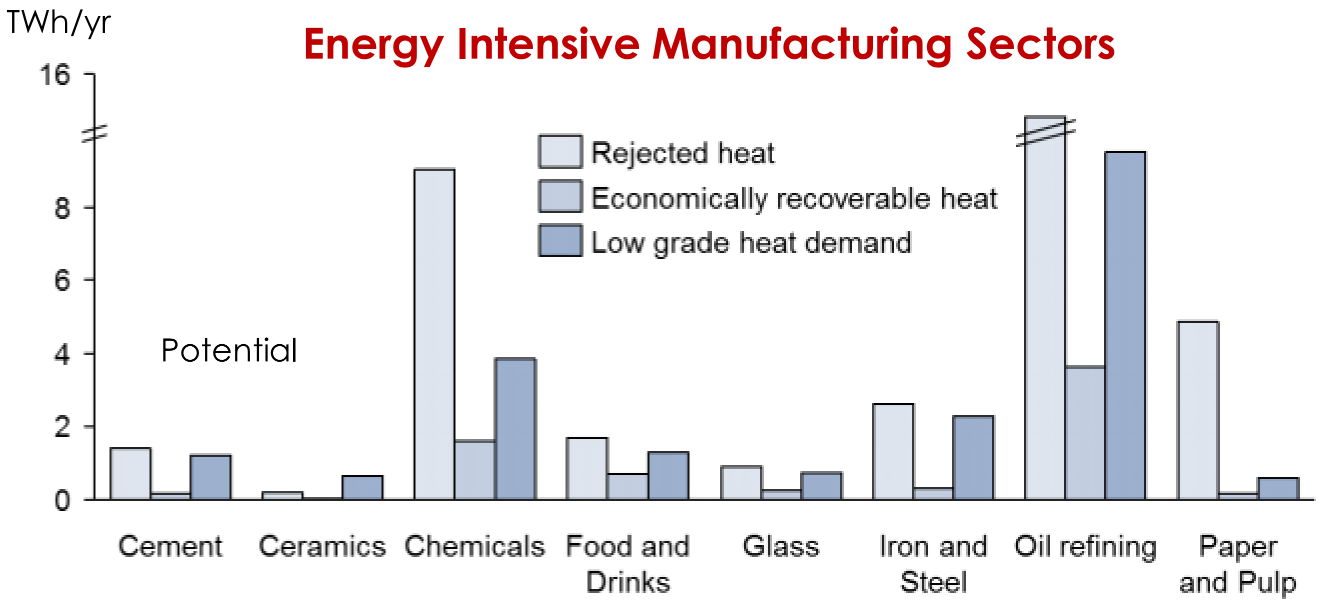
Sector	Process	Cross-sectoral process	Process requirements
Primary iron production	Steam generation	Indirect - Low Pressure Steam	80-140°C
Ethylene	Cracking	Indirect - High temperature	240-600°C
Ammonia	Steam reforming	Indirect - High temperature	240-600°C
Chemicals	High temperature	Indirect - High Pressure Steam	190-240°C
Chemicals	Turbine	Indirect - High Pressure Steam	190-240°C
Food & Drink	"Low temperature process"	Indirect - Low Pressure Steam	80-140°C
Food & Drink	Drying	Indirect - Low Pressure Steam	80-140°C
Paper	"Low temperature process"	Indirect - Low Pressure Steam	80-140°C
Vehicles	Space heating	Indirect - Low temperature	30-80°C
Refining	"Low temperature process"	Indirect - High temperature	240-600°C
Refining	Drying / separation	Indirect - High pressure Steam	190-240°C
Refining	Space heating	Indirect - Low Pressure Steam	80-140°C
Non-metallic mineral	"Low temperature process"	Indirect - Low Pressure Steam	80-140°C
Other industry	"Low temperature process"	Indirect - Low Pressure Steam	80-140°C
Other industry	Space heating	Indirect - Low temperature	30-80°C

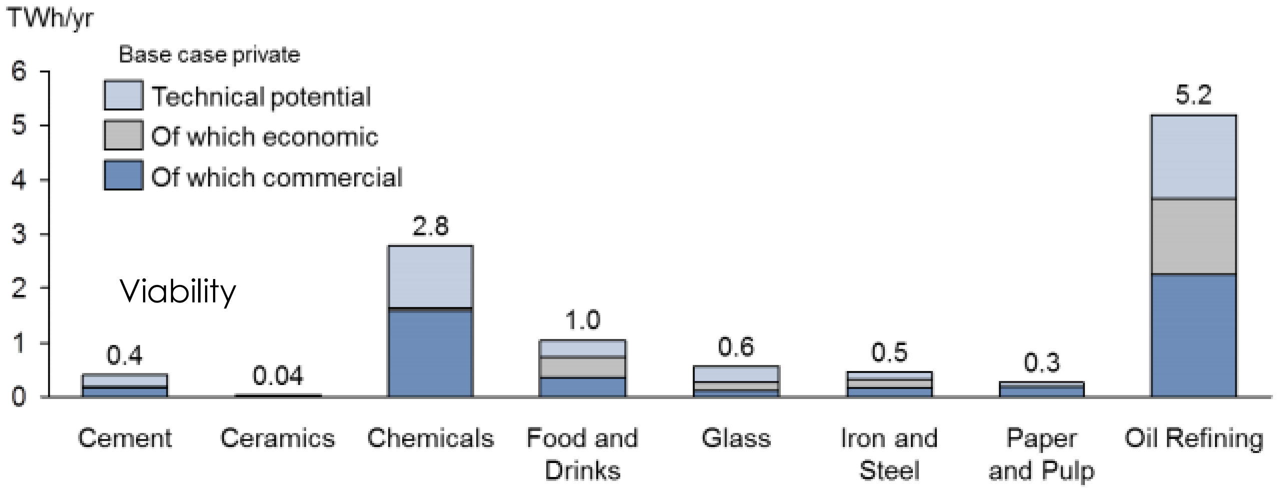
12% CO_2 (Chemicals)

38% CO_2 (Refining)

Source: BEIS, Industrial Fuel Switching Market Engagement Study (2018)

1. Introduction - Sector Heat Recovery Potential (TWh/yr)





Source: BEIS Barriers and Enablers to Recovering Surplus Heat in Industry 2016

[2]Source: Element Energy (Potential for recovering and using surplus heat from industry, 2014)

- A BEIS study[2] identified heat recovery potential of 11 TWh/yr, up to 28 TWh/yr if district heating can be utilised
- 7 TWh/yr was deemed economically viable for recovery
- Technical potential included:
  - Onsite reuse
  - 'Over-the-fence'
  - Conversion to power
- Demand for low grade heat a constraint
- Most economic cases defined as recovery for preheat air or feedwater

2. Challenges - IWHR

Technical / Economic

- Can be difficult to calculate
- Maintenance concerns
- Limited funds
- Reluctance to sign ‘over the fence’ deals
  - Lack of flexibility / dependences
  - Non-core competency
- Little secondary benefits (e.g. quality, sales)
- Supply / demand imbalances
- Perceptions of heat value (owner / buyer)
- Termination (large capital expenditure)
- Too risky!!

2. Challenges - IWHR

Technical / Economic

- Established industries and infrastructure
- Operations typically 24/7
- Global competitiveness demands high productivity
- Margins are modest, downtime needs to be minimised
- Infrastructure investments typically at renewal, cycles lasting decades

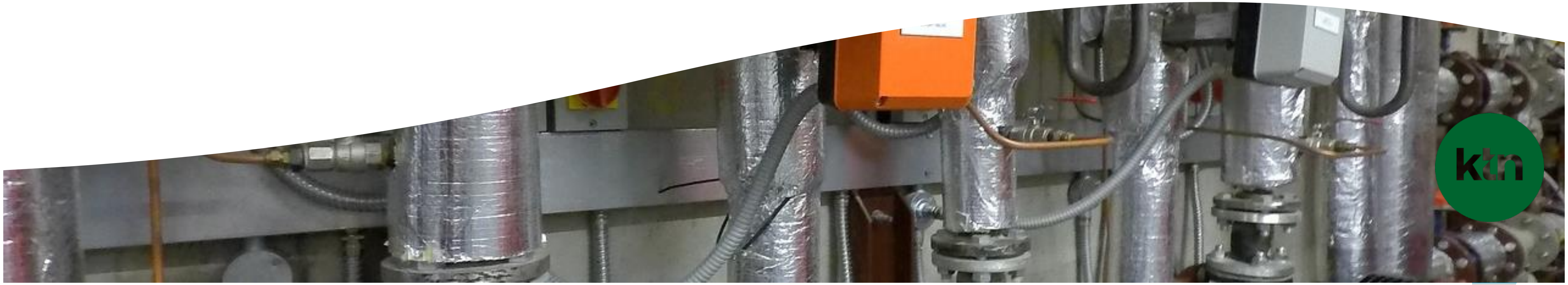
- Infrastructure investments typically at renewal, cycles lasting decades

- Designs make retrofitting tough
- Changing process away from the norm, perceived as a threatening productivity
- Risk adverse behaviour
- Solutions must be guaranteed to deliver

2. Challenges - IWHR

Data & Energy Management

- Primary energy consumption data, typically available via bills, but not always available at daily / hourly
- Process energy data typically focused on supply not a demand profiles
- Detailed data typically focused on prime energy process, not supportive services where waste heat opportunities exist
- Data onsite or offsite heat demands (space or process heat)



3. Policy - Government White Paper Net Zero (Heat Fiscal)

Energy Efficiency

CCA scheme extension 2025

Electric..

40GW of offshore wind by 2030
Heat pumps, from 30,000/yr to 600,000/yr by 2028

Bioenergy

Green Gas Support Scheme
2.8TWh of renewable heat in 2030/31 (Biomethane)

RHI

NDRHI closes Mar'21
Ground S. Heat Loops
Green Gas Levy
Q3 2021 (Q2 2022)

Industrial Clusters

CCUS

Clean Hydrogen

Revenue Mech.

£1 billion
X2 project 2025
X2 projects 2030
10 $MtCO_2$/pa

£240M fund 2024/5
42 TWh/pa blue hydrogen

UKETS 2.0

UK Carbon Trading Scheme

(Significant IWHR role)

Heat Networks

Green Heat Network Fund
£270M 2022

Heat Network Transformation
£122M 2025 (HNIP 2.0)

Decarbonisation & Hydrogen strategy due to be published !!

3. Policy - Heat Incentives

- **£18 million Industrial Heat Recovery Support Programme, competition (closed)**
- £20M Industrial Fuel Switching Competition (**closed**)
- £315M Industrial Energy Transformation Fund (39 projects, 2020) 2021 round now open
- £8M R&D Industrial Strategy Challenge Fund (Transforming Foundation Industries) open
- Energy Entrepreneurs Fund £70M
  9 years, 130 companies (Round 8a open)

3. Policy - Industrial Heat Recovery Support Programme (IHRS)

- Jul 2020 – Mar 2022 31 Projects (8 projects in Yorkshire)

Sectors

- Glass
- Paper & Card
- Cement
- Iron, Steel & Aluminum
- Bricks
- Chemicals
- Plastics
- Food, Dairy & Meat Production

Supply

- Flue gas
- Process heat
- Flash steam
- Chiller waste heat

Conversion

- Air to air
- Air to liquid
- Liquid to Liquid
- ORC

Demand

- Boiler feed water
- Electricity Generation
- Process heat
- Combustion air
- District heating

3. Policy – IHRS (Case Studies)

Brickworks

- Tamworth
- £10,000 grant (Feasibility)
- 130,000 tonne/yr brick kiln
- Process preheat / ORC
- Savings v's cost appraisal
- 11% annual gas saving
- 1,927 tCO2 /yr

Petrochems

- Manchester,
- £41,000 grant (FEED study)
- Process heat to provide the re-boil duty for distillation
- 17,000 MWh/yr natural gas
- 3,500 tonnes of CO2/yr
- Further benefits: loads on pumps & cooling tower fans

Chemicals

- Newport South Wales
- £197,000 grant (25% capital)
- Condensing economiser waste heat recovery unit on CHP unit
- 2-year payback
- Savings 1.1MWh and 1400tCO_2

4. Opportunity- Waste Heat Recovery

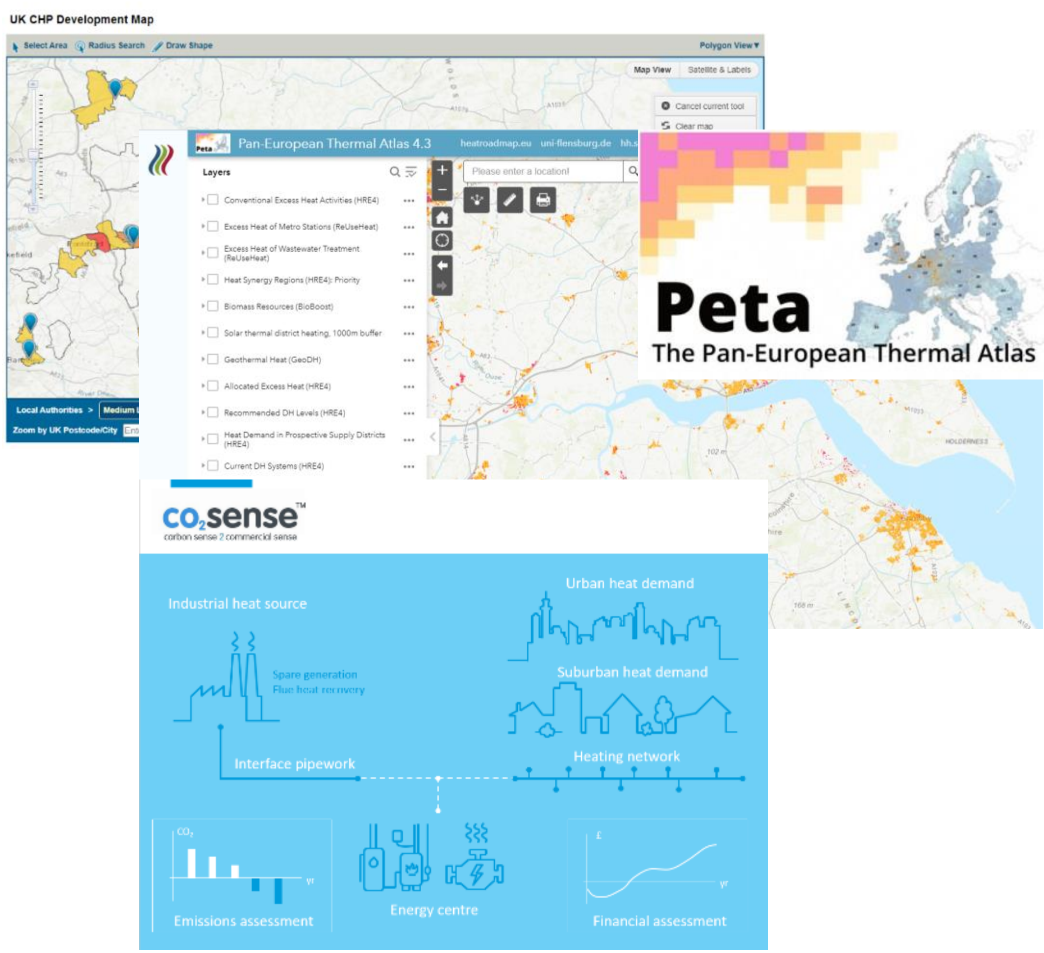
- New business models to valorise waste heat
- Novel uses for waste heat
- Lower the costs of HR systems, especially to make systems practical at smaller scale
- Develop new process specific heat recovery technology
- Novel thermal energy storage equipment or applications
- Low cost novel materials that can withstand high temperatures and/or have better resistance to corrosive contaminants or scaling
- Develop systems which are easy cleaning
- New manufacturing techniques that reduce corrosive contaminants in exhaust gases
- Improve the efficiency and/or cost effectiveness of WHR technology
- Design new heat exchangers with improved coefficients of performance
- Unconventional ways of capturing heat, e.g. side wall losses
- More compact designs that allow installation where there is limited space
- Adaption of environmental control and abatement equipment to minimise drop in performance due to HR

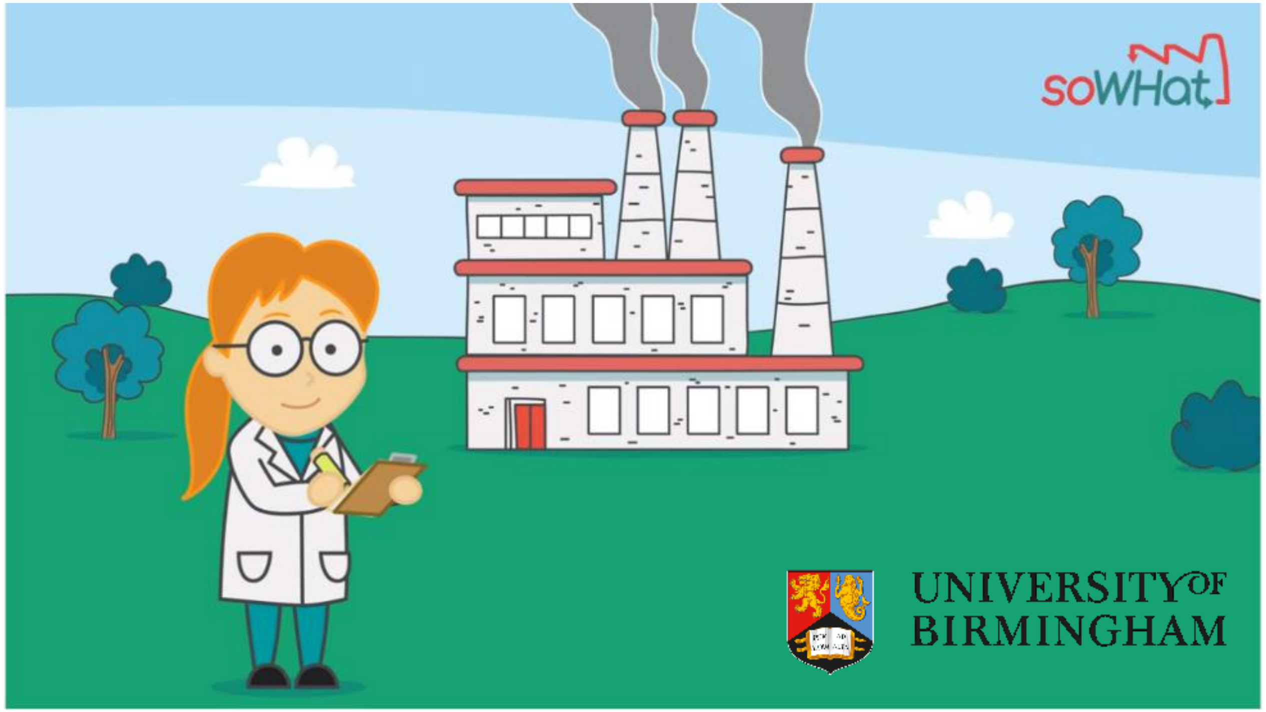
Innovate UK

Source: Innovate UK

4. Opportunity- Local Energy Planning

Heat Mapping / Spatial Planning





- SaaS Horizon - 2020 project est. 2019
- 20 partners, 9 countries
- A simulation platform to deliver cost benefit
- Integrated decision support tool (40 technologies)
- Comprehensive justification for selection & finance
- Entering validation phase

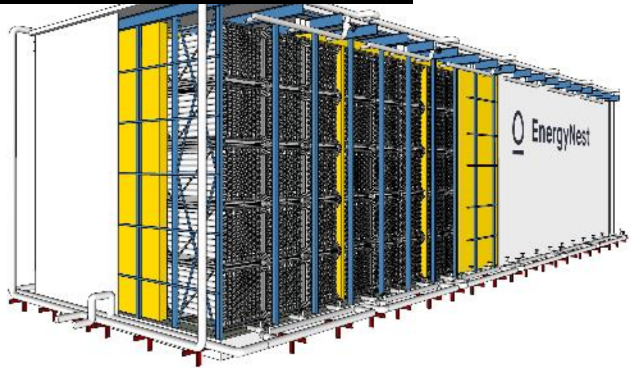
[Heat Network Tool]

[soWHat Project]

4. Innovations - Waste Heat Recovery

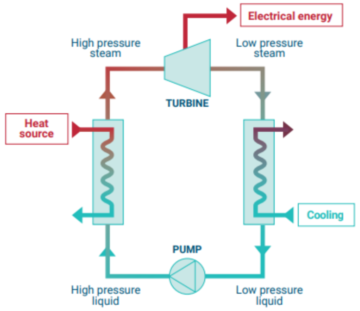
Commercial

EnergyNest
The Thermal Battery company™



- Latent heat storage
- Proven & certified
- Implemented across Europe
- Modular & scalable
- HEATCRETE® storage
- Cost competitive €30 to 60/kWh
- 7 to100' MWh
- 97- 99% round trip efficiency
- Low maintenance
- +30 year life

CLIMEON
Business for a better world



- Low grade heat to power
- Low pressure (less than ORC)
- Proven
- Compact 4m2
- Modular & scalable (e.g. 50MW)
- 70 – 120 °C heat source
- High efficiency

ENOGIA
The Small Turbine ORC Company

- Heat to power conversion
- Organic Rankine Cycle (ORC)
- Patented micro-turbine technology
- 170 – 120 °C heat source
- 10 – 180 kWe
- $1m^2$ – $4.6m^2$

4. Innovations - Waste Heat Recovery

SPIRE
Sustainable Process Industry through Resource and Energy Efficiency

Research & Development (Europe)

Carbon4PUR
Imperial College London

- Industry driven, multi-disciplinary partnership
- Turning industrial waste gases (mixed CO/CO_2 steams) into intermediates for polyurethane plastics for rigid foams/building insulation and coatings.
- **End Sep 2020**

DryF

- A four-year project funded by Horizon 2020 Research & Innovation
- Heat streams at higher temperature levels up to 160 °C
- Two high temperature heat pumps: x1 closed loop heat pump for air drying processes and an open loop heat pump for steam drying.
- **End Jan 2020**

EMB3Rs
Heat and Cold matching platform

- The EMB3Rs platform will allow users to determine the costs and benefits related to excess H/C utilisation routes and help establishing conditions for implementing the most promising solutions.
- **End Sep 2022**

ETEKINA
Thermal energy recovery
econotherm
WASTE HEAT RECYCLING TECHNOLOGY
Brunel University London

- EU funded research project
- Solution is based on heat exchanger technology (HPHE) using heat pipes for thermal recovery.
- **End Sep 2021**

4. Innovations - Waste Heat Recovery

SPIRE
Sustainable Process Industry through Resource and Energy Efficiency

Research & Development (Europe)

I-TheRM

- Investigate, Design, Build And Demonstrate Innovative Plug And Play Waste Heat Recovery Solutions
- 70 – 1000 °C
- **End Mar 2019**

EINSTEIN thermal energy industry audit

Indus3Es
Industrial Energy and Environment Efficiency

- Upgrade low temperature waste heat streams to process heat streams at higher temperature levels and then use them in internal industrial process
- Absorption Heat Transformers (AHT) <130°C feasibility tool
- **End Apr 2020**

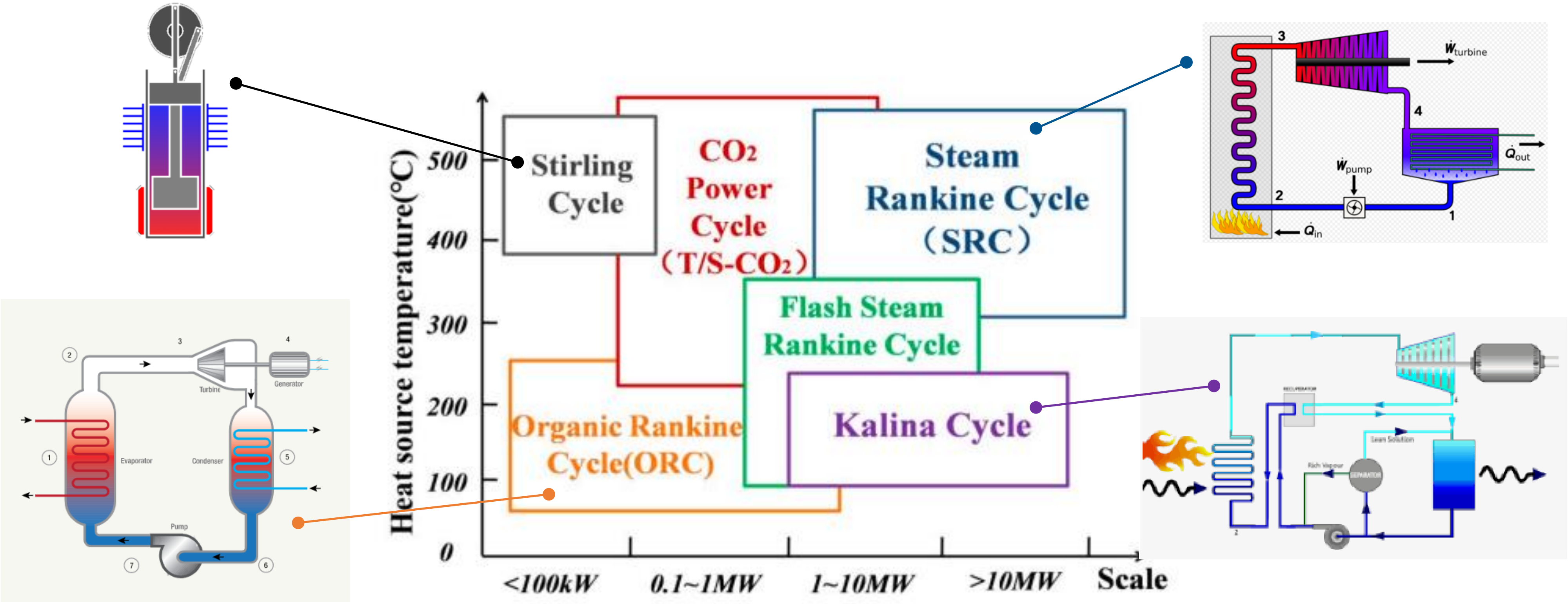
INCUBIS ENERGY SYMBIOSIS INCUBATOR

UNIVERSITY OF HULL

- A methodology whereby five (5) regions around Europe, each with different regulatory context, governance structure, and climate are being chosen to set up a local Incubator
- Industrial clusters symbiosis supporting waste heat and cold valorization
- **End Apr 2023**

4. Innovations - Waste Heat Recovery

Thermodynamic cycles for waste heat recovery



4. Innovations - Waste Heat Recovery

UK Research and Innovation

Brunel University London

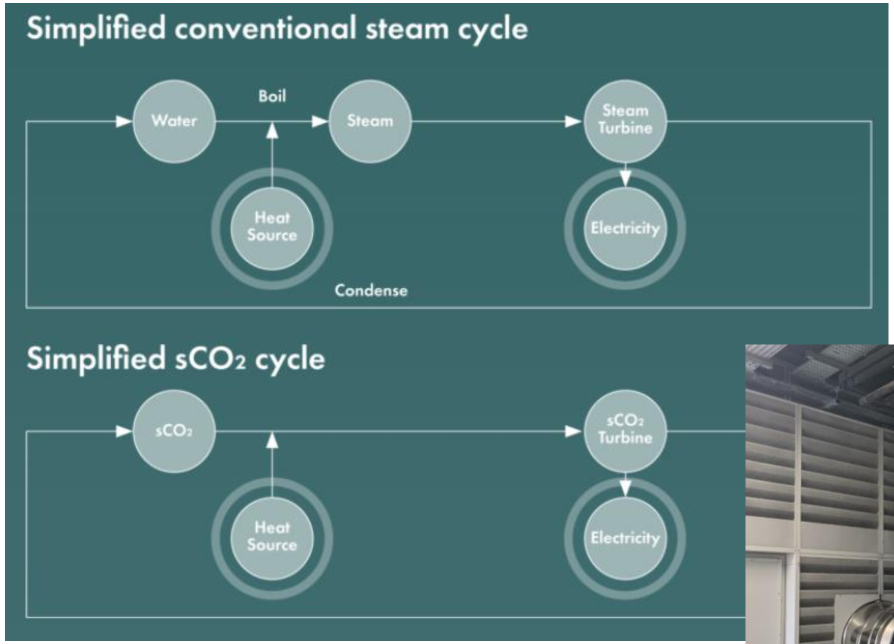
Reaction Engines

ENOGIA

Research & Development

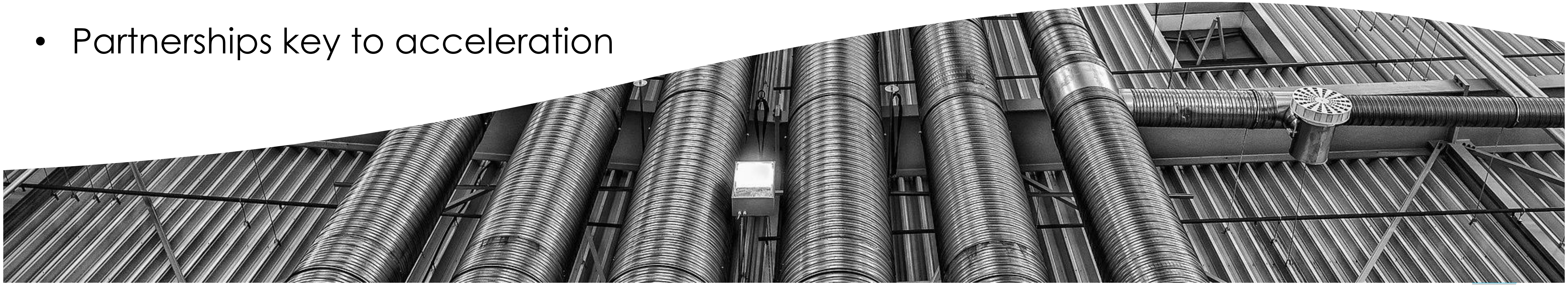
Small Scale Supercritical CO_2 (sCO_2) Power

- Working to develop industrial demo
- Research challenges:
  - Metallurgy / corrosion
  - Thermal stresses
  - Heat exchangers / costs
- Seeking funding for 50kWe
- Plans to develop 2MWe
- Looking to develop industrial partnership to utilise 2MWth (400 – 550°C) to provide 300 to 400 kWe



5. Summary

- **No one** technology pathway to NetZero
- Efficiency and industrial WHR is the bedrock to maximising industrial decarbonisation
- According to CCC IWHR can offer 0.5 $MtCO_2$ per year saving
- Low and mid range temperatures are accessible, commercial technologies available
- Tools are available and user friendly, but perhaps need greater promotion
- Improved ‘how to’ transparency, data quality, feasibility & self determination, support
- Greater floodlighting on fiscal incentives, grants and new business models
- Partnerships key to acceleration



6. Q&A

How can CATCH support the Humber with IWHR acceleration?

- INCUBIS
- Industrial Heat Recovery Support Programme 2.0? (Lobby)

What are your IWHR questions and needs?

CATCH

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