The University Of Sheffield.

S.U.W.I.C

DISTRICT HEATING MATTERS

Envisaging district energy network expansions from local to national scale through advanced technologies

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SUWIC presentation – Newcastle - October 2015

Sheffield City Council

Creativesheffield. Transforming Sheffield's Economy

Issues and Big Opportunities

- **Conventional power production from a hot flame with a thermal thermodynamic cycle inevitably provides low grade heat - that is usually wasted!**
- **UK electricity power plant efficiency is less than 40% because low grade heat is not used, hence its electricity output is a flawed energy vector.**
- **Building heating only requires low grade heat. Heating rooms to 20°C using boiler gas flames at 1500°C is fatally flawed technology.**
- **Combined Heat and Power (CHP) exploits both high and low grade heat.**
- **Sheffield Energy from Waste plant gives an overall CHP power station efficiency >85%!**

Issues and Big Opportunities

Combined Heat and Power (CHP) is essential for low carbon and energy efficiency, since fossil fuel now used for heating buildings is saved

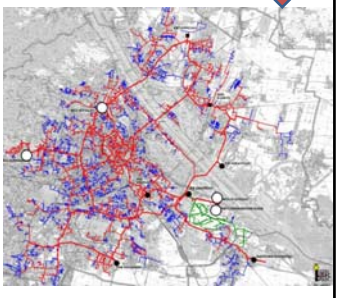
- **To exploit CHP, the heat consumer should be reasonably accessible to the power generator heat network**
- **We need new CHP Power stations embedded in towns or cities**
- **A Key message is that the availability of CHP heat increases significantly with a network of several CHP plants since standby boilers are not required**
- **The heat main in Denmark is more that 100km long across the heart of the country.**
- **Should we use the HS2 and HS3 rail-track routes for a main UK district heating network!?**

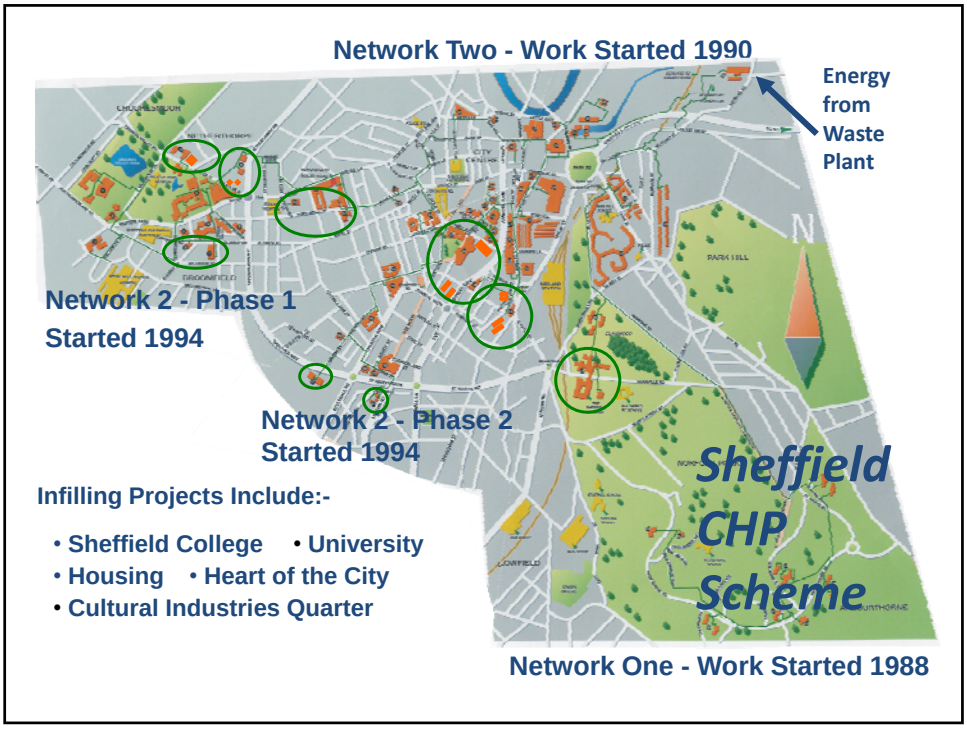
Sheffield; existing award-winning citywide, district energy network

- Network was founded in 1988 by Sheffield Univ.
- Largest, most successful in UK. Supplies ~10% of building heat.
- Huge opportunity to expand both here and throughout UK.
- Sheffield system consists of a CHP energy recovery facility connected to a 44-km pipeline 60MW network
- Now joined by a biomass power station

Compare Vienna , 1100 km network, 4 incinerators & 5 power stations

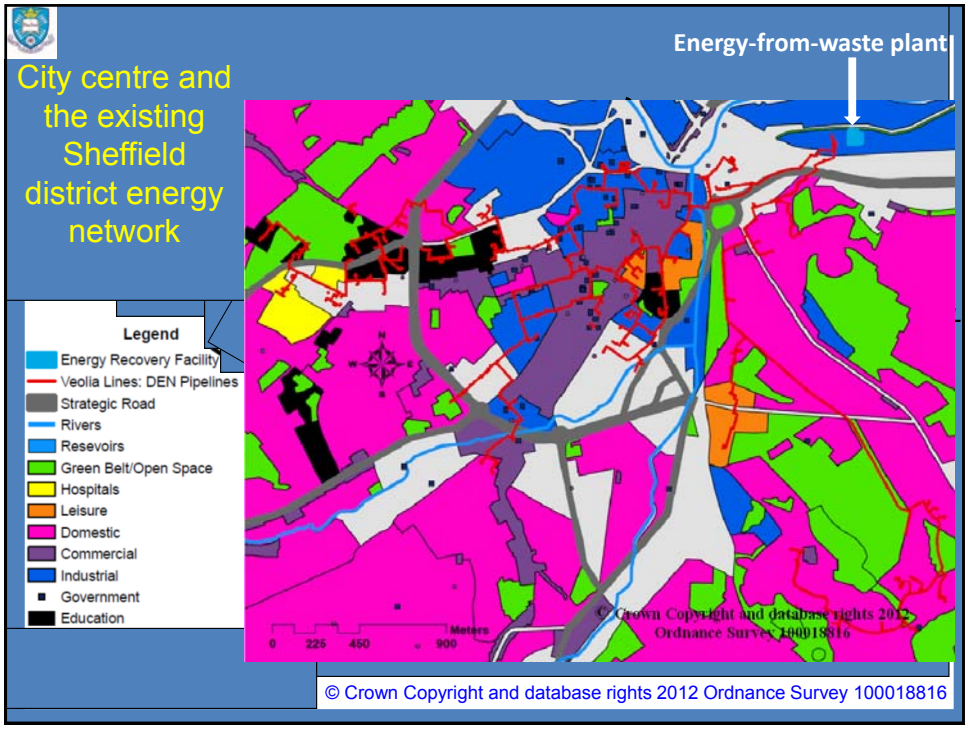
Plant Overview
Fuel Feedrate: 225,000 t/a local municipal waste
Electrical Capacity: ~20 MW_e for National Grid
Thermal Capacity: 60 MW_{th} for district heating
System Back-Up: 3 stand-by boilers (84.6 MW capacity)
Heat Delivered: 120,000 MWh/a **(5,580,000MWh/a)**
CO_2 Mitigated: 21,000 t/a **(300,000t/a)**
Connected Sites: ~3000 residences and 147 other buildings (including shops, offices and both universities)





Our Techniques for heat mapping

	☺	☹
GIS (geographical information systems)	quick to upload, map and alter/manipulate data and maps	can be complicated to get appropriate data to map (relies on other methods)
Remote sensing using LandSat imagery	fast method	availability, expensive to get up-to-date data, and errors can be up to 25%
Questionnaires	accurate data for heat usage in specific buildings (from meter readings)	response rates are low (sometimes less than 10%)
Thermal imaging	can identify areas of waste heat being dumped to atmosphere	seasonal data, not useful for heat demand/usage, can be expensive
Estimation calculations	simple, quickly generate data for large areas using annual averages	errors of 20-25%


City centre and the existing Sheffield district energy network
Energy-from-waste plant
Legend
Energy Recovery Facility
Veolia Lines: DEN Pipelines
Strategic Road
Rivers
Resevoirs
Green Belt/Open Space
Hospitals
Leisure
Domestic
Commercial
Industrial
Government
Education
Meters
0 225 450 900
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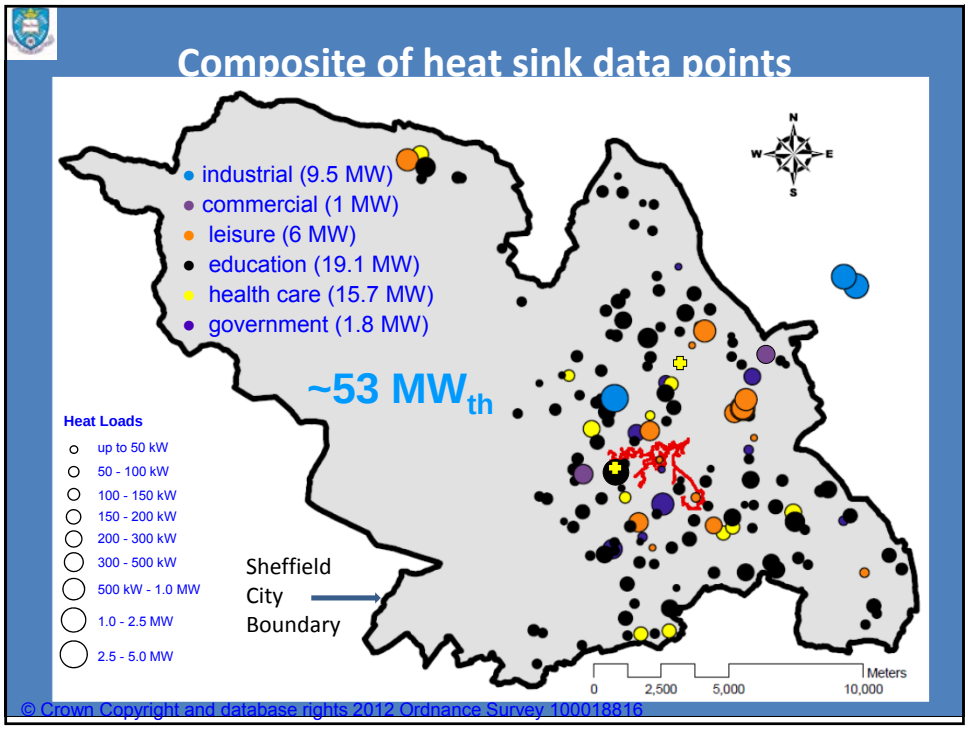
Composite of heat sink data points
industrial (9.5 MW)
commercial (1 MW)
leisure (6 MW)
education (19.1 MW)
health care (15.7 MW)
government (1.8 MW)
~53 MWth
Heat Loads
up to 50 kW
50 - 100 kW
100 - 150 kW
150 - 200 kW
200 - 300 kW
300 - 500 kW
500 kW - 1.0 MW
1.0 - 2.5 MW
2.5 - 5.0 MW
Sheffield City Boundary
N
W
E
S
Meters
0 2,500 5,000 10,000
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Identifying key 'heat source zones'

LOCATION OF HEAT SOURCES	SURPLUS HEAT (MW) EXISTING	EMERGING
1 Lower Don Valley	>9.0	5-50
2 Upper Don Valley	-	-
3 Hospital Area	-	30?
4 M'boro/Beighton	-	-
5 Sheaf Valley	-	-
6 Ecclesall Road	-	30-60?
TOTAL	>9.0	up to 140

LOCATION OF HEAT SINKS	HEAT DEMAND (MW) DOMESTIC	EXISTING	EMERGING	TOTAL
1 Lower Don Valley	40	9.3	30.3	79.6
2 Upper Don Valley	80	6.8	0.02	86.8
3 Hospital Area	138	10.2	1.0	149.2
4 M'boro/Beighton	60	0.8	0.3	61.1
5 Sheaf Valley	40	2.3	1.1	43.4
6 Ecclesall Road	200	9.2	-	209.2
TOTAL	556	38.3	32.7	629

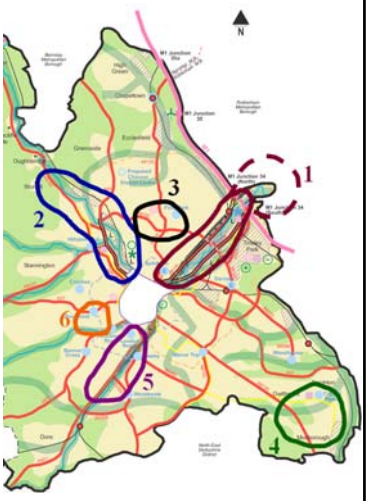
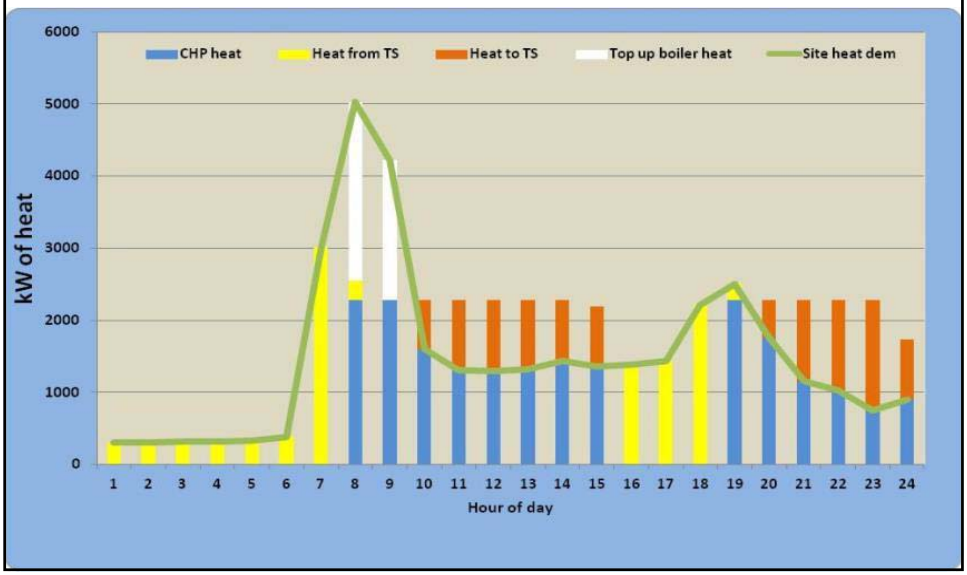
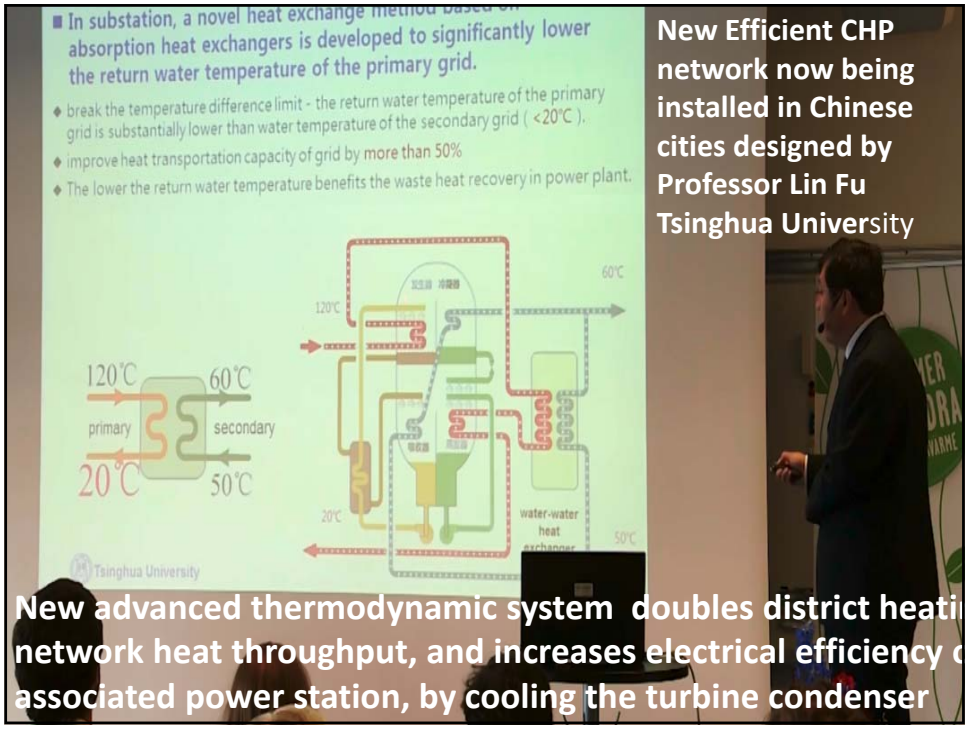


Illustration of modelling with thermal store (TS) over a typical 24 hour period





Future Disruptive Technologies in the CHP Energy/Power Market, about 10 years per Phase

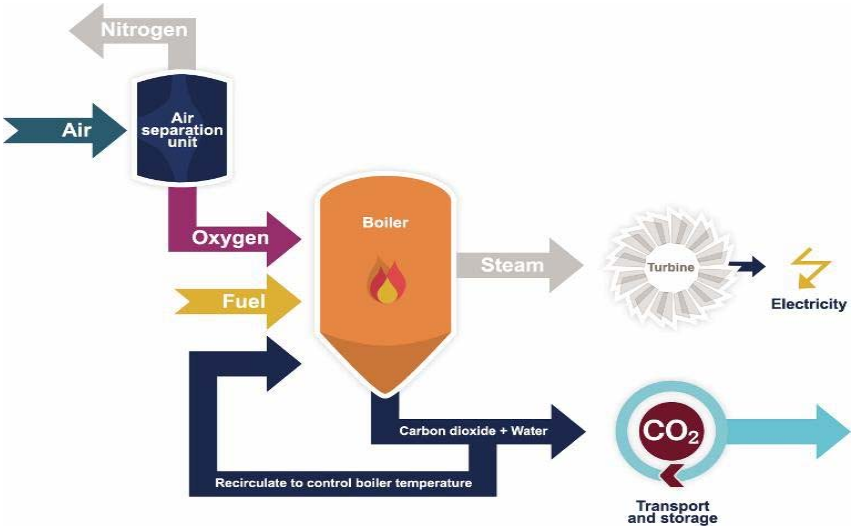
- ***Phase 1.*** Current power generation based on fossil fuels burned in air.
  - CHCP with absorption chillers plus Prof Lin FU absorption system
- ***Phase 2.*** OxyCoal technology with CCS. CHP with heat storage.
- ***Phase 3.*** OxyNatGas advanced technology with CCS
  - Ship CO_2 transport and propulsion
  - The Allam high efficiency power generation system
- ***Phase 4.*** Fossil fuel entrained flow gasification, wind turbines and PV
  - Hydrogen energy storage and fuel cells
- ***Phase 5.*** Alternative energy sources for CHP with hydrogen storage to match system dynamics

Some Industrial Impacts:

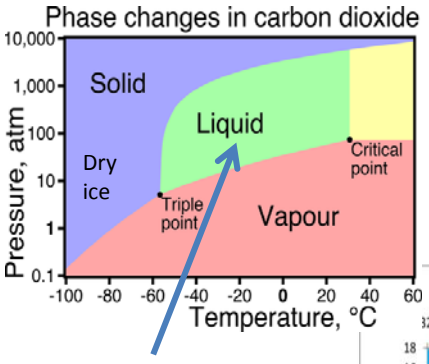
Huge opportunities in; PV and offshore wind, new CHP networks, disruptive diversion to the transport of LNG and CO_2 , gas and hydrogen distribution networks, fully integrated energy/waste/transport systems for sustainable cities.

Sea level increase means that major civil engineering work will be required worldwide.

Schematic of the oxy-fuel combustion process

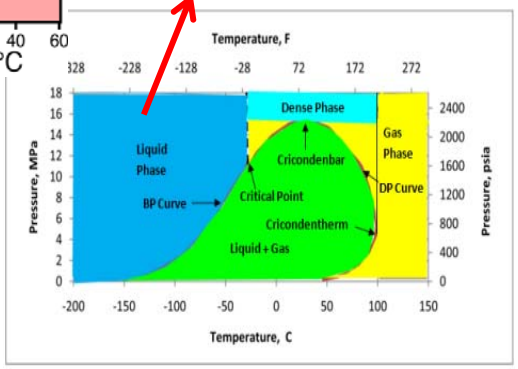


The Allam Cycle



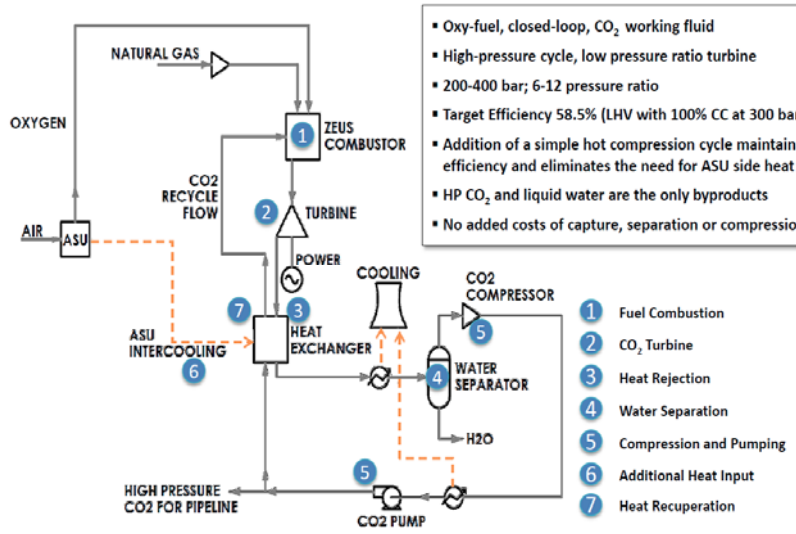
Oxy-fuel Power cycles using recycled CO2 can pump this liquid to high pressure much more efficiently than compressing gaseous CO2. This is concept is exploited in the Allam engine and other new cycles involving liquid air, liquid oxygen and LNG.

The cold from LNG fuel can be used to capture CO2 flue gas as dry ice for CCS power (or CHP) systems, eg in Singapore. New mobile applications include zero emission marine propulsion, non-electric trains and large trucks.



Phases for a typical natural gas

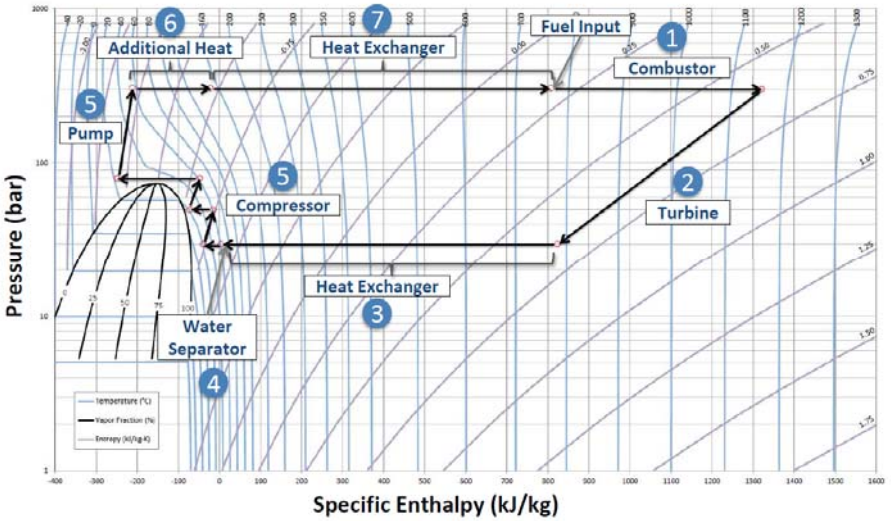
The NET Power natural gas system



- Oxy-fuel, closed-loop, CO_2 working fluid
- High-pressure cycle, low pressure ratio turbine
- 200-400 bar; 6-12 pressure ratio
- Target Efficiency 58.5% (LHV with 100% CC at 300 bar)
- Addition of a simple hot compression cycle maintains efficiency and eliminates the need for ASU side heat
- HP CO_2 and liquid water are the only byproducts
- No added costs of capture, separation or compression of CO_2

Hideo Nomoto, Toshiba Corporation, Rodney Allam, NET Power, Presentation to 7th Trondheim Carbon Capture and Sequestration Conference, June 5, 2013

NET Power natural gas cycle



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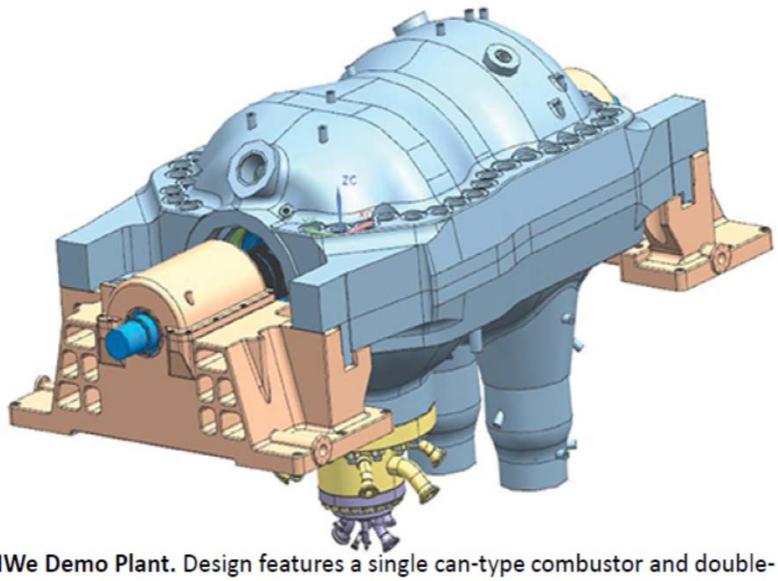

25MWe Demo Plant. Design features a single can-type combustor and double-shell turbine structure, scaled-down model of a 250-300MWe turbine design for a commercial plant.

Conclusions

- Sheffield is the leading centre for citywide CHP-district heating in the UK – key opportunity to establish the city as the national demonstrator
- Many reasons for further expanding the energy network to national scale; e.g. using pipes following HS2/HS3 routes
- GIS-based heat mapping developed to be used for this purpose
- A range of potential sources and sinks of additional thermal input/output to expanded network – redistribute heat through the cities
- New absorption technology could increase the capacity and efficiency of the CHP Network
- Opportunity to achieve a 30% step reduction in UK CO_2 emissions
- **Research work is required on new gasification systems, new engine cycles and hot gas clean-up.**
- New technologies can meet the carbon neutral target in the future.
- Small scale CHP in suburban homes will use existing gas pipes to reduce network installation costs, initially using natural gas and by 2100 will use solar/wind generated hydrogen
- **CHP is in great danger of becoming a missed opportunity in the UK!**