Low Carbon Summit

9 September 2016

#lowcarbonsummit

IChemE Energy Centre

KTN the Knowledge Transfer Network

Professor Stefaan Simons

Chair

IChemE Energy Centre

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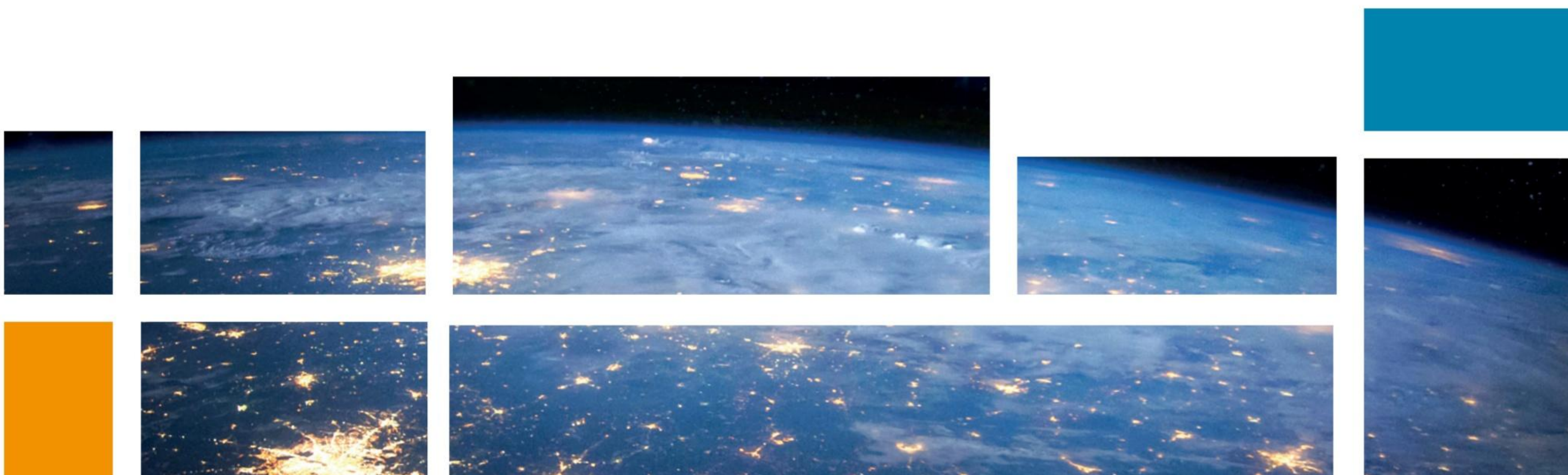
Welcome

#lowcarbonsummit



The IChemE Energy Centre

Systems thinking solutions for the global energy economy

- launched in March 2015
- the Centre provides an evidence-based chemical engineering perspective on global energy challenges

To find out more visit www.icheme.org/energycentre, email energycentre@icheme.org or tweet @EnergyIChemE

What next after Paris?

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This is a Summit not a Lecture

A Summit is a meeting between people who are interested in the same subject

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Dr David Clarke

Chief Executive Officer

Energy Technologies Institute

www.eti.co.uk

Where now for the UK energy system …. ?

Progressing towards a low carbon future – some thoughts to provoke a debate

Dr David Clarke FREng

Chief Executive ETI

9th September 2016

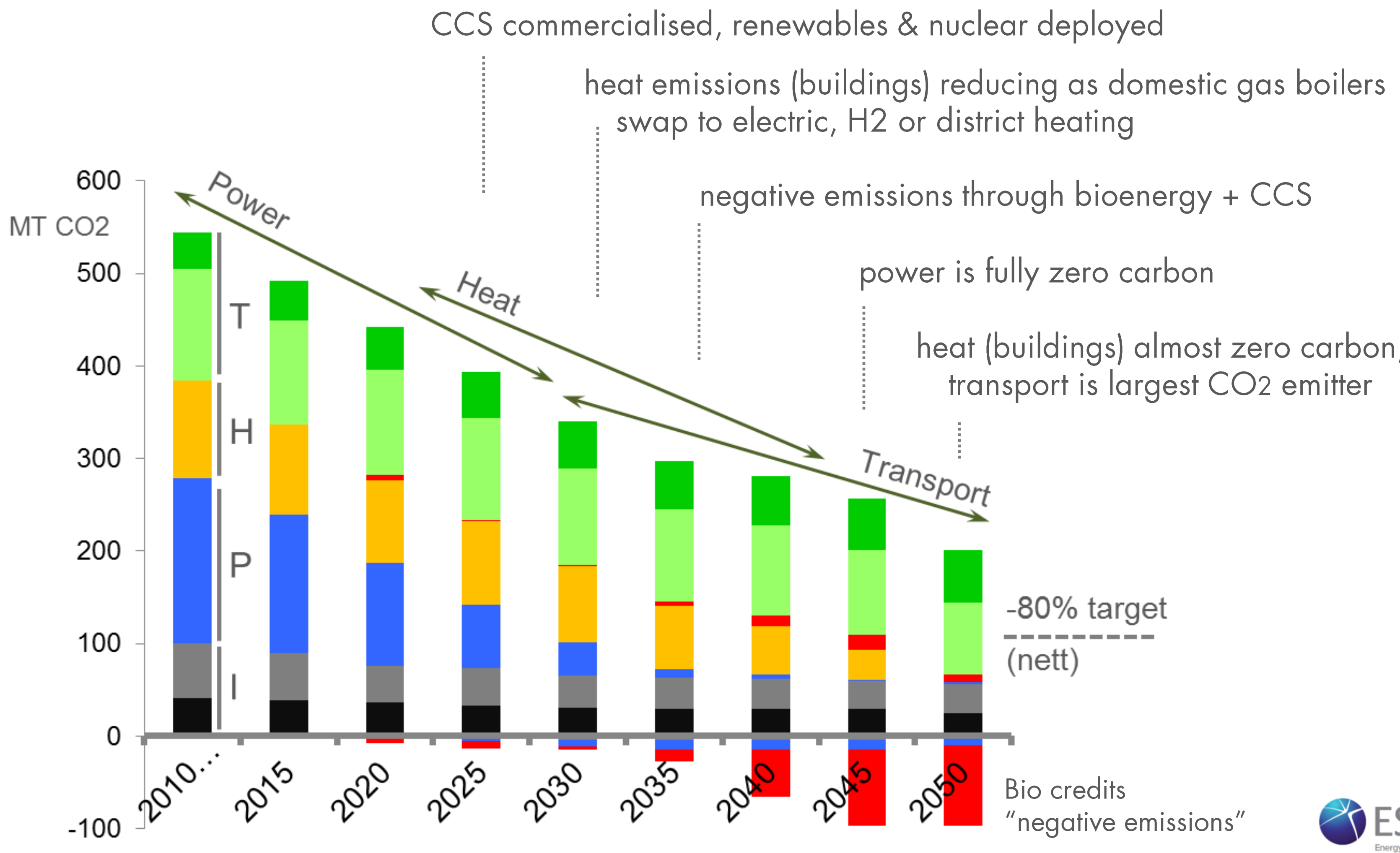
The 'logical' economic route forward for the UK is clear

But implementation is not just about logic and risk – it's political and societal

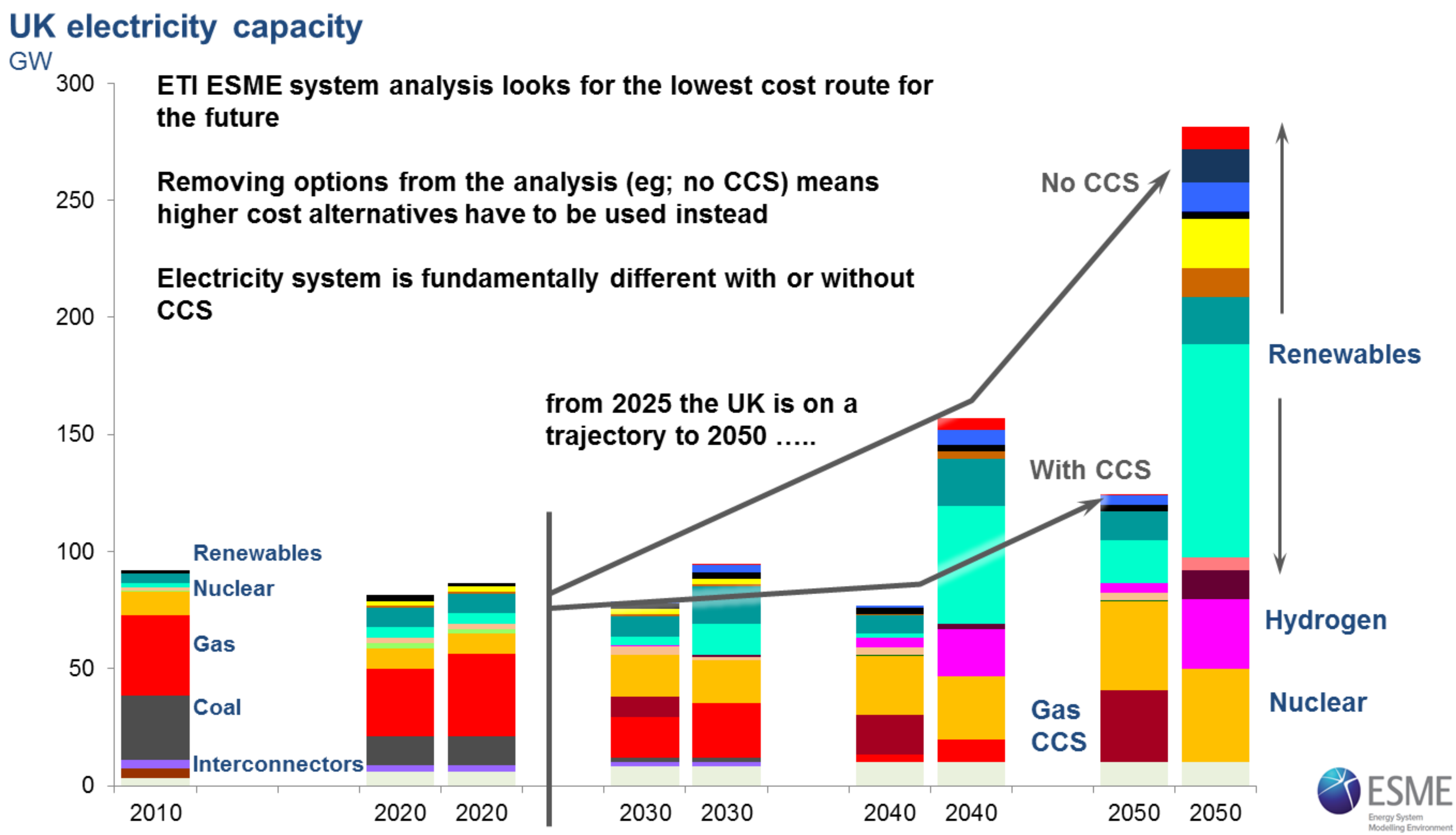
- In a world where we ……
  - Require energy security
  - Need to deliver affordability
  - Aspire to meet climate change targets including nett zero emissions
- The logical economic route forward is clear …..
  - Decarbonise **electricity** by 2030 – gas, CCS, nuclear, renewables (wind), bioenergy
  - Then accelerate decarbonisation of **heat** (electricity, non-fossil gases, CHP, efficiency) and **transport** (efficiency, biofuels, electricity, hydrogen)
  - Retain centralised grids but 'smarter'
- BUT …..
  - All groups considering UK energy strategy, policy and economics are essentially working from the same assumptions and the same key data – challenge is needed
  - Failure to deliver a secure energy system is 'not an option'
  - Uncertainties are increasing
  - Consumer led solutions are on the increase but integration is haphazard
  - Political will is needed to deliver any direction of change at scale and at speed ……

An emissions reduction plan

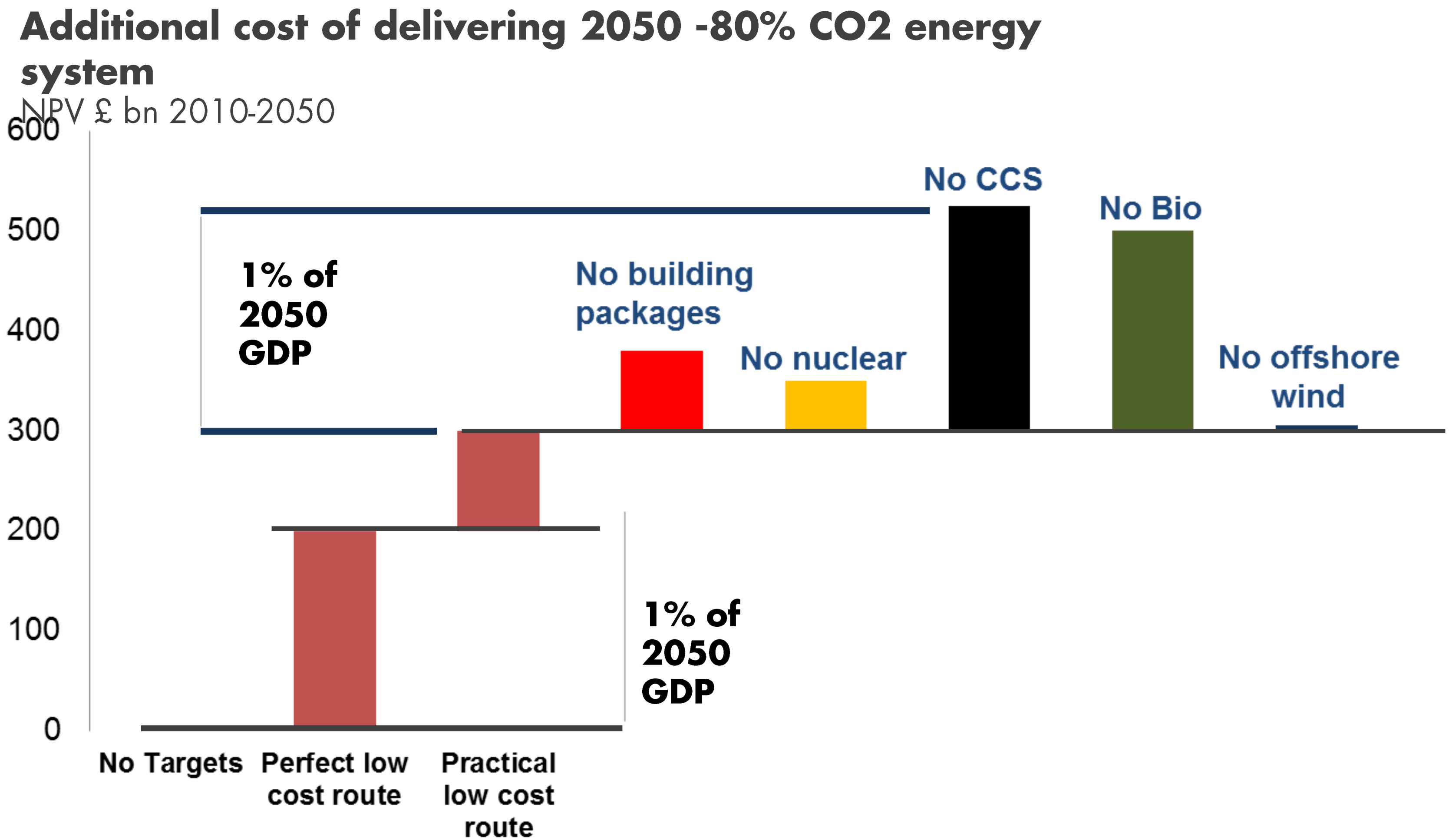
Power now, heat next, transport gradual – cost optimal



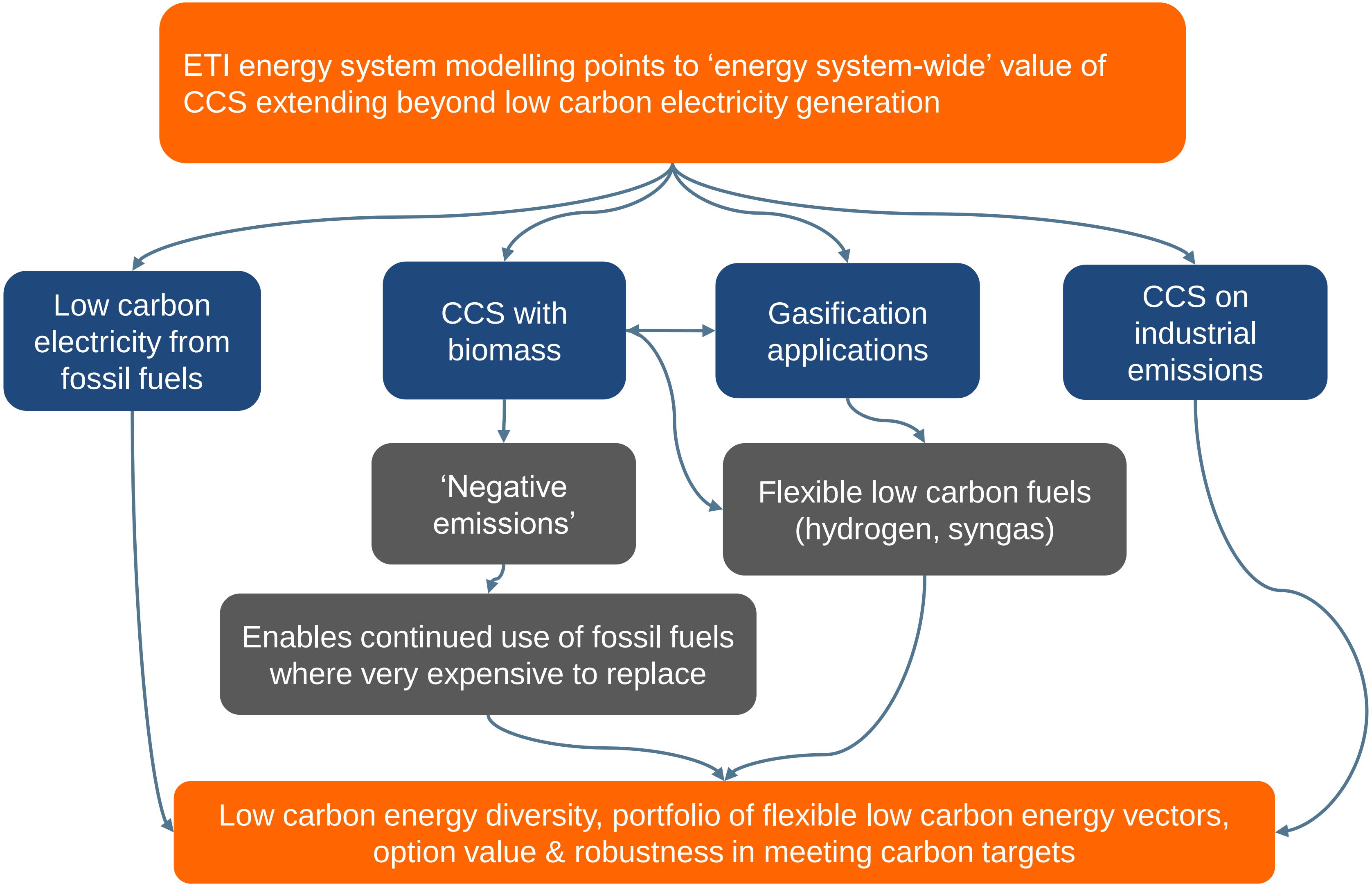
There are major options and drivers in how we develop the UK energy system …..



The UK can achieve an affordable transition (1-2% of GDP) but system optimisation is key

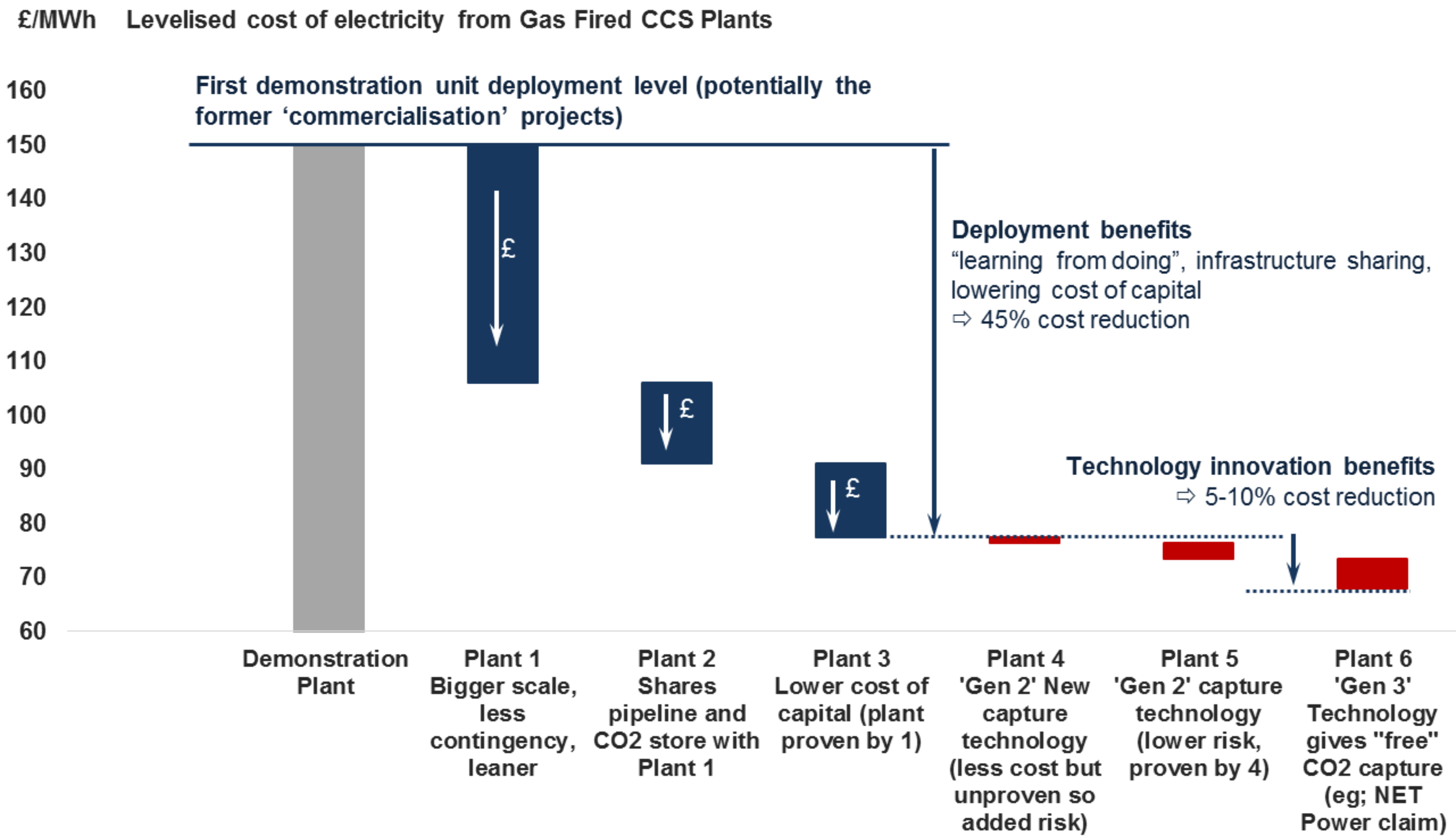


The Value of CCS is in its many roles



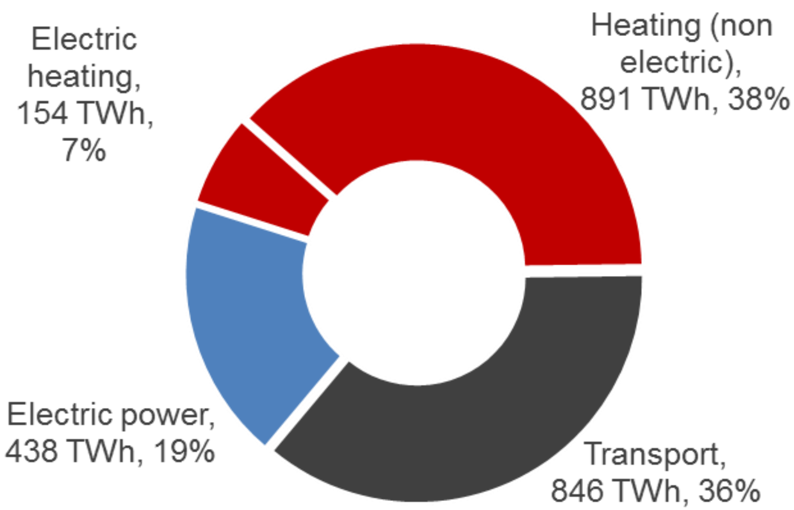
CCS cost reduction potential

primarily driven by increasing scale and sharing infrastructure



*Levelised costs are in UK£ 2013, capital costs are +/- 40%(EPC *1.4), discount rates are adjusted for risk (range 9-16%). Gas £24/ MWht and CO_2 emission £31/te. All plants other than first demonstration plant are 860MW net output.*

What do we use energy for ….



DUKES (2014 data)

What do we want storage for ?

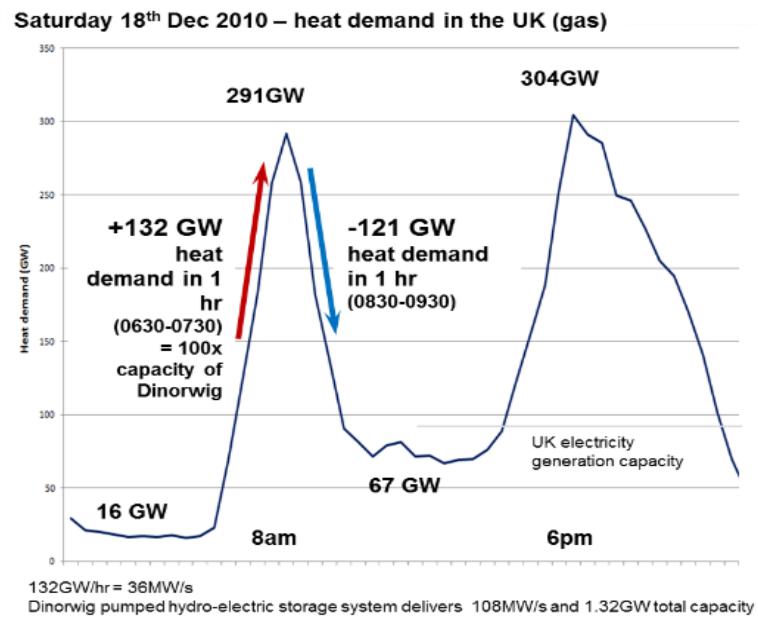
- Mobility (road vehicles)
- Responsiveness / flexibility
- Reserve / back-up
- Load levelling

All different, all changing markets ….

Effective large scale energy storage needs to support multiple integrated demands – across the system …..

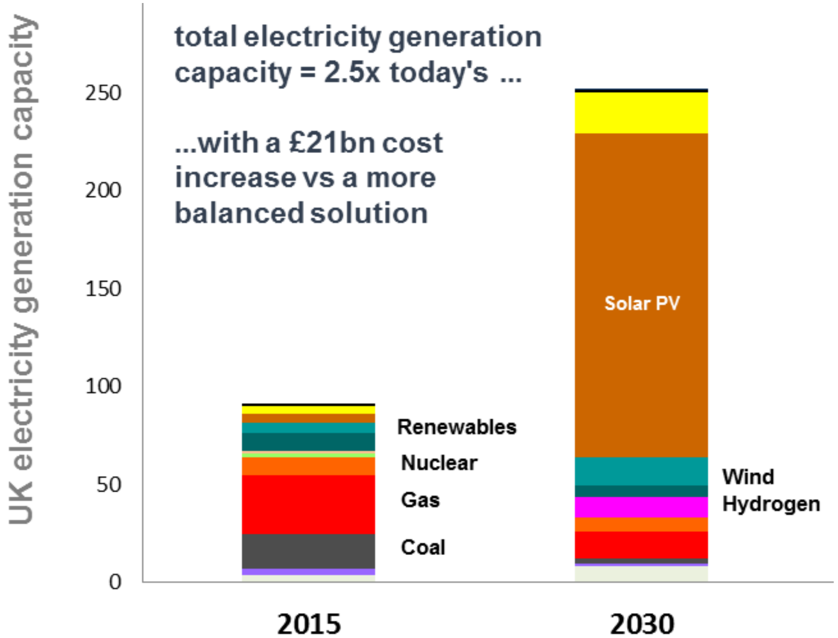
….. and the system may need considerable adaptation to incorporate it …..

Gas is an easy example …..



Reset :
could we meet 2030 emissions reduction targets on solar ?

- Current outlook suggests by 2030 there could be no CCS, very limited bio, up to 10GW additional offshore wind, maybe no new nuclear
- How far can solar PV, storage and gas take us?



- 188GW of solar PV delivering just over half of current total annual demand (~163KWh)
- Less than half (47%) could be used at the time of production
- 20-50GW of storage needed to shift supply to meet evening demand

- Land required equivalent to 4 national parks in south of England

- Winter demand met by gas – annual CO2 intensity >100g/kWh
- To remove gas use requires further 80GW of solar and 60TWhs of storage (equating to a 40ft shipping container battery pack for every person in the UK)
- **Not a basis for the electrification of cars and home heating which will increase winter demand and overall system flexibility required**

ETI scenarios – Clockwork, Patchwork

central control vs locally based decisions

25% increase in abatement cost to 2030 (+£33bn)

→

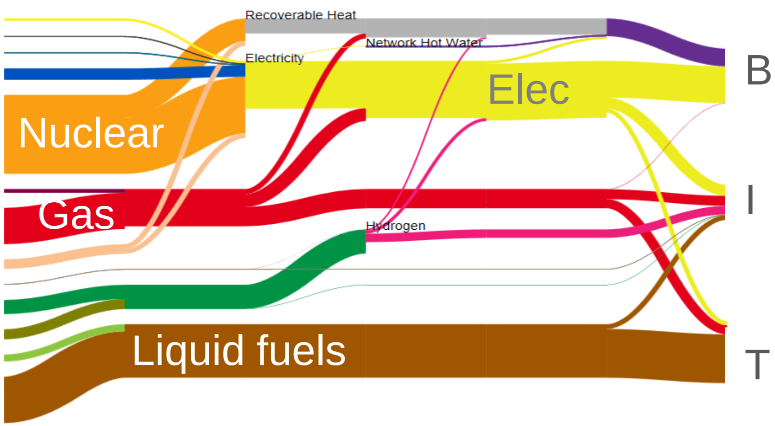
100% increase in system capex cost to 2030 (+£450bn)

Clockwork

Well coordinated, long-term investments

National planning

2050

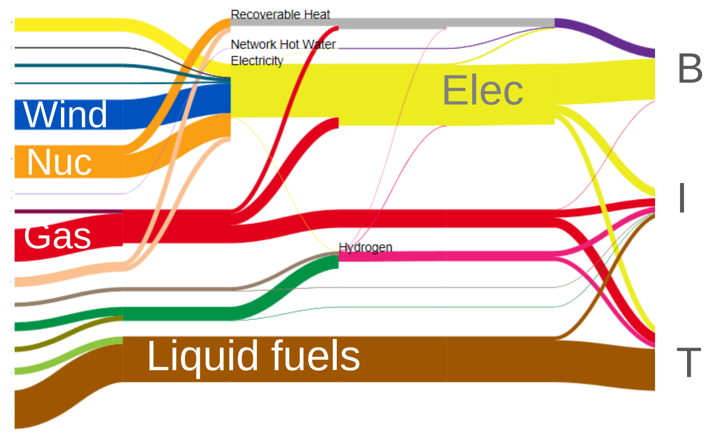


Patchwork

Regional and community decisions

Larger number of (generally) smaller capital projects

2050



Less coordination increases costs

– but may be faster in today's UK ?

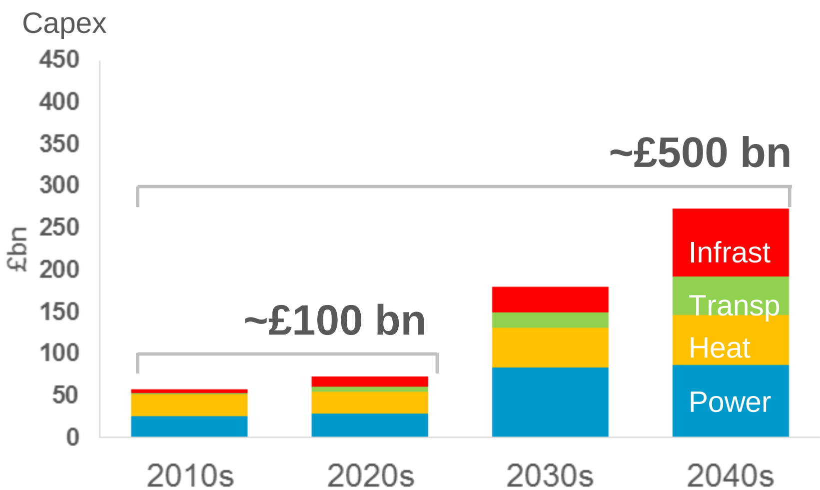
Reality - somewhere in the middle?

£150bn capex to 2030

+£2-3bn p.a.vs 'do nothing' on carbon reduction

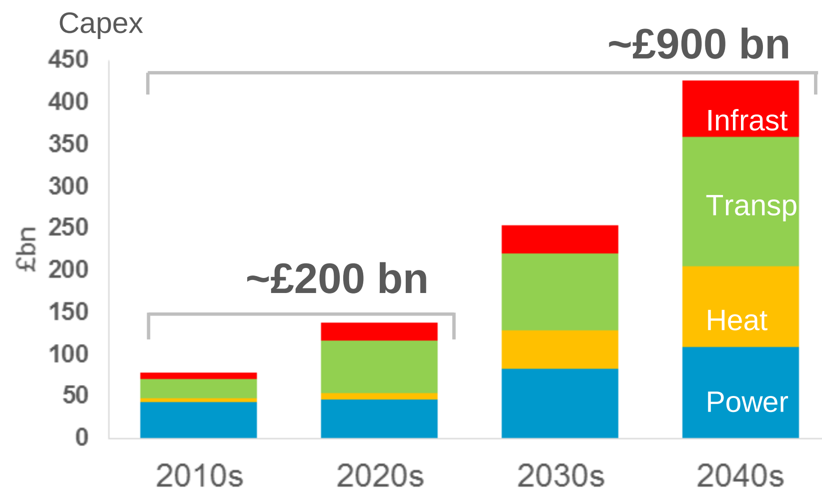
Clockwork – steady progress

lowest cost
greatest economic benefits …



Patchwork – fast decisions at regional level, diverse solutions

Adaptability for shocks and diversions?



Way forward is clear - implement 'no regrets' solutions, test new options

Seek to understand scale of uncertainties and evaluate potential impacts

- The logical, economic, route forward is clear …..
  - Decarbonise **electricity** by 2030 – gas, CCS, nuclear, renewables (wind), bioenergy
  - Then accelerate decarbonisation of **heat** (electricity, non-fossil gases, CHP, efficiency) and **transport** (efficiency, biofuels, electricity, hydrogen)
  - Retain centralised grids but 'smarter'

- The details of all these need to be tested …..
  - Drive forward new capacity in the main low carbon electricity generating technologies — nuclear, carbon capture and storage (CCS, on gas powerplants) and offshore wind
  - Press ahead with local and regional whole-system, large-scale pilot projects to establish real-world examples of how the future system will work
  - Move beyond current 'single technology' demonstrations and incorporate all aspects of the energy system along with consumer behaviour and financial mechanisms
  - Develop policies to accelerate demand reduction, especially in the domestic heat sector, and the introduction of 'smarter' demand management.
  - Clarify and stabilise market mechanisms and incentives in order to give industry the confidence to invest.

ROYAL ACADEMY OF ENGINEERING

‘A critical time for UK energy policy’

some concluding sound bites

“ in developing energy policy, the whole system must always be considered ”

“ what is required now is a combination of known technologies, scaled-up to unprecedented levels, integrated in smarter ways ”

“ failure to work together by all stakeholders may be the single biggest risk for delivery of the future energy system ”

“The future is closer than it might seem ……”

Dr David Clarke FREng
Prof Nigel Gilbert FREng
Dr Martin Grant FREng
Dr Keith MacLean
Richard Taylor FREng
Dr Alan Walker
Dr Nick Hughes

http://www.raeng.org.uk/publications/reports

Dr David Clarke

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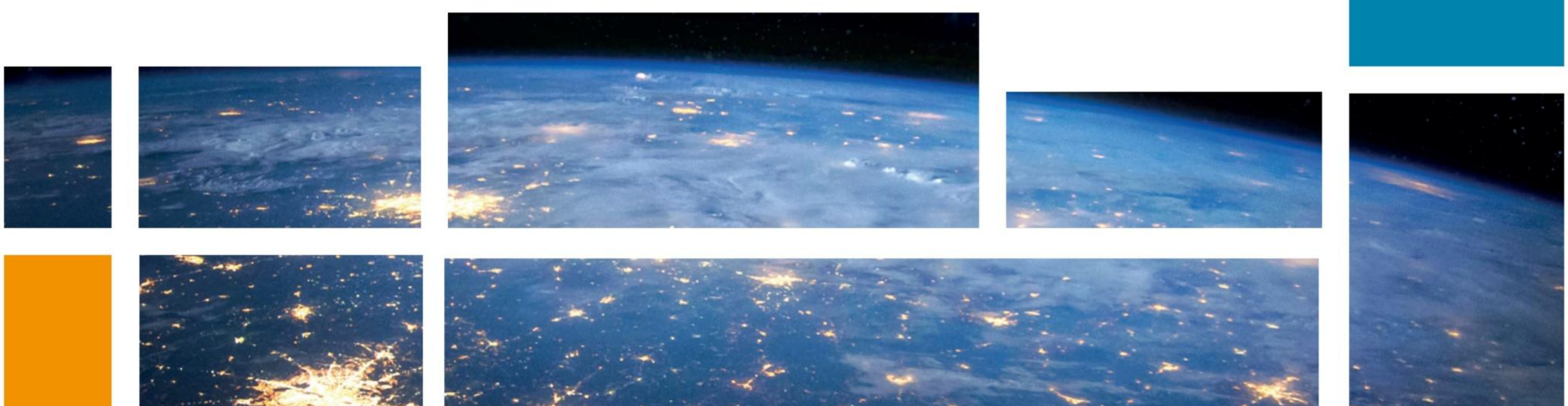

Jonathan Graham

Head of Policy

The Association for Decentralised Energy

IChemE Energy Centre

KTN the Knowledge Transfer Network

Jonathan Graham

A district heating network, covering 250,000 houses, saves 0.25-1.25 $MtCO_2$

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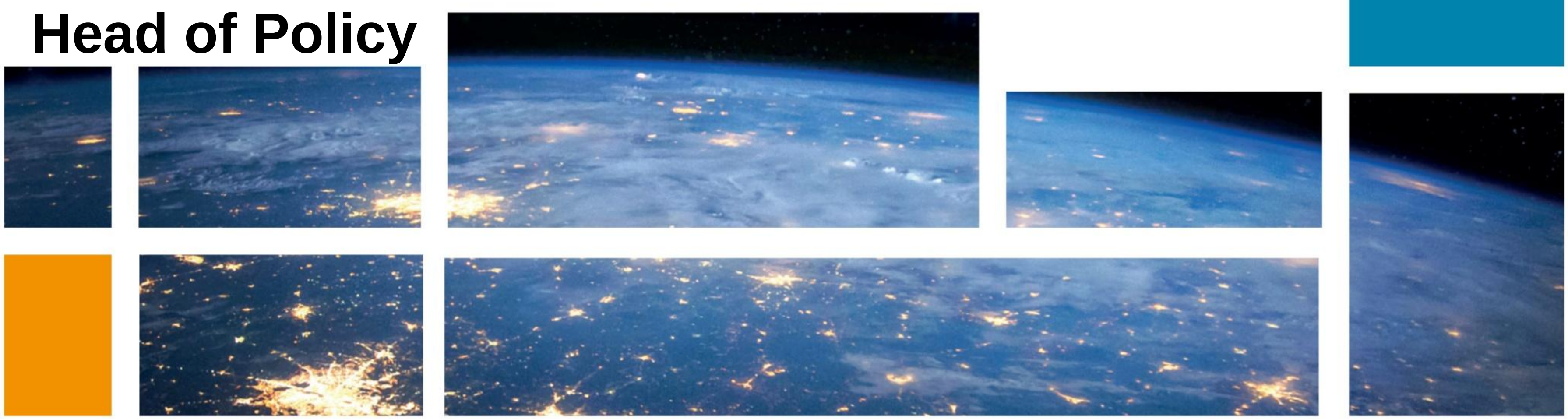
The carbon benefits of heat networks and combined heat and power (CHP)

9 September 2016

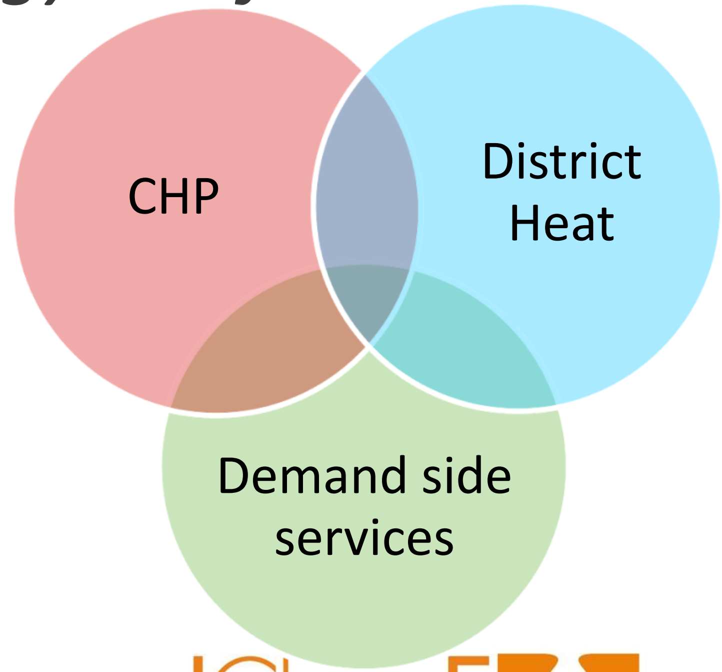
Jonathan Graham
Head of Policy



About the ADE

The voice for a cost effective efficient, low carbon, user-led energy system; a market in which decentralised energy can flourish

- Areas of focus
  - Combined heat and power
  - District heating and cooling
  - Demand side energy services, including DSR and storage



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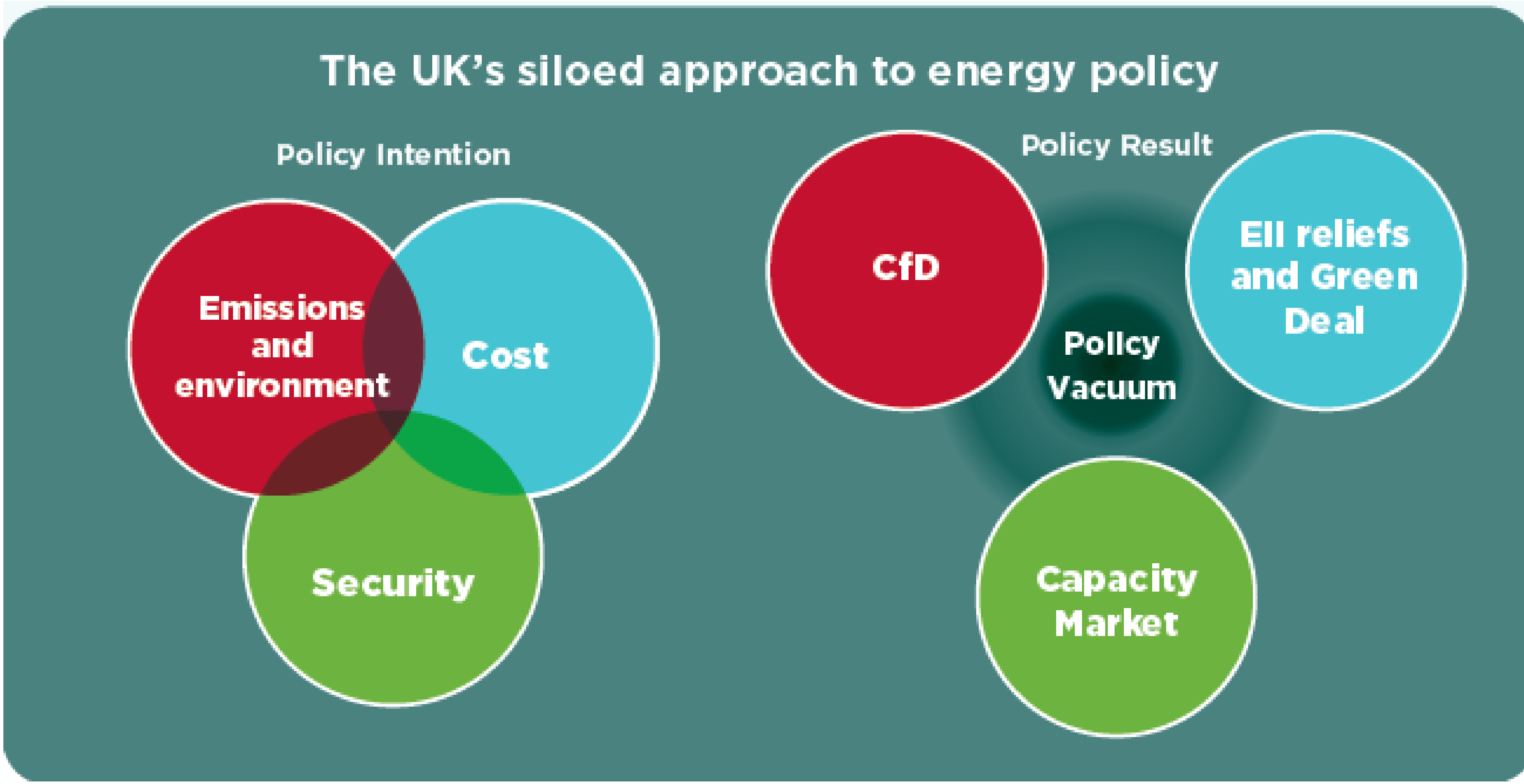
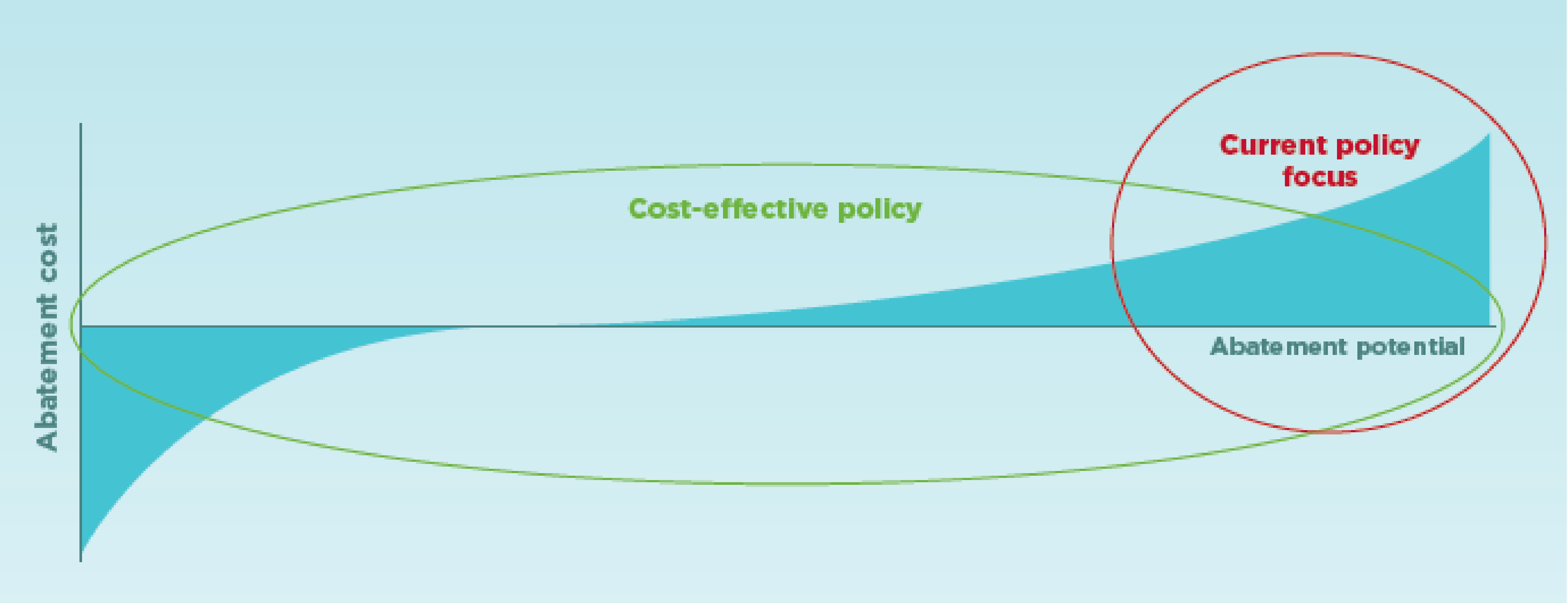
Two key problems with energy policy for efficiency


The UK's siloed approach to energy policy
Policy Intention
Emissions and environment
Cost
Security
Policy Result
CfD
EII reliefs and Green Deal
Policy Vacuum
Capacity Market

Where are we aiming energy policy?



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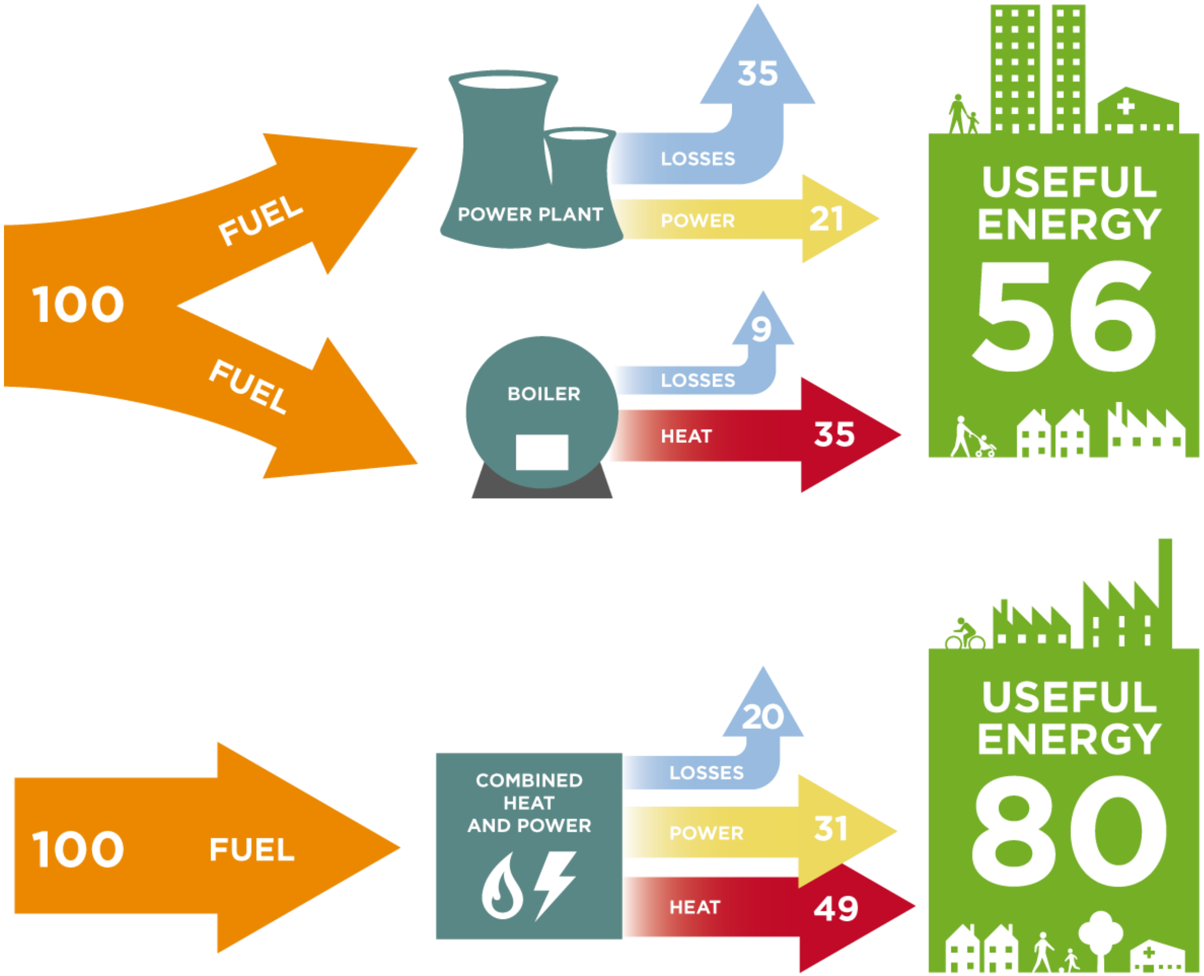
CHP and carbon emissions

CHP is best use of thermal fuel



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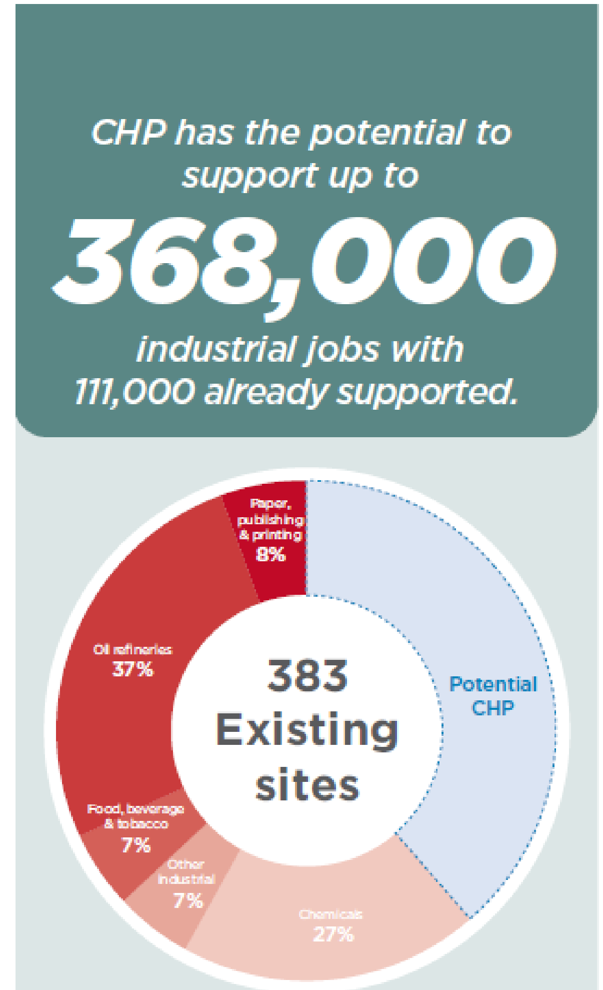
CHP is backbone of modern UK economy

- CHP meets 6% of UK electricity supply – 5.9 GWe
- Delivers heat to key industrial sectors – chemicals, paper, refining, food and drink, steel
- Growing role in public sector and commercial organisations as an efficiency tool
- Potential economic CHP capacity is three times higher



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Gas CHP savings today

- The CO2 savings from all 5.9 GW of good quality CHP plants is 14.24 MtCO2 per year.
- A MWe of good quality CHP capacity reduces carbon emissions by 2,419 tCO2 per year
  - Against the UK fossil fuel basket across all CHP fuel types and technologies.
- The net cost of carbon abated by a CHP project varies depending on investability of project
- An investible gas CHP project is -60 to -100 £/tCO2 compared to separate generation

Gas CHP savings tomorrow

- From the early 2030s, gas CHP is at risk of increasing carbon emissions.
- The effect of the electricity grid decarbonisation on CHP carbon emission savings will result in diminishing savings.
- However, how much it diminishes will depend on what happens within the rest of the electricity system.
  - E.g. CHP without on-site demand (i.e. on heat networks) could save CO2 into 2045

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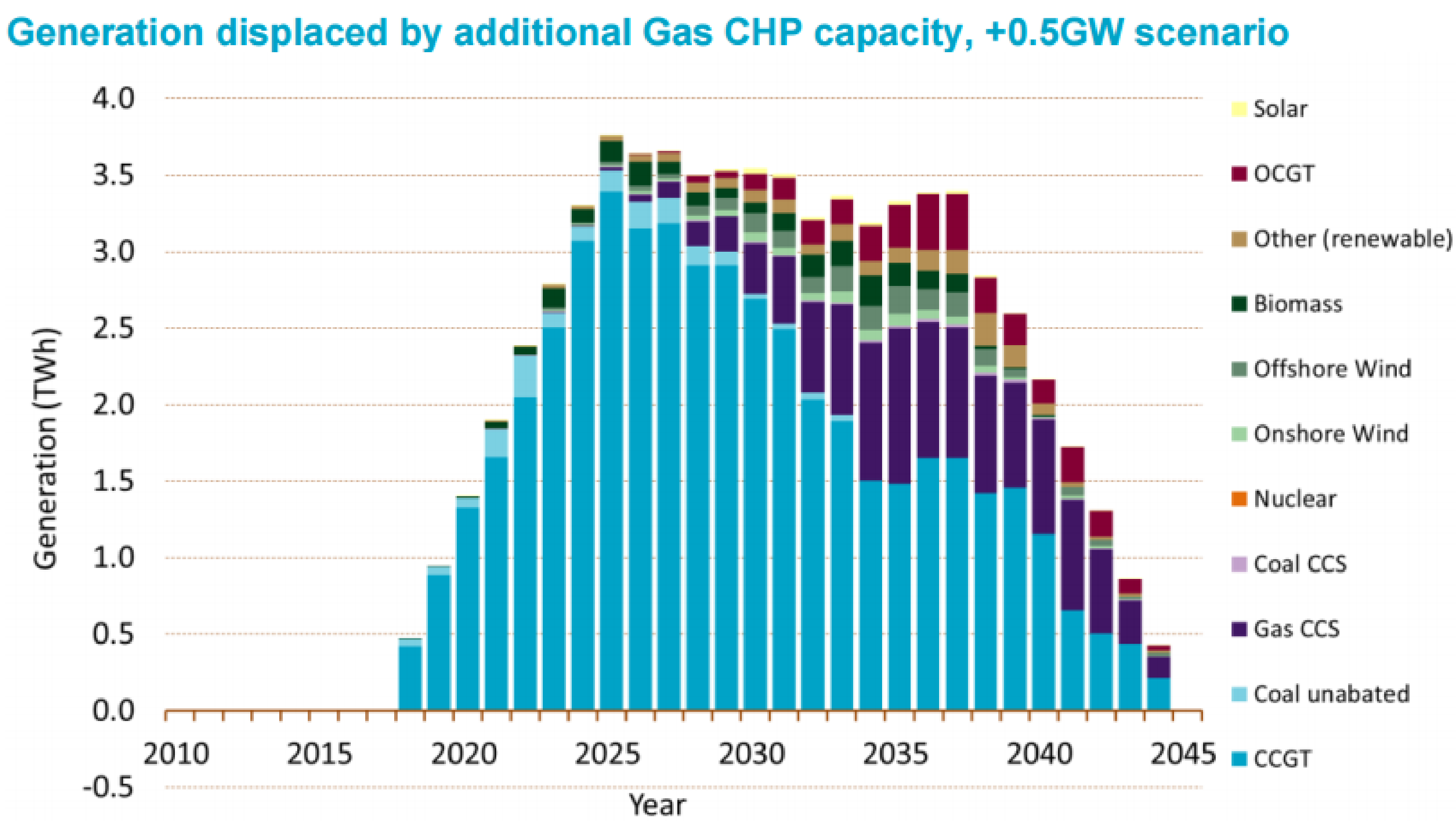
What does gas CHP displace?



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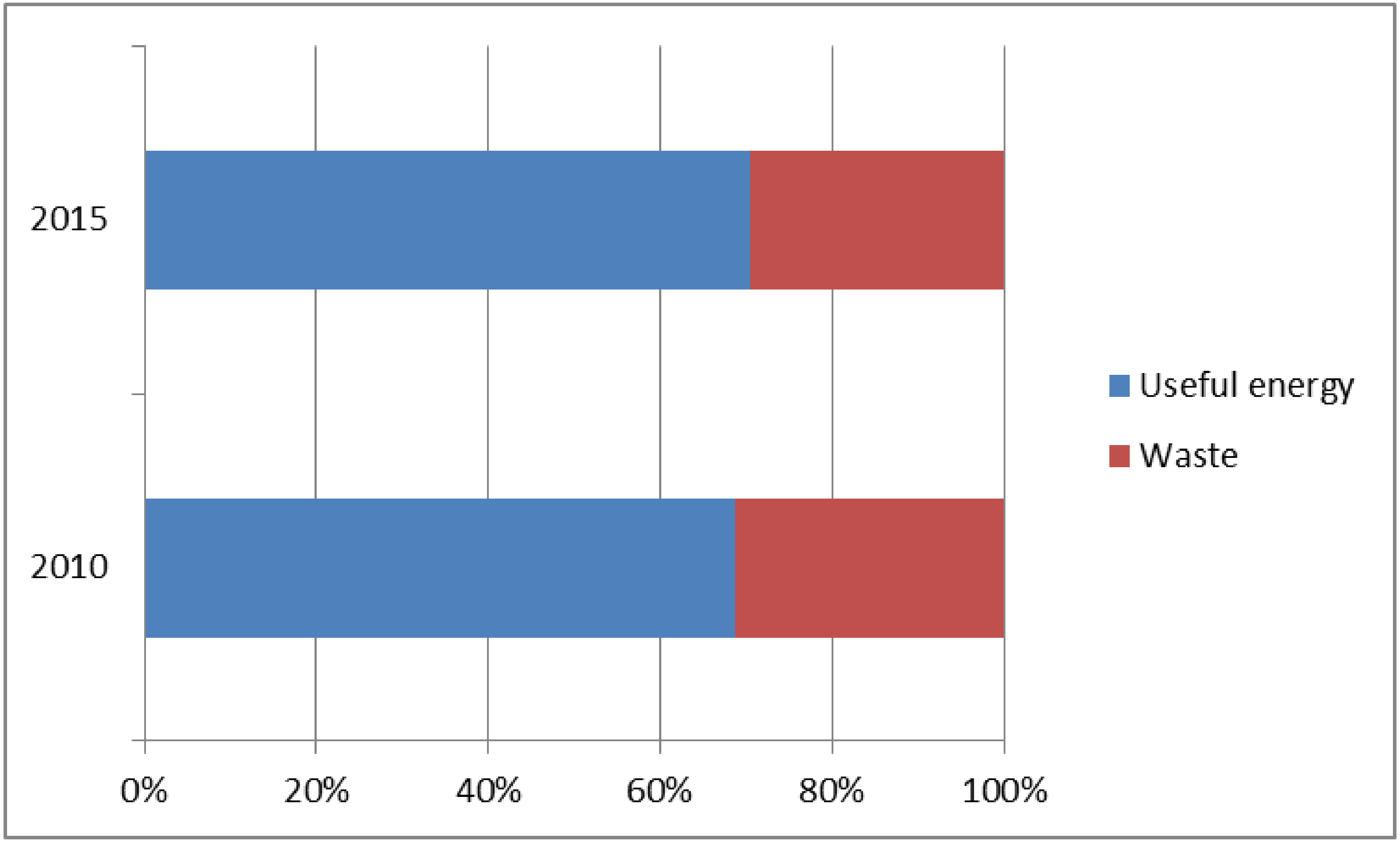
Limited gains in energy productivity



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The role of heat networks

Some heat network CO_2 estimates

- A district heating network covering 250,000 houses could save between 0.25 and 1.25 Mt CO_2 (depending on fuel source) a year compared to conventional heating systems
- Element energy estimated that the total carbon abatement from district heating schemes is 5.6 $MtCO_2$ in 2030 and 15.1 $MtCO_2$ in 2050.
- Element energy estimated that the average carbon abatement cost from district heating is from 2025 onwards ranges between £65/tCO_2 and £140/tCO_2 in its work for the CCC.

Networks vs. generation

- What is the carbon content of this?

- Or the carbon content of this?

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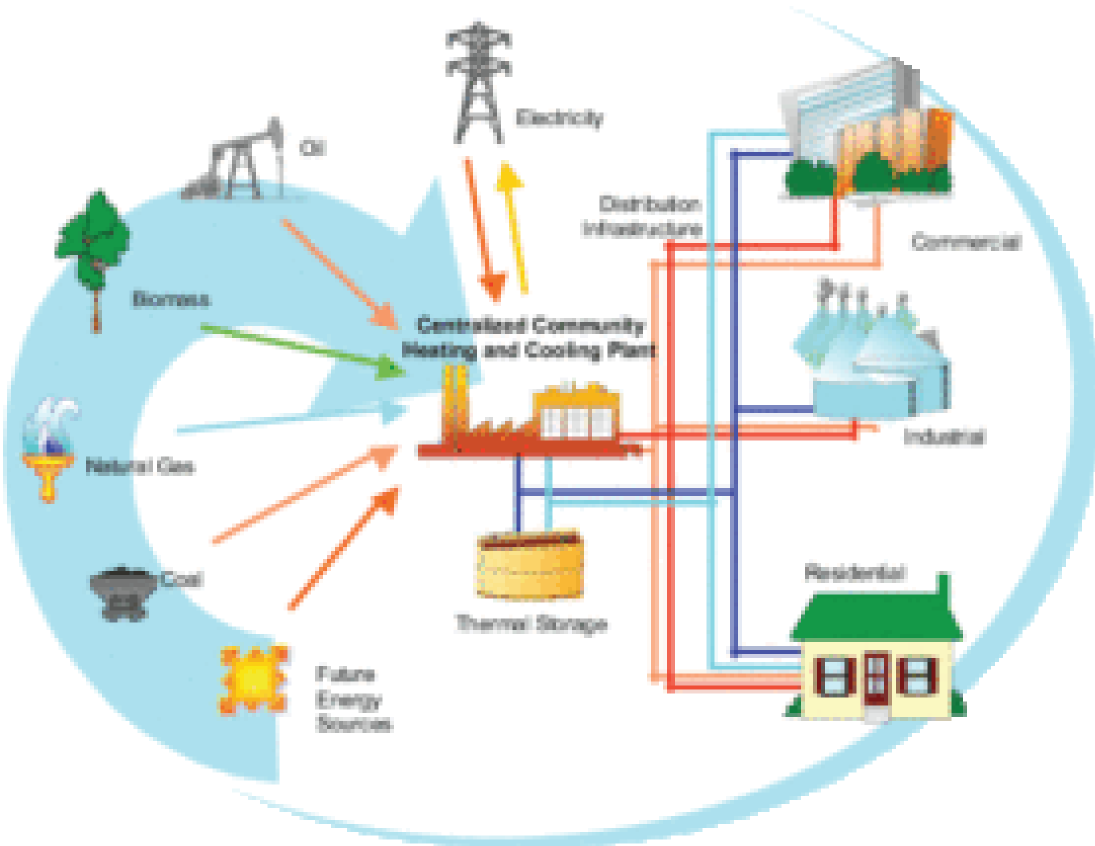
Heat networks capture new heat sources

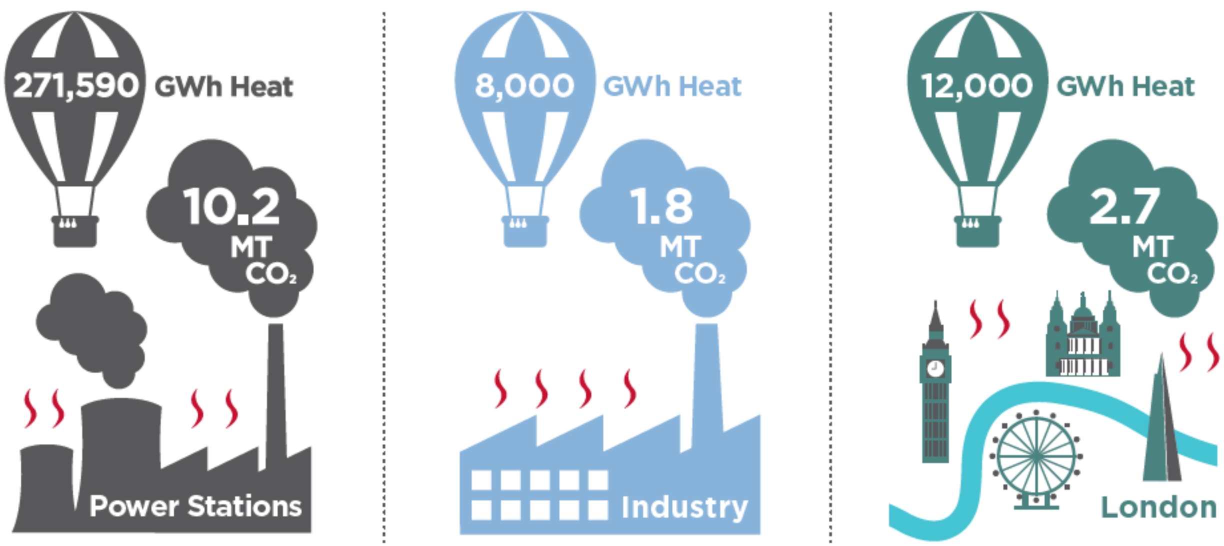


The size of the waste heat prize

Power stations, the industrial sector and cities like London all waste heat.

Together they waste more heat than is used by every home in the UK.

Where is this heat wasted?



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District heating in the UK

- Current:
  - 405,000 dwellings
  - ~4% heat demand
- Government ambition to grow to 14% of heat demand by 2030, where suitable

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Policy and regulatory evolution

Last Parliament

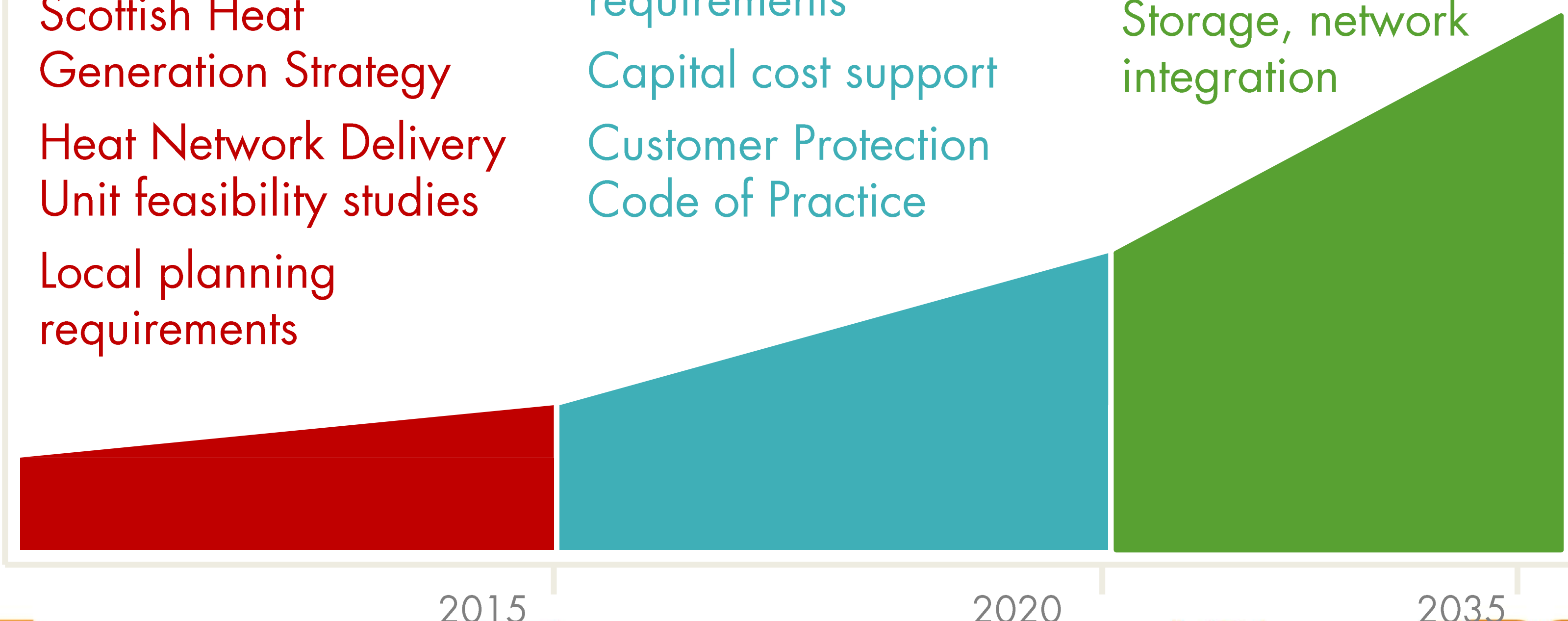
- Heat strategy development
- Scottish Heat Generation Strategy
- Heat Network Delivery Unit feasibility studies
- Local planning requirements

This Parliament

- Increased HNDU role
- National planning requirements
- Capital cost support
- Customer Protection Code of Practice

Post-2020

- Investment framework
- Fair business rates
- Storage, network integration



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Further questions?

Thank you

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- Twitter: @theade_UK, @enerjg

the Knowledge Transfer Network

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Dr Chris Williams

Manager Energy Optimisation

Tata Steel

IChemE Energy Centre

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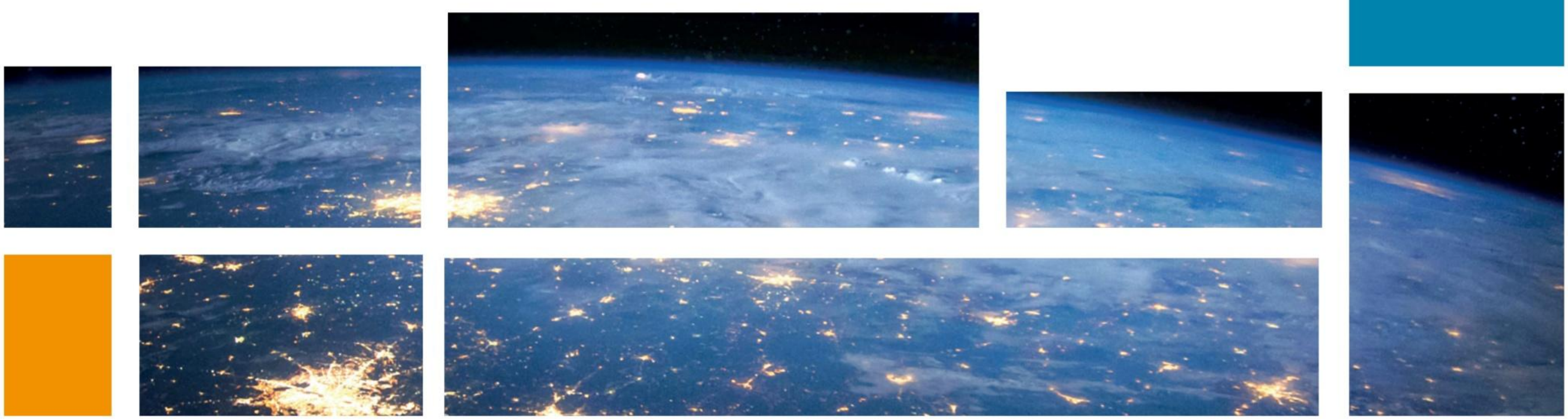
Dr Chris Williams

Waste heat recovery increased onsite generation by 12 MWe and saved over 50,000 tonnes of CO_2 emissions

Industrial Waste Heat Recovery

A Steelworks Case Study

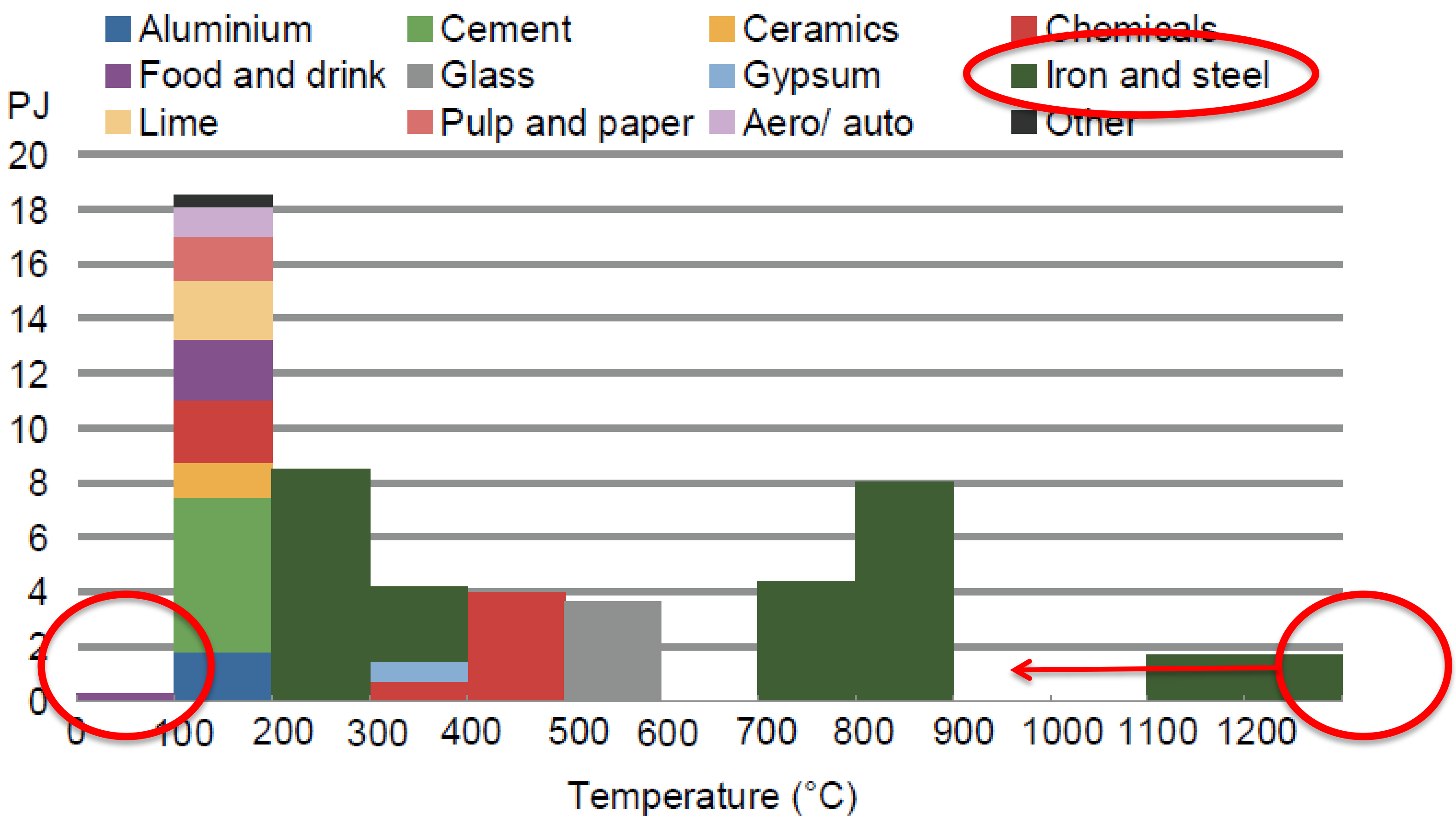
Dr Chris Williams, Manager Energy Research , Tata Steel Strip Products UK



Overview

- Industrial Waste Heat
- Case Study Steel Works
- WHR analyses & Modelling
- The WHR and steam system strategic plan
- The results of the installation
- FLEXIS – the future

Industrial Waste Heat Recovery



HEAT RECOVERY OPPORTUNITIES IN UK MANUFACTURING, Hammond & Norman, Bath University, 2012)

http://opus.bath.ac.uk/43201/1/A10069.pdf

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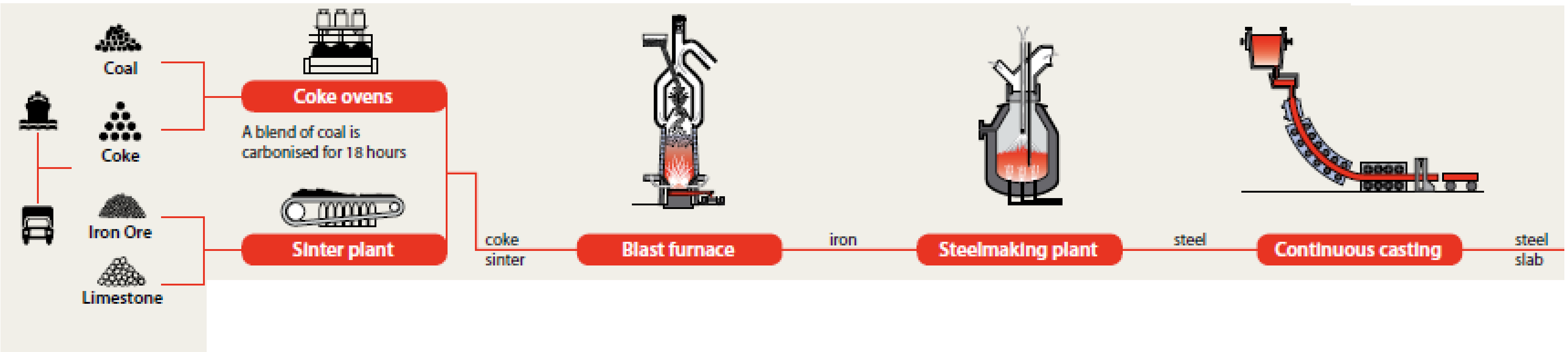
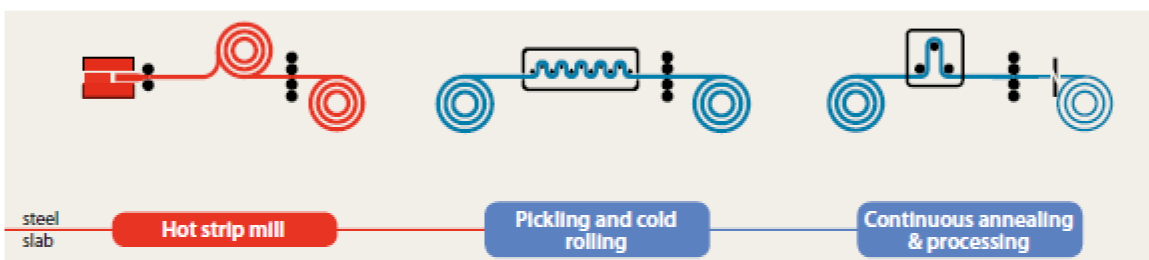
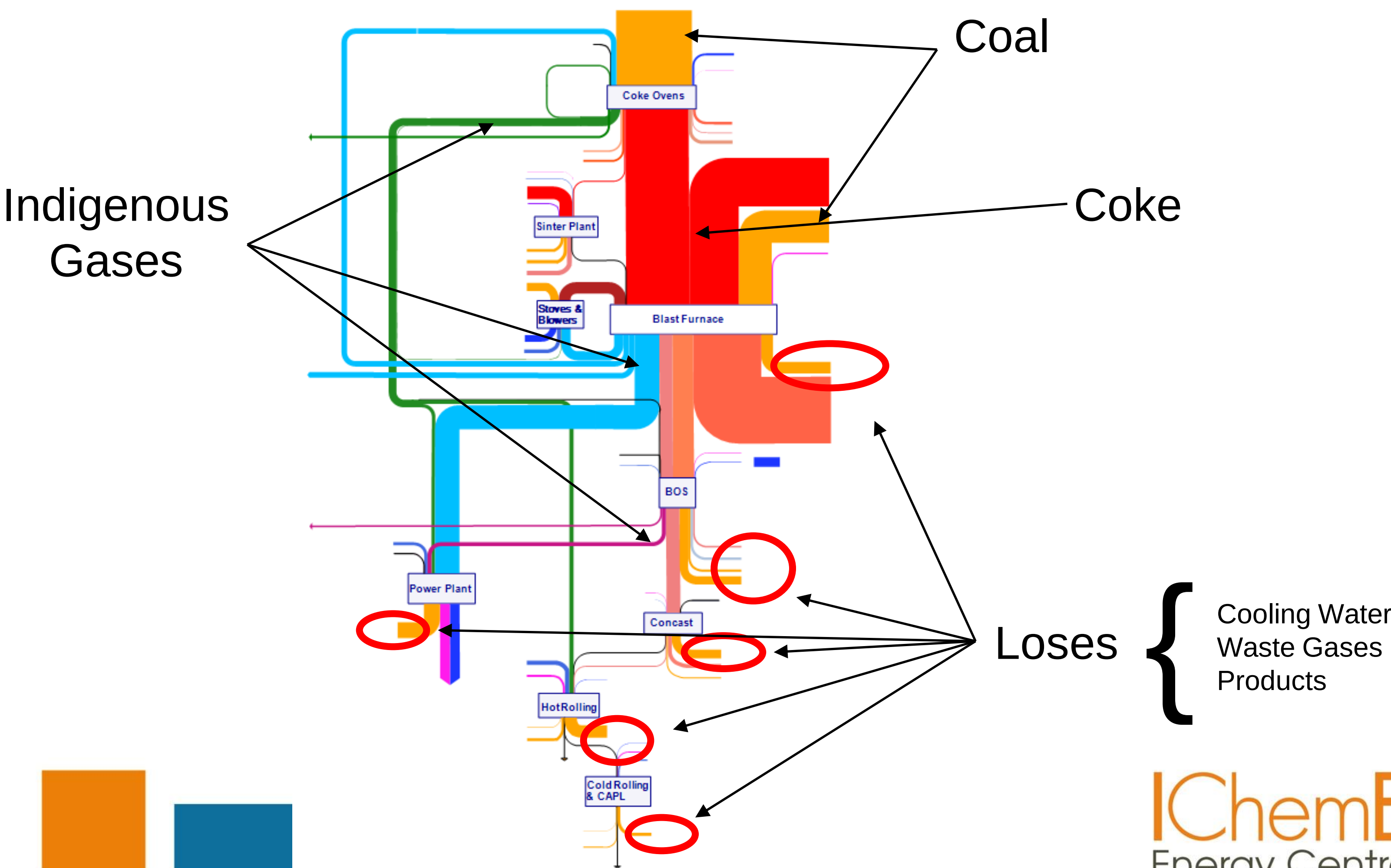
The Case Study Steelworks





Typical Energy Flows

<u>Import</u>
Electricity & Natural Gas



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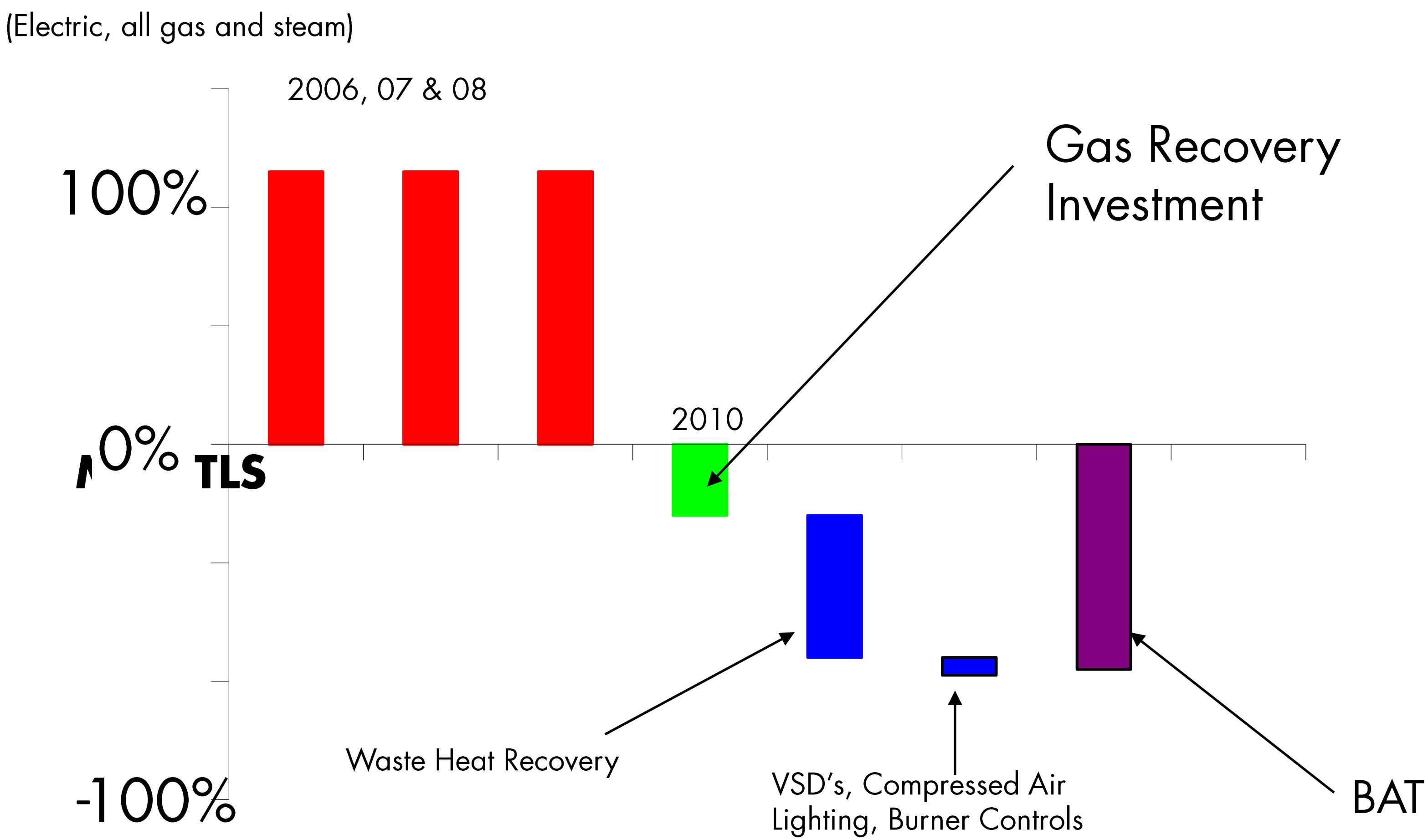
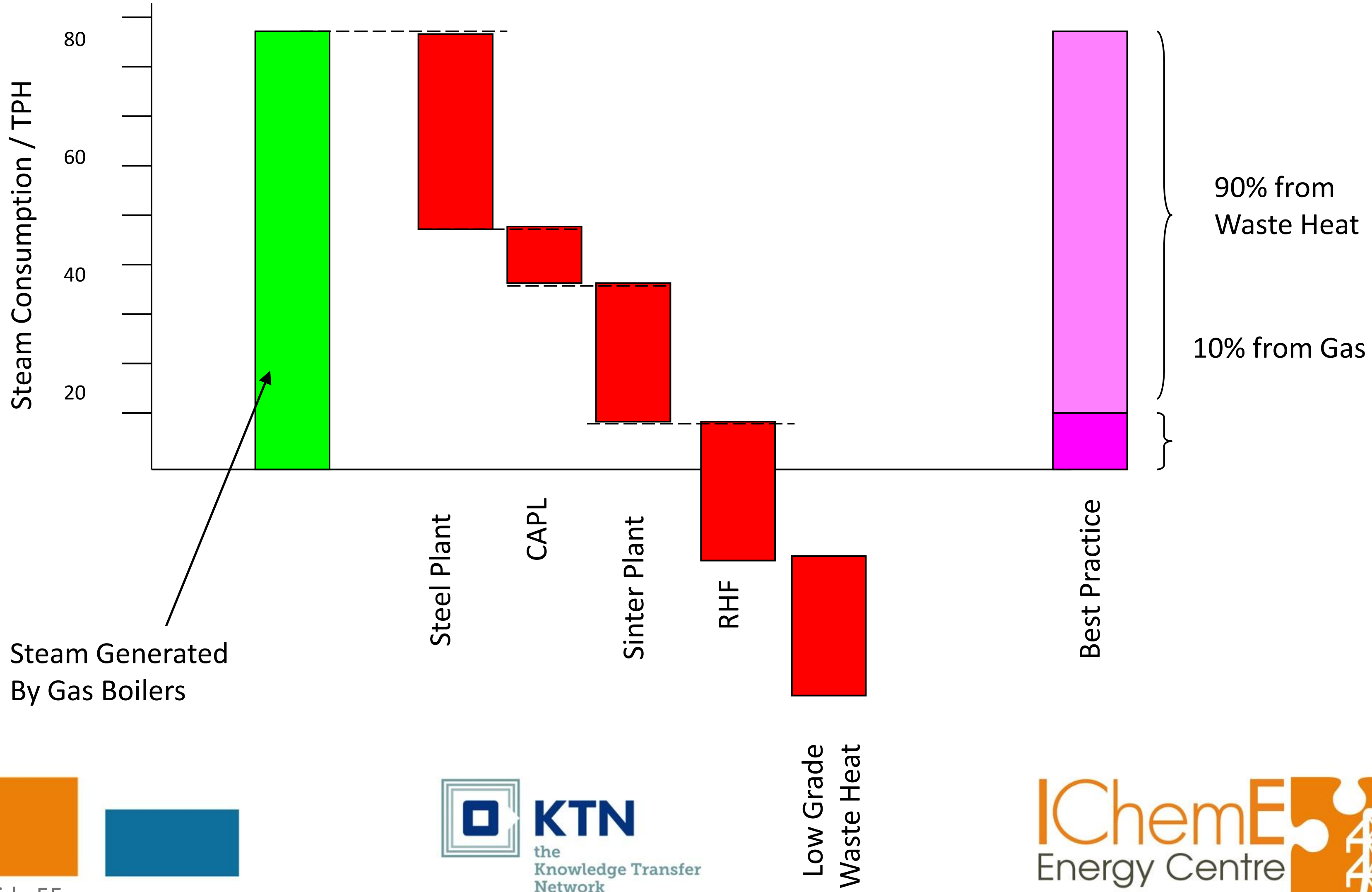
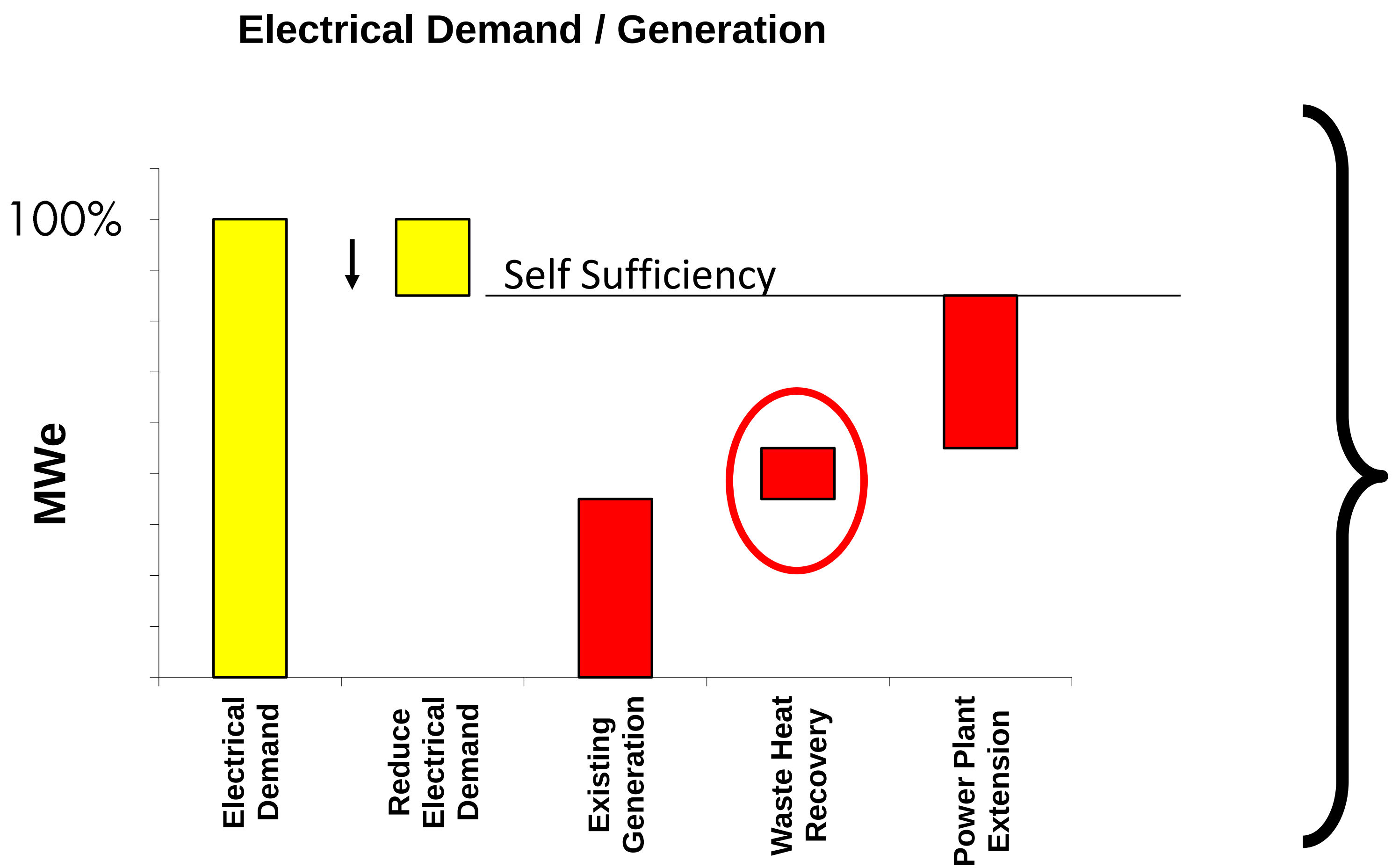
Steel and Slab Works Area



WHR for the steelworks



Energy Strategy



Reduce electrical Demand

&

Recover waste heat to generate steam

&

Maximise generation from process gases

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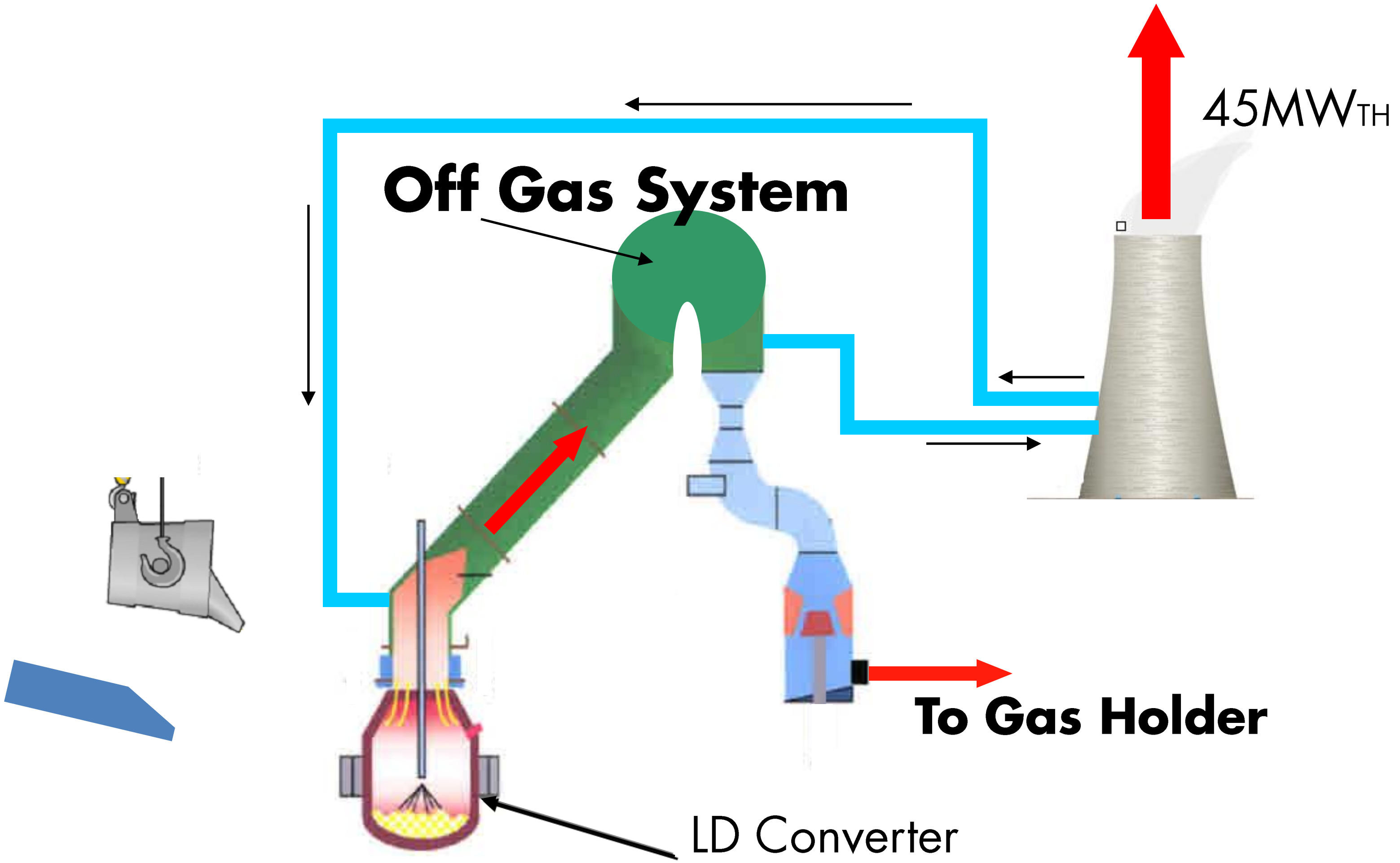
Basic Oxygen Steelmaking



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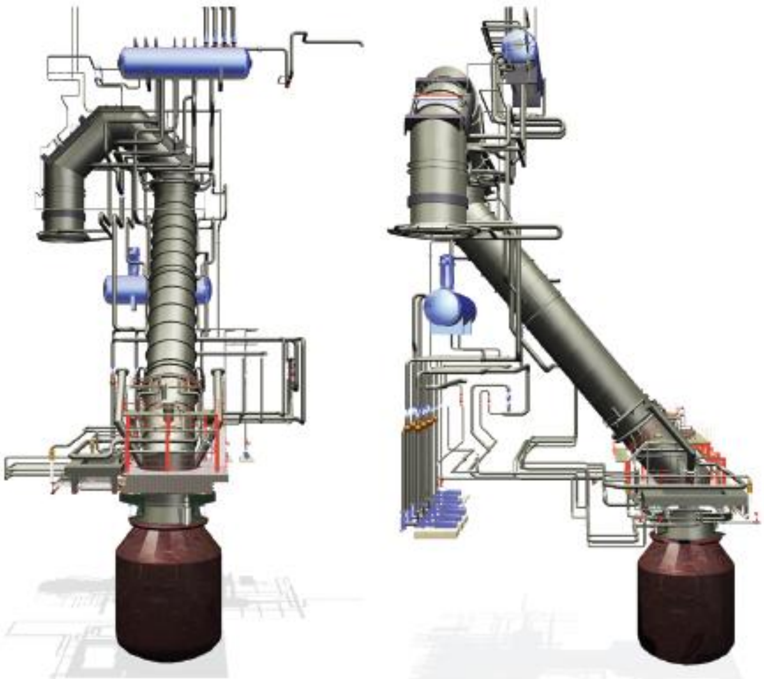
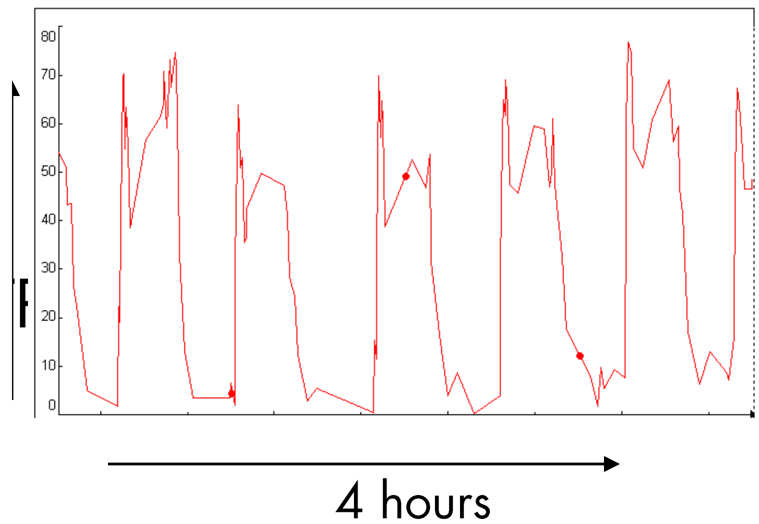
WHR Boiler



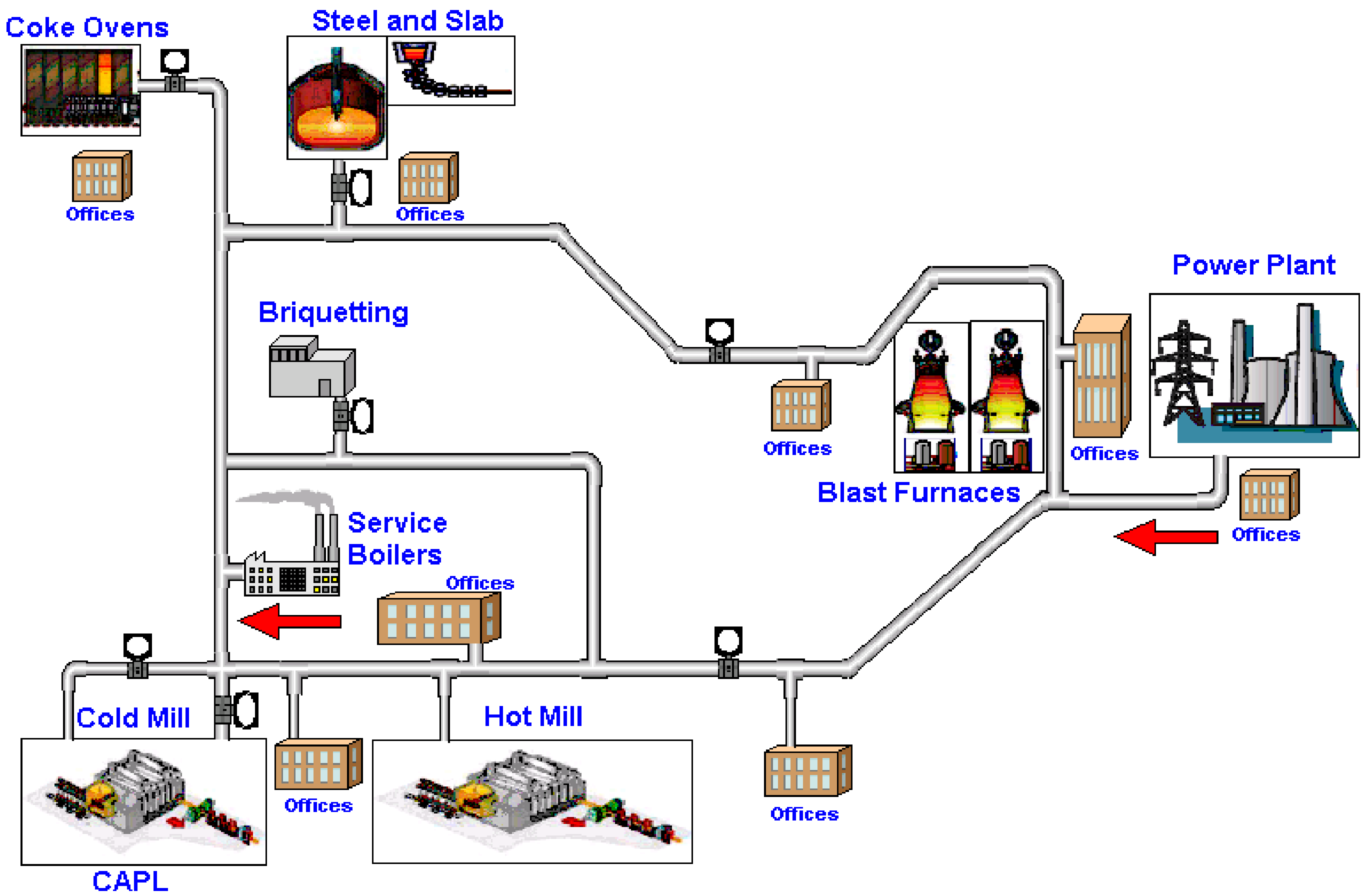
UTILIZATION OF EVAPORATION WASTE GAS COOLING SYSTEMS TO COUNTERACT RISING ENERGY COST

By Josip Kasalo

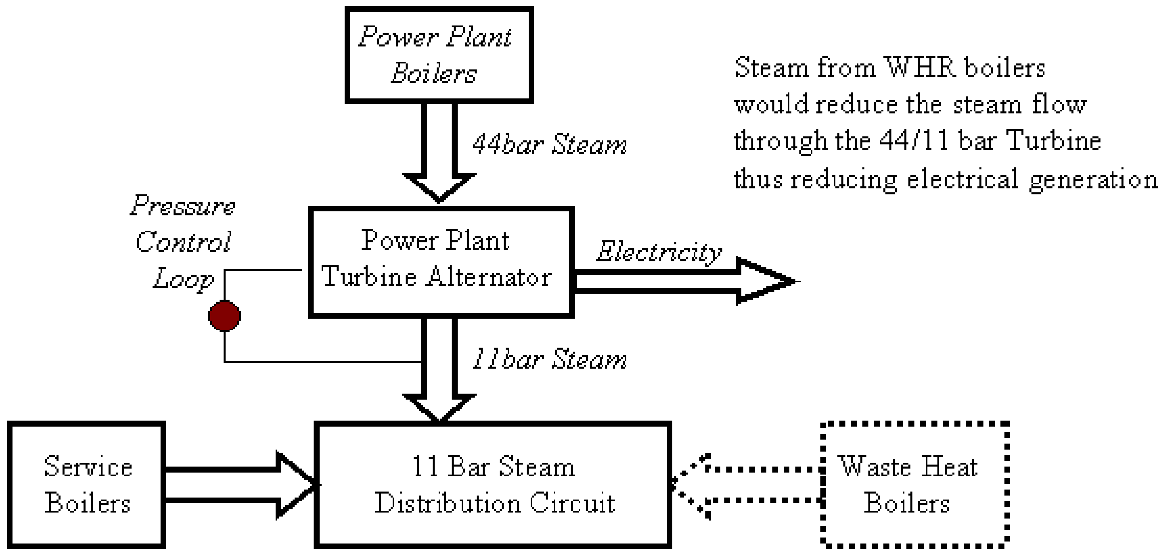
'End Use' ??



Steam Distribution Circuit



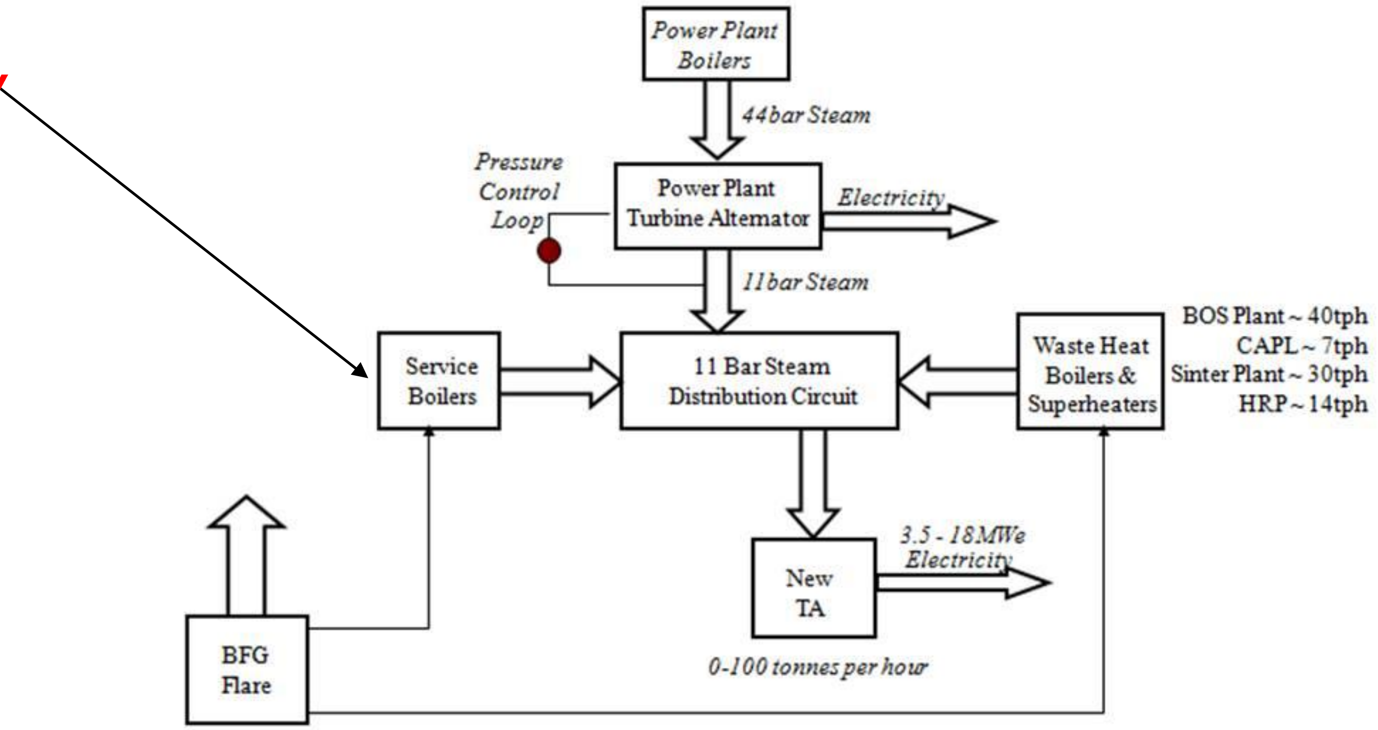
Old Steam Control



Explored Local Turbines

New Steam Strategy

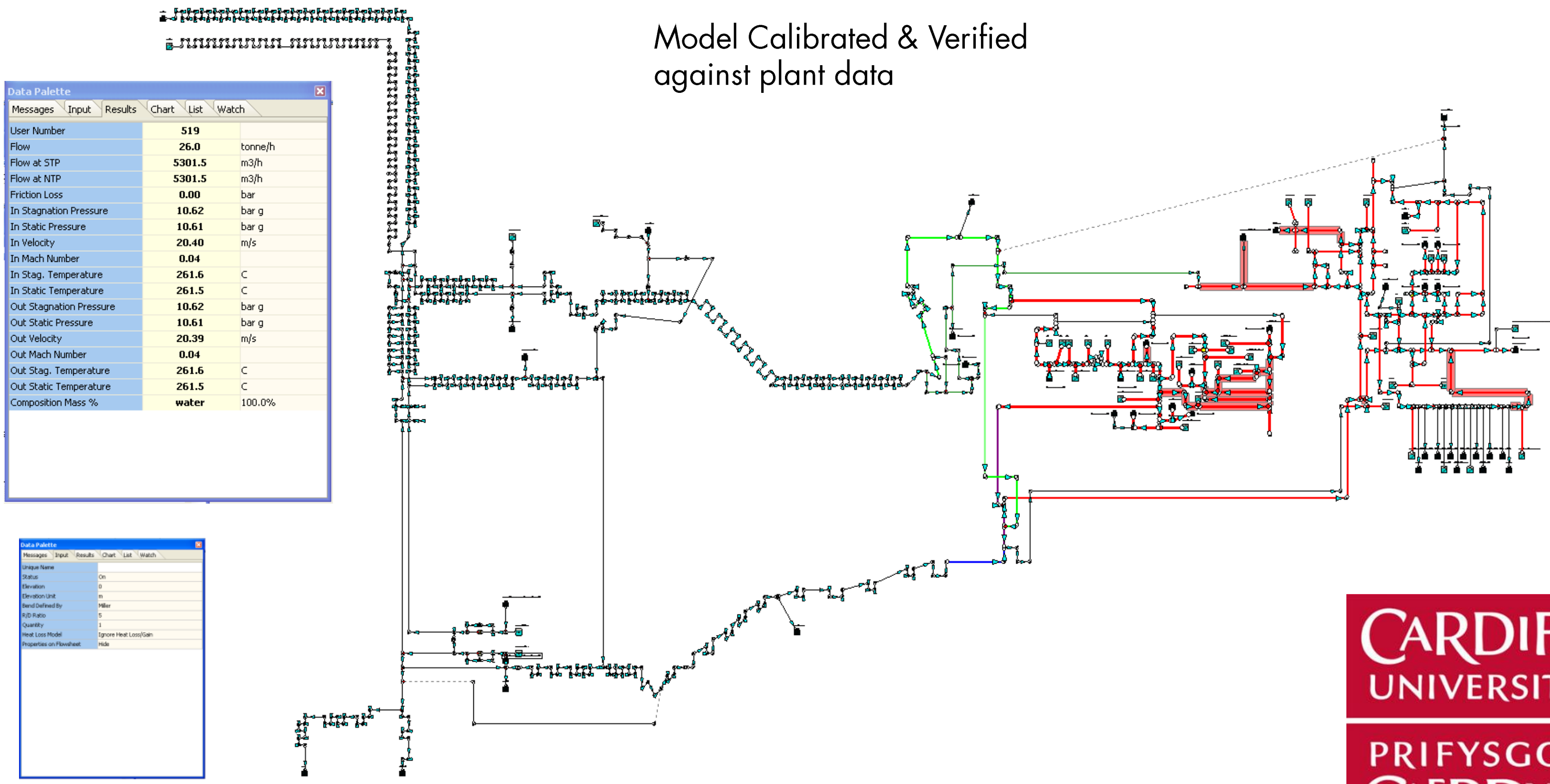
Spare Capacity



New TA enables:-
- excess BFG can be used for extra steam generation in the Service Boilers
- the existing powerplant steam export can be maximised
- efficiency improvements on the steam distribution circuit can now be justified

Steam Distribution Circuit

Model Calibrated & Verified
against plant data



FluidFlow3
PIPING SYSTEMS BY DESIGN

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

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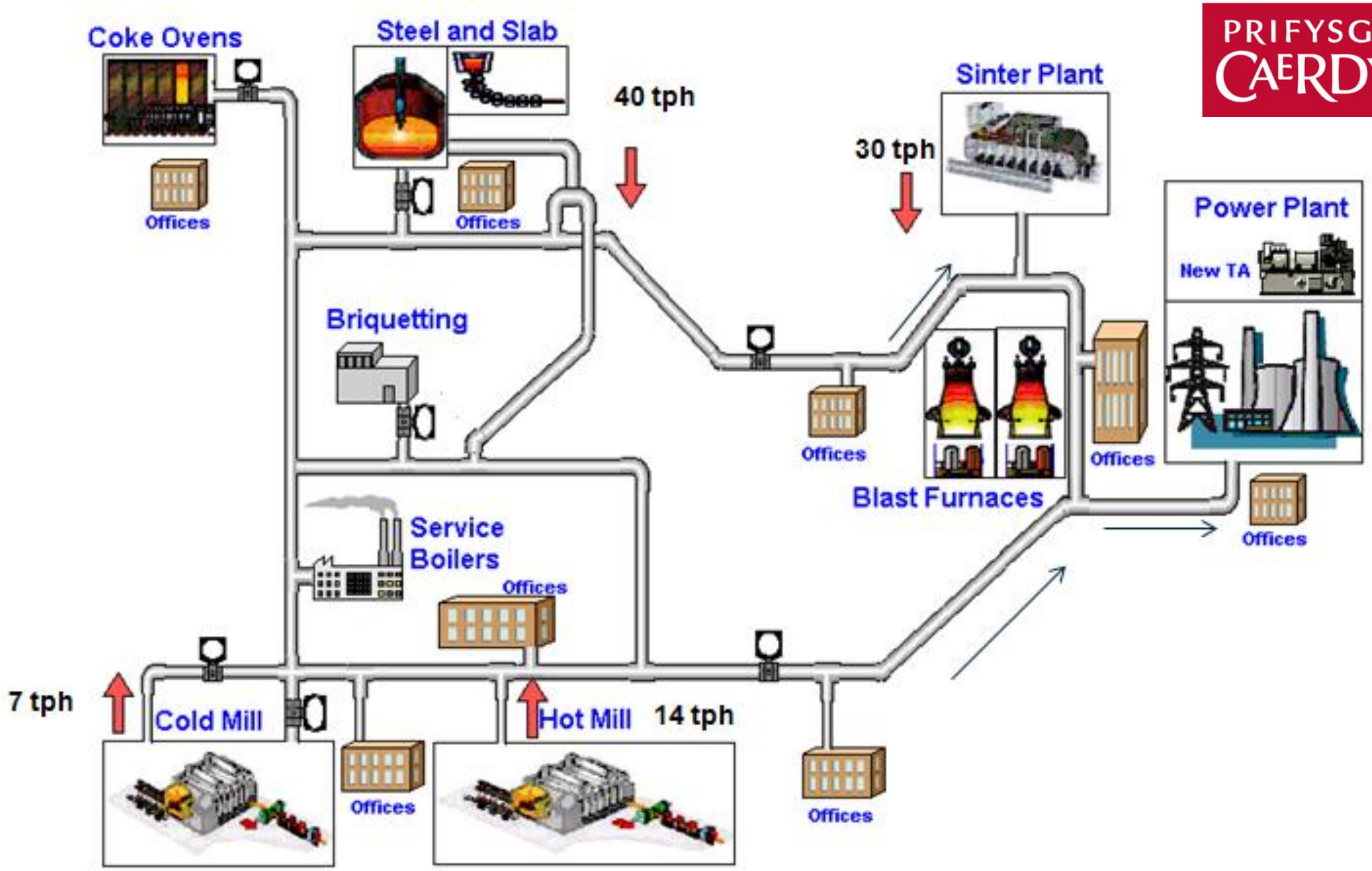
High Grade WHR potential



Capital Investment

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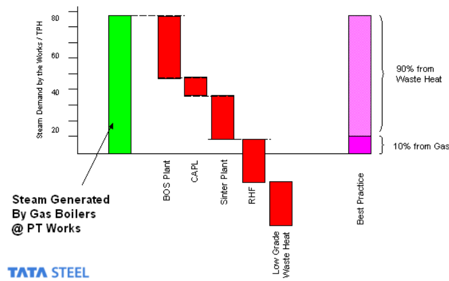
Summary of University Project

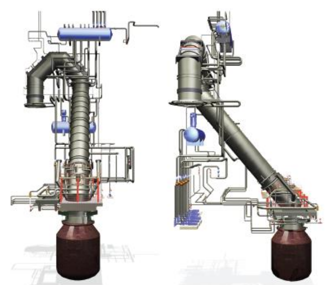
1. Quantify Waste Heat

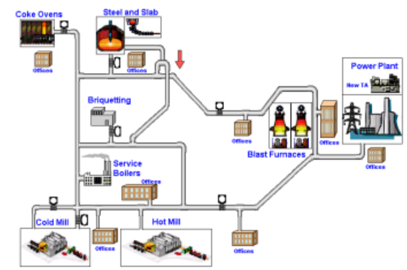


TATA STEEL

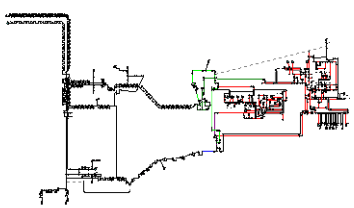
CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

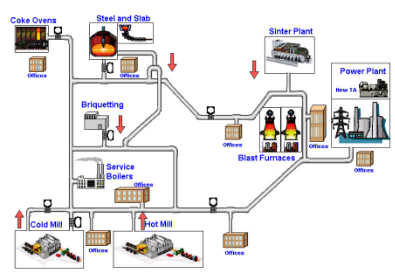
2. Technology to Capture it

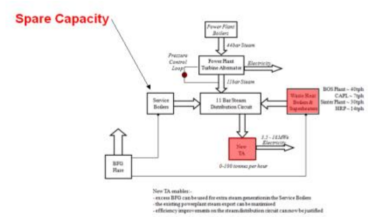




3. Optimum ‘end use’ : The Centralised Heat Recovery Strategy







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Flexible Energy Solutions for Wales

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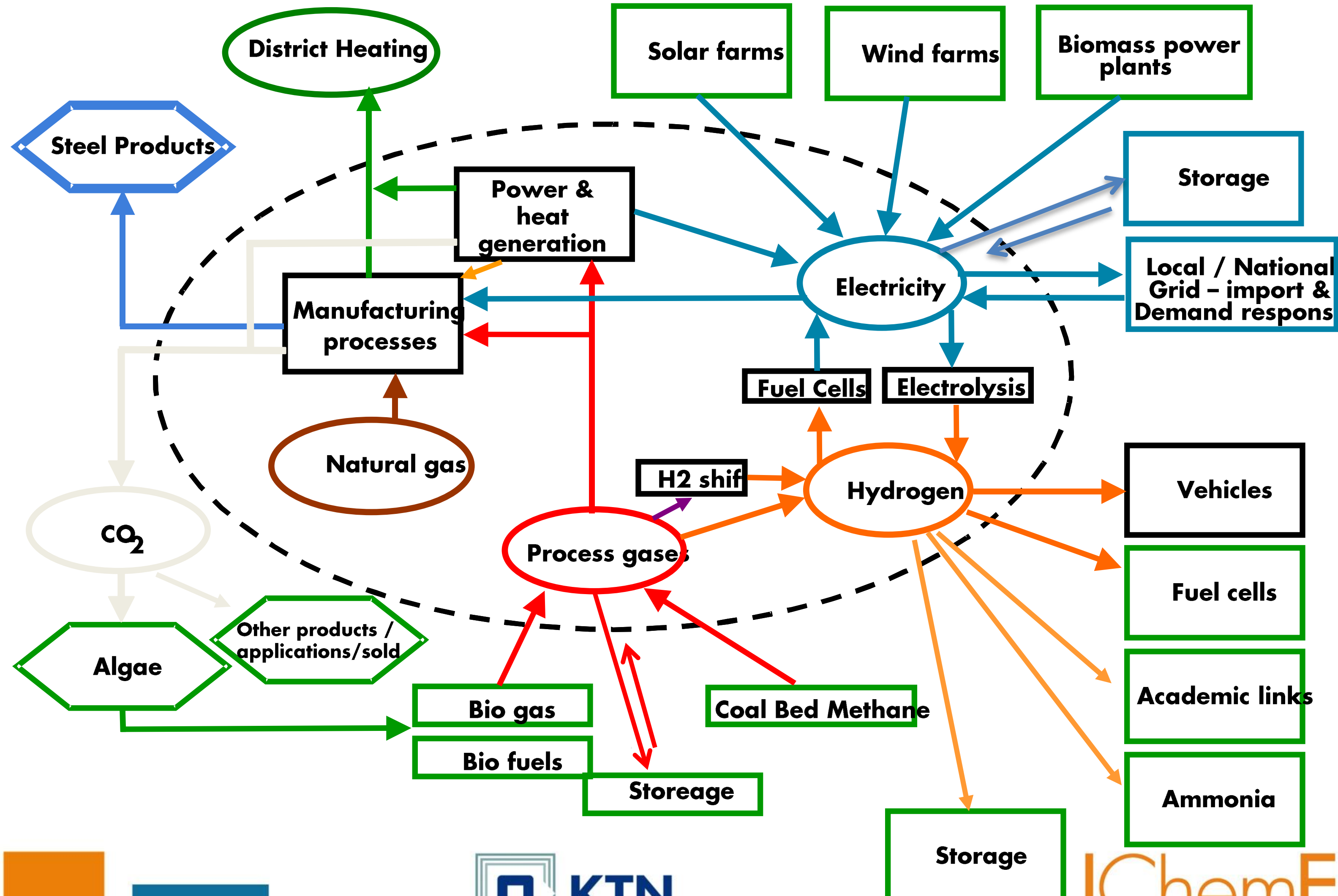
SMART STEELWORKS



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Thank you

Tea break

10:30-11:00

Tom Greatrex

Chief Executive

The Nuclear Industry Association

IChemE Energy Centre

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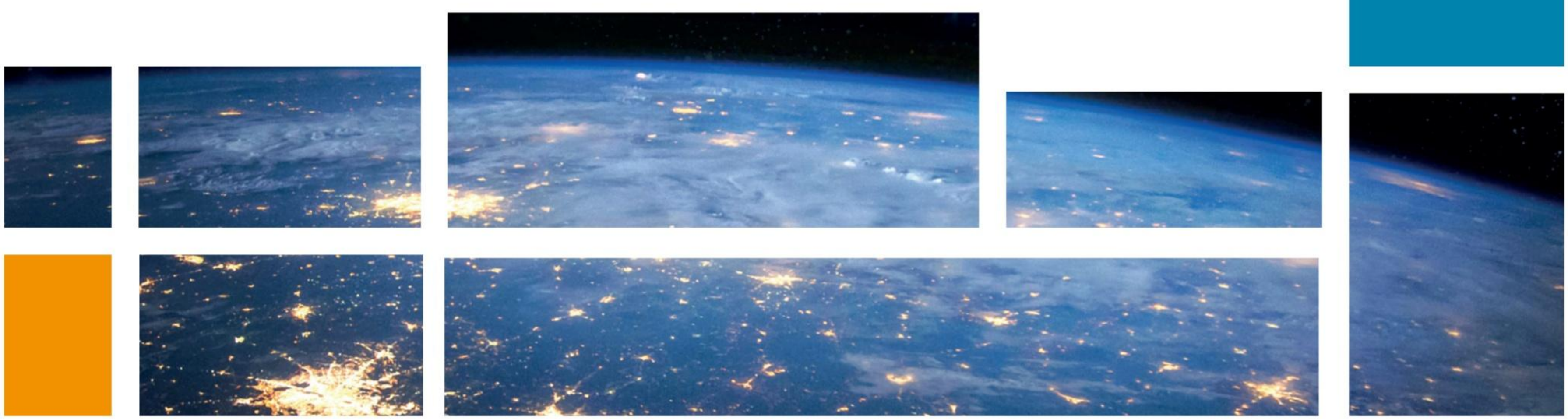
Tom Greatrex

Nuclear energy in the UK saved more than 49 million tonnes of CO_2



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Professor Rob Holdway

Co-founder and Director

Giraffe Innovation

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Professor Rob Holdway

By using CO_2 as a catalyst in plastic and through recovery of precious metals we can save 3.8 million tonnes CO_2

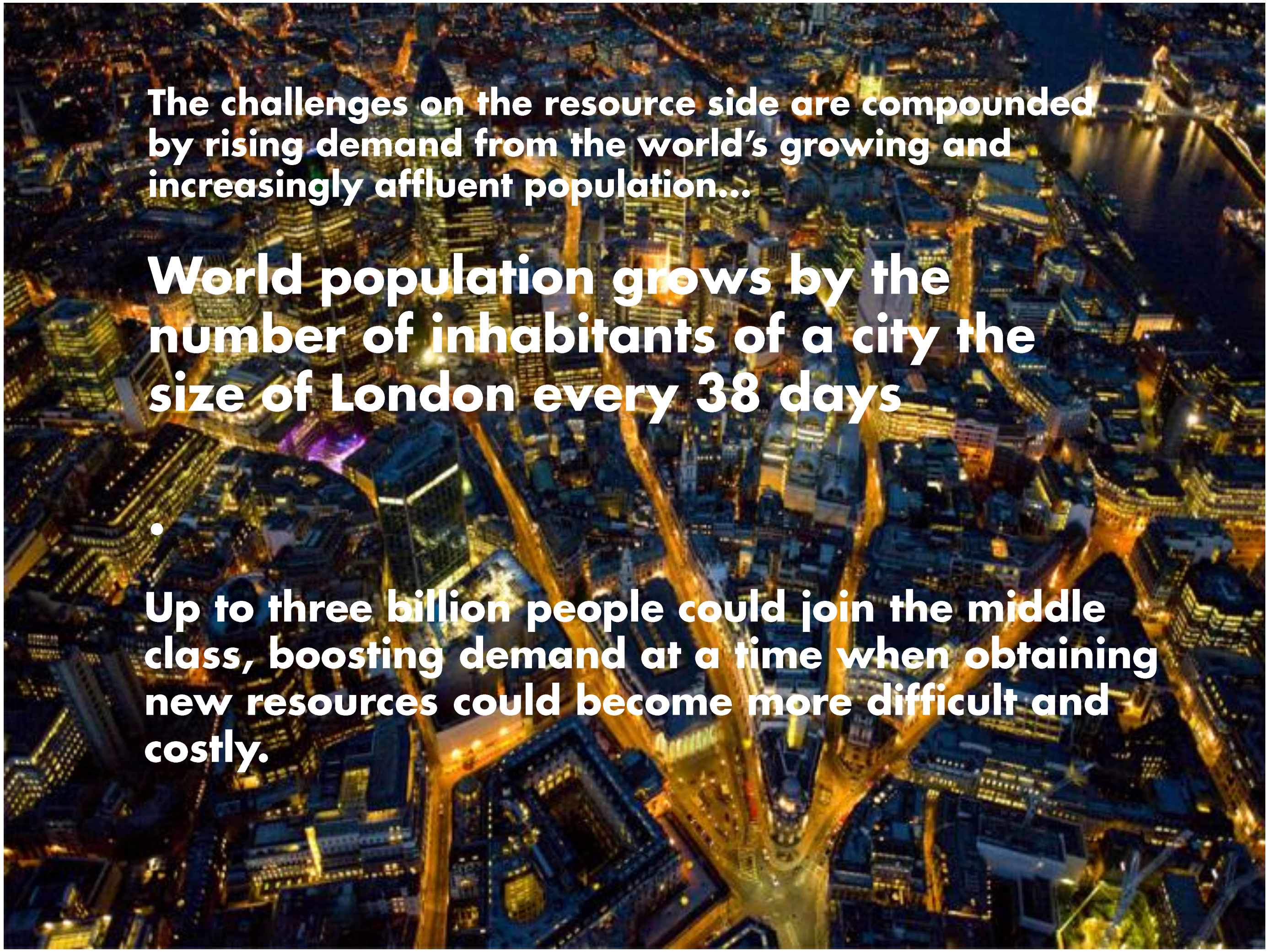
What is the Circular Economy & Does it Matter?

Professor Rob Holdway FRSA - Director, Giraffe Innovation

@giraffeinnov

Decarbonisation

- The UK government is committed to moving to a low carbon economy.
- But how can industry decarbonise and increase energy efficiency whilst remaining competitive?



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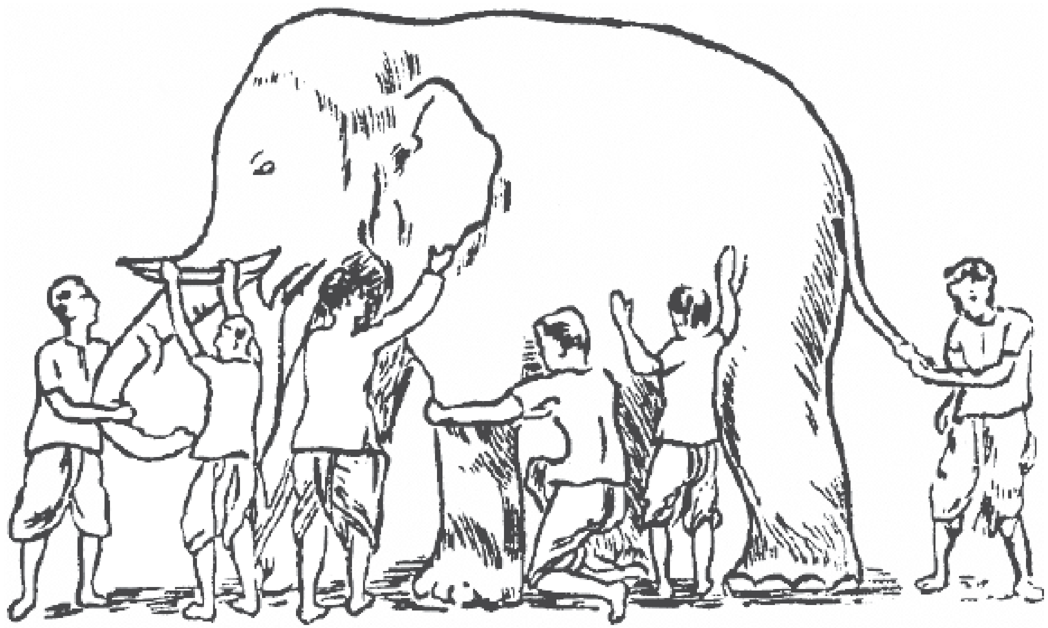
‘A diffuse subject’



Reality may be viewed differently depending upon one’s perspective

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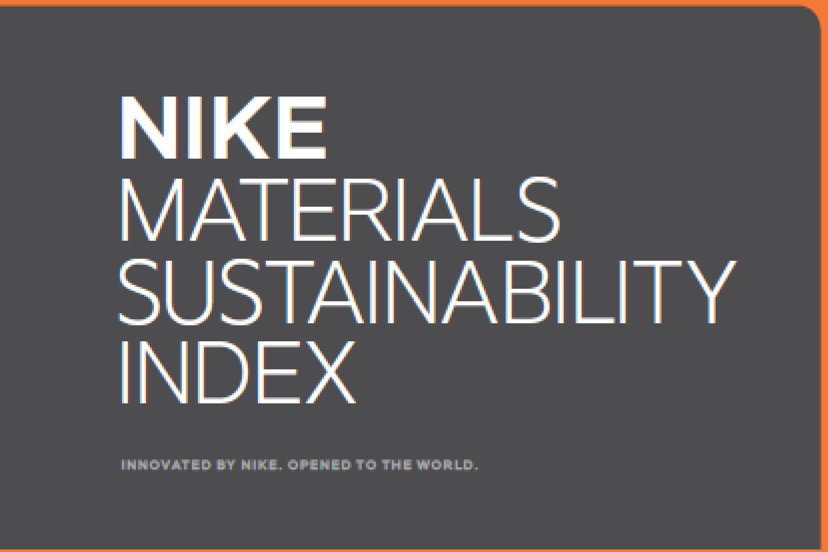
LEADERSHIP?


NIKE
MATERIALS
SUSTAINABILITY
INDEX

INNOVATED BY NIKE. OPENED TO THE WORLD.

SEPTEMBER 26, 2011
PRE -RELEASE

Donald Trump takes campaign against windfarms to UK supreme court

Republican presidential contender and golf course owner says planned turbines would be 'monstrous' blight on Aberdeenshire coastline

Leadership

Designed in Germany built in Poland ☺

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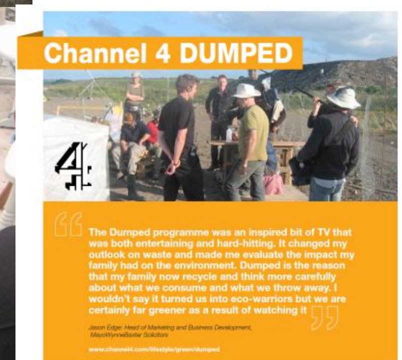
Pro-Environmental Behaviour



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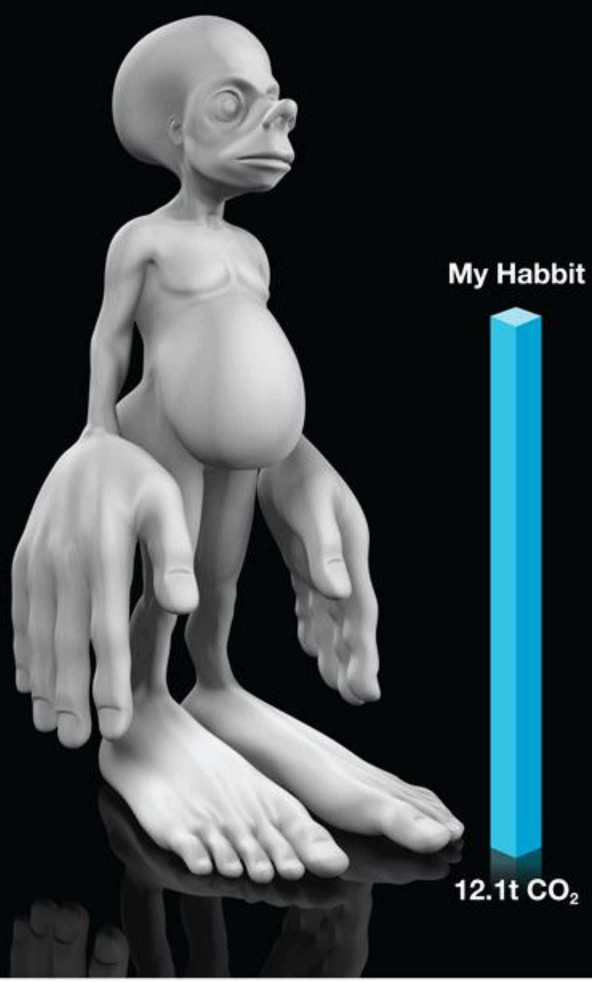
CHANGING HABBITS

www.changinghabbits.org



CHANGING HABBITS

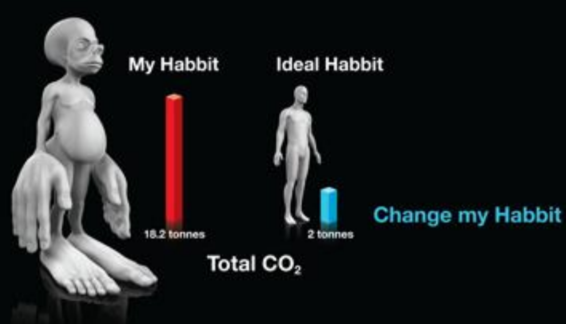
www.changinghabbits.org

are humanoid forms with body parts distorted relative to the environmental impact of common activities.

Each body part is assigned to one impact:

- feet - travel
- hands - home energy
- mouth - water usage
- belly - food
- bum - waste
- head - electrical goods

The body parts are grown where your impact is higher.

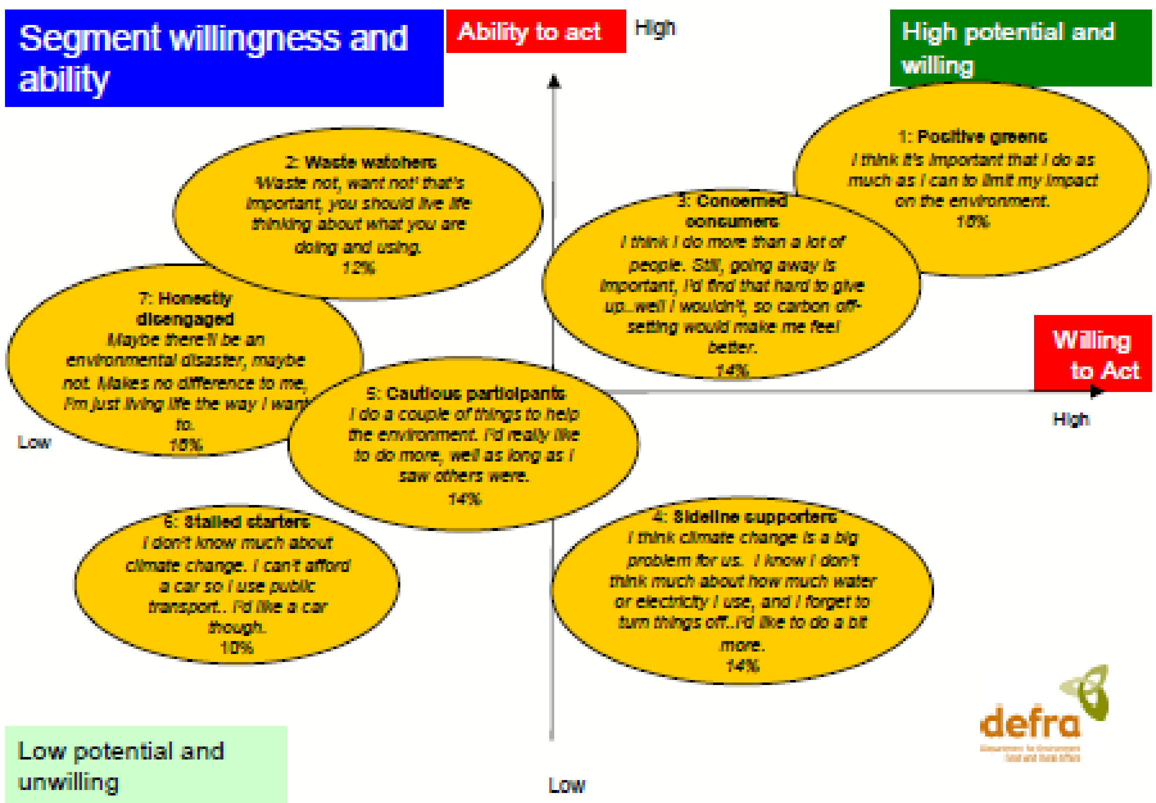


Create your Habbit to see which parts of your lifestyle have the greatest environmental impact and receive tips and advice on how to do your bit to reduce your carbon emissions and save money.

giraffe

Pro-Environmental Behaviour

The seven population segments



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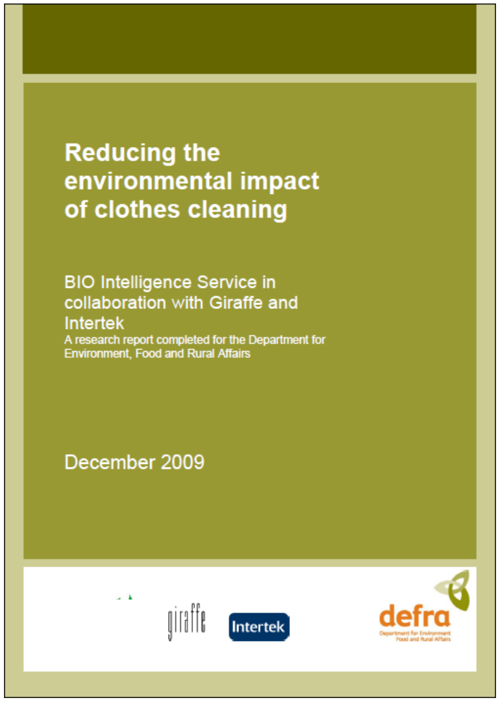
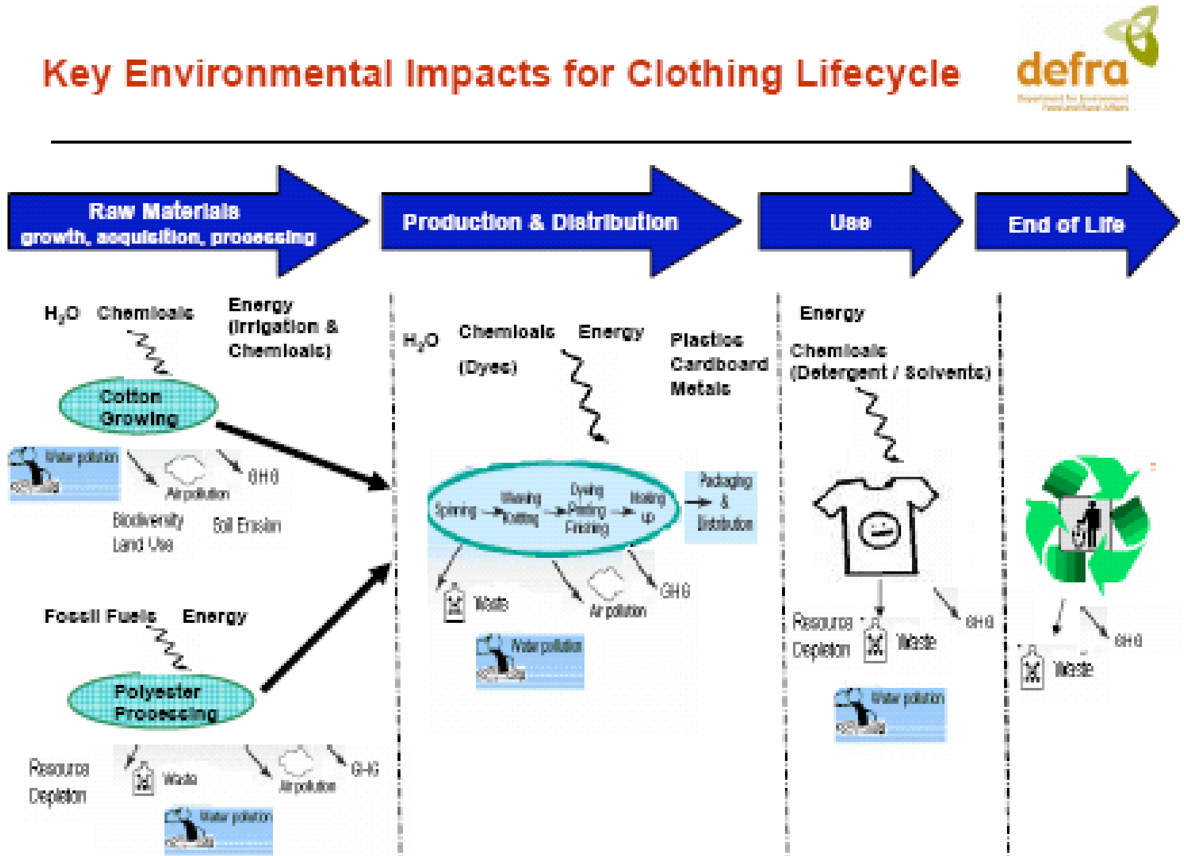
Tech Roadmap – Clothes Cleaning





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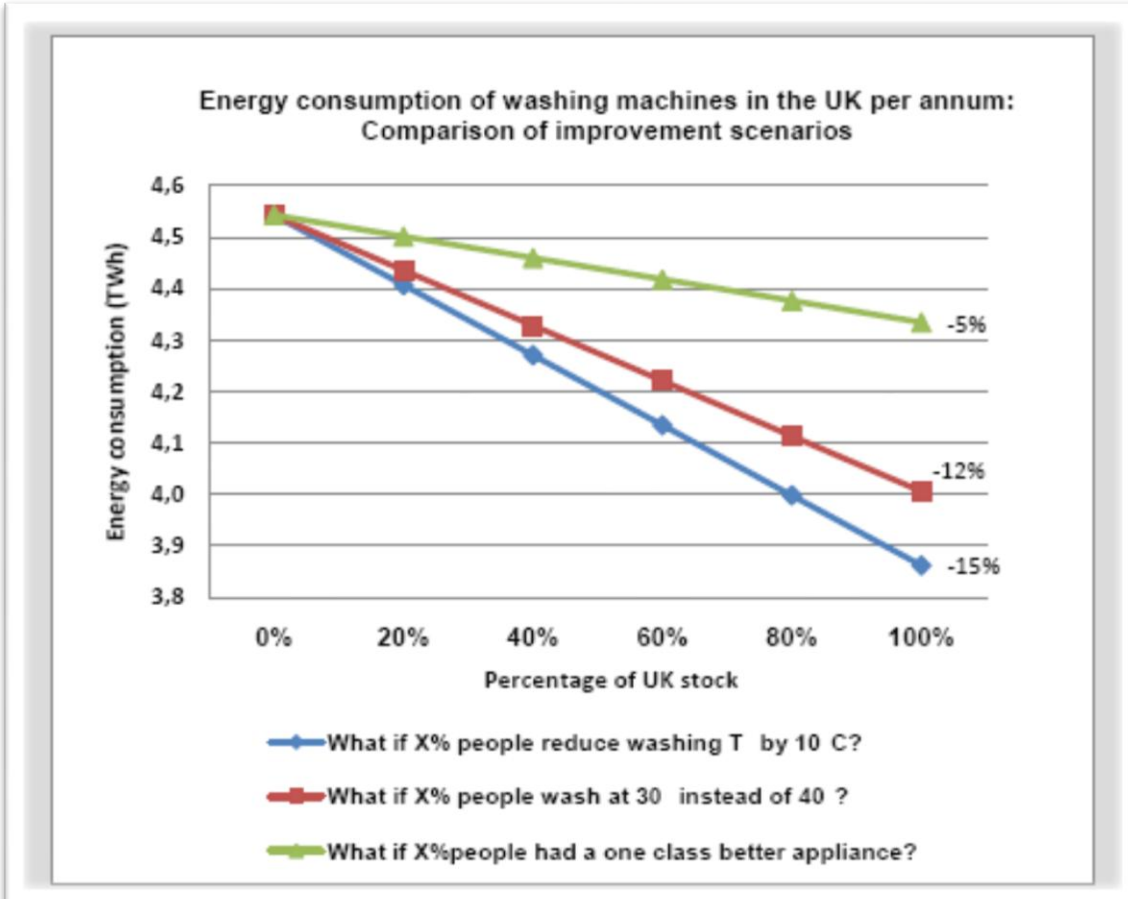
Energy & Usability Evaluation



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Circular Economy

An economic model that aims to decouple economic growth from the consumption of finite resources.

- ✓ Restorative by design
- ✓ Aims to keep products, components and materials at their highest utility or value ('zero waste')
- ✓ "We need a more circular economy. This means **re-using, repairing, refurbishing and recycling** existing materials and products. What used to be regarded as **'waste' can be turned into a resource**. The aim is to **close the loop** (…), all resources need to be managed more efficiently throughout their **life cycle**."

European Commission

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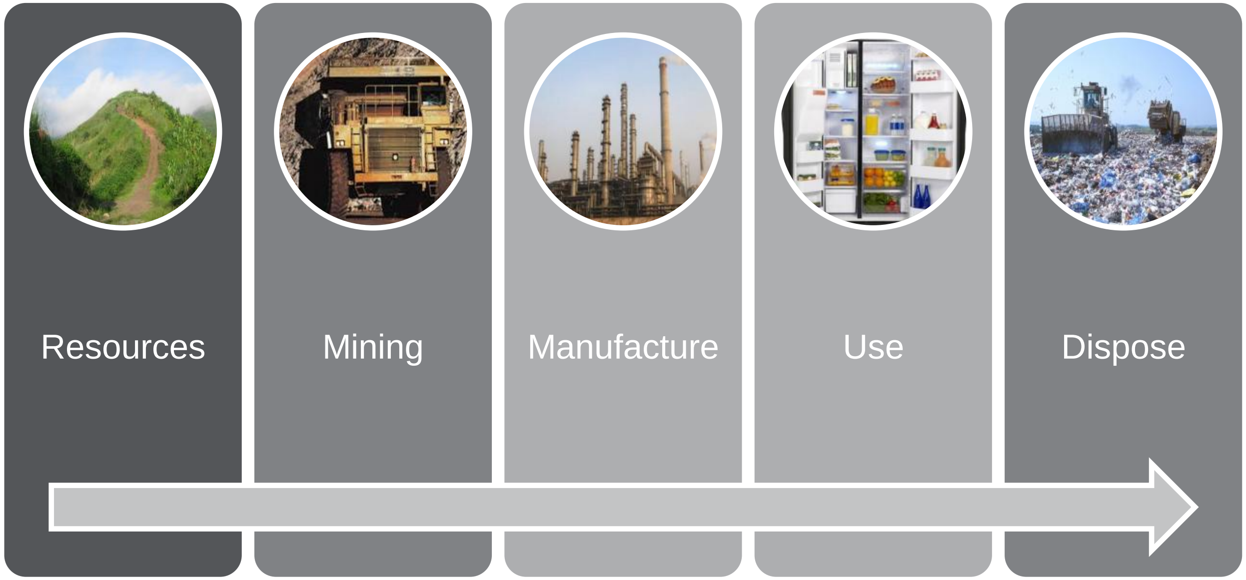
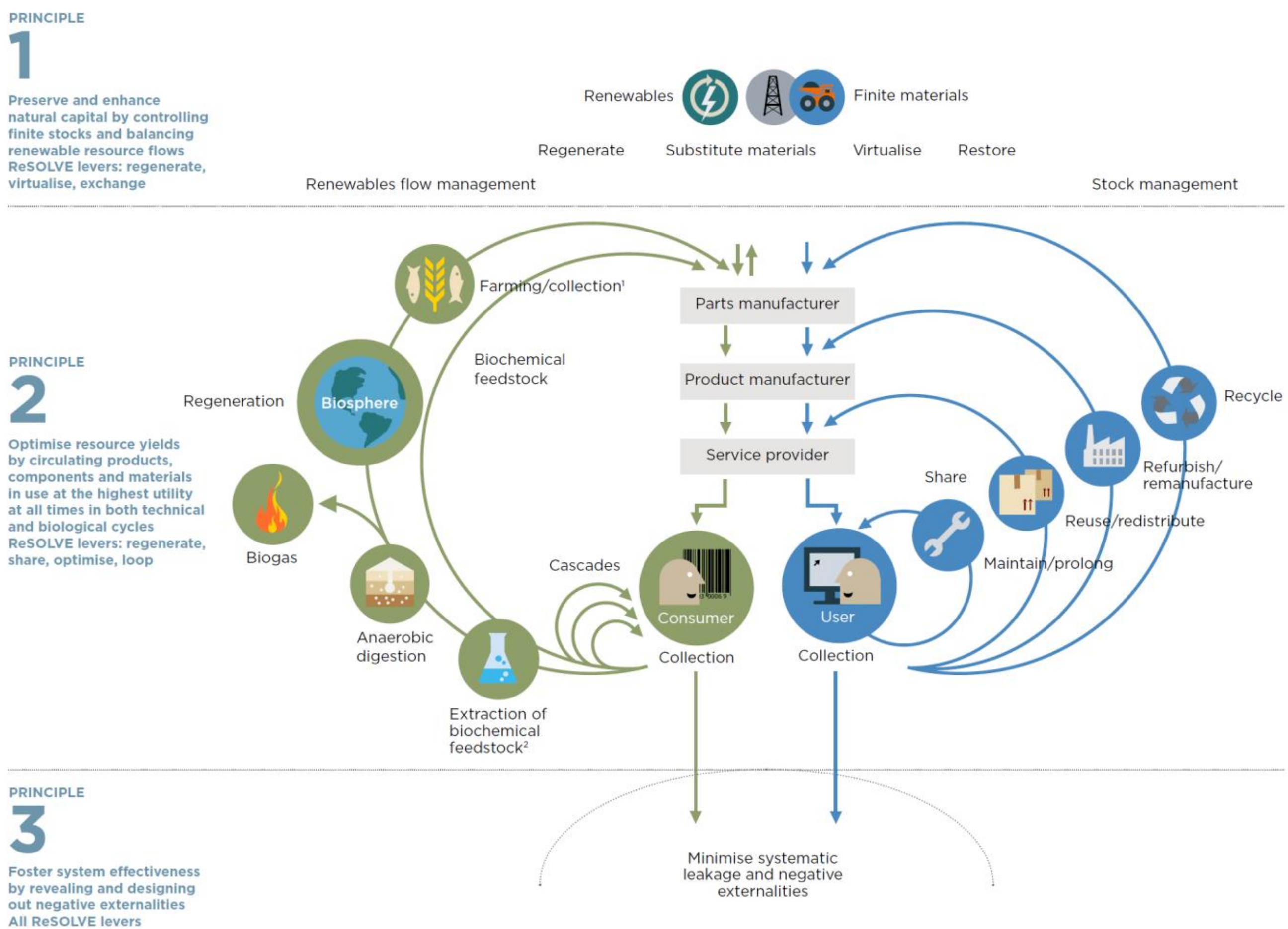
Circular Economy

Risks

- Rising prices for materials and energy;
- Supplies of precious materials running low;
- Environmental damage from resource extraction, landfilling and waste disposal;
- Improving efficiency offers only short term gains.



Circular Economy



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House of Commons
Environmental Audit Committee

Growing a circular economy: Ending the throwaway society

Third Report of Session 2014–15

Report, together with formal minutes relating to the report

Ordered by the House of Commons to be printed 17 July 2014

HC 214
Published on 24 July 2014
by authority of the House of Commons
London: The Stationery Office Limited
£0.00

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Carbon Capture and Utilisation of Waste CO_2

Case Example: Econic Technologies (Imperial)

- Econic Technologies have developed catalysts to be used with captured CO_2 for co-polymerisation;
- The catalyst reduces the amount of activation energy needed in the creation of polymers such as polyurethanes and polycarbonates.

Polymers from CO_2

- Poly(cyclohexene carbonate) (PCHC) is produced from cyclohexene oxide (CHO) and CO_2. PCHC contains 31% CO_2;
- Alternative to 'traditional' polycarbonate which uses phosgene and Bisphenol A in its production.

Life Cycle Analysis (LCA) - Giraffe

- LCA (with sensitivity analysis)
- Carbon capture technologies;
- Production of the catalyst;
- Pilot plant production of the polycarbonate;
- Estimated impacts of full scale plant;
- Production of report on potential environmental impacts and benefits of PCHC compared to ‘traditional’ polycarbonate.

Results

- PCHC - estimated saving of 4kg of CO_2 per kg of product compared to traditional polycarbonate ~ 56% CO_2e (tbc);
- Global production 4.5 million tonnes of polycarbonate;
- If 20% PC was manufactured using captured CO_2 technology this would save 3.6m tCO_2.
- Other applications – Polyurethanes (20Mt p.a./$50Bn) - hard and soft foams, elastic films, coatings, adhesives or transparent sheets.

WEEE Man

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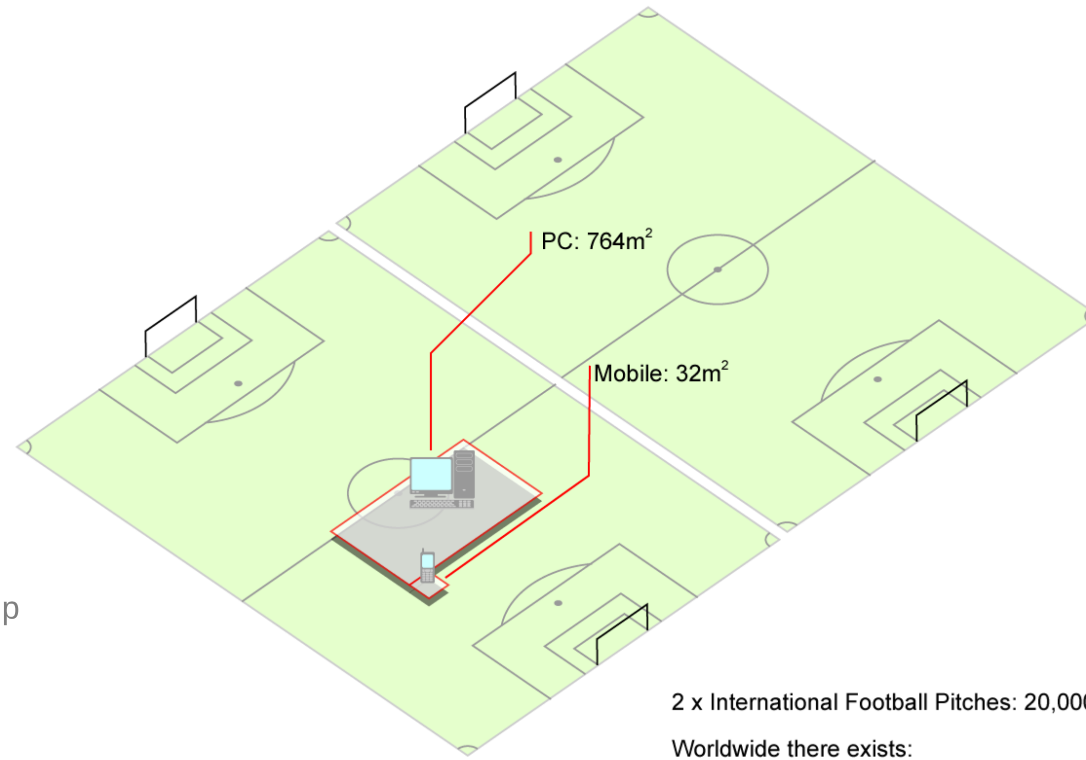
Ecological Footprint

- The EF measures the land space that is needed to mine the materials contained in a product, and the energy required for manufacturing, using and disposing it.
- We each have 1.8 - our ‘fair earth share’. [Already using 2.2 (+21%)]
- How much land (fair earth share) your mobile phone and personal computer require to absorb all the environmental impacts in a given year.
- 566 phones and 24 PCs would each use up the available earth share for one ‘world average citizen’.



2 x International Football Pitches: 20,000m^2

Worldwide there exists:
19,000 biologically productive m^2 per person

giraffe

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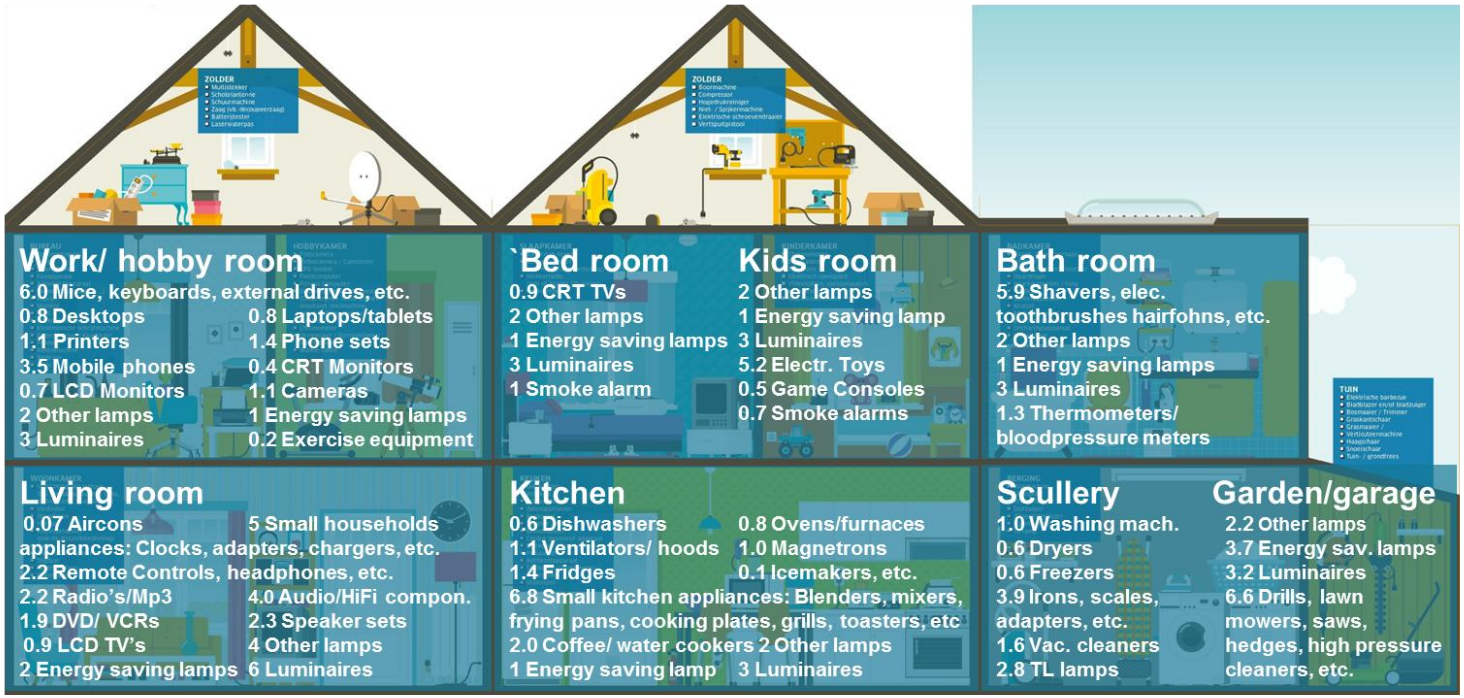
E-Waste



Britain - 5th in the world in terms of the quantity of e-waste per head in 2014 (23.5kg).

E-Waste Monitor 2014, UNU

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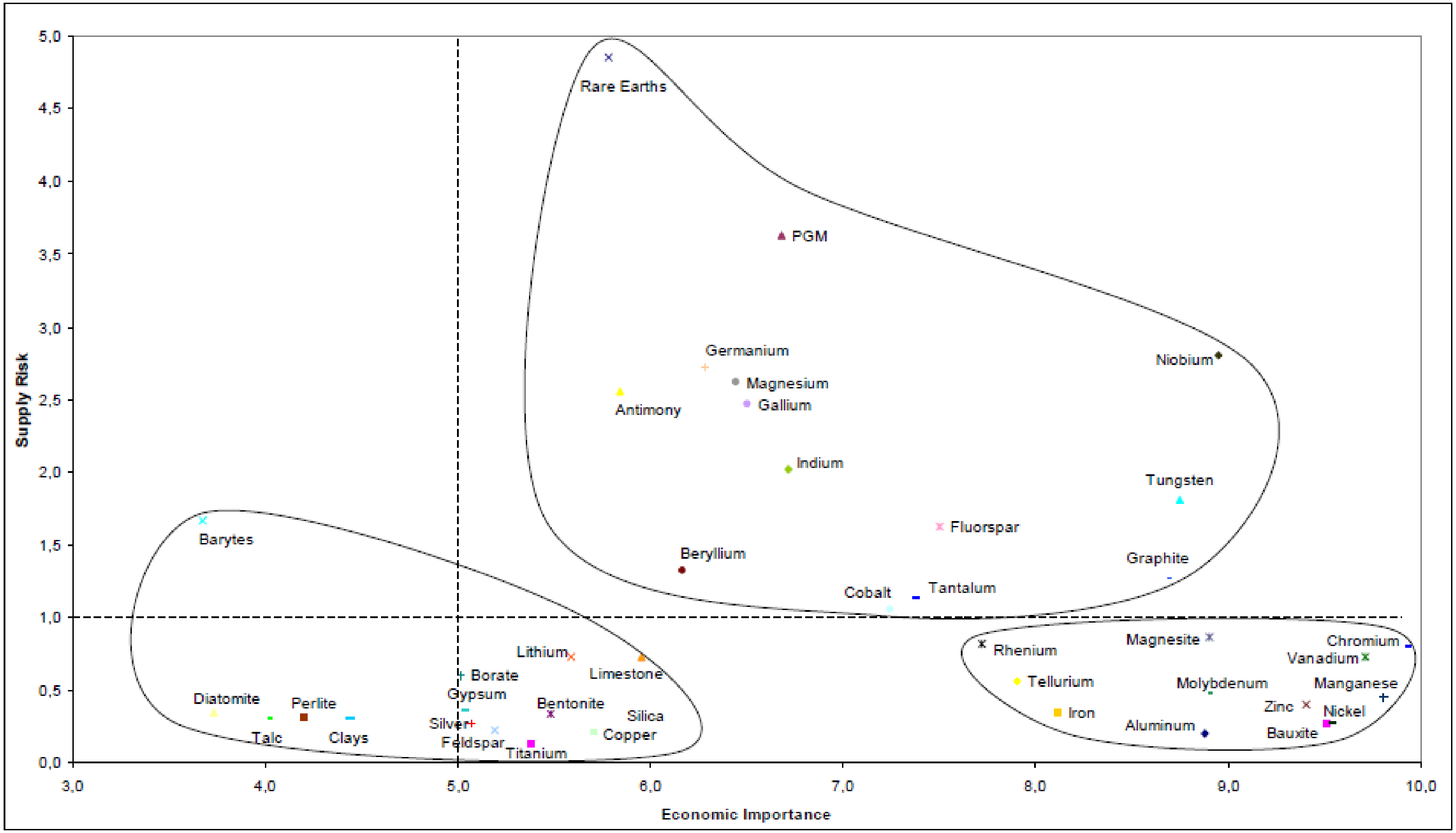
Traditional linear consumption patterns (‘take-make-dispose’) are coming up against constraints on the availability of resources.
Bingham Canyon copper mine, largest man-made hole in the world.
0.75 miles (1.2 km) deep, 2.5 miles (4 km) wide, and covering 1,900 acres (7.7 km²)
Copper makes up only 1% of everything taken from the mi
down from 4% in the 1900s.

Electronic Waste (WEEE)

- 100 million electronic units discarded annually in the UK alone (~1Mt);
- One of the fastest growing waste streams worth an estimated £1bn.
- ~ 85% of all PCB scrap board waste goes to landfill.
- (70% of this being of non-metallic content with little opportunity for recycling);
- Economic loss – export.

Critical Raw Materials (CRMs)



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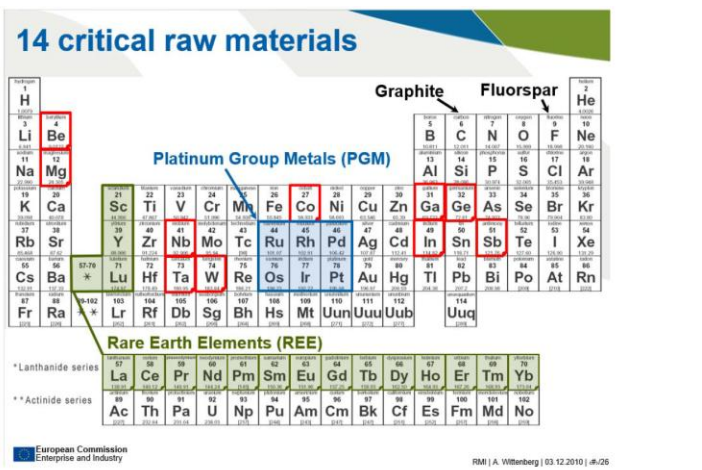
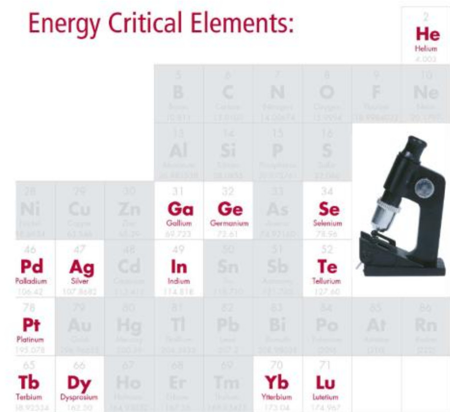
Critical Raw Materials

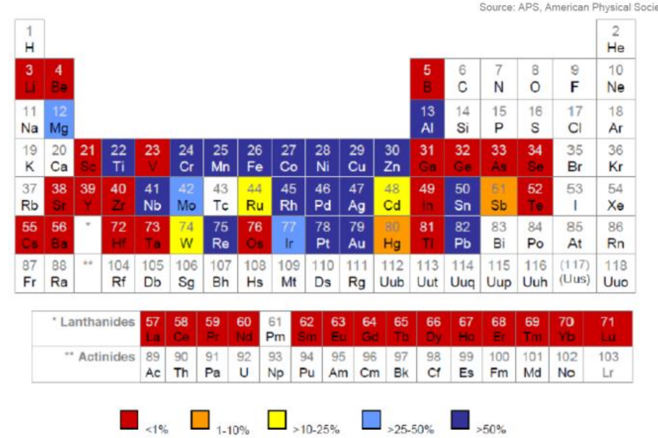
- Criticality through:
  - Geopolitics
  - Recycling Rates
  - Sector Relevance



Source: http://www.energy.gov/sites/prod/files/Session_A2_Wittenberg_0.ppt



Source: APS, American Physical Society



Source: UNEP/EU Working document

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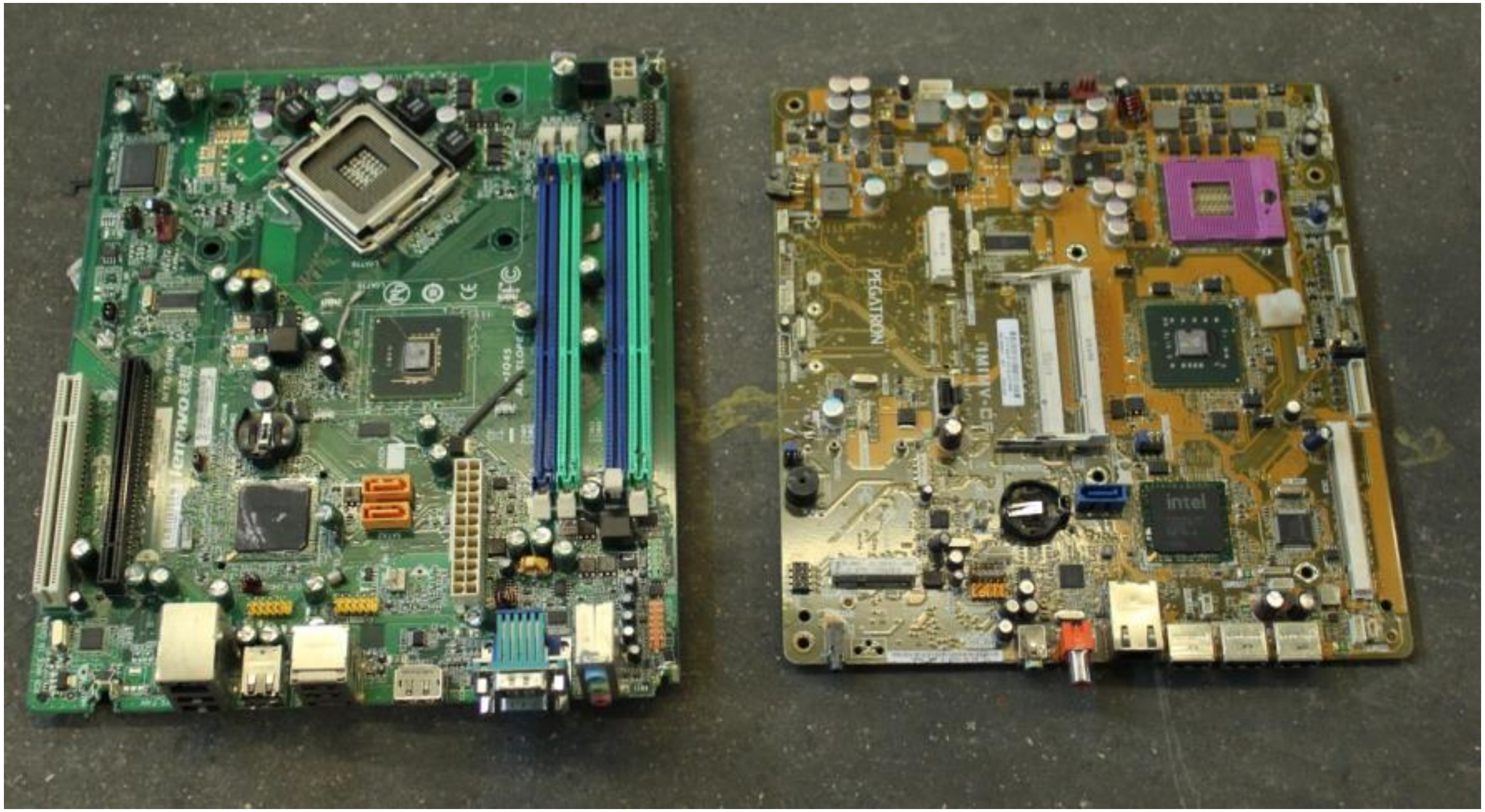
Asset Recovery



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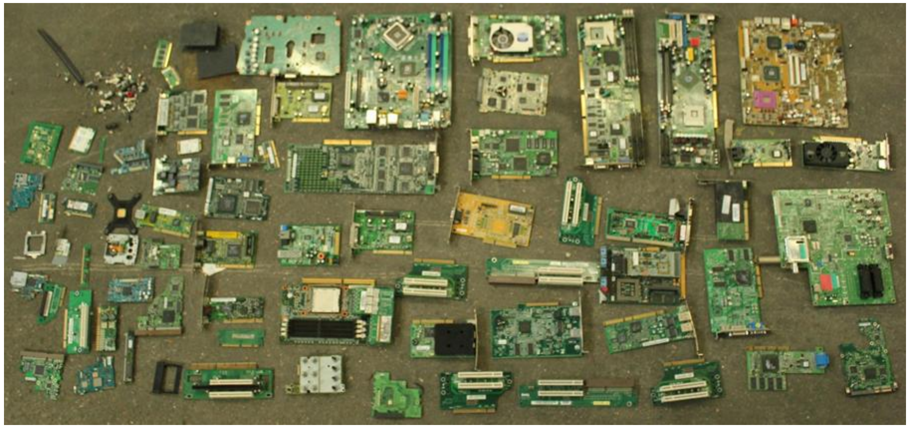
Giraffe Innovation Trial - CRMs

- Medium and high value PCBs (WEEE) sampled and analysed to determine the presence and concentration of PMs and CRMs;
- XRF Analyser used to detect the presence of CRMs, AAS testing and inductively coupled plasma optical emission spectrometry (ICP-OES) to quantify the concentration of CRMs.

Locating PGMs and CRMs



Component	Au	Ag	Pd	Ru	Co	Sb	Nb	Ta	Y	Dy
Lead free solder		✓								
Gold contacts	✓		✓							
Surface Gold	✓									
ICs		✓	✓		✓	✓	✓			
Chip resistors		✓	✓	✓	✓					
Ceramic chip capacitor			✓						✓	
Diode	✓	✓				✓				
Transistors	✓	✓				✓				
Ta capacitor		✓				✓		✓		
Crystal Oscillators					✓					✓
Ru bearing component		✓		✓						
Nb bearing component		✓	✓				✓			

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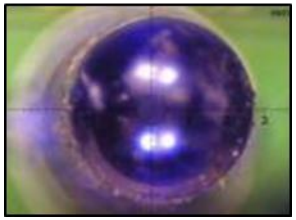
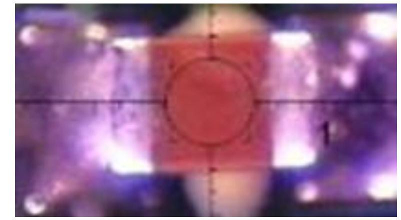
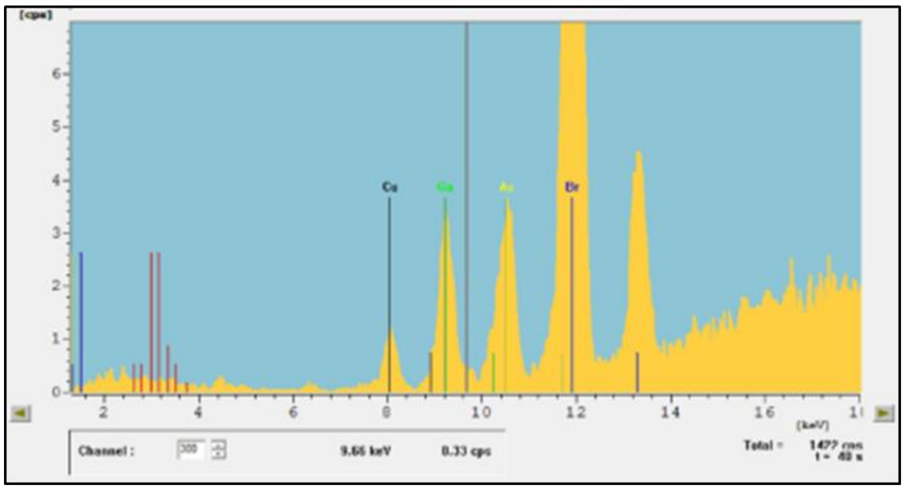
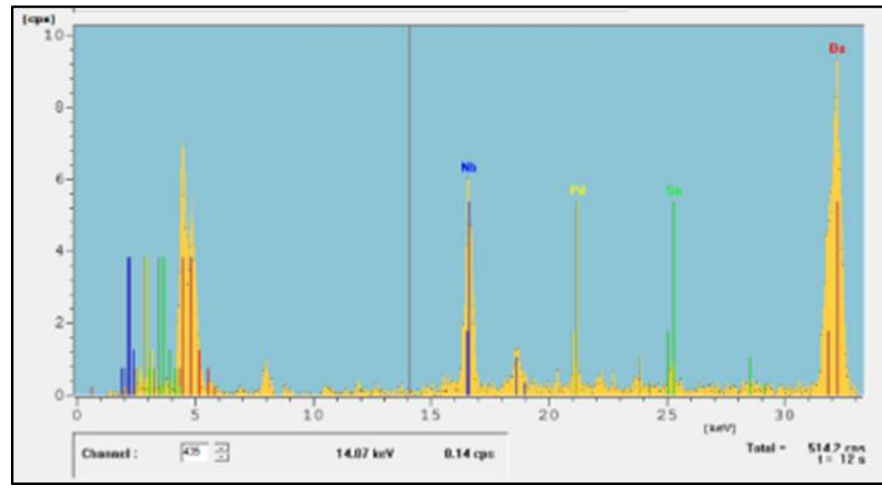
XRF analysis example









Green LED: Gold & Gallium

Component: Niobium & Lead.

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Plasma Arc Collector Metal

- Copper rich sample, organic materials – (volatile gas)

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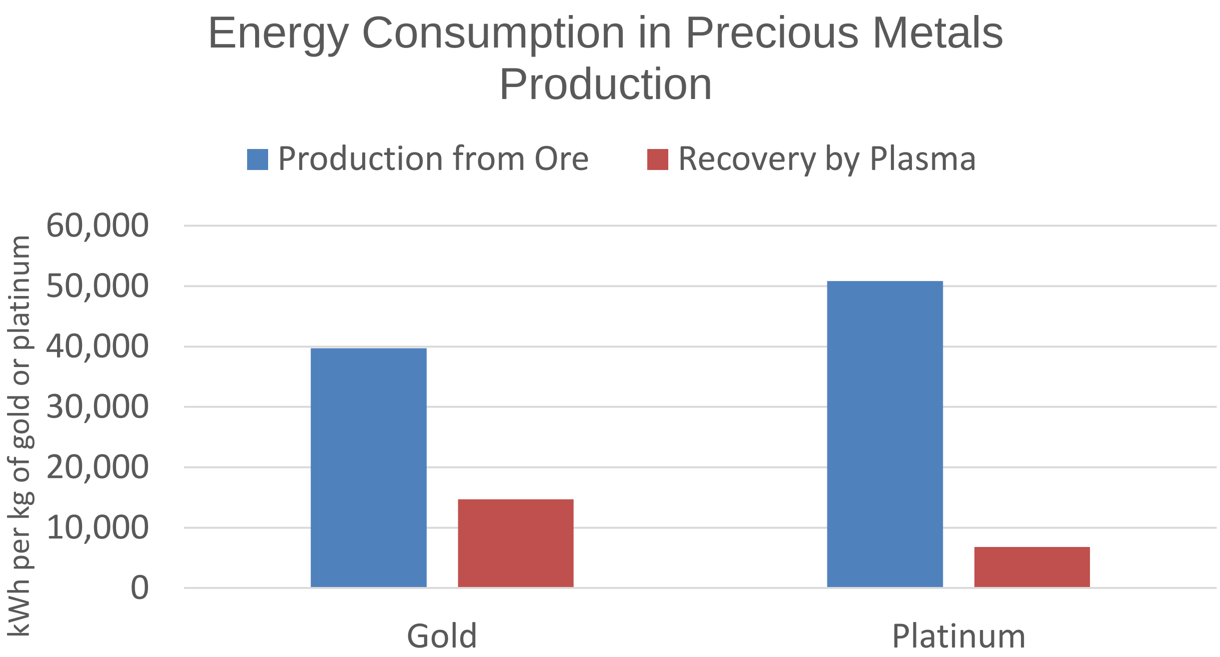
Plasma Arc Collector Metal



- Only a third of e-waste in the EU makes its way into recycling schemes;
- **One tonne of gold, worth about £24 million, is sent to landfill in the UK annually;**
- 10 million tonnes of e-waste is generated each year in the EU, containing over 100 tonnes of gold worth around $4bn every year;
- Gold and silver value in discarded e-waste in EU probably more than $1.5bn every year.

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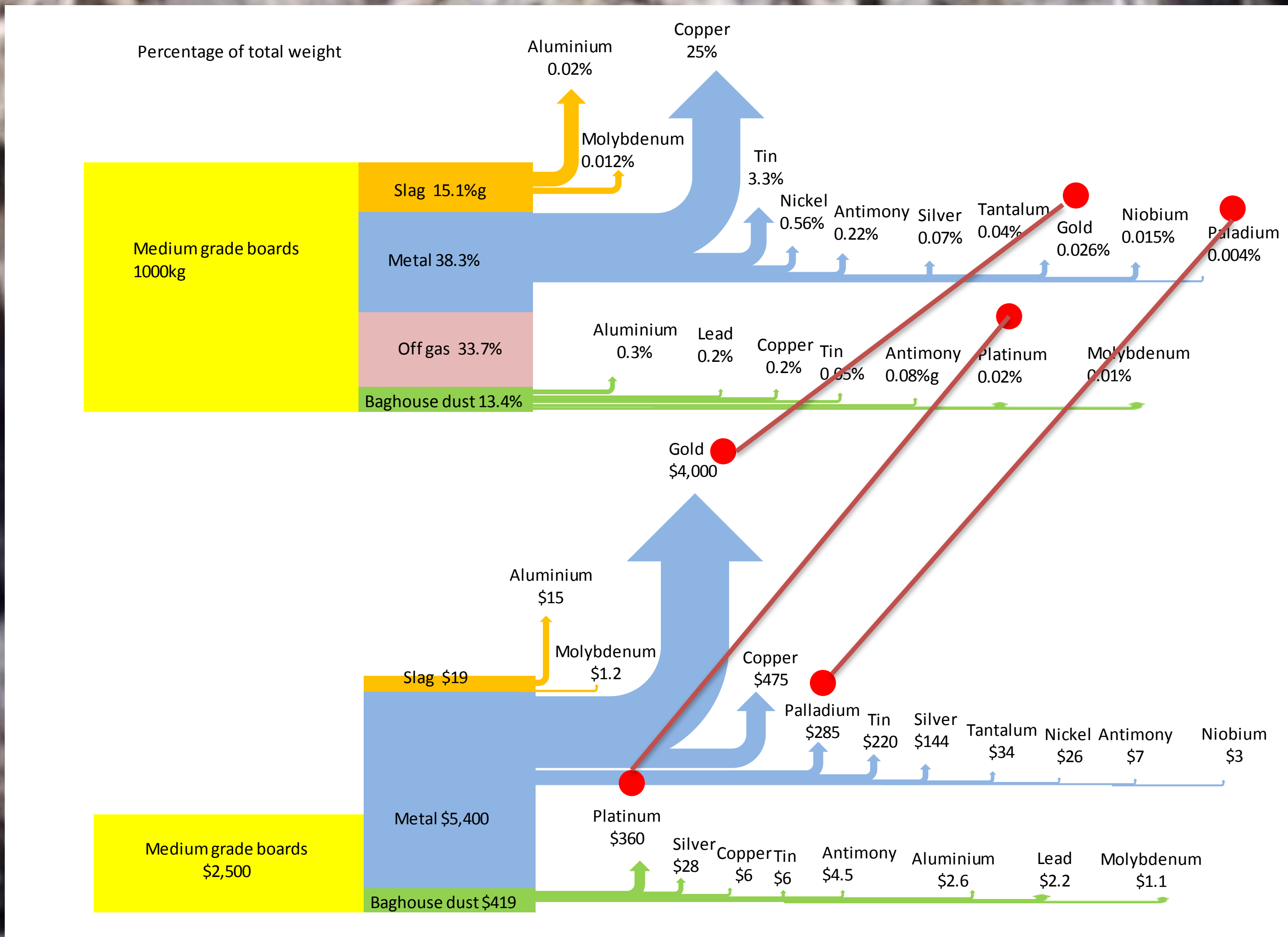
CRM/PGM Recovery from Electronics



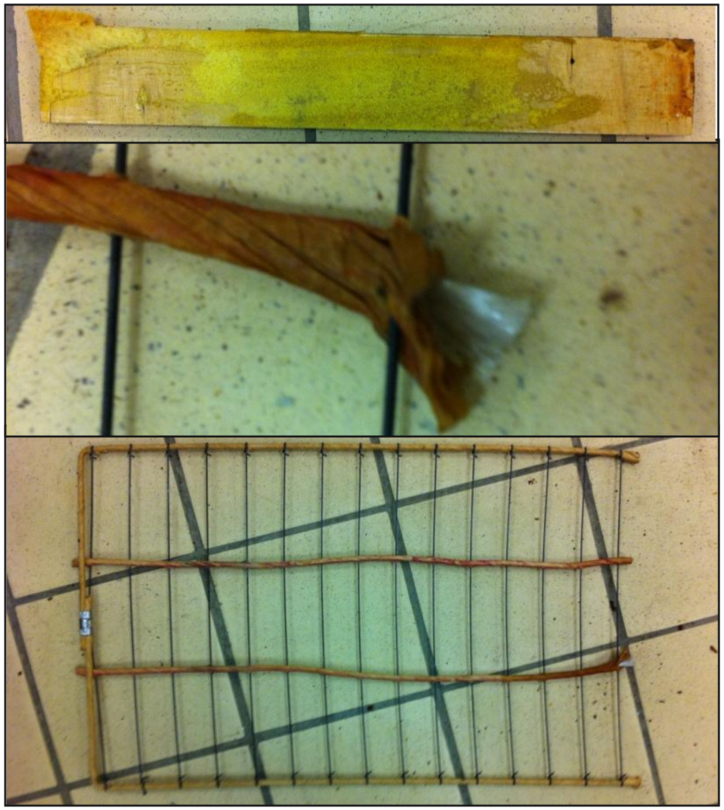
Results

- Over 90% recovery of gold, platinum, silver and over 85% recovery of most CRMs;
- Carbon footprint of gold (Embodied) 17.2tCO_2e per kg;
- 75% of gold is lost in traditional WEEE recycling methods*
- ~500kg** of gold is 'lost' per annum by WEEE processors (8,600tCO_2e);
- One tonne p.a. lost direct to landfill ~17,200tCO_2e.

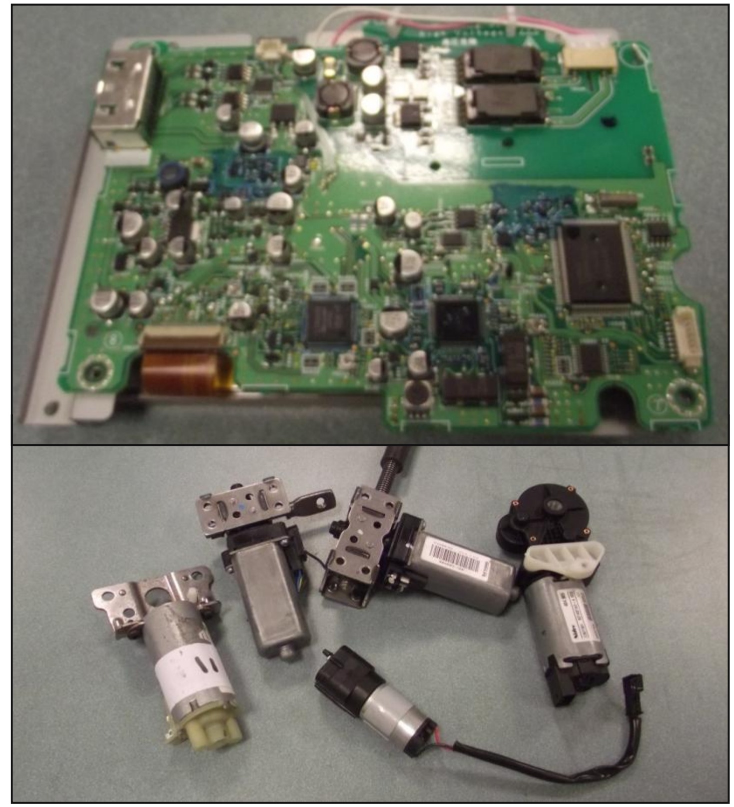
*www.wrap.org.uk/sites/files/wrap/2012%2005%2024%20Sustainability%20Live%20WRAP%20WEEE%20FINAL.pdf
**http://www.wrap.org.uk/content/wraps-resources-limited-conference

Automotive

1988 Range Rover Seat

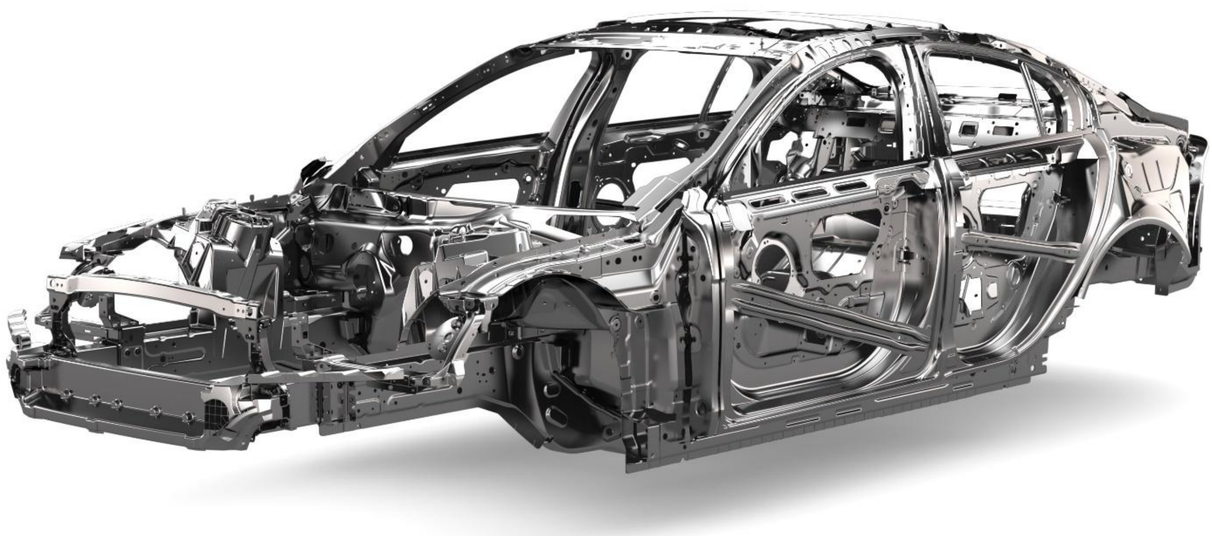


2010 Range Rover Seat



REALCAR
RECYCLED ALUMINIUM CAR

REALCAR



6-10tCO_2 over life
Saving 20-30% material costs
£5.8m investment

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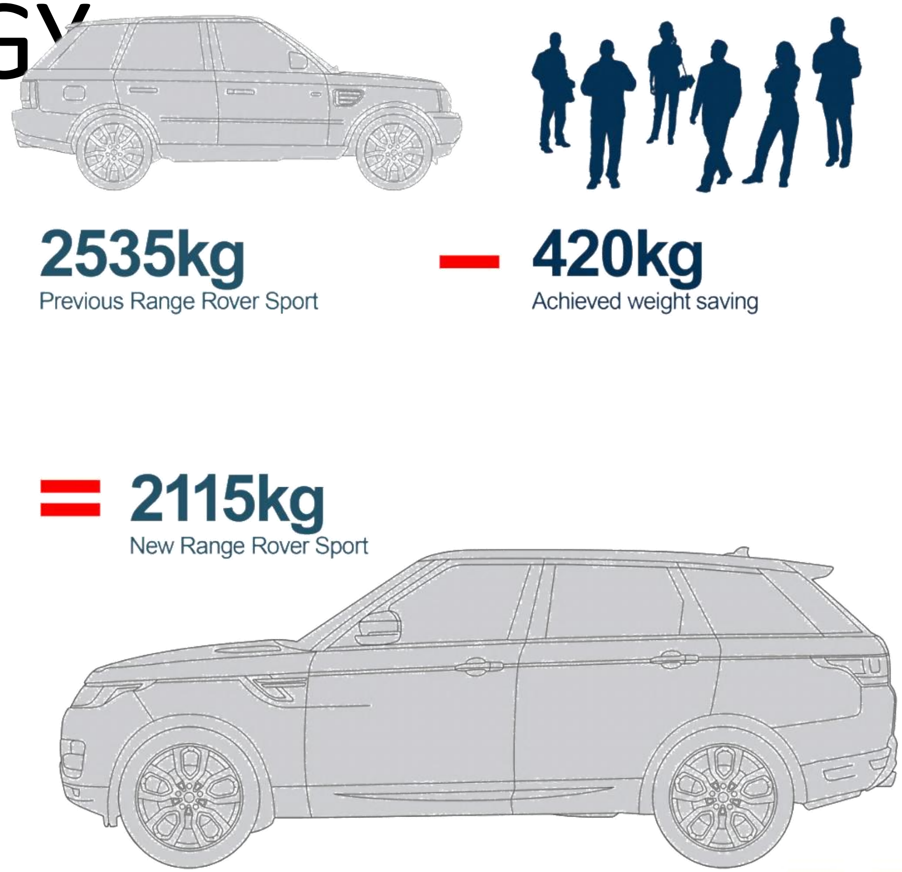
REALCAR LIGHT WEIGHT VEHICLE STRATEGY

Achieved weight saving of 420kg – equivalent to the weight of six adults

Every 100kg saved in the vehicle mass saves around 2% in fuel consumption



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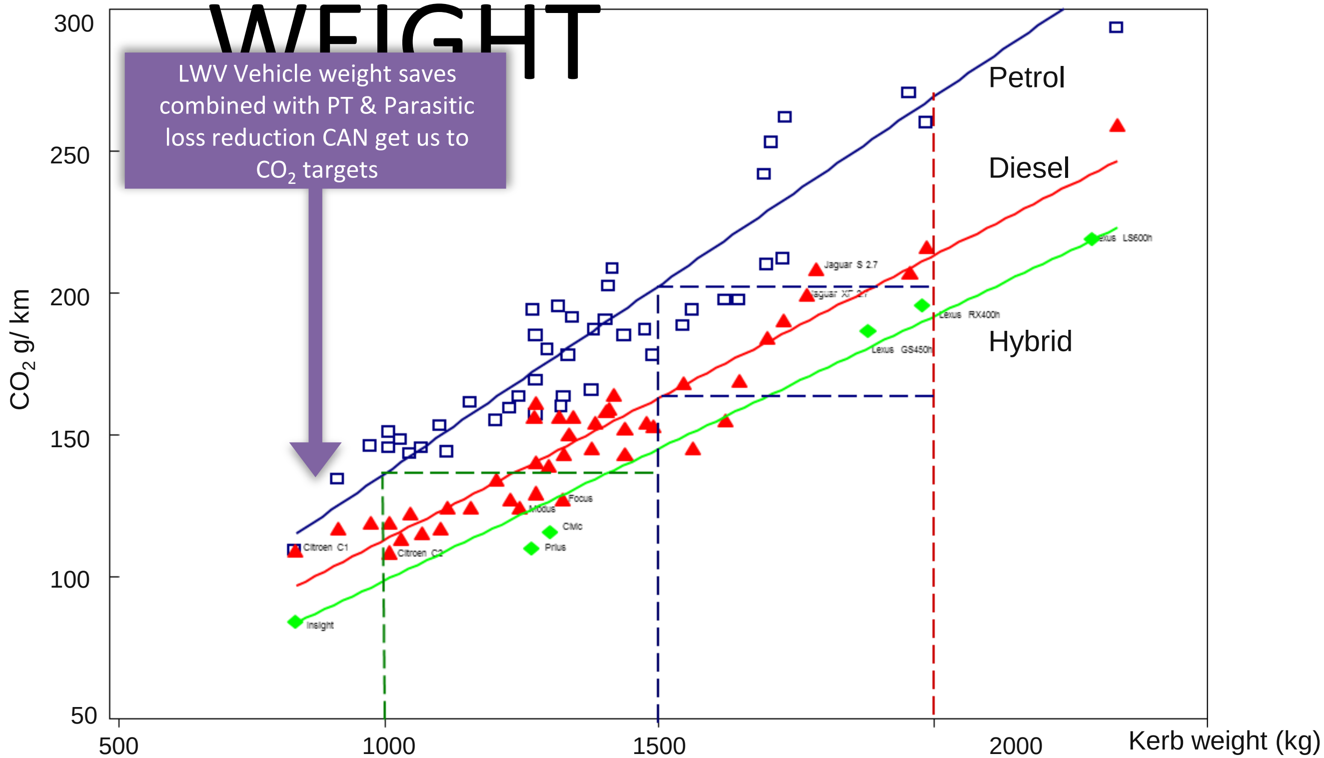
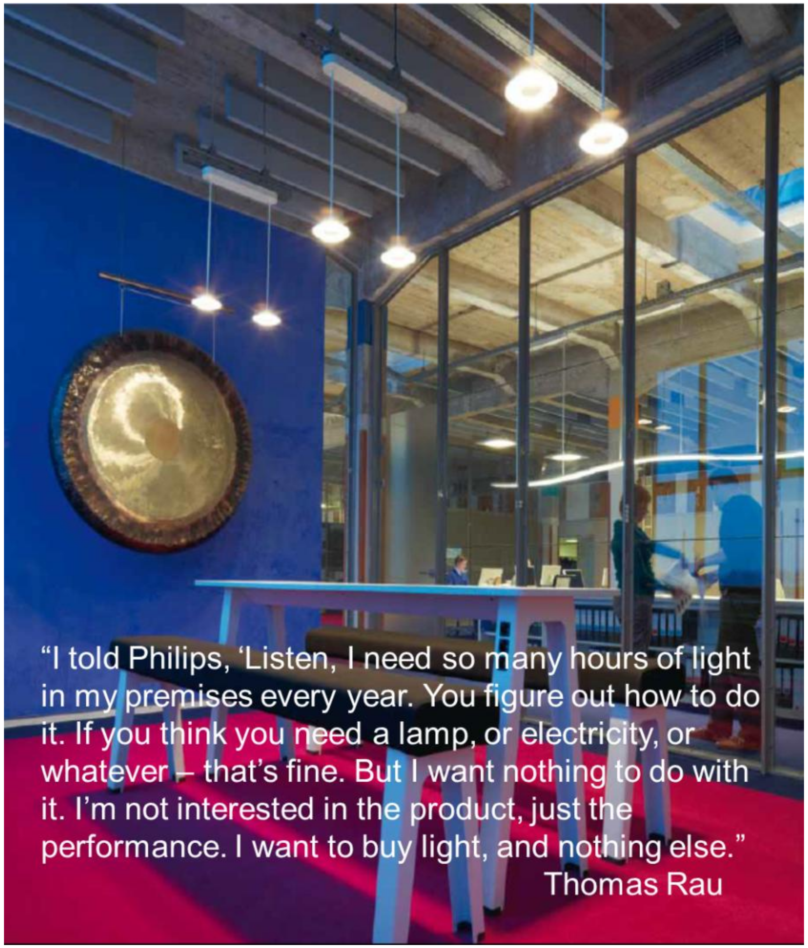
SUSTAINABILITY CHALLENGE CO_2 EMISSIONS BY VEHICLE WEIGHT



Reduction in Kerb Weight can be Equivalent to Improving Drivetrain Technology

Performance Economy (Stahel)



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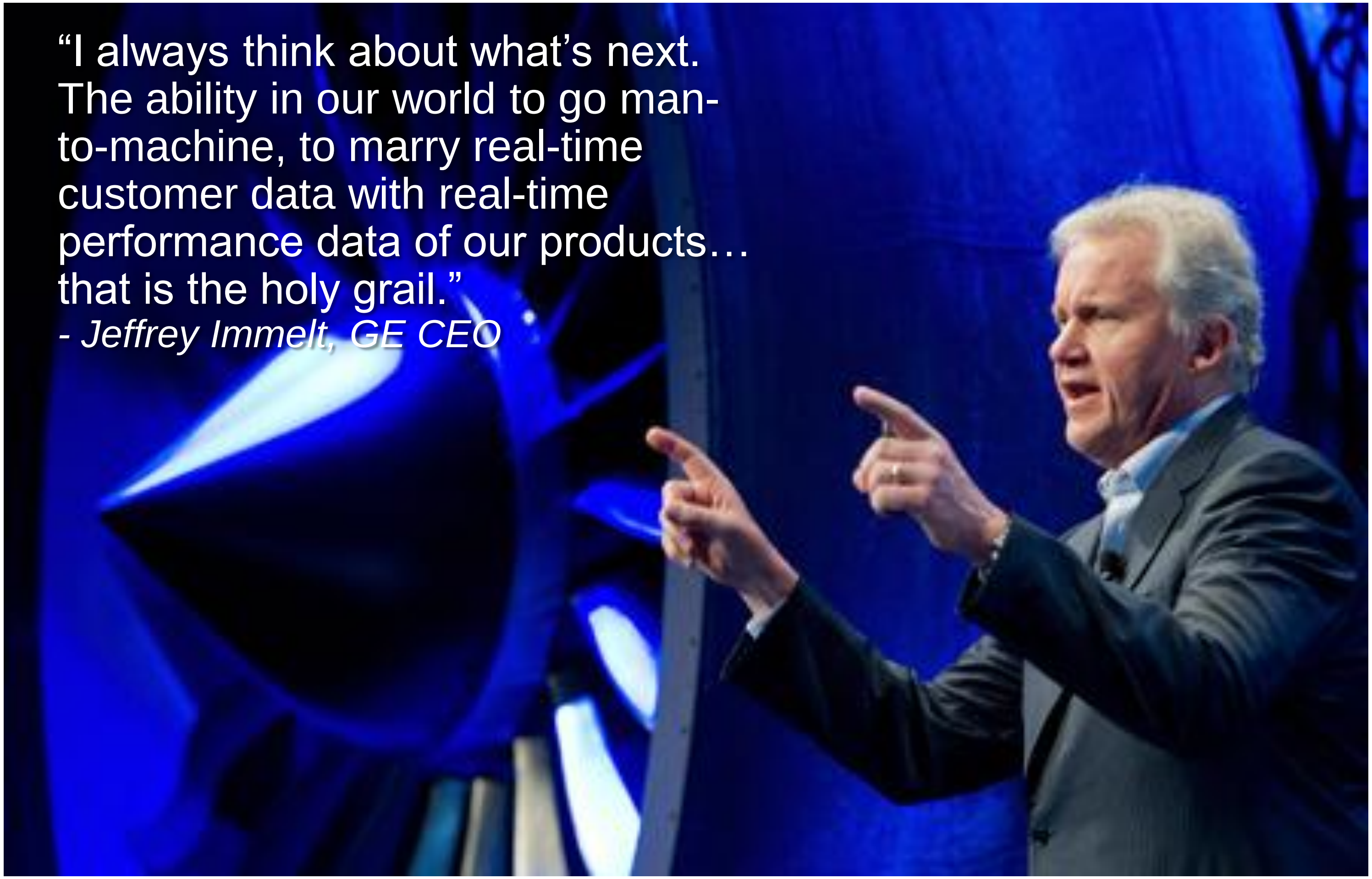
GE – Industrial Internet Vision



Product Design Reviews

- **Maintenance costs on monitored assets are 10-30% lower than un-monitored assets**

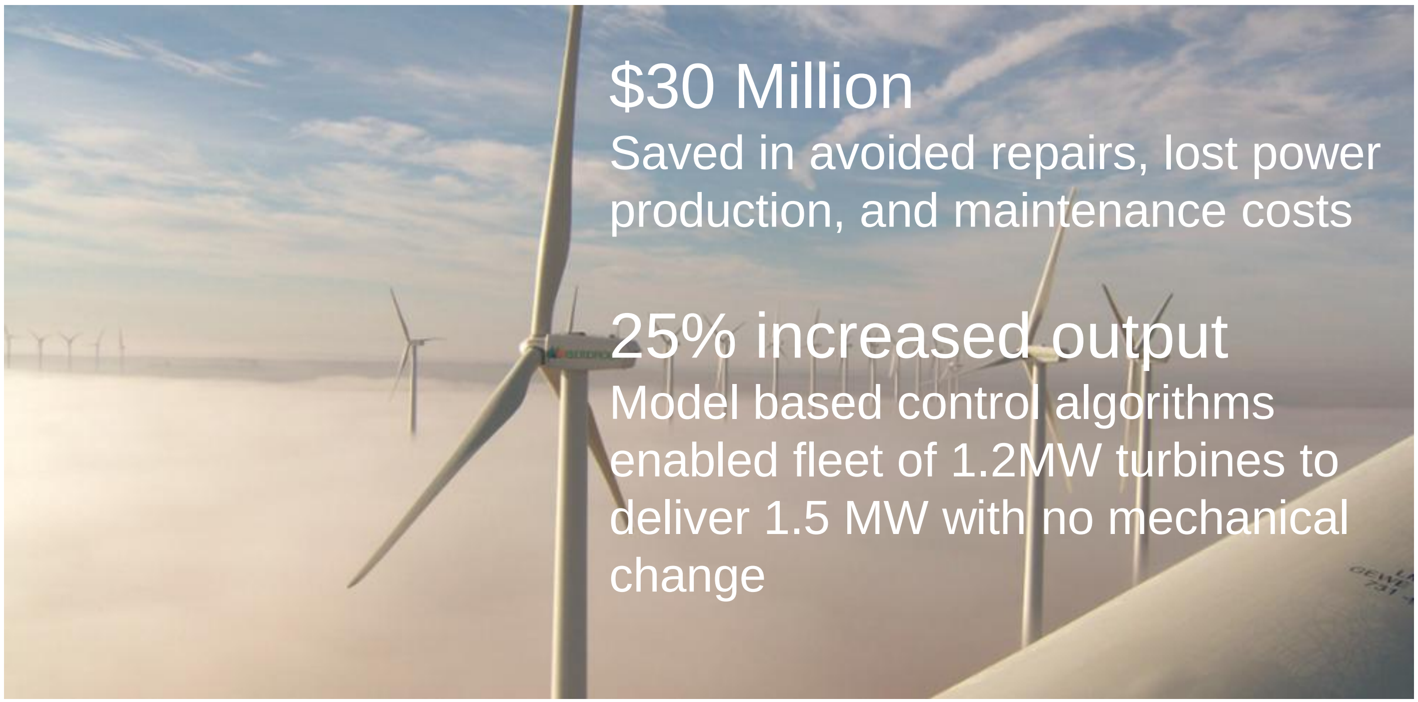
- GE is spending $1B / year on the Industrial Internet Real time monitoring & analytics (1000 staff Silicon Valley)

GE Aviation myEngines

- Tracks engine parts and communicates real-time to GE and airlines to manage engine fleets and improve productivity.

GE – Wind's Fleet Monitoring & Diagnostic Services

- Using data to impact reliability & performance



GE – Energy Storage Systems

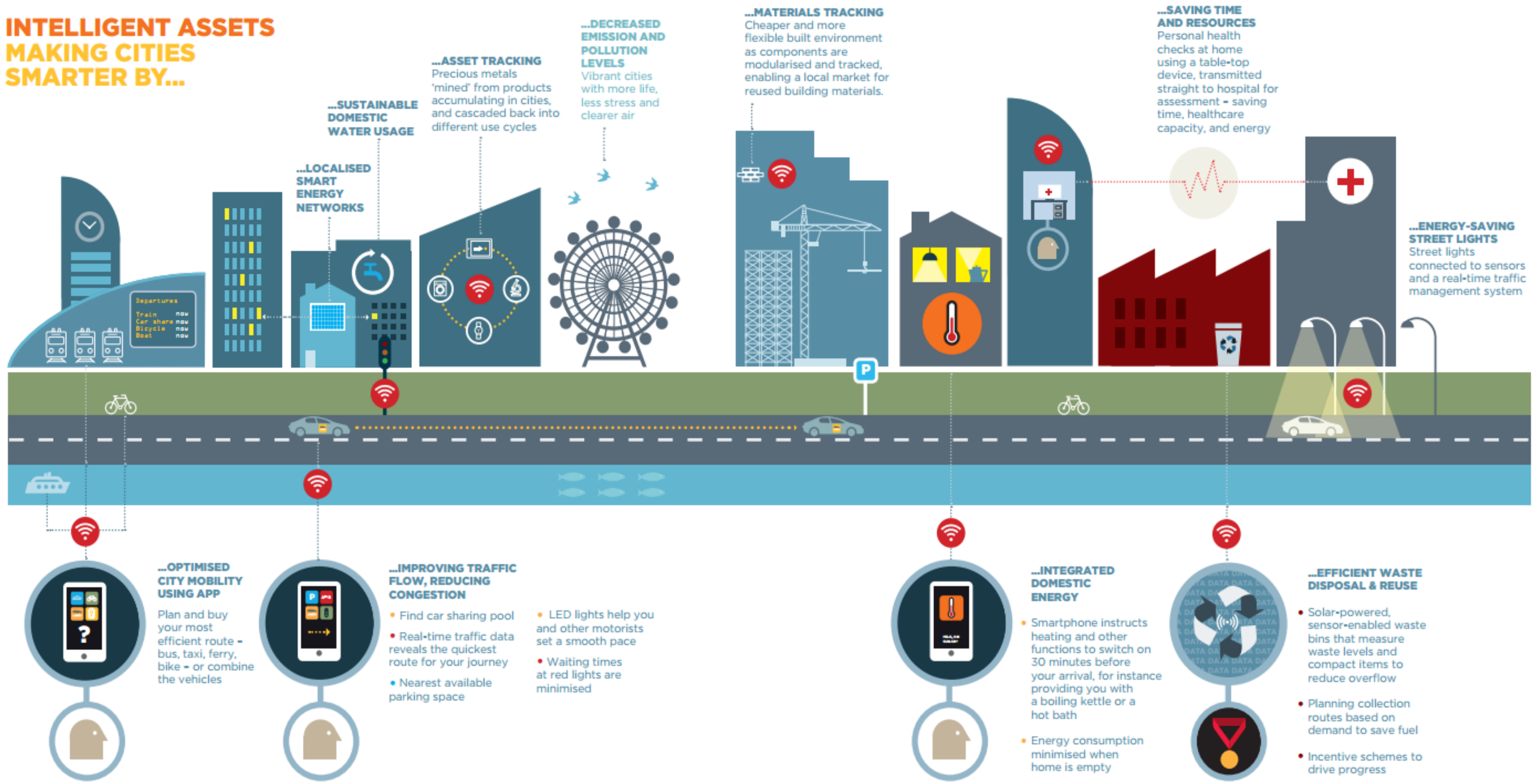
- Manufacturer of energy storage systems sold performance guarantees but had no long term performar data of battery cells in this application

- Able to monitor discharge/ charge capacity of each cell over time, reducing risk

IoT

'Network-enabled' smart devices 500 billion by 2050 (International Energy Agency)
By 2030 $236 Bn in services spending will be supported by IOT (Gartner)
Data Security an issue – Hoarding of devices.

Smart Cities



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IoT

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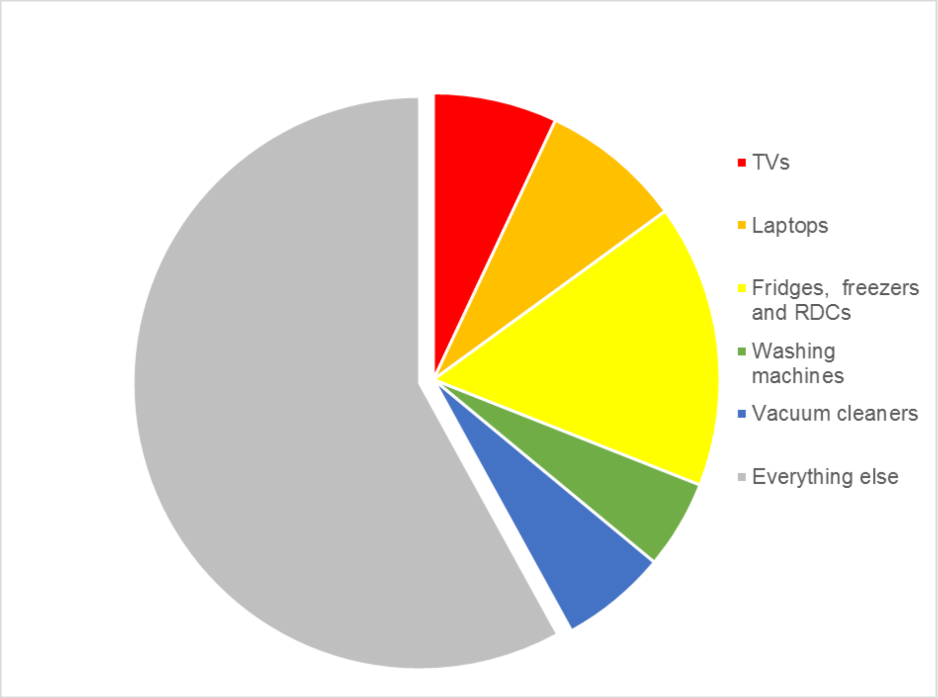
Highest GHG Impact products

- Collectively these products are >40% of the total embodied GHG impacts of the UK market of EEE



http://www.wrap.org.uk/sites/files/wrap/2012%2005%2024%20Sustainability%20Live%20WRAP%20WEEE%20FINAL.pdf

Product Design Reviews

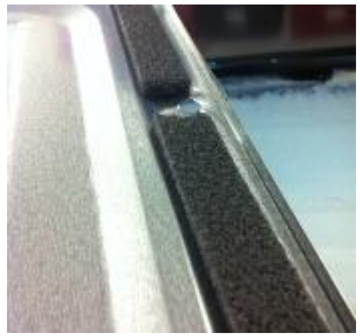
- Fridges/Freezers
- Vacuum Cleaners (ODM/retailer)
- Washing Machines/Washer Dryer
- Tumble Dryers
- Laptop Computers/Tablets
- Small Household Products

Product design reviews

- Initial Response: What can you tell us that we don't already know?

Answer:

- Washing Machine: £560,000 (per 100,000 units), 740 tCO_2e and 470t;
- TV: £180,000 and 600tCO_2e;
- Vending machines: £140,000 and 600tCO_2e;
- Microwave: £320,000 and 300tCO_2e;
- Vacuum Cleaner £111,740 per annum, 3,994tCO_2e,1,126 tonnes material.



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Eco-Design - Manufacture

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Eco design - Manufacture

- Plasterboard manufacture 12,500tCO_2e
- Concrete beam manufacturer 1,000tCO_2e
- Brick manufacturer 5,600tCO_2e
- Sanitary ware 4,300tCO_2e
- Vinyl flooring 1,200tCO_2e

- ~ Savings of over £3.1 million

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Technology

- Exhaust heat kilns could be used to pre-dry or pre-warm the products prior to kiln;
- Installing regenerative Burner (Twin Bed Burners) to recover waste heat from furnace exhaust gases to preheat combustion air;
- Installing oxygen control loop to improve ovens and kiln efficiency;
- Replace/add insulation to ovens and kilns to reduce heat loss.

Thank you

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@giraffeinnov

Panel discussion – Energy and the circular economy

Professor Richard Darton

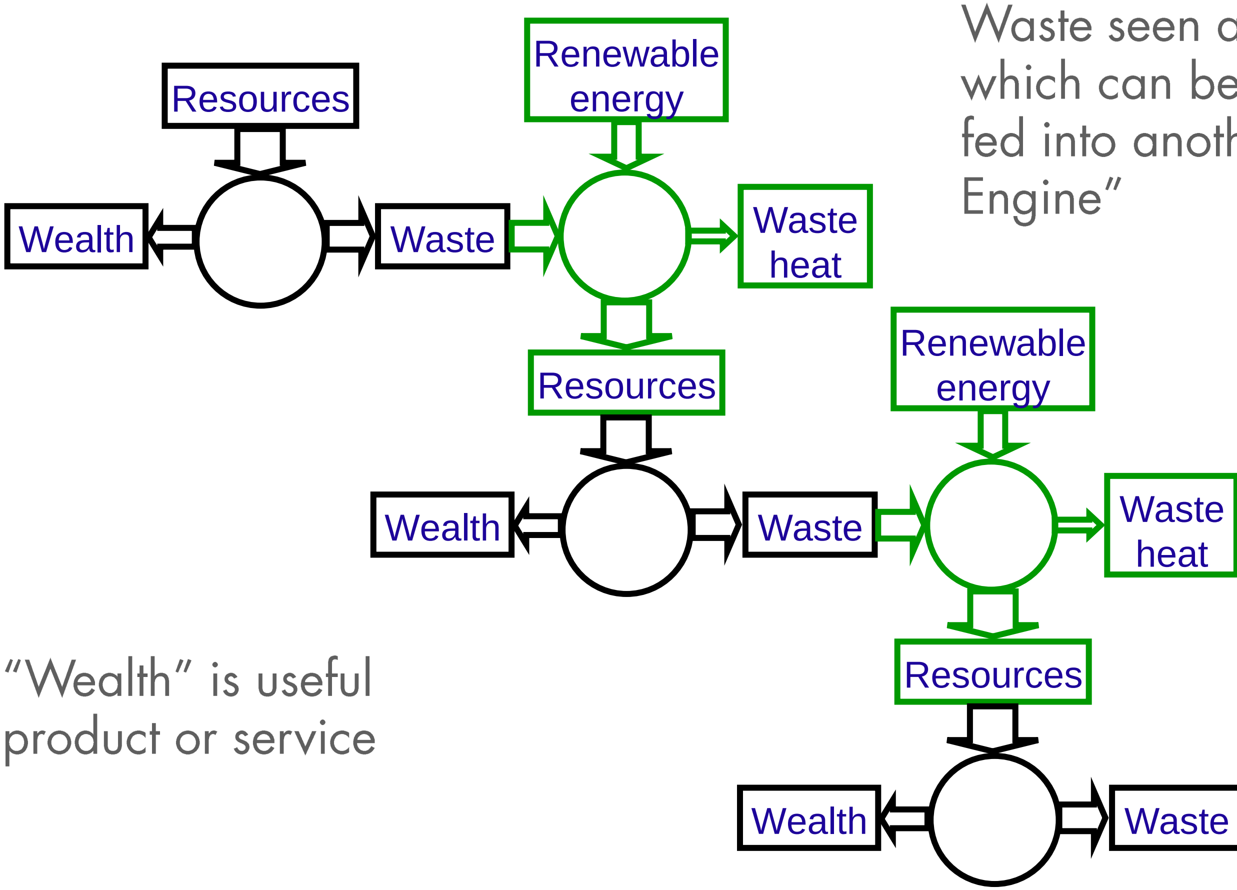
University of Oxford

Energy and the Circular Economy

Panel discussion

Chair: Prof Richard Darton

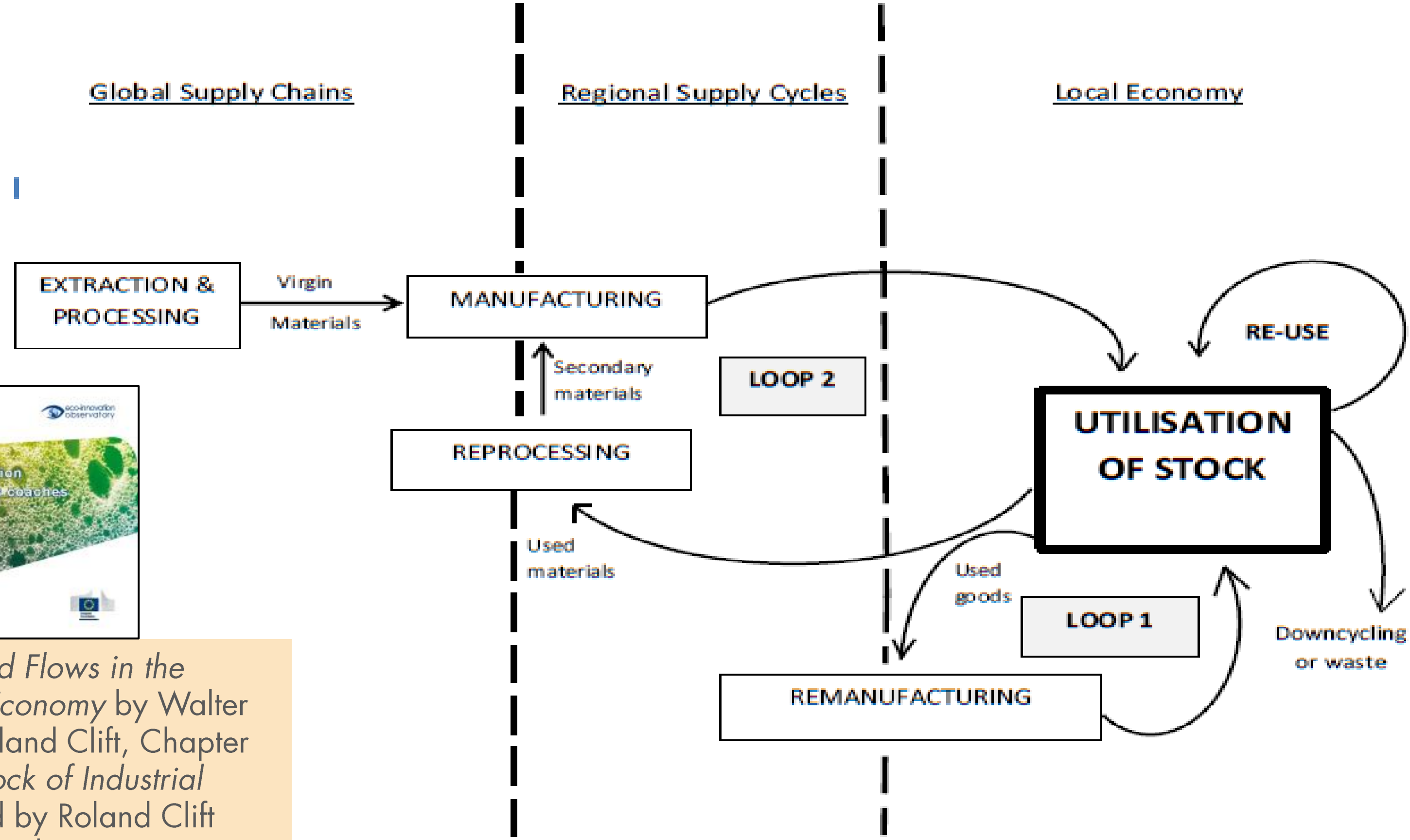
Industrial ecology 1



Waste seen as resource which can be upgraded and fed into another "Wealth Engine"

"Wealth" is useful product or service

Industrial ecology 2



See *Stocks and Flows in the Performance Economy* by Walter R. Stahel & Roland Clift, Chapter 7 in *Taking Stock of Industrial Ecology* Edited by Roland Clift and Angela Druckman, Springer, 2016. **Available free on-line**

Panel discussion – Energy and the circular economy

Lunch

13:00-14:00

IChemE Energy Centre

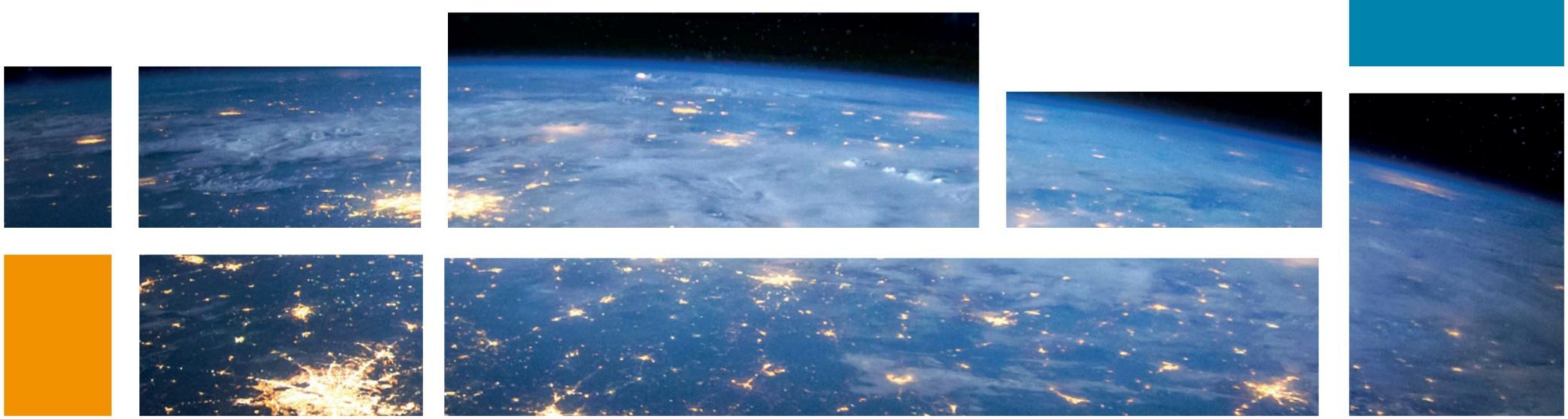
KTN the Knowledge Transfer Network

Professor Patricia Thornley

Director

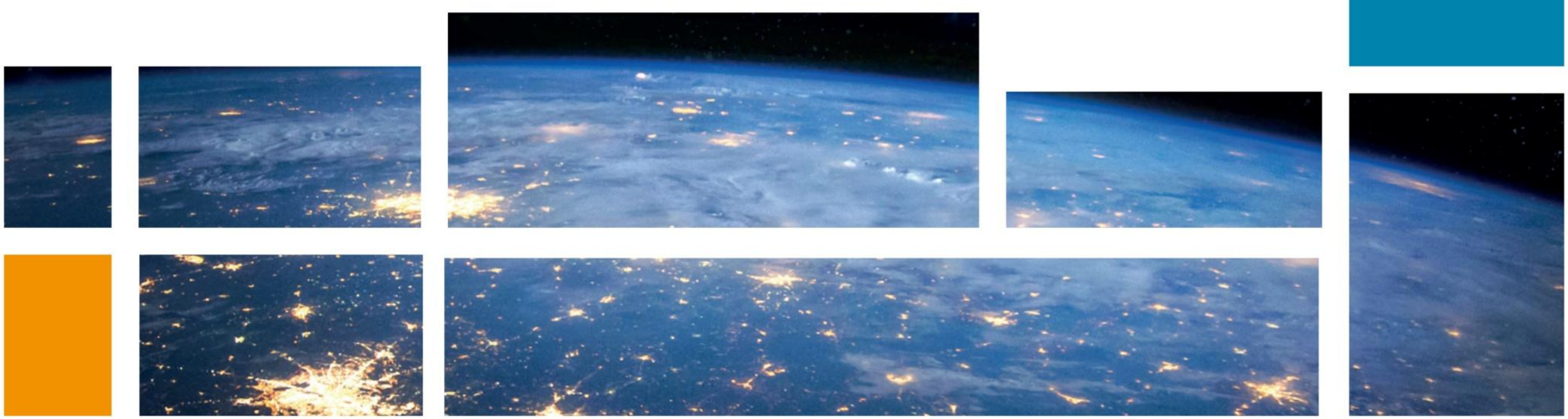
SUPERGEN Bioenergy Hub,

University of Manchester



Professor Patricia Thornley

Bioenergy can give carbon reductions of 80-90%



Professor Patricia Thornley

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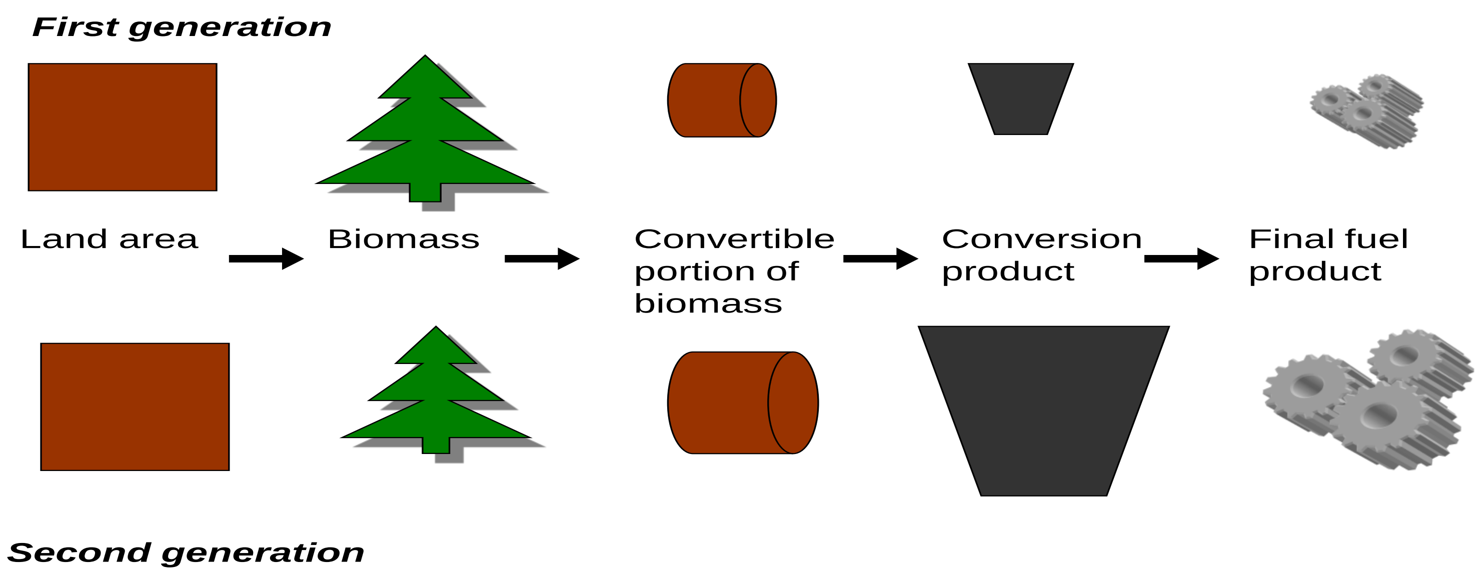
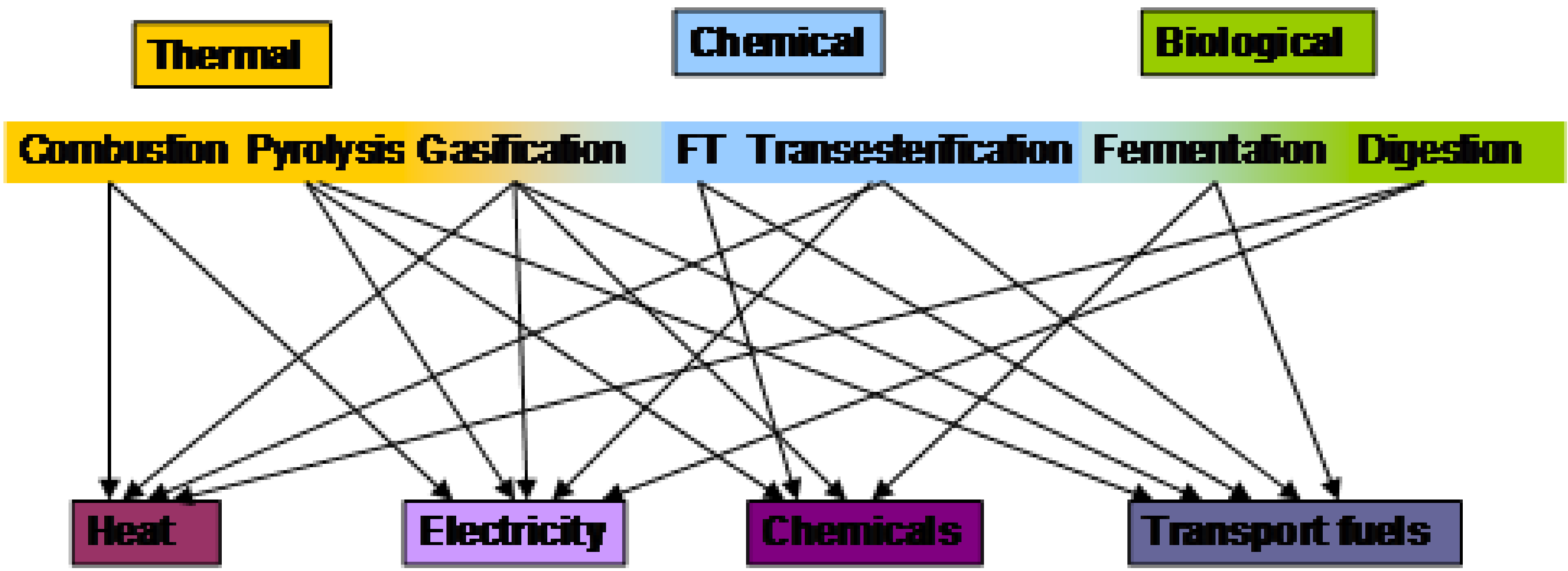
Feedstocks

Supply chains

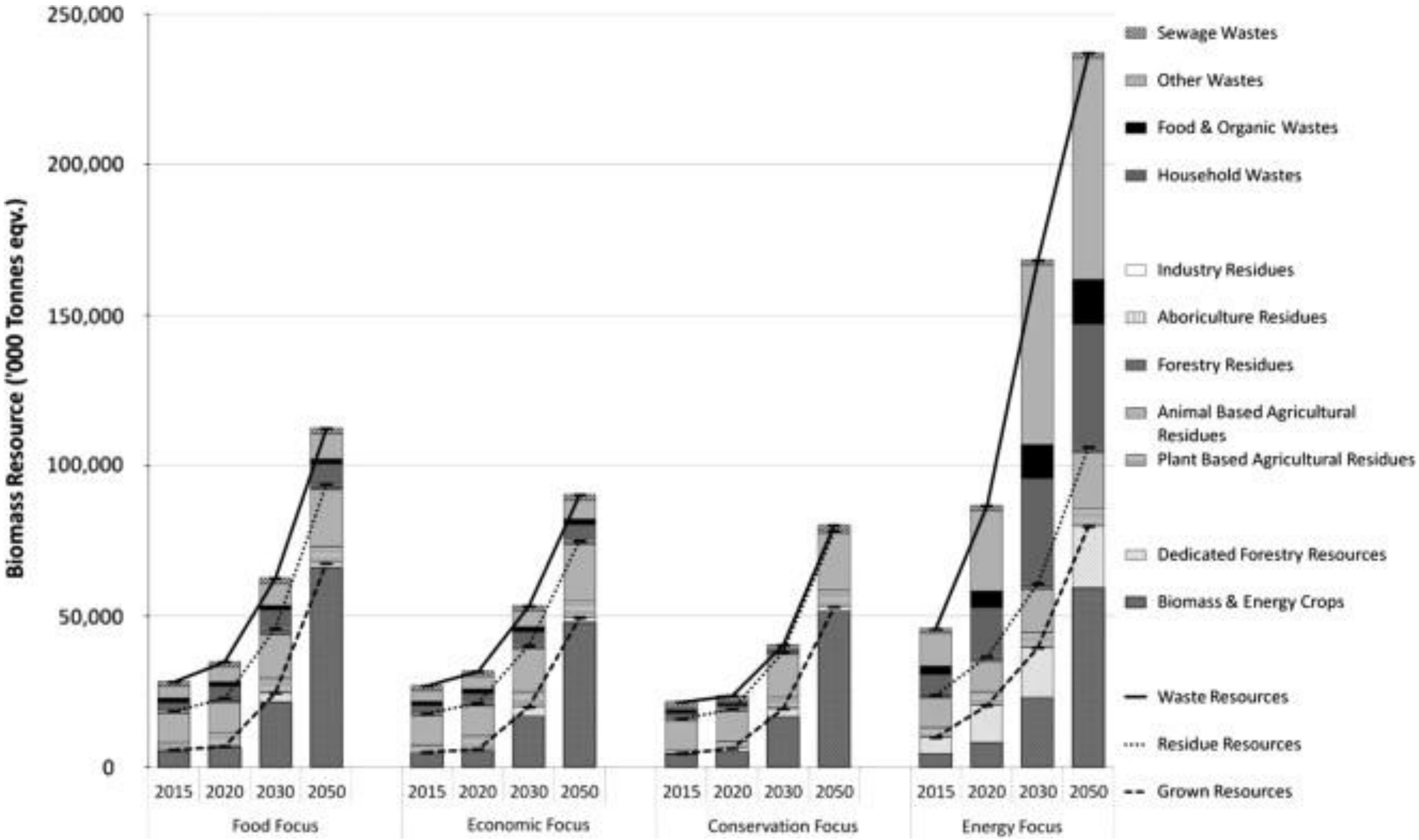


Thornley, P., "Biofuels Review", Report for Government Office for Science, prepared as part of the Foresight Programme, June 2012

Pathways and products



Can supply 44% UK energy demand



Welfle A., Gilbert P., Thornley P., Securing a bioenergy future without imports, Energy Policy, vol 68, 2014

UK systems for life cycle evaluation

Table 1 – Systems studied.

	Feedstock	Scale	Product	Technology
1	Wood chip from UK energy crops	Small (250 kWe)	Electricity	Gasification
2	Imported forest residues	Large	Electricity	Combustion
3	Imported pellets from forest products	Small (domestic)	Heat	Combustion – individual boiler
4	Wood chip from UK energy crop	Community (100 houses)	Heat	Combustion – district heating
5	Wood chip from imported forest products	Large	Ammonia	Gasification & ammonia synthesis
6	Wood chip from UK energy crop	Medium	Biochar	Slow pyrolysis & application of char to soil

Thornley P., Gilbert P., Shackley, S., Hammond, J., Maximizing the greenhouse gas reductions from biomass: the role of life cycle assessment, Biomass and Bioenergy, vol 81, 2015

Methods

Life cycle assessment (LCA)

- Scope includes feedstock production, processing and conversion to final product *(LUC not inc)*
- Consistent assumptions across systems

Investment appraisal

- Discounted cash flow techniques (net present value)

Indicators

1. GHG emissions from the bioenergy system per unit of product
2. Absolute GHG savings from the bioenergy system per unit of product
3. GHG reductions (relative percentage) per unit of product
4. GHG reductions per unit of biomass utilised
5. GHG reductions per unit of land occupied
6. Cost per unit of GHG reduction

Relative GHG reductions

- District heating chip boiler gives largest reductions – *making use of heat & electricity*
- Electricity systems (large pellet and small chip) are next best – *carbon intensity of counterfactual*

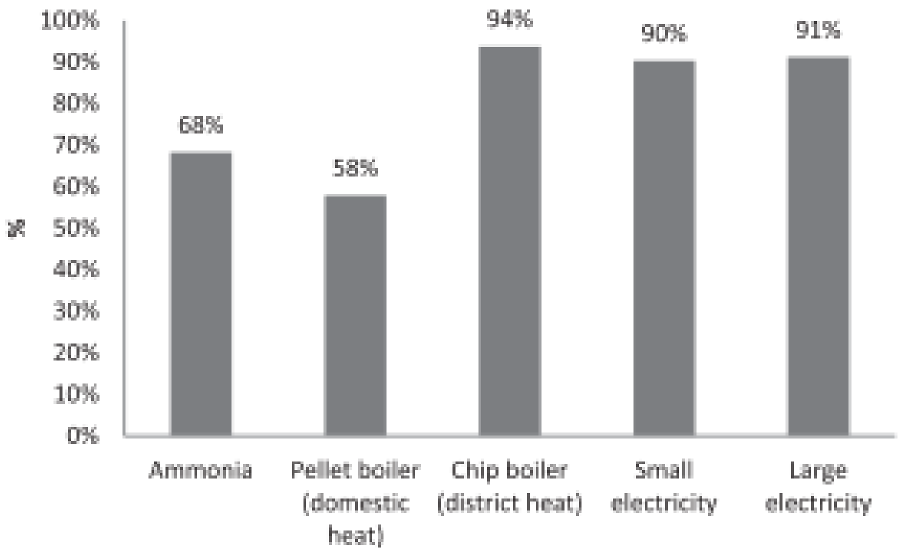


Fig. 3 – Relative greenhouse gas reductions compared to the reference case.

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Absolute GHG reductions

- Electricity systems best – *displacement of high C electricity*
- Pellet boiler worst – relatively *low C intensity natural gas counterfactual*

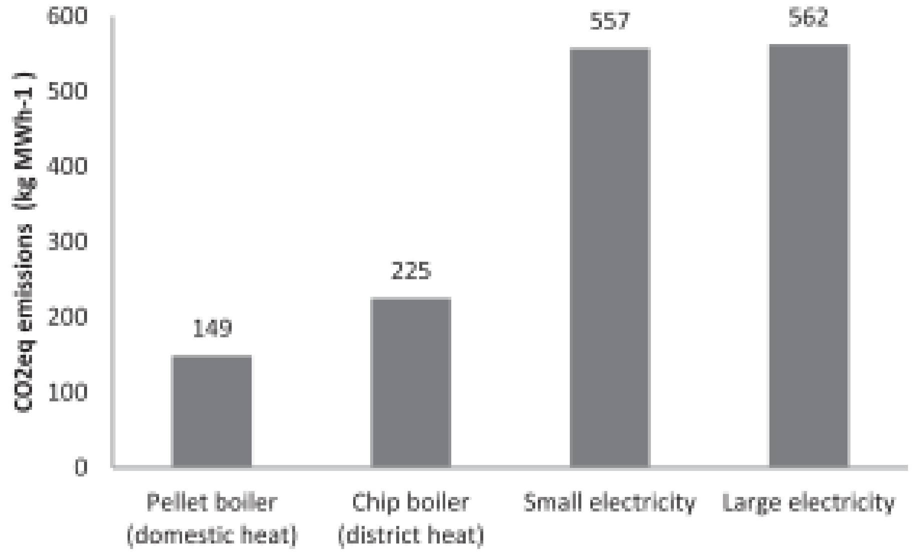

Fig. 2 – Absolute greenhouse gas savings per unit of energy delivered.

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GHG reductions per unit of biomass

- Wood chip boiler for district heating delivers the greatest GHG reduction impact per unit of biomass; followed by the ammonia and large electricity systems

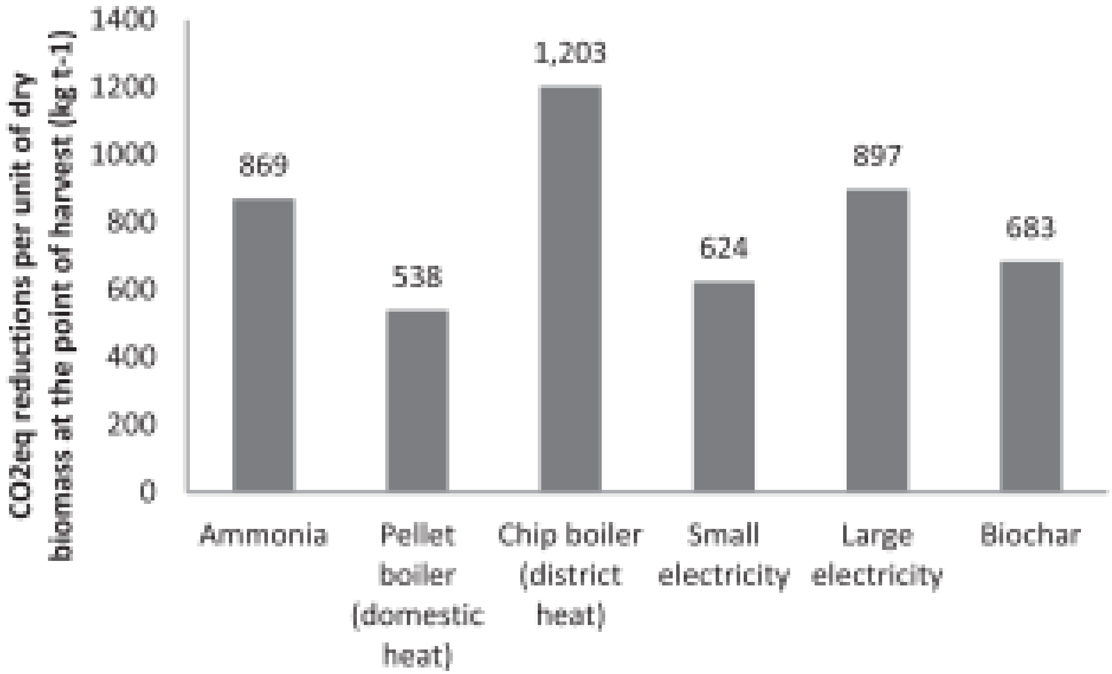


Fig. 4 – Greenhouse gas reductions per unit of biomass.

GHG reductions per unit of land

- Biochar maximizes reductions because of process efficiency and carbon intensity of displaced product

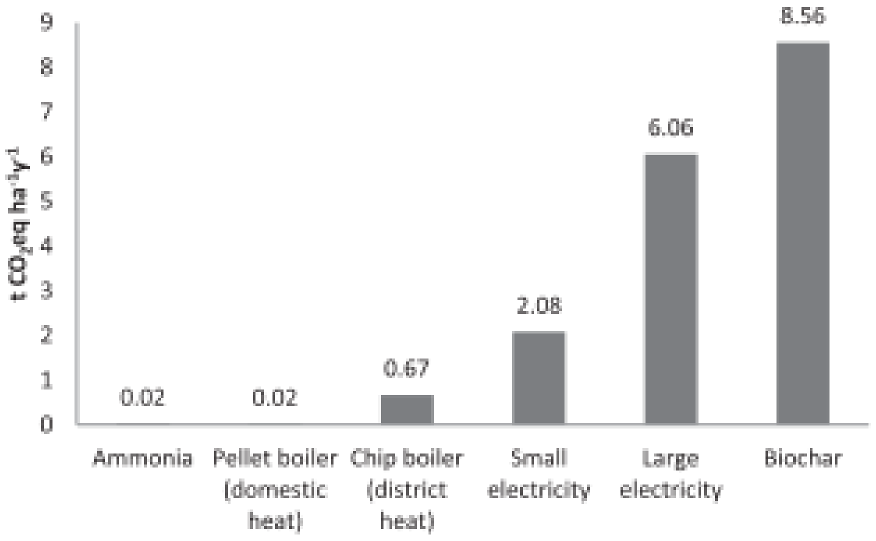
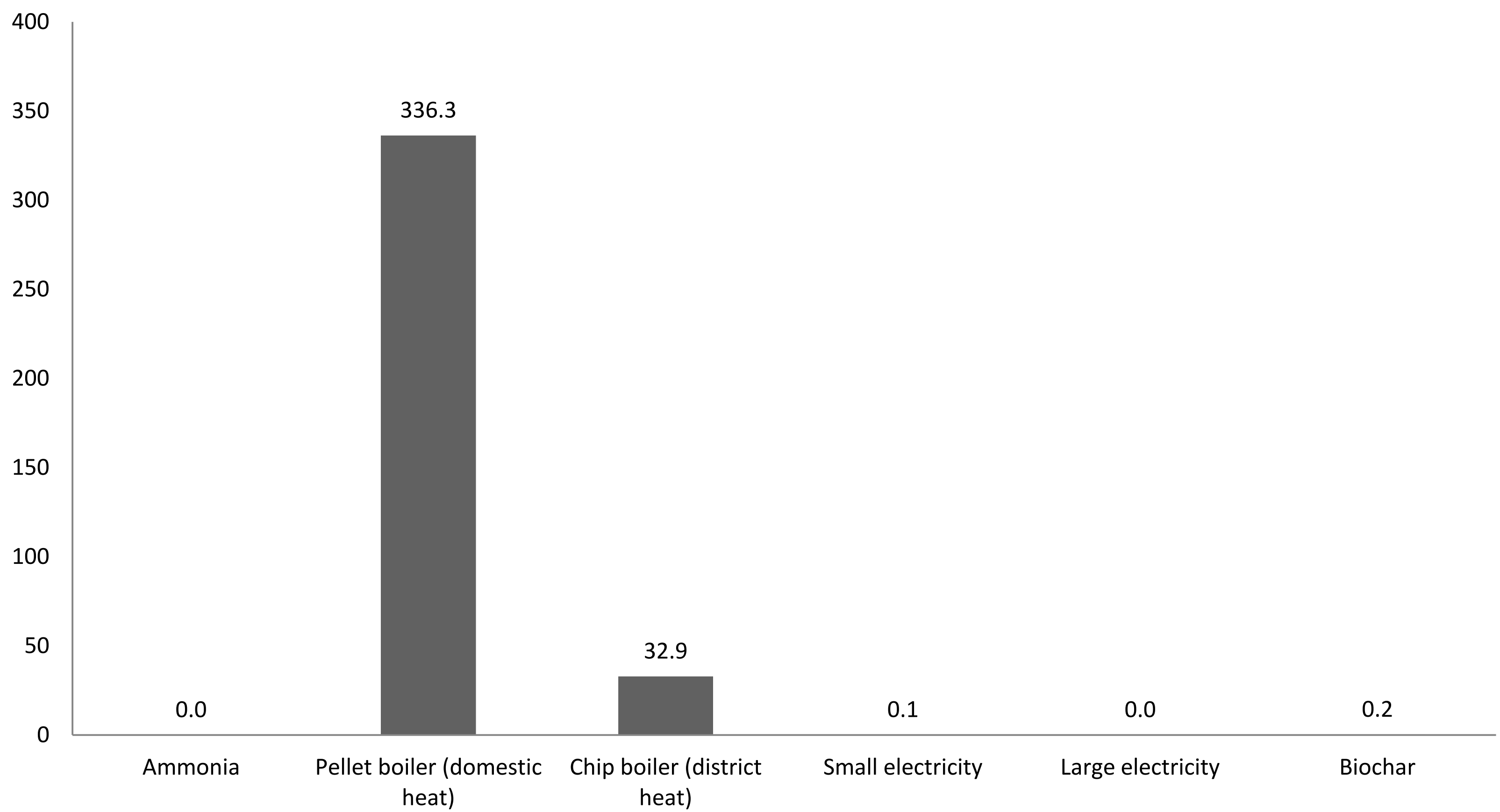


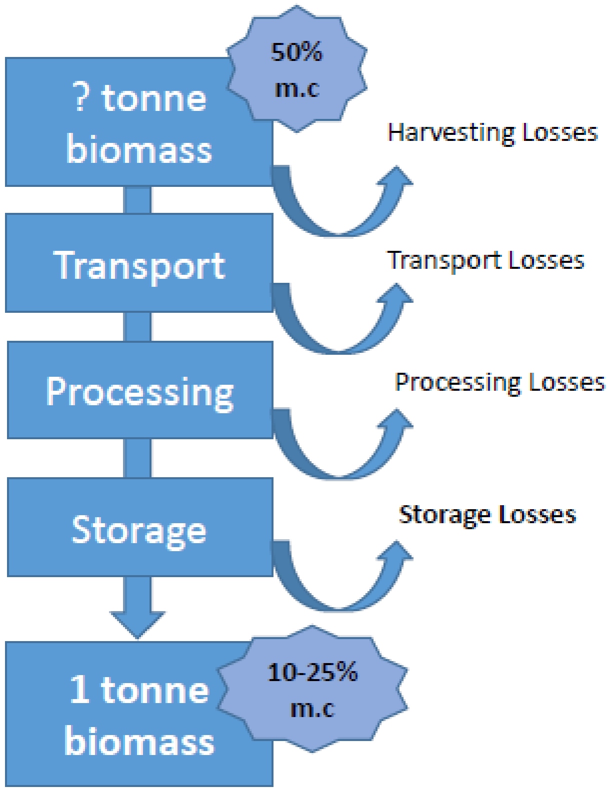
Fig. 5 – Greenhouse gas reductions per unit of land occupied.

Cost per unit of GHG saved (£/kg CO_2

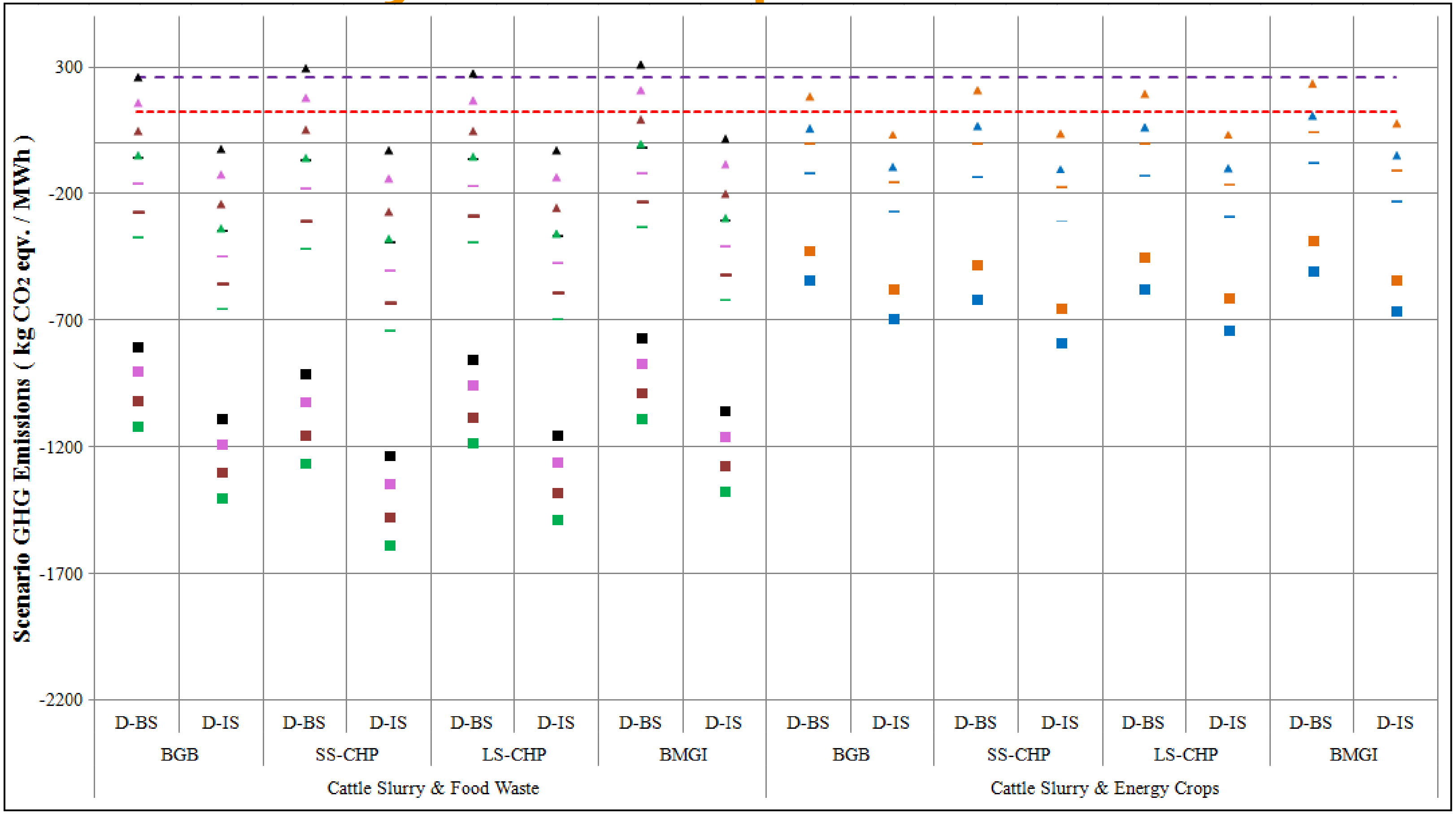


Variability due to supply chain losses

- e.g. Short rotation coppice storage in wood chip heaps loses ~20% dry matter in 3-6 months
- When displacing natural gas for heating this increases GHG emissiosn and land area required by 26%

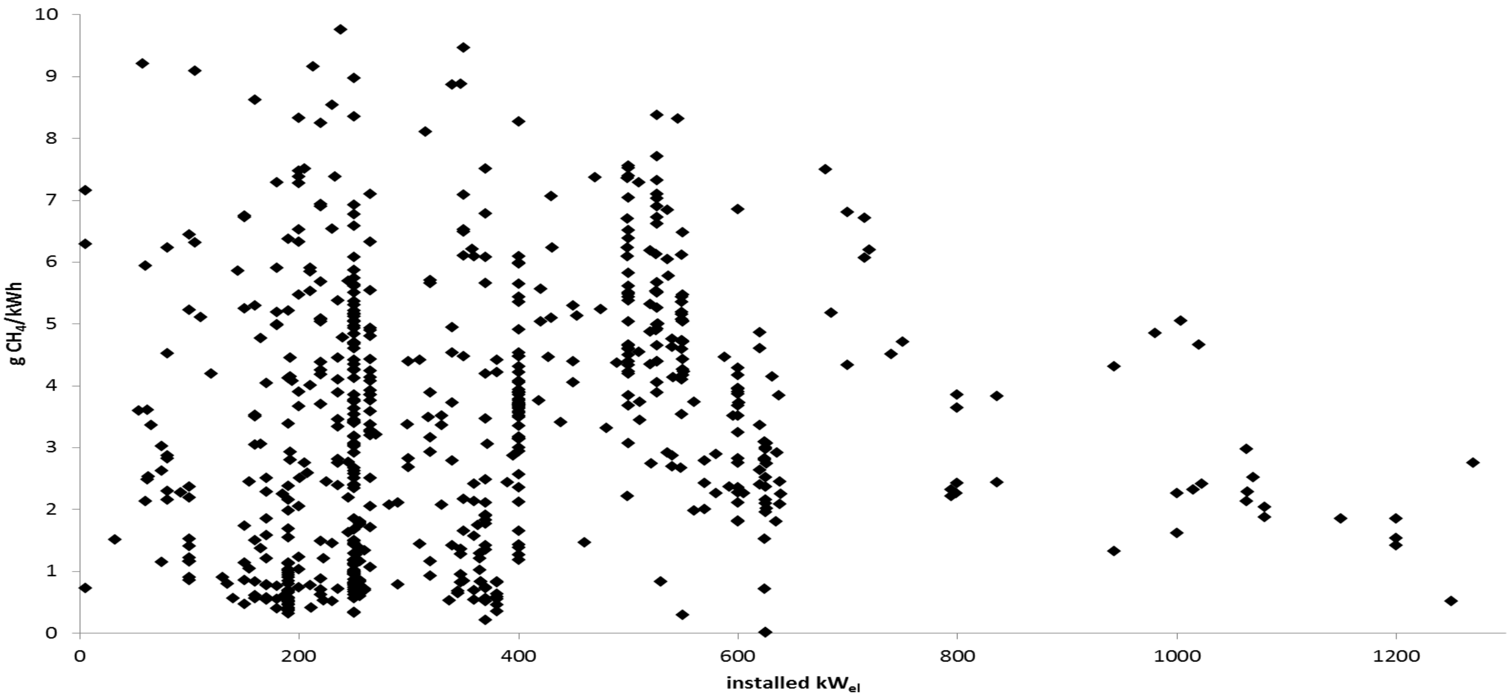


Variability due to process variations



Welfle A., Gilbert P., Thornley P., The potential for generating low carbon heat from biomass resources: life cycle assessment of bioenergy and counterfactual scenarios, forthcoming

Variability from site to site (methane)



Adams, P., McManus, M. & Holgrem, M.A., 2016. European Biogas Conference, Gent, Belgium, 27-28 September 2016

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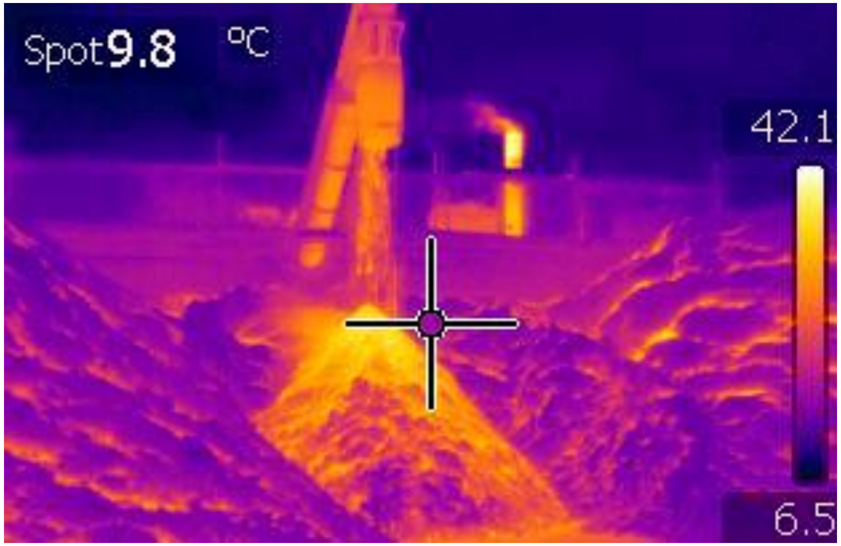
Variability due to difficulties in measurement:N2O, fugitive emissions



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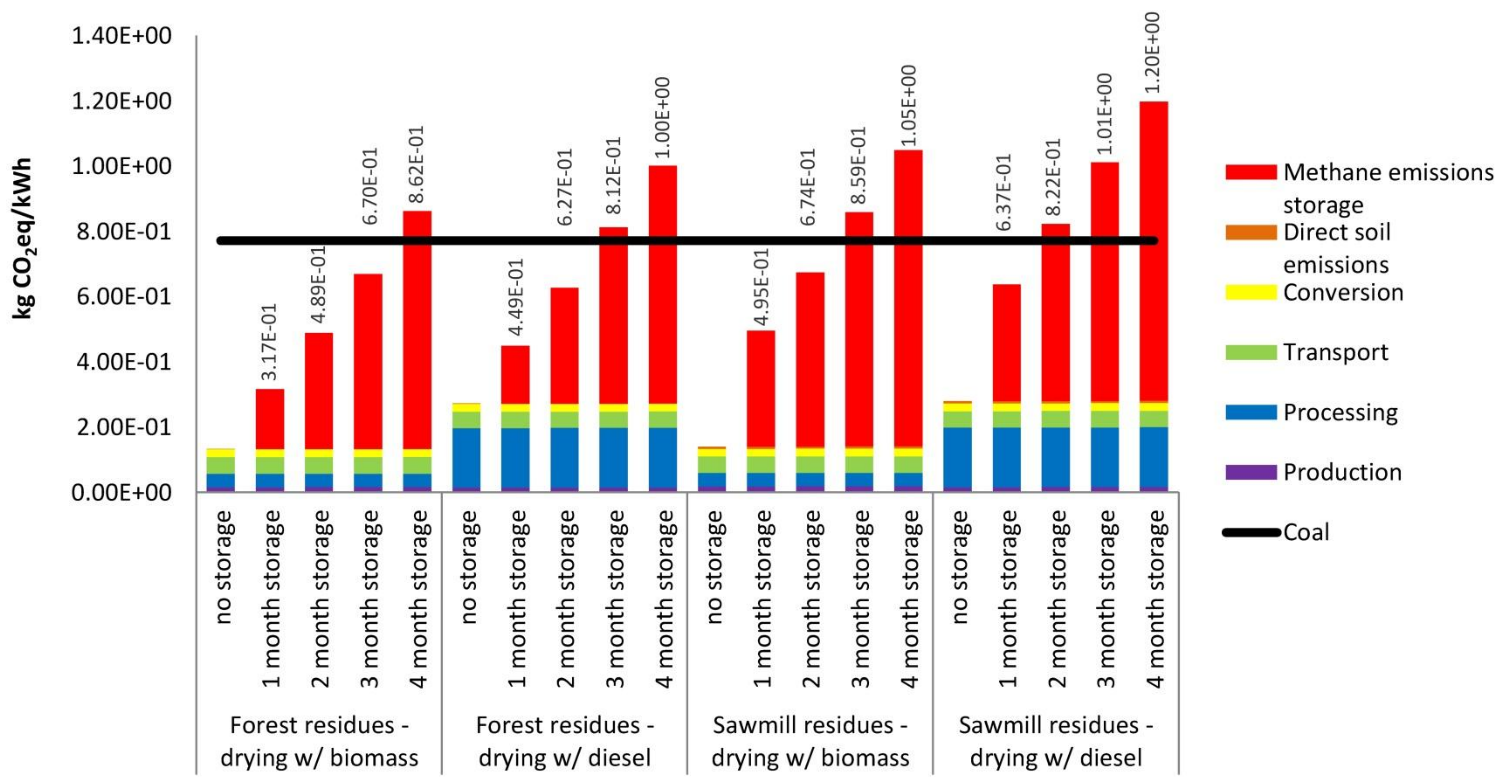
Variability due to assumptions



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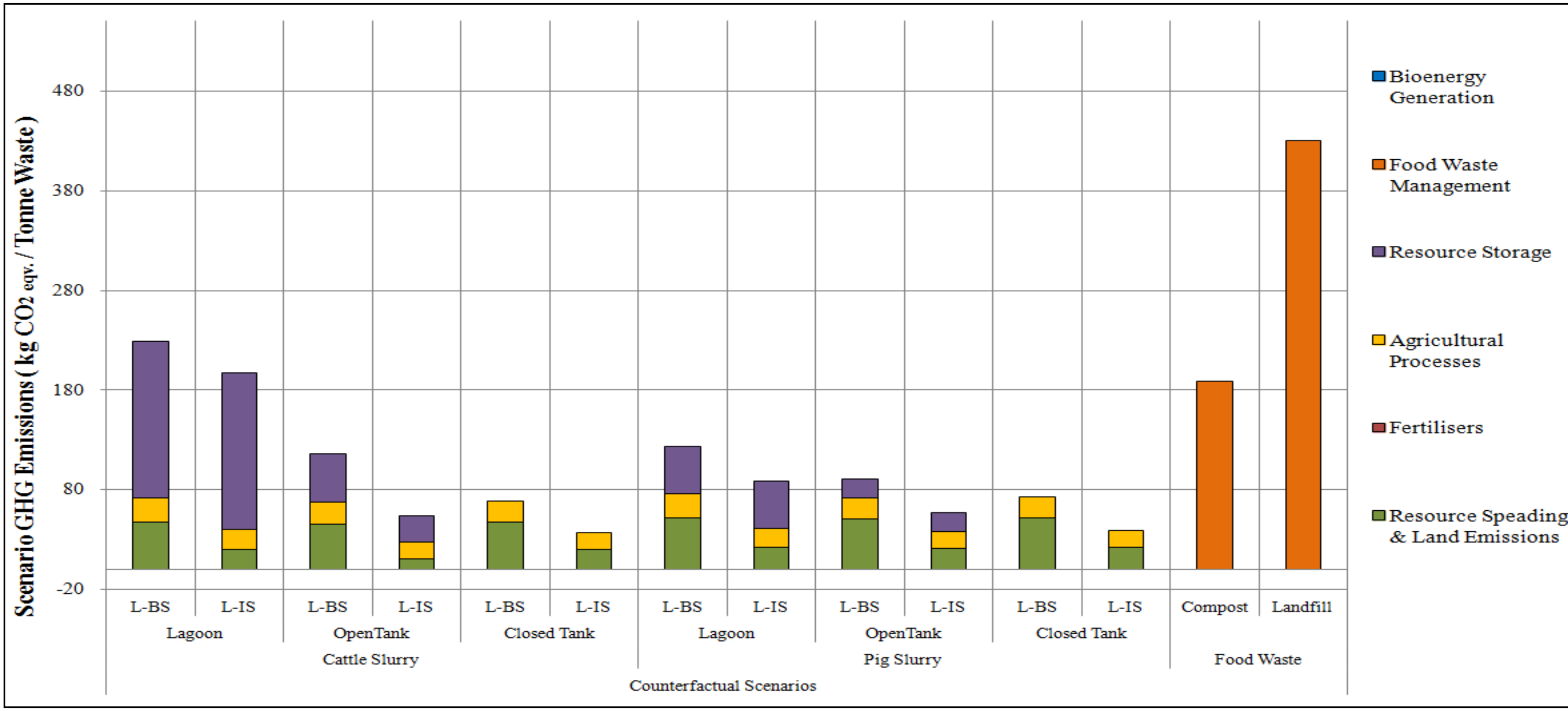

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Biomass can make very substantial cost effective GHG savings but care is needed in system analysis!

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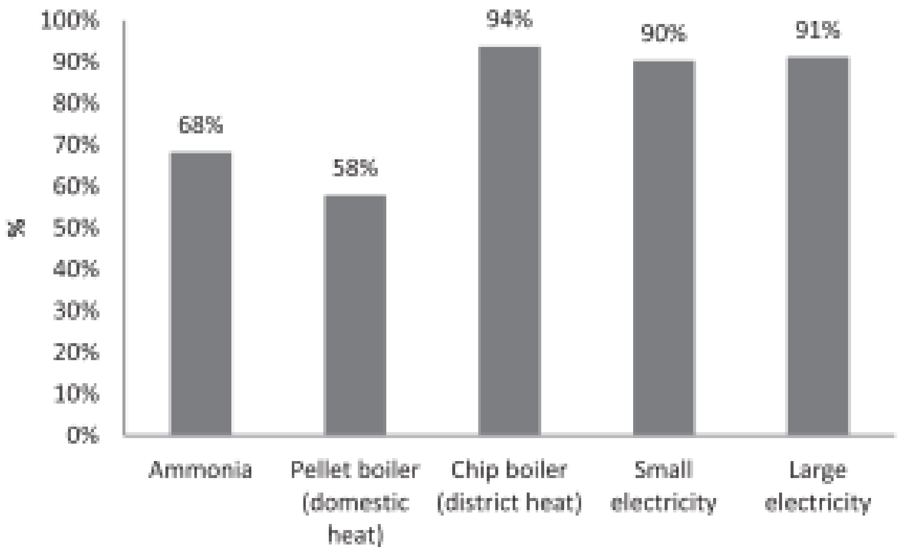

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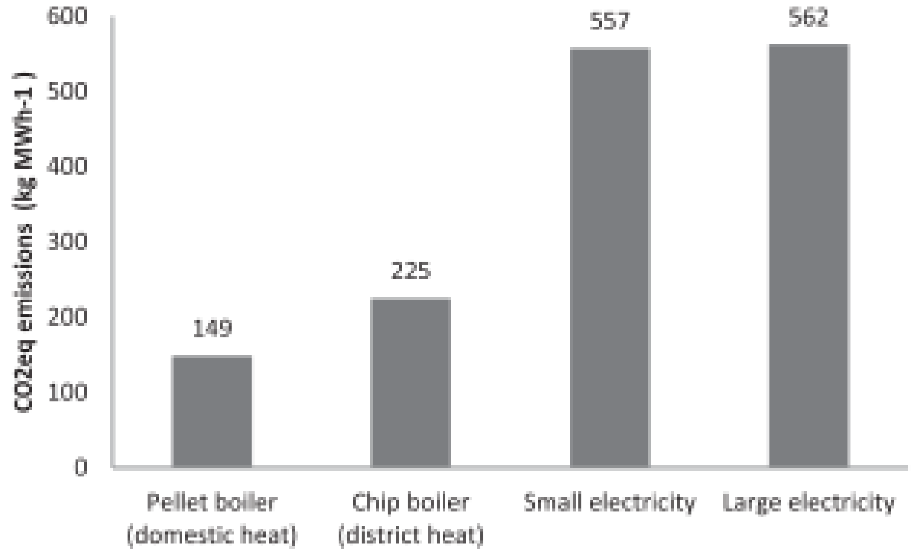

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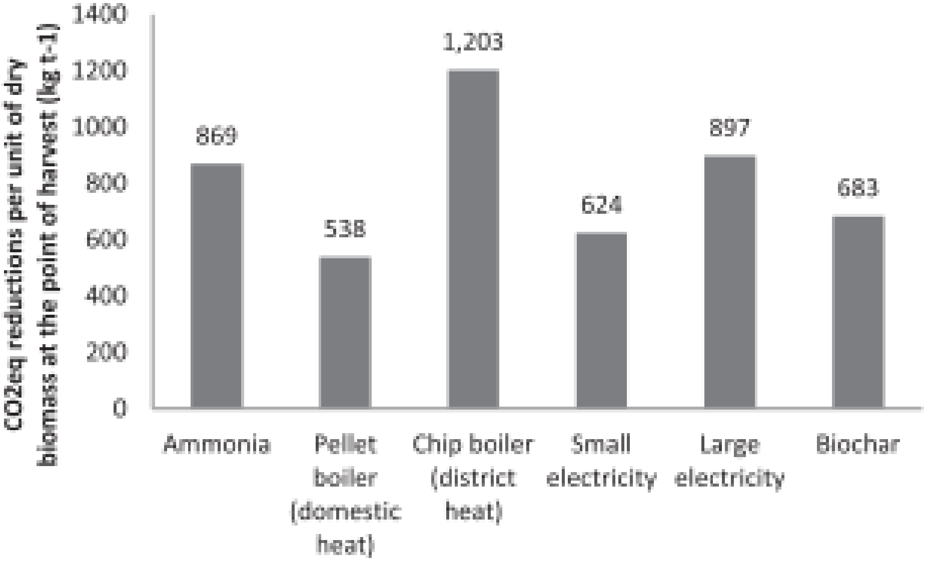

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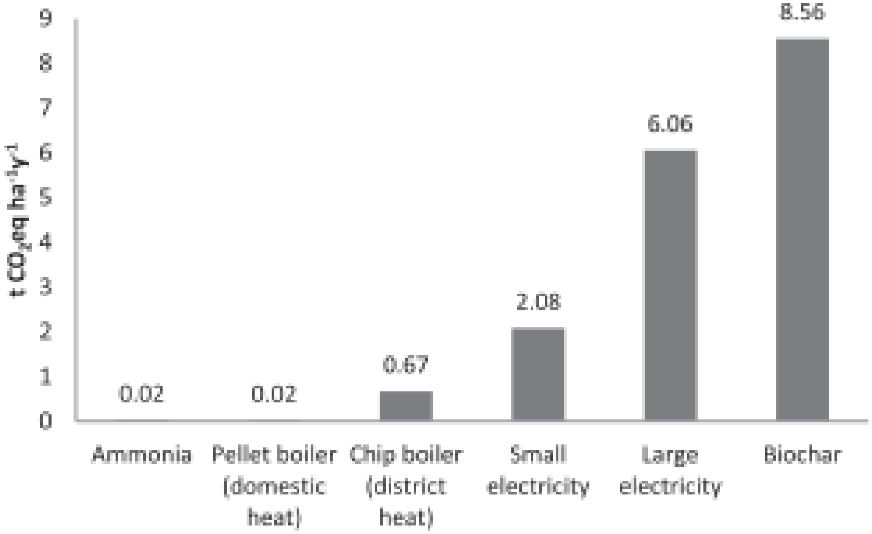

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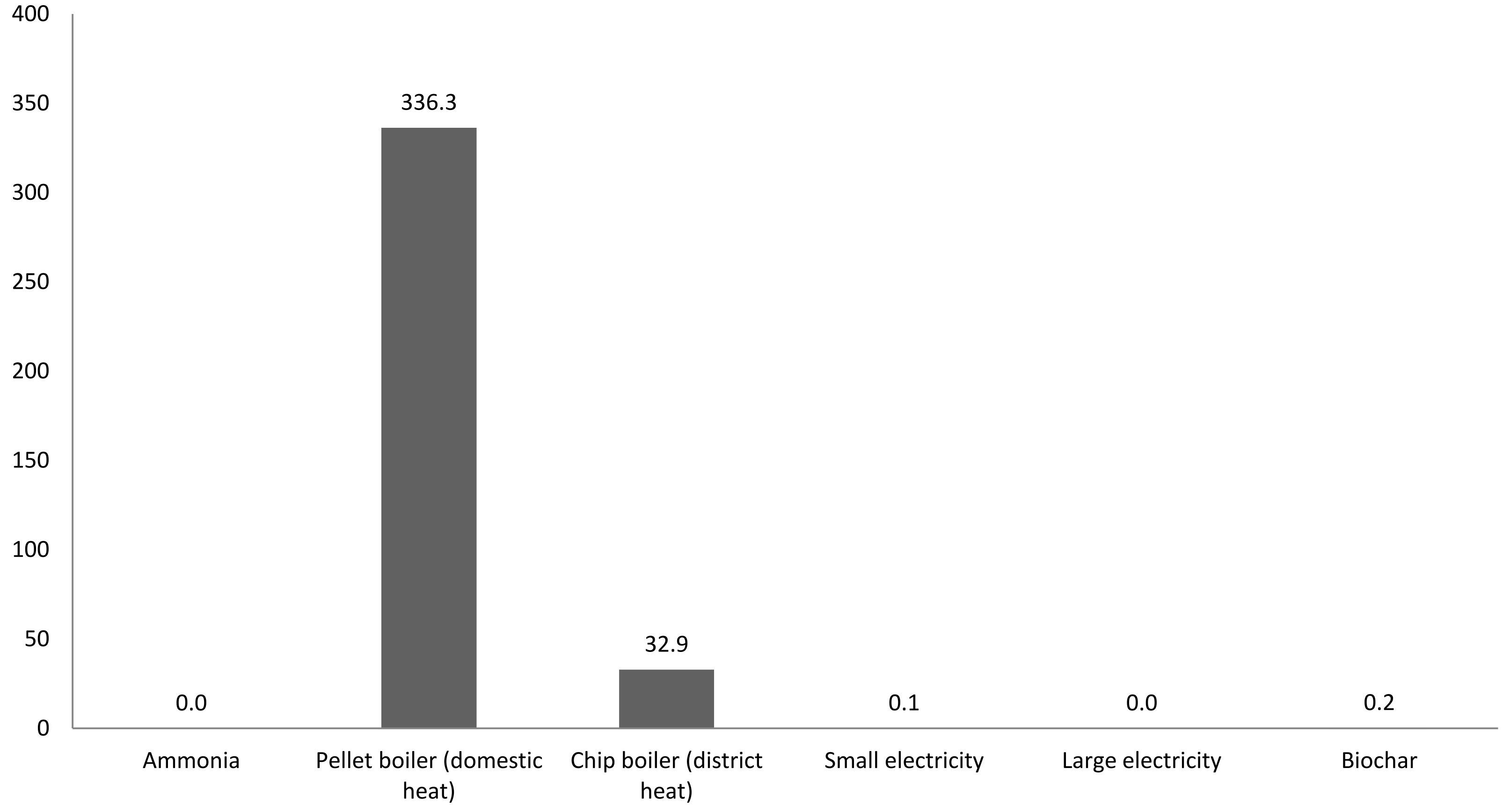
Cost per unit of GHG saved (£/kg CO_2



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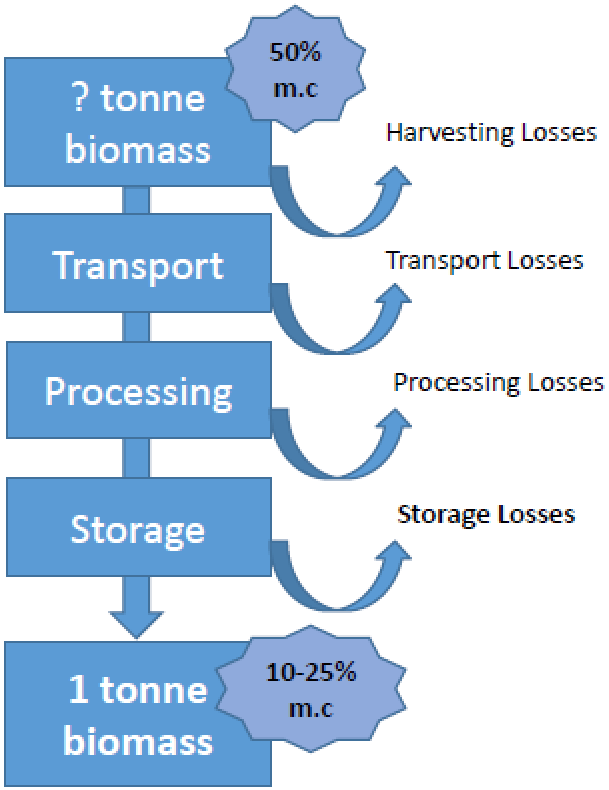

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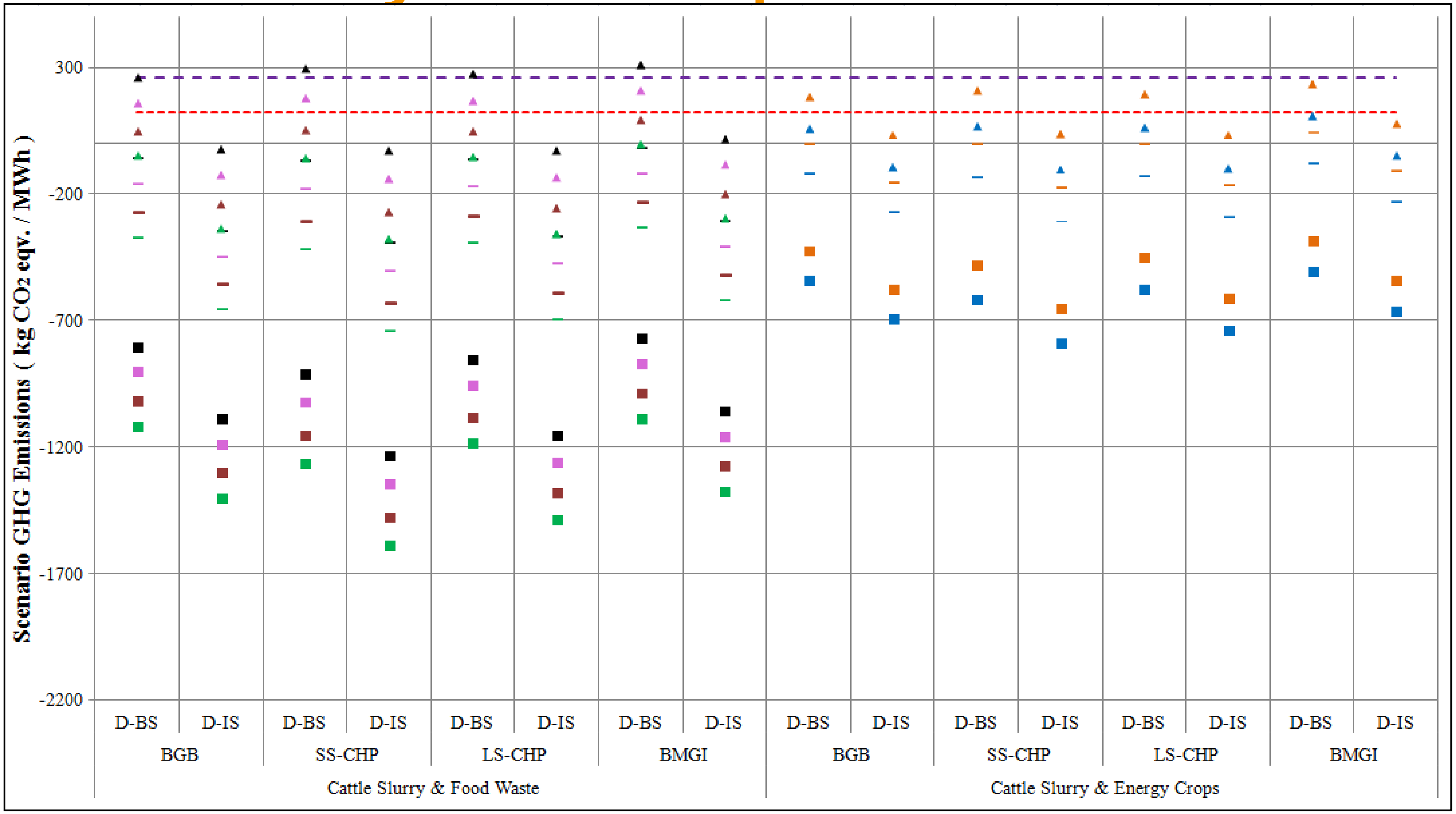

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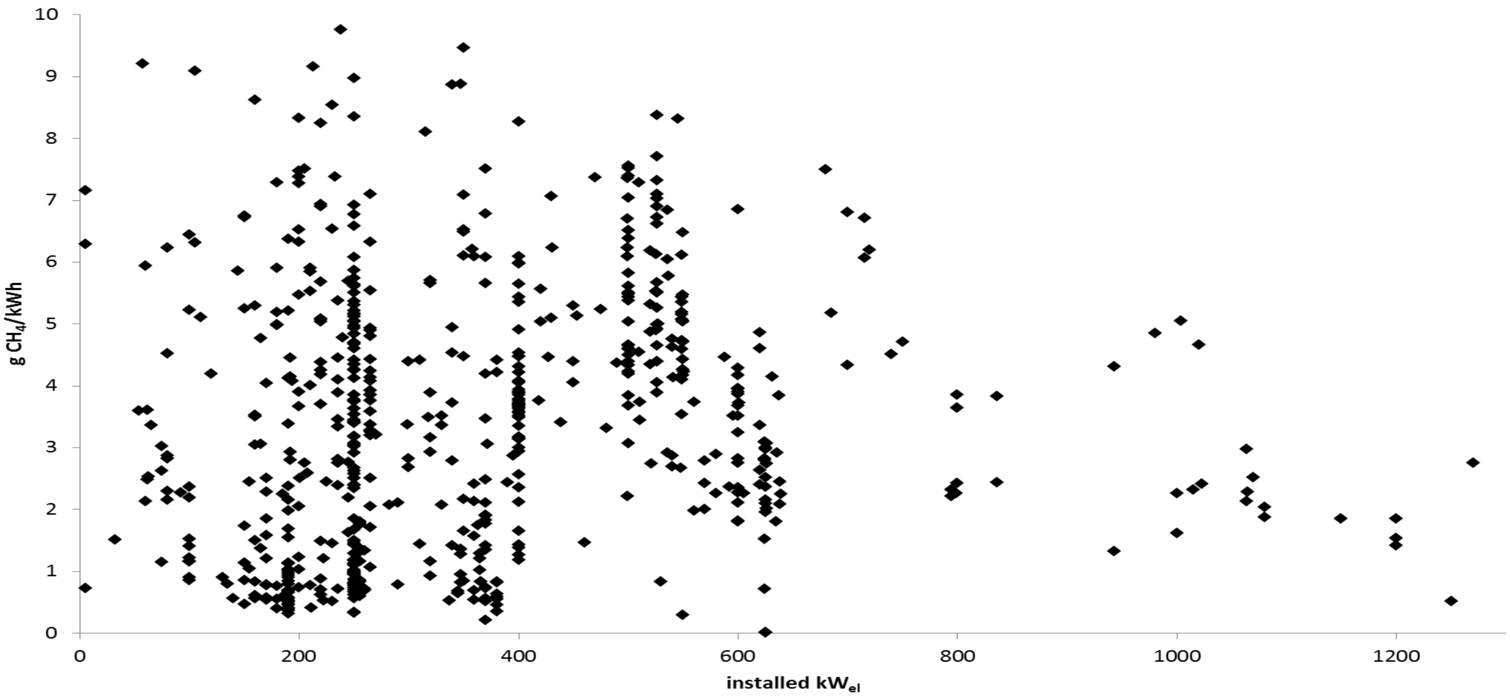

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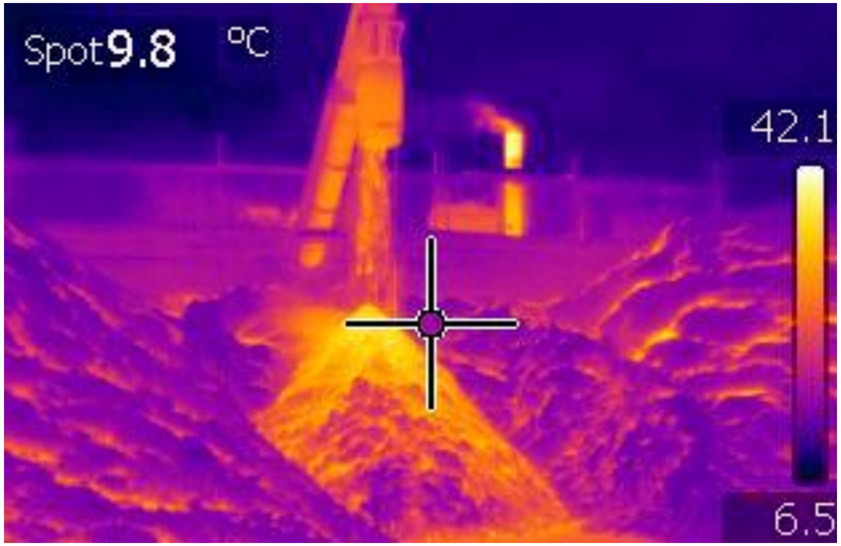

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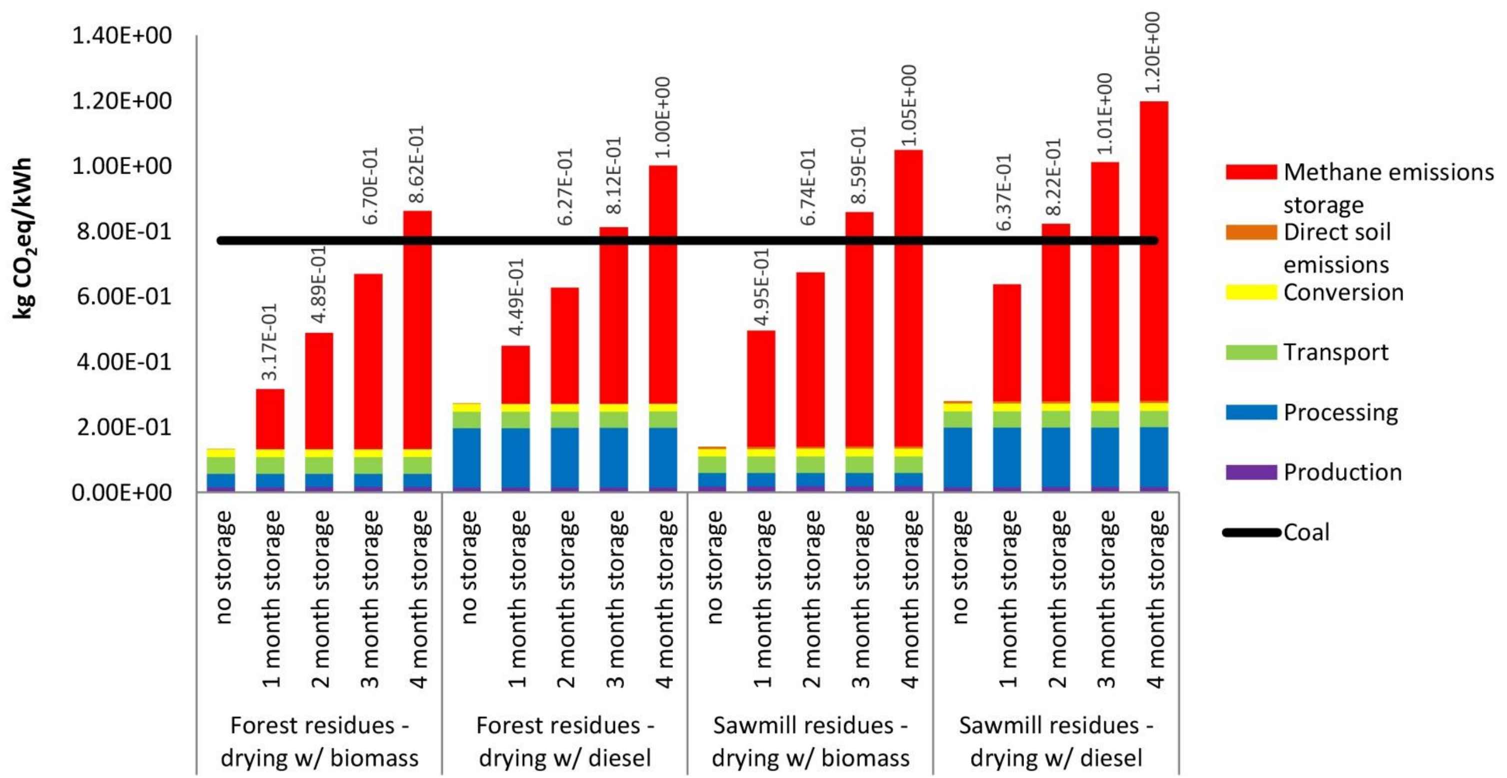
Variability due to assumptions



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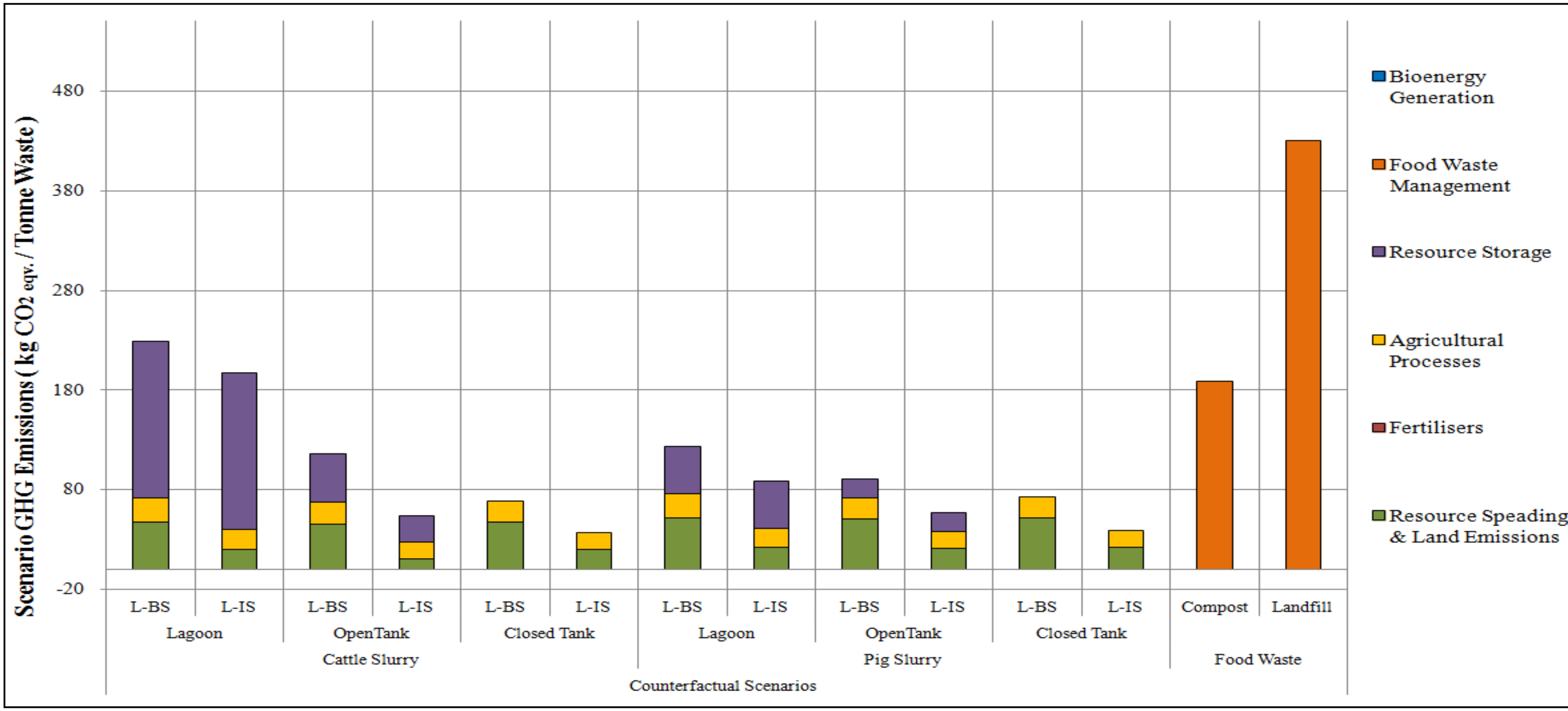

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Dan Sadler

Head of Energy Futures

Northern Gas Networks

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Dan Sadler

Switching to hydrogen could reduce carbon levels by 73%

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http://www.northerngasnetworks.co.uk/2016/07/watch-our-h21-leeds-city-gate-film/

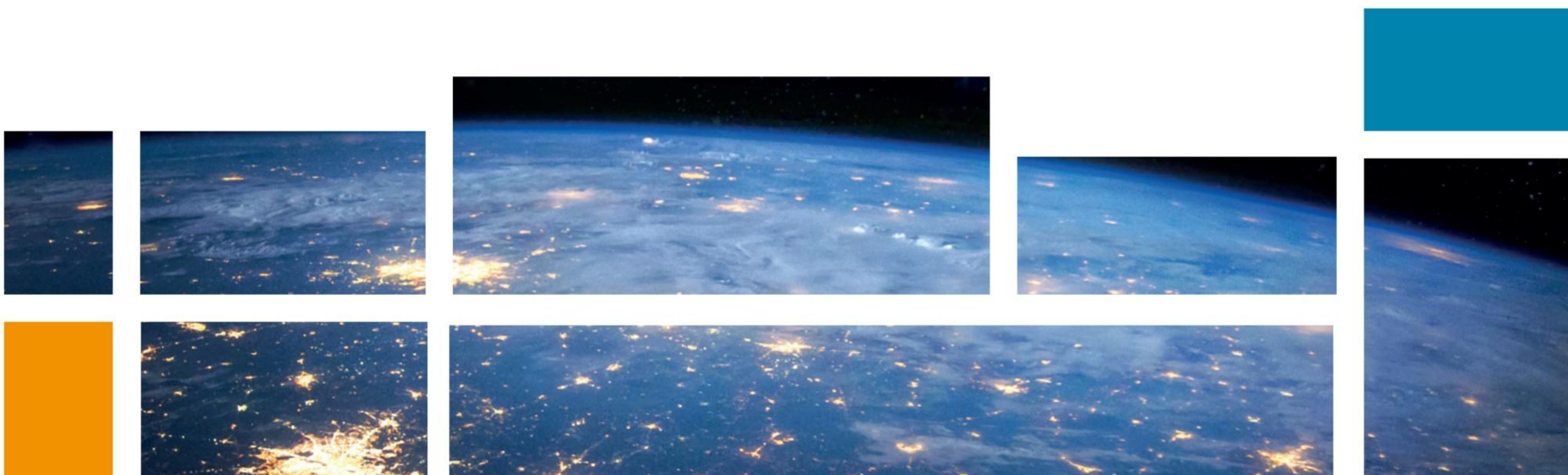
Tea break

15:15-15:35

Mark Lewis

Low Carbon Consultant

Tees Valley Combined Authority



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Mark Lewis

Tessside aims to save over 2m tpa CO_2 from members of the collective

CCS - Making it happen in the Tees Valley

Why ICCS/U and Why Teesside?

TEESSIDE COLLECTIVE
A NEW INDUSTRIAL FUTURE FOR THE UK

Teesside is responsible for
58%
of the UK's chemicals industry

2 million tes/yr CO2 from **Teesside Collective**

Teesside industries are responsible for
5.6%
of industrial emissions in the UK

Regional emissions per person are almost
3x
the UK average

Teesside produces polyester resin for
15 bn
recyclable drinks bottles a year

Northeast England process industries contributes
£26bn
to the UK economy
(NEPIC)

Teesside is home to
5
of the **UK's top 25 CO_2 emitting plants**

Costs of CO_2 permits are expected to
quadruple by 2030

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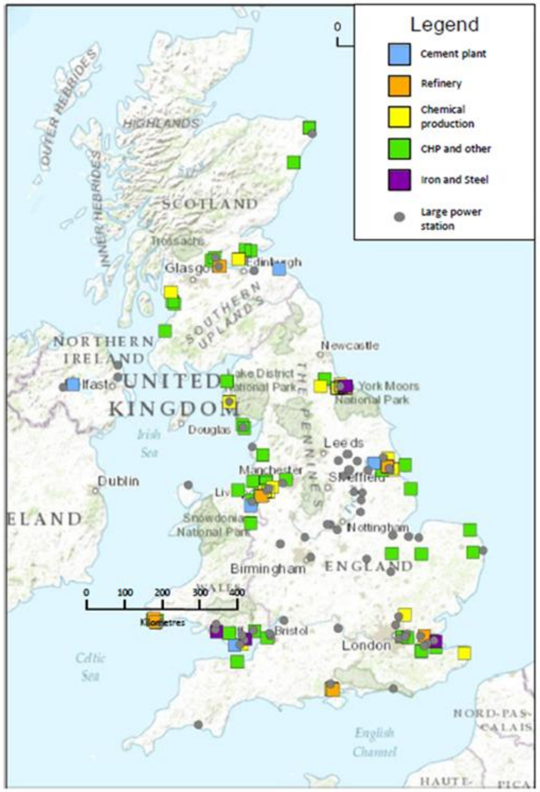
Why Clusters?

TEESSIDE CO2LLECTIVE
A NEW INDUSTRIAL FUTURE FOR THE UK

East Coast Process Industry Clusters

- **Concentration of Emitters on coast – lower cost network**
- **Significant direct & indirect employment impact**
- **High GVA per employee**
  - **Average in chemical sector in e.g.Teesside is £104,000 pa**
- **High wages**
  - **Average chemical wage in e.g. Teesside is £35,600**
- **Consistent trade surplus**
- **Early mover advantage & investment attraction**



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Teesside Collective

Multinational companies based in Teesside aiming to create Europe's first CCS equipped industrial zone

BOC	Largest steam methane reformer in UK
Growhow	Largest UK ammonia fertiliser producer
Lotte Chemicals	Produces PET for 15bn drinks bottles per year
Sembcorp	Global Power and Industrial Park operator
SABIC	Global Petrochemical Company
Tees Valley Unlimited	Arm of Tees valley Combined Authority
NEPIC	Industry Cluster Body

The Teesside Collective Vision

https://youtu.be/UwOJqKhKuZg

Teesside Collective now

- Continued Industrial Support
  - Additional industrial partners
  - Working with other clusters & projects

- Delivering a low carbon action plan
  - Identifying CO2 conversion & utilisation options (with Sheffield University)
    - Mineralisation, chemicals
    - Existing infrastructure and production allows demonstrate at scale
  - Developing the circular economy with CCS/U
    - New integration options (Cluster Study)
    - Industrial and renewable heat use (HNDU Study)
    - Energy Storage
    - Biofuels and Biorefining

Teesside Collective future

TEESSIDE CO2LLECTIVE
A NEW INDUSTRIAL FUTURE FOR THE UK

- Demonstrate practical applications
  - Capture & Utilisation from Industrial Emitter
  - Demonstration Facility

- Policy and project developments
  - Financing Options
  - Shipping Options

- Decarbonising Heat
  - The H21 project

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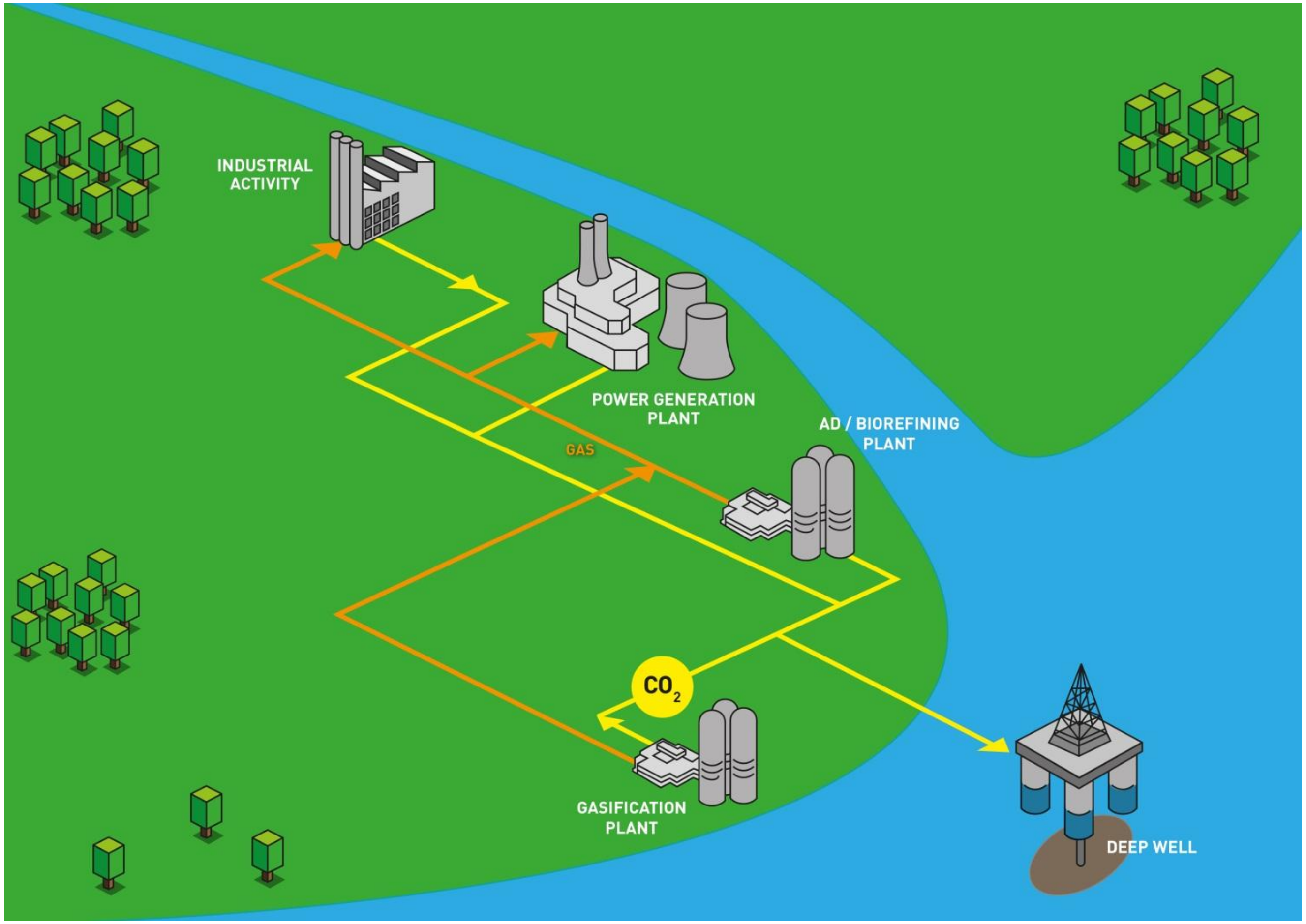

From CCS

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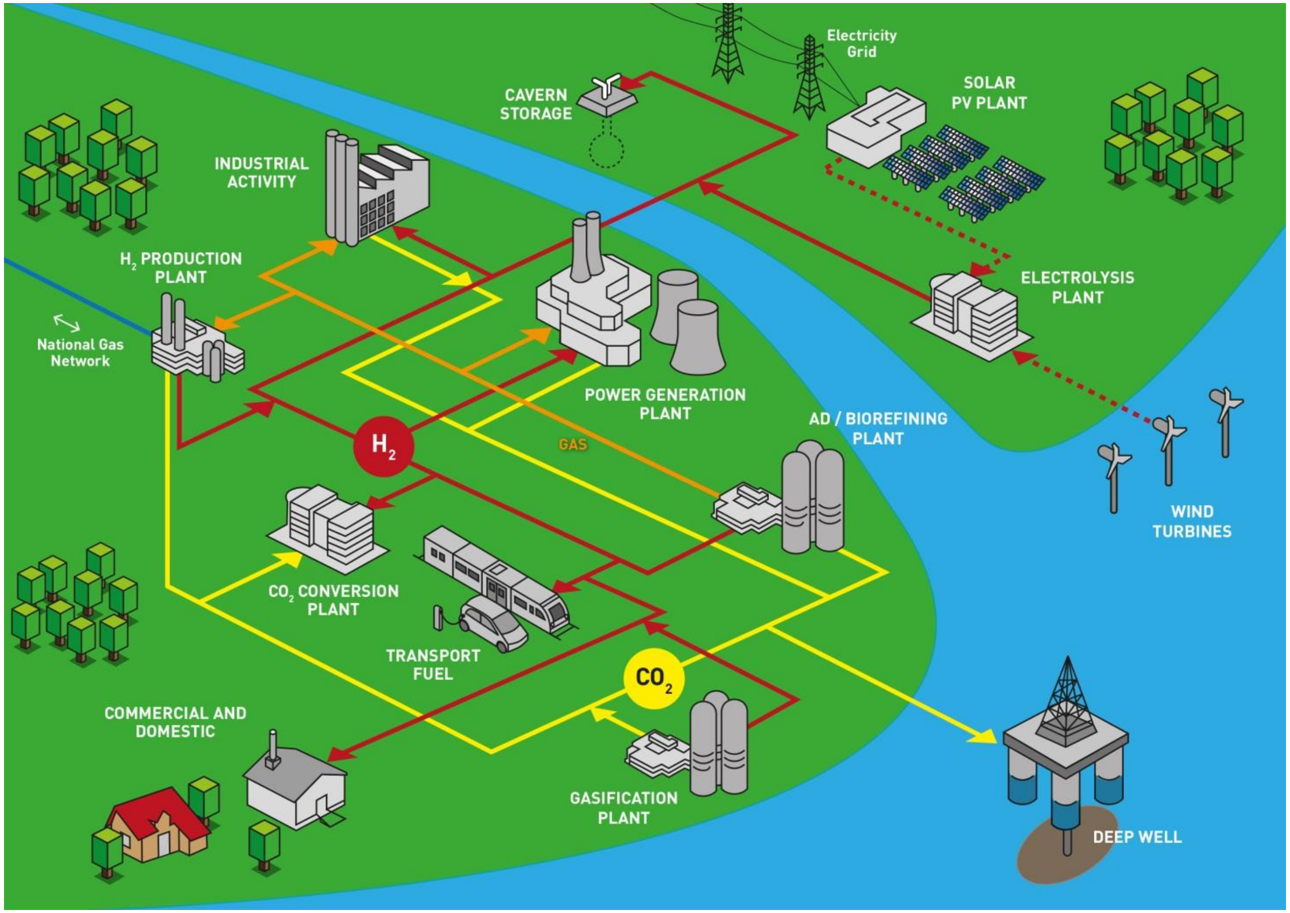

To a Low Carbon Economy

KTN the Knowledge Transfer Network

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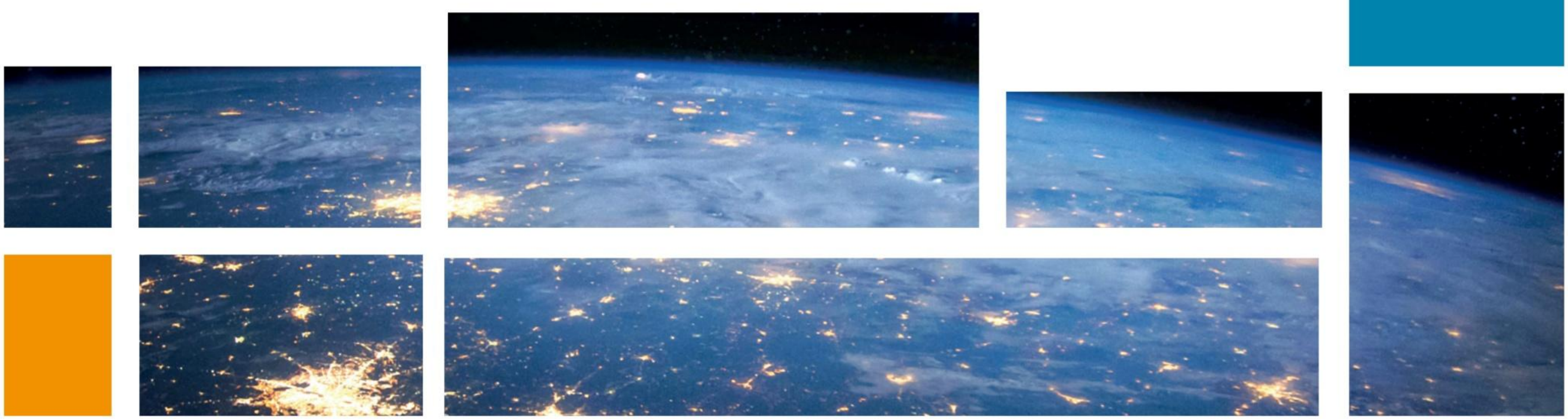
Pawel Kisielewski and Peter Hammond

CEO and CTO

CCm Research

Pawel Kisielewski and Peter Hammond

New methods of producing fertiliser offer a carbon reduction of 92%



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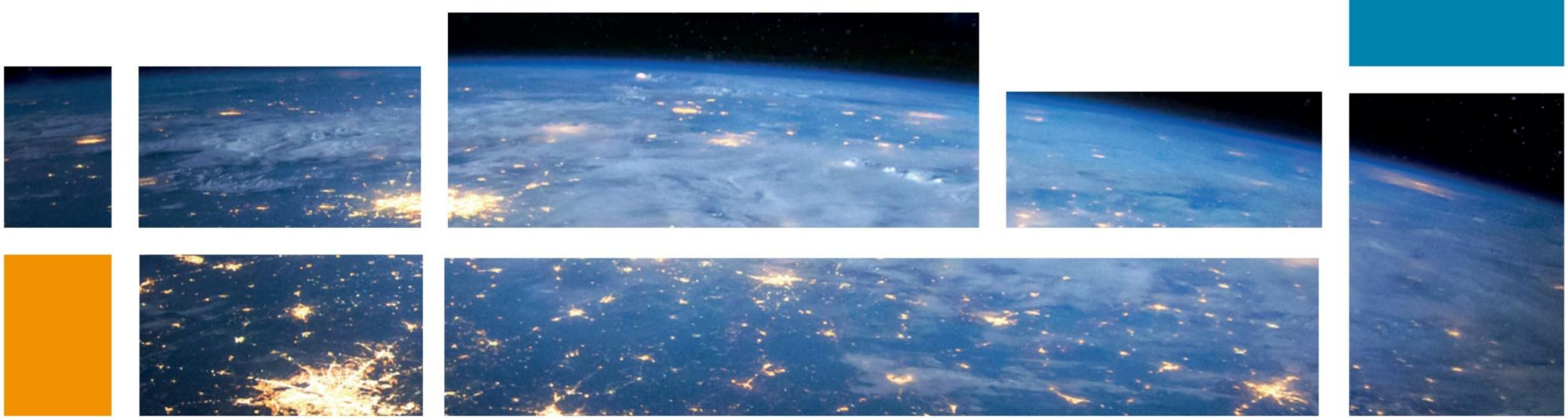
The Role of Waste Feedstocks, including CO_2, in the Creation of Value and the Reduction of Carbon

ccm research



https://youtu.be/vmf1s9aliSA

Objectives

- An explicit description of the anticipated carbon reduction
- An indication of the cost per tonne of carbon abated
- When will the technology will be ready for market?
- What is CCm's carbon reduction figure?

Objectives

- Total CO_2 emissions from the manufacture of fertiliser
- An indication of the cost per tonne of carbon abated
- When will the technology will be ready for market?
- What is CCm’s carbon reduction figure?

Total CO_2 emissions during fertiliser manufacture

- Conventional methods

6.98 tonnes of CO_2

for every tonne of fertiliser produced

Source: NNFCC

- CCm's basic process

0.44 Tonnes of CO_2

for every tonne of fertiliser produced

Source: CCaLC

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92% less

Objectives

- Total CO2 emissions from the manufacture of fertiliser
- CCm's process generates income (*not cost)* of approx £9.69 per tonne at the basic formulation
- Project IRRs forecast in excess of 15% Source: Mott MacDonald)
- When will the technology will be ready for market?
- What is CCm's carbon reduction figure?

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Objectives

- Total CO_2 emissions from the manufacture of fertiliser
- Project IRRs on base level process are in excess of 15% (Source: Mott MacDonald)
- The technology is TRL 7/8 and will be ready for market in Q2 2017
- What is CCm's carbon reduction figure?

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Objectives

- Total CO_2 emissions from the manufacture of fertiliser
- Project IRRs on base level process are in excess of 15% (Source: Mott MacDonald)
- The technology is TRL 7/8 and will be ready for market in Q2 2017
- A CCm plant producing 10,000 tonnes of fertiliser pa. would abate approx. 65,000 tonnes of CO_2 carbon

ccm research

sustainable materials

KTN the Knowledge Transfer Network

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Panel discussion – Open innovation and new energy solutions

Dr Richard Bonser

Brunel University London

Open innovation and new energy solutions

Richard Bonser, Brunel University London

Introduction

- How can industry engage with academia
- Case studies
- What to expect

Engaging with the knowledge base

- Government support schemes
- KTNs
- University outreach

Why?

- R&D when you need it
- Drive product innovation

How?

- Various levels
- Student projects, interns
- PhDs
- Matched funding schemes
- Consultancy
- Contract research

Helping SMEs to innovate

co-innovate

- Brunel/ERDF funded
- Help SMEs in Greater London to access knowledge base
- Provides staff time and students to undertake research

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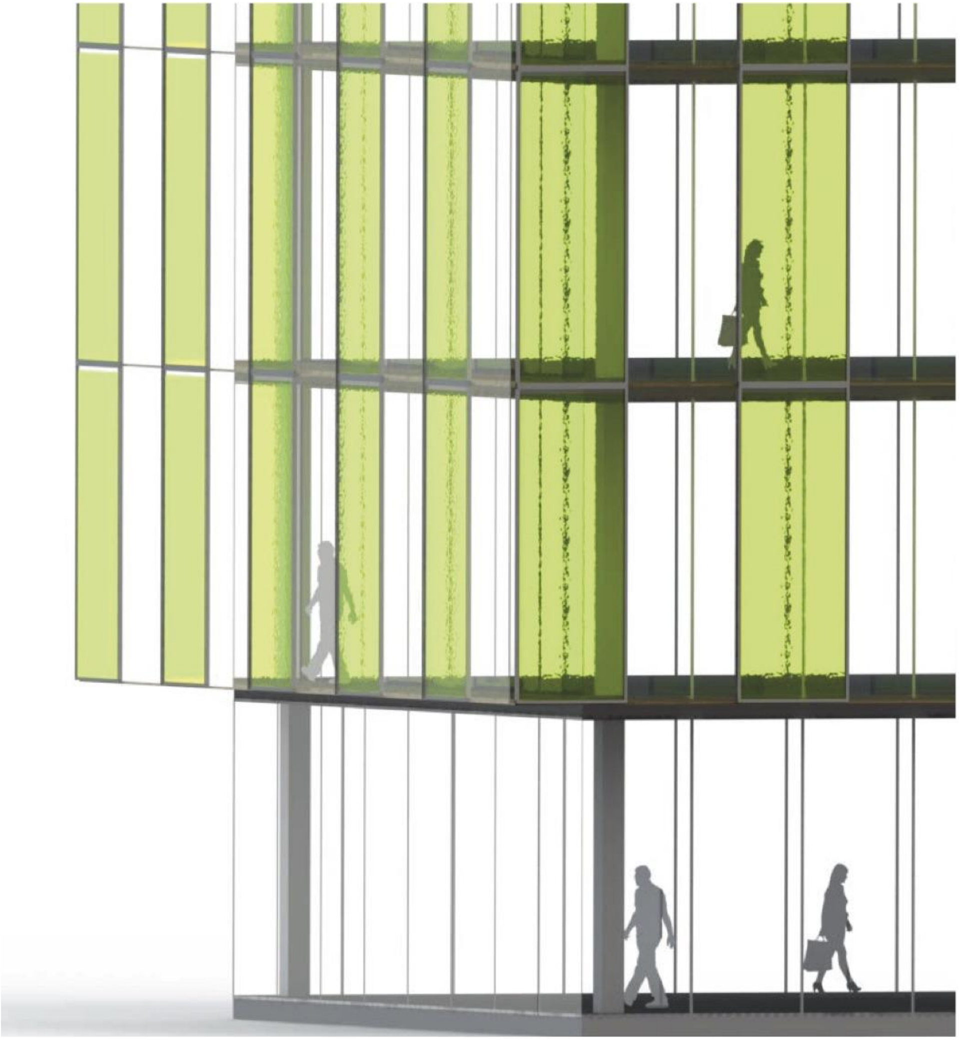
A Studio algal facade

- Ray Wilkes
- Aim to develop a photobioreactor incorporated into a building façade
- Research into algal growth rates
- Design of cultivation system
- Each panel could power 10m^2 floor space
- Potential to sequester 156kg of CO_2 per annum
- www.astudio.co.uk



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Solarbotanic e-leaf solar wind tree

- Elise Hounslow
- Aesthetically pleasing alternative to wind turbines and pv
- Looked at alternative pv technologies
- Manufactured and tested leaf-like arrays
- Work continuing with further students
- www.solarbotanic.com

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Culture and expectations

- Different academic and industry cultures
- With student projects, need to satisfy academic requirements as well as industry goals
- Academics tend to look for novelty whereas industry often seeks relevance
- Timely delivery

Innovating with academia

- Many organisations can help
- Can provide R&D capacity that small firms may lack
- Examples of renewables applications from Brunel Design
- Things to be mindful of!

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Thank you for listening

Richard.Bonser@brunel.ac.uk

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Knowledge Transfer
Network

IChemE
Energy Centre

IChemE Energy Centre

KTN the Knowledge Transfer Network

Panel discussion – Open innovation and new energy solutions

Closing remarks and drinks reception

17:30-18:30