Transport Energy Network

What does the future hold for thermal propulsion systems and fuels?

Philippa Oldham, Gloria Esposito, Penny Atkins
23 July 2019

ADVANCED PROPULSION CENTRE UK | FUNDING. EXPERTISE. COLLABORATION.

LowCVP Low Carbon Vehicle Partnership | Connect Collaborate Influence

University of Brighton
Advanced Engineering Centre

Workshop agenda

- 10.00 - 10.30 Arrival & breakfast
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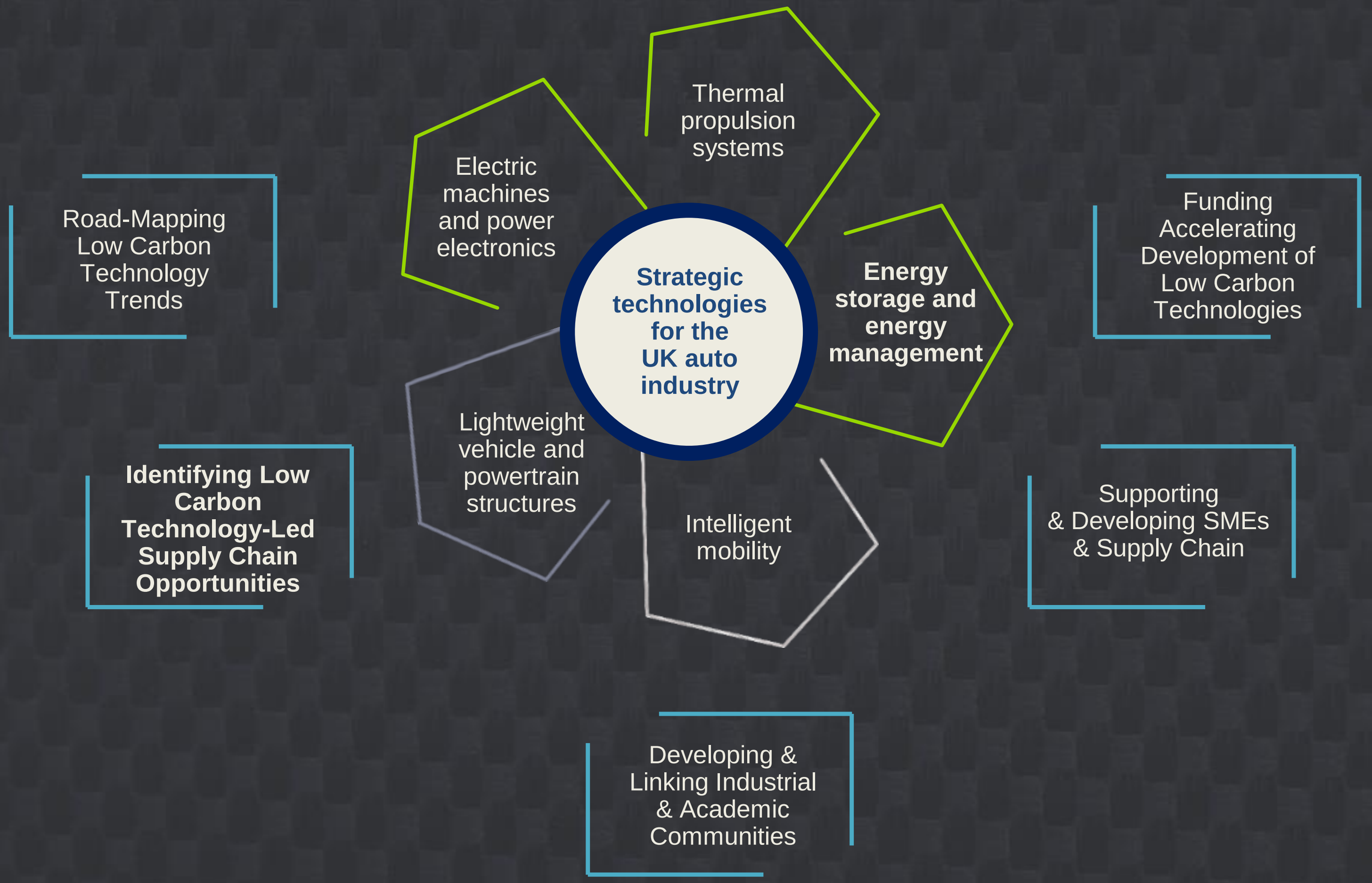
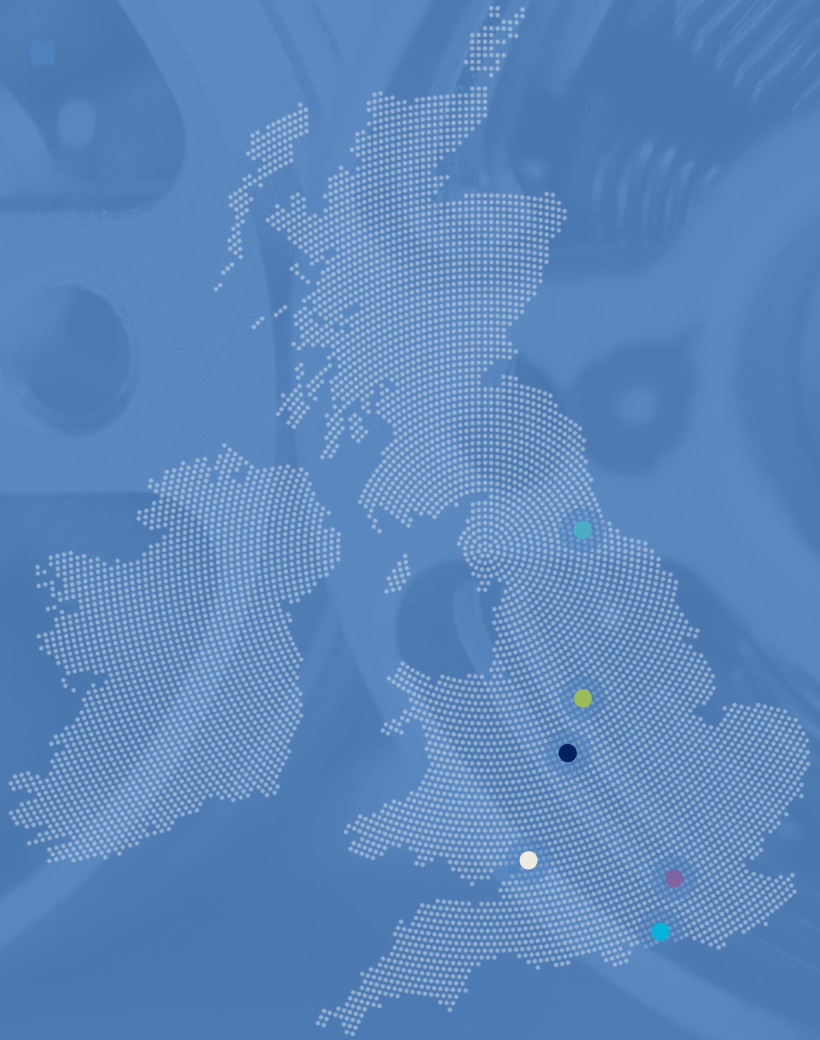
- 15.15 - 15.30 Wrap up and close

HELPING THE UK AUTOMOTIVE INDUSTRY CAPITALISE UPON
LOW CARBON TECHNOLOGY OPPORTUNITIES



ADVANCED PROPULSION CENTRE UK

DEVELOPING AND LINKING
INDUSTRIAL AND ACADEMIC COMMUNITIES



- ELECTRIC MACHINES SPOKE
  Newcastle University
- POWER ELECTRONICS SPOKE
  University of Nottingham
- ELECTRICAL ENERGY STORAGE SPOKE
  University of Warwick
- TPS SYSTEM EFFICIENCY
  University of Bath
- DIGITAL ENGINEERING AND TEST SPOKE
  Loughborough University (London)
- TPS THERMAL EFFICIENCY
  University of Brighton

Transport Energy Network

Industry need

ADVANCED PROPULSION CENTRE UK

automotive council UK

Policy & Regulation

LowCVP
Low Carbon Vehicle Partnership

Research solutions

University of Brighton

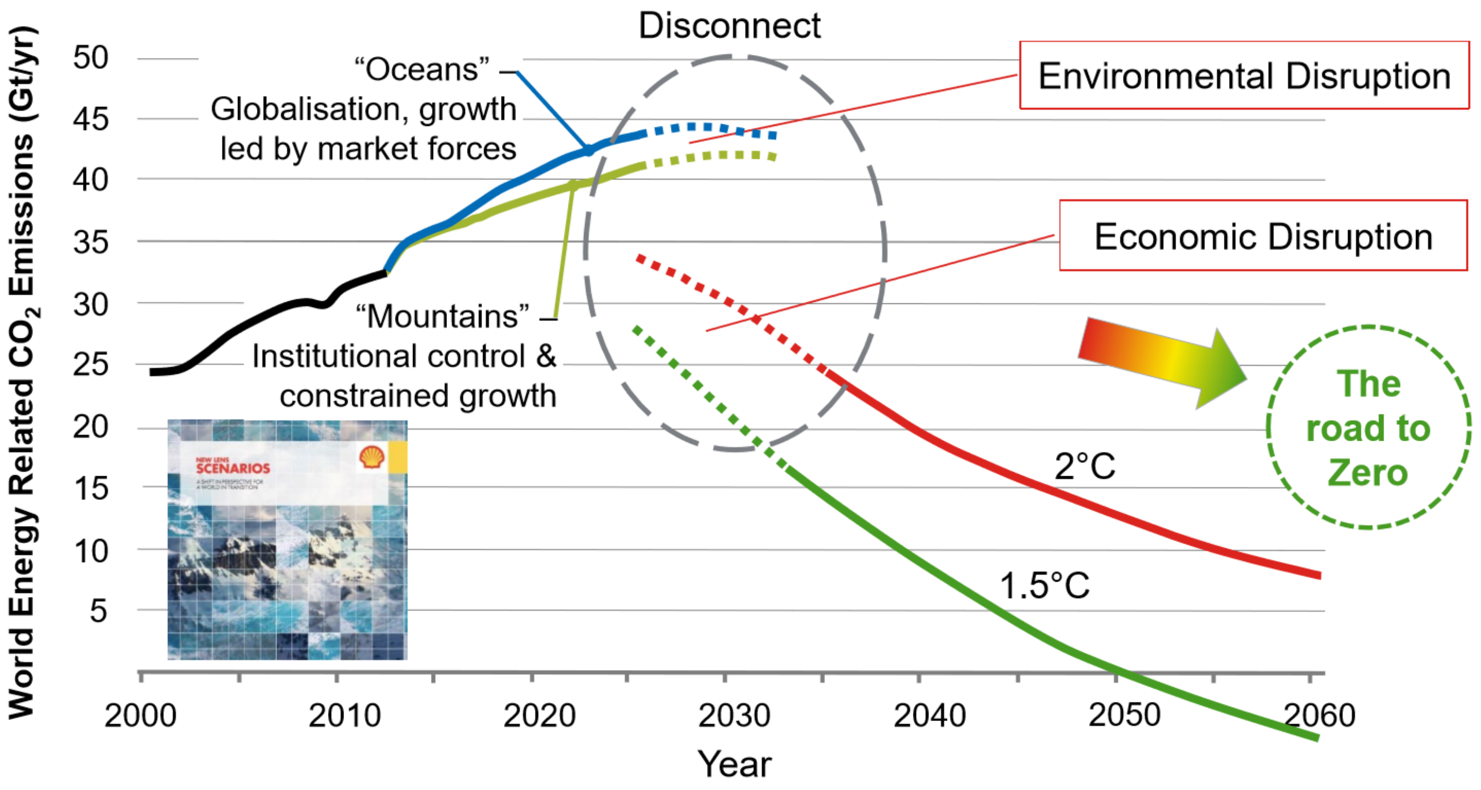
Automotive, Heavy Duty & Off-highway

Challenge for all our transport

The need to decarbonise transport is increasingly urgent…

The Energy/Climate challenge and projected future energy scenarios reveal a significant discontinuity – disruption the likely outcome

RICARDO



- Policymakers in Europe increasingly focused on "Zero" emissions for road transport
- Reducing carbon intensity in other sectors perceived to be more difficult

Source: Shell New Lens Scenarios; Gert Jan Kramer, Utrecht University

The Transport Energy Network aims to accelerate decarbonisation through targeted collaboration between fuels, powertrain and energy systems communities

Objectives

- Understand long term R&D priorities for low carbon fuels and clean efficient thermal powertrains
- Enhance collaboration between fuel and thermal powertrain developers
- Develop links to energy systems work and R&D community

Scope

- Timescale: Now to 2050, Transport Modes: on road, off highway, marine, rail (consider synergies with aero)
- Liquid and gaseous fuels
- UK focus, but recognising global supply chain

Work programme 2019/20

- Four workshops (April, June (x2), November)
- Deliverable report – cross discipline roadmaps

Working in collaboration with APC, LowCVP and Automotive Council

Transport Energy Network work programme

2019/20 work programme

Workshop 1	April 19 Background for roadmaps
Workshops 2 & 3	July 19 – Roadmap detail
Workshop 4	November 19 – Stakeholder review
Report	March 20 – Roadmap publication and dissemination

2020/21 work programme

Assess R&D priorities based on roadmaps
Dissemination
Feasibility studies (funding dependent)

Transport Energy Network Workshop 1 output – Discussions covered transport decarbonisation landscape, collaboration and technology

Landscape

- Potential for loss of powertrain engineering skills
- Role of government - Carbon pricing to encourage uptake of low carbon technology, support to resolve chicken and egg dilemma?
- Importance of LCA

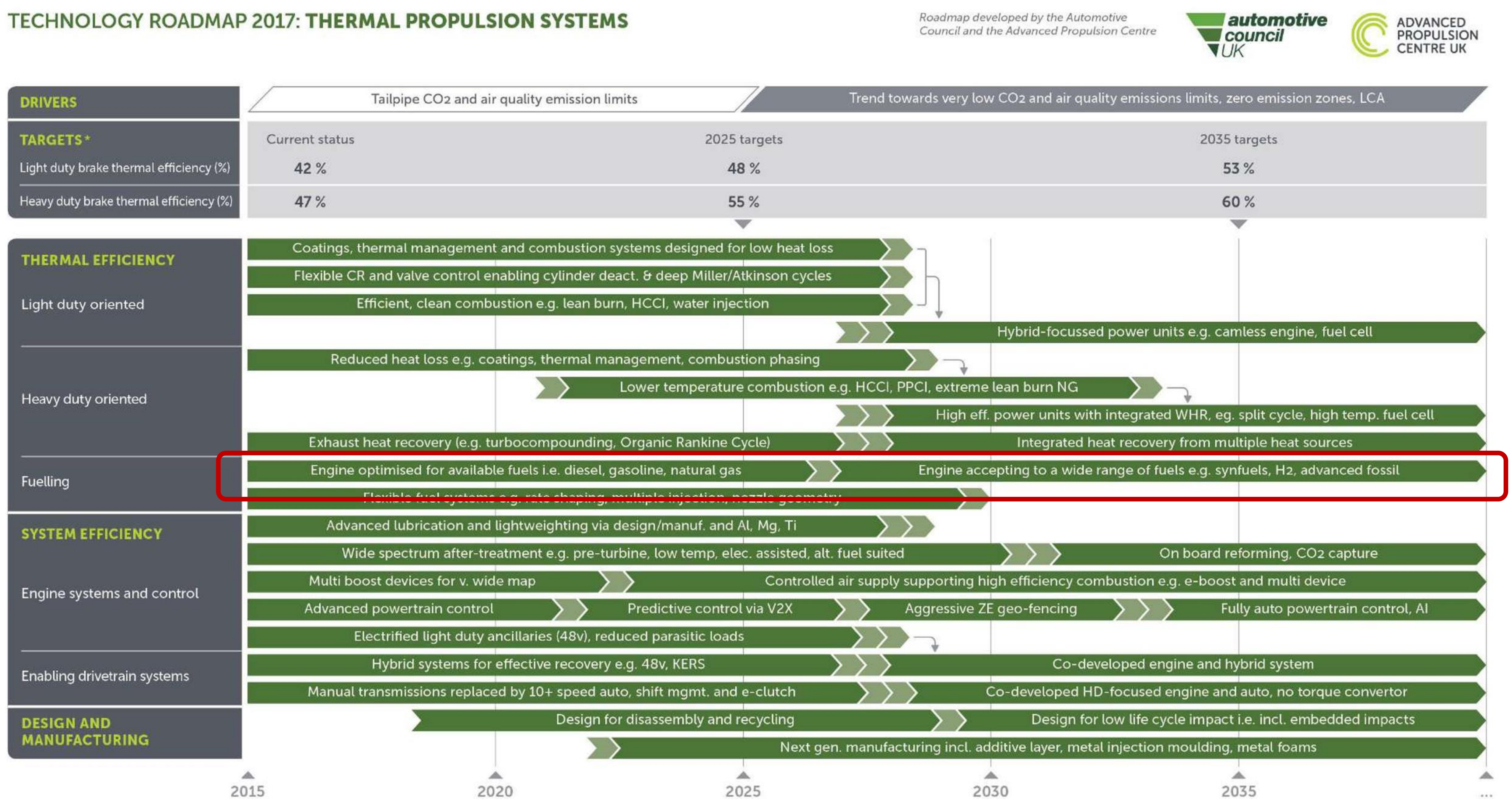
Collaboration

- Fuel and engine development separate – both working towards a fixed spec
- Balance cost/GHG of fuel production (variation in spec/impurities) vs effect on powertrain performance – match applications to fuels, considering whole supply chain cost
- Global vs local specification and supply chain

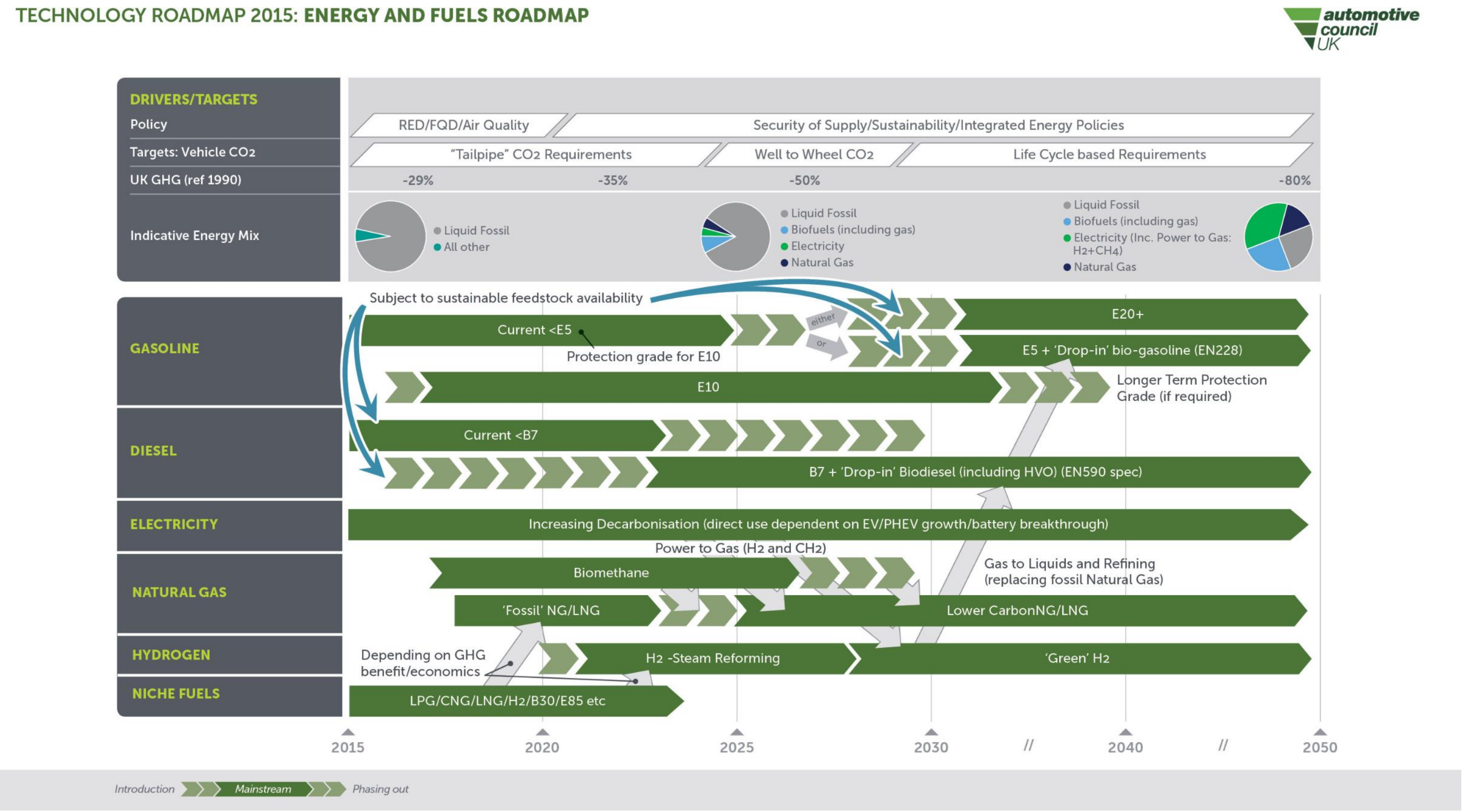
Technology

- View that engine is flexible, whereas fuel production more difficult – tolerant engine
- Map effect of fuel chemistry on engine performance – is there a sweet spot balancing fuel spec range and WTW GHG/cost
- Role for smart technology – communicate what fuel is in use and adjust calibration

This workshop aims to develop insight for cross discipline roadmaps – building on Advanced Propulsion Centre propulsion system roadmaps..



.. and Automotive Council Energy Roadmaps developed in 2015



Workshop sessions this afternoon aim to generate scenarios for the evolution of propulsion, fuels and energy system and highlight cross disciplinary R&D needs

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Session 1 – Scenarios for net zero at 2050

- In groups, consider different sectors:
  - Pass car
  - HD
  - Off highway
  - Marine
  - Aviation
- Consider different ways of achieving net zero
- Record your ideas on the flip charts

Session 2 – Enablers for these scenarios

- In groups, consider enablers for the selected scenarios
- You could consider
  - Vehicle technology
  - Infrastructure
  - Policy
  - ….
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Transport Energy Network

Low Carbon Fuels Policy Landscape

Gloria Esposito, Head of Projects, LowCVP
gloria.Esposito@lowcvp.org.uk

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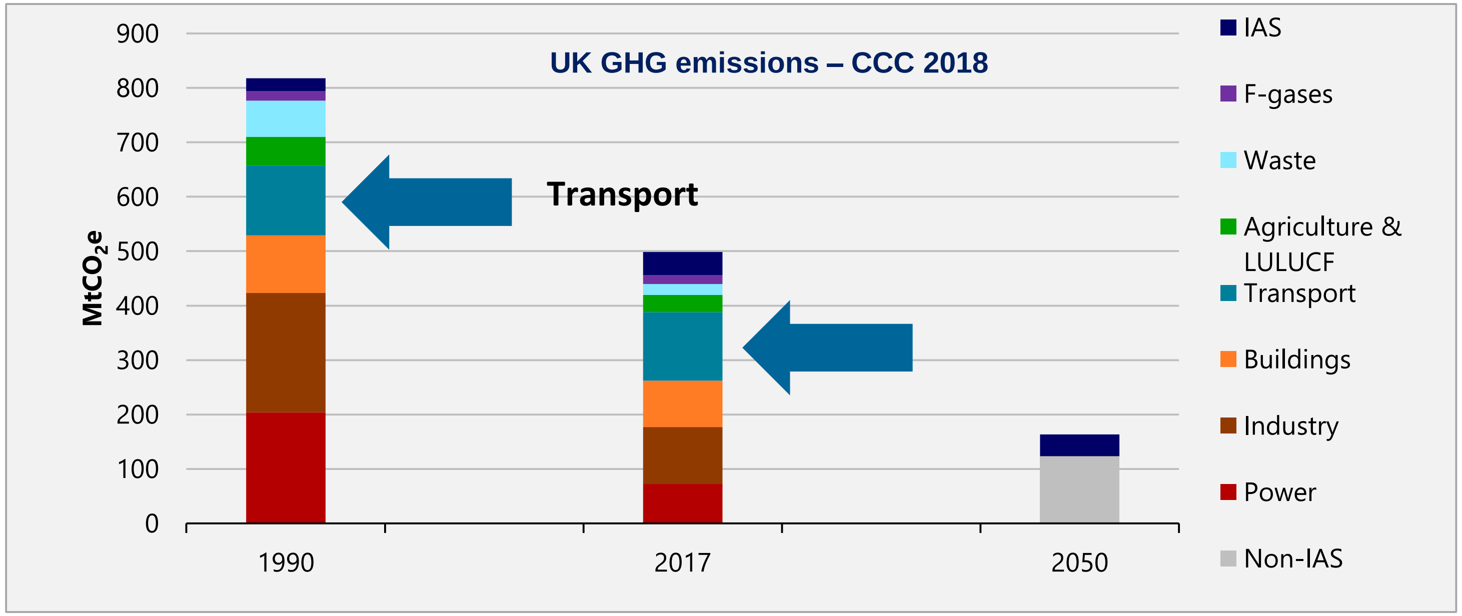
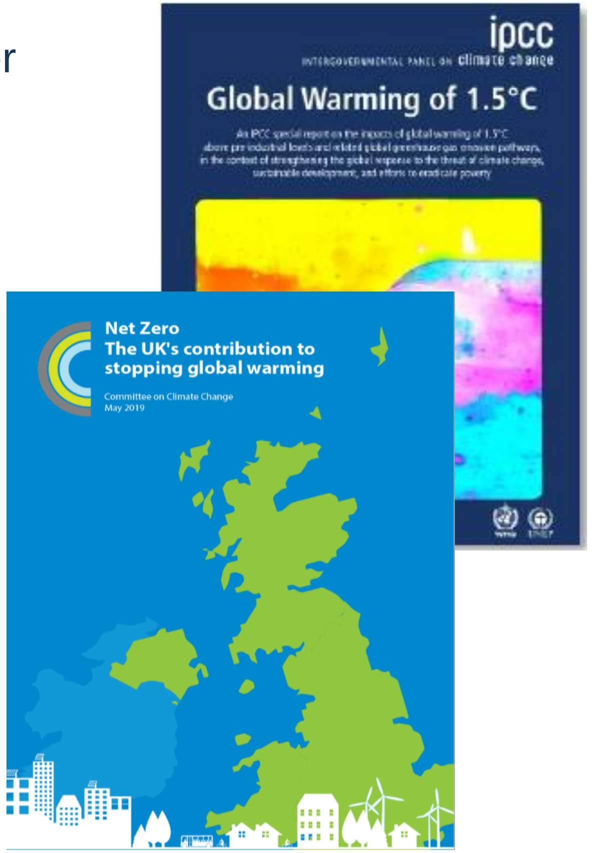
UK Government has set a long-term vision of ‘net’ zero emissions by 2050

Transport sector will require low carbon liquid and gaseous alongside electrification over the next two decades to achieve the following:

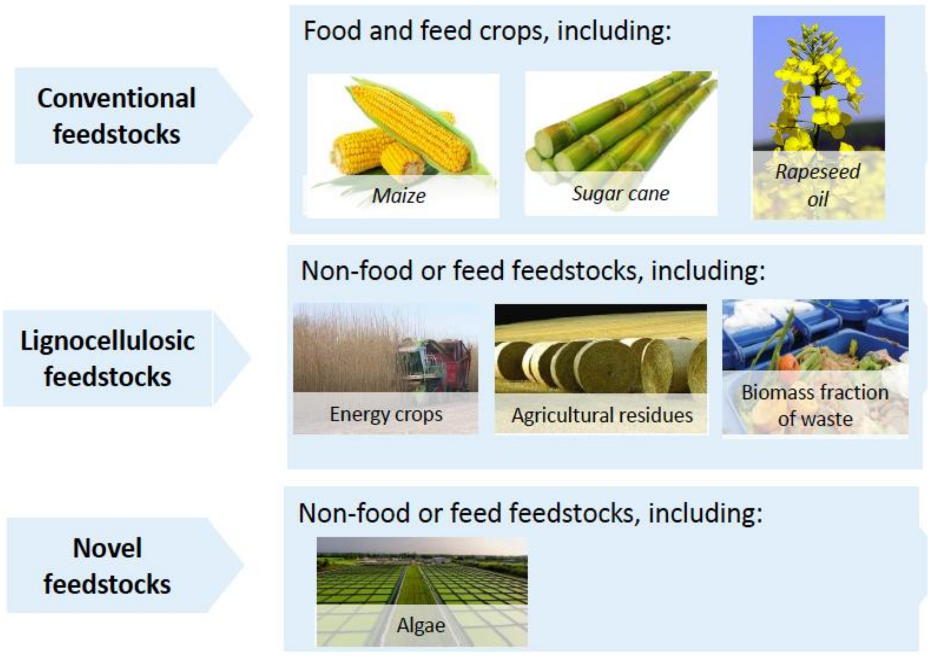
- Decarbonising road transport today, and while alternatives increase
- Decarbonising aviation, shipping and freight – long distance/high energy demand
- Policy has a critical for stimulating the supply and demand for low carbon fuels, whilst ensuring production is low carbon and sustainable.





Taxonomy of low carbon fuels – current and future

Biofuels



A variety of feed-stocks and pathways exist to produce advanced 'drop-in' fuels for HDV, aviation and the marine sectors.

Deployment influenced by production cost, resource availability, sustainability, GHG intensity, fiscal incentives

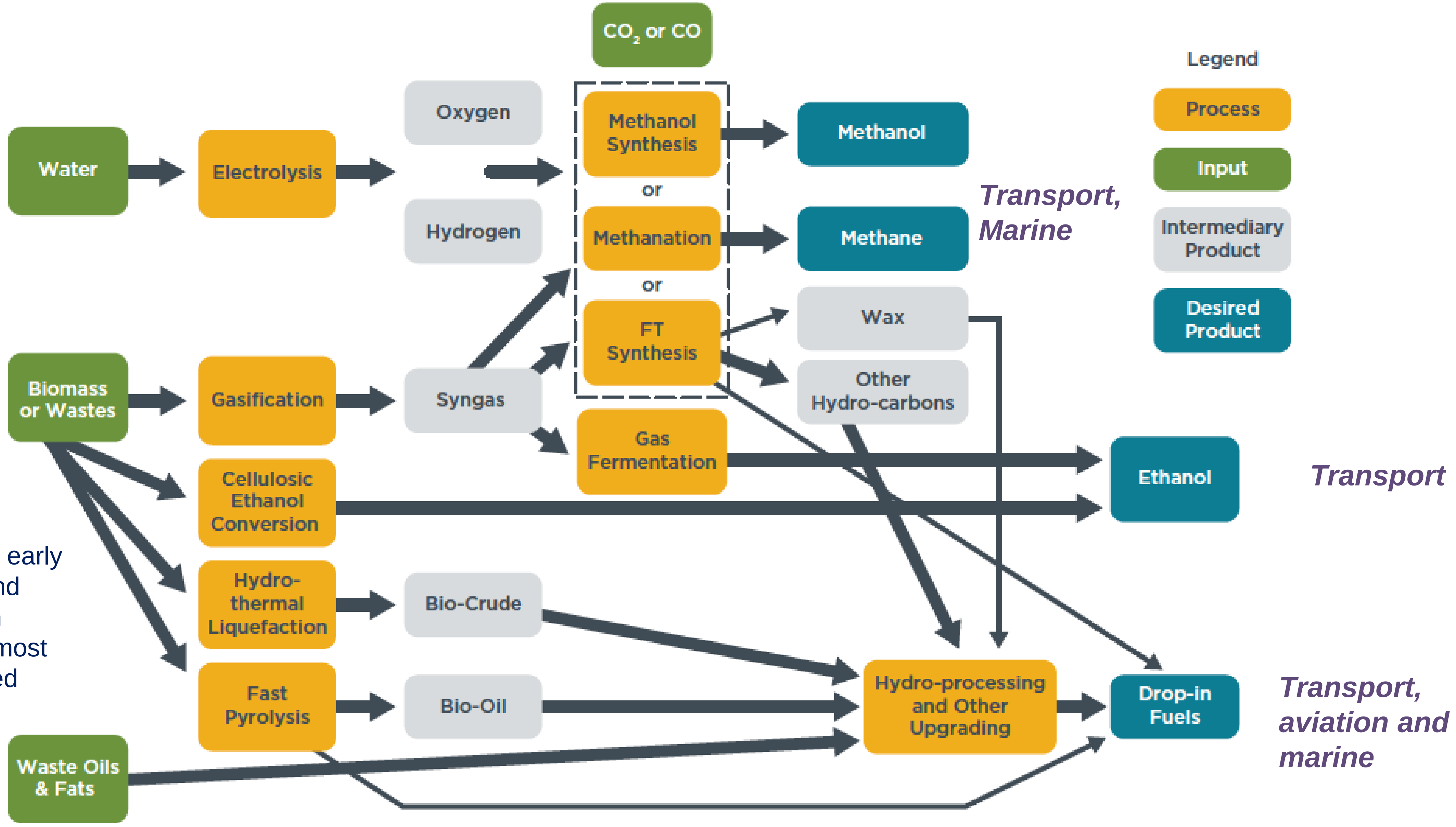
RFNBO

Renewable Fuels of Non-Biological Origin – also called E-fuels, Power to Liquid. Includes hydrogen from electrolysis and synthetic fuels.

Low Carbon Fossil Fuels

Low Carbon Fossil Fuels, also called Recycled Carbon Fuel.
Derived from recycled gaseous or sold fossil wastes or from waste fossil gasses that are unavoidable (Feed-stocks could be MSW, end of life plastic, industrial fuel gas)

Pathways for producing advanced fuels



Majority are in early commercial and demonstration stages, HVO most commercialised

European Renewable Energy Directive

RED up to 2020

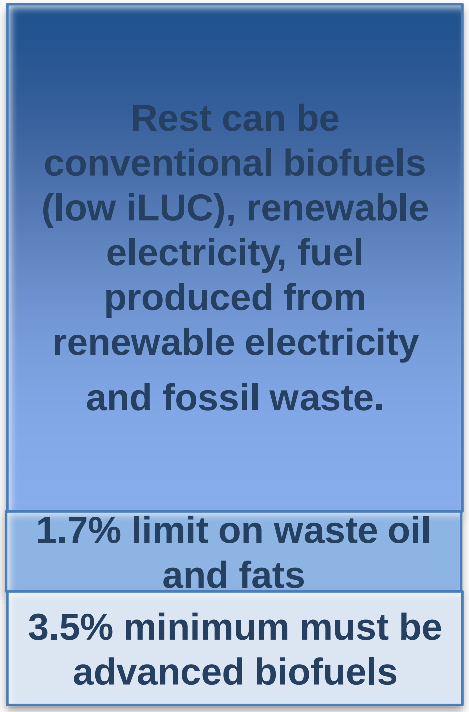
- 10% of transport fuel in Europe to come from renewable energy sources by 2020.
- Feed-stocks arising from organic waste and residues counted twice.
- Carbon and sustainability criteria for biofuel production pathway
  - GHG emission **>60% savings** compared to fossil equivalent *(lifecycle methodology)*
  - Sustainability 'land-use' criteria – **feestocks should not be obtained from land of high biodiversity value and high carbon stock**
- Compliance demonstrated through voluntary sustainability scheme certification, independently audited.
- Concerns of indirect land-use change (iLUC) impacts and escalating rainforest deforestation due cultivation of crops for biofuel production – safeguards introduced.

European Renewable Energy Directive

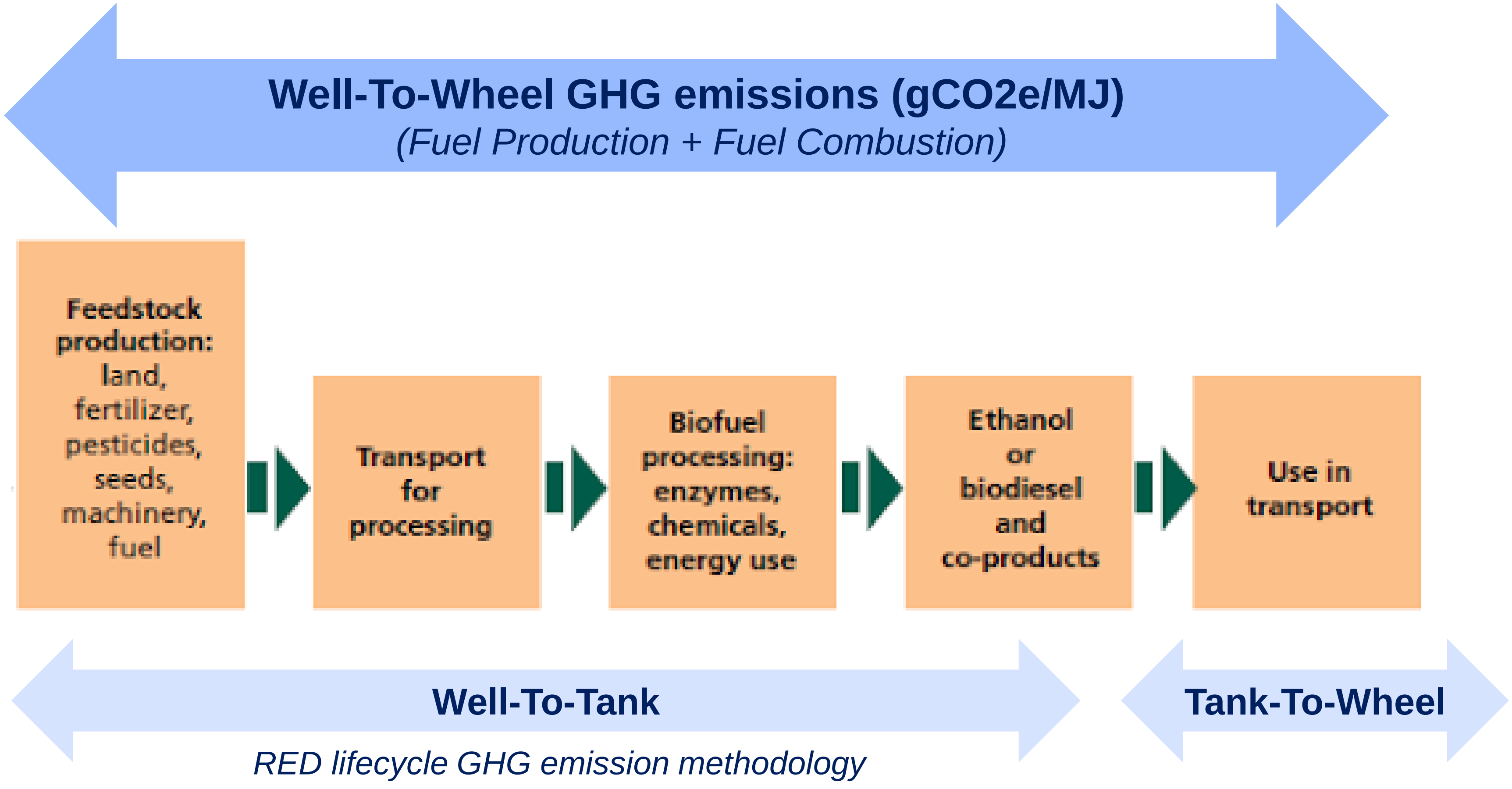
RED II to 2030

- Transport renewable energy target for Europe increased to 14%
- Advanced biofuel target 3.5% by 2030 – double counted
- GHG savings of 65% as from 1st January 2021
- 7% crop-based biofuels cap
- Capped ‘high iLUC’ biofuels, phased out from 2030
- 1.2x multiplier for aviation and marine
- ‘Low iLUC’ feed-stocks require evidence via certification

14% total target

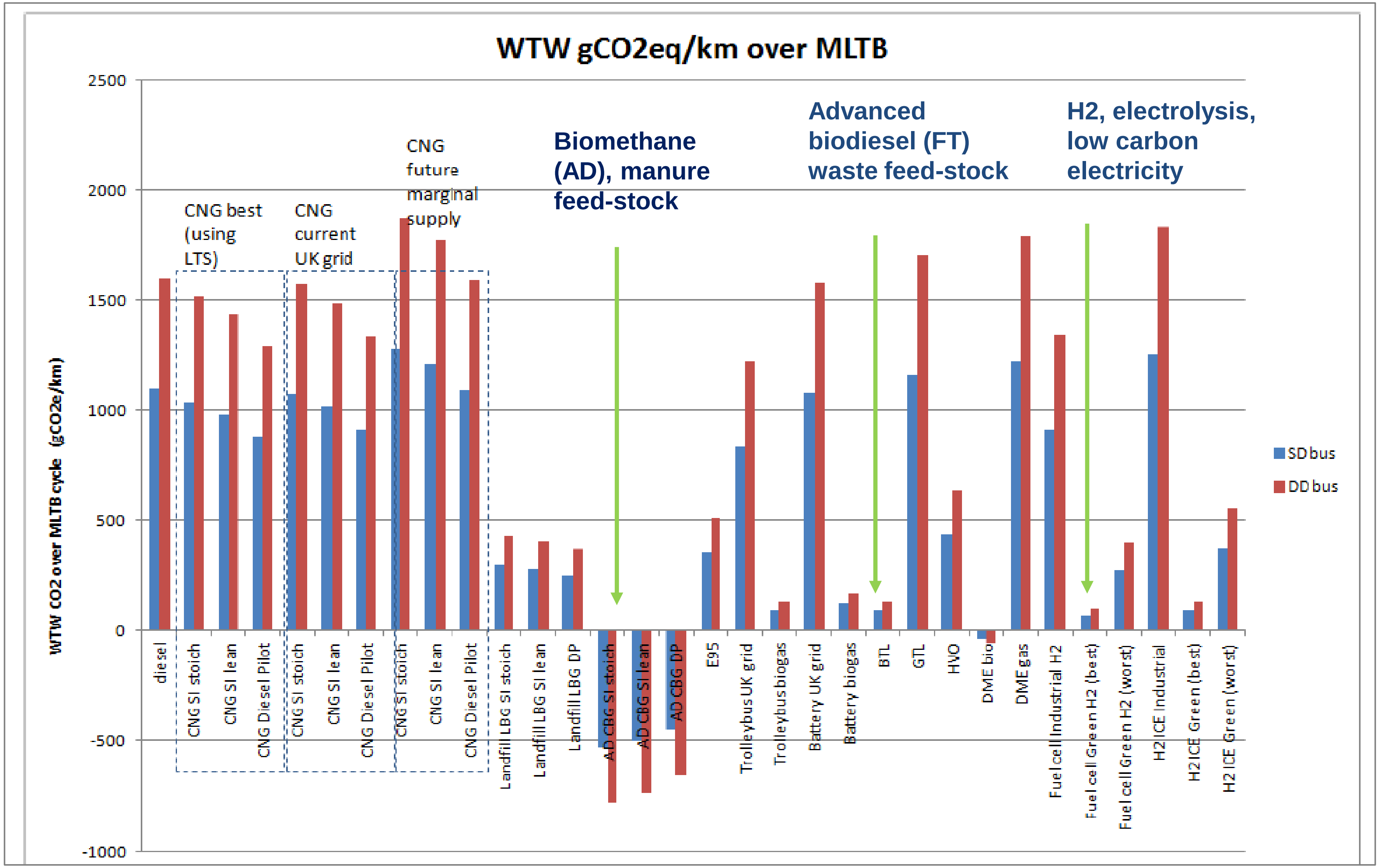


Lifecycle GHG Emissions – where are the boundaries?



Paramount to take into account the WTW GHG emissions in the quest for a 'net' zero carbon future. Efficiency of the fuel production pathway and availability of low carbon electricity will be influential.

Fuel production pathway can have a significant influence of WTW GHG emissions



LowCVP – Low Carbon Bus Roadmap (Ricardo 2013)

International GHG emission reduction - aviation and marine sectors

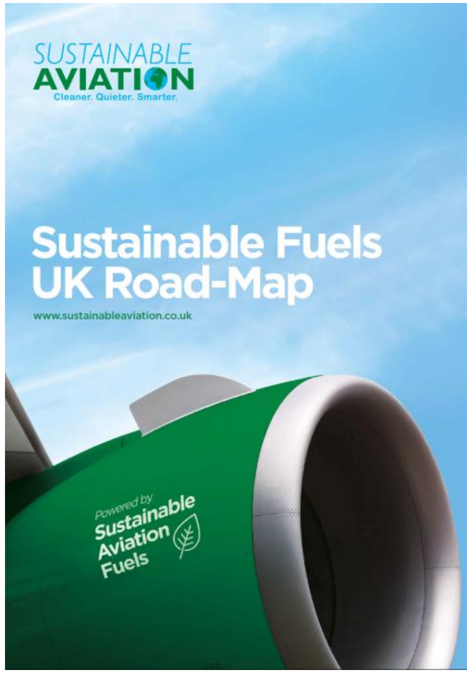
Aviation

Three routes

- Improving airplane efficiency
- **Sustainable fuels** - drop-in liquid fuels, bio-kerosene and e-fuels. UK Roadmap created.

  GHG emission and sustainability criteria introduced
- ICAO Carbon Offsetting and Reduction Scheme (CORSIA)

  Voluntary from 2020, mandatory from 2027

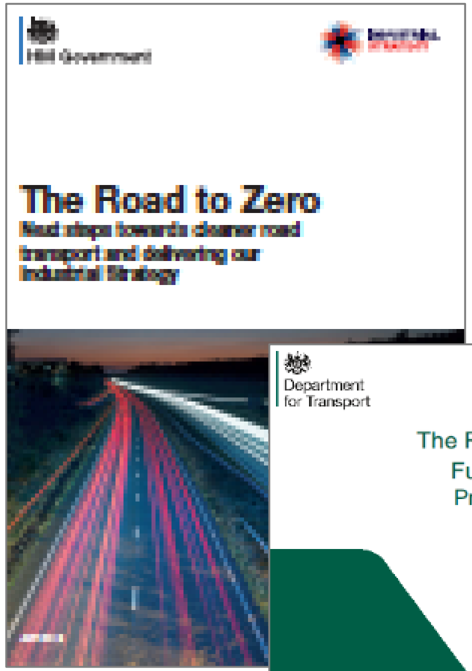


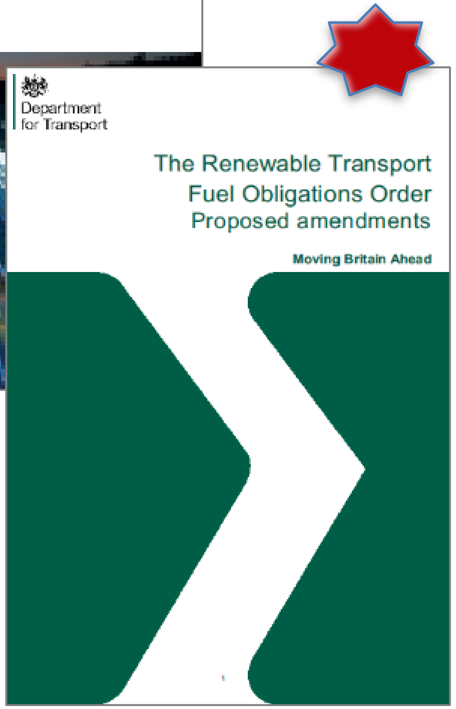
International Shipping

- IMO ‘Initial Plan’ for 50% GHG emission reduction by 2050 based on 2008, but little policy as yet.
- Early opportunities for alternative fuels – LNG, hydrogen, biodiesel

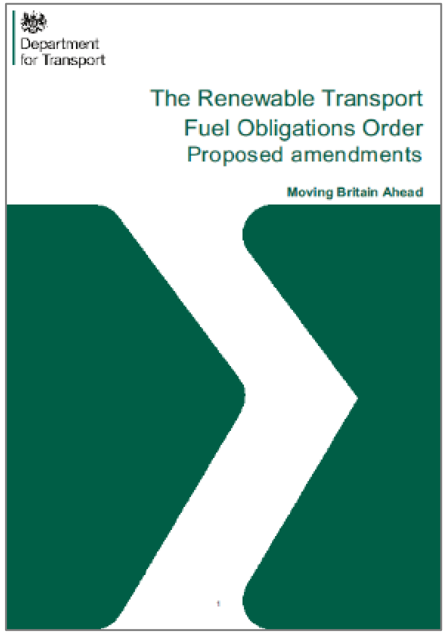
Hydrogen in Norway

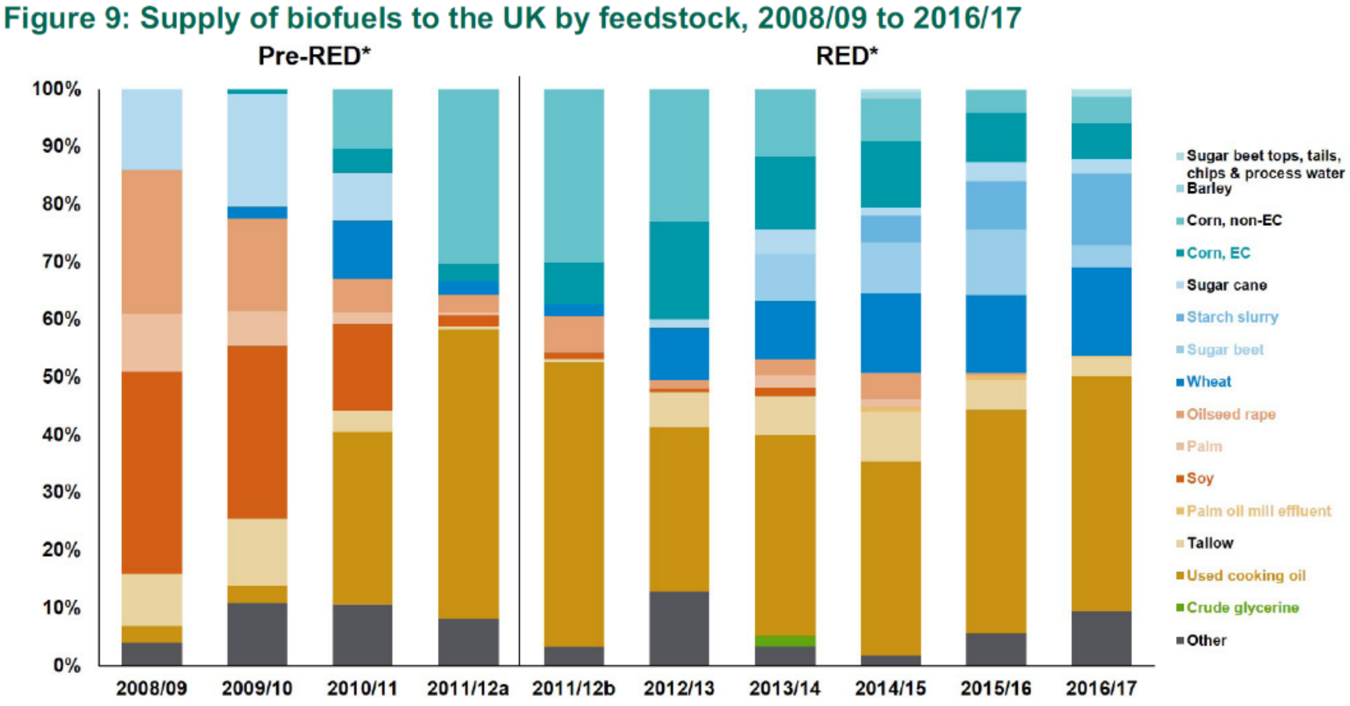
UK GHG Emission Reduction Transport Policies





Renewable Transport Fuel Obligation – 10yrs of GHG savings





* *RED - Renewable Energy Directive*

2018 - Biodiesel produced from waste oils, bioethanol from wheat

Average GHG savings 78%

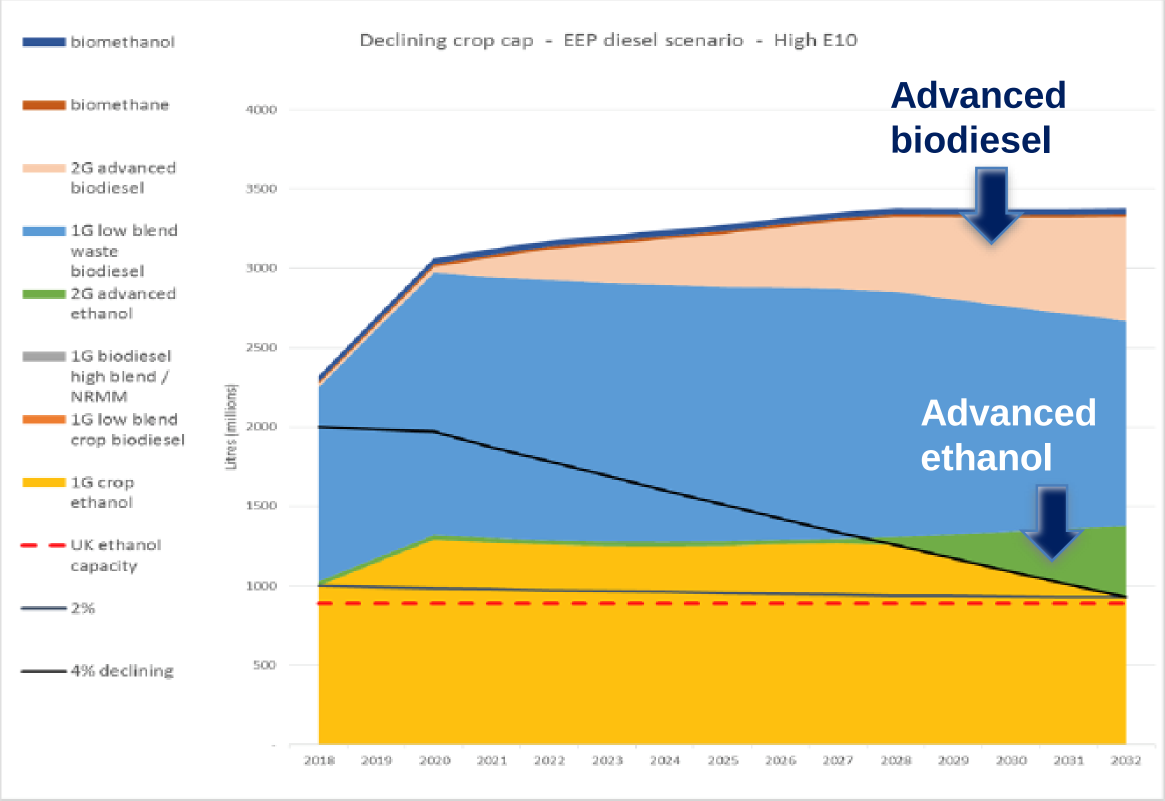
98% certified by a voluntary sustainability scheme

- Legal obligation for UK fuel supplies to supply sustainable renewable fuel – sets mandates
- Incentivises renewable fuel supply through market traded certificates (RFTCs), doubled counted for waste feed-stocks
- Fuel suppliers must meet GHG and sustainability criteria (RED)

- Bio-ethanol (E5) and Biodiesel (B7) – 4.6% by volume, (clearly will not meet 10% target by 2020!)
- High blend biodiesel and biomethane use in trucks and buses.

RTFO beyond 2020, supporting advanced fuels

- 2018 DfT introduced their 15yr policy framework – taking into account REDII
- Increased renewable energy target to 14% by 2032.
- **New 'development fuels' sub target**
  - RFNBOs, aviation fuel, advanced biofuels made from waste feed-stocks, substitutes for natural gas by gasification or pyrolysis
  - 0.1% in 2020 to 2.8% in 2032.
  - 2x RTFCs
  - GHG threshold >70% savings
- Sets a crop cap, tightening over time.
- Considering low carbon fossil fuels



Department for Transport have a 15 yr policy framework for low carbon fuels

Clean Maritime Plan quote – 'Government will consult in 2020 on how the Renewable Transport Fuel Obligation could be used to encourage the uptake of low carbon fuels in maritime'

Looking ahead – wider sustainability impacts and lifecycle GHG metrics must be taken into account when developing future fuels

Emphasis on land-use sustainability criteria in regulations for biofuels, however new feed-stocks and production pathways require evaluation of potential environmental and societal risks.

Use of feed-stocks such as MSW could undermine recycling
Re-use or recycling is nearly always the best use for a resource from an LCA perspective

Increase reliance on fossil fuels fuels (LCFF)
LCFFs could perpetuate fossil fuel supply chains and prevent progress towards GHG reduction goals

Generate more waste
Using wastes for transport fuel production may increase the value of that waste and incentivise increased production and/or discourage efficiency improvements

Cause other environmental issues
Air quality or water consumption

Voluntary certification for advanced fuels will become increasingly important and require broader range of criteria.

Supergen | Bioenergy

Lifecycle assessment of biofuels

Aston University

23 July 2019

We work with academia, industry, government and societal stakeholders to develop sustainable bioenergy systems that support the UK's transition to an affordable, resilient, low-carbon energy future.

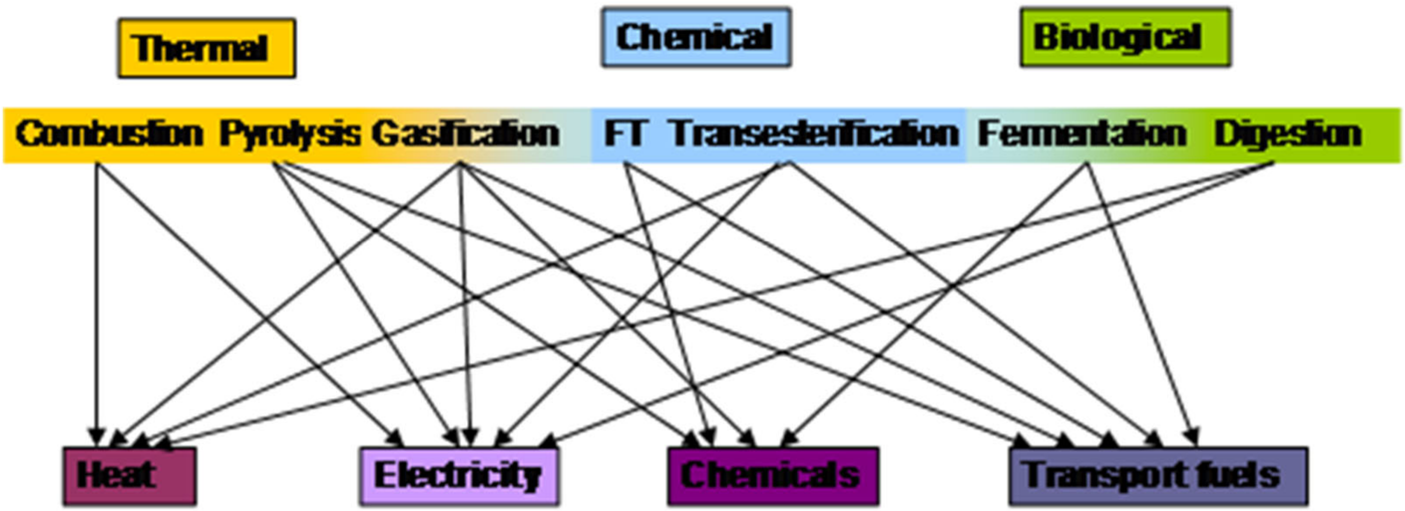
Supergen Bioenergy Hub

Supergen | Bioenergy

Potential for UK Bioenergy

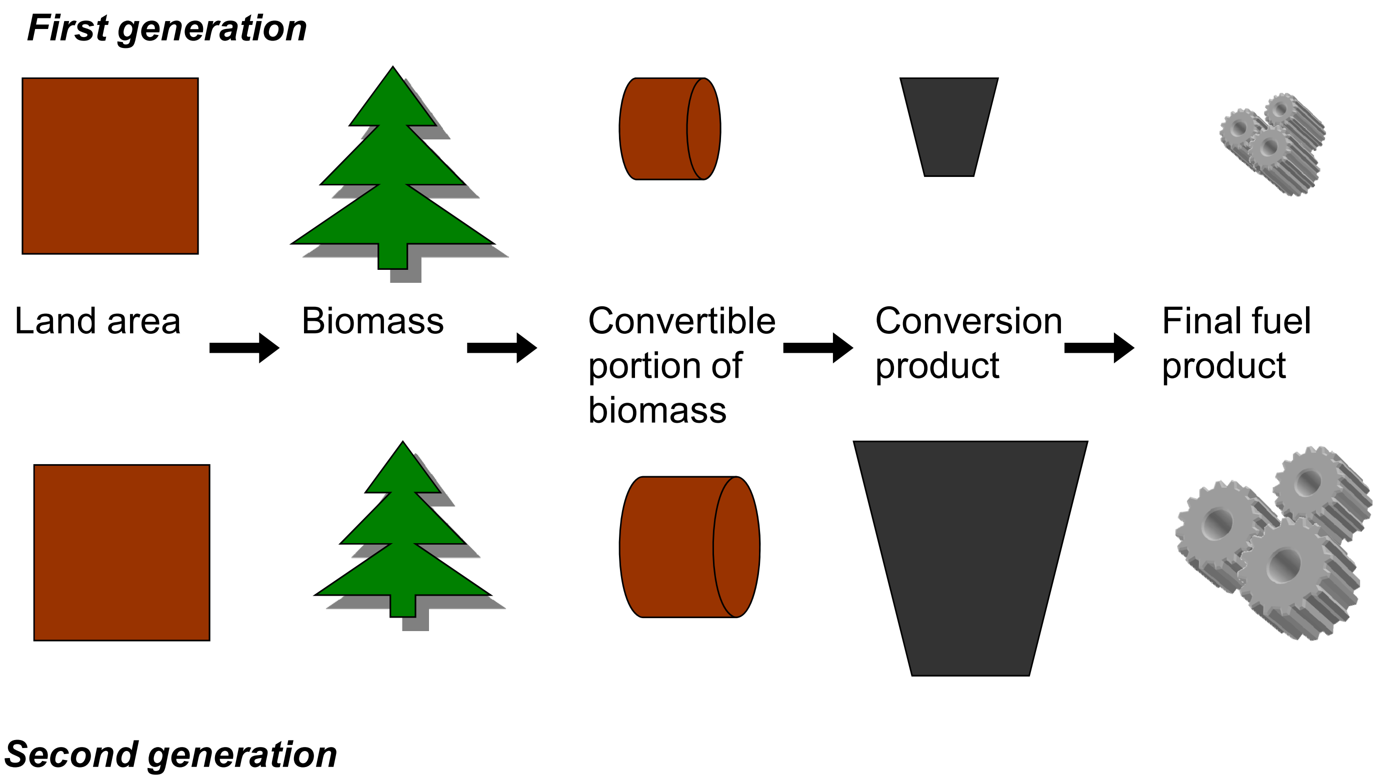
- Up to 45% of UK bioenergy demand*
- 10% electricity (baseload)
- 50% heat (industrial, district, gas)
- 20% liquid fuels (aviation, shipping, heavy duty/mobile plant)

Bioenergy range of pathways and products



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

Supply chain analysis is key to overall evaluation



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

CCC Report: Biomass in a low-carbon economy

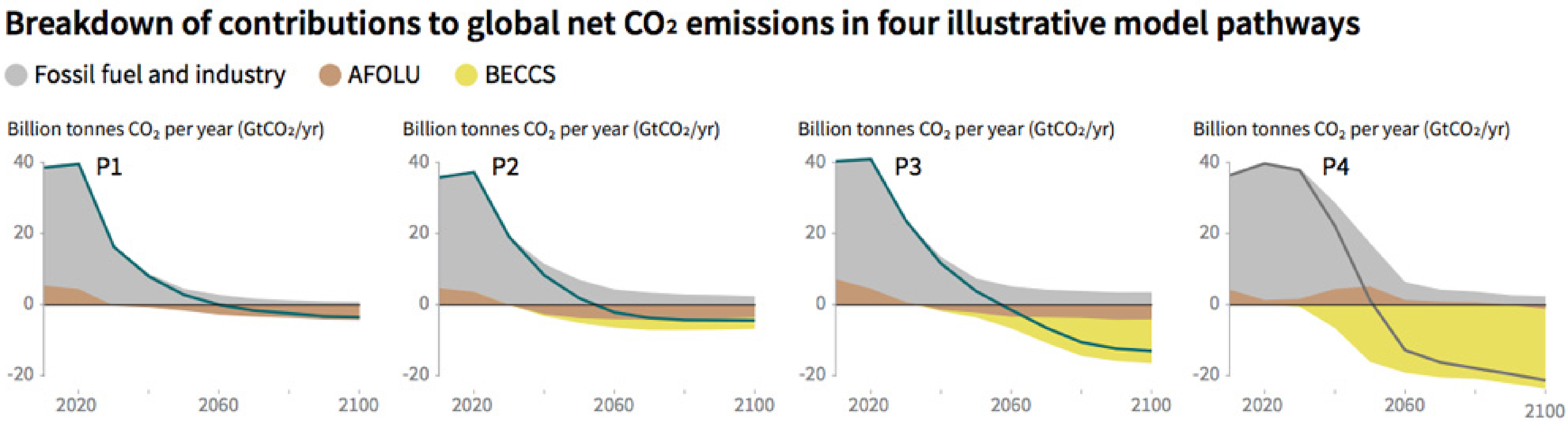
Committee on Climate Change

1. What is biomass and why is it important?
2. When is biomass low carbon and sustainable?
3. Sustainability governance for imported biomass
4. Future sustainable supply
5. What is the role of biomass in meeting UK carbon targets?

www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/

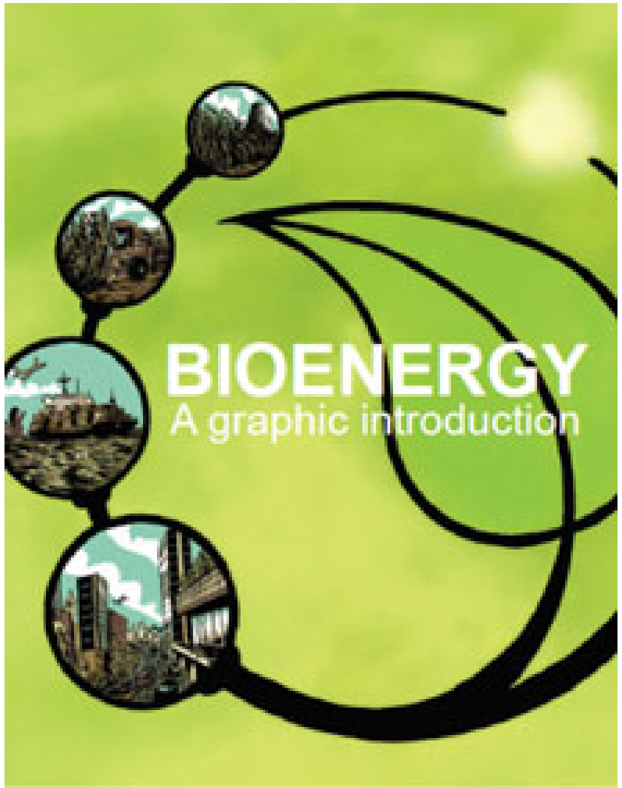
CCC Report: The importance of bioenergy

Bioenergy is particularly valuable in achieving future GHG/climate targets because of its ability to sequester carbon dioxide from atmosphere.



Bioenergy carbon balances

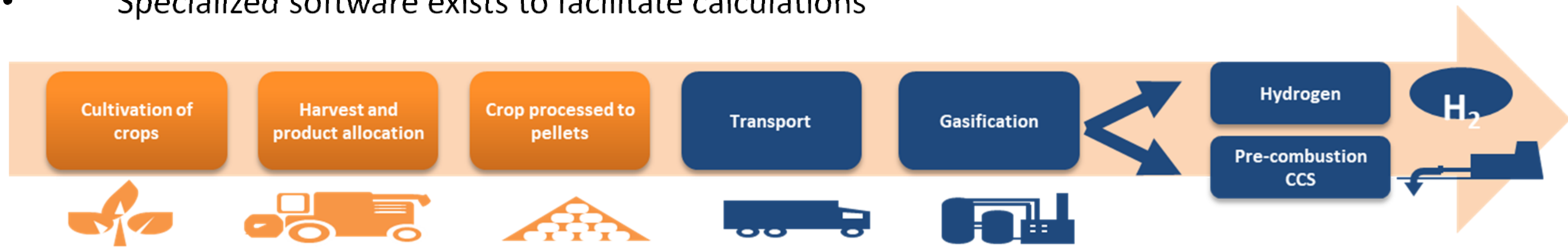
- Bioenergy carbon balances are contentious and disputed.
- Many disagreements arise from differences in the scope, time frame and scale of what is being considered/displaced
- The overwhelming UK academic consensus is that well managed systems can deliver valuable greenhouse gas reductions
- A laymans guide: Supergen Bioenergy Hub Comic http://www.supergen-bioenergy.net/comic/



SUPERGEN Bioenergy Hub

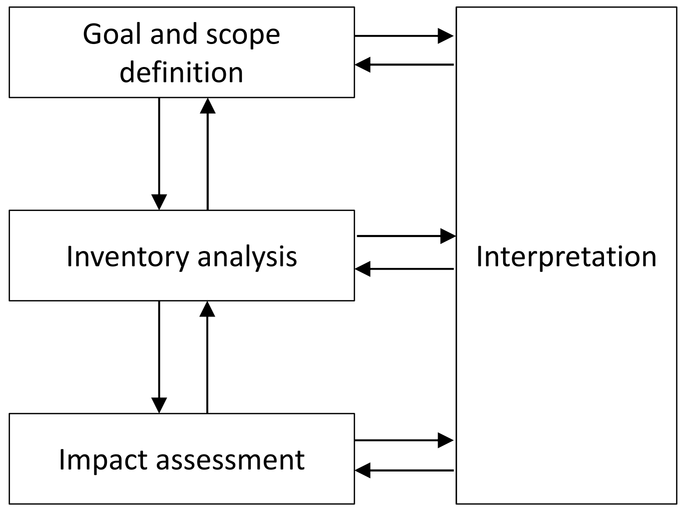
Life cycle assessment

- Life cycle assessment (LCA) is a technique developed to evaluate the “entire” environmental impact of a product or service
- Sometimes referred to as “cradle to grave” assessment
- LCA considers not just the visible/operational/functional elements of the system, but also the equipment and infrastructure required, the material and energy inputs required to produce the equipment, infrastructure and process consumables and the environmental impact associated with output flows from each stage of the production process
- The system being considered and the scope of the calculations should be defined as part of the LCA process
- Standardized methodologies exist e.g. ISO 14044 (2006)
- *Specialized software exists to facilitate calculations*



Stages in life cycle assessment

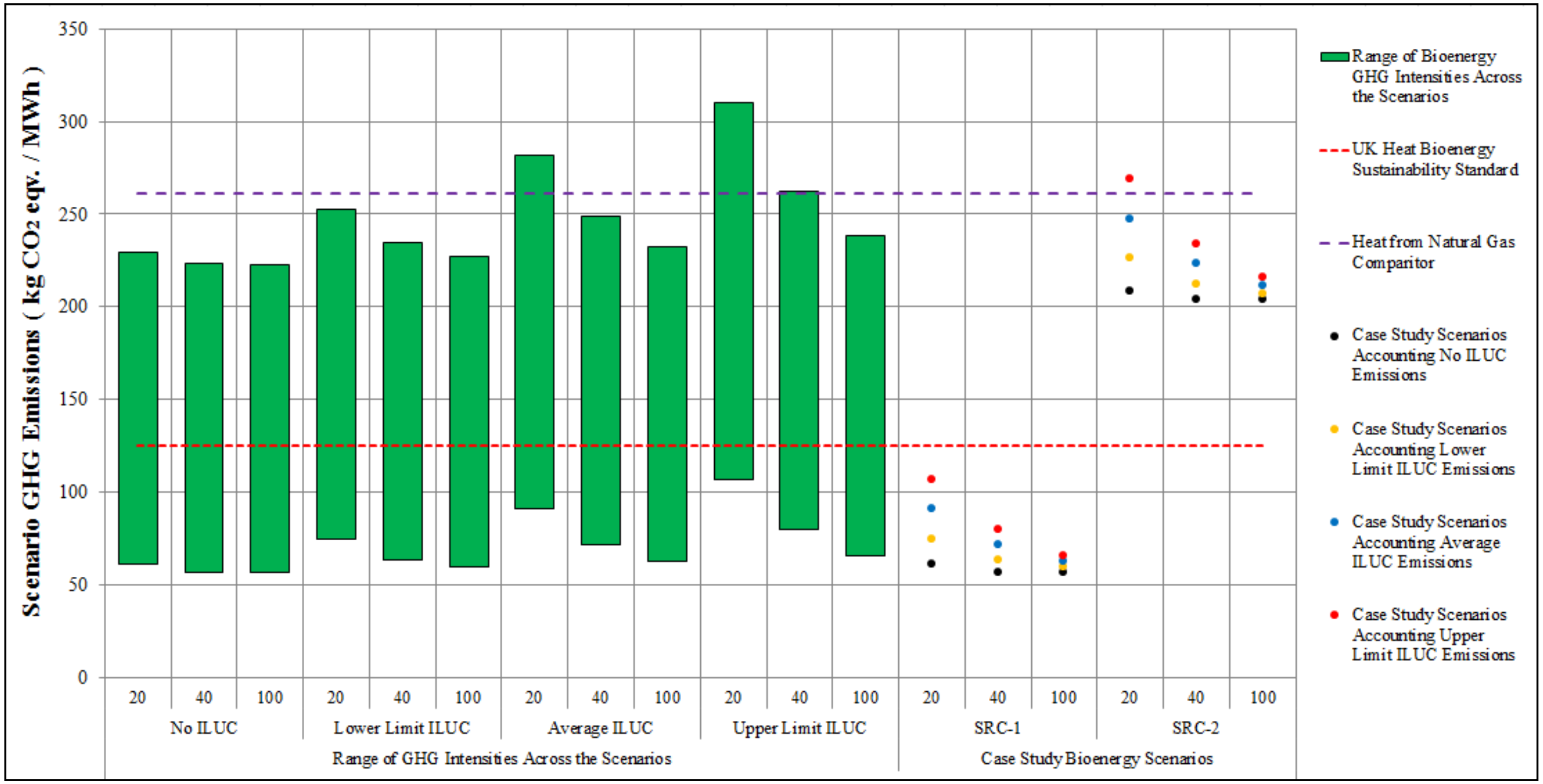
- Goal and scope definition
- System boundary definition
- Data collection – time consuming, but vital!
- Inventory analysis – compilation of all material and energy inputs and outputs at each stage of the process
- Impact assessment – different chemical species have different impacts and these are grouped to allow assessment of the overall environmental impact of the system in different categories
- Some methodologies then group impacts and apply weightings to allow a "single number" point of comparison between different systems
- Calculation protocols are important as are comparison points



Life cycle assessment and sustainability

- LCA ***can*** provide a useful contribution in quantifying releases or consumption of key substances
- Applied consistently LCA ***can*** help compare different process options
- LCA ***can*** help identify process steps which require improvement to improve the overall process impact
- LCA ***can*** provide information on the “trade-offs” between different process options
- LCA ***cannot*** provide “the answer”
- LCA ***cannot*** provide information on social impacts
- LCA ***must*** be tailored to the question being asked
- Great ***care is needed*** when comparing LCA’s

Importance of land use

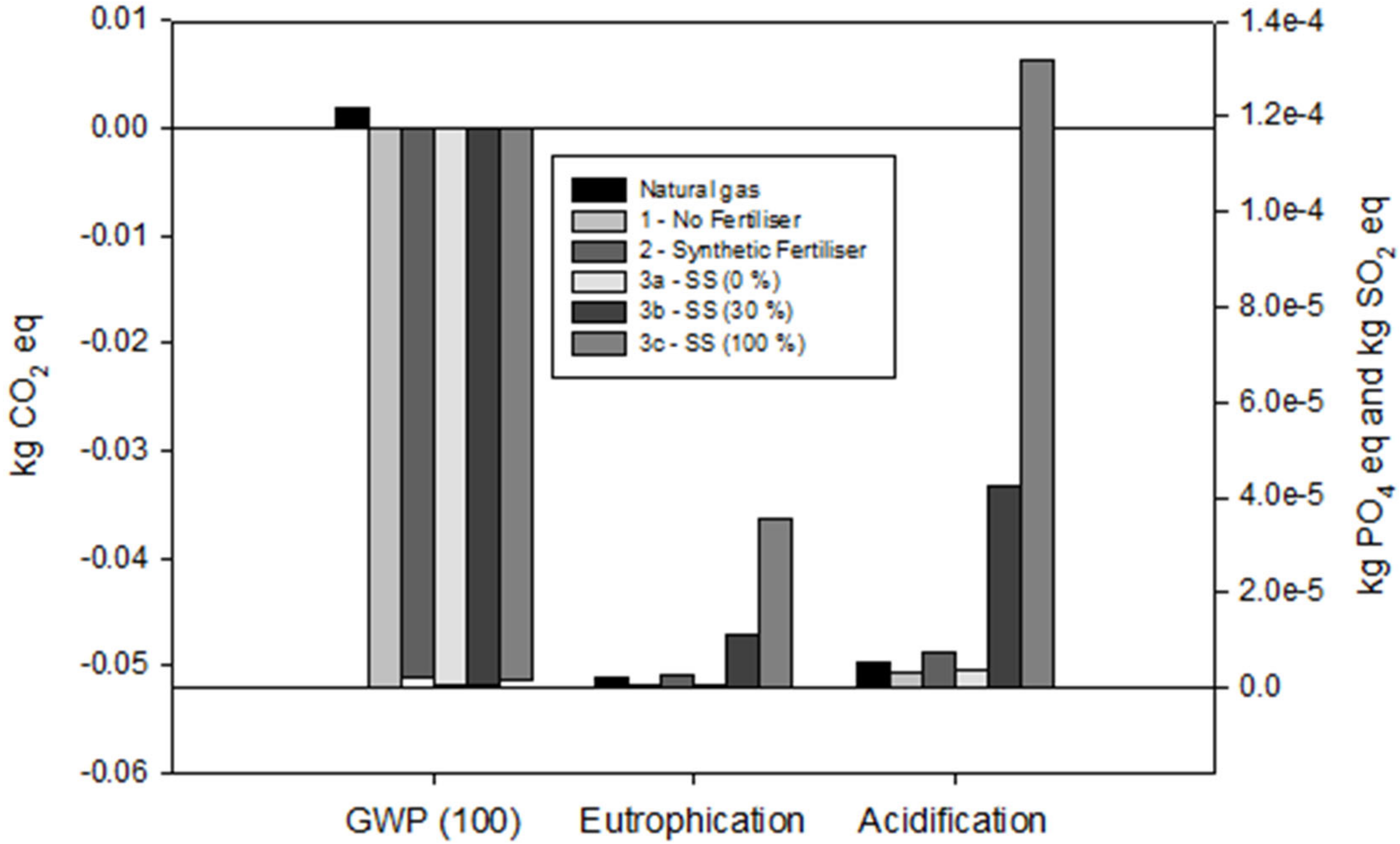


Abbreviation	Bioenergy Scenario Life Cycle Characteristics				
	Previous Land Use	Feedstock	Fuel	Pre-treatment Process Energy	Bioenergy Technology
SRC-1	Arable Land	Willow SRC	Chips	N/A	Large Scale Boiler (≥200 MW_{th})
SRC-2	Arable Land	Willow SRC	Pellets	Diesel Fuel	Small Scale Boiler (≤200 MW_{th})

Welfle et al., Generating low carbon heat from biomass: Life cycle assessment of bioenergy scenarios, Journal of Cleaner Production, 149, pp. 448-460, 2017

Importance of production regime

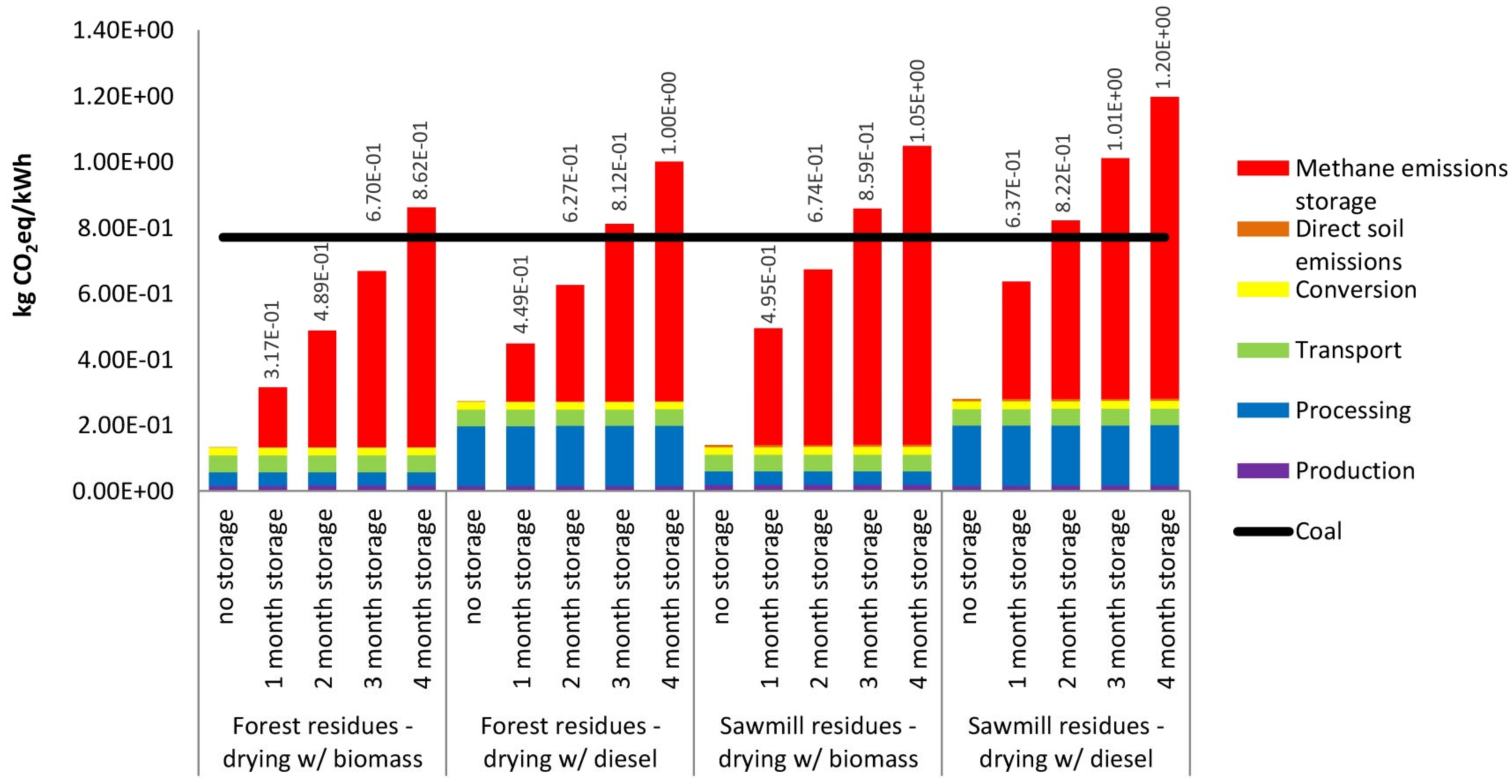
Variation of GHG emissions with fertilizing regime



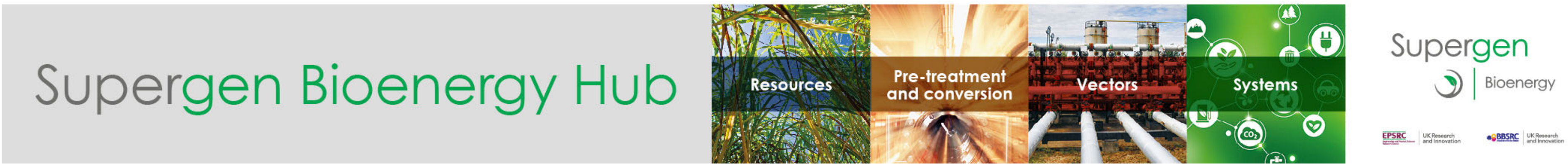
Gilbert et al., ""*The influence of organic and inorganic fertiliser application rates on UK biomass crop sustainability", Biomass and Bioenergy 35 (2011), 1170-1181,*

Importance of supply chain

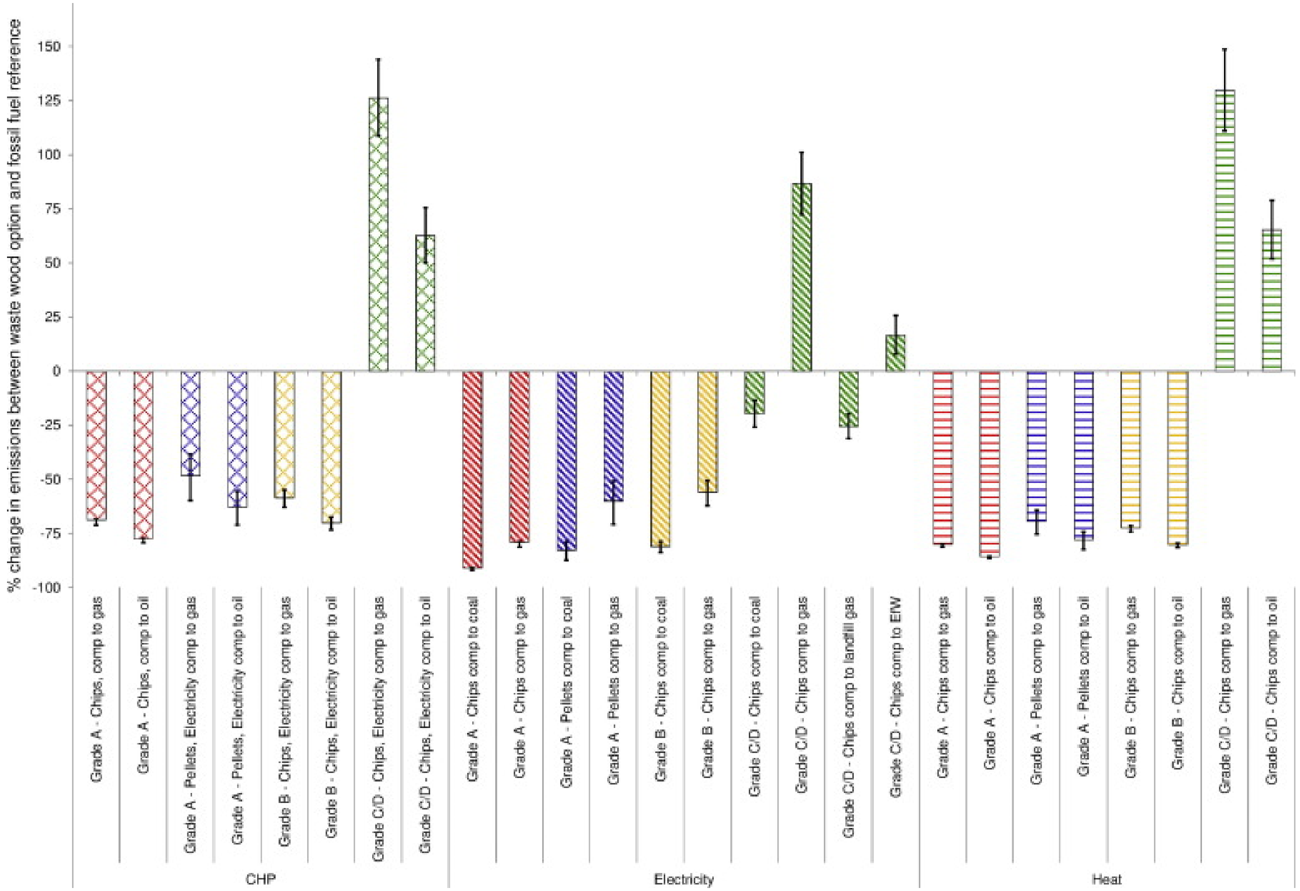
Variation of GHG emissions with wood storage time



Röder et al., "How certain are greenhouse gas reductions from bioenergy?": Life cycle assessment and uncertainty analysis of wood-pellet to electricity-electricity supply chains from forest residues", Biomass and Bioenergy, 79, pp 50-63, 2014



Importance of regulatory regime



Röder & Thornley, Waste wood as bioenergy feedstock. Climate change impacts and related emission uncertainties from waste wood based energy systems in the UK, Waste Management, 2017

Importance of indicators

- Pellet boiler pathway results in largest GHG burden
- Chip boiler pathway has substantially lower emissions
- Both of the electricity systems give very much higher GHG savings than the heating ones
- The district heating system gives the highest percentage reduction of greenhouse gases compared to the reference system

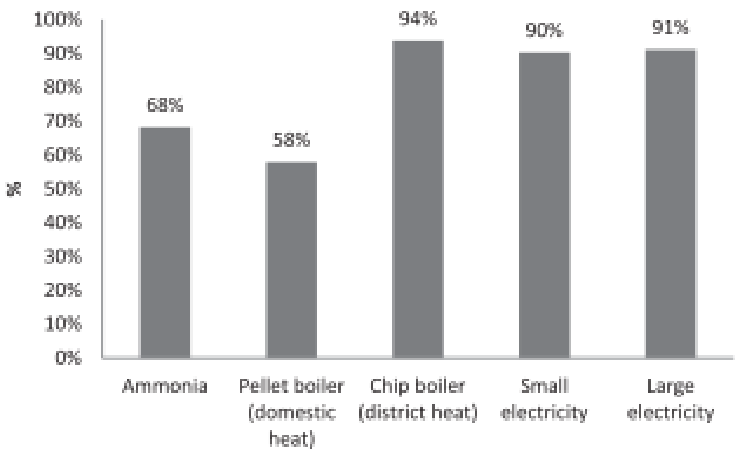


Fig. 3 – Relative greenhouse gas reductions compared to the reference case.

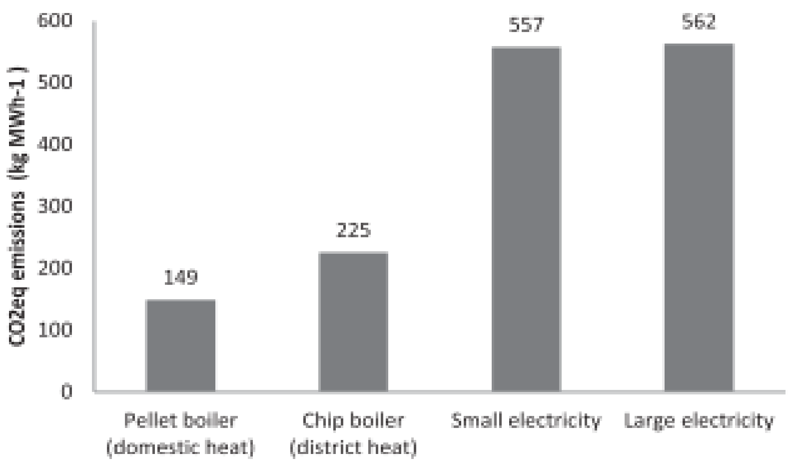
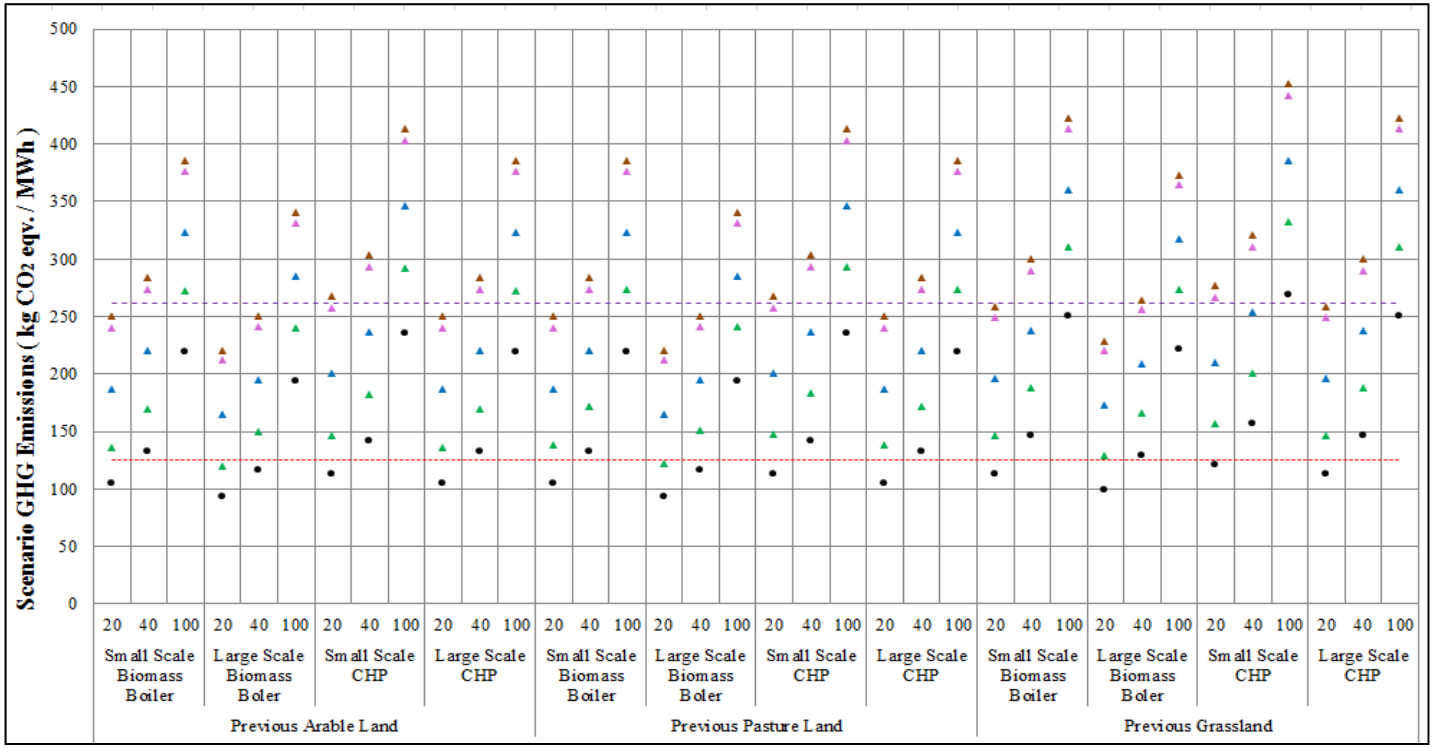


Fig. 2 – Absolute greenhouse gas savings per unit of energy delivered.

Resulting uncertainty/variability!



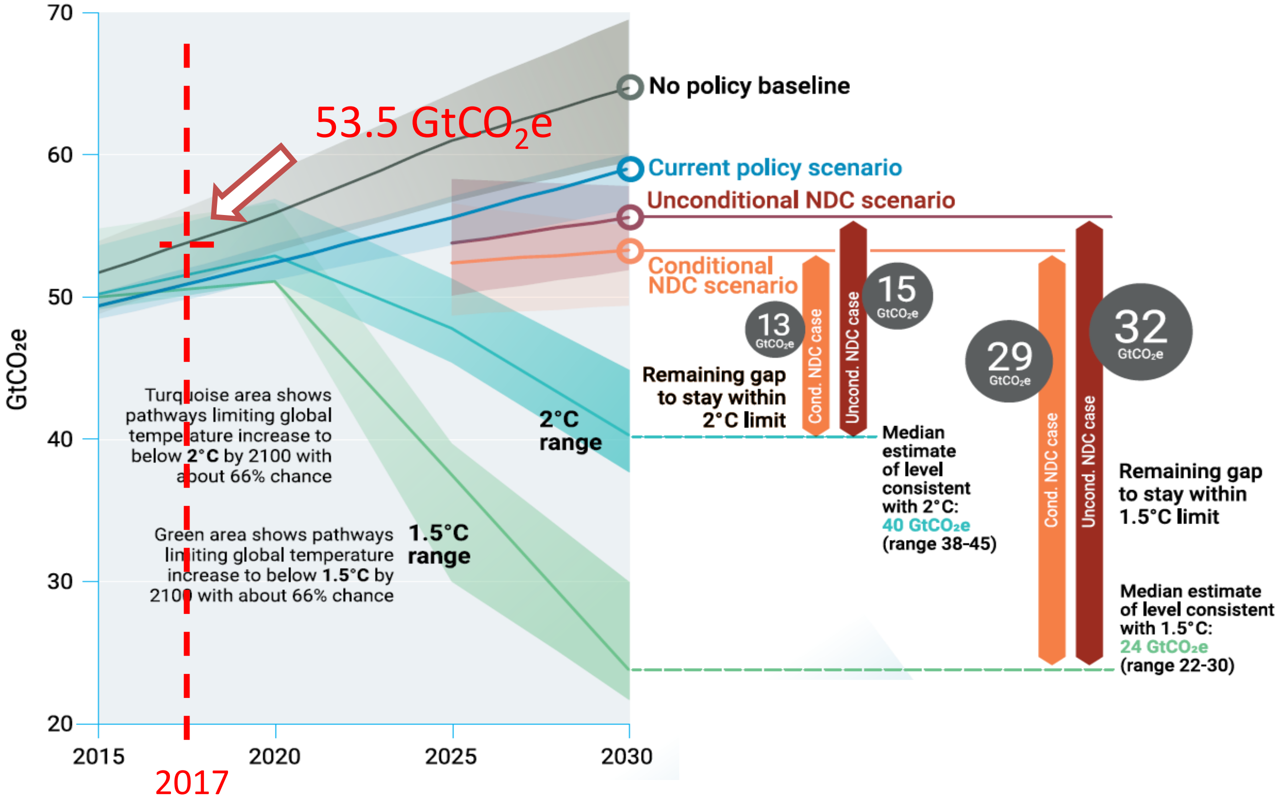
- Energy crop **chips** are **naturally/not dried** prior to bioenergy conversion.
- ▲ Energy crop resources are **dried and pelletised**, the processes driven primarily by **electrical energy**.
- ▲ Energy crop resources **dried and pelletised**, the processes driven primarily by **bioenergy**.
- ▲ Energy crop resources **dried and pelletised**, the processes driven primarily by **natural gas**.
- ▲ Energy crop resources **dried and pelletised**, the processes driven primarily by **diesel fuel**.

Welfle et al., Generating low carbon heat from biomass: Life cycle assessment of bioenergy scenarios, Journal of Cleaner Production, 149, pp. 448-460, 2017

Summary

- Life cycle assessment can support identification of “hot spots” causing environmental impacts
- Life cycle assessment can be used to compare greenhouse gas emissions, biodiversity impacts, land use changes, water impacts etc.
- But parameters are often difficult to quantify/subject to high levels of uncertainty
- It is absolutely critical to adapt the method to the most relevant question, especially for use in regulation

Global GHG emissions under different scenarios and emission gap in 2030



UNEP emission gap report 2018

Current emission trend on "No policy baseline"
Global emissions vs domestic policies

EU28, USA, Canada, fall short of NDCs

Do some policy measures don't work?

NDCs = nationally determined contributions

Recommendations

- Urgency to get on with carbon reductions (cumulative emissions – near term reductions valuable)
- Need to progress technological solutions all the way to drop-in vectors: aviation fuels, syngas, hydrogen
- Intelligent risk management needed for potential negative impacts e.g. monitor land use, displacement, but not everything along supply chain
- Incentive schemes that maximize energy and minimize carbon are needed (current schemes are pass/fail with no incentive for higher performance)

Supergen Bioenergy

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Topic lead Bioenergy Systems
Supergen Bioenergy Hub

supergen-bioenergy@aston.ac.uk

We work with academia, industry, government and societal stakeholders to develop sustainable bioenergy systems that support the UK's transition to an affordable, resilient, low-carbon energy future.

Supergen Bioenergy

Decarbonising the Aviation Sector: Moving towards Sustainable Aviation Fuels & the UK Innovation Landscape

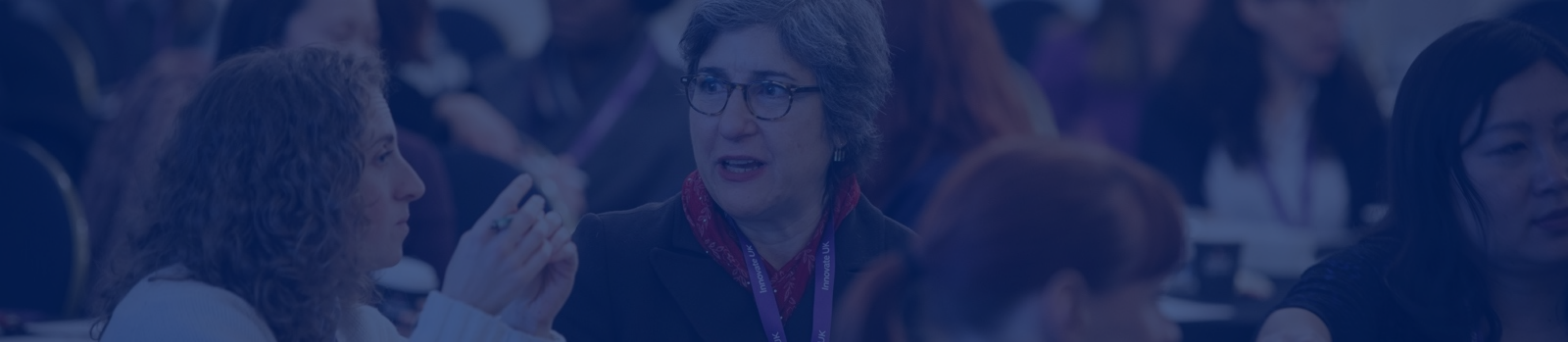
Peter Clark, Knowledge Transfer Manager – Raw Materials, KTN &

Michelle Carter, Head of Transport, KTN

APC Transport Energy Network – Cross Sector Roadmapping Workshops

23 July 2019

Innovate UK
Knowledge Transfer Network



The Innovate UK Family

Department for Business, Energy & Industrial Strategy

UK Research and Innovation

Fund

Innovate UK

Connect

Innovate UK Knowledge Transfer Network

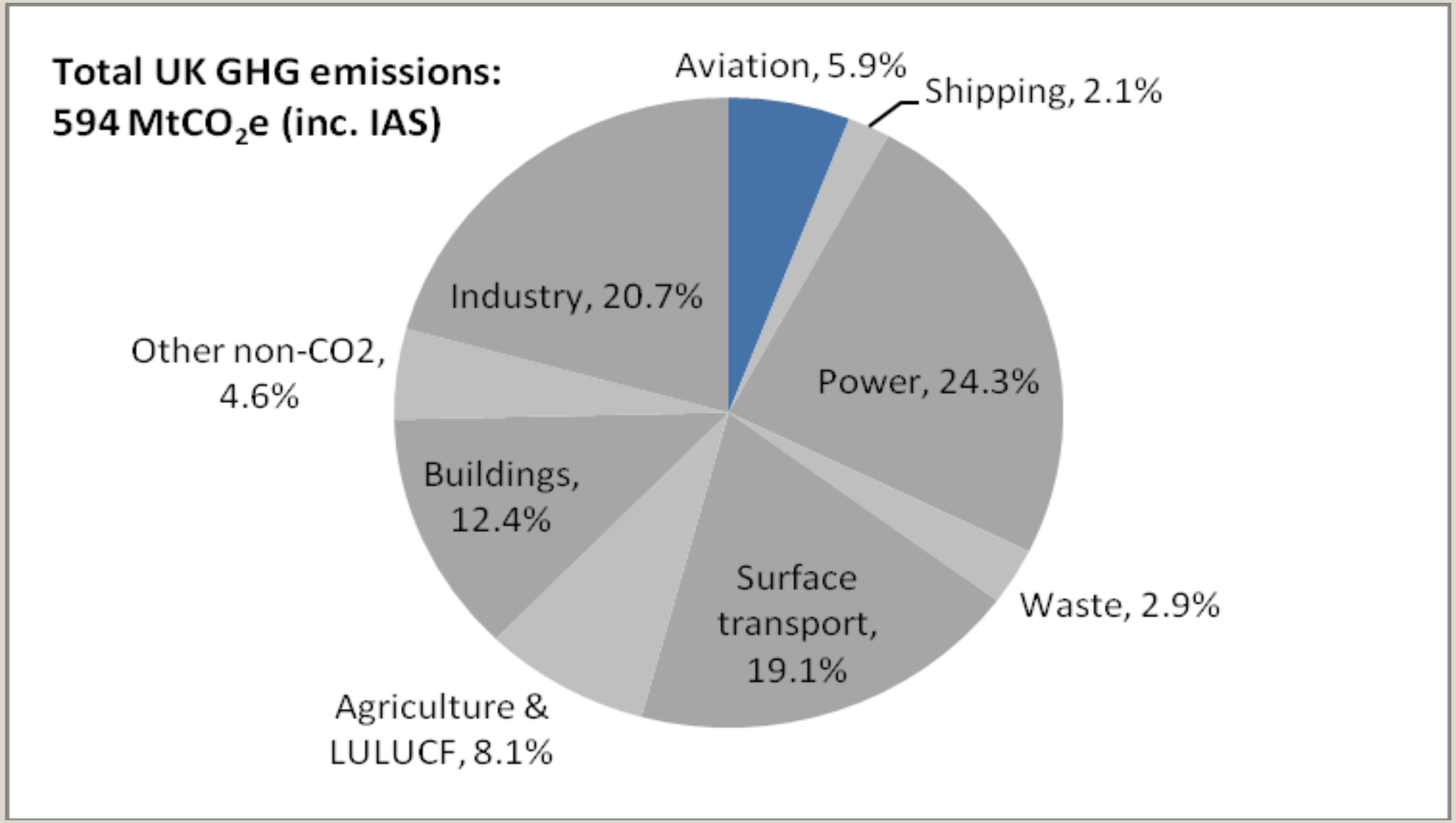
enterprise europe network

Collaborate

CATAPULT

Introduction to the Aviation Sector

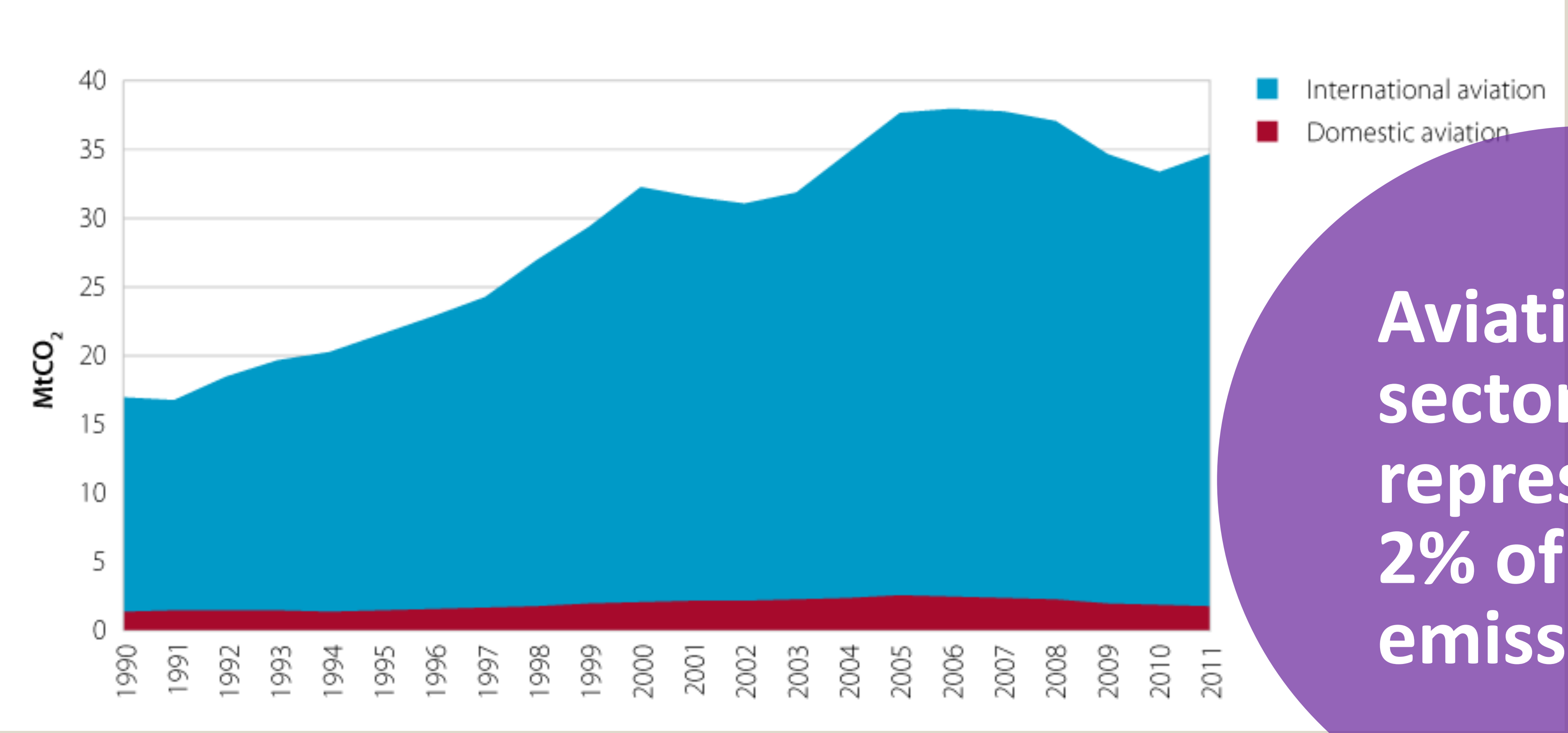
Figure 1. UK greenhouse gas emissions from aviation (2011)



Ref: Committee on Climate Change Aviation Fact Sheet

Introduction to the Aviation Sector

Figure 2. UK aviation CO_2 emissions (1990 – 2011)



Source: DECC (2013); 2011 UK greenhouse gas emissions, final figures.

Aviation sector represents 2% of global emissions

Ref: Committee on Climate Change Aviation Fact Sheet

Optio[...] !

Dutch airline KLM calls for people to fly less

The Netherlands' national airline urges people to 'fly responsibly' and to invest in its carbon-offsetting scheme

▲ An image from the KLM video that encourages travellers to consider the environmental impact of flying

Ref: Guardian, 11 July 2019

Architecture & Interconnect

- Whole Aircraft
- Propulsion
- Systems
- Protection
- Connectors
- Insulation

Electrical Energy Storage

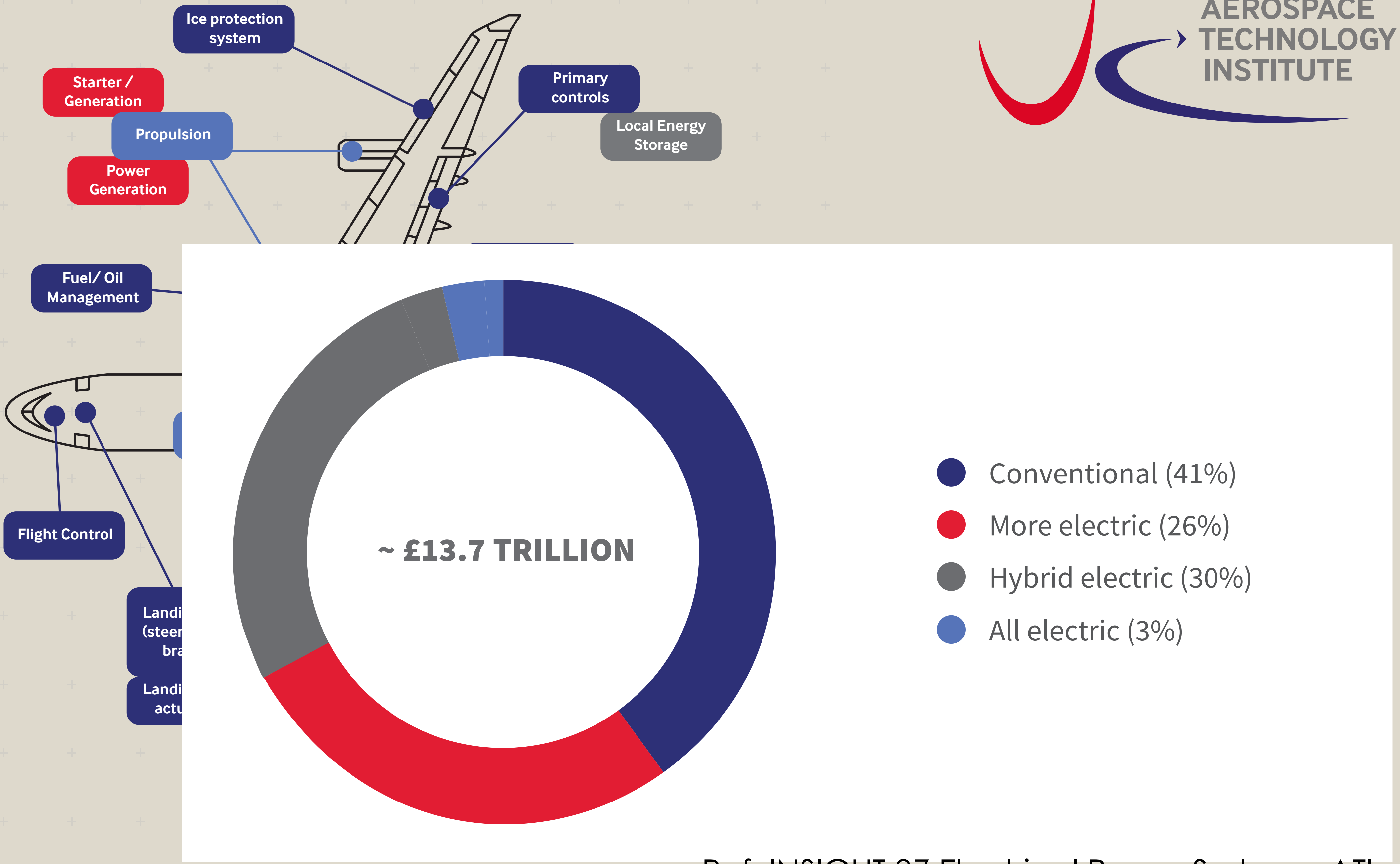
- Energy Storage
- Energy Generation
- Energy Management
- Infrastructure

Electrical Machines

- Motors
- Generators
- Topologies
- Transformers
- Drivers
- Actuators

Power Electronics

- Power Conversion
- Control
- Monitoring
- Switching



The More Electric Aircraft

Ref: INSIGHT 07 Electrical Power Systems, ATI

As an aside, did you see the news yesterday!!

Press release

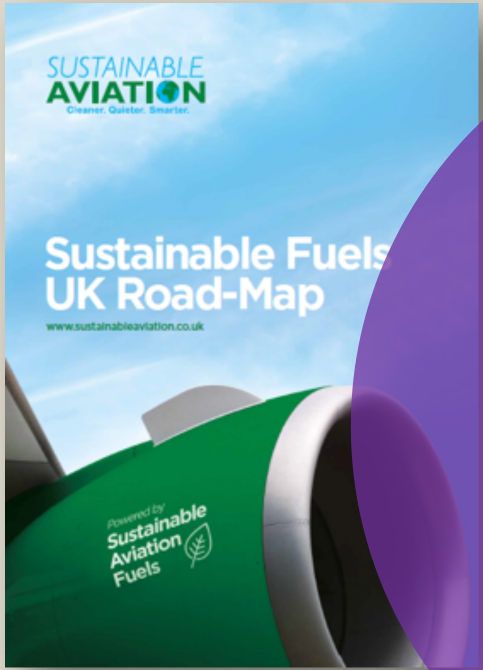
New investment to drive forward next generation of net zero planes and cars

Government unveils £80 million investment to help develop the next generation of electric vehicles and new hybrid aircrafts.

Published 22 July 2019

- government announces £80 million investment in next-generation electric cars and planes through Industrial Strategy
- collaboration with industry and academia could accelerate development of electric and hybrid aircraft
- investment comes from modern Industrial Strategy – keeping the UK at the forefront of new vehicle development and tackling climate change

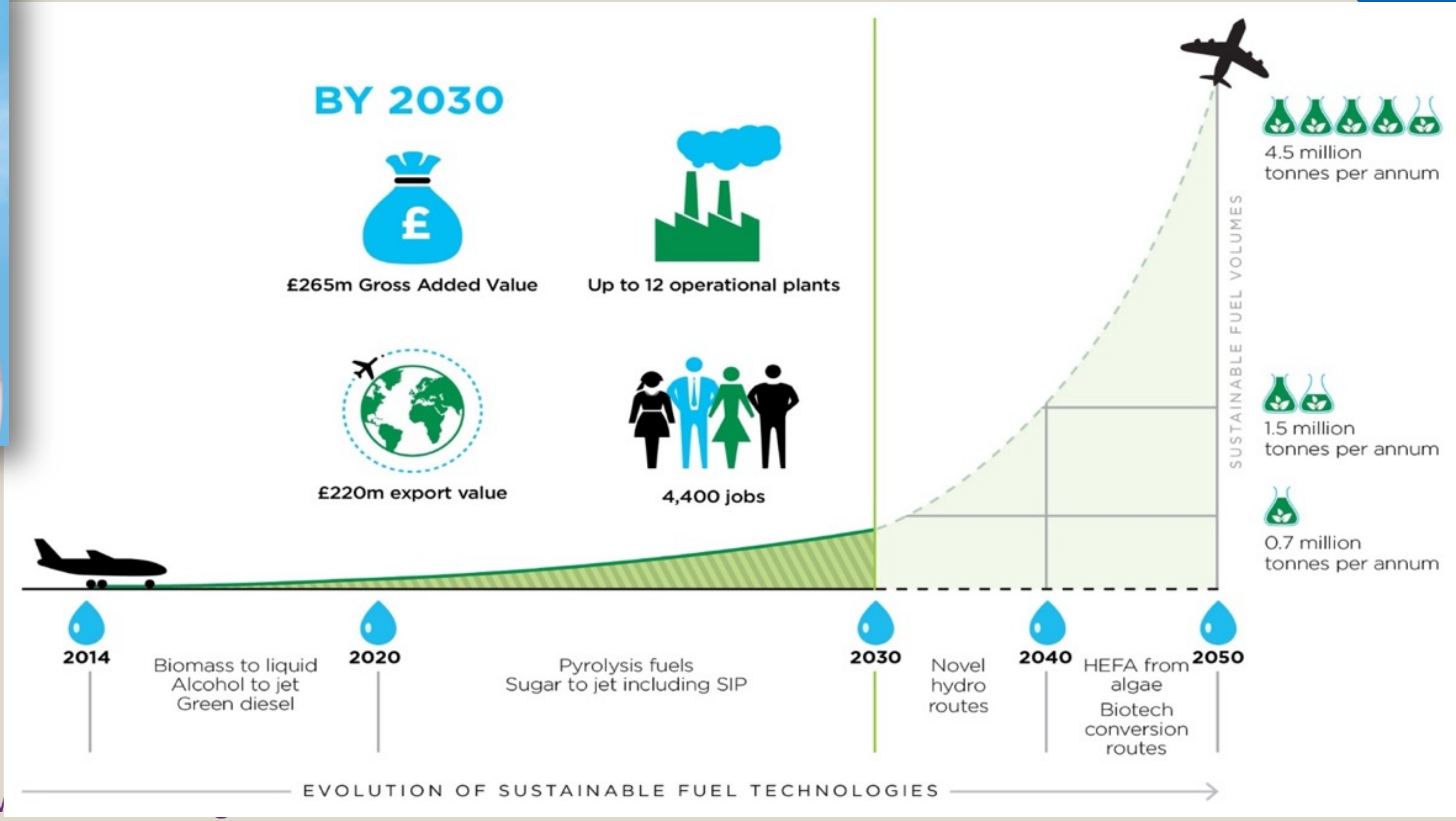
Option #3 to reduce emissions: Sustainable Aviation Fuels



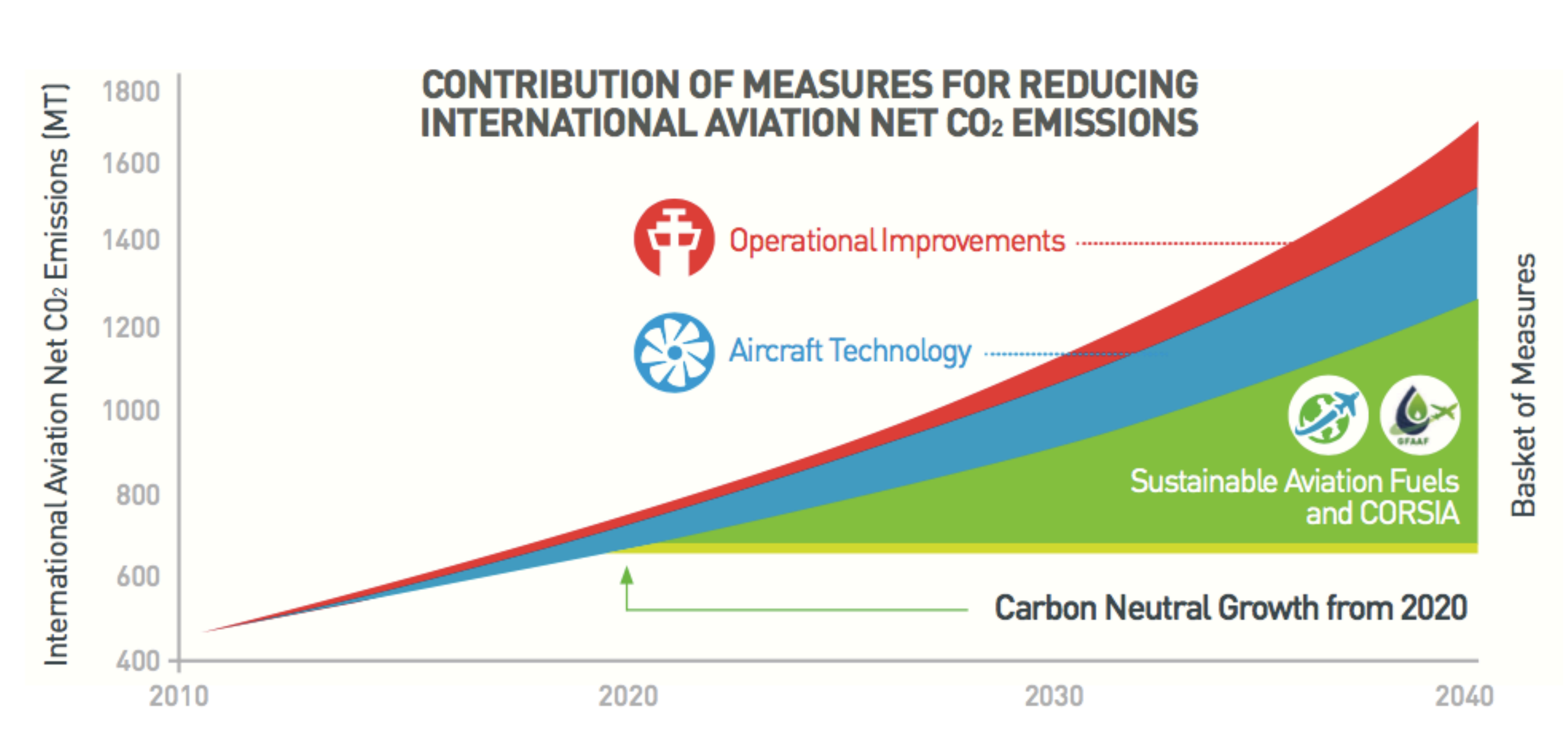
New Roadmap is Imminent!

AOA THE VOICE OF UK AIRPORTS
AIRBUS
BOEING
BRITISH AIRWAYS
Rolls-Royce
TUI Travel PLC More than a smile
virgin atlantic

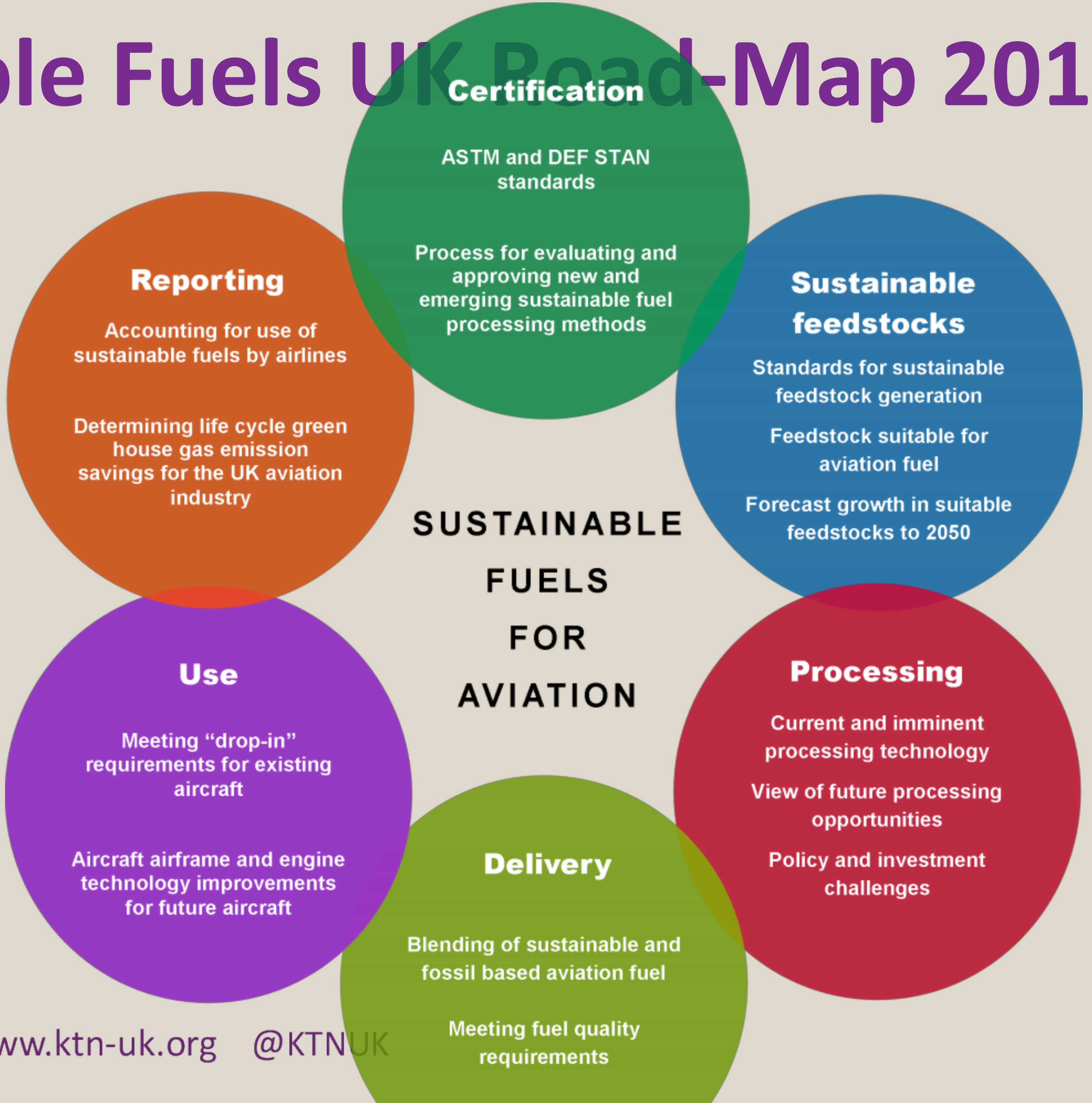
Sustainable Fuels UK Road-Map 2014



Sustainable Fuels UK Road-Map 2014



Sustainable Fuels UK Road-Map 2014



SAF SIG: Building the UK Supply Chain

www.safsig.co.uk

SUSTAINABLE AVIATION
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SAF SIG: Building the UK Supply Chain

1. To enable sustainable aviation fuel development in the UK to advance to commercial scale deployment through multi-disciplinary science and technology-inspired innovation and certification;

2. To connect academia and industry in strategic partnerships for sustainable aviation (drop in) fuel production;

3. To create multi-disciplinary approaches to deliver the development of new sustainable fuels and to ensure that the environmental and sustainability impacts of these are fully understood.

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What did the SAF SIG deliver?

Resources

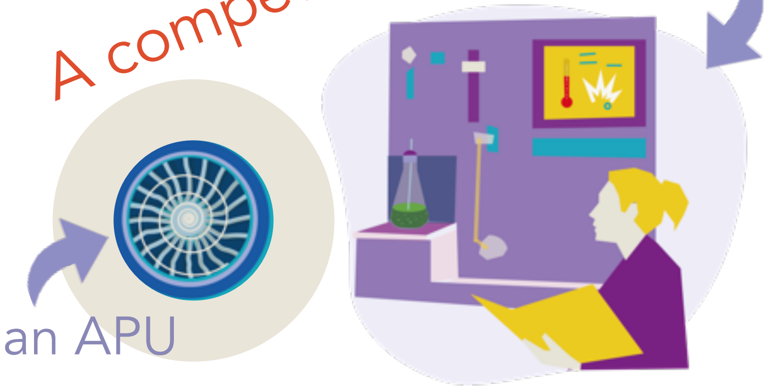
Events & webinars

Connected the supply chain

Made an impact

A competition

2 fuels taken through fit-for-purpose testing



Gave away an APU

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www.safsig.co.uk

Deliverables

Cleared For Offtake

Supplying Sustainable Aviation Fuels

Prepared by:

Knowledge Transfer Network

Sustainable Aviation

Chris Lewis Fuels Consultancy

#SustainableAviationFuel

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Knowledge Transfer Network

development. At present, these methods have not been published and as such we would advise using RSB as a guide.

TECHNICAL
DETAILS

el is a high performance distillate fuel
et rigorous standards and quality
multipurpose fluid that serves
ing being the source of energy on
mary heat transfer fluid. It must
sity and purity, good cold flow
°C and remain a liquid at high temperatures. It must also have good
re that it does not break down and foul control system units. It
to be safe during fuelling operations, but must also combust
e. The fuel will come in contact with a wide range of materials
with all of them. The fuel must not cause unacceptable levels of
ombustion. Of further note is the fact that any additives used
fuel are carefully controlled. In short, new fuels must
isting fossil jet.

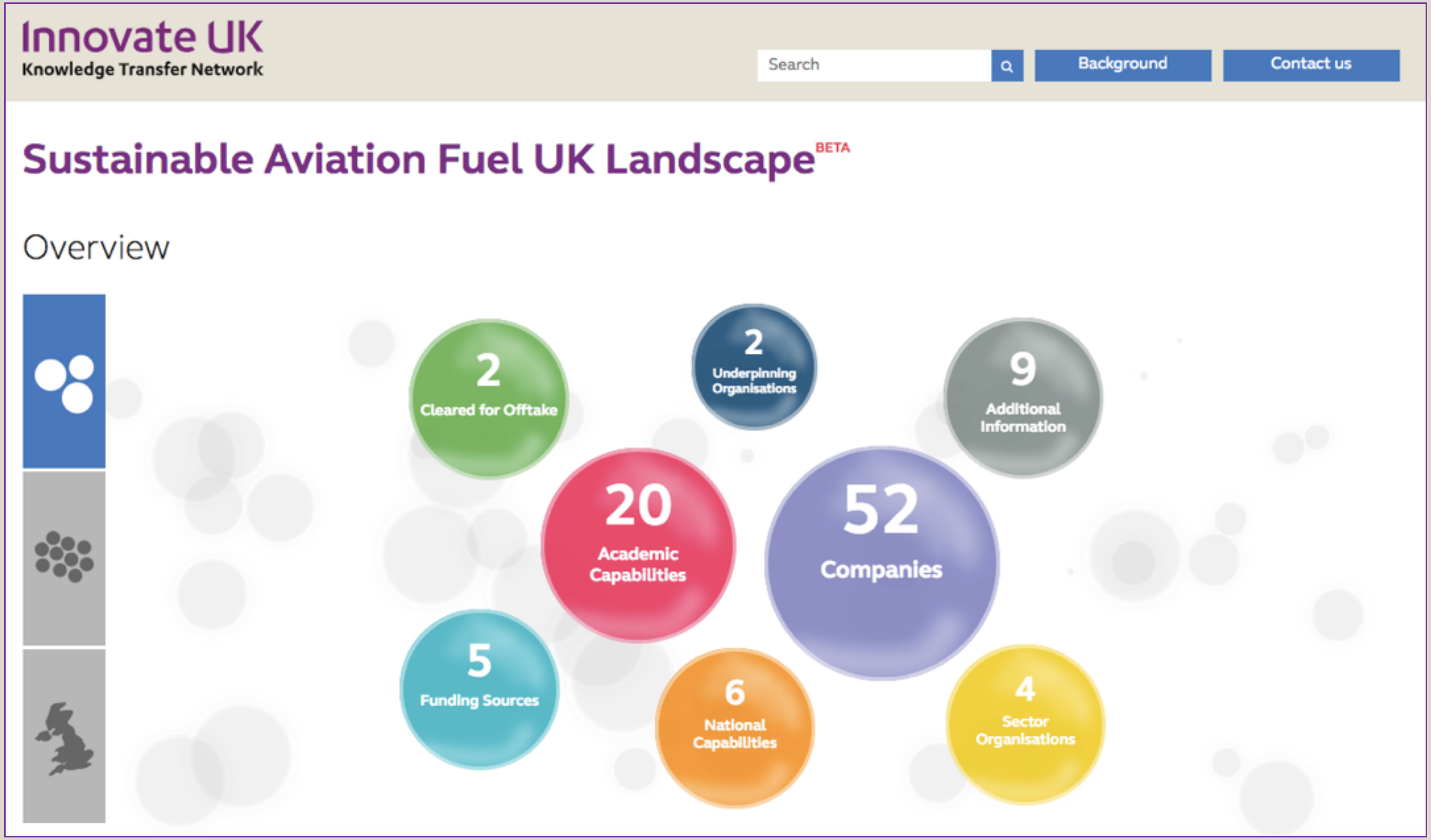
11

1. Fuel economics, commercialisation & scale up
2. Sustainability
3. Technical details
4. Logistics

Sustainable Aviation Fuel
Special Interest Group

https://saf.ktnlandscapes.com/

Deliverables



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www.ktn-uk.org @KTNUK
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Department for Transport

Sustainable Aviation Fuel
Special Interest Group

Deliverables

Across the whole supply chain...

107
companies supported

406
people in the SAF SIG network

82
introductions made

9
collaborations brokered

4
companies signed NDAs with a UK airline

Sustainable Aviation Fuel
Special Interest Group

Deliverables

Innovate UK
Knowledge Transfer Network

About

Industry-led framework to stimulate R&D in SAF

Aims & Objectives

Focus investment priorities along the supply chain

Raise awareness of the challenges

Themes:

1) Feedstock & Sustainability
2) Process & Economics
3) Infrastructure
4) Technical Specification

UK Innovation Landscape in Fuels

Analysis of innovative companies & projects in UK developing transport fuels

Feedstock
Biomass (1st gen)
Biomass (2nd gen)
Biomass (algae)
MSW (and its fractions)
Waste gases (CO, CO_2, H_2)
Plastic or tyres

Initial conversion Step

e.g. Chemo-catalytic,
Industrial biotech.
Thermochemical
Electrochemical

Initial products
C1 & H_2 (Syngas)
C1s (Methane, Methanol)
C2s (Ethanol)
C3/C4 (Propanol, Butanol)

Further conversion

+ Green Hydrogen
Chemo-catalytic

Higher octane products
Naphtha/ kerosene
Diesel
Jet A1

Alternative pathways
e.g. Hydro-cracking,
Transesterification
Hydrothermal liquefaction (HTL)

Other higher-carbon waste feedstocks
Waste cooking oil
Other waste hydrocarbons or biomass

Analysis of innovative companies & projects in UK developing transport fuels

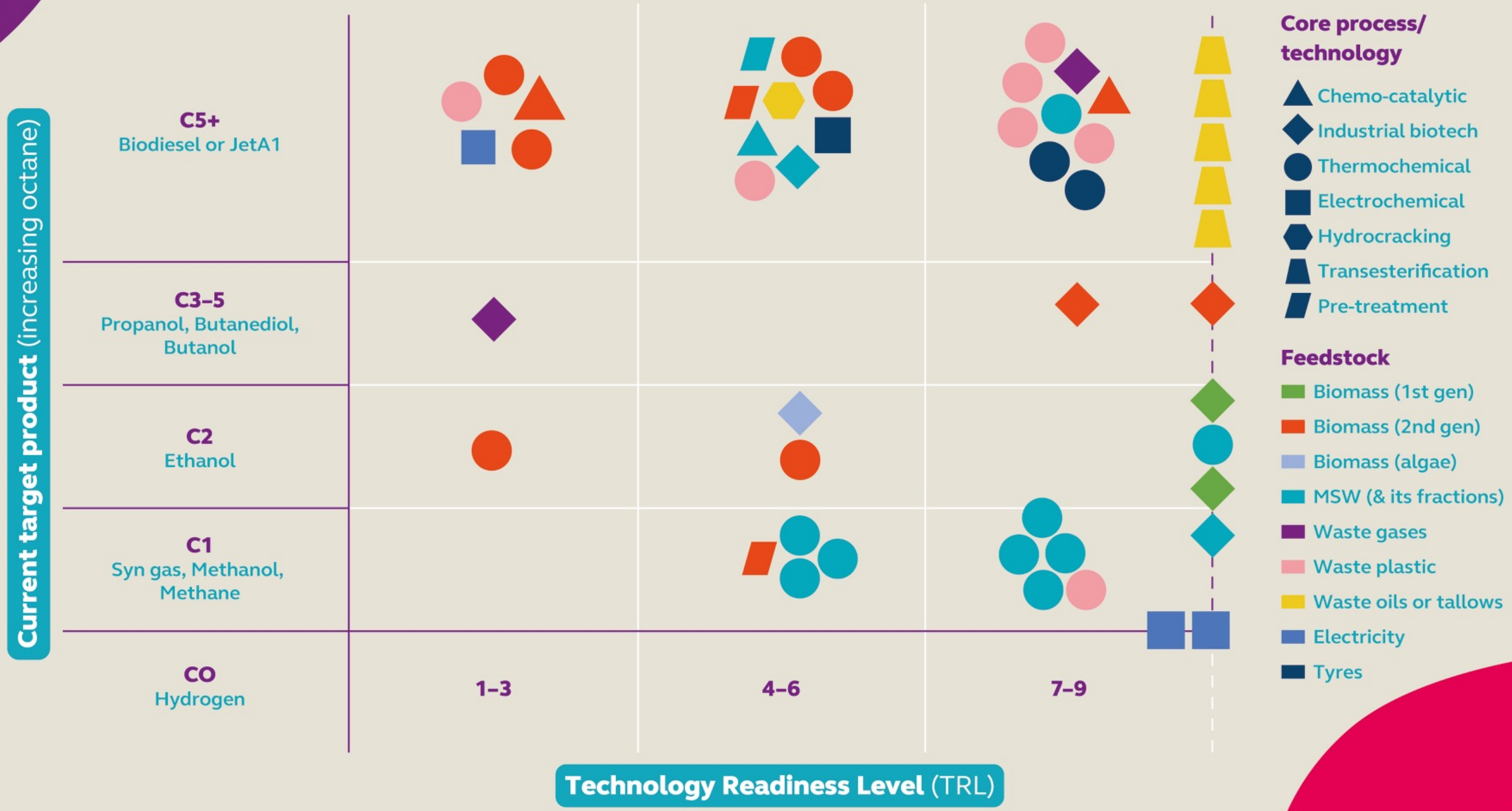
We would ask ourselves:

- *What type of feedstocks are they looking at?*
- *What types of process are innovators in the UK focusing on?*
- *Which fuel products are they focusing on?*
- *What Technology Readiness Level (TRL) are they at and who is close to commercial scale (TRL 9)*
- *Are any of them looking at RTFO & ASTM approved routes?*

Analysis of innovative companies & projects in UK developing transport fuels

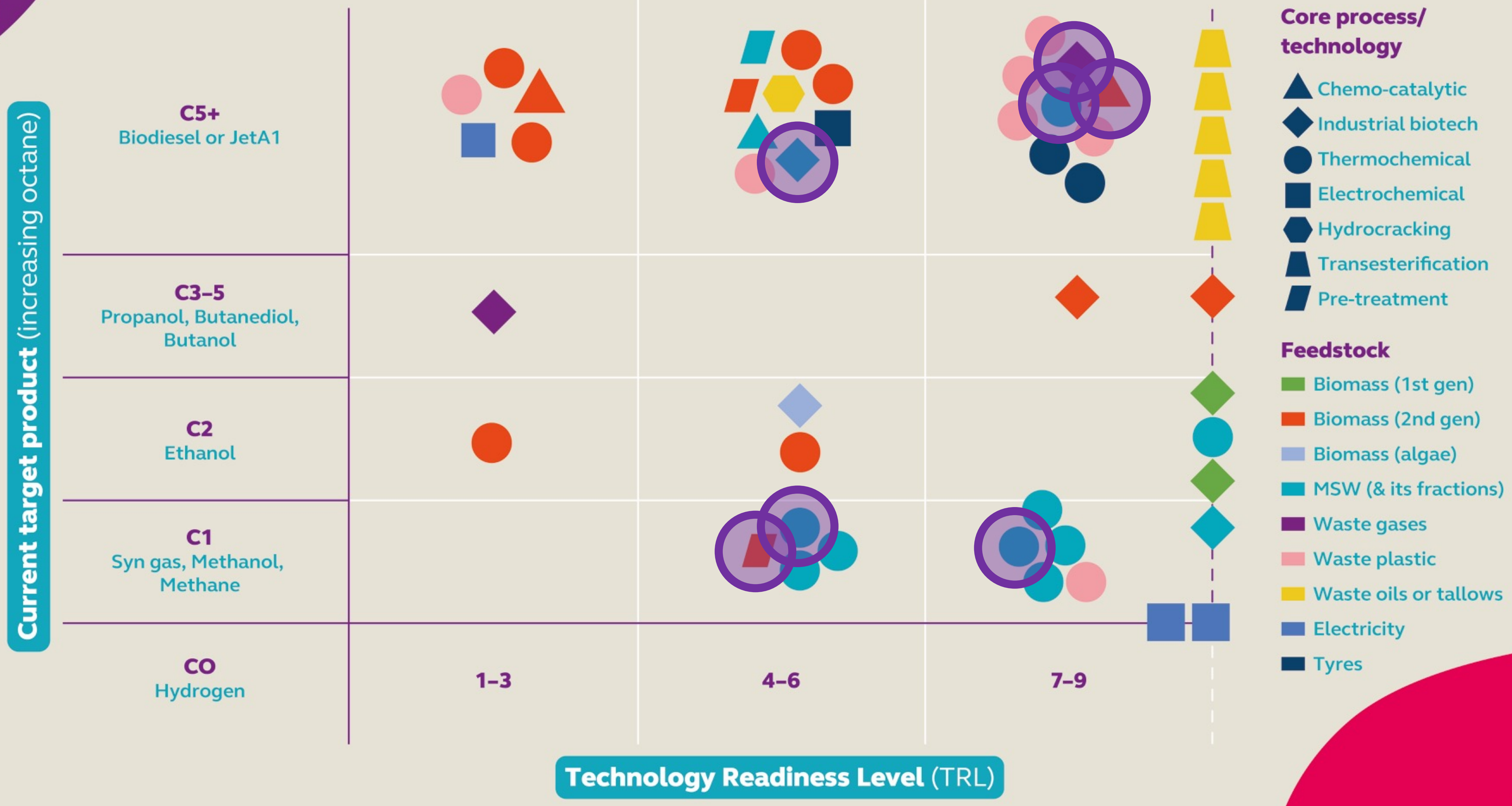
We **analysed 49 companies/ projects** according to our own research (from publicly available information) and knowledge against the following criteria:

- An estimation of the stage of process development using the **Technology Readiness Level (TRL) index** (1-3, 4-6, 7-8 or commercial phase 9)
- **Feedstock** (2nd gen biomass, waste gases, etc)
- **Technology/ Process** (Thermochemical, Electrochemical, etc)
- **Current product focus**
  - **C0** (i.e. Hydrogen), **C1** (e.g. Syngas or Methanol, or Methane), **C2** (Ethanol), **C3-C5** (Propanol, Butanediol or Butanol, etc), **C5+** (e.g. Biodiesel, JetA1)



https://ktn-uk.co.uk/news/analysis-of-uk-companies-producing-carbon-molecules-of-potential-value-to-a-uk-sustainable-aviation-fuel-industry

F4C Winners



Current target product (increasing octane)
C5+
Biodiesel or JetA1
C3–5
Propanol, Butanediol, Butanol
C2
Ethanol
C1
Syn gas, Methanol, Methane
CO
Hydrogen
1–3
4–6
7–9
Technology Readiness Level (TRL)
Core process/ technology
Chemo-catalytic
Industrial biotech
Thermochemical
Electrochemical
Hydrocracking
Transesterification
Pre-treatment
Feedstock
Biomass (1st gen)
Biomass (2nd gen)
Biomass (algae)
MSW (& its fractions)
Waste gases
Waste plastic
Waste oils or tallows
Electricity
Tyres

Sustainable Aviation Fuel

Special Interest Group

Analysis of 49 companies producing carbon molecules of potential value to a UK sustainable aviation fuel (SAF) industry

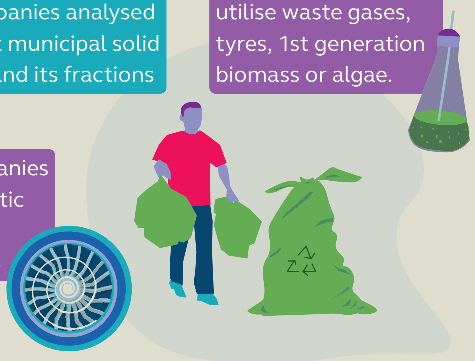
www.safsig.co.uk @ktn_safsig

Feedstock

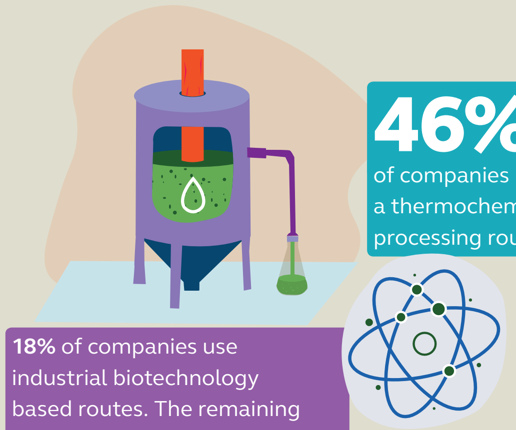
25% of companies analysed convert municipal solid waste and its fractions

24% of companies utilise 2nd generation biomass, whilst **35%** utilise waste gases, tyres, 1st generation biomass or algae.

14% companies utilise plastic waste to make fuels



Technology



46% of companies use a thermochemical processing route

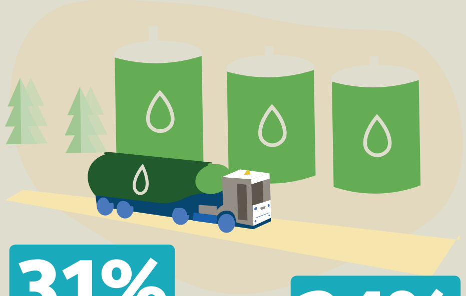
18% of companies use industrial biotechnology based routes. The remaining **36%** use transesterification, chemocatalytic, electrochemical or hydrocracking processes

Product

55% of companies produce high-octane fuels like diesel or Jet A1

45% of companies are developing simpler, less-energy dense fuel products (e.g. syngas, hydrogen, methanol, ethanol) for non-aviation fuel markets

Scale



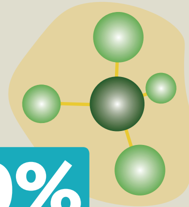
31% of companies operate at **TRL 7-8**, **31%** at **TRL 4-6** and **14%** at **TRL 1-3**

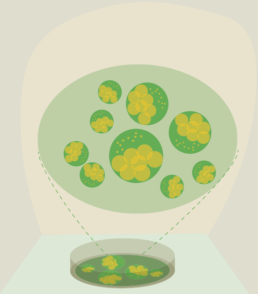
24% of companies are operating at commercial scale

Policy and Approval

Of the 49 companies, KTN estimates:

45% of companies may be producing molecules already approved under ASTM D4054





40% of companies may be producing molecules, if subjected to further refining, could meet ASTM D4054 approval or be fed into a conversion process

81% of companies are using feedstocks that meet RTFO* conditions but only **43%** are working to an ASTM approved route **and** a RTFO approved feedstock

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*Renewable Transport Fuel Obligation

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Knowledge Transf

Thank You

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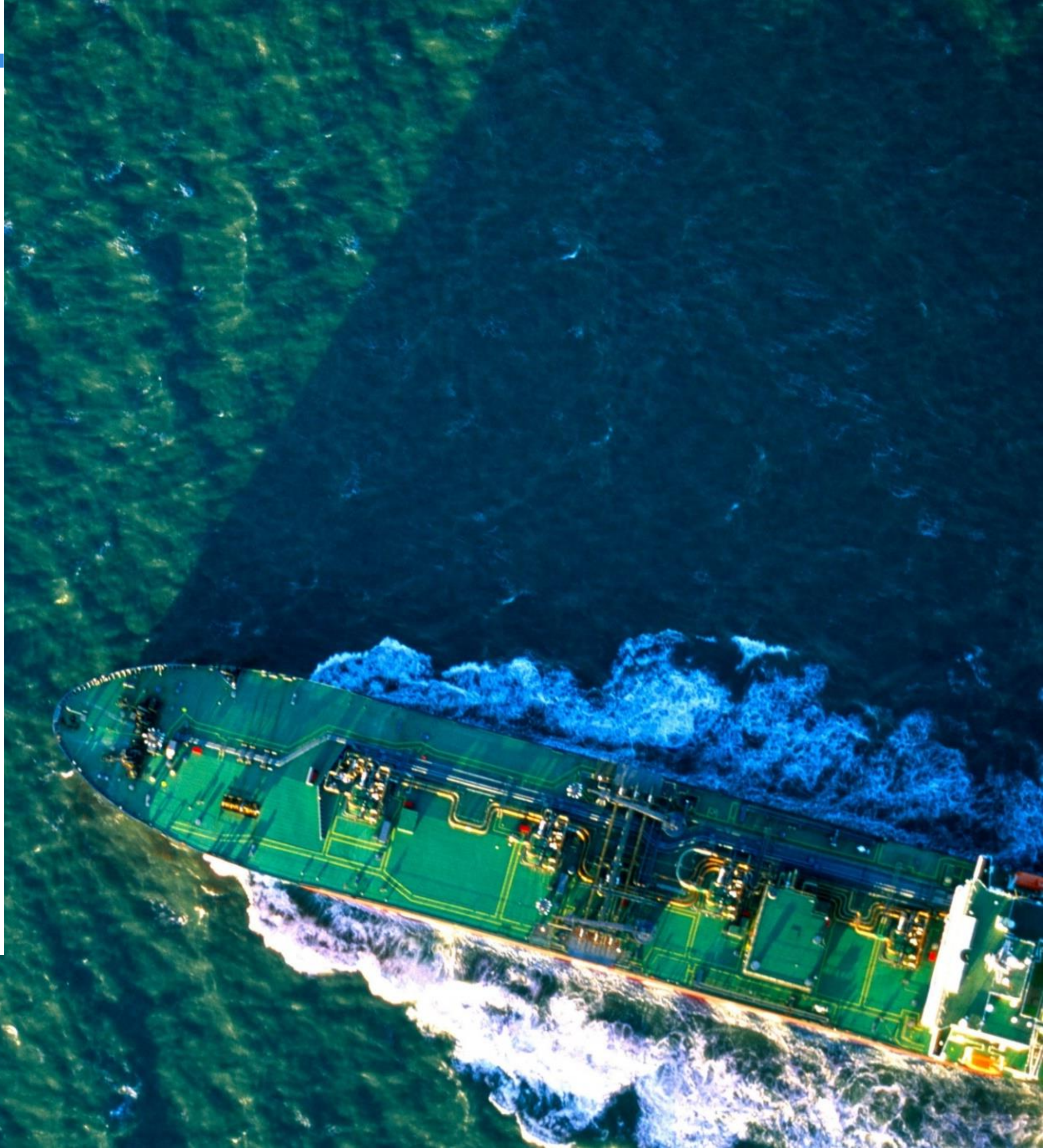
Low Carbon Transport:
Engineering the Fuels of the Future

Decarbonising shipping

Edward Fort BSc, CEng, FIMarEST
Global Head of Engineering
Lloyd's Register, Marine & Offshore

Lloyd's Register



Decarbonising shipping: the shipping industry...

- Over **10 billion tonnes of goods** currently transported by sea each year
- equivalent to approximately **90% of the goods** traded worldwide
- with **lowest carbon emissions** per cargo tonne mile in any transportation sector
- consuming approximately **300 million tonnes** of fuel oil per year
- **unrealistic** freight rates?

Decarbonising shipping: industry ambition...

Absolute reduction in total GHG emissions of at least 50% by 2050 compared to 2008 levels and pursue efforts to phase out entirely.

Reduction in carbon intensity of ships (CO2 emissions per cargo tonne nautical mile) by an average of at least 40% by 2030 and pursue efforts towards 70% by 2050 compared to 2008 levels.

International Maritime Organisation

Decarbonising shipping: the challenge...

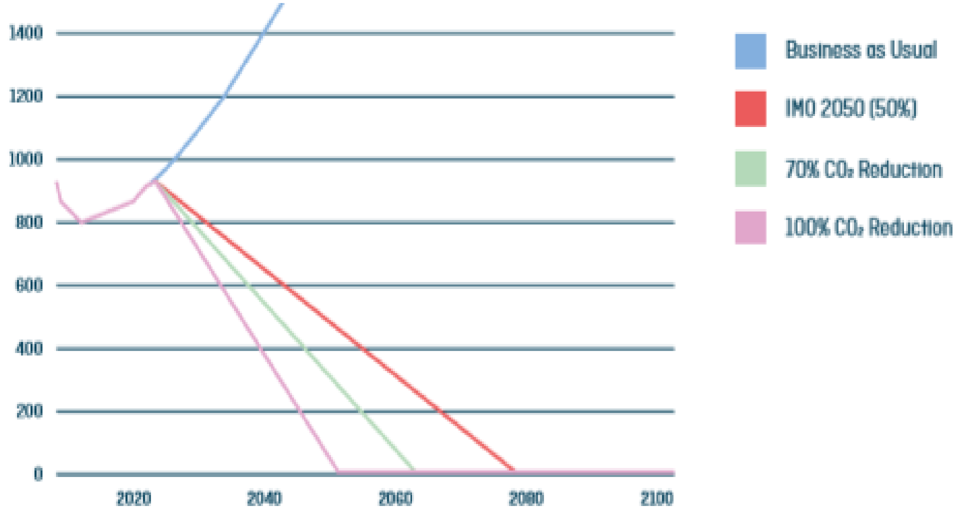
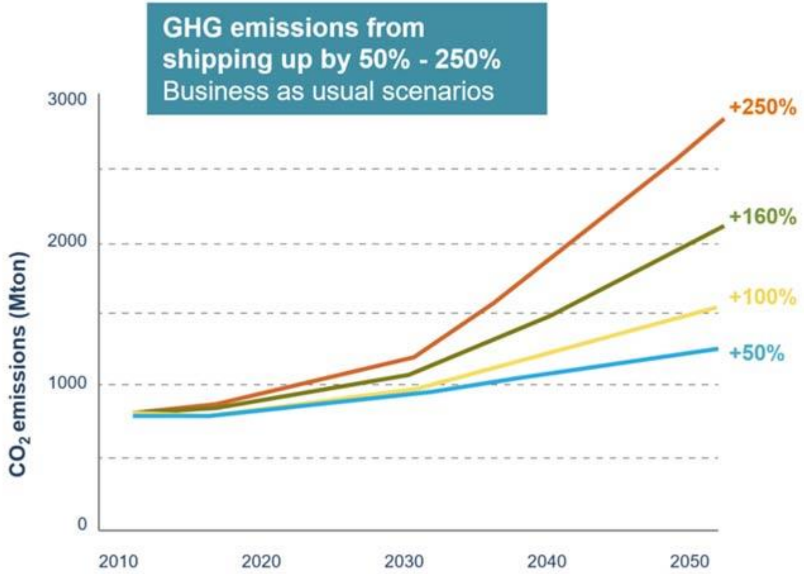


Figure 2.
Global fleet's CO_2 targets and trajectories under IMO targets (million tonnes of CO_2)



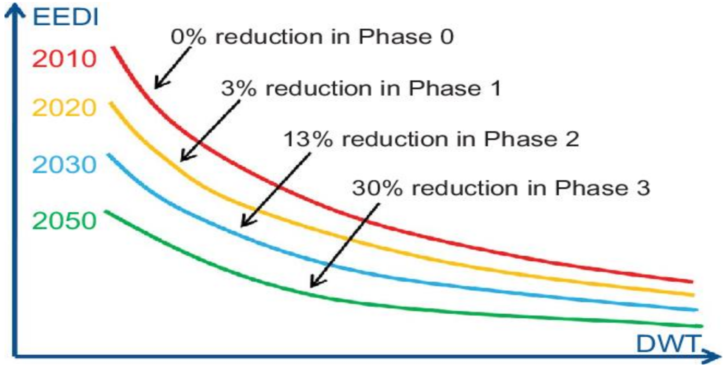
Decarbonising shipping: candidate measures...

IMO currently considering short, medium and long term candidate measures

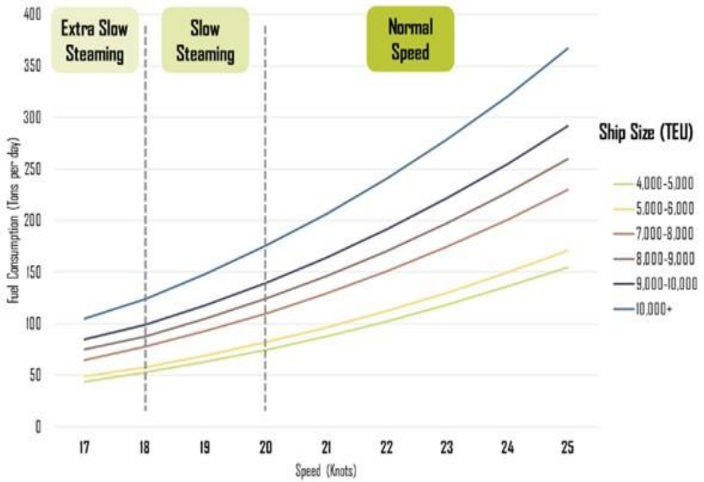
- reduction in energy demand
- use of renewable energy
- use of alternative fuels

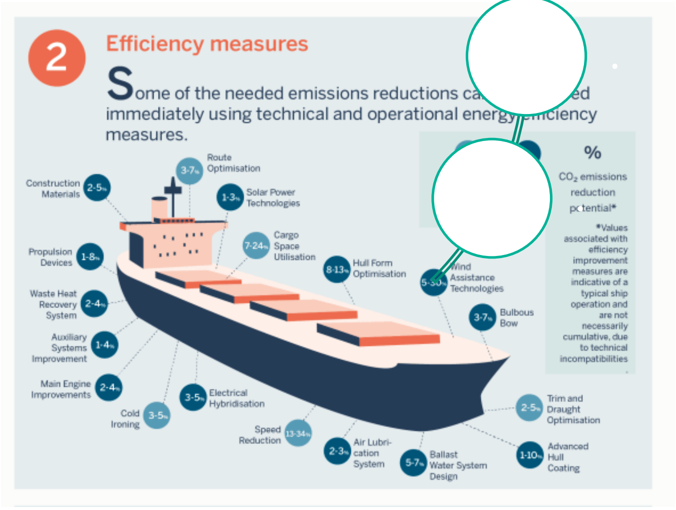
Regulations will enforce a mix of market based and technical measures

Decarbonising shipping: candidate measures...



reduction in energy demand

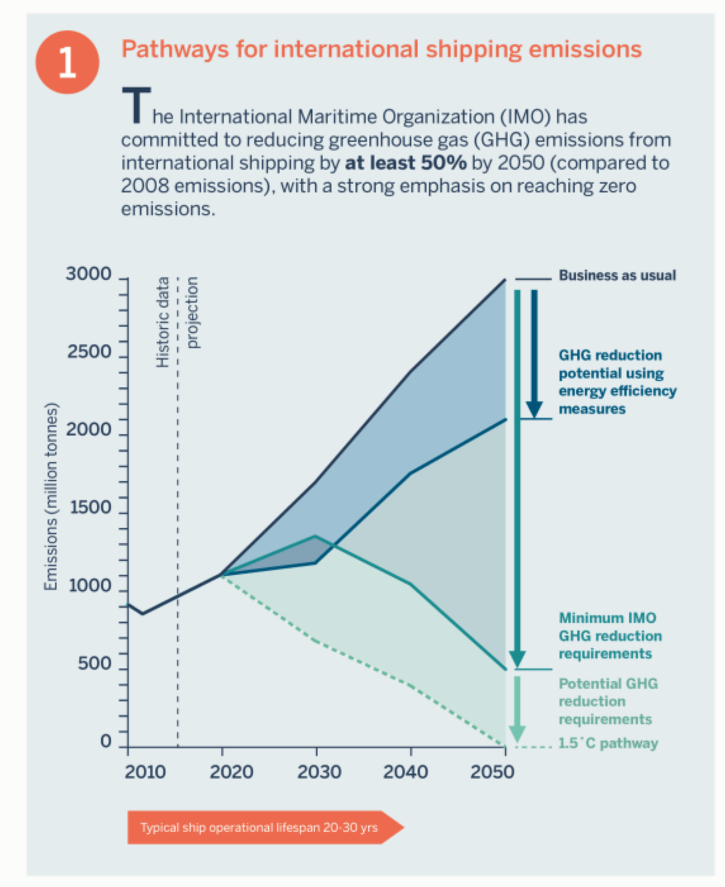


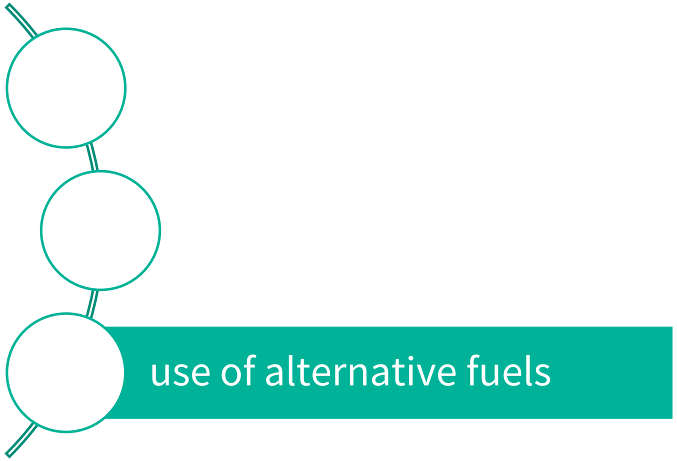


Decarbonising shipping: candidate measures...

use of renewable energy

Decarbonising shipping: candidate measures...





Decarbonising shipping: future fuel options...

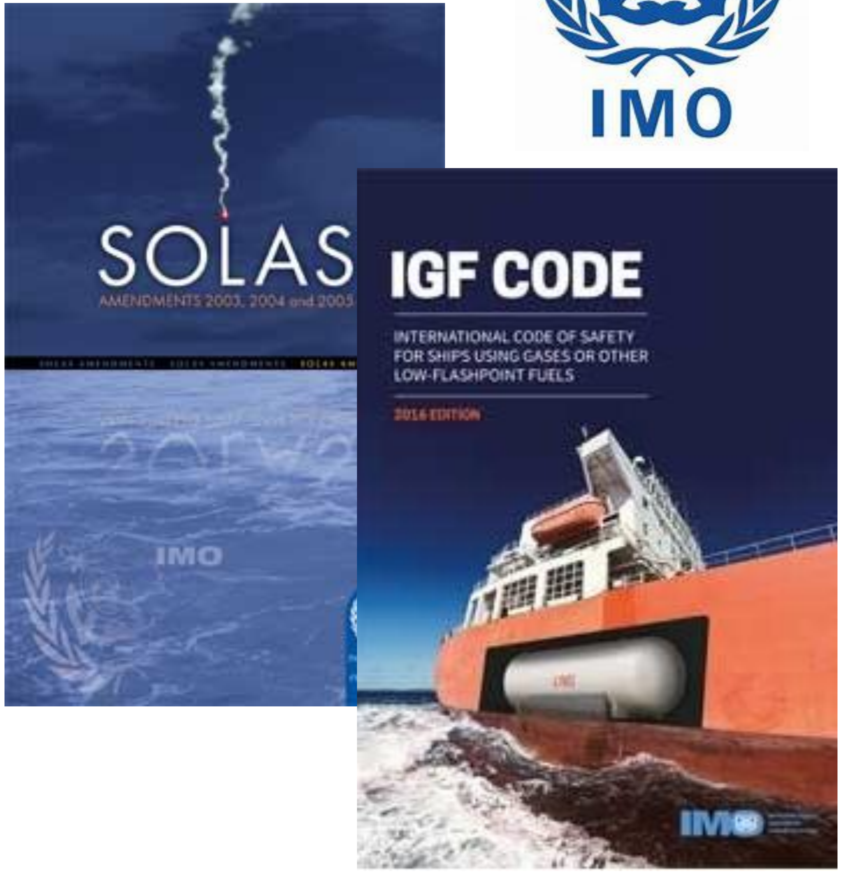
Safety Of Life At Sea (SOLAS)

Until 2017 SOLAS permitted only fuels with a flash point over 60 Deg.C

In 2017 the International Gas Fuel (IGF) Code was introduced allowing the use of gas fuels onboard ships

The Code provides detailed technical requirements for using natural gas

Other fuels permitted subject to risk assessment but no detailed requirements are provided



Ideal characteristics for alternative marine fuels

- Zero carbon/carbon neutral > at point of use and down the supply chain
- Renewably/sustainably sourced
- Lowest production energy intensity > lowest cost
- Uses existing infrastructure > worldwide availability
- Highest volumetric energy density > retain operational profiles
- Safe to use onboard ship!

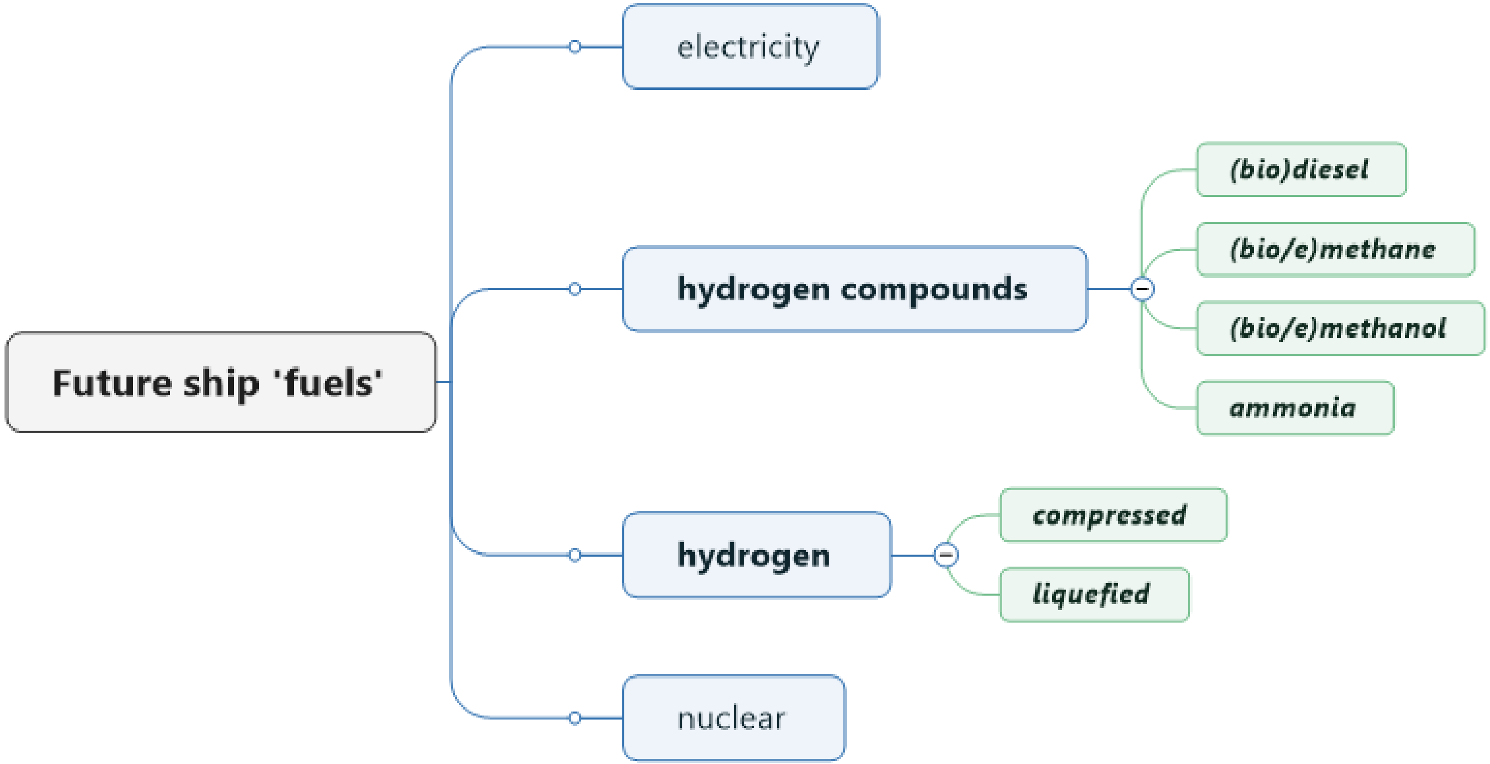
Decarbonising shipping: future fuel options...

Transition to LNG -

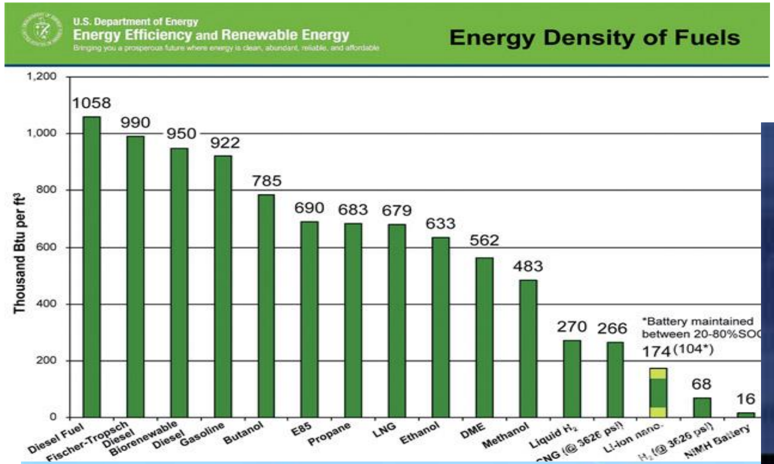
Marine industry is successfully adopting liquefied natural gas (LNG) as fuel

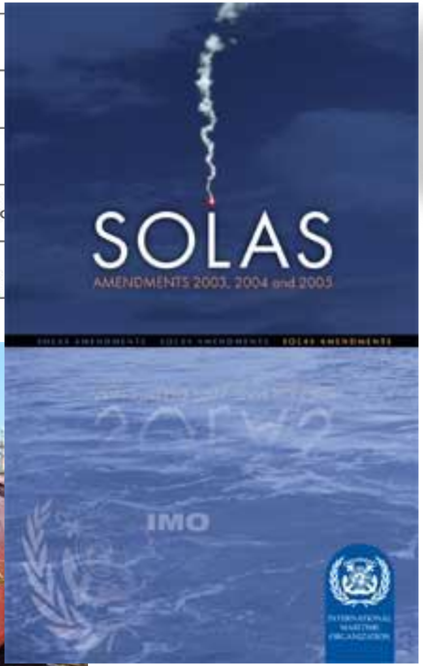
However it is important to recognise the industry has long experience with the transportation of LNG as a cargo with an excellent safety record

Decarbonising shipping: future fuel options...

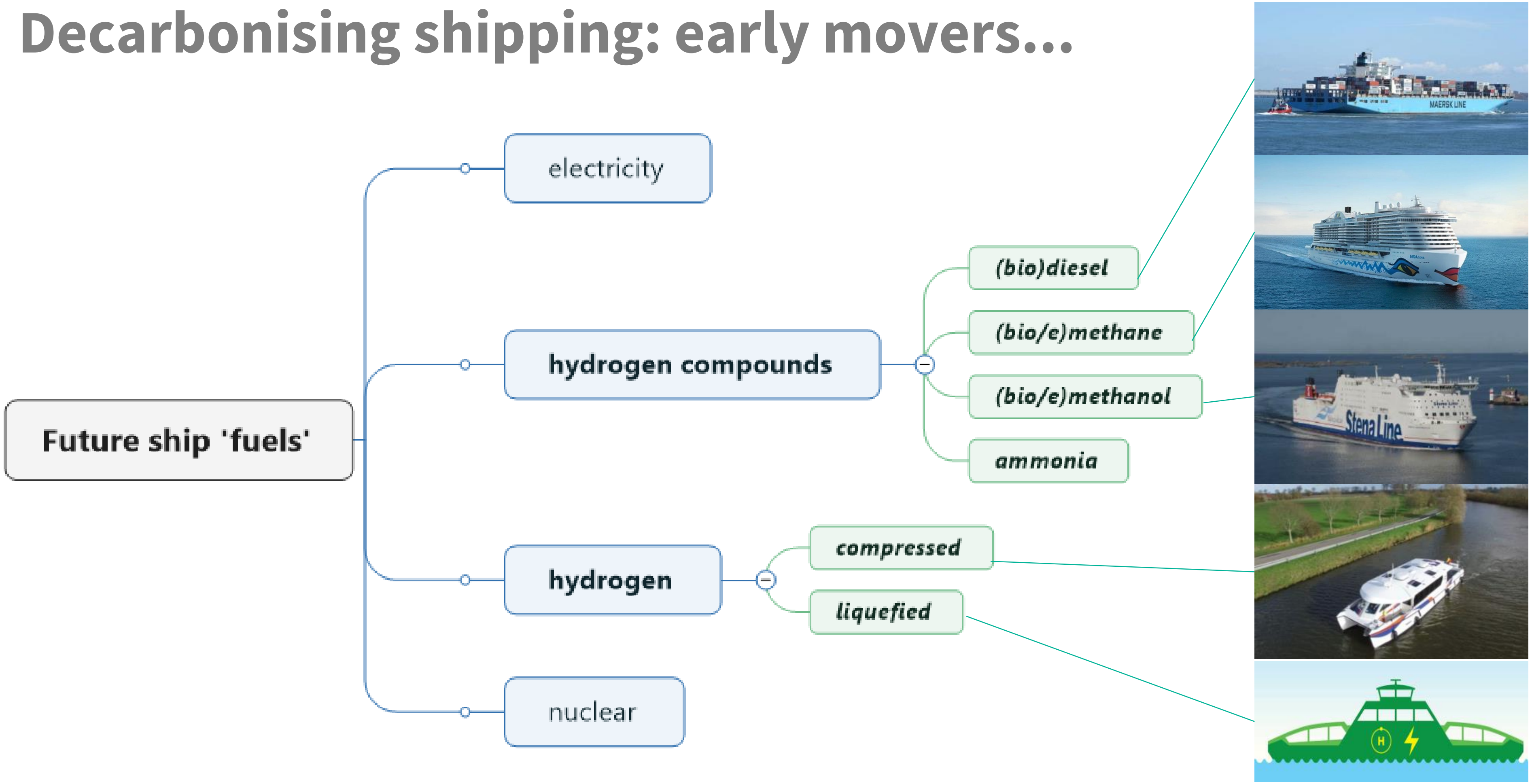


Decarbonising shipping: future fuel challenges...





Decarbonising shipping: early movers...



Thank you

For more information please contact:

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