A long(ish) view of sustainable energy

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- My perspective
- Renewable electricity
- Transport energy
- Hydrogen
- Conclusions

Perspective

My career journey

UNIVERSITY OF BIRMINGHAM

FINA

Imperial College London

FT FINANCIAL TIMES

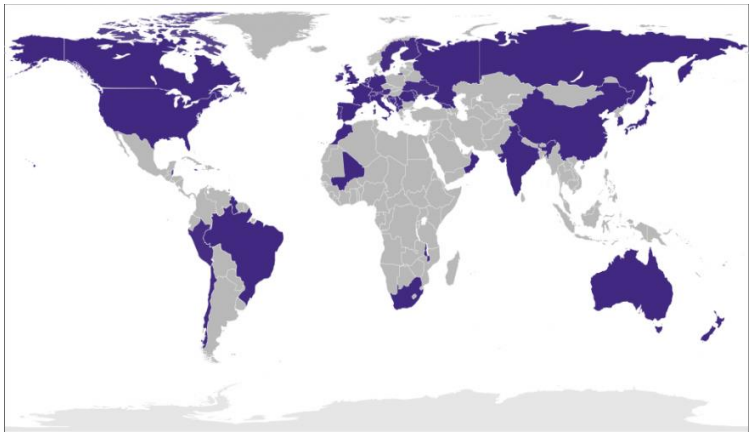
ATKEARNEY

E4tech

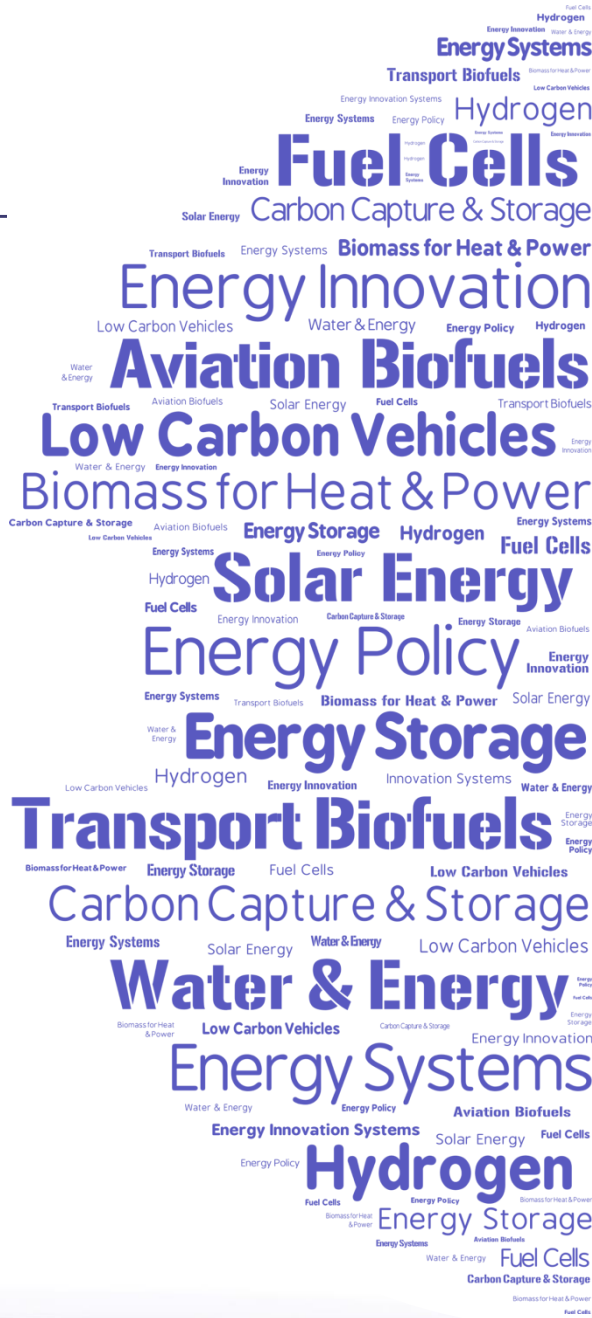
Strategy | Energy | Sustainability

E4tech: Strategy | Energy | Sustainability

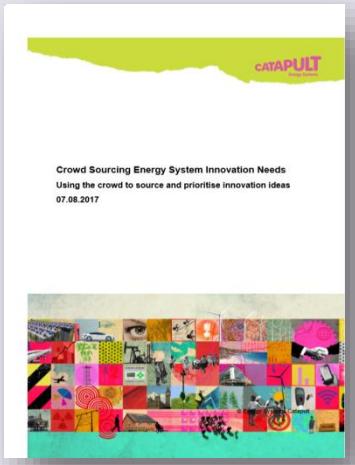
- International consulting firm, offices in UK and Switzerland
- Focus on sustainable energy
- 21 years old this year, always independent
- Deep expertise in technology, business and strategy, market assessment, techno-economic modelling, policy support…
- Spectrum of clients from start-ups to global corporations

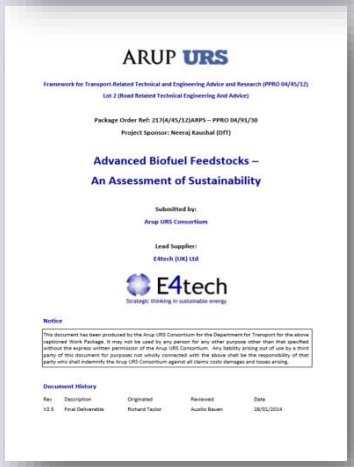


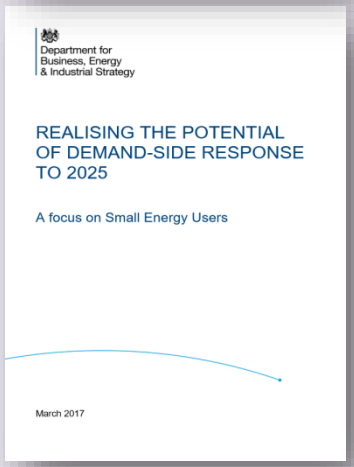
RWE The energy to lead · IFC · Coca-Cola · International Energy Agency · IATA · Goldman Sachs · LONDON · TOYOTA · Linde · bp · DAIMLER · Fraunhofer · NISSAN · ofgem · BRITISH AIRWAYS · CARBON TRUST · CLSA ASIA-PACIFIC MARKETS · e·on · Imperial College London · Unilever · ROLLS ROYCE

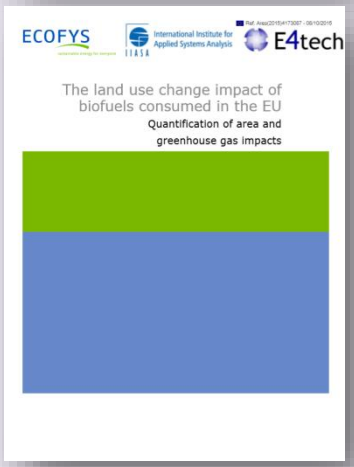


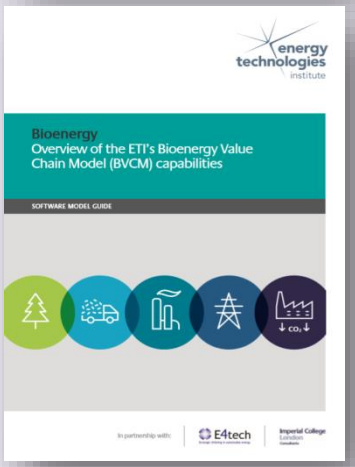
Some of E4tech's (public) work





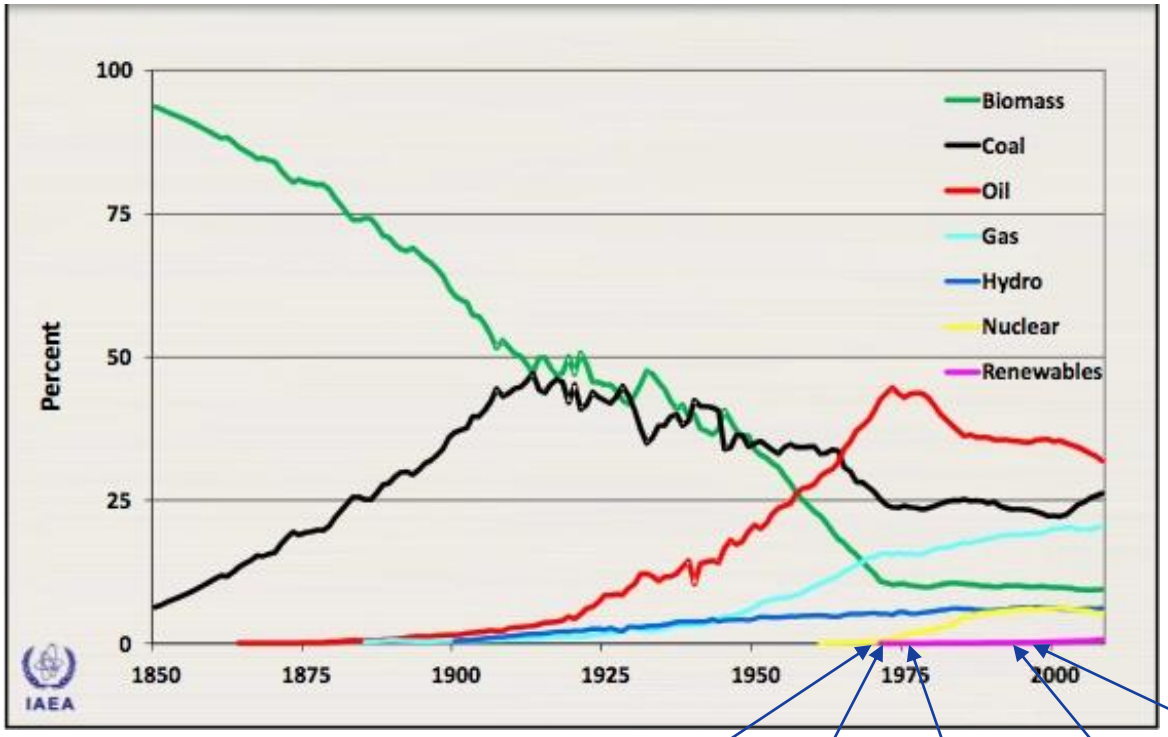






Long view and long(ish) view

Shares of global primary energy forms

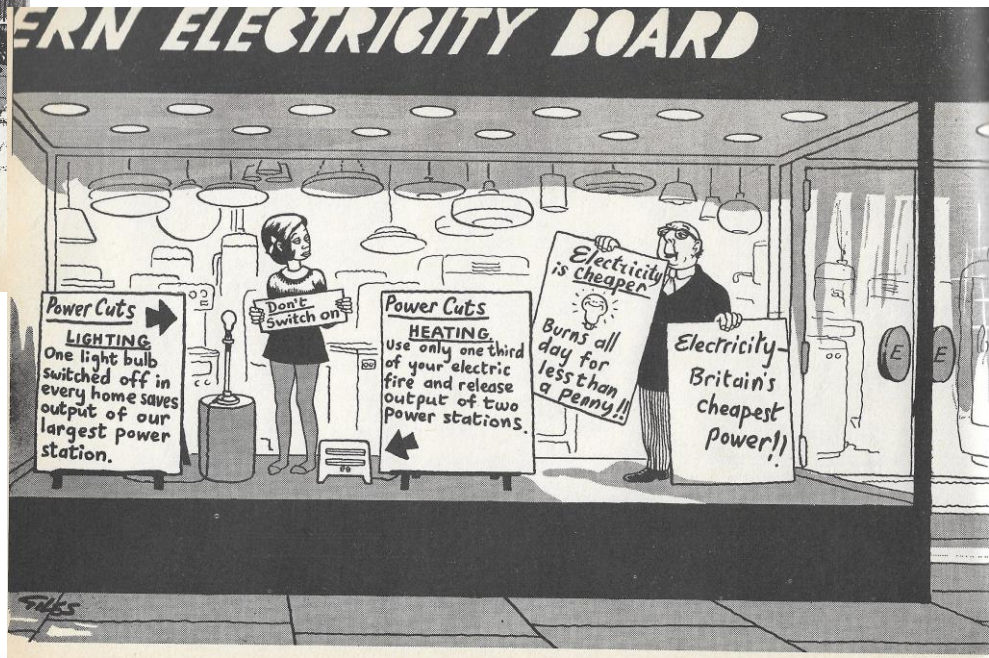


E4tech

Residential energy in 1972

"This gentleman claims your boy sold his boy these two goldfish for his entire stock of coal."

Daily Express, February 1st, 1972

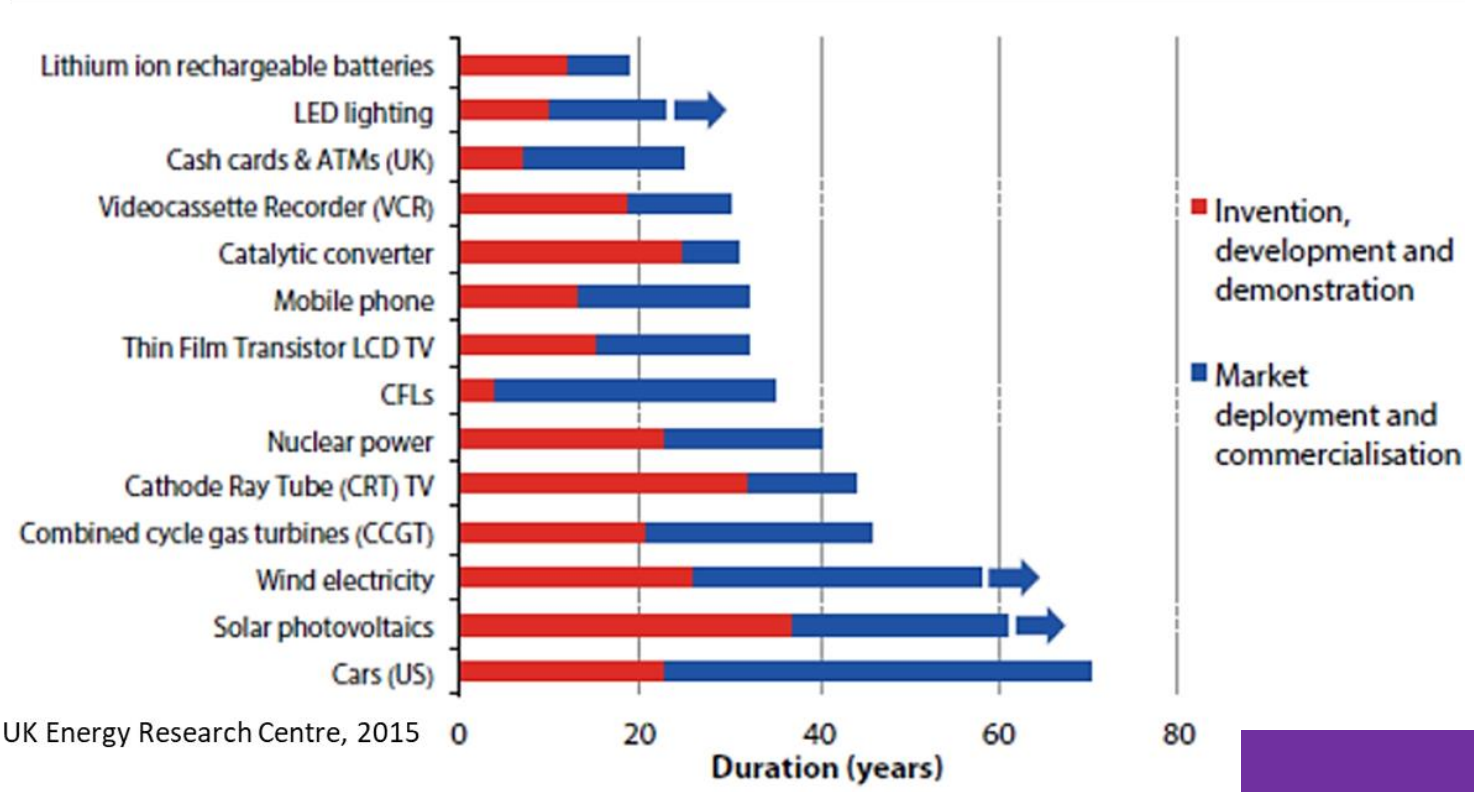


"With the emergency ending I think we can replace the old display cards, Miss."

Daily Express. March 2nd. 1972

‘Hardware is hard’

Time taken for development and commercialisation of a range of innovations



UK Energy Research Centre, 2015

Transitions take a long time

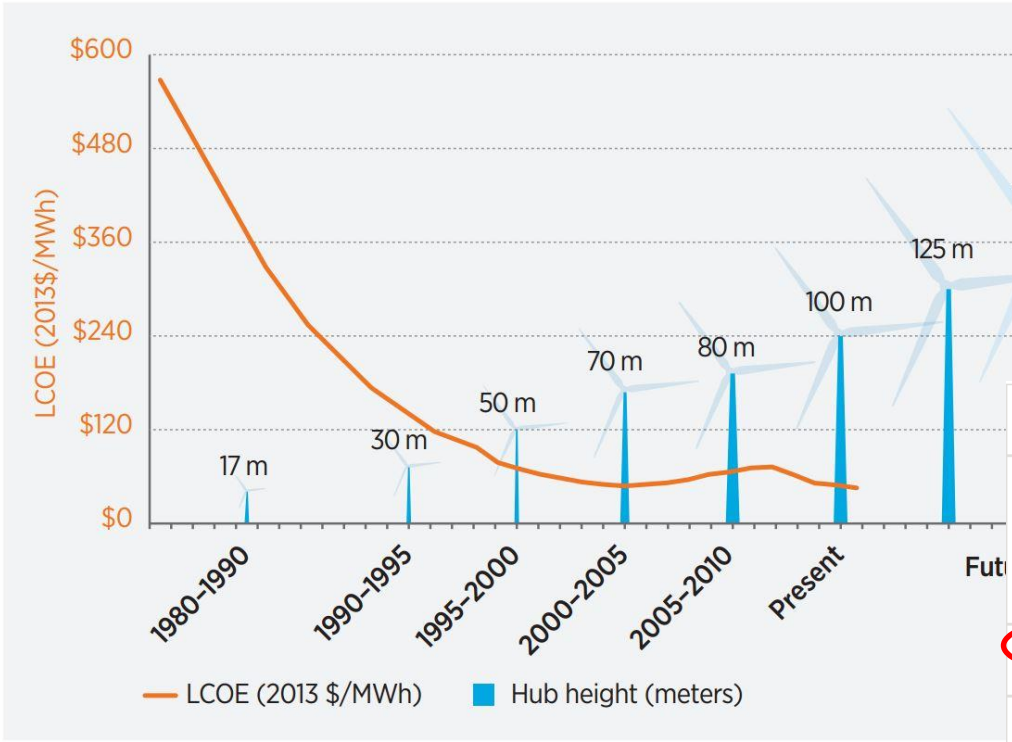
Renewable electricity

Wind – economic success, but public discourse still mixed

Worse yet - these stupid bird mincers will NEVER generate enough power to offset their construction, transportation and installation! They are certainly NOT "green". They actually have to be fed electricity to keep them turning in periods of low wind, to prevent their bearings seizing or flat-spotting!

People care about life cycle impacts

Scale-up of wind technology has supported cost reductions.

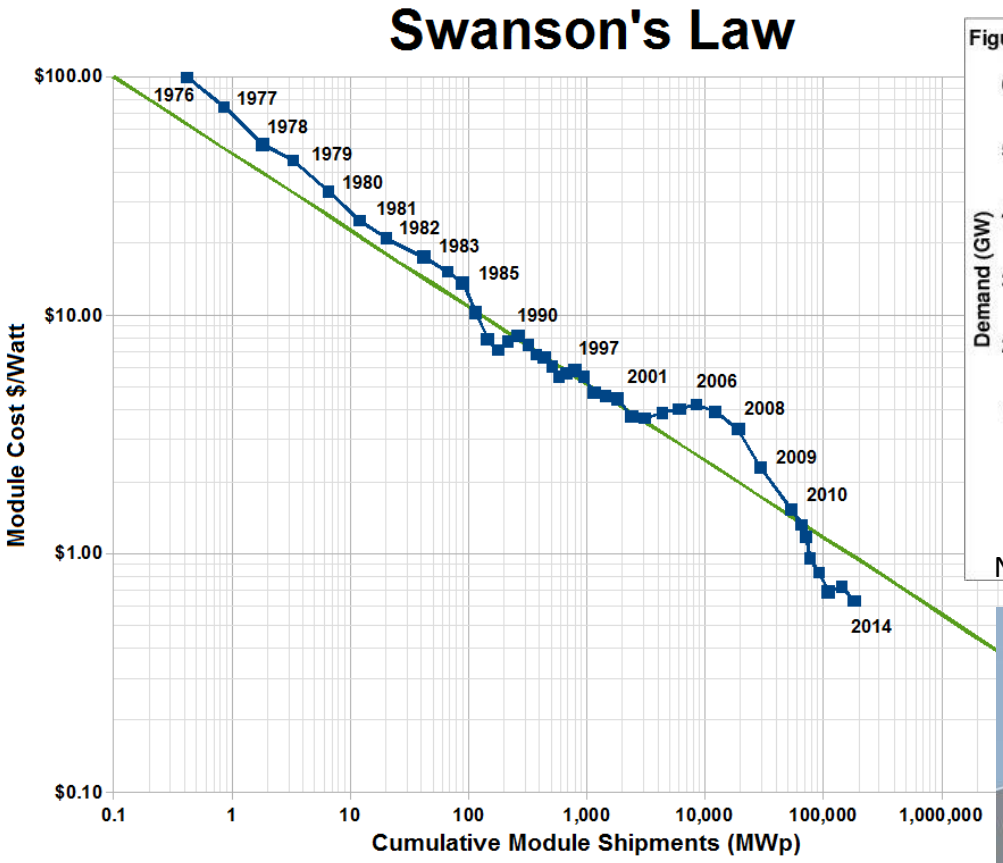


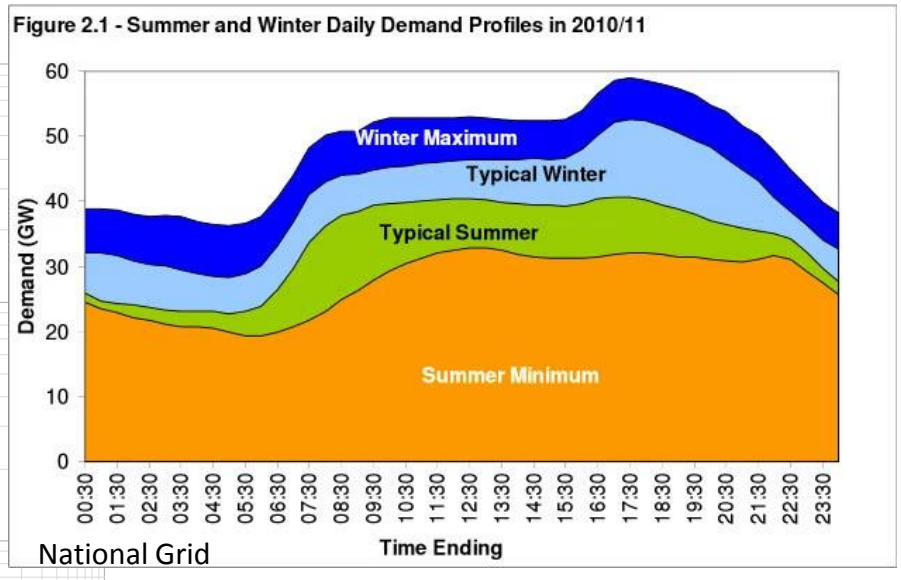
Note: LCOE is estimated in good to excellent wind resource sites (typically those with average wind speeds
federal production tax credit. Hub heights reflect typical turbine model size for the time period.

US Department of Energy

Technology	Energy payback period (years)	Expected lifetime of technology (years)	Reference
Solar PV modules	0.5–1.8 1.5	25 30	Fthenakis (2012) Raugei et al (2012)
Wind turbines (large)	0.25–0.75	20–25	Martinez et al. (2009)
Concentrated solar thermal (CST), parabolic trough	2	30	Desideri et al. (2013)
Nuclear (high-grade uranium)	6.5	30	Lenzen (2008)
Nuclear (low-grade uranium)	14	30	Lenzen (2008)

Solar – huge scale potential, some challenges in UK





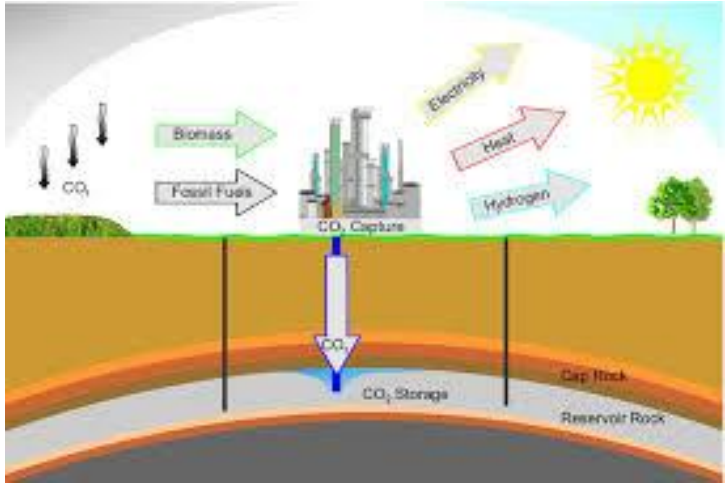
National Grid

CETC Solar

Simple scale mechanisms are very powerful

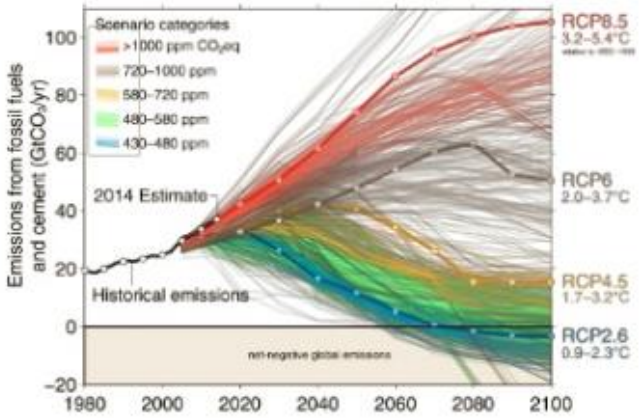
Delphi234

Biomass (and CCS) – probably essential despite drawbacks



The need for negative emissions

- IPCC AR5: Achieving 2°C is still possible, but it entails huge contributions from bioenergy - in most scenarios combined with Carbon Capture & Storage to go "negative".
- BECCS need → 2-10 Gt CO_2/yr in 2050 ≈ 5–25% of 2010 CO_2 emissions
- Current global mean removal of CO_2 by ocean and land sinks is 9.2 ± 1.8 Gt CO_2 and 10.3 ± 2.9 Gt CO_2, resp.



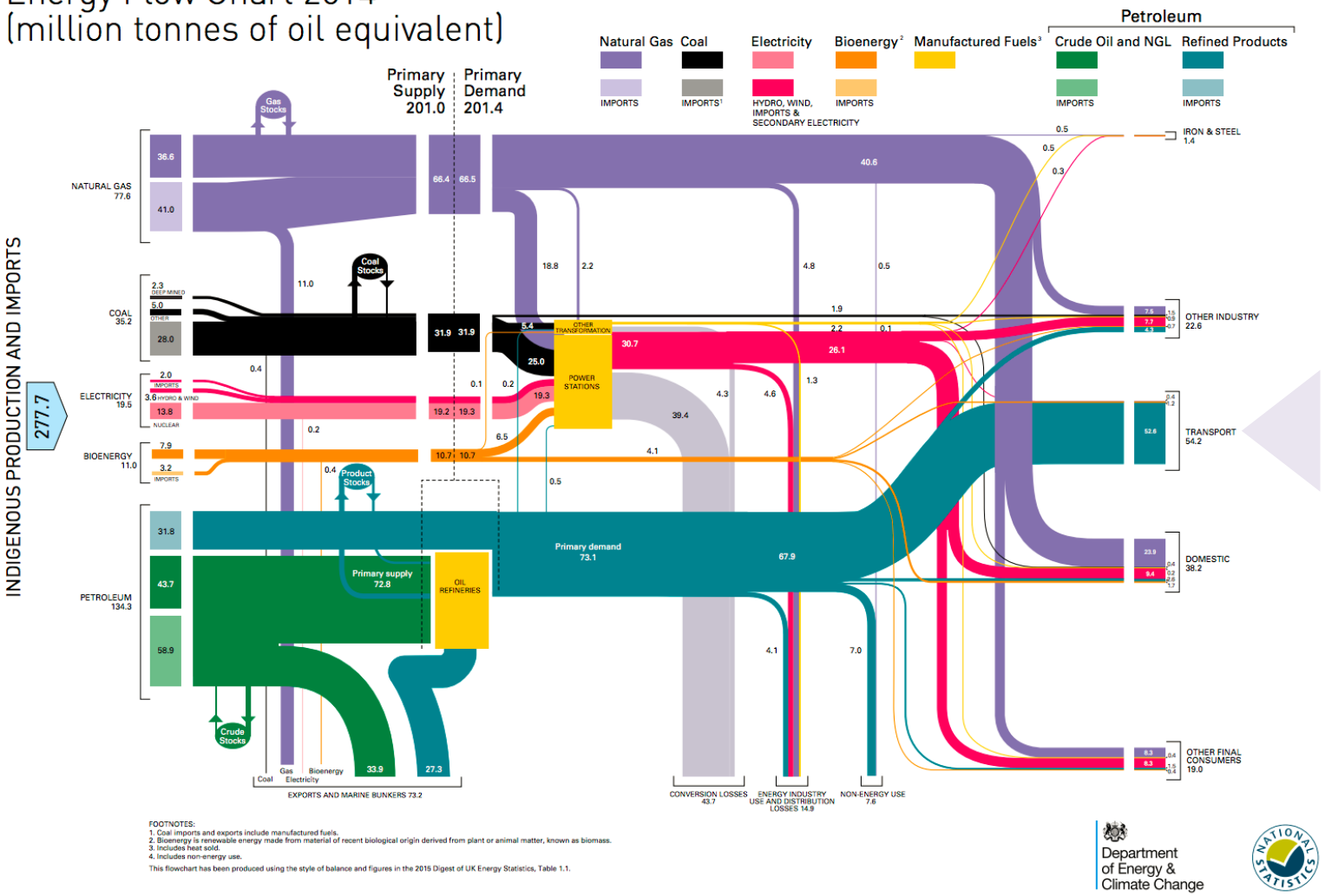
Data: CDIAC/GCP/IPCC/Fuss et al 2014

Fuss et al. (2014), Nature Climate Change

Huge market failures require long term investments

Transport energy

Transition = from this….



FOOTNOTES:
1. Coal imports and exports include manufactured fuels.
2. Bioenergy is renewable energy made from material of recent biological origin derived from plant or animal matter, known as biomass.
3. Includes heat sold.
4. Includes non-energy use.

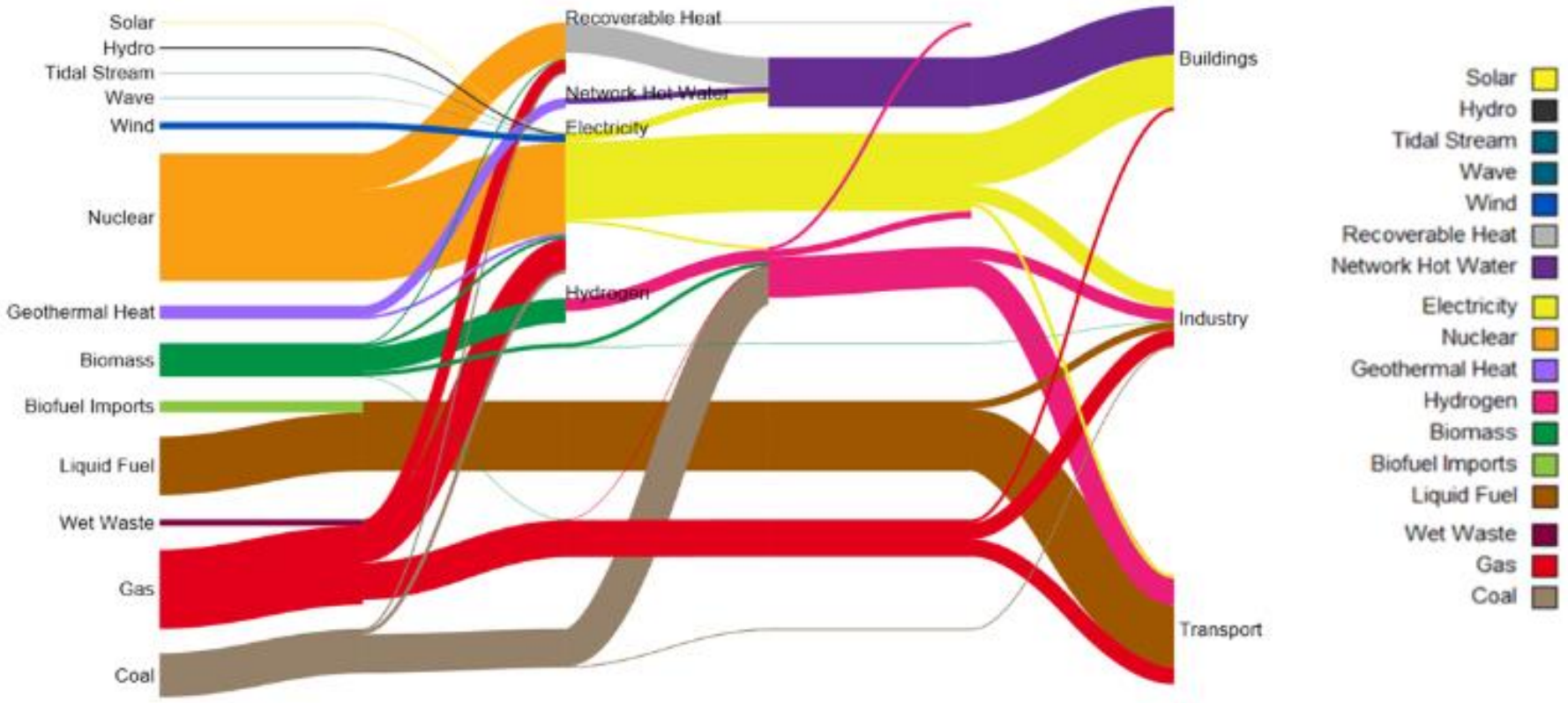
This flowchart has been produced using the style of balance and figures in the 2015 Digest of UK Energy Statistics, Table 1.1.

Department of Energy & Climate Change

Transport ~40% of UK energy

…To something like this

ETI 2050 scenario



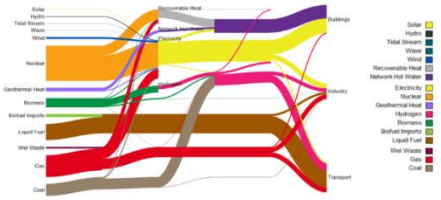
Source: ETI

Change needs to accelerate in energy and transport

1983

2018

2050



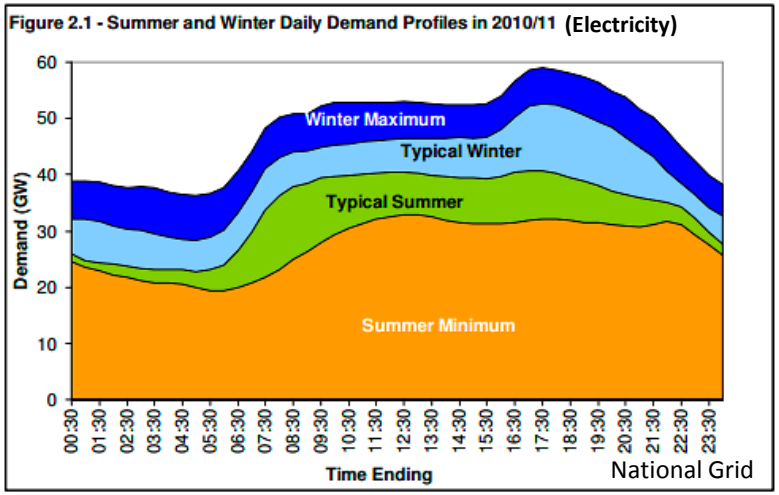
35 years

32 years

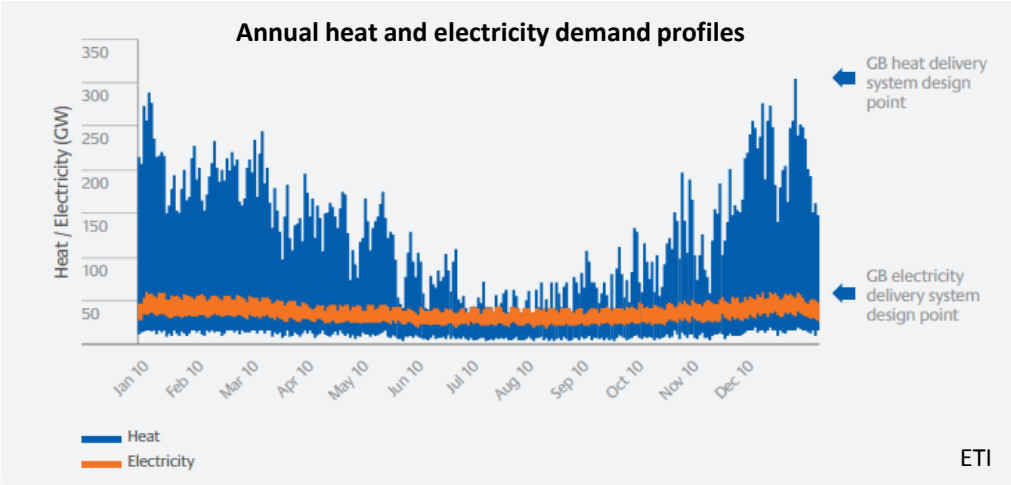
Somehow we need to speed up

Added complexity: the system is dynamic

Daily (and weekly)

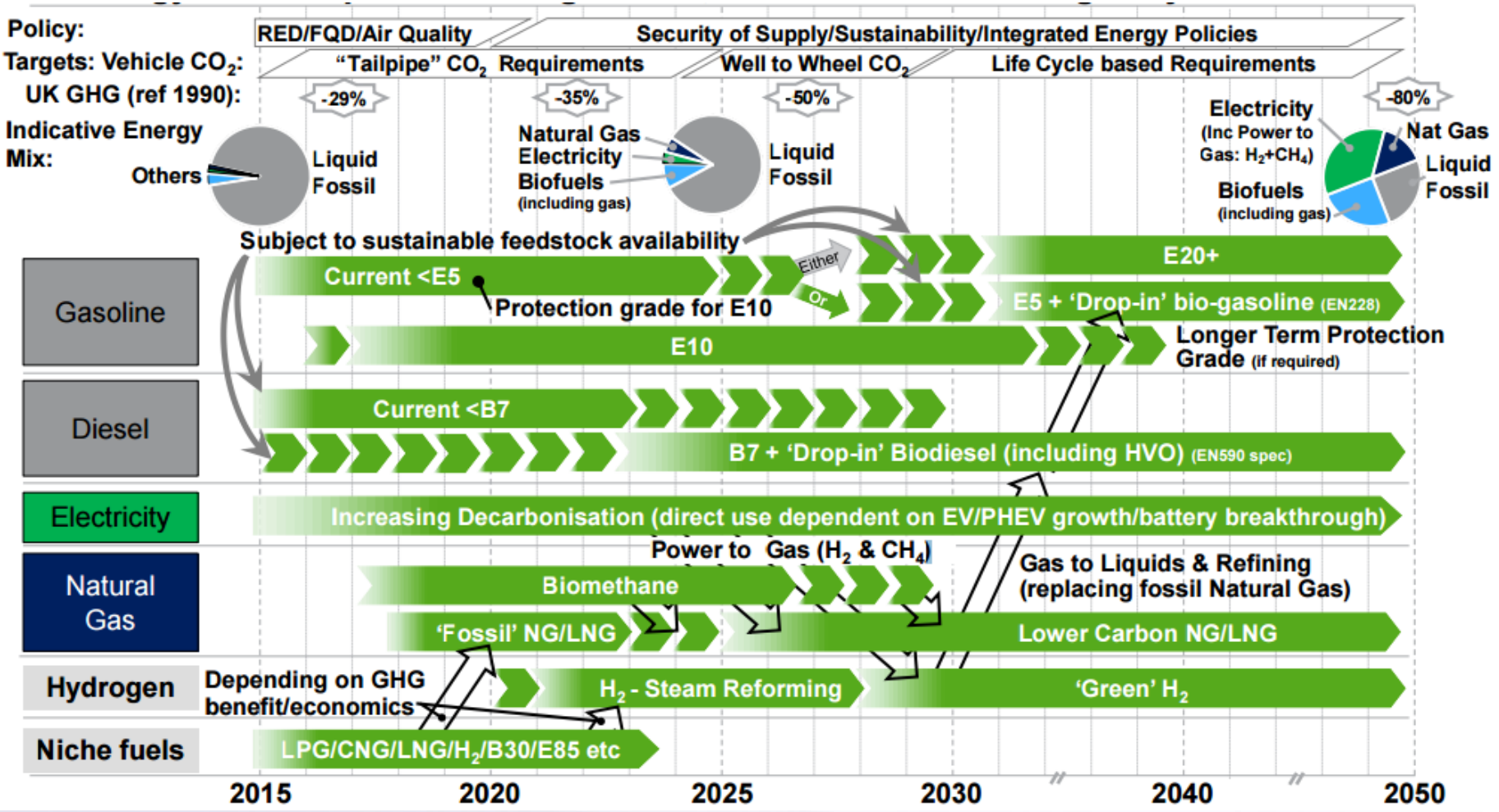


Seasonally (and annually)



Transport energy transition does not have a simple solution

UK Automotive Council Energy & Fuels Consensus Roadmap

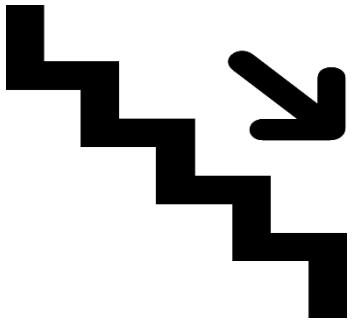


Different overall approaches to carbon reduction

Conventional thinking

Work through GHG reduction challenges in order of increasing difficulty:

1. Electricity
2. Heat
3. Industry
4. Transport



System thinking

Least cost optimised pathways that recognise key features of low carbon energy:

- Inflexible demand for energy services
- Long life assets
- Technology uncertainty
- Lock-in and path dependency

System-level approaches are most logical

System approach: UK-TIMES modelling for CCC's 5th Carbon Budget

- 5thCB proposed 57% reduction vs 1990, consistent with 80% reduction by 2050
- Cost effectiveness is key (costs more to get back on track later)
- EU 40% target for 2030 is not cost effective or 'fair' means to stay within 2°C warming (may increase)
- Transport central assumptions:
  - 2030 EU new car target 86g/km[1]
  - Plug in vehicles 9% of new LDV sales in 2020, 60% in 2030
  - FCEV buses 25% of 2030 sales
  - 24% HGV efficiency gain 2010-30
  - Some behavioural reductions
- Stronger use of H_2 in Max scenario

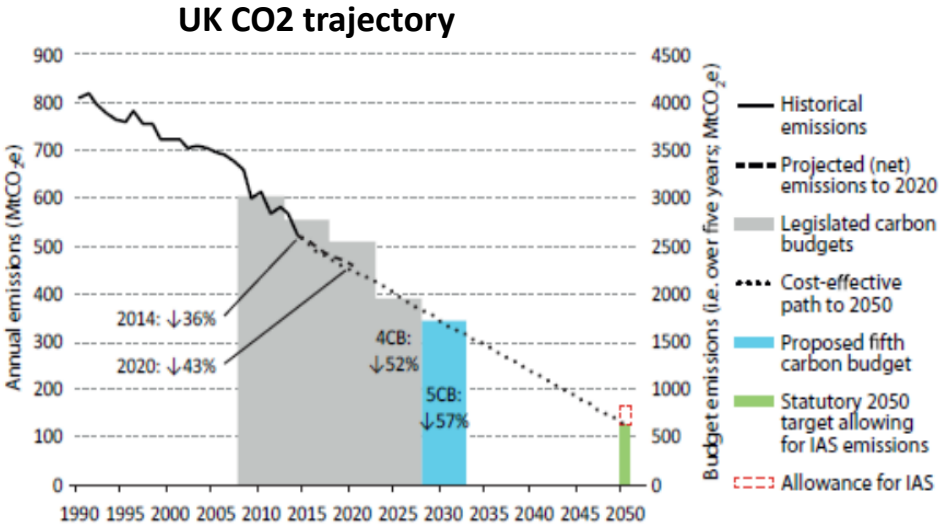
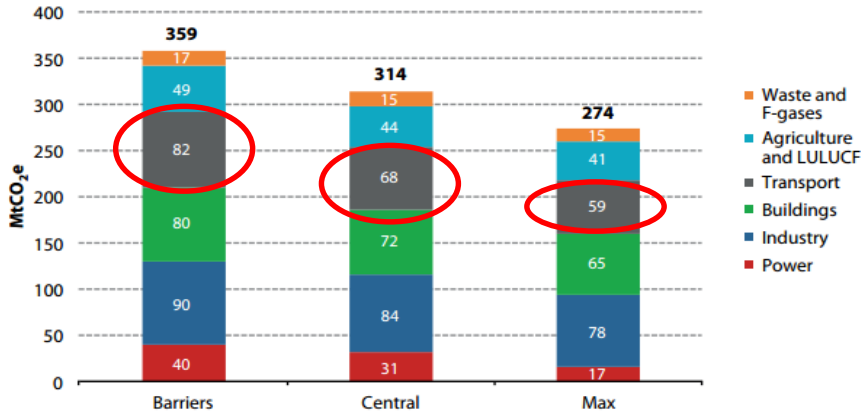


Figure 3.11: Total emissions under Barriers, Central and Max scenarios in 2030



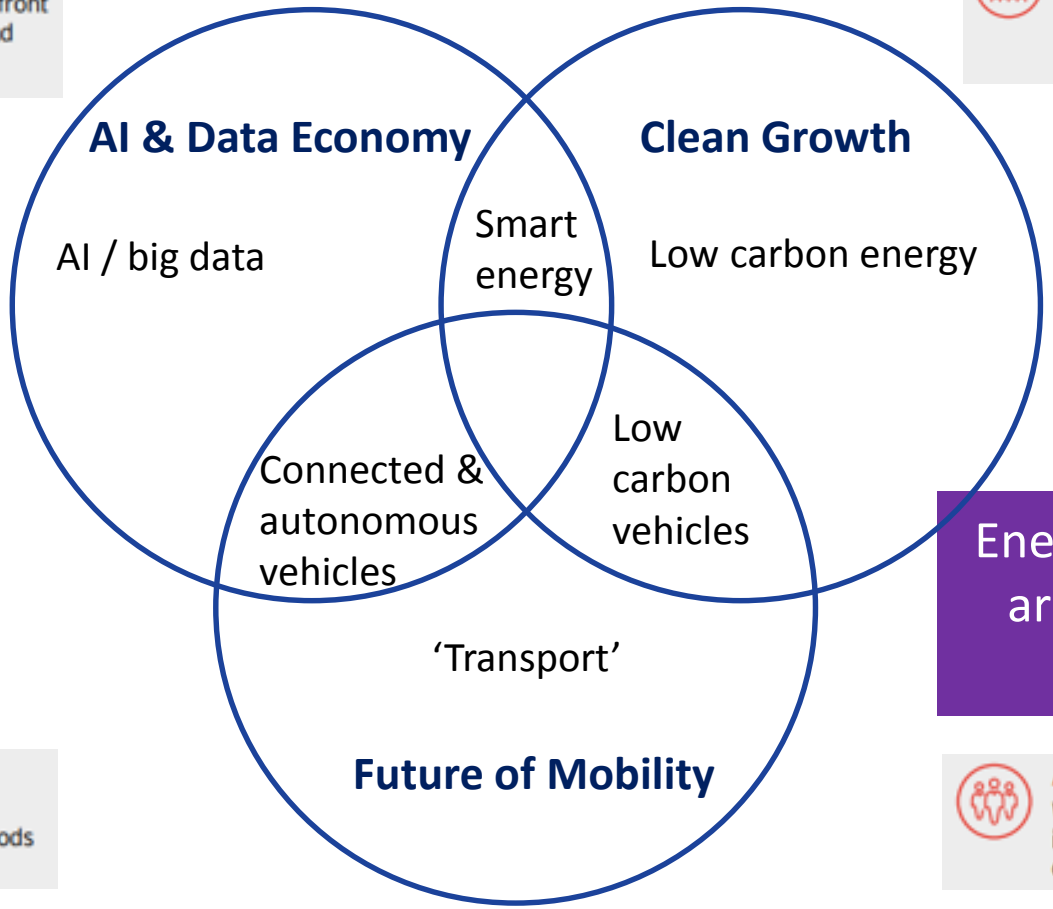
Source: CCC analysis.

[1] As measured on WLTP. Assumed real world = 108g/km

In UK vehicles and powertrains sit in the context of industrial strategy

AI & Data Economy
We will put the UK at the forefront of the artificial intelligence and data revolution

Clean Growth
We will maximise the advantages for UK industry from the global shift to clean growth



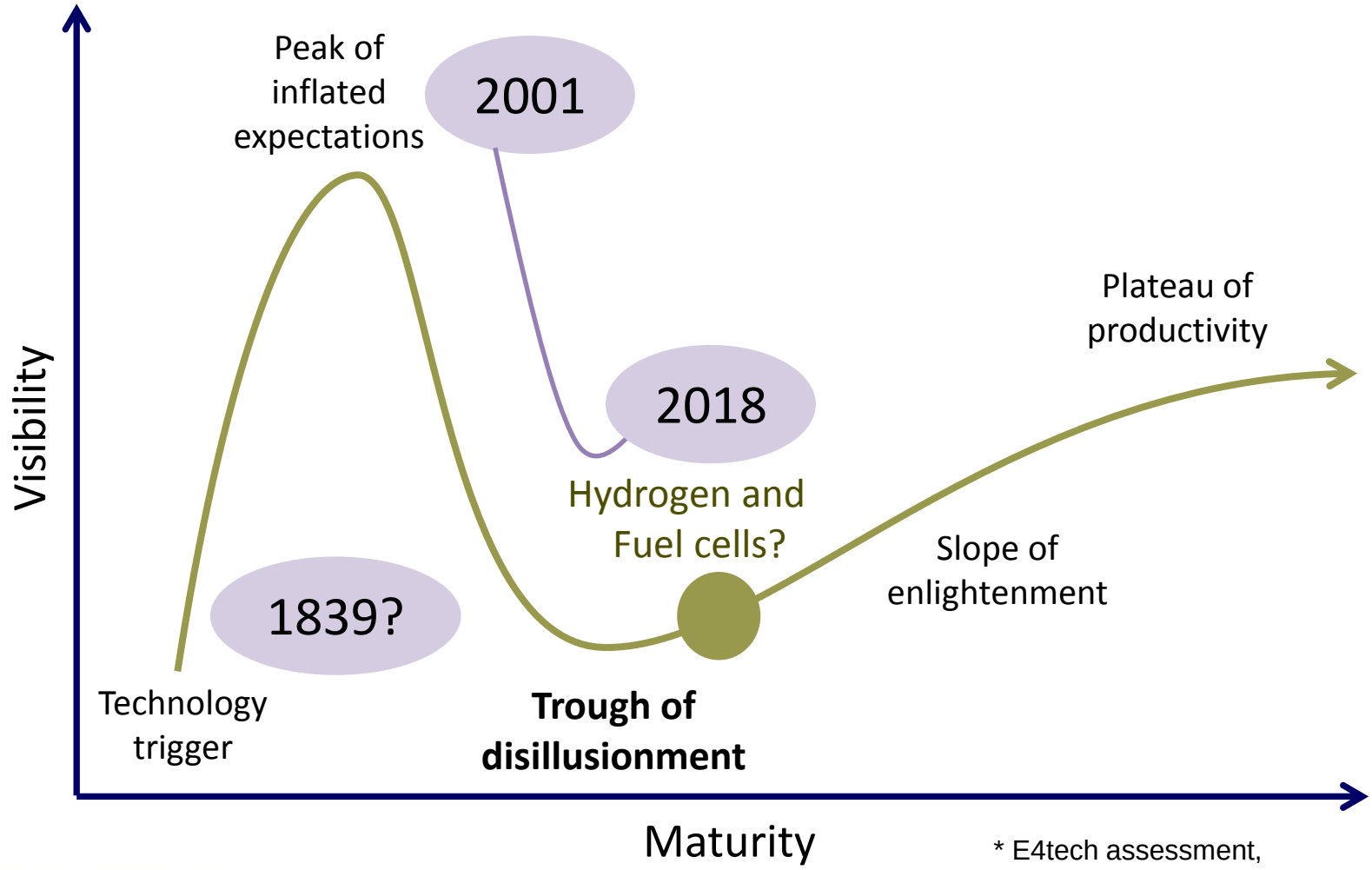
Energy and climate are not the only story

Future of Mobility
We will become a world leader in the way people, goods and services move

Ageing Society
We will harness the power of innovation to help meet the needs of an ageing society

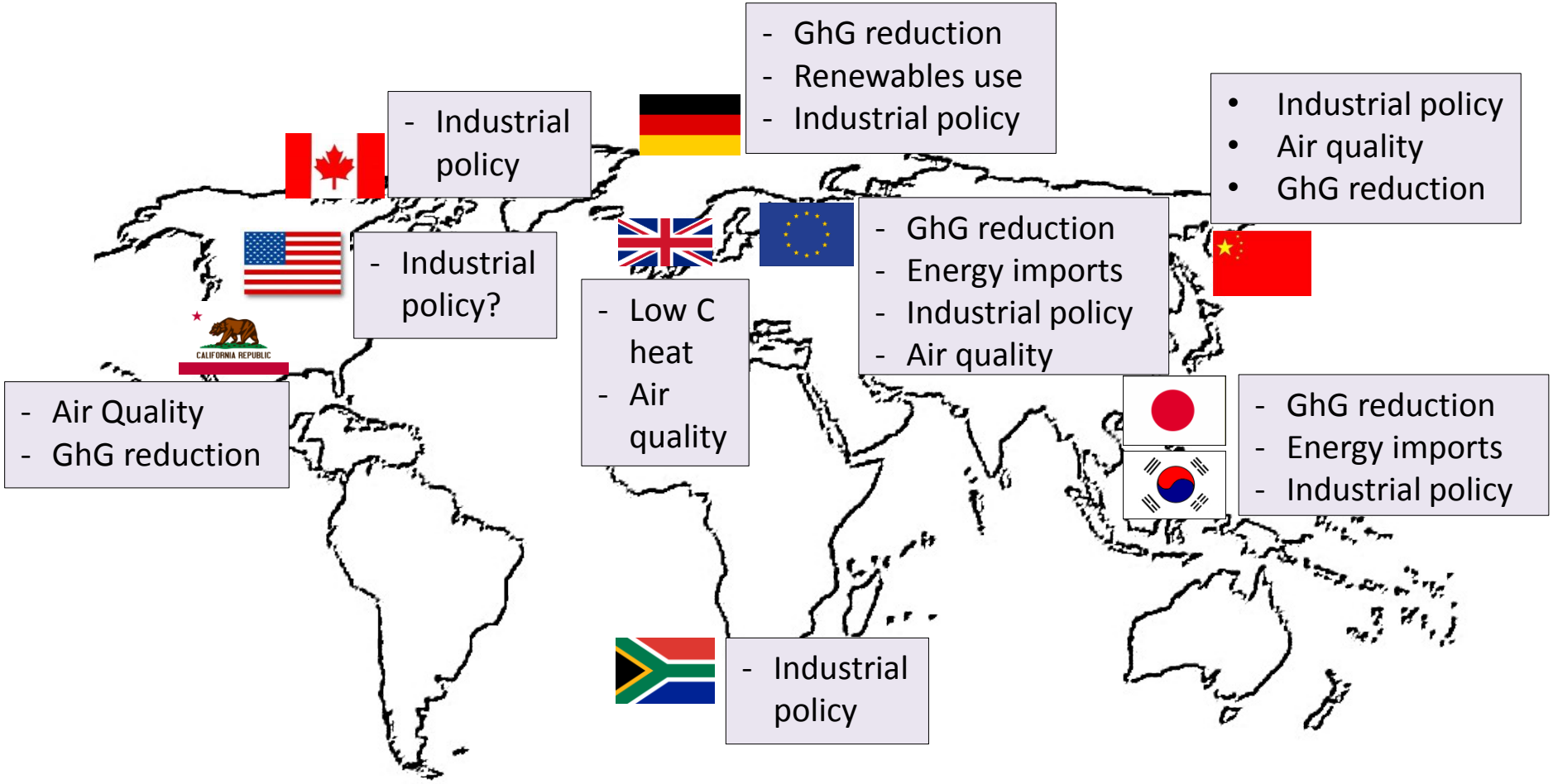
Hydrogen

Where is hydrogen on the hype cycle?



* E4tech assessment,
'Hype Cycle' framework by Gartner

To date ‘national’ policy has been the main driver for hydrogen developments



The *hydrogen* story is evolving, and is mainly about policies and systems

'Stranded' renewables

Dramatic uptake of renewables
Strong development of electrolysers

Low emission transport

Urban pollution
Multiple CO_2 targets
Decarbonising fuel is the only long term option

Decarbonising heat

Late to the game
A neat piece of the system puzzle

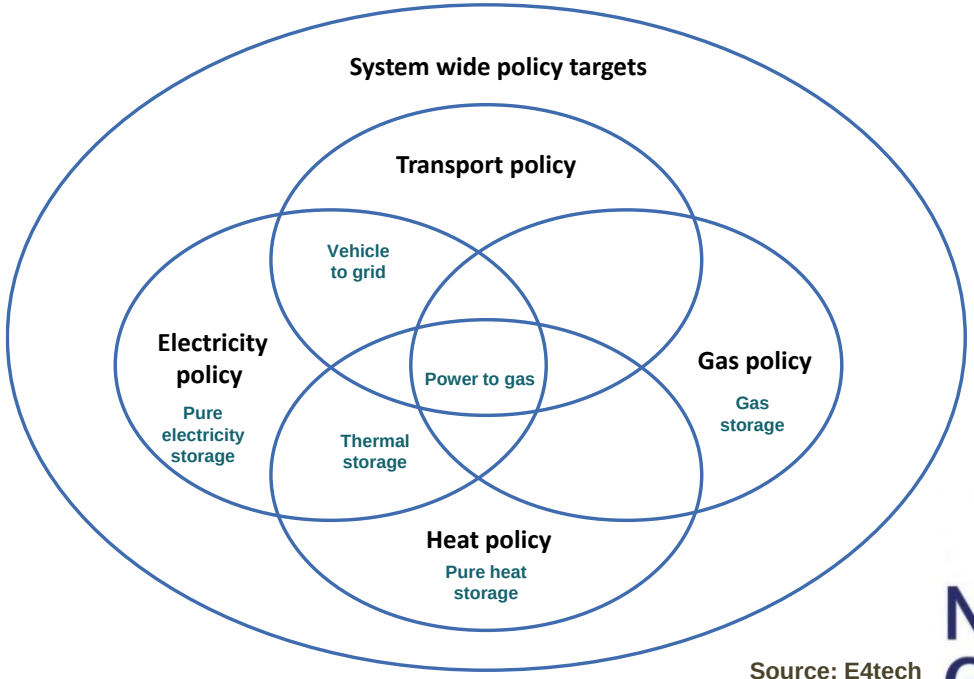
Flexible markets, dynamic systems, new technologies and cheap renewables: hydrogen enables 'Sector Coupling'

Nissan and OVO announce a new collaboration to accelerate the adoption of home battery storage in the UK

Press release

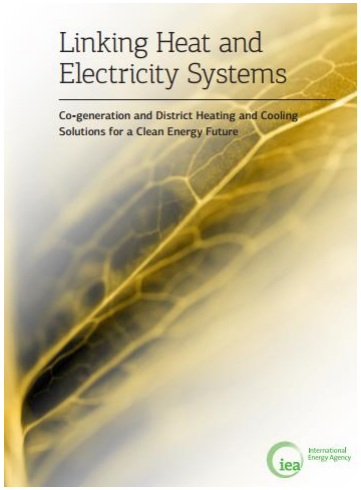
Audi e-gas plant helps stabilize German public power grid

July 15, 2015 | INGOLSTADT/WERLTE, Germany



Source: E4tech

Hydrogen offers unique system benefits



Northern Gas Networks

H21 Leeds Citygate Project

from Northern Gas Networks

The *fuel cell* story is more about products and companies

Portable power

Vast attrition – very few companies and products survive
Beating new batteries is hard

Stationary power

Some attrition, some M&A
Deep pockets and resilience are needed... plus policy support

Transport

BEVs came as a surprise, some passenger car OEMs wavering
Heavy duty and rail rising
Fuel cells fit within long-term vision

Some recent milestones

- 2013:
  - Steve Chu moved on
- 2014:
  - FCH 2 JU funding was agreed
  - The 100,000th Ene-Farm unit was installed
- 2015:
  - Car numbers started to ramp up
- 2016:
  - NOW received further funding
  - Ene-Farm units neared 200,000
- 2017:
  - The Hydrogen Council was launched
  - … and China started to get serious…

Hyundai Tucson iX35 **2013**

Toyota Mirai **2014**

Honda Clarity Fuel Cell **2016**

Mercedes GLC plug-in FCEV **2017**

China has (longer term) ambitions for FCEVs

Hydrogen Fuel Cell Vehicle Technology Roadmap

Developed by the

Strategy Advisory Committee of the Technology Roadmap for Energy Saving and New Energy Vehicles

SAE CHINA 中国汽车工程学会 Society of Automotive Engineers of China

China's **hydrogen energy and fuel cell industry innovation strategic alliance** established in Beijing on 11th Feb 2018

Year	HRS	FCV
2020	Over 100 stations	5,000 FCVs in demonstration, among which 60% are FC commercial vehicles and 40% are FC passenger cars
2025	Over 300 stations	50,000 FCVs in service, among which 10,000 units are FC commercial vehicles, and 40,000 units are FC passenger cars
2030	Over 1,000 stations, and 50+% hydrogen production from renewable resources	Over one million FCVs in service

IHFCA 国际氢能燃料电池协会 International Hydrogen Fuel Cell Association

Beijing 2022 Applicant City Olympic Winter Games

Heavy-duty FCH truck, bus and rail orders are increasing worldwide

Hydrogen vehicles are still a serious prospect

- Buses and materials handling have strong drivers and early deployment, HGVs are in development
- Thousands of vehicles are deployed or being ordered

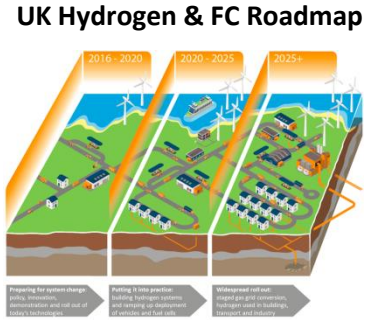


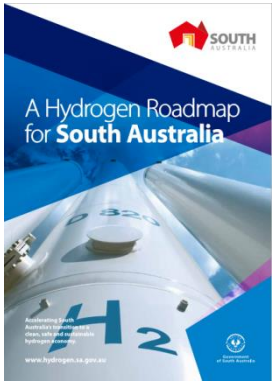


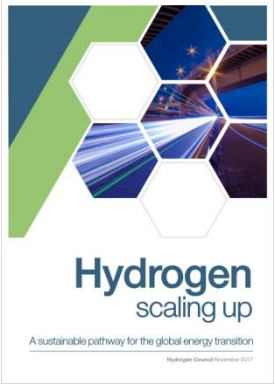




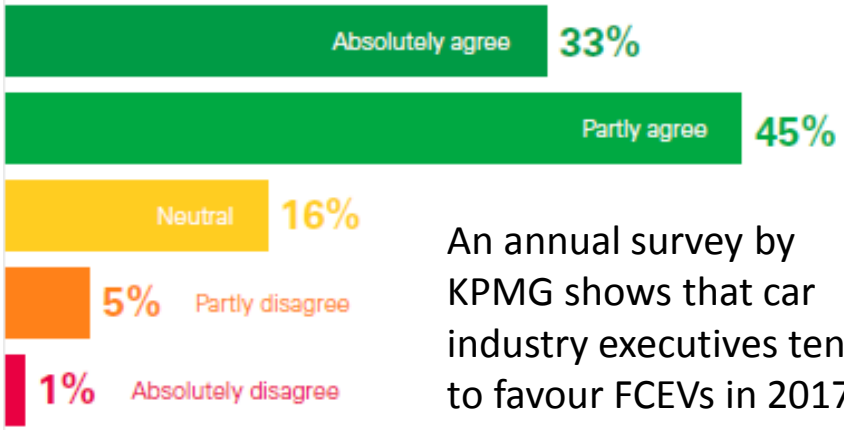
Hydrogen (and fuel cells) are now part of corporate and government thinking, both near term and big picture



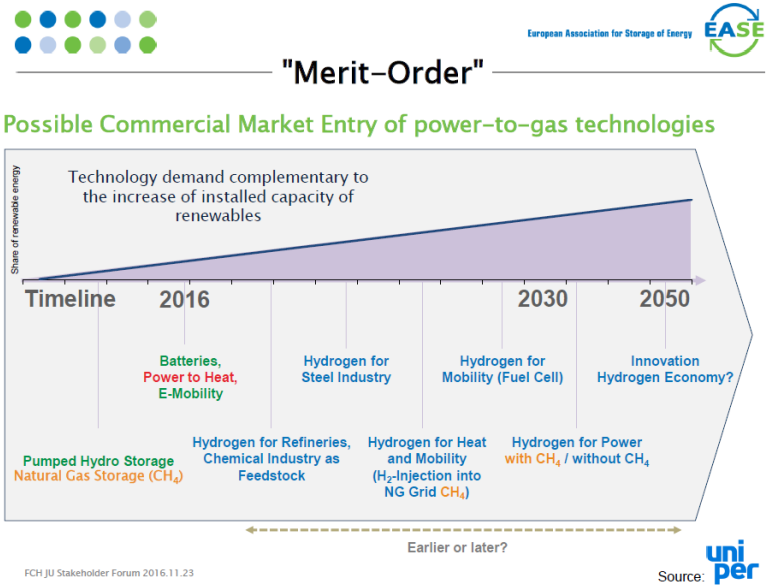




Survey hypothesis: FCEVs will be the real breakthrough for electric mobility



An annual survey by KPMG shows that car industry executives tend to favour FCEVs in 2017



Conclusions

Summary

- Transitions take a long time
- People care about life cycle impacts
- Simple scale mechanisms are very powerful
- Huge market failures need long term investments
- Somehow we need to speed up
- System-level approaches are most logical
- Energy and climate are not the only story
- Hydrogen offers unique system benefits
- Hydrogen vehicles are still a serious prospect

Thank you

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