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Energy Slam!

How it works

8 presentations

Each of up to 10 slides

Each lasting no more than 5 minutes

Answering the question:

‘What is most likely to transform the energy scene between now and 2030?’

Questions, sandwiches and vote at the end

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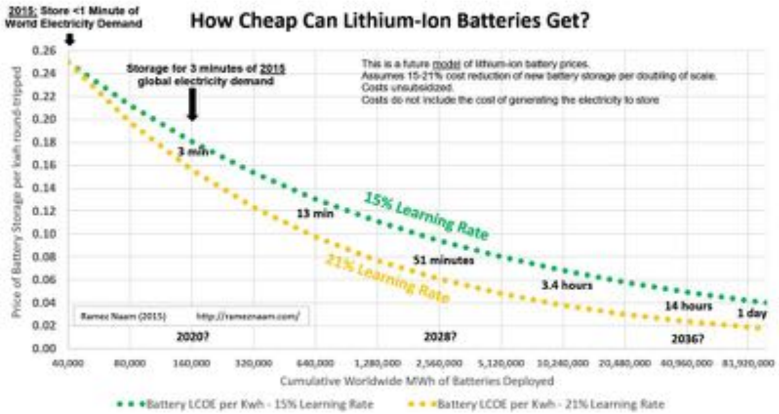
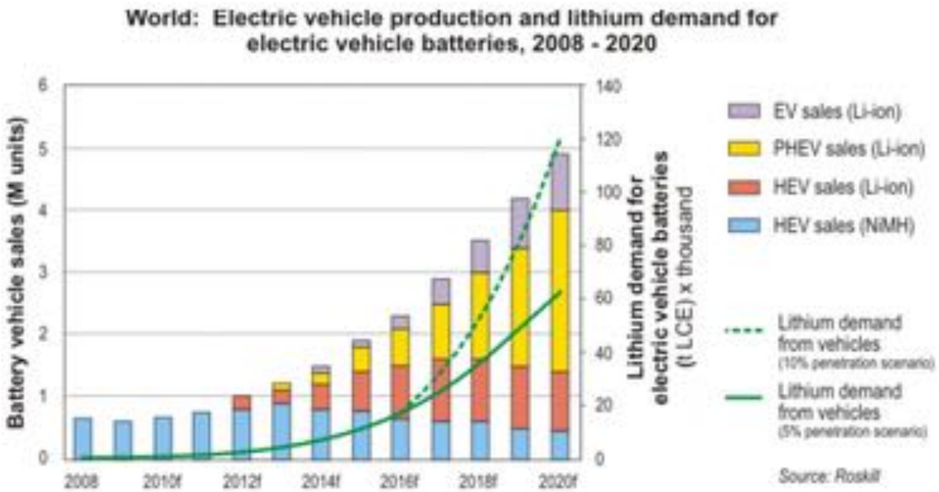
Humphrey Douglas

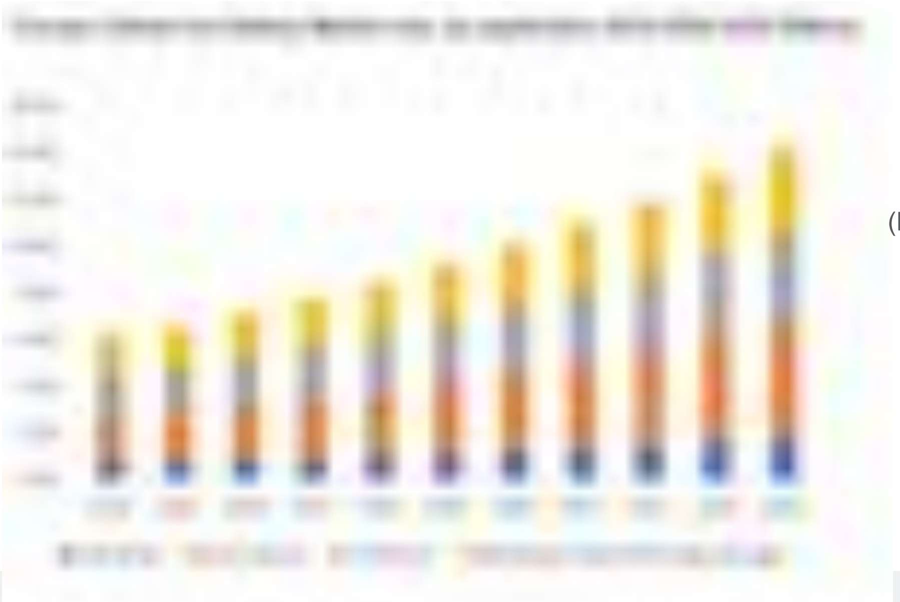
The Rise of the Battery



How Cheap Can Lithium-Ion Batteries Get?
2015: Store <1 Minute of World Electricity Demand
Storage for 3 minutes of 2015 global electricity demand
This is a future model of lithium-ion battery prices.
Assumes 15-21% cost reduction of new battery storage per doubling of scale.
Costs unsubsidized.
Costs do not include the cost of generating the electricity to store
3 min
13 min
51 minutes
3.4 hours
14 hours
1 day
15% Learning Rate
21% Learning Rate
2020?
2028?
2036?
Ramez Naam (2015)
http://rameznaam.com/
Price of Battery Storage per kwh round-tripped
Cumulative Worldwide MWh of Batteries Deployed
Battery LCOE per Kwh - 15% Learning Rate
Battery LCOE per Kwh - 21% Learning Rate

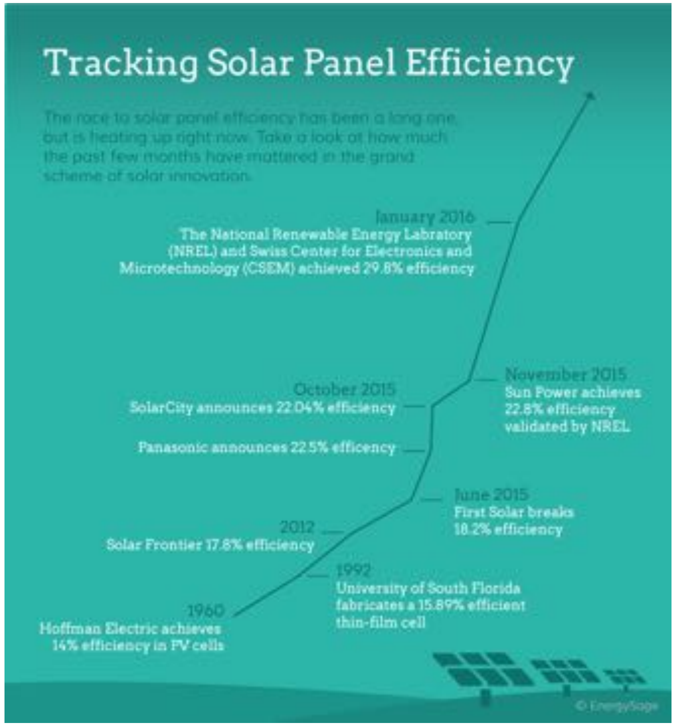


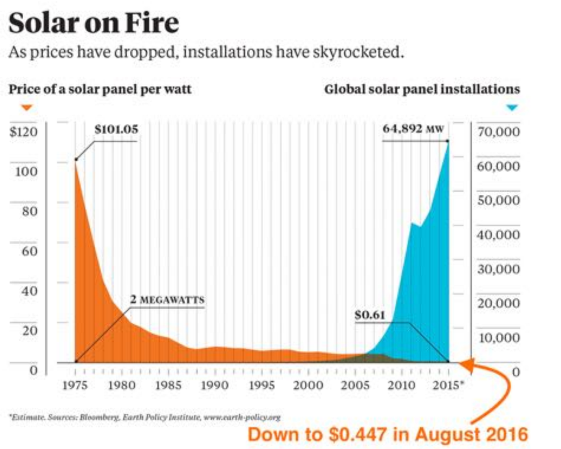
World: Electric vehicle production and lithium demand for electric vehicle batteries, 2008 - 2020
Battery vehicle sales (M units)
Lithium demand for electric vehicle batteries (t LCE) x thousand
EV sales (Li-ion)
PHEV sales (Li-ion)
HEV sales (Li-ion)
HEV sales (NiMH)
Lithium demand from vehicles (10% penetration scenario)
Lithium demand from vehicles (5% penetration scenario)
2008
2010f
2012f
2014f
2016f
2018f
2020f
Source: Roskill

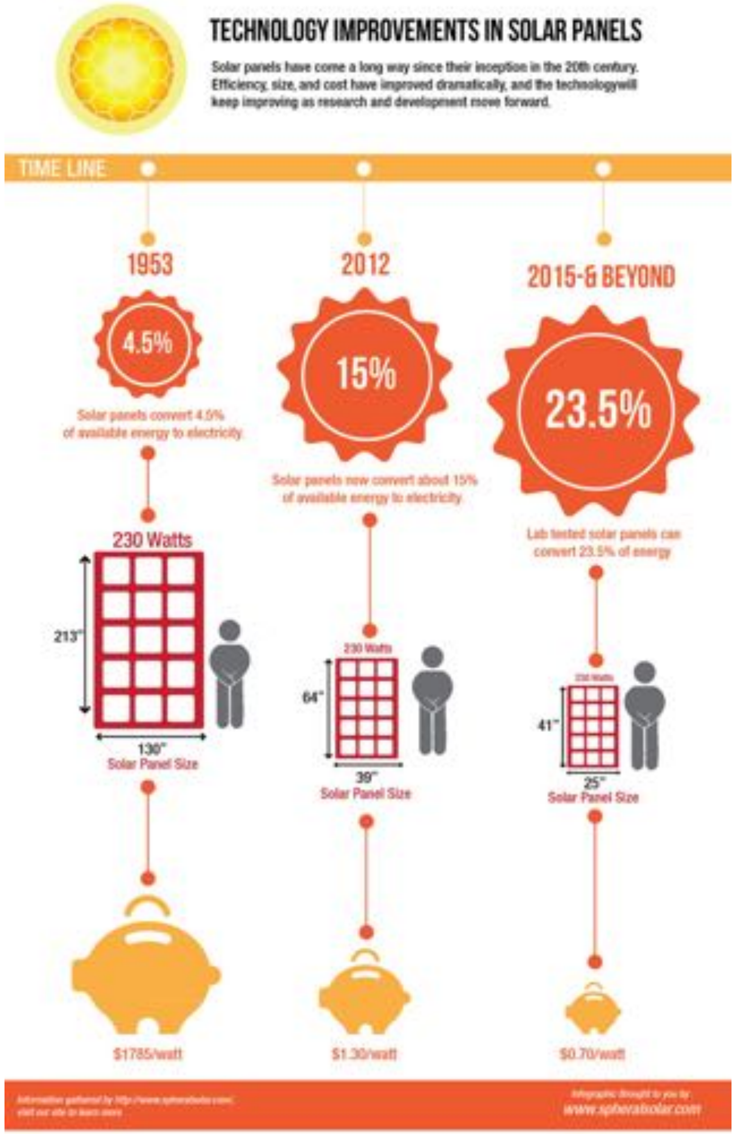


(Per year)

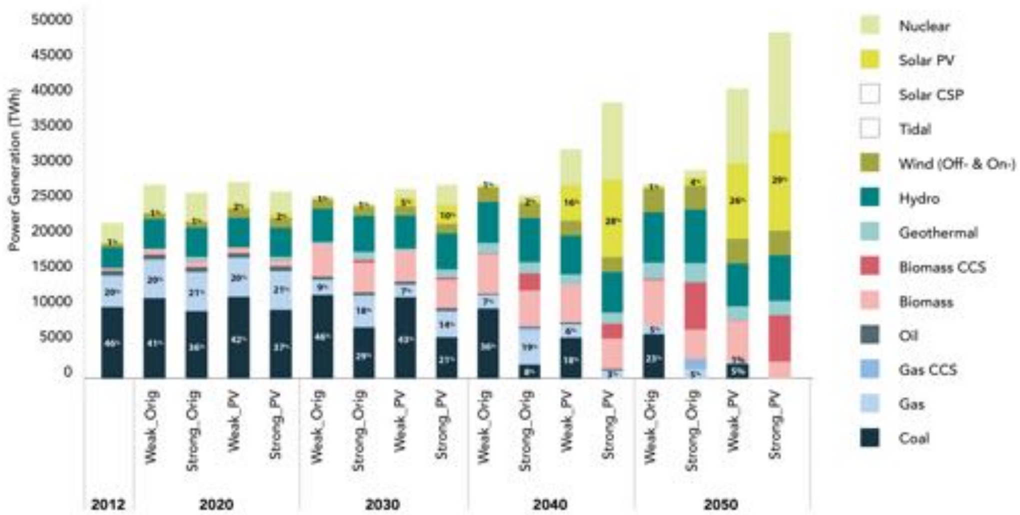
2. Increase in solar PV efficiency



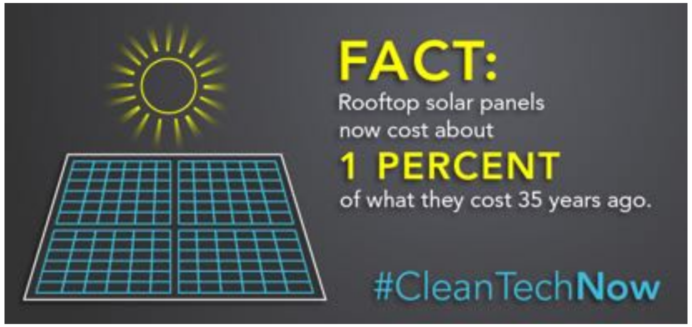




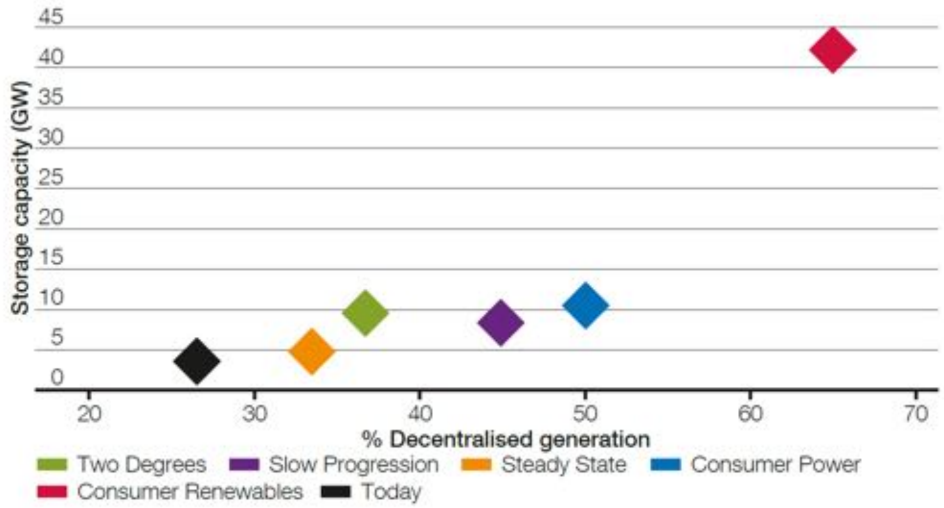
Decline in solar PV costs



Lower costs shifts the balance towards Solar PV from fossil fuel alternatives




Beta
VHS
BASF L750



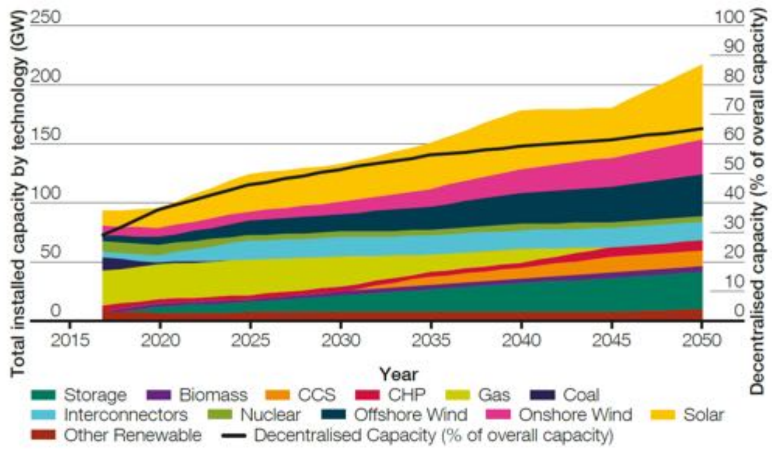
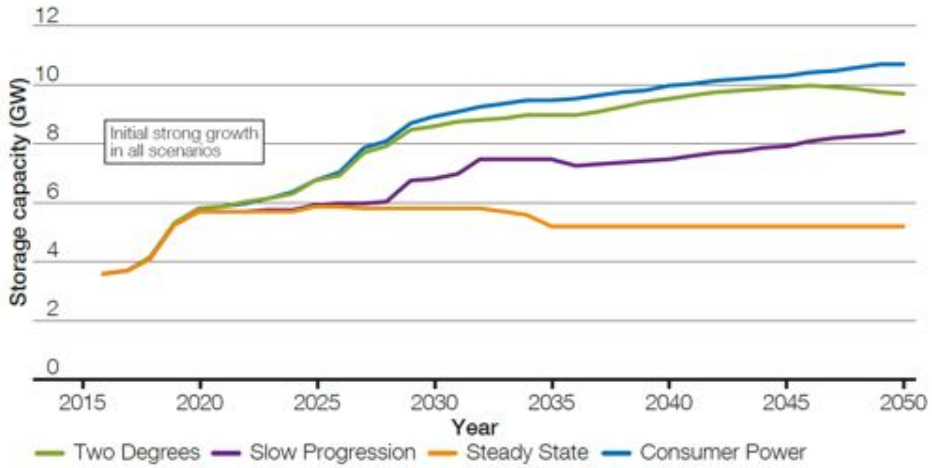
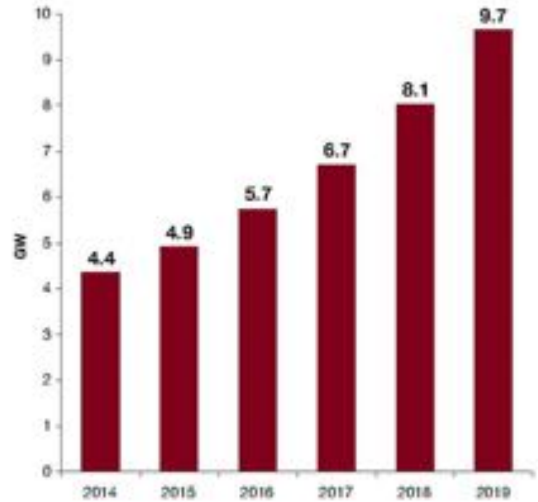


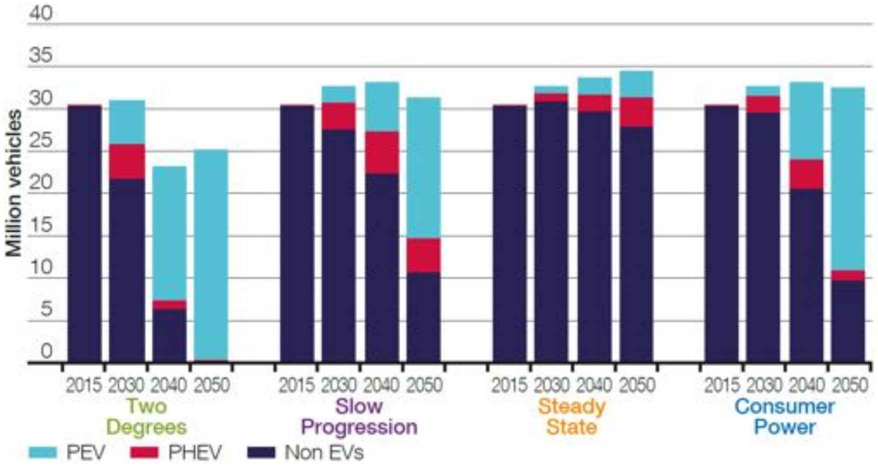
Figure 7: Global micro-grid market (GW capacity)



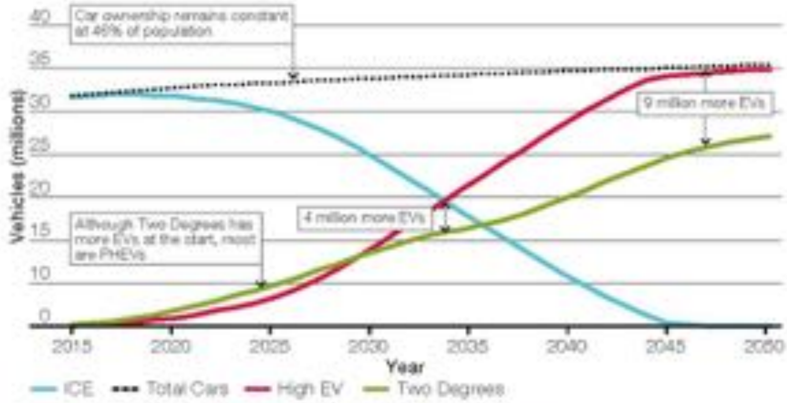


A home in the consumer renewable world.

The growth of EVs



Electric vehicle uptake

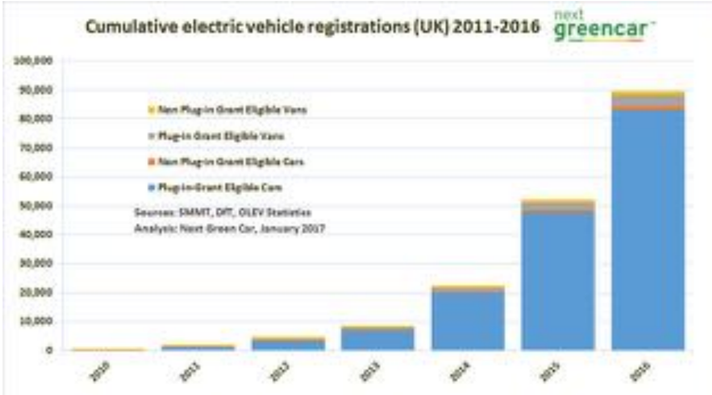


By 2030 the annual demand required to supply just these EVs is 21 TWh. By 2040 this increases to 65 TWh and by 2050 to 88 TWh.

Electricity supply

Gas generation peaks, in 2040, at 223 TWh. Imports are the next largest source of electricity; the full make-up of the generation mix is illustrated in Figure 5.8.

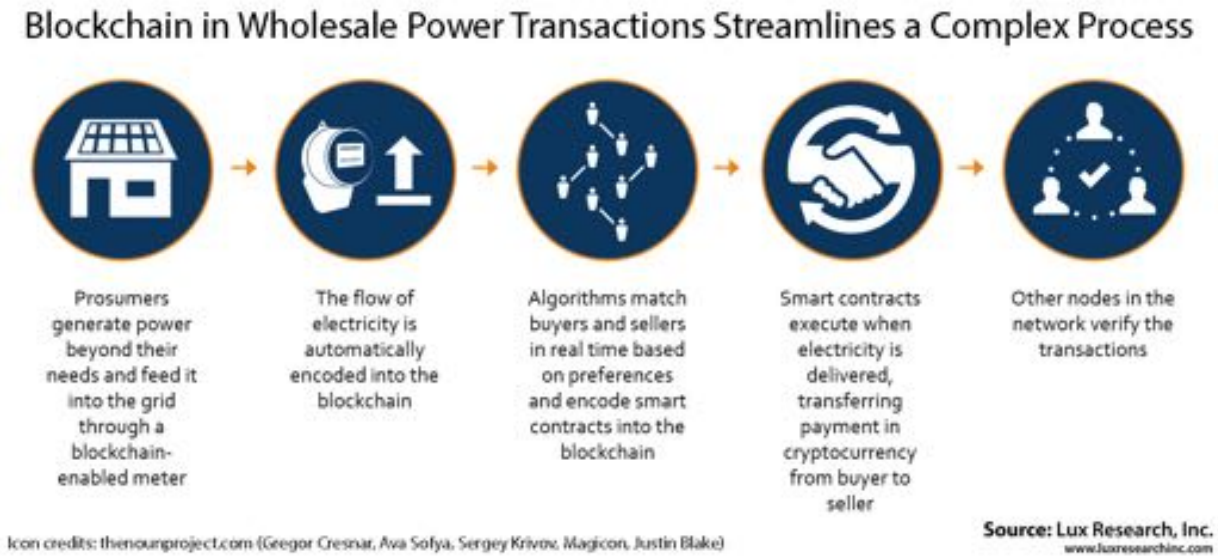
EV 5 Minute Charging!!!

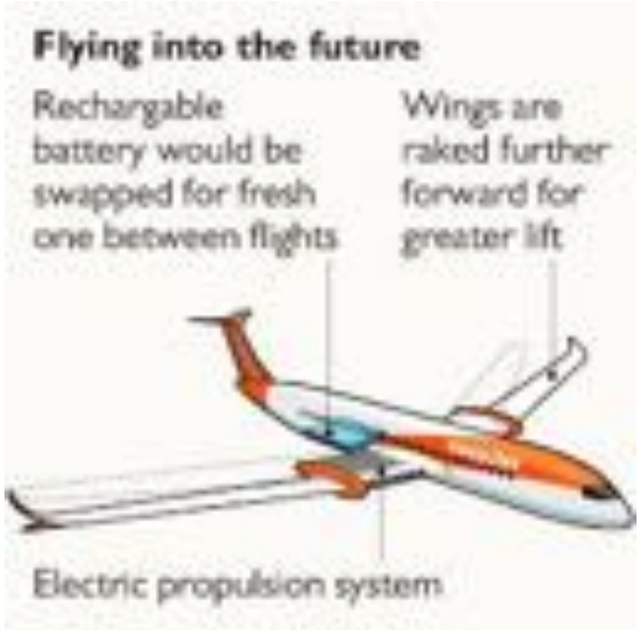



BUT WHAT DO WE DO WITH THE BATTERIES?
sustainablog.org


THE INTERNET of THINGS


BLOCK CHAIN


Blockchain in Wholesale Power Transactions Streamlines a Complex Process
Prosumers generate power beyond their needs and feed it into the grid through a blockchain-enabled meter
The flow of electricity is automatically encoded into the blockchain
Algorithms match buyers and sellers in real time based on preferences and encode smart contracts into the blockchain
Smart contracts execute when electricity is delivered, transferring payment in cryptocurrency from buyer to seller
Other nodes in the network verify the transactions
Icon credits: thenounproject.com (Gregor Cresnar, Ava Sofya, Sergey Krivov, Magicon, Justin Blake)
Source: Lux Research, Inc.
www.luxresearchinc.com


Flying into the future
Rechargable battery would be swapped for fresh one between flights
Wings are raked further forward for greater lift
Electric propulsion system


Color Line
HYBRID

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Dr Roger Bentley

Peak Oil

Energy Institute: 'Energy Slam' - Nov. 13th 2017.

Peak Oil

The <u>resource-limited</u> peak in the global production of 'all-conventional' oil is about now: Expect price and supply problems!

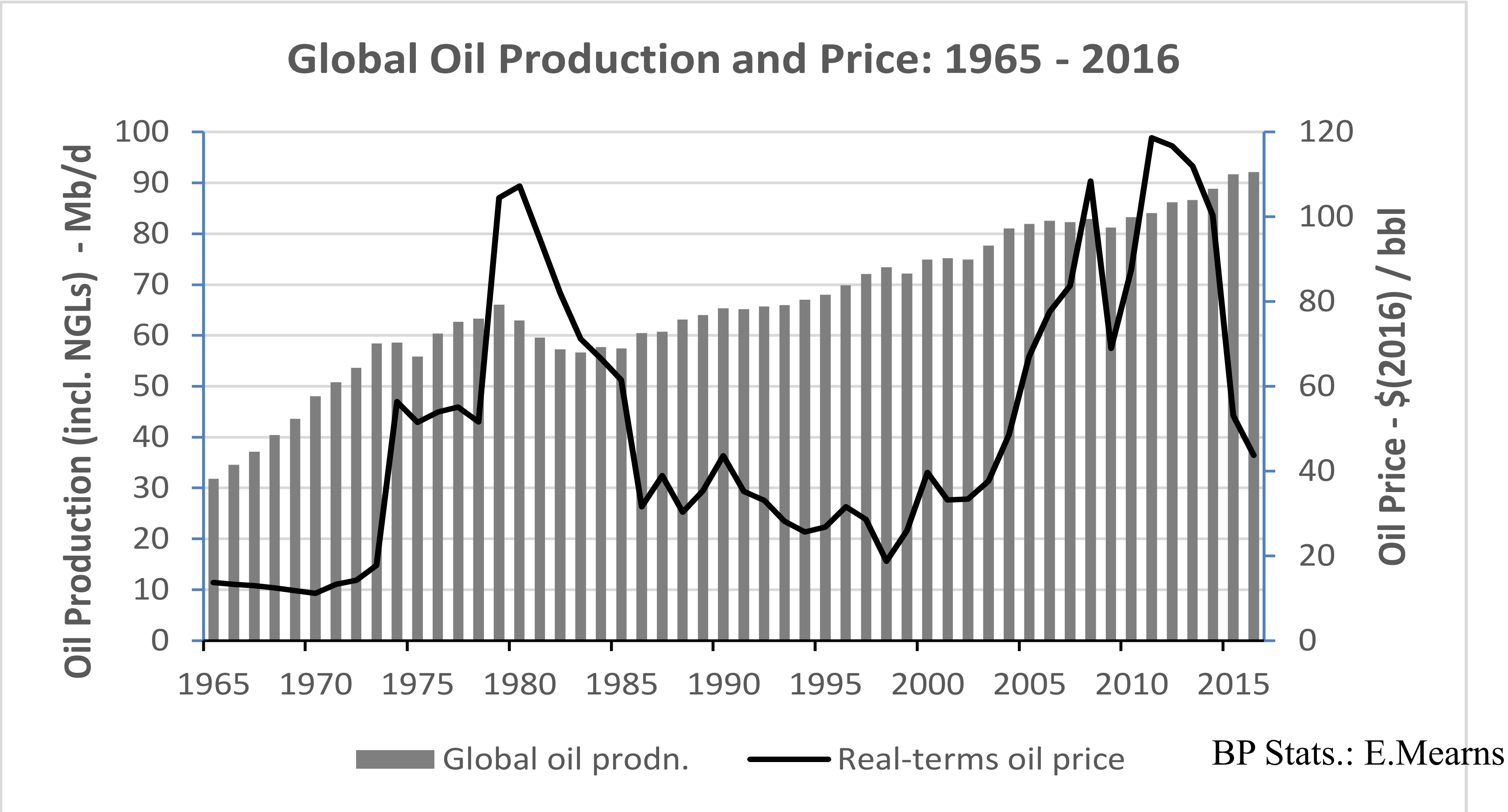
Also, we need to understand:

Energy Return Ratios (EROIs) of Energy Sources

These must go into all energy forecasting

R. W. Bentley MEI, Editor 'The Oil Age'
Petroleum Analysis Centre
Former Visiting Research Fellow
Dept. of Cybernetics, University of Reading, UK.

Global Oil Production and Price, 1965-2016



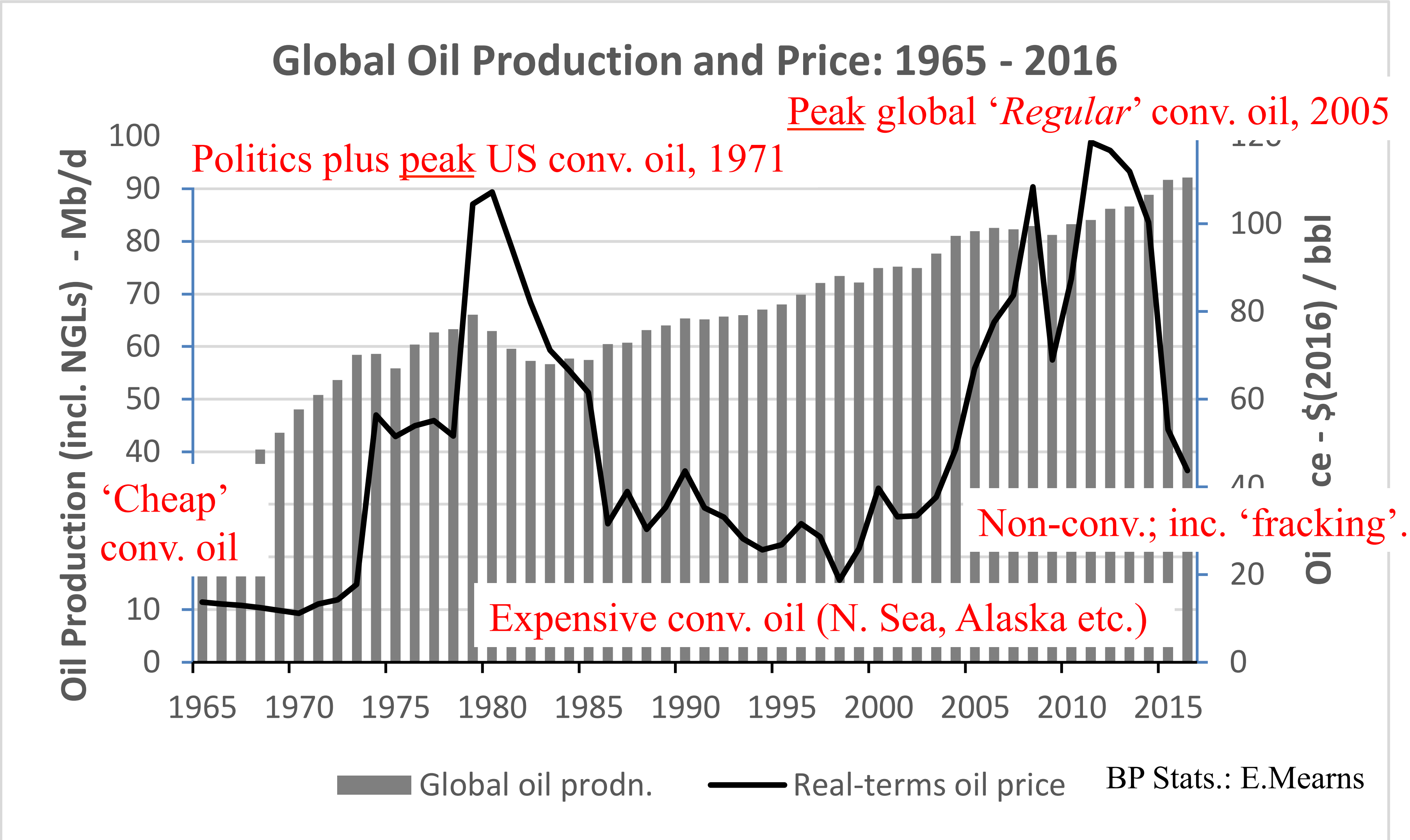
Real-terms oil price**: Half-century pre-1973;* ***~$15/bbl

1973 / 1978 price shocks

1986 – 2005: ***~$30/bbl***

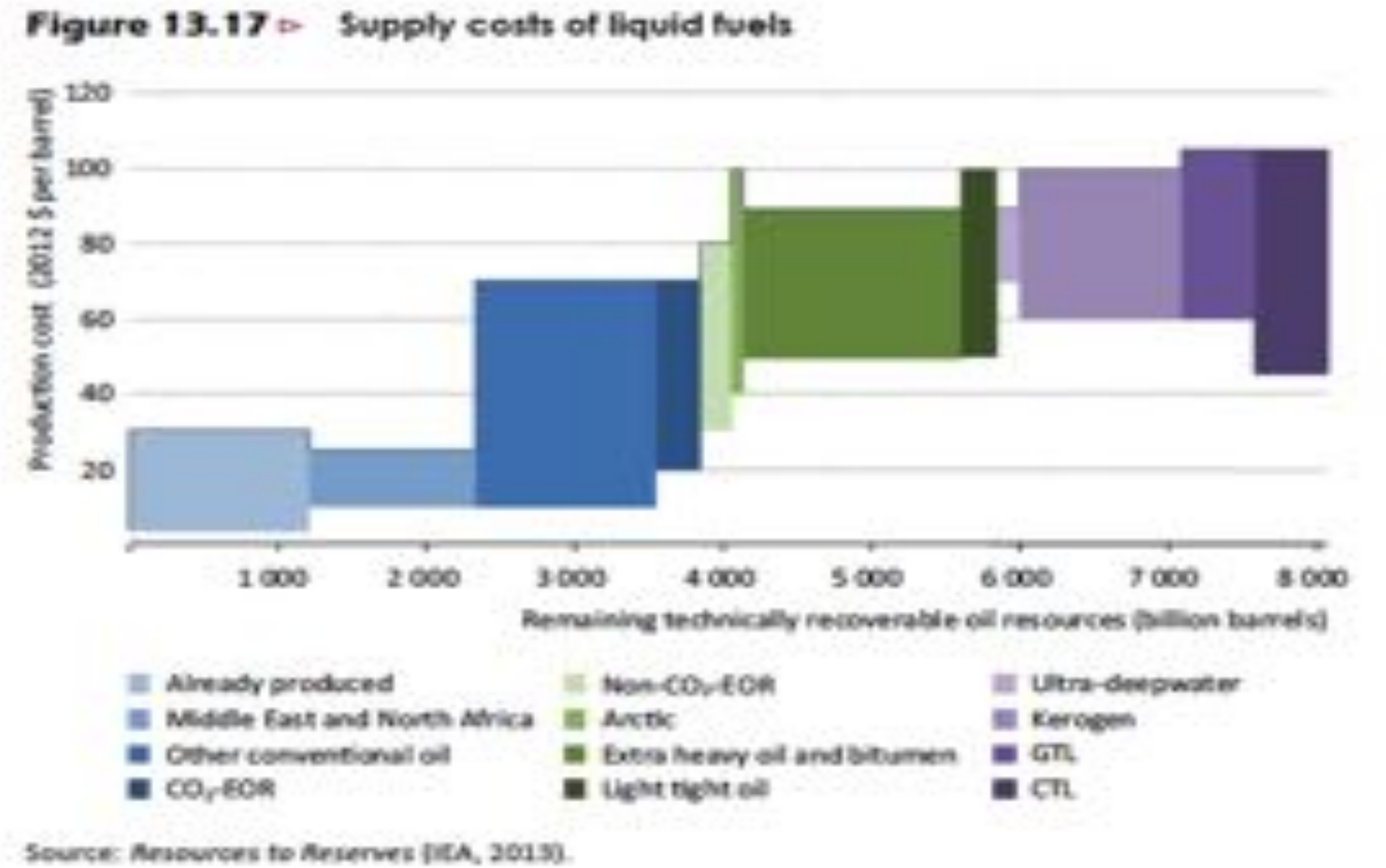
Post 2005: avg. ~$80/bbl; now at ***$60/bbl****.*

Global Oil Price, 1965-2016: Two *resource-limited* prodn. peaks



'*Regular*' conv. oil excludes deepwater (>500m), Arctic & very heavy (>17.5 API).

There is a lot of Oil & 'nearly Oil'



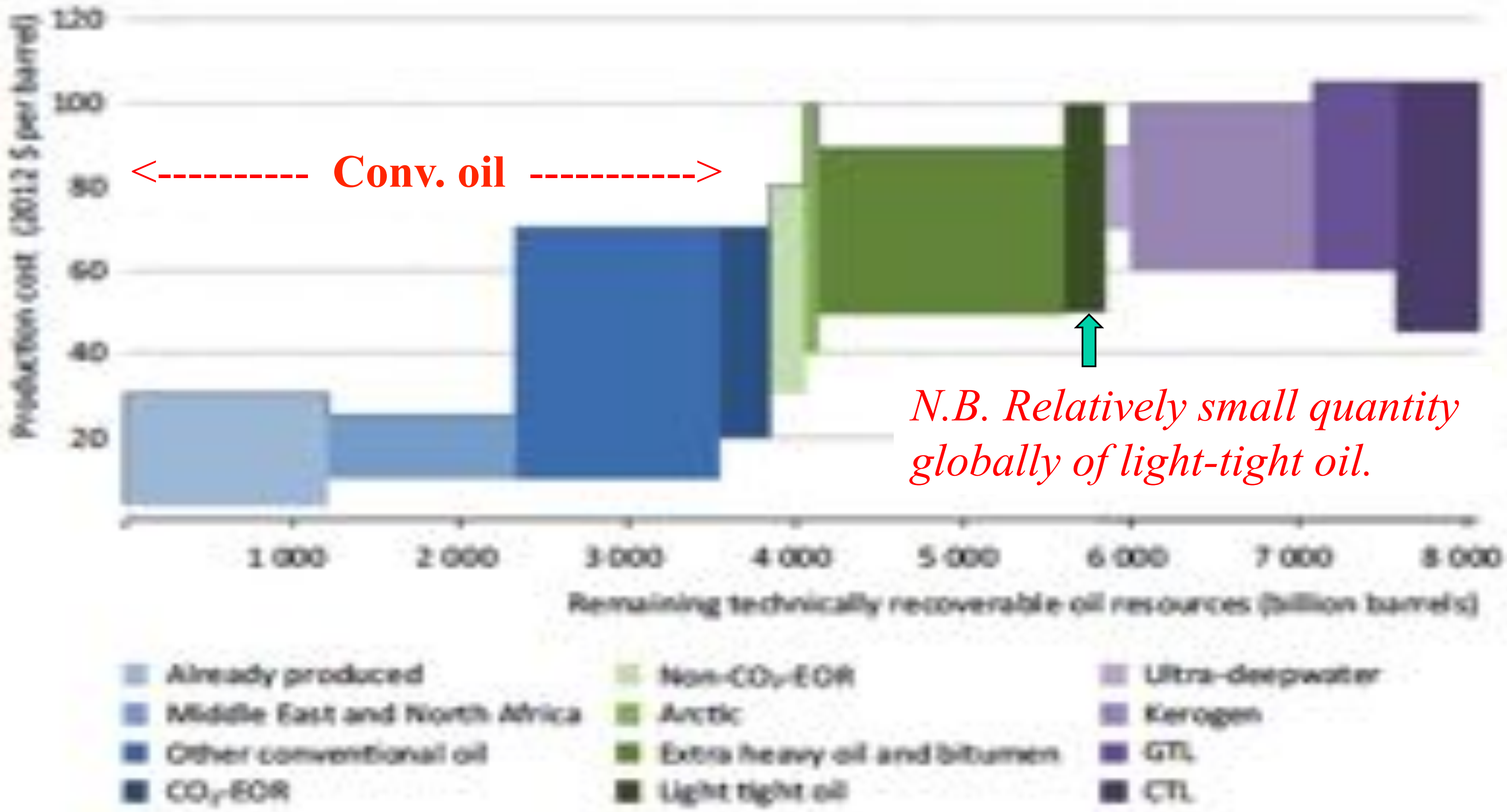
Estimated global remaining technically recoverable volumes of oil available, by category (in Gb), vs. Production cost range (in $2012/bbl).

EOR: Enhanced oil recovery; CO_2-EOR: EOR using CO_2; GTL: Gas to liquids; CTL: Coal to liquids.

There is a lot of Oil & 'nearly Oil'

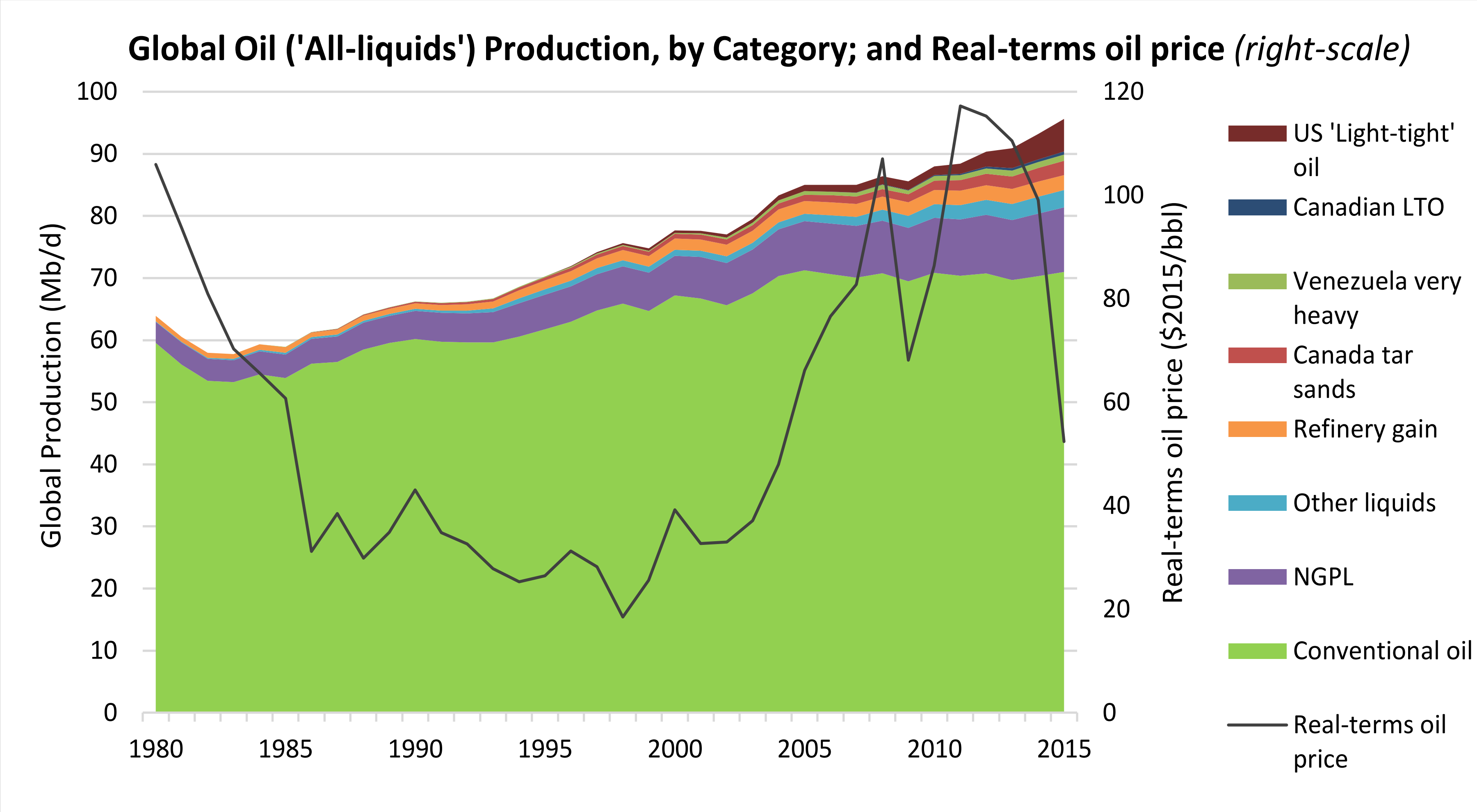
- But of *conv. oil* about half used, so *resource-limited* peak <u>is ~ now</u>.

Figure 13.17 ▷ Supply costs of liquid fuels



Source: *Resources to Reserves* (IEA, 2013).

Global *All-conventional* oil is at ~Mid-point; hence its production has been on-plateau since 2005 despite high avg. oil price.



Data from US EIA (crude-plus-condensate, NGPLs, other liquids, and refinery gain; other categories from Laherrere et al. *Oil Forecasting – Data Sources and Data Problems*, Part-1, The Oil Age (2) 3; 2016. Real-terms oil price: BP *Stats. Review*.

Most Alternative Energies (fossil as well as non-fossil) have low Energy Return ratios: *Must be included in energy models*.

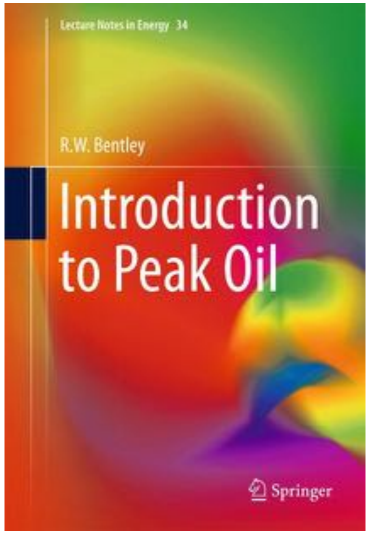
Hall *et al*. suggest that modern society needs a minimum energy return on energy invested (EROI) of ~10 -15x.

Even where ratios are higher than this, falling EROI ratios reduce society's overall wealth.

	Approx. EROI range
Conv. oil: 1930 / 1970 / today	30 / 40 / 14
Tar sands	1.5 - 8
Coal	40 - 80
Nuclear fission	4 - 16
Wind	10 - 28
PV	2.5 - 8 (- 14?)
Biodiesel, gasohol	~3

Most data: C. Hall & J. Day, *American Scientist*, 97, 230-237, 2009. (Gives EROI of PV as ~8; value of 2.5 is from Prieto & Hall, Springer Briefs in Energy, 2013.) Note PV EROI can be ~20 if calculated on a primary energy basis.

Sources & References



Book: R. Bentley - Introduction to Peak Oil (2016)
'Draws on information held in oil industry datasets that are not widely available outside of the specialist literature, and describes a number of methods that have been successfully used to predict oil peaks.'
Springer

Journal: The Oil Age
A quarterly peer-reviewed print journal addressing all aspects of the evolving 'Oil Age', including physical, economic, social, political, financial and environmental characteristics.
To subscribe, contact:
Noreen Dalton
+353 85160 7001, theoilage@gmail.com

Sources & References, contd.

Globalshift Ltd. (Dr. Michael Smith) website: www globalshift.co.uk

Colin Campbell *et al*.: '*Atlas of Oil & Gas Depletion*'; published by Springer, 2013.

IEA: 'World Energy Outlook', from: www iea.org

BP *Statistical Review* – *but do not use the Proved oil reserves data; nor the R/P ratios!*

UKERC report: *Global Oil Depletion*, 2009; look under TPA's in: www ukerc.ac.uk

IHS Energy's 'PEPS' dataset, via www ihs.com

Papers from Uppsala University: www fysast.uu.se/ges

C. Campbell (Ed.).'Peak Oil Personalities', from Inspire Books – very readable.

K. Aleklett. 'Peeking at Peak Oil'. Springer, 2012.

J. Leggett. 'Energy of Nations', Routledge, 2013.

There are many other good sources of information. These include papers in academic journals, ASPO conference papers; data from The Shift Project on energy production and consumption by fuel type and country (http:// the shiftproject.prog.org), and the resource assessments of all fossil fuels from Germany's BGR (www bgr.bund.de).

There are also very useful websites, such as Ron Swenson's www hubbertpeak.com (the first website on the topic), the Oil Drum, ASPO Newsletters (discontinued but still available), ODAC Newsletters, David Strahan's 'Last Oil Shock' (http:// davidstrahan.com), and the Crude Oil Peak site (http:// crudeoilpeak.info), to name but few. See also:

- Impact of oil price on some Eurozone countries: J. Murray and D. King. '*Oil's tipping point has passed*.' Comment in *Nature*, Vol. 481, 26 Jan. 2012, pp 433-435.
- Past oil forecasts: R. Bentley and G. Boyle. '*Global oil production: forecasts and methodologies*.' *Environment and Planning B: Planning and Design*, vol. 35, pp 609-626, 2008.
- Energy systems modelling: Start with: U. Bardi. '*The Limits to Growth Revisited*'. Springer, 2011.
- EROI, and *Impact of energy cost on economic activity: C. Hall and K. Klitgaard.* 'Energy and the Wealth of Nations.' Springer, 2012.

Thank you for listening

energy institute

Sam Botterill

Algae

Algae

What's happened to all the noise around farming bio-slime

‘Commercial, Technical, Energyst’

- Energy Blockchain strategy and application
  - Recently worked with Electron DLT
- KiWi Power
  - KiWi Power Demand Side Response: regulation lead
- Energy Institute Technical Lead Power Utilities
  - Cyber Security, Safety, Carbon Capture Storage
  - Decommissioning
- MSc School of Maths and Engineering City University London

A 2013 Slime Breakthrough

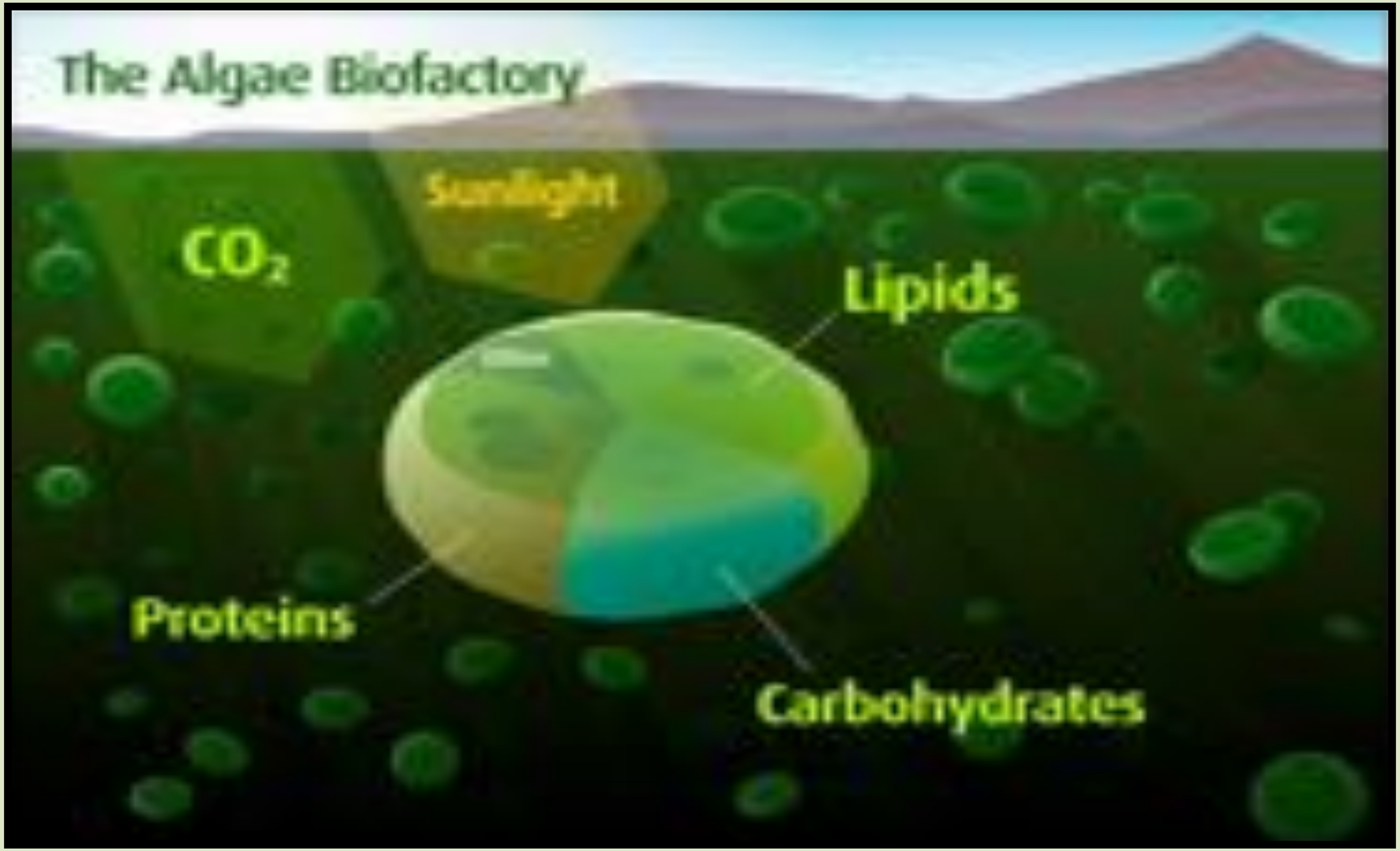

Smithsonian.com SUBSCRIBE SMARTNEWS HISTORY SCIENCE INNOVATION ARTS & CULTURE TRAVEL

Scientists Turn Algae Into Crude Oil In Less Than An Hour

Researchers believe they have figured out a way to make a promising biofuel that is cheap enough to compete with gasoline

The Slimy History

What is Algae



Produce Some Prime Slime

Cooking Time

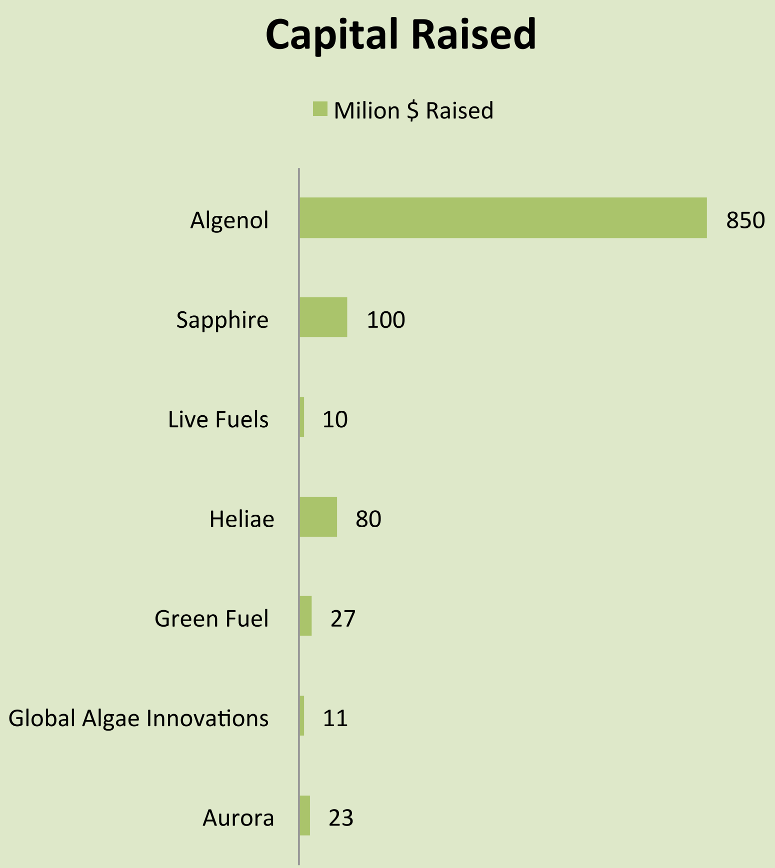
2009 Players

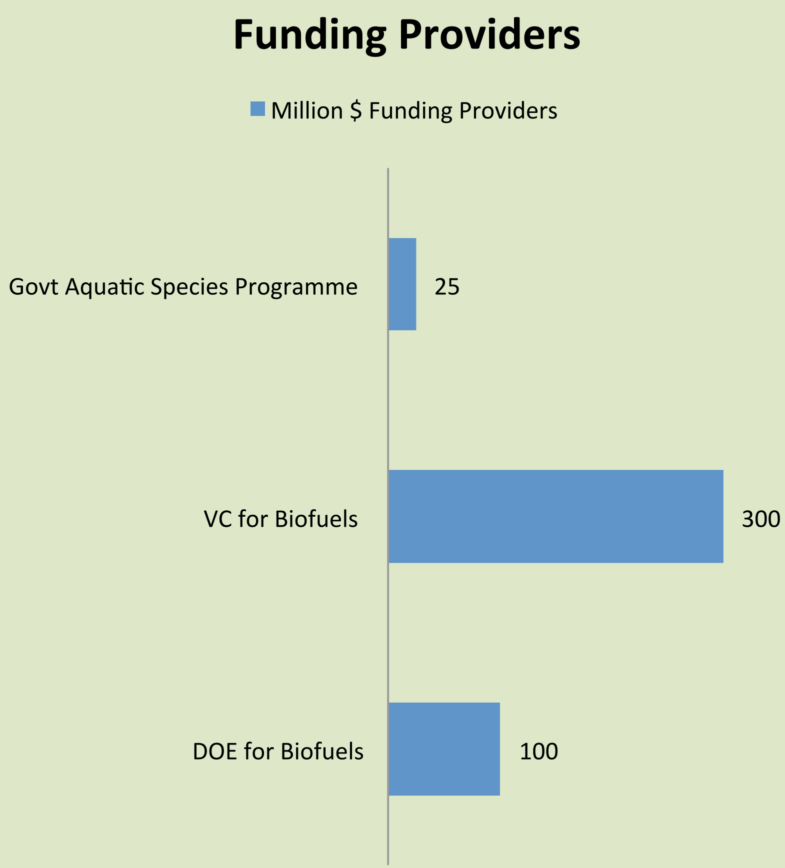
Company	Project	Location	Technology	Production
Algenol Biofuels	$850M	Sonran Desert	Produce Ethanol	2010 Scaled 2012
Solix	Los Alamos National Laboratory	Colorado	Blasting with soundwaves	2009
Sapphire Energy	Built 300 Acre Facility	Southern Mexico		2011
Solarzyme	Fuel to supply US Navy Jet Fuel			2010
Seambiotic		Israel		2009
Exxon	Algae to Crude		Synthetic Genomics	?

What Happened

- Only Gallons of slime produced
- Some firms went filed for bankruptcy
- Companies IP was able to be redirected
- Food production – Carbon Capture!
- It’s been compared to the space race
- Electric cars, low oil price

Idea of Funds





Conclusions Progress ?

Company	Project	Partners	Progress	Technology
Exxon £8bnn over 17 Years On renewables Synthetic Genomics	Algae to Crude products Expand Lipid Production	Synthetic Genomics	19 June 2017 Synthetic Genomics Break through Announced Busy taking out Google Ads to tell us all about it !	Altering Cells

- Manhatten Project was $24BN
- Space Race was $360BN

Peter Gill

Energy policy

Energy Slam!
What will most transform the energy scene between now and 2030?

Changes in Energy Policy!

Peter F Gill November 2017
pfg.energy@gmail.com

PAST ENERGY POLICIES

- A small number of basic considerations largely determined past national energy policies
  - Cost of heat per useful converted heat unit
  - Atmospheric pollution per useful heat unit (aimed at severely reduced SOX, NOX & particulates)
  - Capital costs of necessary installations
  - Conservation of natural resources
  - Relative merits of fuels & electricity as sources of heat

EXISTING ENERGY POLICIES AND STRATEGIES FOR ACHIEVEMENT

- Very strong focus on largely decarbonising the economy by 2050 (i.e. 80% lower COX than the 1990 baseline)
- Various strategies have been developed for the achievement of this goal including use of David MacKay's 2050 calculator to develop various possible mixes of technologies mainly in relation to electricity generation

COMMENTS ON EXISTING POLICY

- Only a handful of MPs questioned the practicability, cost and justification for the aims of the 2008 Act
- The policy has resulted in a dash for ‘renewable’ energy schemes particularly onshore and offshore wind and bio-energy
- With a full renewables agenda the elephant in this room is the question of energy storage at a scale that can deal with intermittency. This point may be over the heads of most MPs

POLICY TARGETS FOR HEATING AND TRANSPORT

- The Climate Change Act requires that by 2045 all gas heating be replaced by electric heating and all cars be electric.
  - The need for new generating equipment to satisfy this requirement is so huge (more than FIVE TIMES EXISTING UK ELECTRICITY REQUIREMENTS) as to be (a) incredible and (b) wholly impracticable in the timescale concerned
- WWF and other like organisations would like all new cars to be electric by 2030 rather than the Government's target of 2040
  - The extra generating capacity needed just to charge electric cars by 2030 is likely to be of the order of 20GW, the equivalent of at least 4 more Drax sized power stations (Drax's capacity is 4GW) and this assumes even charging throughout each 24 hour period

ENERGY PROJECT TIMINGS

- Lead times typically 5-10 years
- Project lives 20 years (short) 60 years long
- Implications:
  - (1) 2017 to 2030 just about enough to start new large energy projects
  - (2) By 2030 many existing installations will still be within their project life periods

ENERGY POLICY IMPLICATIONS

- Irrespective of what you or politicians may feel about the need to reduce or eliminate carbon dioxide emissions:
  - Existing targets simply cannot be met in the timescales envisaged
  - The only reliable electricity generating installations that can be built quickly enough would have to be gas fired
  - The only question is from where we get the gas?

FURTHER POLICY IMPLICATIONS

- The move to all electric cars by 2045 let alone needs to be severely delayed if not abandoned. Sufficient generating capacity will not be available.
- We need a new strategy for the development of base-load electricity generation in terms of both technology and timescale
- In the short term (20 years) we intend to continue with deployment of renewables we must insist on projects co-existing with gas back-up (as large scale energy storage is unlikely to be available in that time scale)

FIVE MINUTE THESIS

- Present Government Energy Policies are unrealistic in their aims particularly with respect to timescales
- The British public will not continue to believe that the reason for increasing energy bills is profiteering by the energy suppliers
- New Energy Policies will be forced upon Government by events, probably involving greater use of gas for electricity generation and continued use of gas in homes.

FINALLY

- David MacKay sadly died last year. Shortly before his death he was interviewed and was asked how he would use his calculator to achieve UK energy policy goals. Regarding electricity generation David said:
  - "Nuclear base load
  - Rest fossil fuels with carbon capture and storage"

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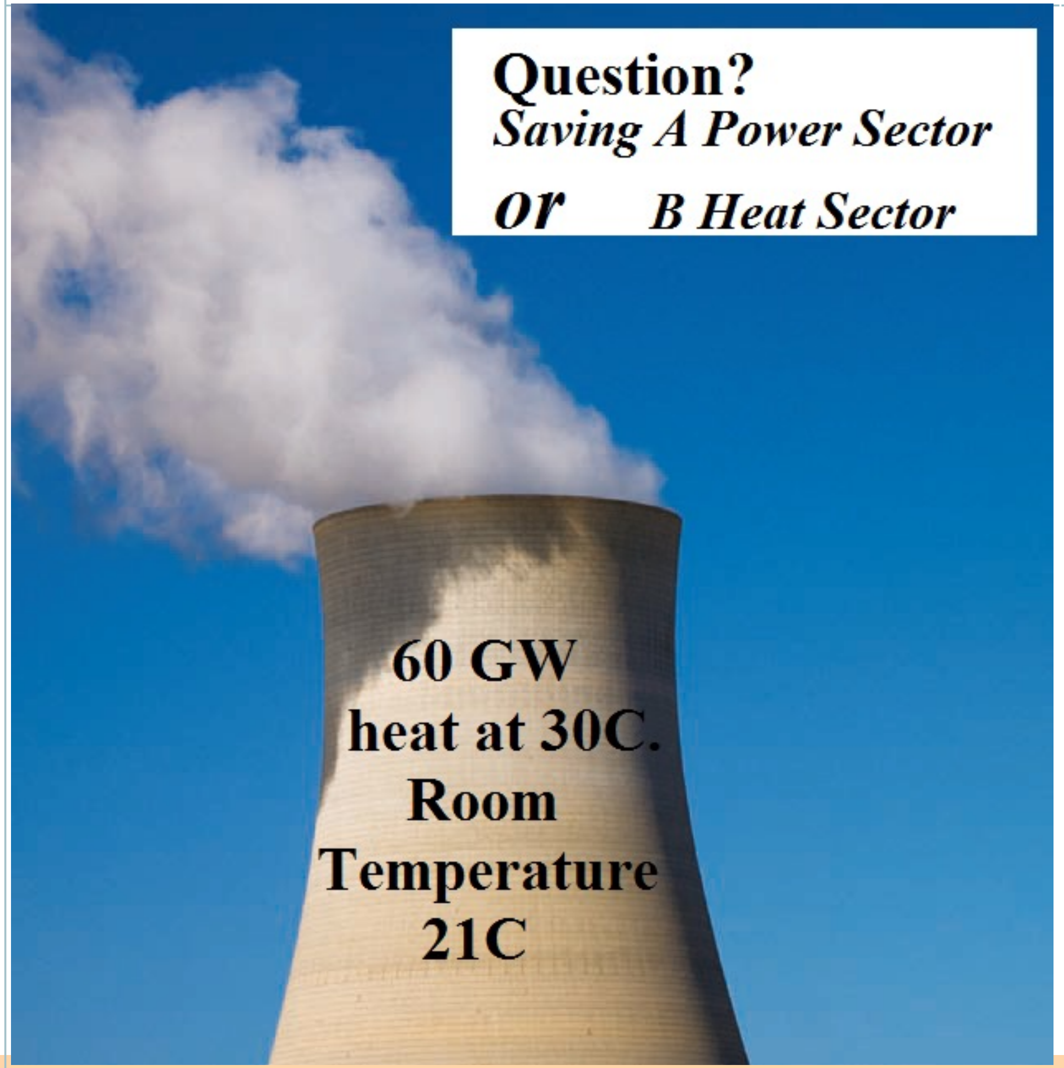
William Orchard

Combined Heat and Power

What do you think? Vote please
Hands up first for A then B then C don't know.

OP



Imagine you decide to build your a house next to this Cooling Tower. You have the idea of using the heat to heat your home.

You know the heat rejected in summer must be hotter than the air say 30C . So you can heat your home in winter to 21C!

Big energy saving power sector reject heat exceeds domestic gas supply.

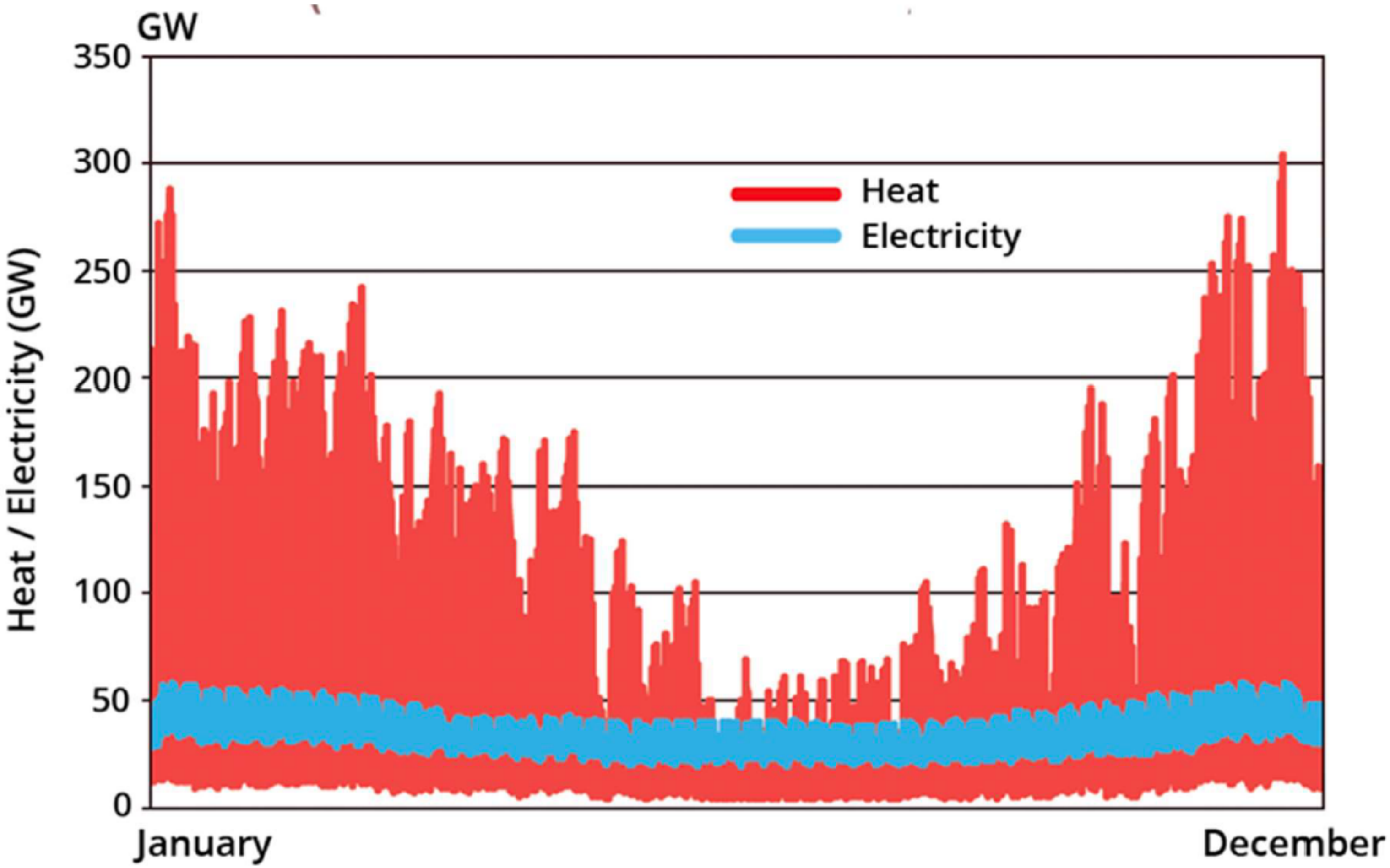
Energy Policy Modelling Question.

Do you save fuel for your boiler to give a heat sector saving B?
Or does your use of the heat
Give a power sector saving A?

Tel 020 8296 8745 email william@orchardpartners.co.uk

Elephant in Room is heat. Answer to Question. DECC and EU A wrong! BRE & SAP B right!

OP



Heat Network & Seasonal Heat Storage?

OP

https://stateofgreen.com/en/profiles/ramboll/solutions/world-largest-thermal-pit-storage-in-vojens

Energy Storage Options	**Size of Store**	**Specific Cost**	**Relative figure**
	MWh	*p per kWh*	*(liquids = ~1)*
Liquid Fuels	20-500	4-5	1
Gaseous Fuels	300,000	10	2
Low-Temperature Heat	**7,000**	**28**	**6**
High-Temperature Heat	1,000	400	80
Electricity Battery	0.01	5,000	1,000

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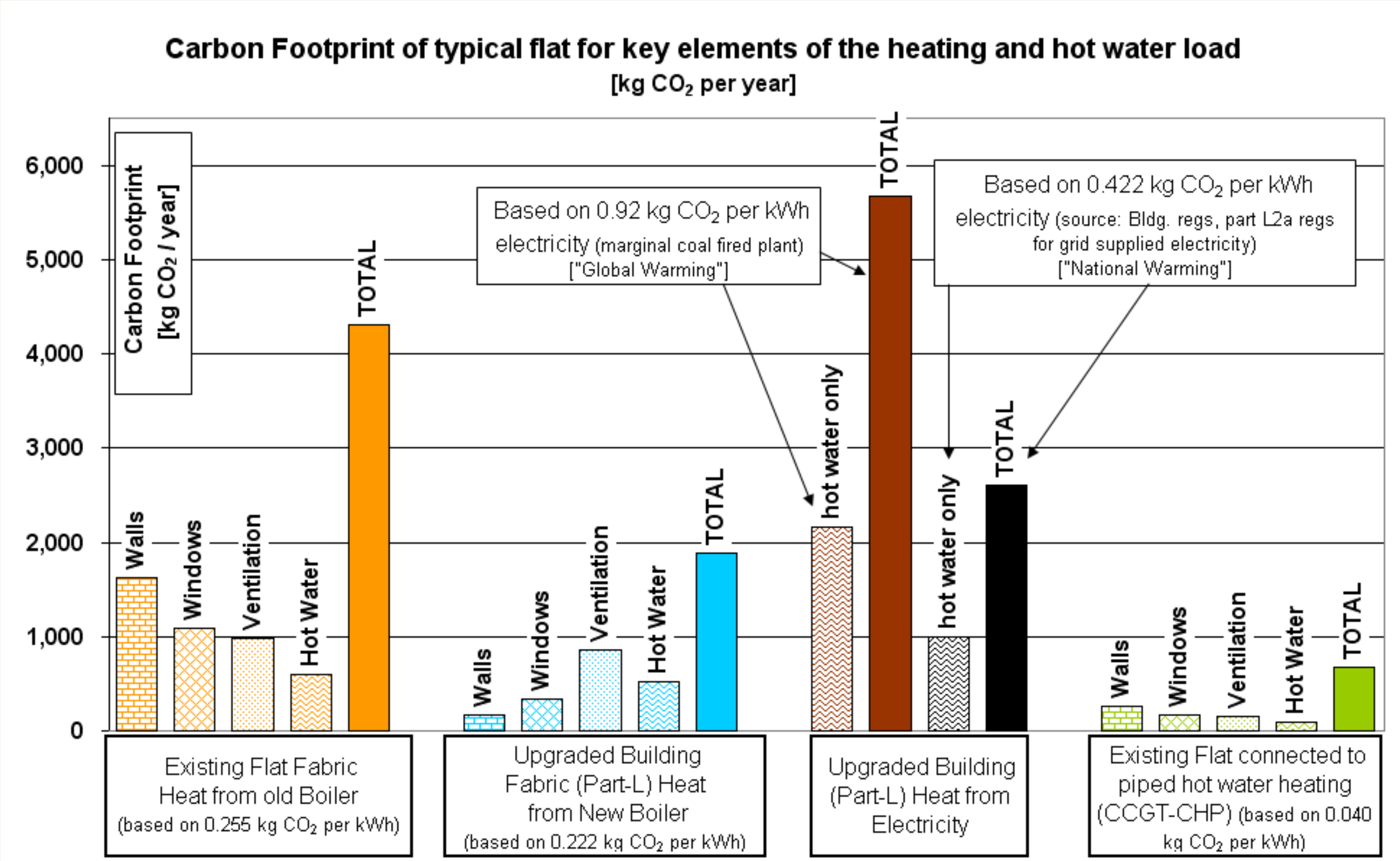
Insulation and low CO2 heat supply.

OP



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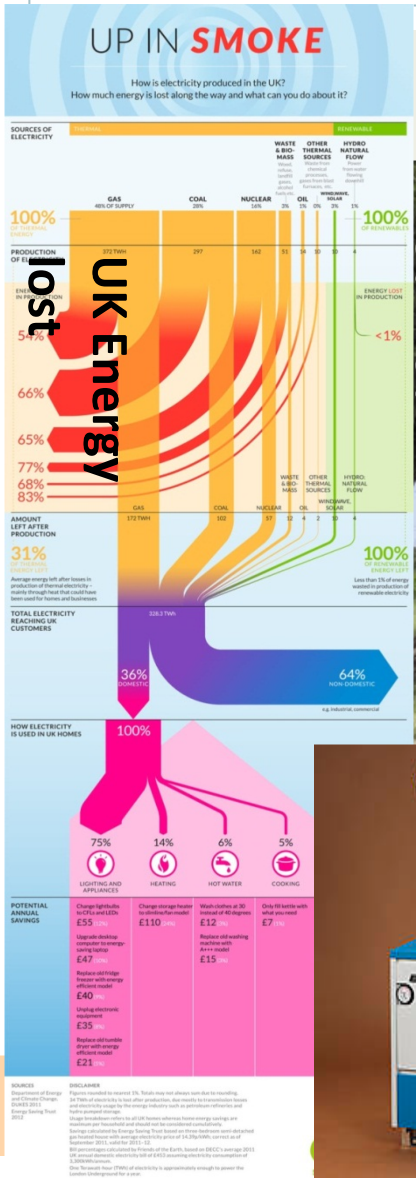
Counter intuitive fact. (1) . Heat rejected in coal fired power generation decarbonises heat compared to heat from gas boilers.

OP

(2) Heat rejected in UK power generation equates to total supply of gas to domestic sector



Heat coal fired CHP COP 10 0.084kg/kWh

Gas boiler 75 % GCV efficiency 0.233 kg/kWh

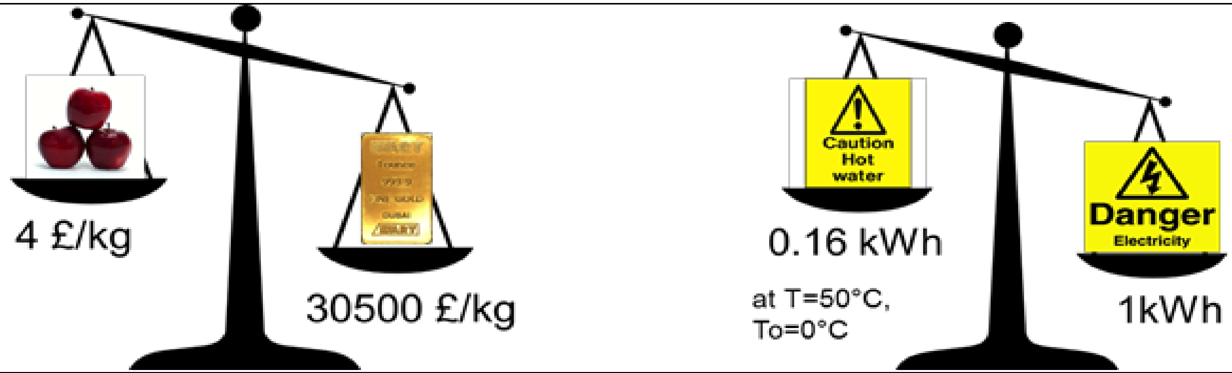
Electricity coal 36% GCV efficiency 0.837 kg/kWh

CHP task for Energy or Exergy Economists ?

Figure 1: First Law Energy Analysis

Source: Dr Audrius Bagdanavicius, Institute of Energy of the Cardiff School of Engineering

Figure 1: Second Law Exergy analysis for water at 50C with reference Carnot temperature zero C



Source: Dr Audrius Bagdanavicius, Institute of Energy of the Cardiff School of Engineering

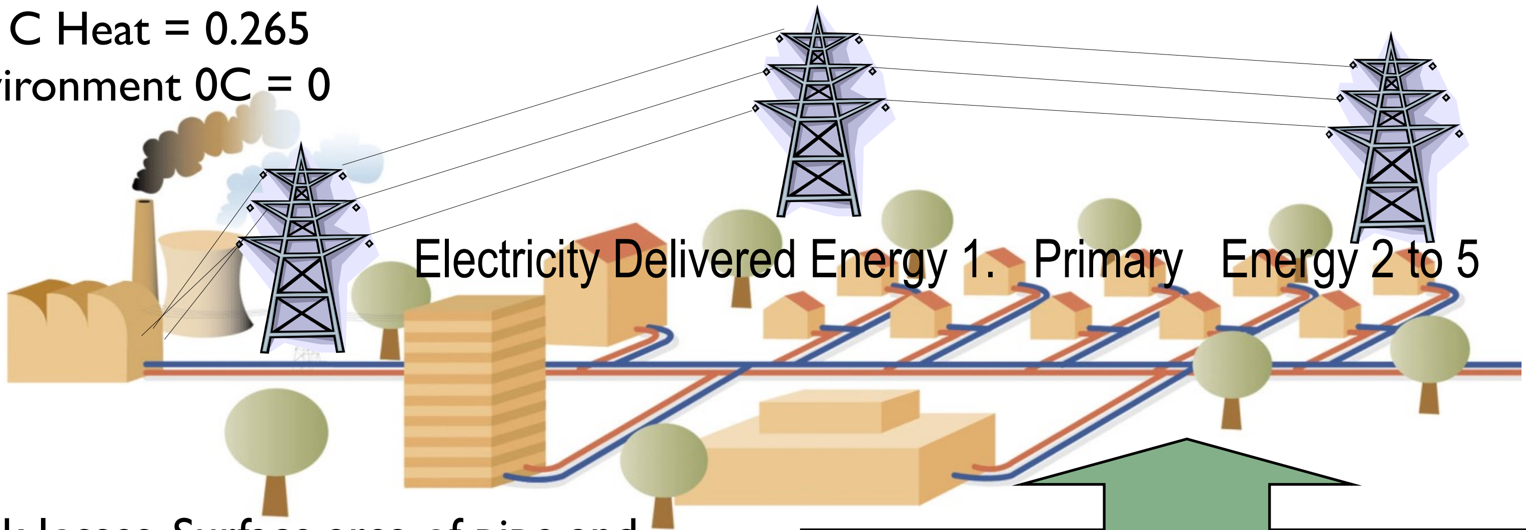
Heat & electrical network losses.
Average & Marginal Energy and Exergy

OP

Electricity network losses i x i x r
i = Current r = resistance.
Double power, loss factor increases by four.

Exergy Measures "Value" of Energy
Exergy Electricity = 1.0
Exergy 100 C Heat = 0.265
Heat in Environment 0C = 0

Electrical Distribution CCGT Energy kWh(e)
10 % (average) to > 20 % (marginal)
Exergy loss average 0.1 marginal 0.2



Heat network losses. Surface area of pipe and temperature. Relatively constant. Pipe carrying capacity. Double pipe size four times capacity.

CHP Heat Distribution Energy Loss per kWh (h)
8 - 20% (average) 0 – 2 % (marginal)
Exergy loss average 0.02 marginal 0.002

Tel 020 8296 8745 email william@orchardpartners.co.uk

£39Bn spend justified on heat networks using 30C reject heat from power (CHP) instead of winter air

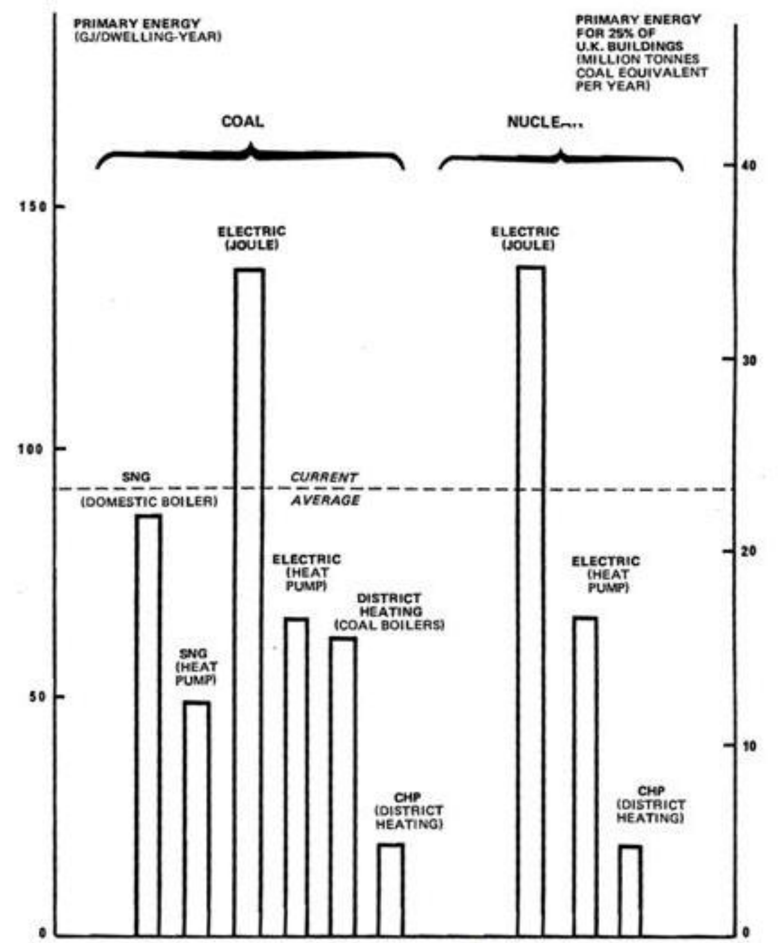


Figure 17 page 48 Energy Paper 20 (1977) Primary Energy Requirements for long term (post 2000 alternatives) ISBN 011410603 7

power station reject temperature	°C	30
equivalent Carnot elect to ASHP	kW	
	kWh/y	
cost of electricity	p/kWh	9
thermal power plant on system	GW	60
power plant average effy elect		0.4
power plant avg effy total		0.75
power plant avg effy thermal		0.35
reject heat available	GW	52.5
cost of ASHP electricity	£bn/y	1.04
discount rate	%	3.5
system life	years	100
lifetime cost of ASHP electricity	£bn	29.88

Calculations use second law Carnot equation to calculate the power to raise the outside air to 30C using half hourly air temperatures from Heathrow. Colder parts of UK even bigger spend justified.

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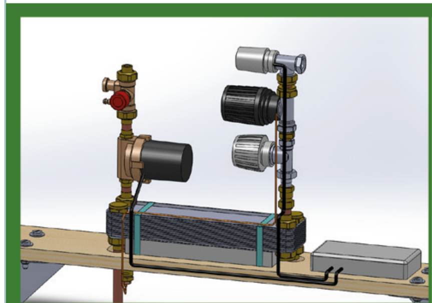
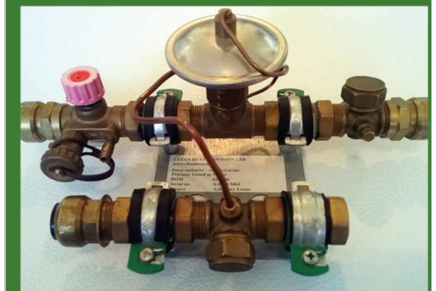
Exergenius & how to retrofit Domestic Sector to heat networks small or city wide.

OP

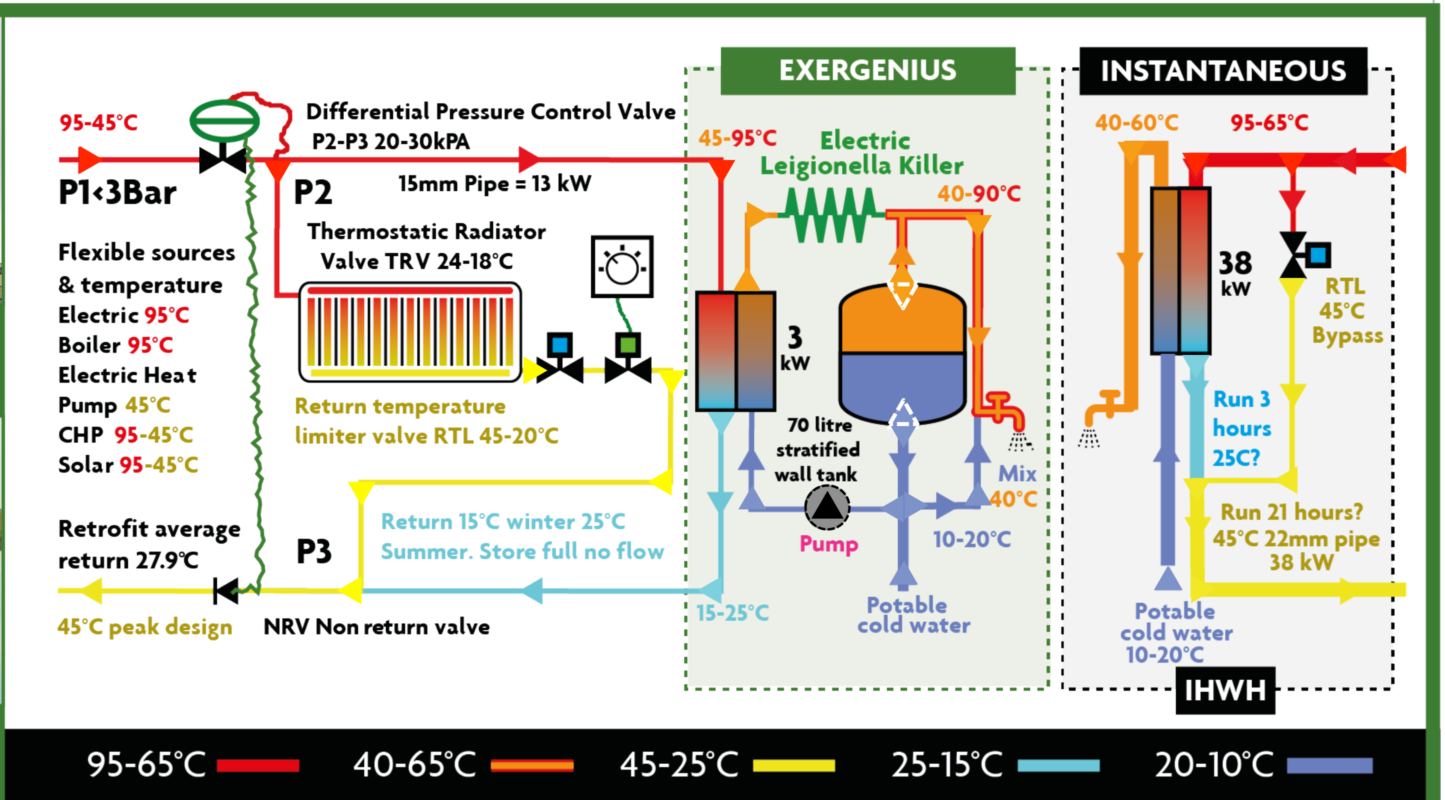
10% energy and exergy saving for heat networks, heat pumps, boilers, solar, combined heat & power



Retrofit for cylinder with Coil for condensing



DPC interface product Roupell



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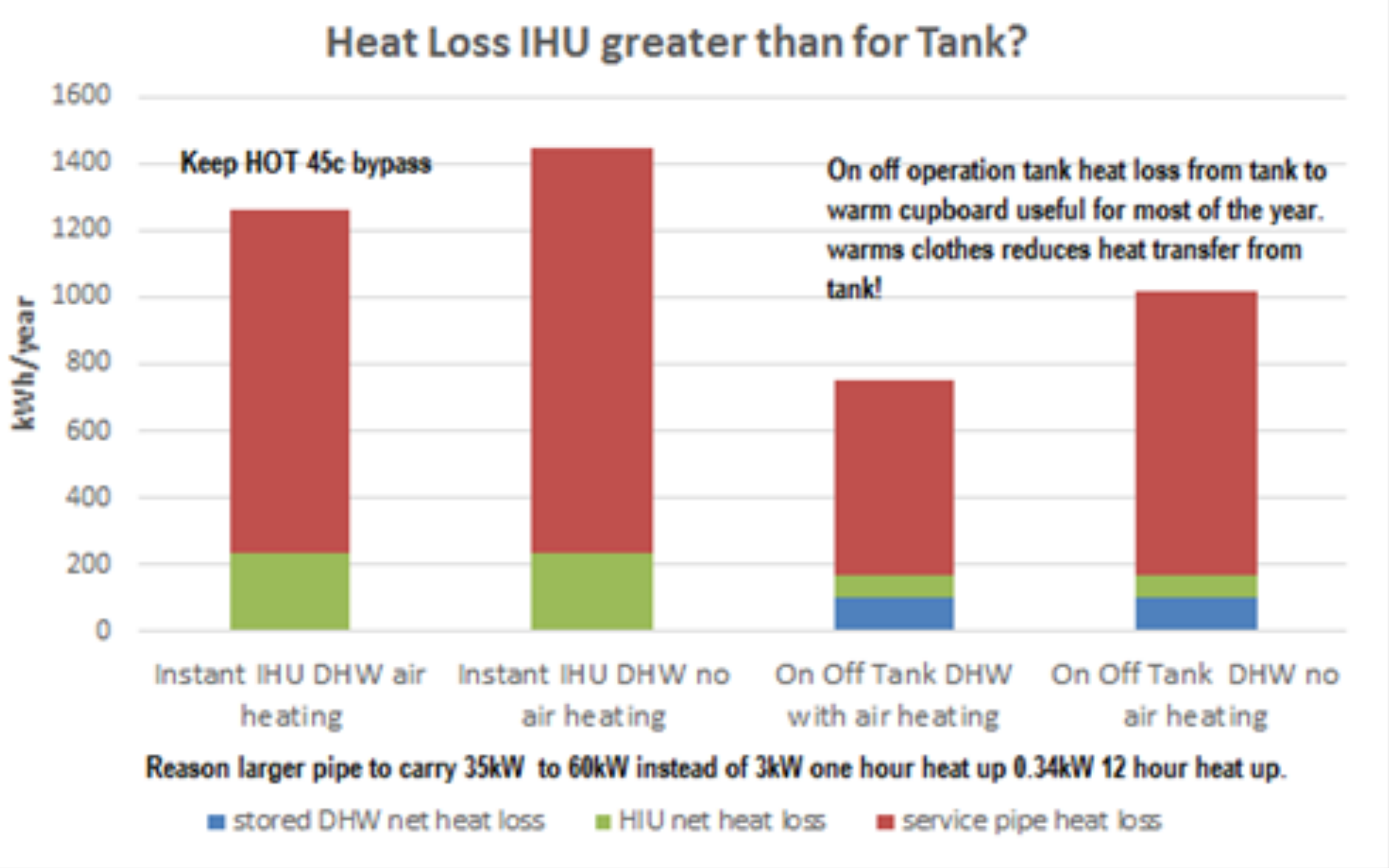
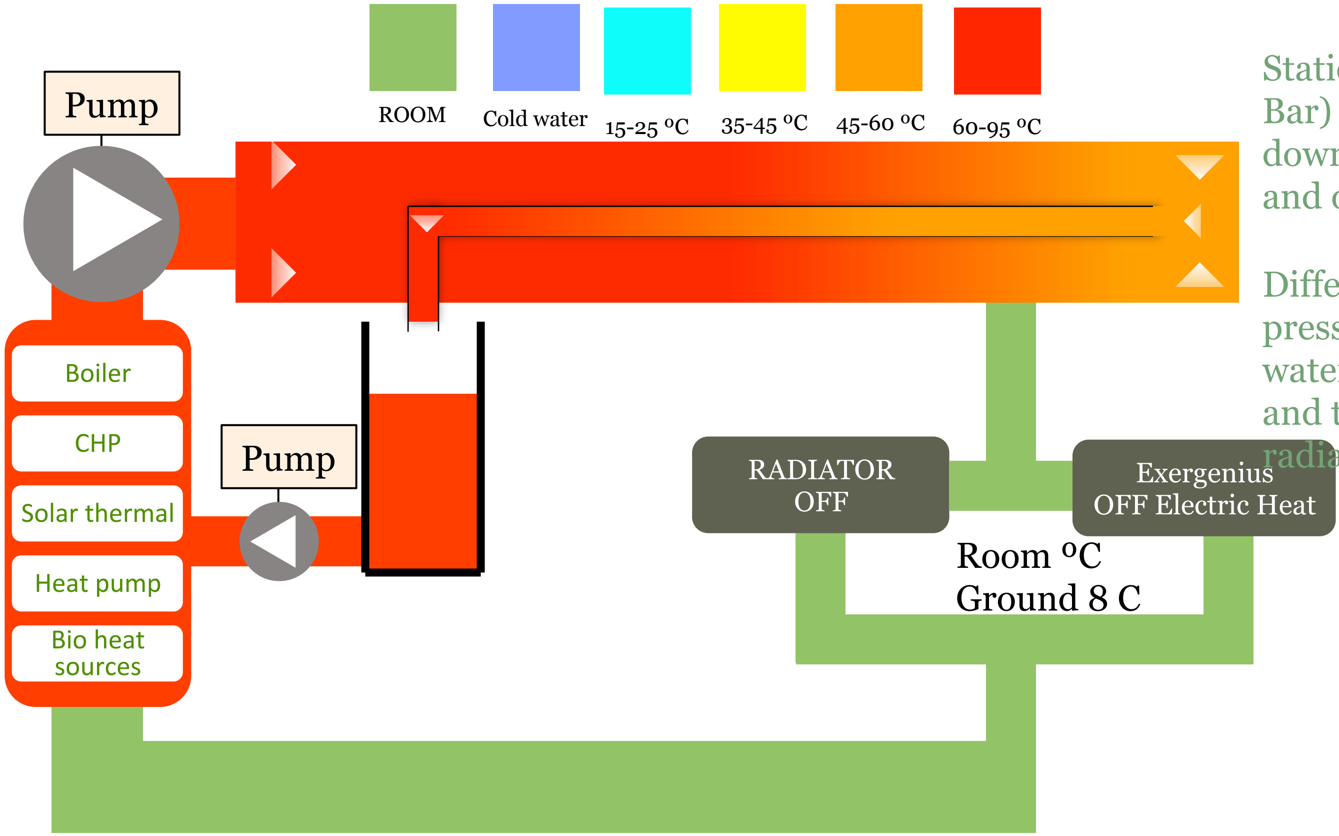
DHW Store Tank on wall with electric standby optimal for Consumers and heat networks?

OP



Keep Hot Pipe. Summer Return Off. Wind PV EL heat water. Return On Solar Thermal EHP.

OP



Static pressure (3 Bar) drives water down middle of pipe and out into tank

Difference in pressure 2 Bar drives water around system and through radiators

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Dr Francisco de la Peña

Floating Technology

Floating Technology

Transforming
the Energy Outlook up to 2030

By Dr Francisco de la Peña

Energy Institute
London, 13th November 2017

Overview

- Definition: infrastructure
  - Floating on water
  - Unsupported by a firm foundation
  - Permanently fixed in a horizontal direction
  - Following vertical variations in water level
- Objective: commercialisation
  - Develop projects in an economically viable way, and
  - Compete with conventional offshore and onshore renewables

Background – Offshore Oil & Gas

- For decades, floating technology has been deployed successfully
  - Off Castellon, Spain (1977)
  - >270 oil FPSOs, worldwide (To date)
- In recent years the objective has been to transfer that knowledge from oil & gas into the renewables

Demand Projections

- US
  - 60% of the new planned 54GW of offshore renewables capacity will be in deep waters
- EU
  - Offshore wind has the potential to deliver 50% of EU's electricity demand by 2050
  - UK can leverage on existing capabilities and become one of the market leaders

Advantages/Benefits - Solar

- Efficiency
  - Water surrounding "floatovoltaic" panels provide cooling effect keeping them running at the highest possible efficiency
  - >10% more efficient than conventional panels that get very hot in the sun all day
- Long reach/New added value
  - Utilize low dams, reservoirs and rivers
- Environment
  - Prevent damage to forested areas

Advantages/Benefits - Wind

- Efficiency: Higher produced electricity per GW of installed capacity due to higher average wind speed

- Greater reach: open up areas of sea not previously suitable
  - Deep waters: >50m deep, where the continental shelf drops off too fast for fixed turbines to be viable
  - Harsh operating environment with stronger and less variable winds

- Flexibility: full assembly of turbines close to shore before being towed out to sea

- Environment: Less impact on wildlife than farms placed closer to the coast and visually less prominent

Floating Solar Platforms

Floatovoltaics Components

- Solar inverters
- Molded cases
- Miniature circuit breakers
- Power-integrated wireless module connections
- Real-time monitoring system

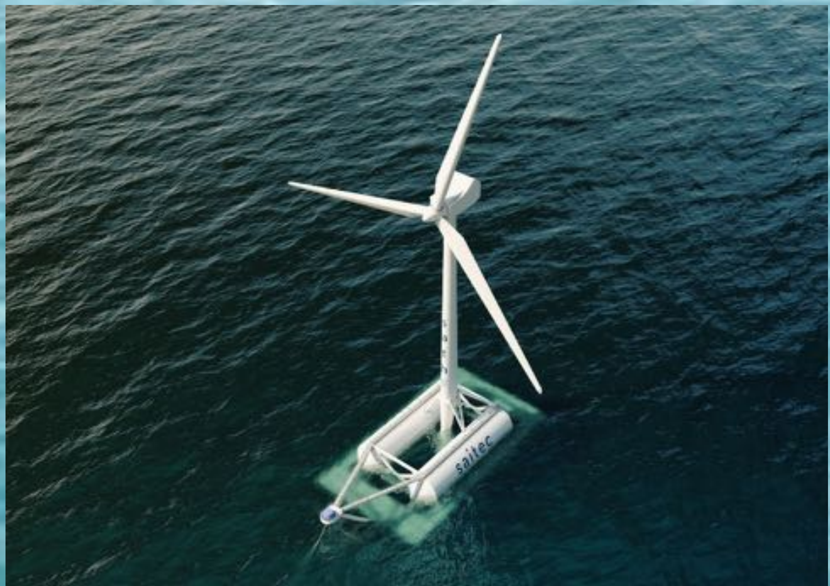
Projects

- Off Sangju, South Korea
- Off Singapore

Floating Wind Farms

Components

- Turbines
- Foundations: spar-buoy, semi-submersible or tension leg platforms
- Subsea cables



Projects

- Off Peterhead, Scotland
- Off Fukushima, Japan
- Off Lecaute, France
- Off Viana do Castelo, Portugal

Challenges

- **Technical**
  - Hold the structures at water depths of up to 700m and ensure they cope with winter storms that whip seas into a froth
  - Maximise capture of wind energy despite bobbing and reduce risk of components being damaged
- **Economic**
  - Expensive gravity bases & stronger steel structures (x8)
  - Economics of renewables *v* oil & gas
    - Much slimmer margins
    - Larger n of smaller platforms rather than small n of large platforms

Conclusion – latest indicators

- The technology has matured enough
  - Future: Lower wind turbines + clever design and material selection should help reduce weight > need for ballast > sub-sea costs
- Tremendous potential for economies of scale
  - Mass production (i.e. reduces the cost of each turbine)
  - Construction and management of vast wind farms offshore
- Technology Readiness Level Index: While many floating concepts are at a relatively early stage of development (TRL0-6), some advanced floating technologies are already at TRL8-9
- Cost: floating turbines <u>today</u> = fixed-bottom turbines a <u>decade ago</u>

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Keith Pullen

Flywheel Energy Storage

Academic excellence for business and the professions

Low Cost Flywheel Energy Storage: Supporting the Transformation to Renewables

Keith Pullen

Professor of Energy Systems, City University of London

13th November 2017

Presentation Outline

- The demand for grid electrical energy storage
- Electrical flywheel storage: How it works
- Comparison with other storage technologies
- The Gyrotricity flywheel solution

The demand for grid electrical energy storage

- Increased penetration of renewables makes balancing of supply and demand more difficult

- Across timescales from sub second to seasonal

- Caused by;

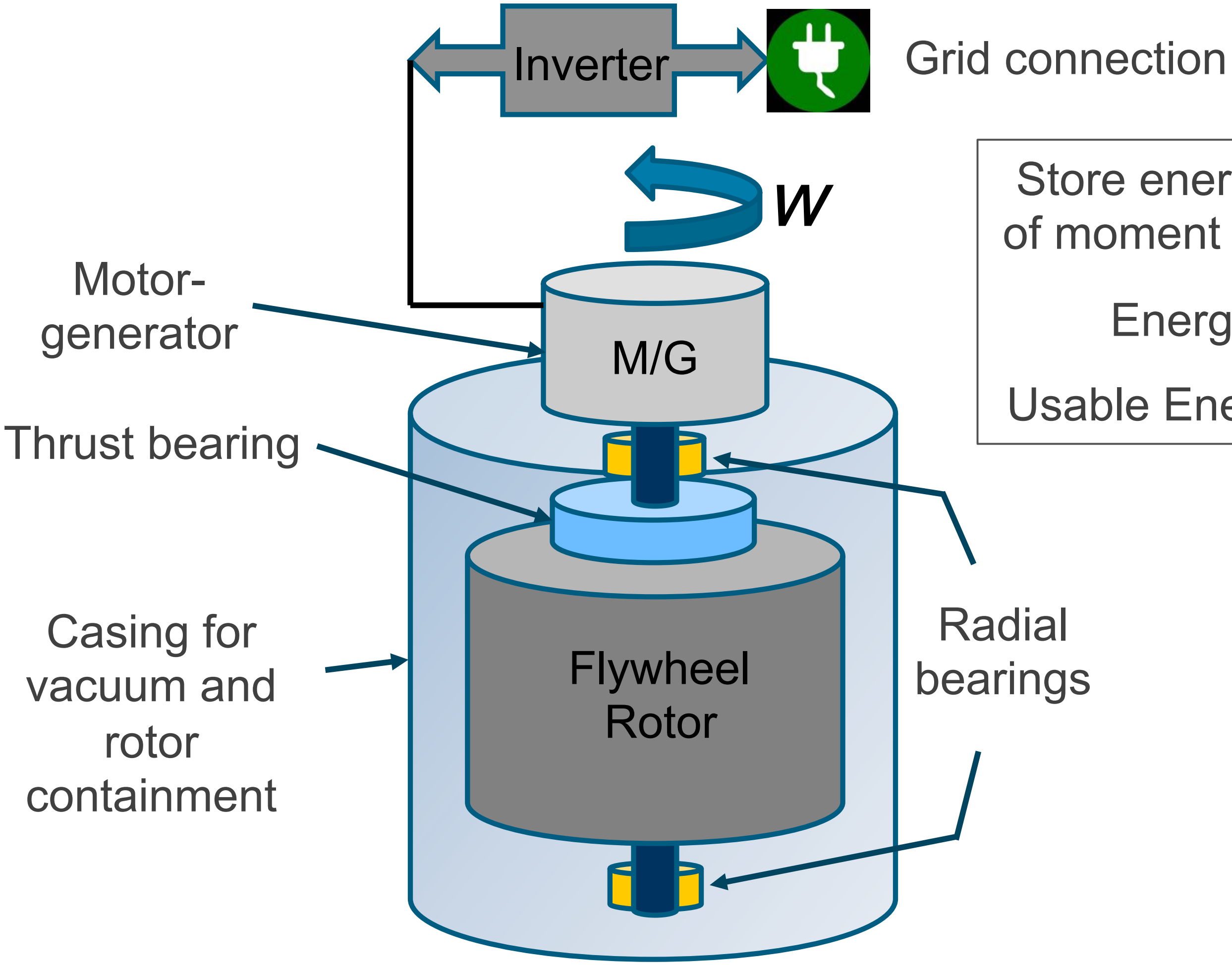
  - Removal of rotating inertia from large power station engines

  - Renewable generation dependant upon the weather  

  - Inability to control demand (May be better or worse with growth of electric vehicles?)

- A clear solution is to store electrical energy as a means of balancing supply and demand

Electrical Flywheel storage: How it works

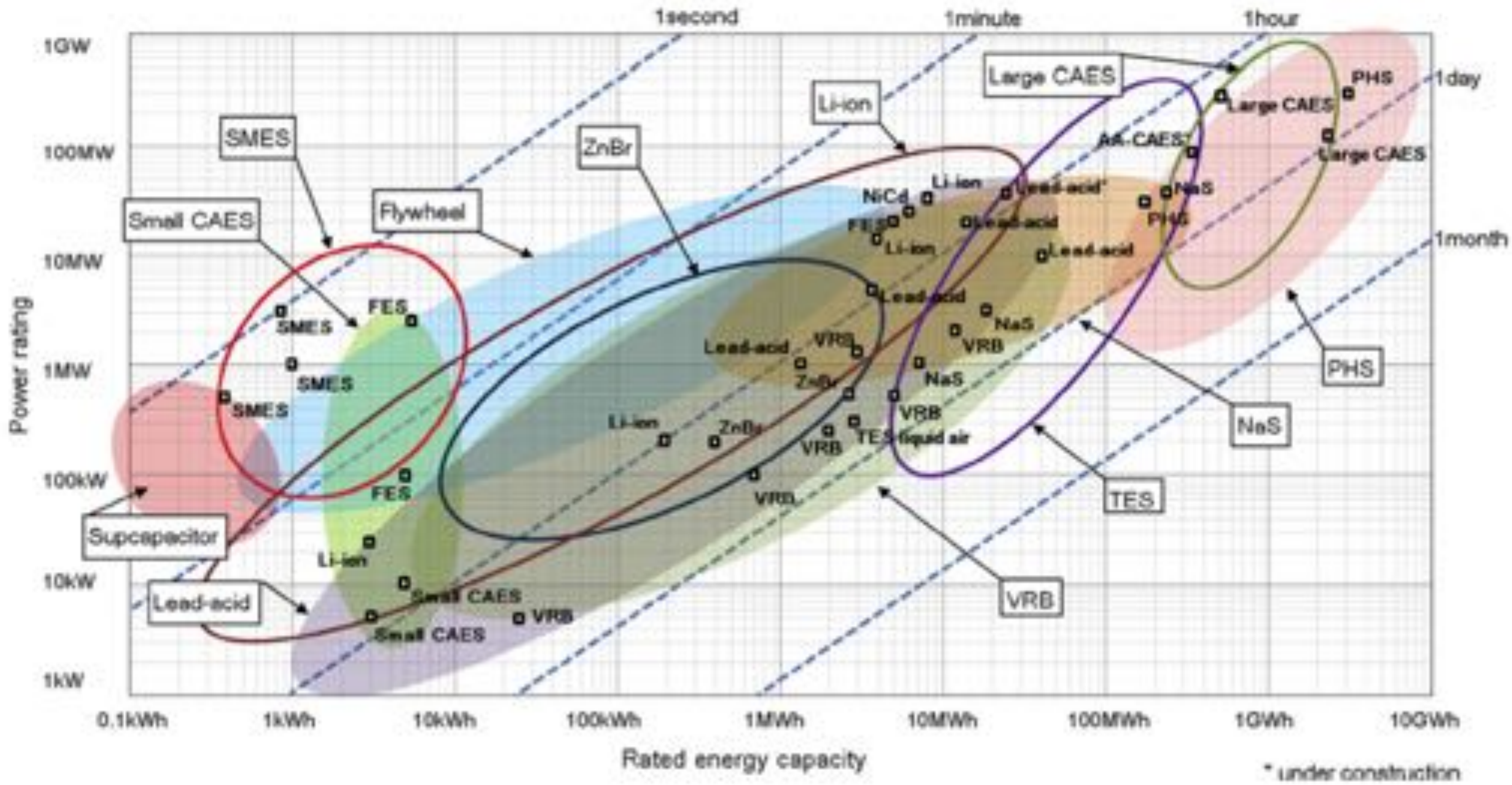


Store energy by spinning a rotor of moment of inertia I_f to speed w_f

Energy stored = $\frac{1}{2} I_f w_f^2$

Usable Energy = $\frac{1}{2} I_f(w^2_{max}-w^2_{min})$

Comparison with other storage technologies



Ref (Xing Luo, Jihong Wang, Mark Dooner, Jonathan Clarke, “Overview of current development in electrical energy storage,” 2014.

Comparison with other storage technologies

	Flywheels	Batteries	Compressed gas (CAES)	Pumped hydro (PHS)
Life (years)	30	10	30-50	40-60
Cycle life	> 500k	5000	> 500k	> 500k
Operating power	Friction loss	Cooling and heating	Low	Low
Maintenance	Bearings	Cell replacement	M + E Overhaul	M + E Overhaul
Response	mS	mS-S	10's	10's
Recyclable	Yes	No	Yes	Yes

- Conclude:
  - Flywheels are good for several cycles per day
  - Ideal for maintaining grid stability
  - Good match to CAES and PHS, also to batteries to extend life under high power, high cycle duties

Gyrotricity flywheel solution

Three main choices for flywheel rotors :

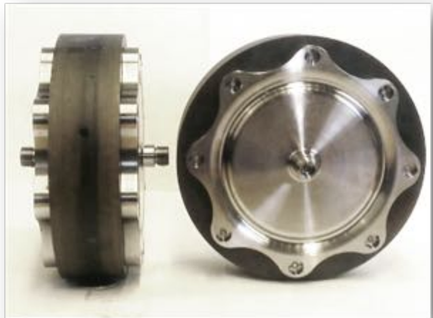
- Solid monolithic (one piece) steel

temporal

- Carbon fibre composite

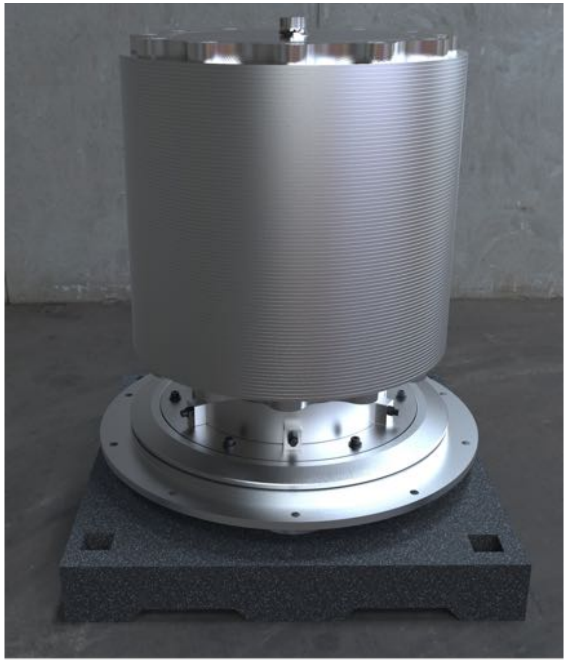
Beacon POWER

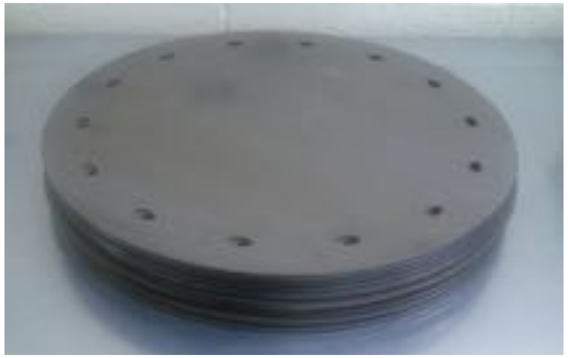
- Laminated steel



Gyrotricity
DURABLE ENERGY STORAGE

The Gyrotricity flywheel solution





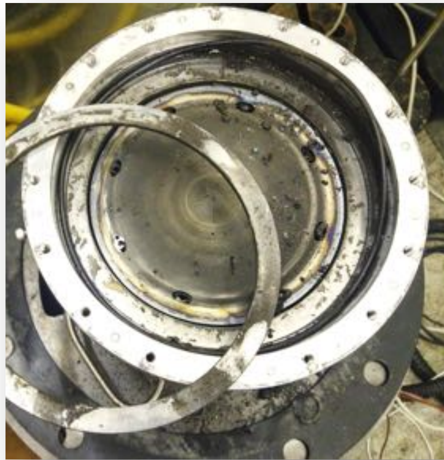
Gyrotricity
DURABLE ENERGY STORAGE

Laminated steel rotor advantage

- If crack occurs, small pieces released so containment can be thinner and lighter
- Steel material properties well understood
- High strength steel available at low cost in sheets
- Does not need to be in a bunker so we can offer a highly compact solution

The Gyrotricity flywheel solution

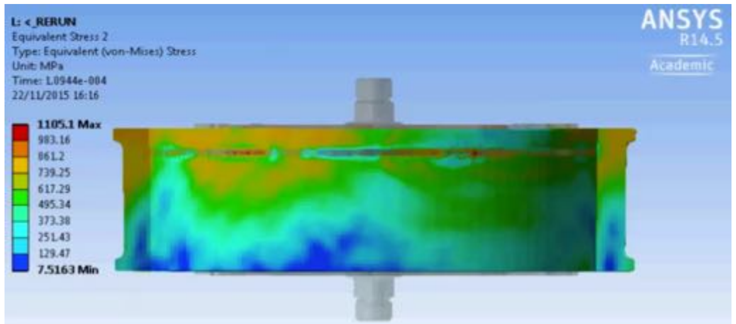
Flywheel safety case analysis and testing



- Fail safe design proven by experiment
- One laminate inserted with major crack and burst at full speed
- No distortion/damage to casing, only light surface damage

- No damage to other laminates
- Burst captured on Photron high speed camera (50,000 fps)

- Results simulated using dynamic Finite Element Analysis



The Gyrotricity flywheel solution

Allows a compact and transportable solution with low installation costs

Thank you for listening

Keith R Pullen,
Professor of Energy Systems

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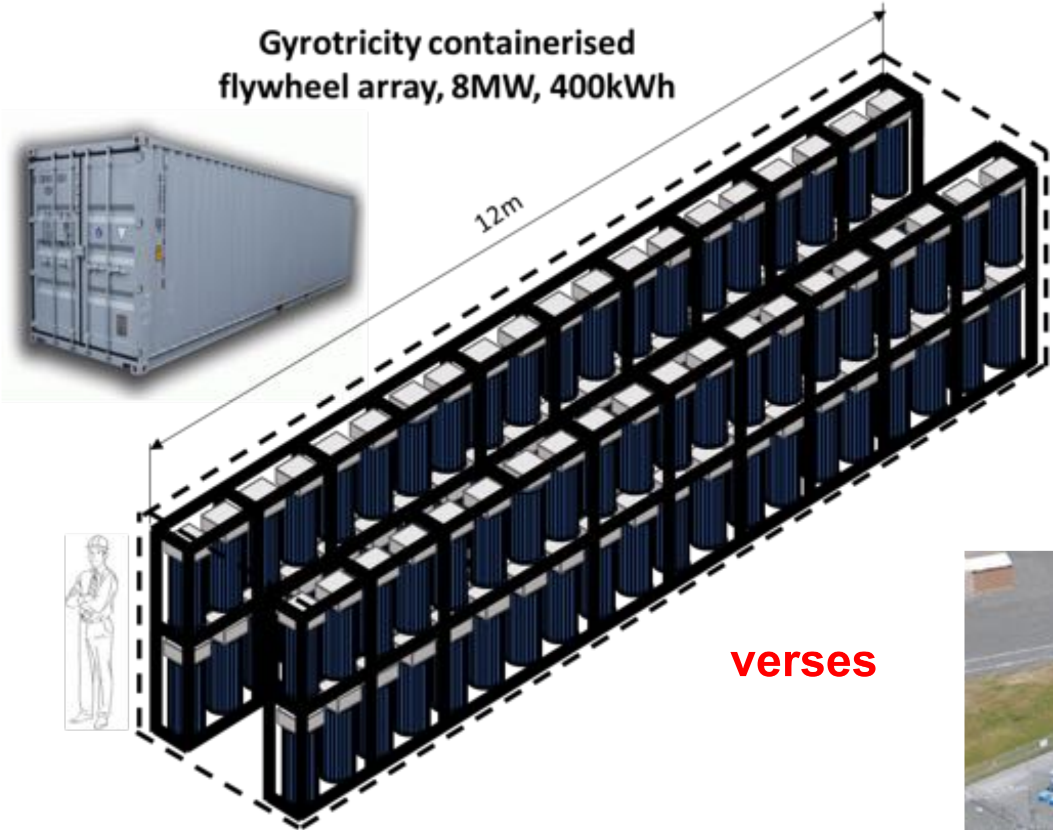

verses

Beacon Power 20MW

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Nic Rigby

Funding for Renewables

Energy Slam – Funding the Future

Nic Rigby

13 November 2017

NRG Management Consultancy
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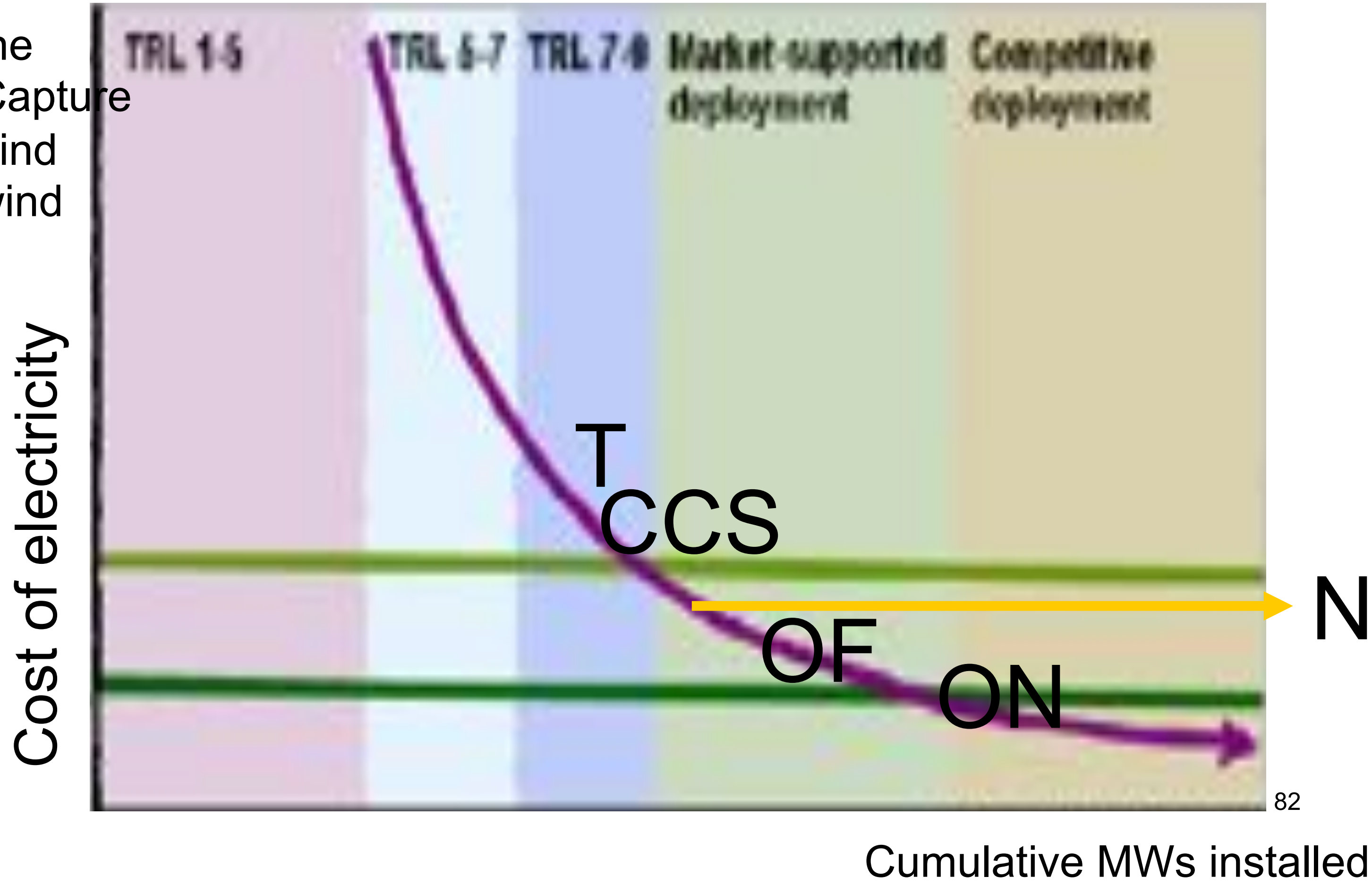
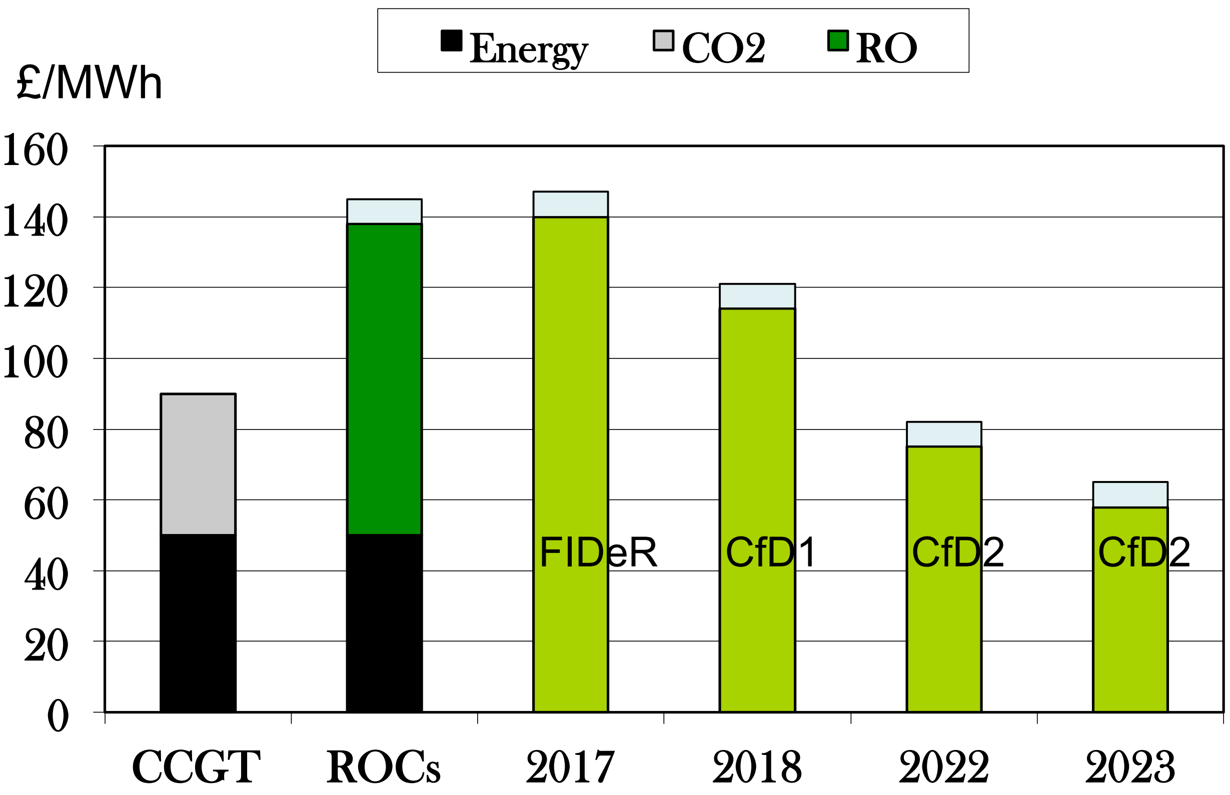
Who needs Support

T = Tidal & Marine
CCS = Carbon Capture
OF = Offshore wind
ON = Onshore wind
N = Nuclear



CCGT versus Offshore Wind



<<<<<<Auctions
>>>>>>>>>

Why is the CfD right?

- Auction
- No double dipping
- Charge for intermittency

What we don't do well

- Transparent
- Certainty of process
- No cost CfD

Strategy

Nuclear	- Lots of jobs
Onshore wind	- Killed by Tories
Solar PV	- Collateral damage
Offshore wind	- Flavour of the month
Biomass	- EU "only with CHP"
ACT	- Energy from waste/small scale
CCS & Tidal lagoon	- Scale issue

Who Should Pay

- Industry & commerce - Don't offshore carbon emissions
- Vulnerable customers - Tax payers should protect
- The rest of us - Stern, pay replacement cost

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Tom Weight

Energy Perspectives

Statoil

Energy Perspectives 2017
Long-term macro and market outlook

Press seminar, Oslo, 8 June 2017

Eirik Wærness, Senior vice president and Chief economist

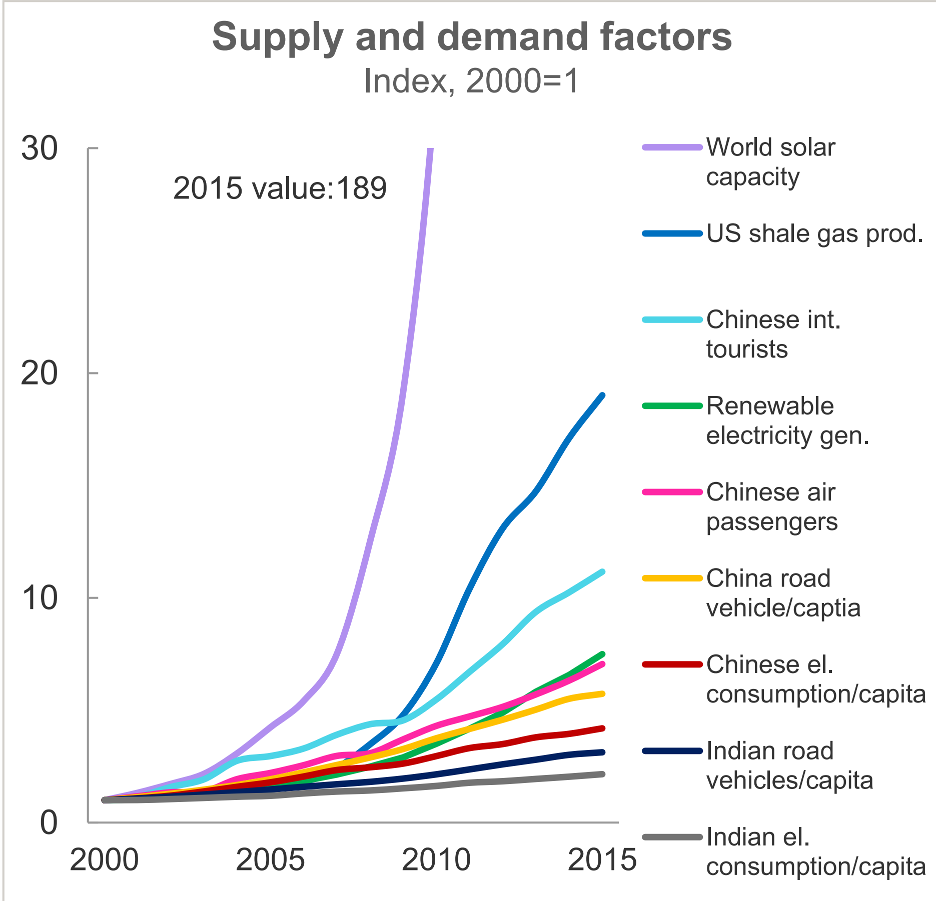
Energy Perspectives 2017

Macro and market outlook to 2050 – www.statoil.com/energyperspectives

Significant uncertainty and large changes

… calling for the use of scenarios

Source: The Economist

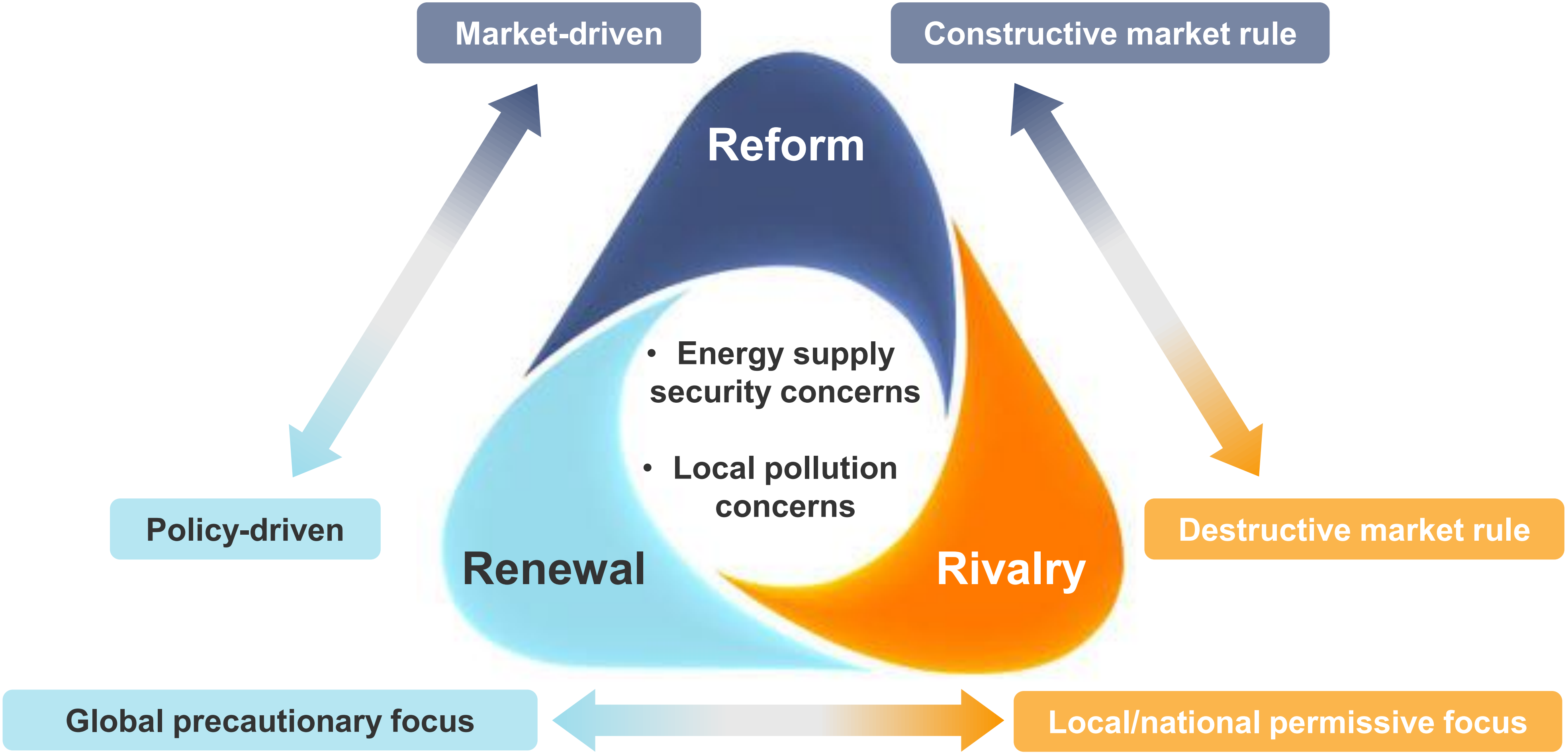


Source: World Bank, IEA, IRENA, EIA

Statoil

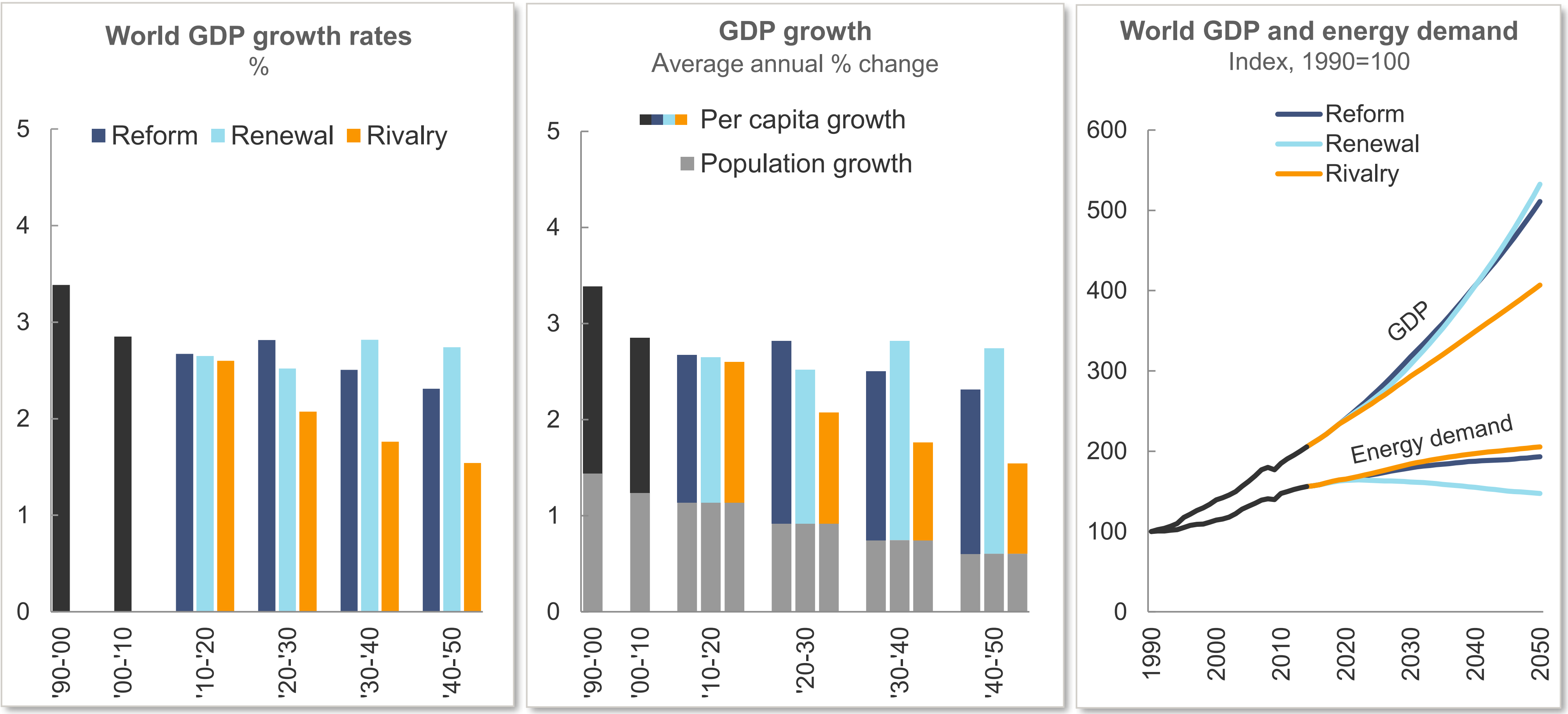
Three different tales of the future towards 2050

None are BAU – Renewal a tremendous challenge, Rivalry unpleasant



Economic growth varies over time and across the scenarios

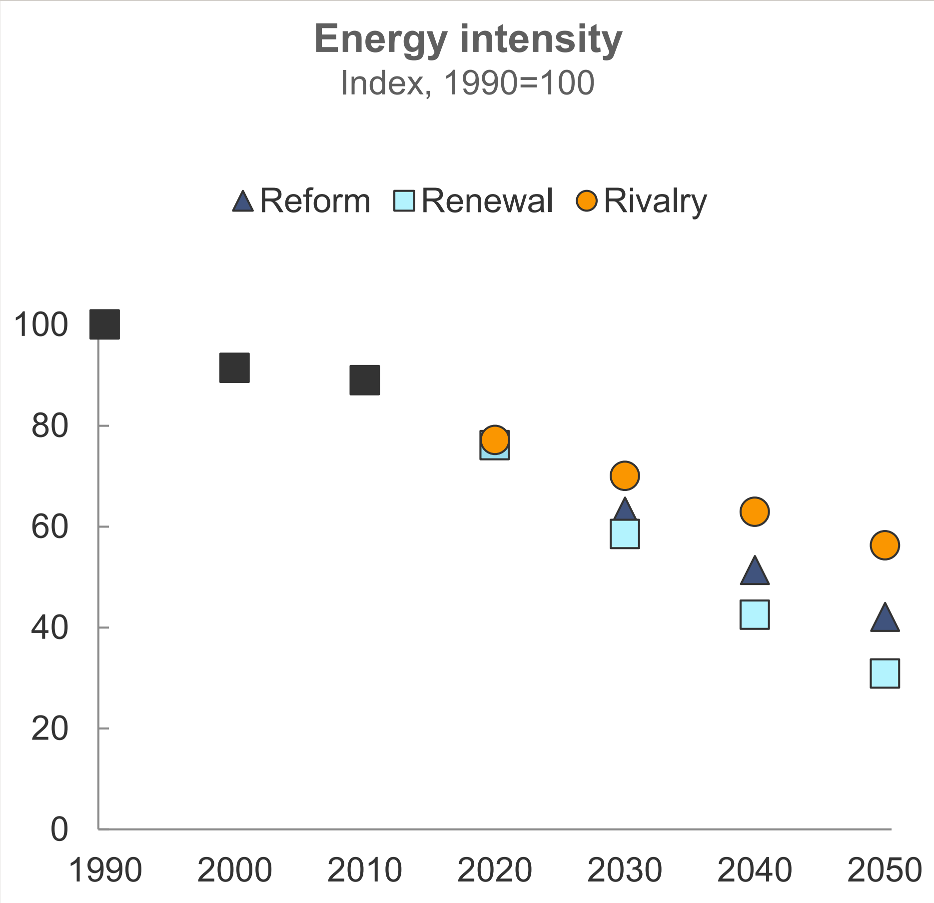
Global GDP 2-2.6 times higher in 2050, Renewal highest, Rivalry lowest

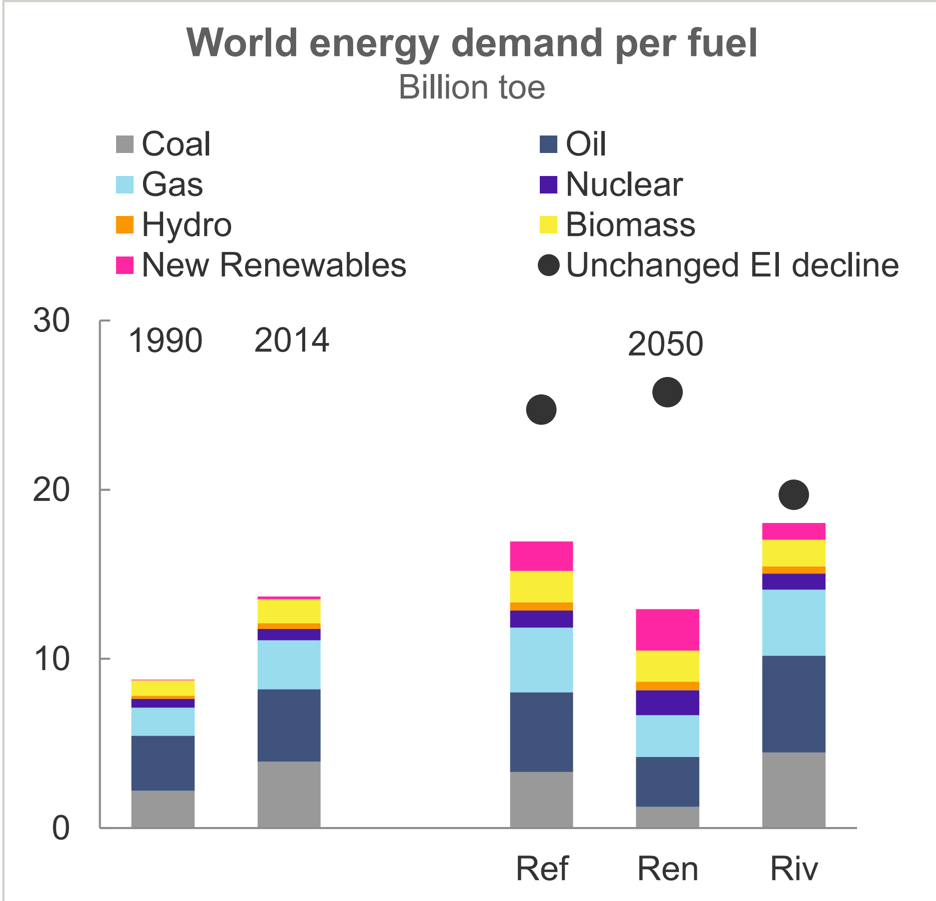


Source: IEA (historical demand), UN (Population/historical GDP), Statoil (projections)

Key #1: Energy efficiency improvement

Reform, and especially Renewal: step change in global energy efficiency



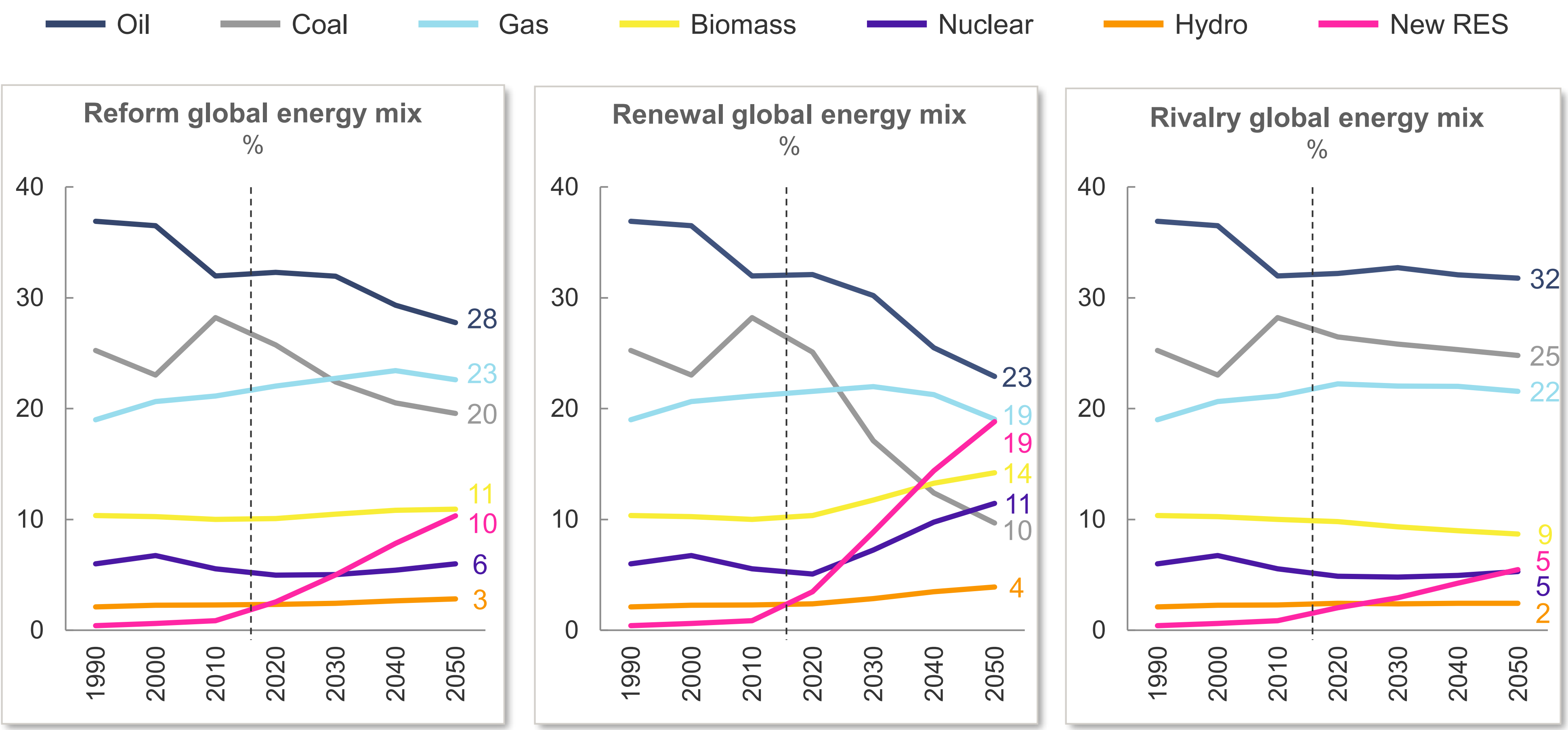


Source: IEA (history), Statoil (projections)

Statoil

Key #2: Speeding up the change in global energy mix

… with Renewal displaying a paradigm shift



Source: IEA (history), Statoil (projections)

Statoil

A strong trend affecting economics and energy

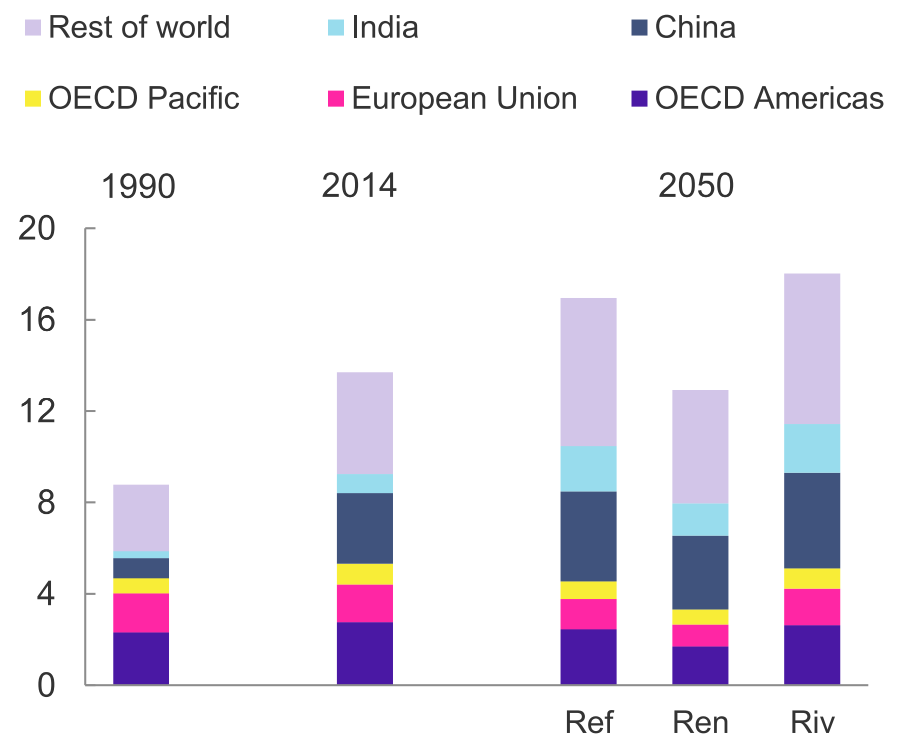
All growth in energy demand in emerging economies, in particular in Asia

The global population centre is in Asia

If the world were a village of 100 people…

World energy demand per region

Billion toe



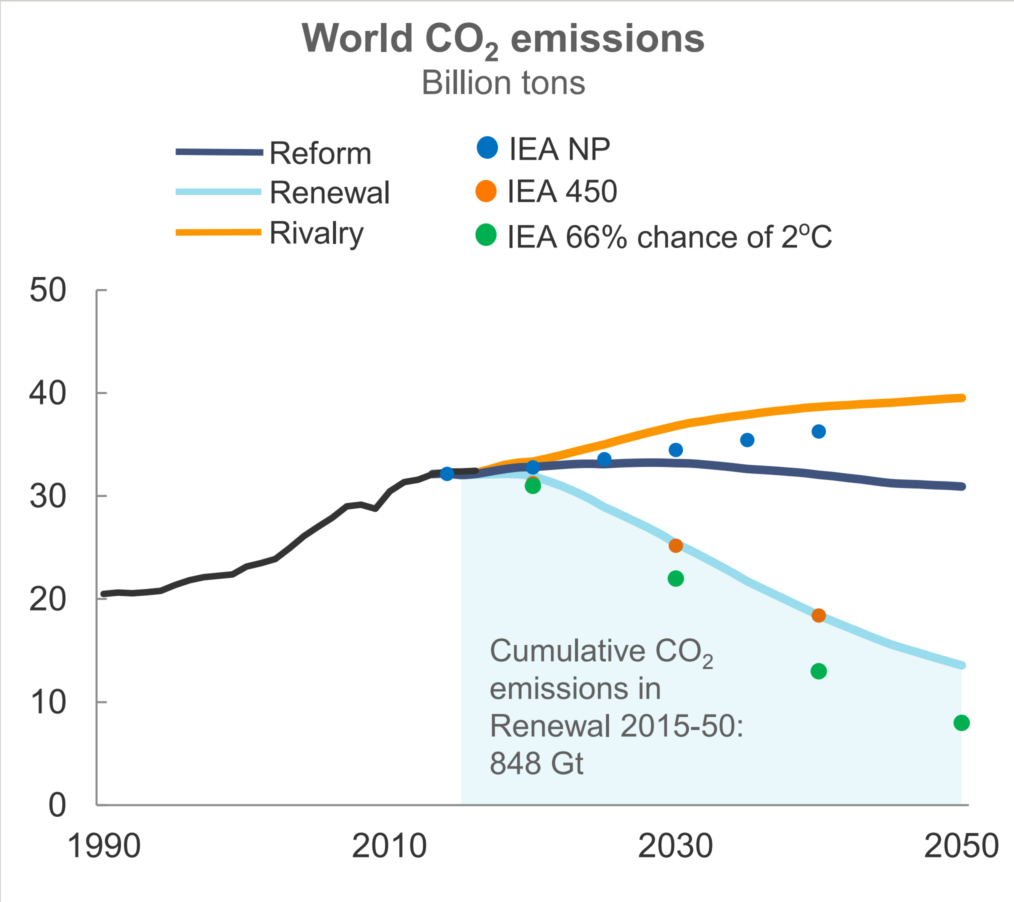
Source: visualnews

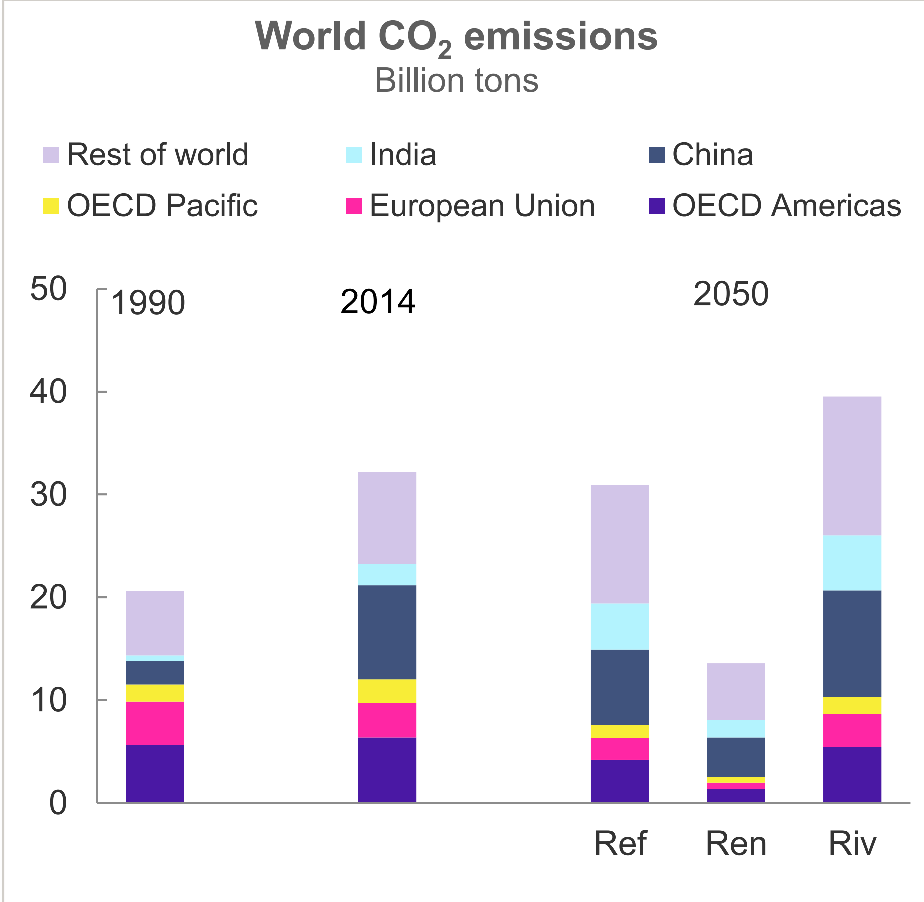
Source: IEA, Statoil (projections)

Statoil

CO_2 emissions determined by demand and mix

Policies, markets, and technology having varying impact



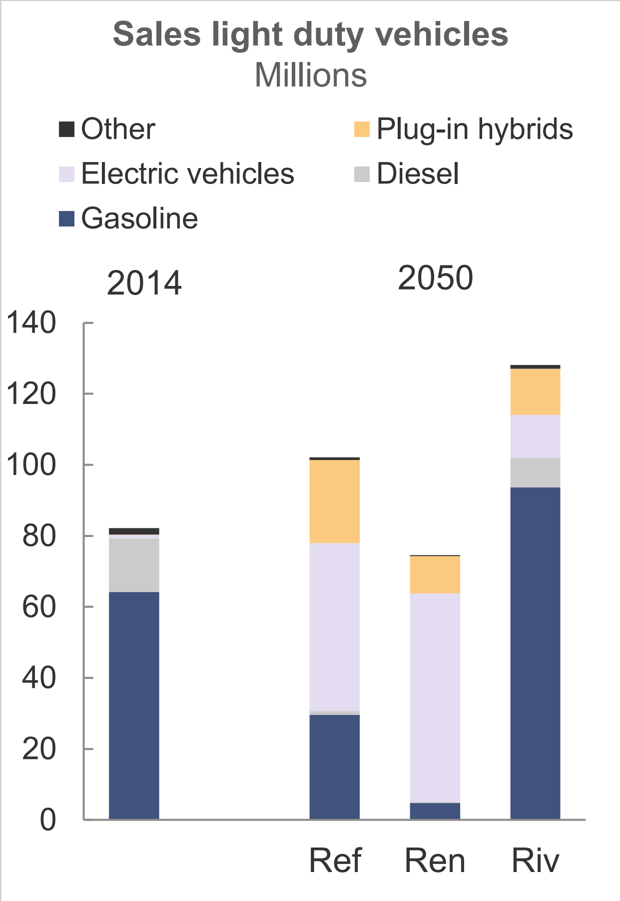


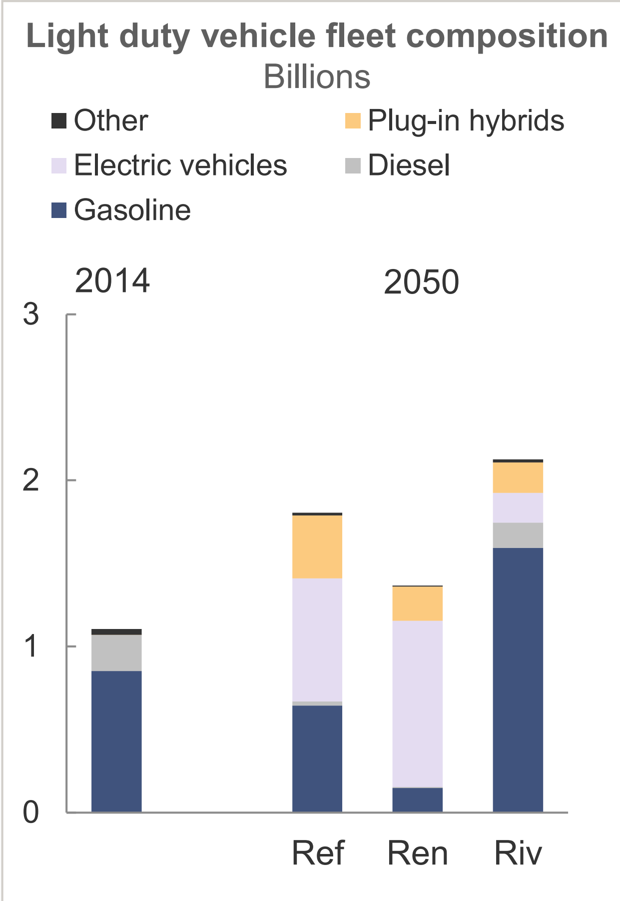
Source: IEA (history), Statoil (projections)

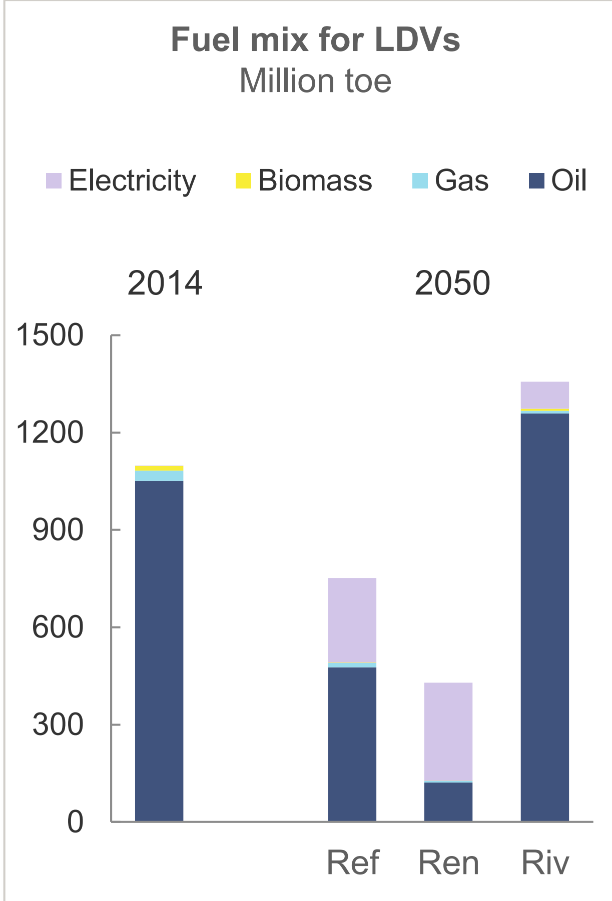
Statoil

Technology shift for light duty vehicles

… in all scenarios, and a revolution in Renewal





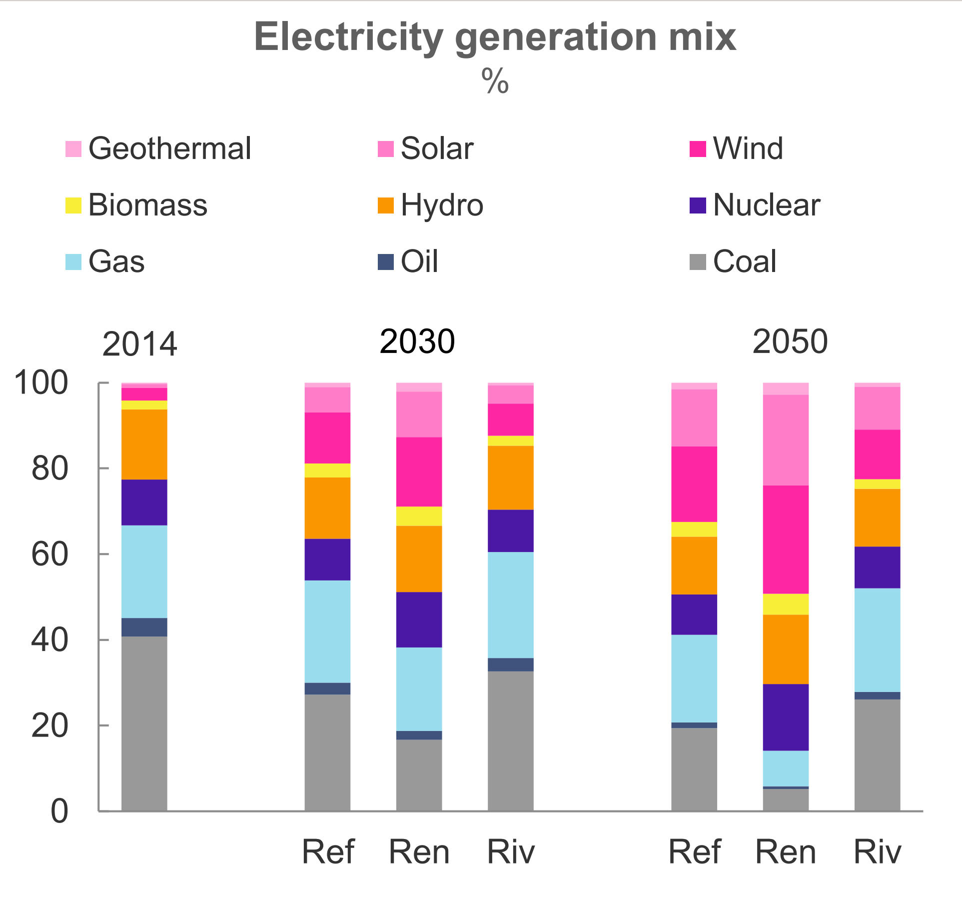


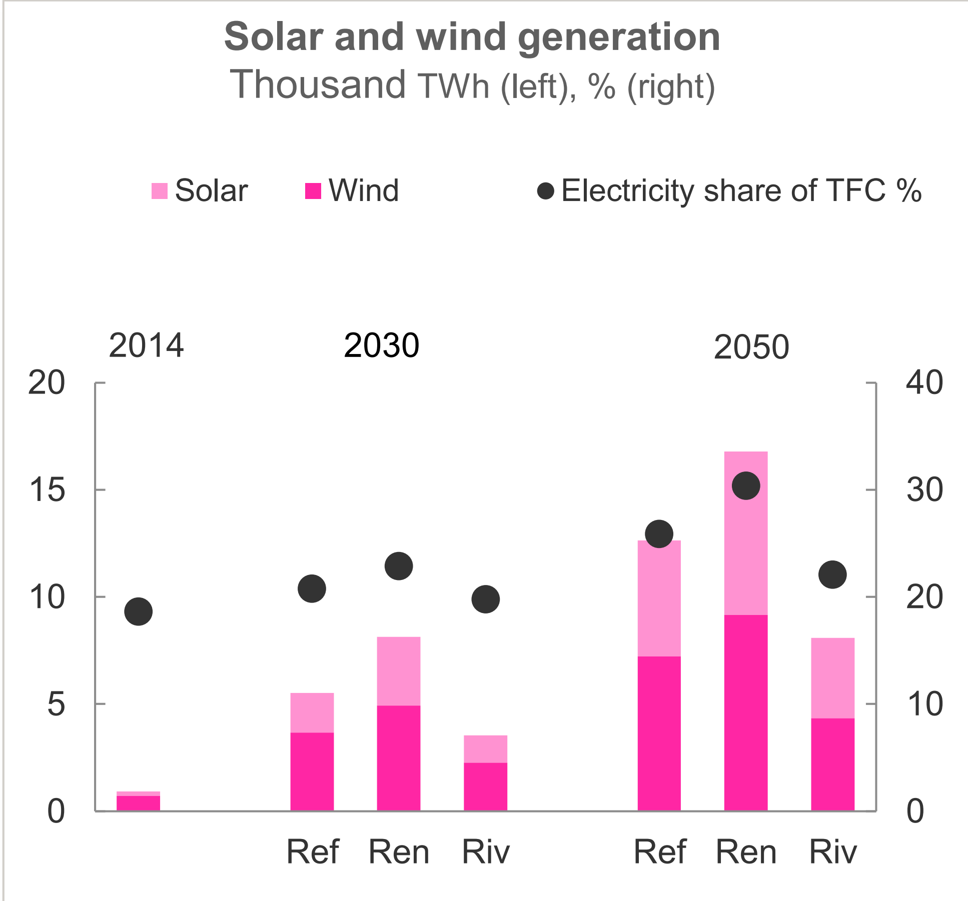
Source: IEA (history), Statoil (projections)

Statoil

Decarbonise electricity, and go electric

13-doubling of wind, 39-doubling of solar generation in Renewal



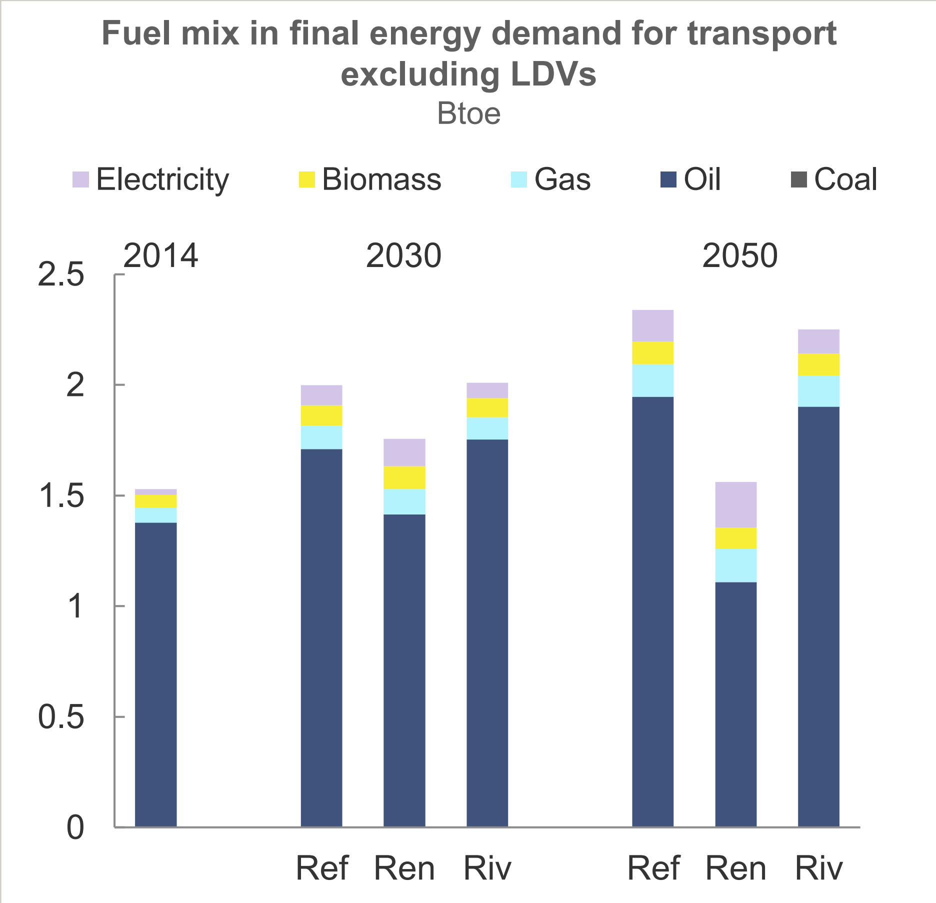


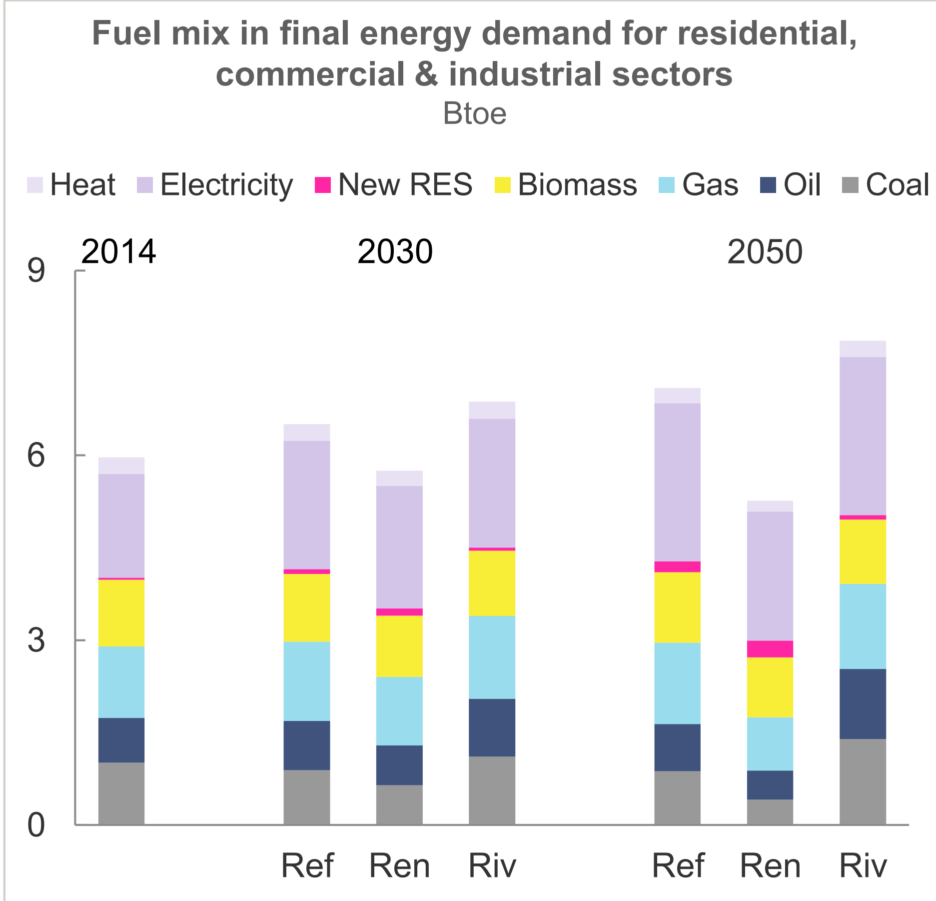
Source: IEA (history), Statoil (projections)

Statoil

Oil and gas dominate in other sectors

… contributing to maintaining demand for fossil fuels



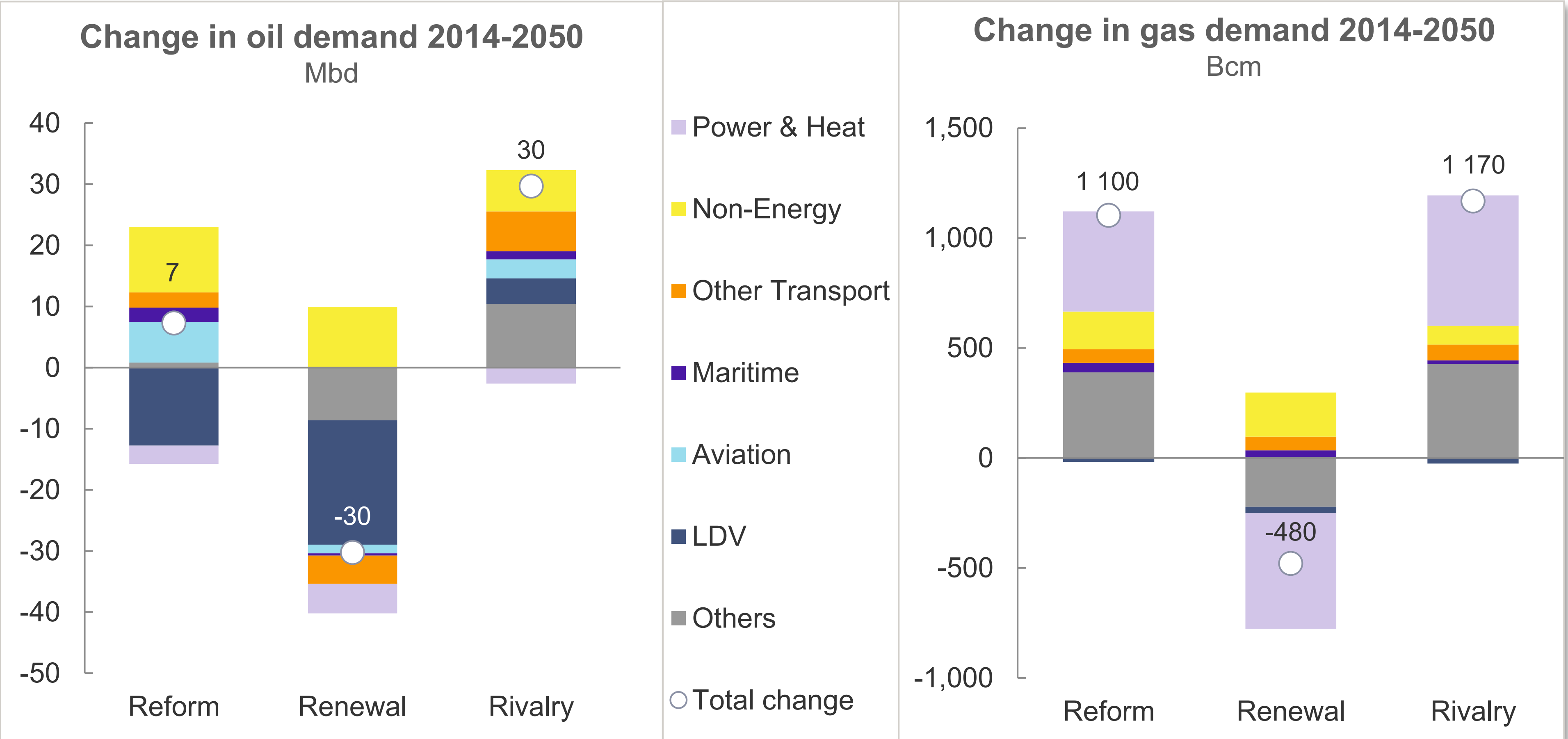


Source: IEA (history), Statoil (projections)

Statoil

Global oil and gas demand growth varies

Depending on scenario – but non-energy demand growth is significant

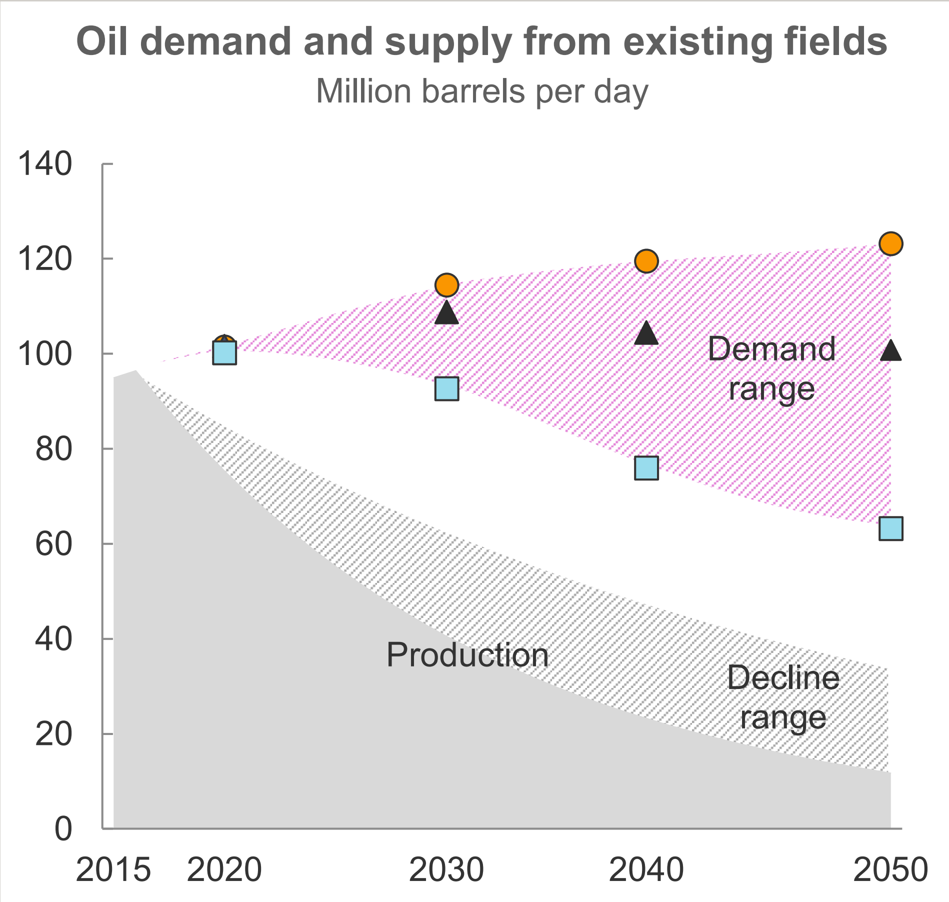


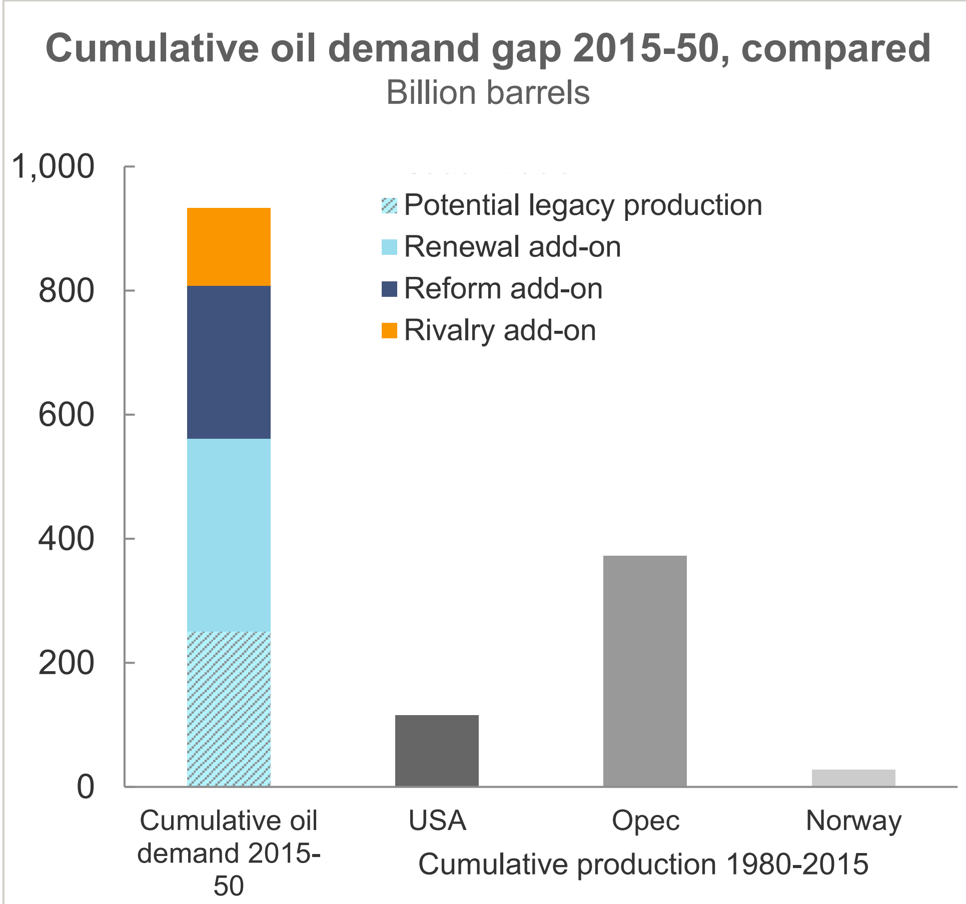
Source: IEA (history), Statoil (projections)

Statoil

Huge investments needed in oil in all scenarios

…to replace production and satisfy demand





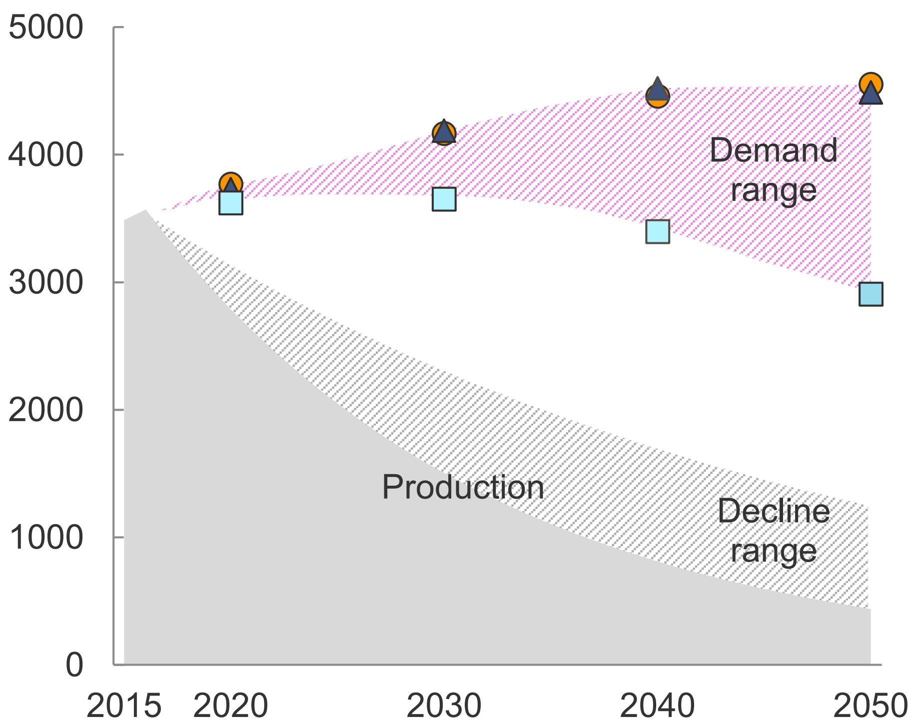
Source: Statoil

Source: Statoil (projections), BP statistical review of world energy (history)

…and the same is the case for gas

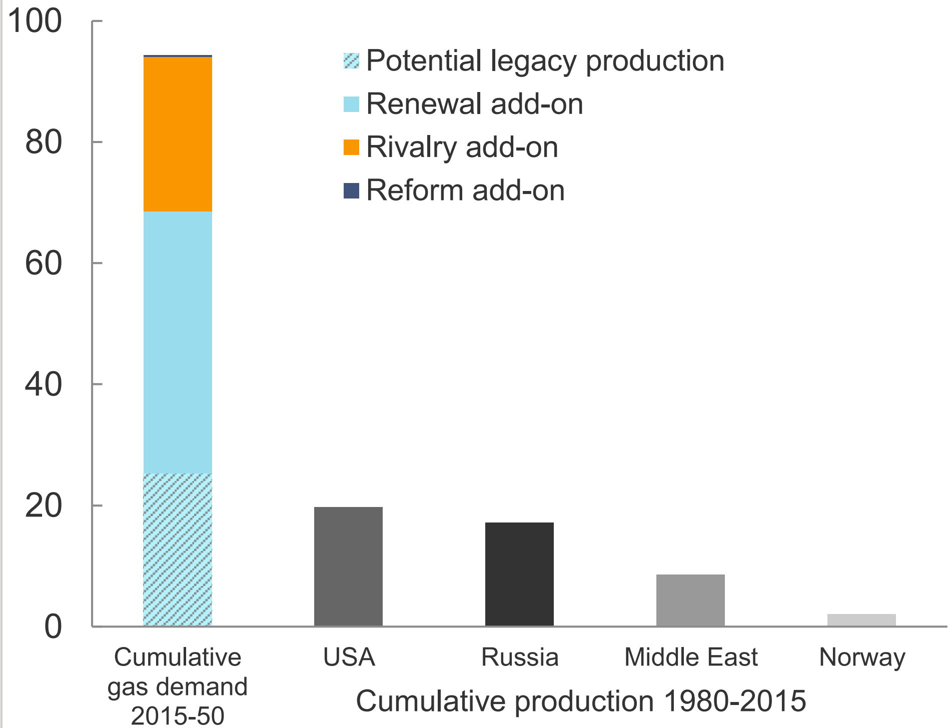
…to replace production and satisfy demand

Gas demand and supply from existing fields
Billion cubic meters



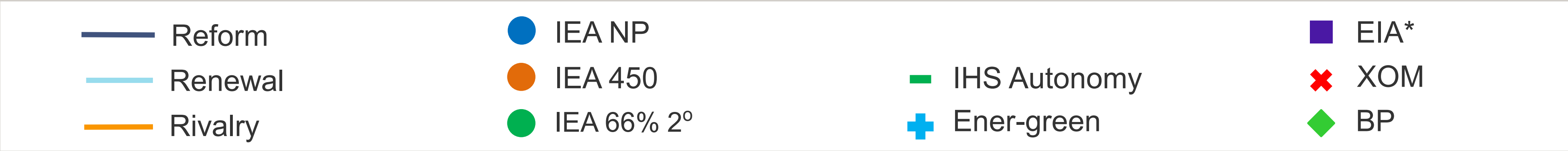
Source: Statoil

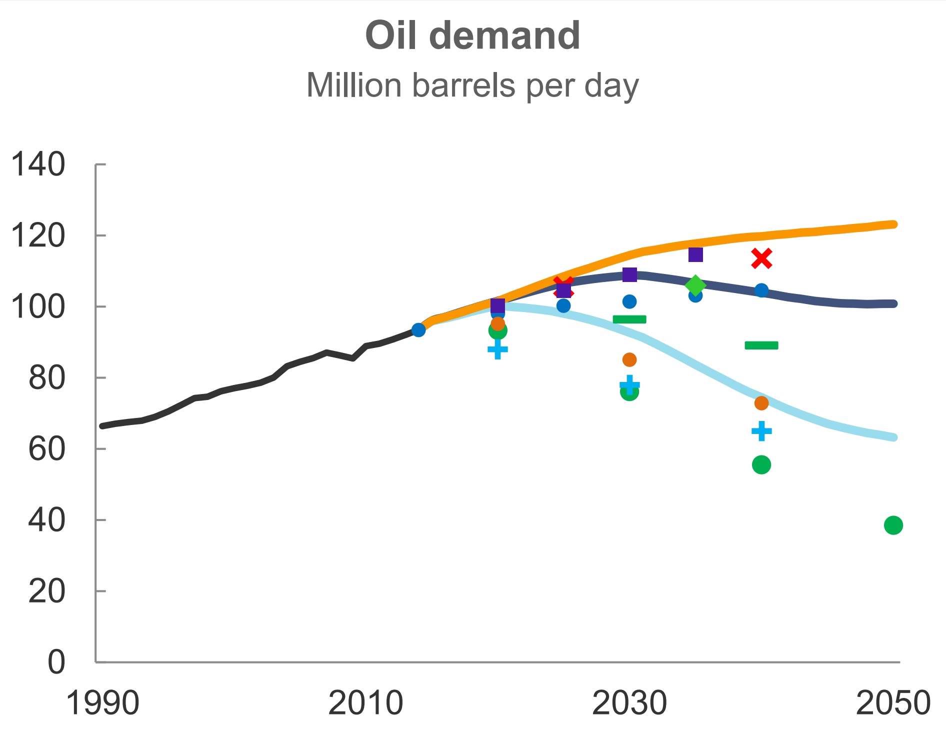
Cumulative gas demand gap 2015-50, compared
Trillion cubic meters

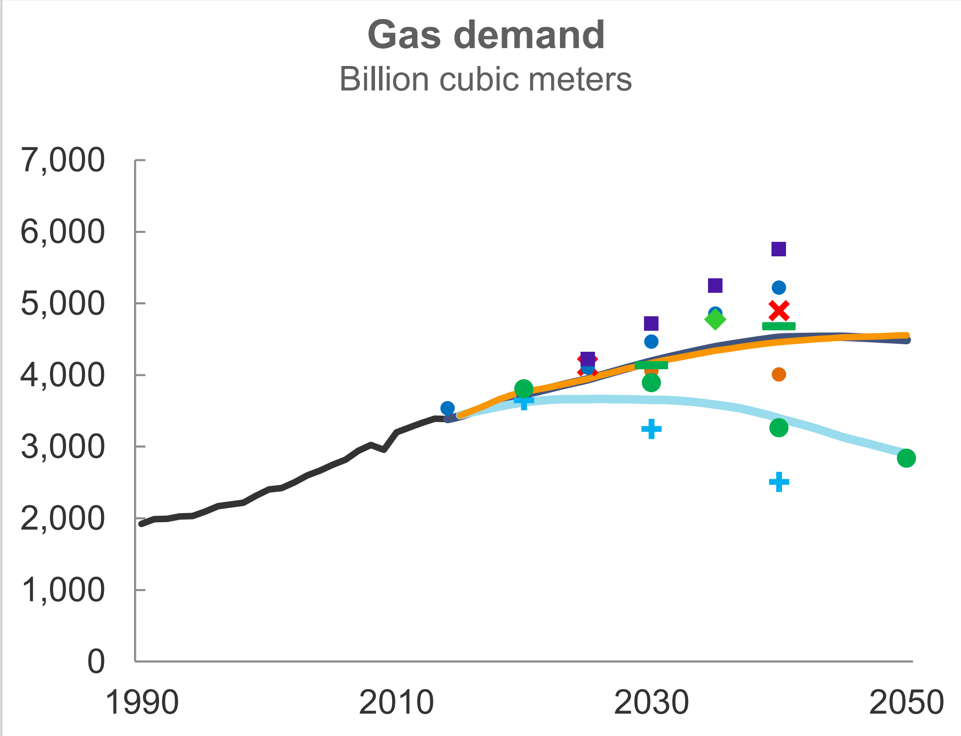


Source: Statoil (projections), BP statistical review of world energy (history)

Wide outcome space for oil and gas demand







* Includes biofuels

Source: History (IEA), projections (Statoil EP17, IEA WEO16, EIA AEO16, IHS Energy-Wide Perspectives 2017, XOM 2017 Outlook for Energy, BP EO17, Enerdata 2017 - Understanding our Energy Future)

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energy institute

Questions?

Vote:

‘What is most likely to transform the energy scene between now and 2030?’

Francisco de la Peña

Floating Technology

Humphrey Douglas

Batteries

Keith Pullen

Flywheel Energy Storage

Nic Rigby

Renewables funding

Peter Gill

Energy Policy

Roger Bentley

Peak Oil

Sam Botterill

Algae as a Fuel

William Orchard

CHP

Thank you