Energy Transitions - Exploring Global Energy Scenarios

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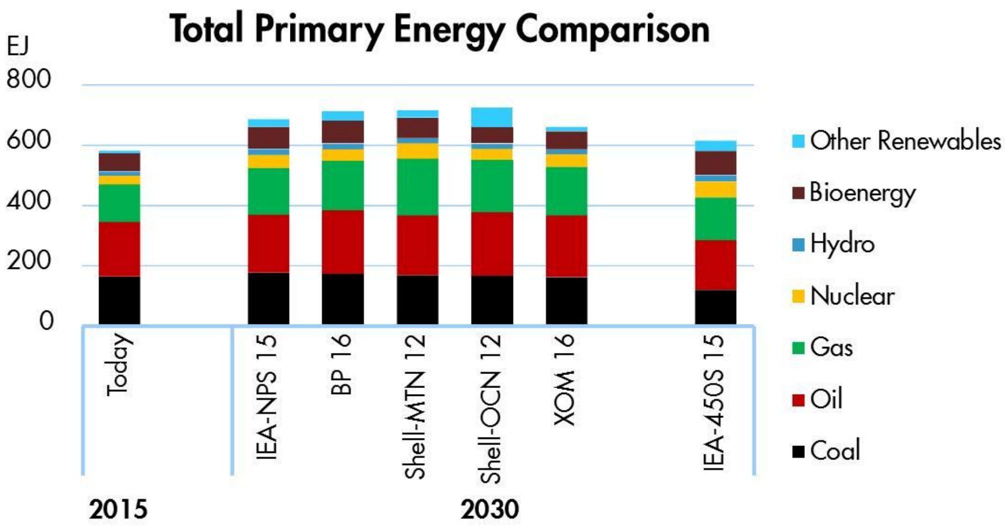
The question if there is a realistic best global energy mix for 2030, a theme at the recently held IEEJ and APRC conference, can be answered from many different perspectives, like for example affordability, environment, or energy security. In this article it is approached mainly from two perspectives; that of human development and that of climate change. Given the inertia of the energy system, the energy mix in 2030 may not seem too different than todays, but the underlying policy framework may be very different, setting the momentum for significant change post 2030. If the goals of the Paris Agreement are pursued in earnest, the global energy system will need to transform to a net-zero emission from energy not later than around 2070.

Introduction

When comparing scenarios from different organisations, the energy mix around 2030 is not much different, although the absolute level of overall energy consumption may vary depending assumptions around the pattern of economic growth and efficiency uptake. The main reason for so little differentiation in the mix is caused by the inertia in energy systems. It can take up to 40 years before a power plant is replaced, or a building to see a major refurbishment or rebuild. The transport sectors are relatively faster changing with ships and planes having an economic lifespan



Sources: IEA, BP, XOM, Shell analysis

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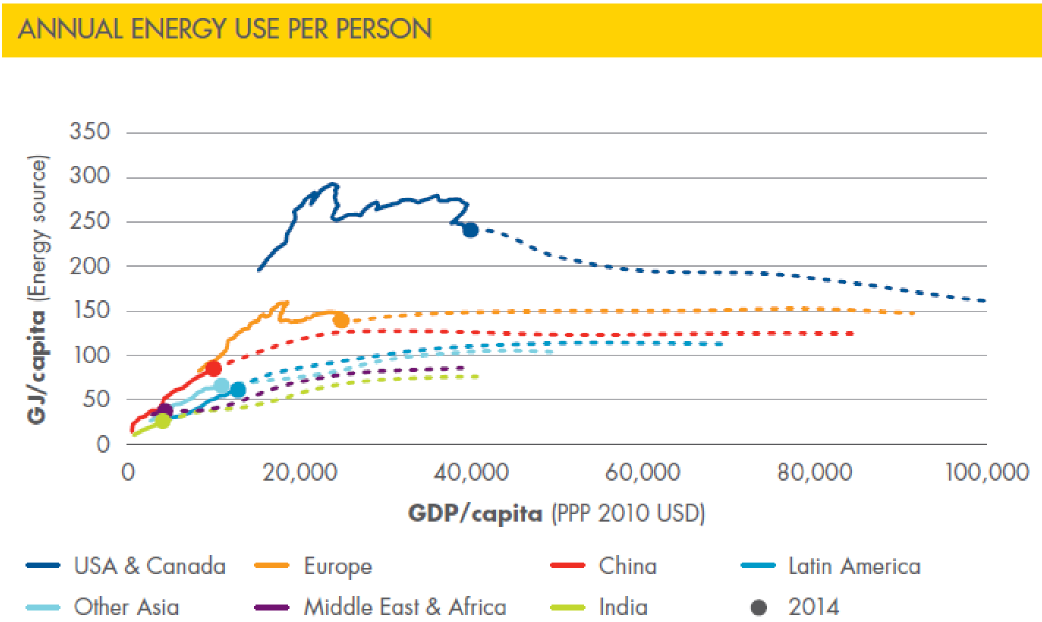
of some 25 years, while cars are normally in use for some 15 years.

Future Energy Demand

To start answering the question of what the realistic best energy mix could be, lets first estimate how much energy a world of 9-10 bln people would need. Energy consumption is a function of people's income. It normally rises proportionally with GDP per capita till around $20,000 per year as basic needs are fulfilled through the development of infrastructure, industries, services and amenities. Thereafter saturation begins to set in. Historically in North America this saturation level of primary energy use is around 300 gigajoules per capita per year, while in more efficient Europe and Japan the level is around 150 gigajoules per capita per year. Looking ahead, for developing nations there is an opportunity to use more efficient technologies from the start. They could create structural efficiencies through for example compact integrated cities with a high level of energy neutral buildings, electrification and good public transport. In such case it may be possible to achieve a decent quality of life with primary energy use saturating around 100 gigajoules per capita per year. This means that with a global population of 10 billion people, about a 1,000 exajoules would be needed for the world, which is about twice the size of the current energy system.



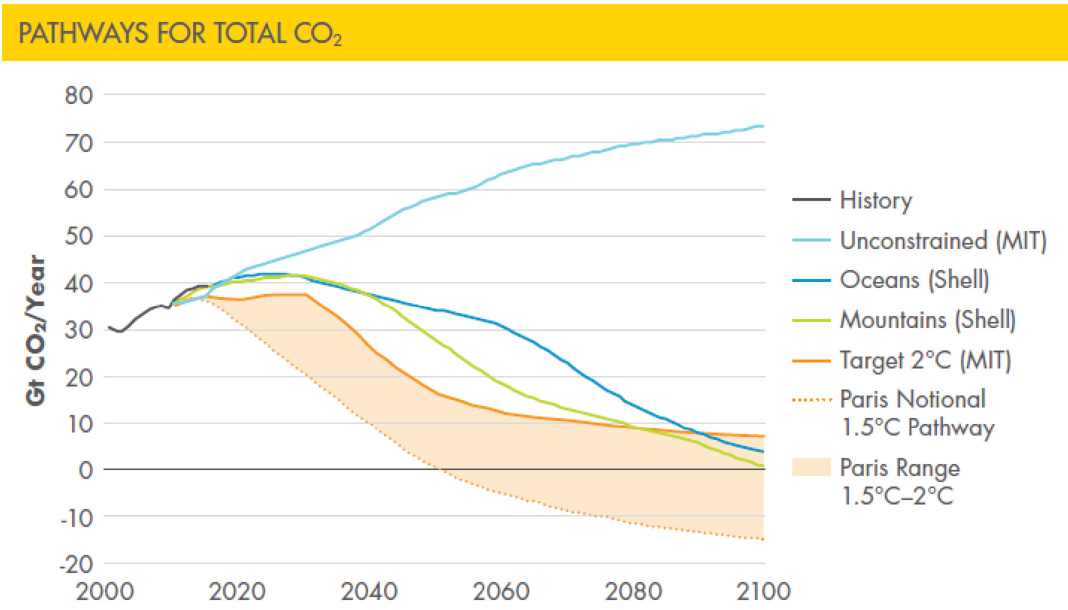
Source: Shell analysis – World Energy Model

Efficiency is Paramount

Limiting global energy demand to 100 gigajoules per year for every person on this planet, can only be achieved with heroic efforts on efficiency improvement. Cars need to be 3 times more efficient than today, industry at least two-thirds more and households 2 times better in heating and 5 times better in lighting and appliances! The development and application of high levels of insulation in buildings, light weighting of transport, more efficient drives, heat-pumps, LED lighting, improved industrial processes and more recycling, will all be needed. As well as structural efficiencies from compact cities designs with good public transport and integrated utilities. A high level of efficiency and decarbonisation go hand-in-hand with electrification, which poses a new challenge in expanding sustainable power generation.

Net-zero Emissions

To stop the accumulation of energy related CO_2 emissions into the atmosphere, overall emissions will eventually need to drop to net-zero. However, a net-zero emissions world is not necessarily a world without any energy related CO_2 emissions anywhere, but a world where unavoidable emissions are offset elsewhere in the system. Some sectors will be hard to decarbonise, such as air travel, heavy freight and iron/steel/cement manufacture . This means that 'negative' emissions need to be created through applying Carbon Capture and Storage (CCS) to biomass applied in electricity generation. Also a widespread deployment of CCS will be required to mitigate remaining emissions in sectors that will continue needing fossil fuels like for example heavy industry. Also chemicals will continue needing fossil hydrocarbon as feedstock, but as long as the plastics are not burnt it will not add CO_2 to the atmosphere. Lastly, also changing agricultural practices that raise the carbon content of the soil, and reforestation are options. Although there are many options, it needs to be recognised that certain regions will likely decarbonise at a slower pace,



Source: Shell analysis – World Energy Model and MIT's Outlook

The orange area illustrates a range of potential trajectories that match the ambition embedded within the Paris Agreement. At the top of the range is the MIT 2°C case and at the bottom of the range equates to 1.5°C, being the 50% probability line taken from Rogelj, et al. Other trajectories consistent with Shell's Mountains and Oceans scenarios and MIT's Outlook 2015 are shown for comparison. MIT's Outlook reflects current and planned policies and recognises that its projections requires further policy measures to stabilise atmospheric greenhouse gas concentrations.

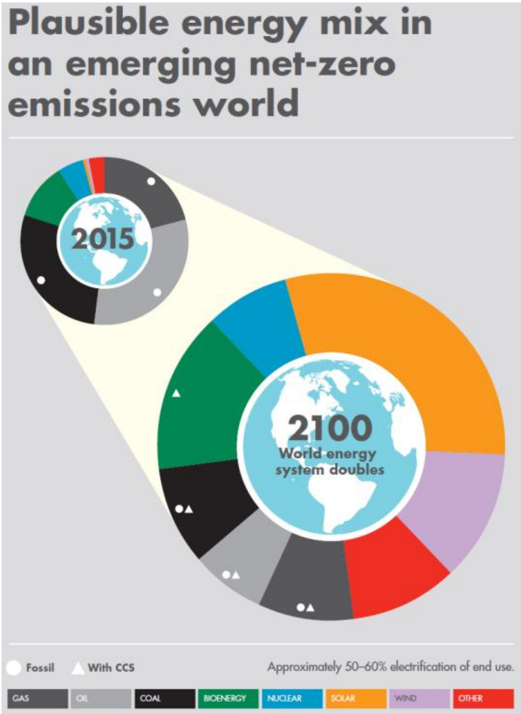
either for political, economic or geographical reasons, or simply because there is less institutional capacity available.

Hydrocarbons Alongside Renewables

The global and local energy systems in a net-zero emissions world will be something of a patchwork with different degrees of decarbonisation achieved at different paces and in different places. Some sectors of the economy can move faster than others, as well as countries, having different financial, technological and organisational means as well as access to renewable resources. Renewable energies have a crucial role to play, but also market design to cope economically efficiently with intermittency, storage and transport over long distances. The largest renewable resource base is wind and solar, and in principle there is enough resource available globally to provide all energy. However, they produce electricity, and the world will also need hydrocarbons as chemicals feedstock and high density fuels for heavy transport.

Electricity accounts currently for less than one-fifth of total final consumption of energy, while in a net-zero world it will need to cover some 50-60% of end-use energy needs. Whole sectors need to 'electrify' by changing for example already highly efficient hydrocarbons based heating infrastructure. Vastly improved battery technologies, conversion of electrons into hydrogen to store and transport energy from wind and solar will all be required.

It is very unlikely that the world can function on electricity from renewables alone. Beside the heavy industry in iron, steel and cement making, and heavy freight / air transport that will continue needing high energy density fuels, the production of chemicals and plastics would also continue to rely on hydrocarbons as feedstock. The available biomass not competing with food needs, can only provide a fraction of this. So fossil hydrocarbons will continue to be needed and will likely see a co-evolution and integration with the renewable components of the energy system.



Source: Shell Analysis

Policy Measures will be Key

To balance economic, environmental and energy security, policies that shape, incentivise or mandate these changes, are as important than technological developments. Policies can help, but also hinder, the accelerated deployment of technology and behavioural change required. Ideally they need to focus on financial incentives around carbon in general to allow the market to find the optimal energy mix. This means removal of distorting energy subsidies where they still exist and putting a value on avoiding emissions. But there are also other measures to consider such as efficient urban-planning, land-use and agrarian practices.

Moving forward at pace will need high levels of collaboration between policymakers, businesses and civil society. This will not be easy, and different parts of the world as well as economic sectors will move at different paces. But it is also not impossible. The potential rewards are high as well as the risks if we fail.

Some sensible measures for progress towards ultimately a net-zero emissions world, which will affect the energy landscape already around 2030 are:

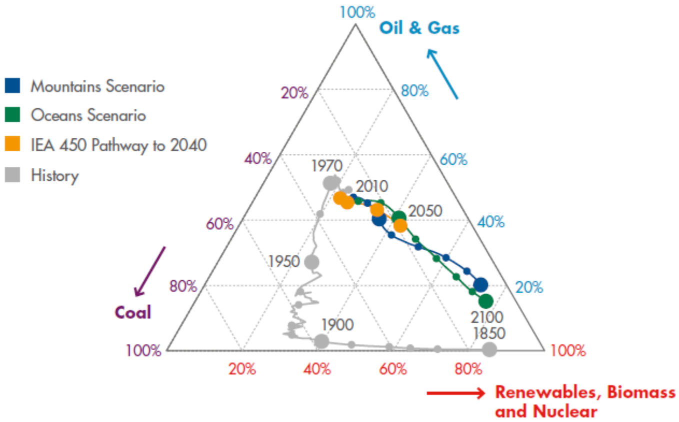
- Carbon pricing or equivalent incentives to motivate investments in emissions reduction and energy efficiency. This will also encourage the deployment of renewables, CCS and nuclear, as well as efforts to reduce the use of coal.
- Financial support for R&D, and for the early-stage deployment of promising technologies.
- Measures and incentives to help people move from traditional biomass to more efficient and convenient commercial energy sources.
- Smarter practices and stricter regulations for compact urban development, integrated infrastructures and efficient buildings.
- Regulations or incentives to invest in low-emissions transport.
- Removal of energy subsidies where they still exist and fiscal measures to maintain relatively elevated energy prices for end users – enough to encourage efficiency and investment in technology development, while not stifling economic activity.
- High energy-efficiency standards for a wide range of end-use applications.
- Land-use, reforestation and soil regeneration.
- Measures to prevent cross-border carbon leakage through trade between jurisdictions.

〈References〉

1) IEA World Energy Outlook, November 2015
2) Shell New Lens Scenarios, 2013
3) Shell Net-zero Emissions supplement to the New Lens Scenarios, May 2016

Box: Energy Transitions are Not New

It is increasingly clear that the global energy system is entering major changes. Transitions are not new though. During the nineteenth and twentieth centuries, first coal followed by oil and then natural gas saw spectacular growth and now provides for some 80% of all energy consumption. It increased economic growth and prosperity became more widespread. But with rising concerns over local pollution and global CO_2 emissions, new technologies such as wind and solar power are now seeing spectacular growth rates and comprises some 1% of the global energy system – a threshold for further growth.



The grey line in this graphic depicts how the relative shares of different primary energy sources (coal, oil and gas, and nonfossil) have evolved since 1850 through to the early 21st century. The blue, green and orange lines have been added to the original chart to reflect the future evolution of the energy mix described in the Shell *Mountains* and *Oceans* scenarios and in the IEA 450 Pathway. This shows the potential rise in the share of new non-fossil sources, including renewables, hydrogen, and nuclear. Perhaps surprisingly, as expressed in these buckets (coal, oil and gas, non-fossil), the energy mix has stayed constant in the almost 50 years since the 1970s, in spite of oil shocks that induced a shift from oil to gas in the past half century (not visible in this chart).

Source: Graph based on L. Barreto, *et al., Int. J. H2 Energy* 28 (2003) 267. Data prior to 1960 was taken from the IIASA PFU database (Version 0.0.2) https://tntcat.iiasa.ac.at/PFUDB; data 1960–2014: IEA and Shell; data 2015–2100: Shell *New Lens Scenarios*.

Writer's Profile

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He is heading the Energy Analysis Team in Shell's Global Scenario Group, which is part of the Corporate Strategy Department. He leads a team responsible for worldwide energy analysis and long-term global energy scenarios, and advises Shell companies on a wide range of energy issues. He has been with the Shell group of companies for some 30 years, with prior positions in drilling operations, subsurface reservoir management, and commercial and regulatory affairs in gas. He is chairman of the UK national committee of the World Petroleum Council and a former chairman of the British Institute of Energy Economics.

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