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Energy Transitions - Exploring Global Energy Scenarios
The Role of Nuclear and Renewables

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The question posed during the 2nd joint IEEJ-APERC symposium in May 2017 was "What are realistic roles for Nuclear and Renewables in the global energy mix over the long term". This question could be answered from many different perspectives, like for example affordability, environment, energy security, or societal acceptance. In this paper, it is approached mainly from two perspectives; affordability and climate challenge. Given the inertia of the energy system, the energy mix will only slowly turn around under lasting policy frameworks. If the goals of the Paris Agreement are pursued in earnest, the global energy system will need to transform to net-zero emissions from energy not much later than around 2070. For that, all technically and economically viable low carbon options need to be considered.

Introduction

Shell's Scenarios, which are not forecasts, explore extensively increasing environmental legislation and technology innovation, and clearly show the onset of an energy transition with an upcoming trend break in overall energy growth by the mid-2020s. This is due to enhanced efficiency uptake including strong growth assumed for Electric Vehicles, the rise of renewables, a resilience in nuclear energy, while gas benefits from strong supply growth due to among others US shale gas and possibly later as a transition fuel replacing coal. In comparison to today's overall energy consumption, by 2035 it could be around 25% higher, and some 35% higher by 2050. However, the present growth rate of about 1.2% per annum (pa) is expected to halve post 2030 as new technologies with higher end-use efficiency scale up. Oil may peak in the first half of the 2030s with increasingly efficient internal combustion engines and higher uptake of electric vehicles.

Not surprisingly, the fast-growing non-OECD is expected to be the engine of overall energy demand growth, but also for nuclear and renewables.

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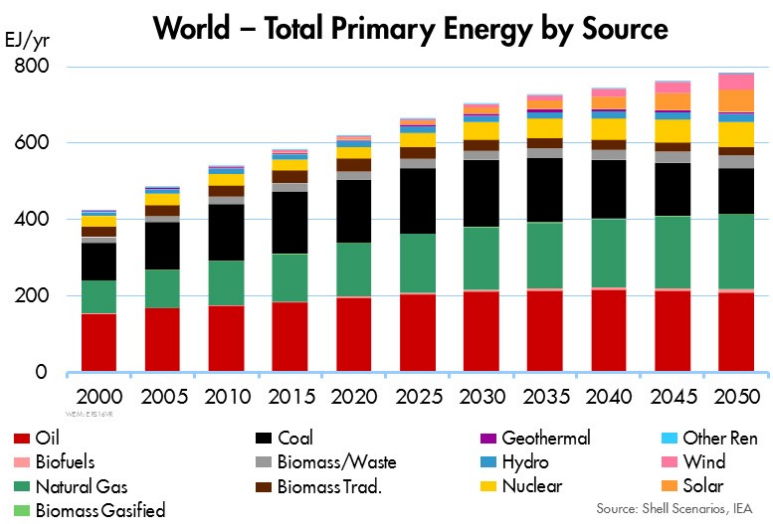
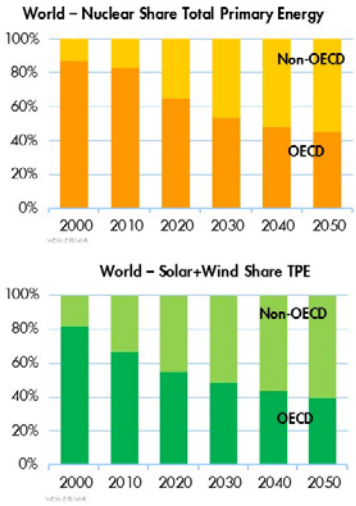


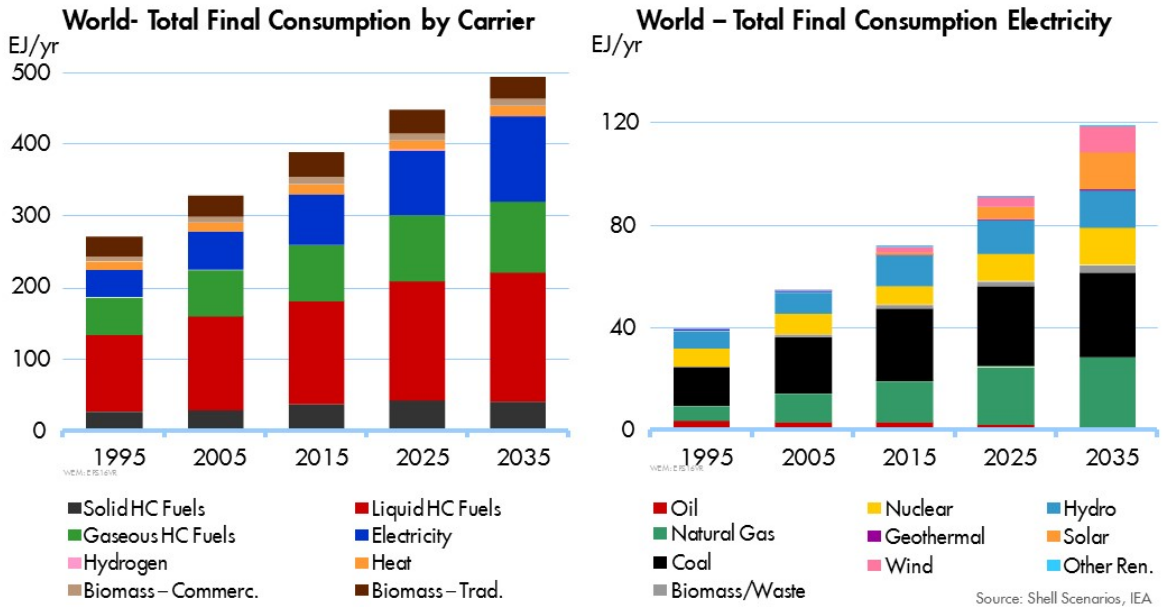
Source: Shell Extended Policy Scenario and IEA historical data



Source: Shell

The Role of Electricity in a Lower CO_2 World

In a world where lower emissions and higher efficiency are valued, a far greater share of end-use of energy consumption needs to be from electricity. Presently only 18% of overall global end-use is provided by electricity, but that will need to increase to around 25% by 2035, and 30% by 2050. Electricity's share of overall final consumption by end-users has been growing some 1.3% per annum in the past, but that will increase to around 1.6% per annum.



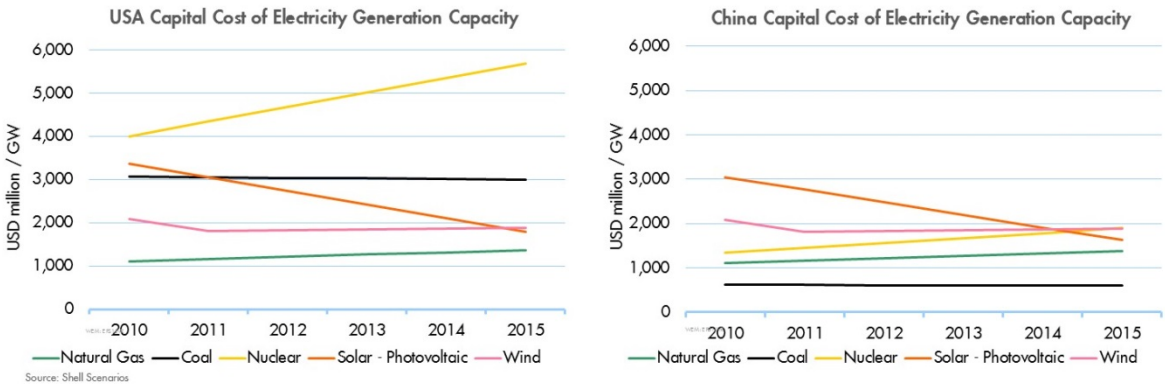
Source: Shell Extended Policy Scenario and IEA historical data

Under such scenario, wind and solar will see its market share in global electricity generation more than quadruple (from 4.5% to 21%) between today and 2035, while nuclear and gas shares remain about the same throughout. Coal is losing out though, with its share dropping from just under 40% today to just over 25% by 2035, and sees its status as dominant fuel cease a couple of years later. The OECD is leading this transition with peak coal around 2025, with non-OECD following some 10 years later.

In Shell's "Mountains" and "Oceans" Scenarios, published in 2013, CO_2 emissions from energy didn't peak until the 2030s, and a much accelerated policy and technology scenario would be needed to see global emissions from energy reducing earlier.

Affordability

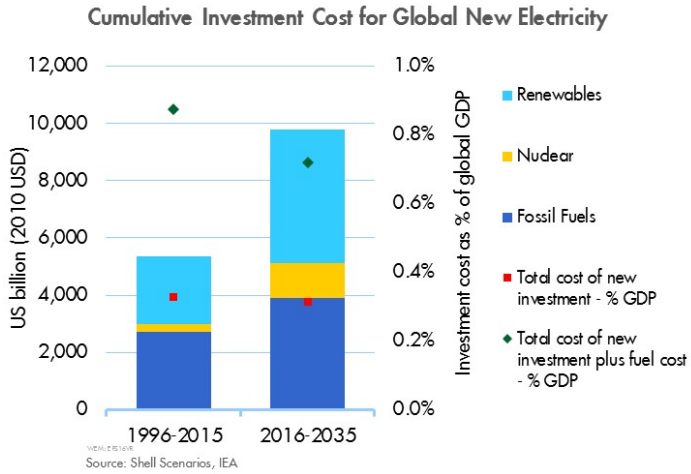
The past five years have seen significant increase in the reported cost of new nuclear power plants by on average ~50%. A quick internet search shows France' Flamanville going towards €10.5 billion, Finland's Olkiluoto costs tripled to €8.5 billion and the United Kingdom's Hinkley Point stands at £18 billion presently. In the meantime, solar has seen a spectacular ~50% drop in costs. Cost improvements are expected to continue for wind and solar. The bidding price for offshore wind in the North Sea has dropped to around €5.5 cts/kWh with government subsidies in the form of guarantees no longer required in some cases. In this scenario, we have assumed a further 25-30% drop in cost for wind and 50% for solar between now and 2035. What is striking, is that China can build coal and nuclear power plants that are much cheaper than anywhere else in the world, while gas, solar and wind are only marginally cheaper.



Source: Shell Extended Policy Scenario

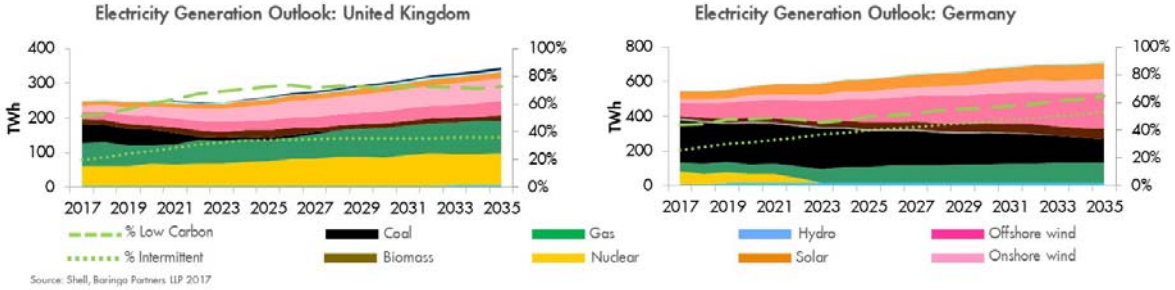
The challenge to double electricity's global production capacity over the next 20-25 years remains affordable, and is not envisaged to cost more than in the past as a percentage of global GDP. There will be regional differences, but the onset of cheaper distributed solar and wind may unlock economic activity earlier, increasing affordability, than if a traditional centralised network is set-up. This should benefit the billions of people who do not yet have access to modern, clean

energy to improve their lives.



If variable fuels costs are added, then the overall cost for generating electricity becomes more affordable in terms of percentage of GDP.

Two other often quoted issues are intermittency and market failure to recover costs. An example of two European countries' electricity mix show that countries with more wind and solar have indeed a higher intermittency risk. Present consensus is that up to 30% is considered manageable through back-up capacity, (battery) storage and demand management. Thereafter it becomes more uncertain how intermittency can be cost effectively managed, especially inter-seasonal fluctuations. There is still time to gain insights and knowledge "by doing", but the question remains if it is societally, and therefore politically, acceptable for things to go wrong occasionally. After all, electricity has become a common good, and is expected to be always available. Many health, safety and security systems rely on its continuous availability.



The ability of recovering capital costs in the future in a pure market-driven world will be variable across technologies. The offsetting dynamics of variable supply and demand with increasing penetration of renewables was simulated[2] to estimate future wholesale power prices on an hourly basis for different EU countries. Average wholesale prices over the year ranged €35-45/MWh between different scenarios. On an operating basis, nuclear should generate

comfortably within such merit order, while gas technologies on average sit at the margin and are subject to capacity factor volatility, while renewables all generate cash surplus. However, such wholesale market prices will be insufficient to recover capital investment for most technologies. According this study, between 35% and 60% of the required revenues for new build will not be captured by wholesale prices across a range of market scenarios. This means that urgent market reform is required for successfully integrating renewables in the electricity mix. Capacity auctions become more and more applicable, with capacity costs recovered through system operator charges to the end-consumer.

Policy Measures will be Key

In balancing economic, environmental and energy security objectives, policies that shape and incentivise these changes are as important as technological developments. Policies can help, but also hinder, the accelerated deployment of technology and shaping market changes required. Ideally they need to focus on incentives around reducing carbon in general and providing predictable longer term financial contexts, while leaving it to industry to find the optimal technical solutions. This means designing a viable market for capital investments in electricity generation and putting a value on avoiding emissions.

Moving forward at an accelerated pace will be required to pursue the goals of the Paris Agreement, which will need high levels of collaboration between policymakers, businesses and institutes. Different parts of the world as well as economic/energy sectors will move at different paces, depending institutional and economic capacity, but this can be accommodated within the overall framework towards a lower CO_2 emission world.

In conclusion, the Shell Scenarios show

- Society’s drive for higher end-use efficiency and cleaner fuels with less CO_2 emissions requires higher rates of electrification of energy use
- Post 2020, renewables are expected to deliver the cheapest MWh across most parts of the world
- Nuclear remains a relative expensive option, but some countries will continue developing new capacity for security of supply reasons
- Electricity market reforms will be required to allow capital cost recovery of all technologies needed.

〈References〉

1) Shell New Lens Scenarios, 2013
2) Baringa Partners LLP 2017, Scenarios to 2050, Northwest European Power Market Study.

www.shell.com/scenarios

This paper contains data from various Shell Scenarios. Scenarios are a part of an ongoing process used in Shell for 40 years to challenge executives' perspectives on the future business environment. We base them on plausible assumptions and quantifications, and they are designed to stretch management to consider even events that may only be remotely possible. Scenarios, therefore, are not intended to be predictions of likely future events or outcomes and investors should not rely on them when making an investment decision with regard to Royal Dutch Shell plc securities.

It is important to note that Shell's existing portfolio has been decades in development. While we believe our portfolio strategy is resilient under a wide range of outlooks, including the IEA's 450 scenario, it includes assets across a spectrum of energy intensities including some with above-average intensity. While we seek to enhance our operations' average energy intensity through both the development of new projects and divestments, we have no immediate plans to move to a net-zero emissions portfolio over our investment horizon of 10-20 years.

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.