Key questions and uncertainties of the energy transition

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Abstract

The energy system is changing. There is a well-known transition towards a lower carbon system, led by the rapid deployment of solar and wind energy. But that is only one dimension. The pattern of energy demand is also in transition, driven by growing prosperity in the developing world. In this context, this article explores the following five key issues that could shape the energy transition in the next two decades: first, how much more energy does the world need?; second, what might happen if the trade wars escalate?; third, how important are plastics for the future of oil demand?; fourth, how quickly could renewable energy grow?; and fifth, what more needs to be done to ensure a rapid transition to a lower-carbon energy system? The key message from this article is that the world is facing a dual challenge: it needs more energy to support continued growth and prosperity in developing world, whilst reducing carbon emissions. This is the key challenge facing all of us.

Keywords: Energy transition, dual challenge, carbon emissions, energy scenarios.

1. INTRODUCTION

The world of energy is in transition. Today, it is very clear that the energy mix in 2040 is going to be significantly different than the current one, with renewable energy leading the shift. It also very clear that energy demand is growing in less developed economies, while in OECD countries is, in the best of the cases, flat. Finally, there is growing consensus about the need to reduce carbon emissions as fast as possible. There is a transition to a new energy system. But the certainties about the future of energy end here. It is not clear what is the speed of this transition, what is the role of different energies, which sectors are going to need more energy, or where the energy is going to be consumed.

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In this context full of uncertainties, the *BP Energy Outlook 2019* is a document designed to help company managers and policymakers in their decision-making process. It is very obvious that the distant future is impossible to forecast. In the case of energy, literally hundreds of different variables can critically impact the demand for energy and the energy mix. No one can anticipate accurately the future path of technologies, policies, prices, and social preferences and, therefore, it makes little sense to forecast the energy mix in 2040 or 2100. For this reason, the analysis and conclusions of this BP Energy Outlook 2019 are based on scenarios. These scenarios are designed to explore and better understand the uncertainties surrounding the energy transition. There is no central or base case: the probability that the world will unfold exactly in line with any one of these scenarios is almost zero.

The analysis and narrative of this study is based around the Evolving Transition scenario. This scenario gives a sense of the broad path the global energy system might travel along, if government policies, technology and social preferences all continue to evolve in a speed and manner consistent with the recent past. However, the value of BP's Energy Outlook is not the statistical description of this scenario, rather it is in identifying some of the key issues and questions affecting the energy system and how different assumptions can critically change the path of the energy transition. In particular, in this paper, we consider five key questions:

- How much more energy does the world need?
- What might happen if the trade wars escalate?
- How important are plastics for the future of oil demand?
- How quickly could renewable energy grow?
- What more needs to be done to ensure a rapid transition to a lower-carbon energy system?

The rest of the document is organized as follows. Section 2 describes the Evolving Transaction Scenario, which is used as an anchor in the rest of scenarios, section 3 to 7 answers the five key questions developing alternative scenarios, and section 8 concludes.

2. DESCRIBING THE EVOLVING TRANSITION SCENARIO IN 2017-2040

The first relevant idea of this scenario is that energy demand increases by around a third by 2040 compared with 2017, around 1.2% per year. This increase is broadly equivalent to the current energy consumption of the US, the EU, and Japan combined (BP, 2019).[1] The growth in energy demand is the result of three different elements: global population growth (0.9% per year) (United Nations, 2017), GDP per capita growth in PPP (2.3% per year) (Oxford Economics, 2018), partially offset by improving energy intensity (1.9% per year).

The main driver for the increase in energy demand is not population growth, but growing prosperity, measured by GDP per head, as productivity in developing economies increases. In this Evolving Transition scenario, billions of people move from low to middle incomes,[2] increasing their access to electricity and clean-cooking facilities, improving the housing in which they live, and the way in which they travel. This increasing prosperity –the emergence of a growing middle class in the developing world, especially in Asia– is the major factor accounting for global economic growth over the next 20 years and, likewise, it is the major factor accounting for the growth in global energy demand. Without plentiful supplies of energy, this increase in global living standards would be suppressed and with it the major factor driving global economic growth. The worlds need more energy to continue to grow and prosper.

The amount of additional energy needed to support this rising prosperity is offset by significant gains in energy efficiency which is assumed to improve at an average rate of around 2% a year, somewhat quicker than the average over the past 20 years. As a result, although global GDP more than doubles, energy demand increases by only around a third.

Any energy scenario at a global level can be explored using three different perspectives or windows: a) how the energy is ultimately used: across industry, in

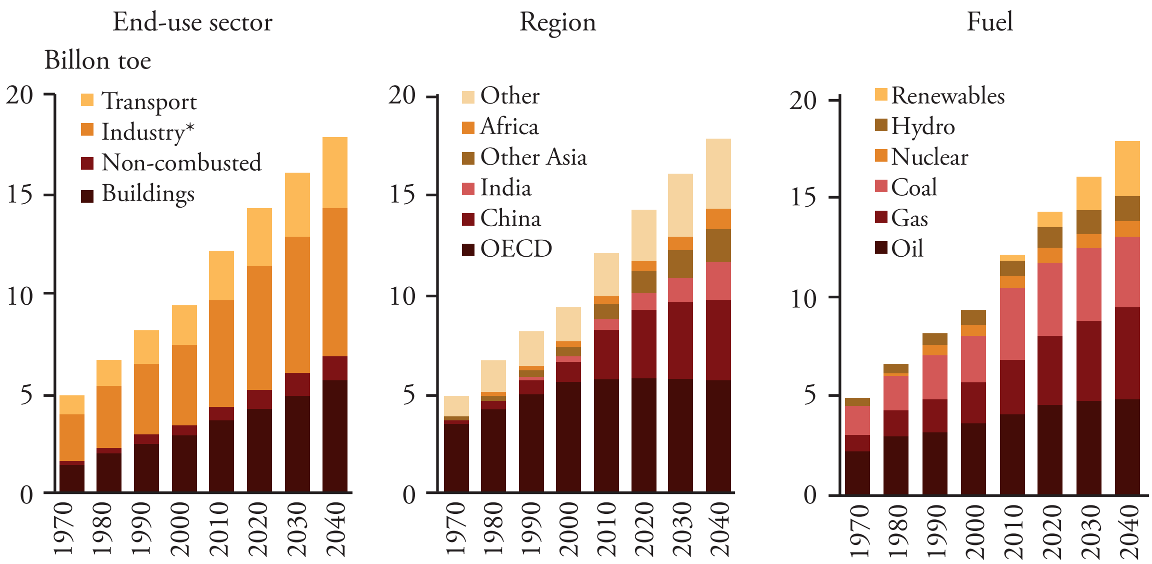
1 The primary energy consumed by these countries is around 4.400 Million of tonnes of oil equivalent.

2 Middle class and rich are as defined by the World Bank as living on more than $10 a day (measured at 2005 constant purchasing power parity (PPP)).

buildings and powering transport; b) where in the world that energy is produced and consumed; and c) what types of fuels and energies are growing to meet demand. Three different windows onto the same changing energy landscape. Figure 1 presents the same scenario from these three windows.

Exhibit 1

Primary energy demand



Despite the considerable attention many of us pay to emerging trends in the transport sector it accounts for only around 20% of energy consumption. It is important not to overweigh the significance of the transport sector (International Energy Agency, 2018). Indeed, although it typically attracts far less media and policy attention, the use of energy within industry accounts for around 50% of all the energy the world uses: almost two and a half times that used in transport. How industry's use of energy changes over the next 20 years, both in terms of efficiency and fuel choice, will have a major impact on the energy transition. Residential and commercial buildings is the fastest growing sector in terms of energy in this scenario. The vast majority of that additional use within buildings takes the form of rising power demand, as increasing prosperity and living standards in the developing world lead to greater use of lighting, household appliances and air conditioning.

From a geographical perspective, energy demand in the developed countries is essentially flat. There is no significant growth. All of the growth in energy demand comes from the developing world, led by Asia. The importance of India increases even further, overtaking China to be the largest growth market for energy over next 20 years. The big factor driving this switch is the sharp slowing in Chinese energy demand as economic growth moderates and the pattern of that growth shifts to less energy-intensive activities.[3]

Finally, this section looks at energy demand through the third window: which fuels are increasing to meet this demand. Renewable energy,[4] led by wind and solar power, is the fastest growing source of energy in this scenario, accounting for around half of the increase in primary energy, with its share increasing to around 15% by 2040. Oil demand continues to grow during the next decade, before broadly plateauing in the 2030s. All of the growth in oil consumption stems from the developing world, with a combination of US tight oil and OPEC meeting this increased demand. Natural gas grows much faster than either oil or coal; overtaking coal to be the world's second largest energy source and converging on oil around 2040. The demand for natural gas increases in almost every country and region considered, supported by the expansion of exports of liquified natural gas (LNG). Renewables and natural gas together account for almost 85% of the growth in primary energy. Nearly 85% of new energy is either clean or cleaner energy. In contrast, global coal demand is essentially flat, with falls in China and the OECD barely matched by increasing demand in India and other parts of emerging Asia.

The last critical element of this scenario is CO_2 emissions from energy use. In the Evolving Transition, CO_2 emissions continue to edge up, increasing by around 7% over the next 20 years. The good news is that this pace of growth is far slower

3 The share of industry in Chinese GDP was 41% in 2016 from 48 in 2006, according the World Bank Database. https://www.worldbank.org

4 It is important to highlight that "renewables" includes solar, wind, biomass, and geothermal. Hydro energy and traditional biomass are not included this category of energy.

than in the past two decades when emissions increased by almost 45%. So, the world is making some progress. The bad news is that the pace of this progress is nowhere near fast enough. To be consistent with the Paris climate goals, CO_2 emissions need to fall substantially over the next 20 years, not simply grow less quickly.

A sectoral analysis of emissions shows that the power sector accounts for around 40% of CO_2 emissions in 2040. It is the single biggest source of CO_2 emissions from energy use, both today and in 2040 despite the unprecedented growth in renewables envisaged in the Evolving Transition scenario. Industry and transport each account for around a quarter of emissions in 2040, and finally, buildings about 10%.

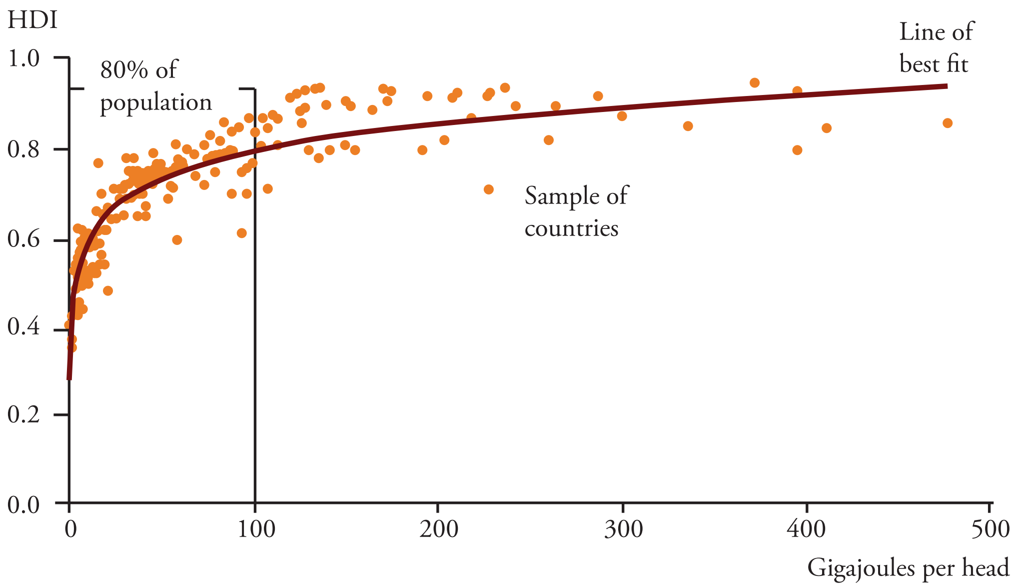
3. FIRST QUESTION: HOW MUCH MORE ENERGY DOES THE WORLD NEED?

There is a strong link between human progress and energy consumption. Figure 2 (BP, 2019) shows the relationship between human development, as measured by the UN human development index (2018) (United Nations, 2018), and energy consumption across a large number of countries.

It suggests that increases in energy consumption tend to be associated with improvements in human development, with those improvements particularly pronounced for increases in energy consumption of up to around 100 Gigajoules per head,[5] after which the relationship begins to flatten out. It is really striking is that around 80% of the world's population today live in countries where average energy consumption is less than that 100 Gigajoules per head, where increases in energy consumption and human development are particularly pronounced. In the Evolving Transition scenario, despite the substantial growth in energy demand, this proportion is still around two-thirds in 2040. The world will need substantial amounts of more energy as it grows and prospers.

5 It is similar to the annual consumption of two average dwellings in the UK or one could drive more than 16,000 miles with an average UK new car.

Exhibit 2
Human development index and energy consumption per head, 2017



Source: United Nations, 2018.

BP Energy Outlook 2019 presents an alternative scenario in which the share of the world's population living in this 'low energy' region is reduced to one-third by 2040. Other things equal, that requires around 25% more energy by 2040 than in the Evolving Transition scenario, so roughly equivalent to China's entire energy consumption in 2017. In a more prosperous world, which implies reducing the share of the world's population living in that 'low energy' region to a third, energy demand is around 65% higher than today.

As mentioned in the previous section, in the Evolving Transition scenario CO_2 emissions edge up by around 7% by 2040 compared to 2017 levels. *BP Energy Outlook 2019* develops another alternative scenario named the Rapid Transition scenario, in which CO_2 emissions fall by around 45% by 2040. This reduction by 2040 is broadly consistent with meeting the Paris climate goals.

And this is the central idea behind the dual challenge: the need to provide both more energy and less carbon. In other words, how to make compatible an increase in energy by around 65% and a reduction in emissions by around 45% by 2040? The world needs increasing levels of energy as the global economy grows and living standards improve. But at the same time, it needs a sharp reduction in carbon emissions for there to be a good chance of meeting the Paris climate goals. There is no simple solution to this challenge, but any viable, sustainable path for the energy system needs to take account of both elements: more energy, less carbon.

4. SECOND QUESTION: WHAT MIGHT HAPPEN IF THE TRADE WARS ESCALATE?

The world is facing a period of uncertainty regarding international trade. This section explores the issue of the recent trade disputes, and how they might affect the global energy system if they were to escalate further. To be clear, the aim is not to consider the implications of any particular dispute, but rather the more general issue of how the energy system may be affected if these types of disputes became more frequent and commonplace. Figure 3 shows the energy balance in different regions in 2017 and in 2040 in the Evolving Transition Scenario.

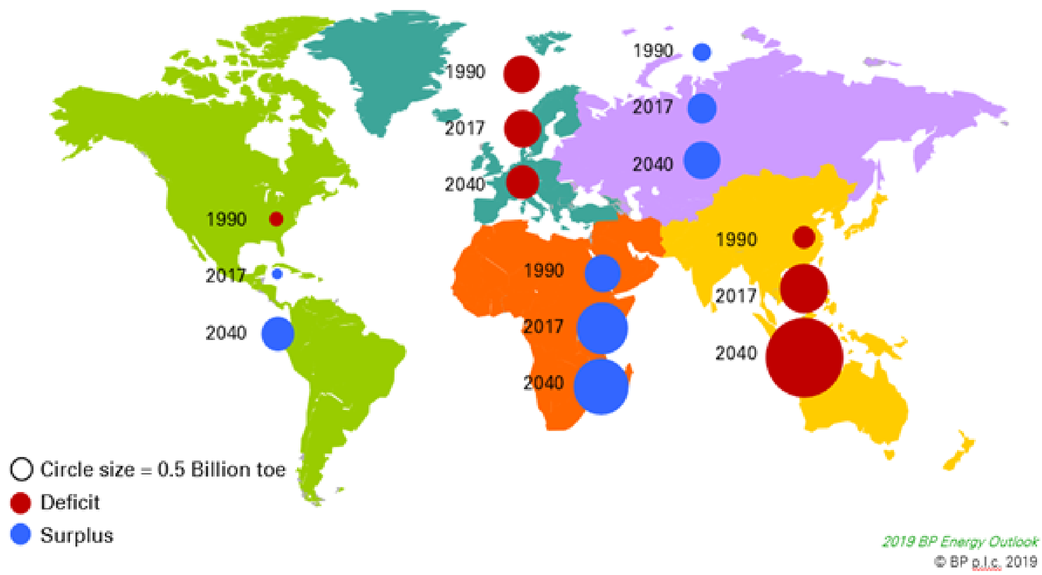
To assess their possible impact of persistent trade disputes, we consider a scenario in which increasing trade disputes lead to two persistent effects. First, the reduced level of openness and trade causes productivity advances in one part of the world to spread more slowly to other regions, leading to a slight reduction in the trend growth of global GDP. And this is based on well-documented impacts in the economics literature (See for example, Alcala and Ciccone, 2004; Ahn *et al.,* 2019; Kultina-Dimitrova and Lakatos, 2017).

In this new scenario, the level of global GDP in 2040 is around 6% lower than in the Evolving Transition scenario, and global energy demand is around 4% lower. This 4% may sound quite small, but that reduction in energy demand by 2040 is roughly equivalent to India's entire energy consumption today.

The second effect is that increased concerns about energy security leads countries to attach a small risk premium – of 10% – on imported sources of energy. So, for example, for a country importing oil, if the global oil price was $60 per barrel,

Exhibit 3

Energy balance of traded fuels (oils, gas, coal)



they would be willing to pay up to $66 for domestically produced oil or an equivalent substitute, given the extra security this provides.

This change in domestic policy to favour domestically produced fuels has an impact on trade. There is a reduction in traded fuels, particularly oil and gas, as countries switch from imported energy. The lower level of energy demand, together with the bias for domestically produced energy, leads to a sharp reduction in energy trade.

Although the assumed size of these two effects is pretty modest, it is striking is that the impacts on the global energy system in this alternative scenario are significant. For example, China's net imports of oil and gas in 2040 are 20% lower than in the Evolving Transition scenario, as they switch into domestically-produced coal and renewables. This, in turn, has a knock-on effect for energy exporters. US net exports of oil and gas in 2040 are around two-thirds lower than in the Evolving Transition scenario – with the emerging US trade surplus in oil and gas severely dented.

To put the recent trade disputes in an historical context: the share of oil in the global energy system peaked in 1973, the year of the oil embargo, and has pretty much declined ever since. The message from history and from this scenario is that concerns about energy security can have persistent and damaging effects.

5. THIRD QUESTION: HOW IMPORTANT ARE PLASTICS FOR THE FUTURE OF OIL DEMAND?

This section explores the impact of plastics on oil demand. In the Evolving Transition scenario, consumption of liquid fuels increases around 10 million of barrels per day (Mb/d) over the next 2 decades. Demand rises from around 98 Mb/d to 108 with the majority of that growth occurring over the next 10 years, after which demand gradually plateaus. This growth stems partly from increasing demand from the transport sector but the impetus from transport gradually fades as vehicle efficiency increases and other fuels penetrate the transport system.

The single largest and most persistent source of demand growth is from the non-combusted use of liquid fuels in industry, especially as a feedstock in the petrochemical sector. Much of the growth in the non-combusted use of liquid fuels is driven by the increasing production of plastics, which is by far the fastest growing source of non-combusted demand. So what might happen if increasing environmental concerns cause the regulation of plastics to tighten significantly? How could this affect the growth of oil demand?

The likelihood of some material tightening in plastics regulation is already built into the Evolving Transition scenario. In particular, the scenario includes a doubling of recycling rates to around 30%. As a result, the growth rate of plastics in next two decades almost halves relative to the past 20 years, despite only a slight slowing in GDP growth. This means the growth of oil demand decreases by around 3 Mb/d relative to a continuation of past trends. But it is possible that regulation may tighten by even more.

We consider an alternative scenario which focuses on plastics for packaging and other single uses –plastic bags, bottles, straws, etc.– which account for around 3.5 Mb/d of liquid fuels today, rising to around 6 Mb/d by 2040 in the Evolving

Transition scenario. It is worth remembering that around two-thirds of all plastics are used to produce durable products and these long-lived products are not the focus of current concerns. The alternative scenario considers the question of what would happen if the regulation of plastics tightened even faster than assumed in the Evolving Transition scenario, culminating in a worldwide ban on the use of all plastic packaging and other single uses from 2040 onwards.

The demand for oil and other liquid fuels used in the non-combusted sector still grows relative to current levels but not much. More importantly, the overall growth of oil and other liquid fuels is reduced to around 4 Mb/d, compared with 10 in the Evolving Transition scenario.

There are two main conclusions of this alternative scenario. First, although a complete worldwide ban on all single-use plastics is unlikely, it highlights that the speed and extent to which the regulation of plastics does tighten over the next 20 years could have a material impact on the pattern of oil demand growth. Second, the scenario does not account for the energy needed to produce the alternative materials that are used in place of single-use plastics. The point here is that the reason why the demand for plastic packaging and other single uses is set to increase so substantially over the next 20 years is because they provide an effective and efficient solution to many everyday needs. It is not easy to substitute these plastics without further advances in alternative materials and widespread deployment of efficient collection and reuse systems.

6. FOURTH QUESTION: HOW QUICKLY COULD RENEWABLE ENERGY GROW?

Renewables are the fastest growing source of energy in the Evolving Transition scenario, accounting for around half of the increase in primary energy and around two-thirds of the growth in power generation in 2017-2040. This rise of renewable energy is led by wind and solar power. Wind increases by a factor of 5 and solar energy by a 10 in the same period, accounting for broadly similar increments in global power. The growth in renewable energy means it replaces coal as the primary source of global power generation by 2040.

The growth of renewable energy is dominated by the developing world which accounts for around two-thirds of the increase. The particularly rapid growth of renewables in developing countries is helped by strong growth in power demand, which ensures there is considerable scope for renewables to grow. In contrast, the much slower expansion of power demand in the OECD means that the scope for renewables to grow in most developed economies is largely limited by the pace at which existing thermal power stations are retired. Indeed, *BP Energy Outlook 2019* includes an analysis which shows that a doubling in the rate at which existing thermal power stations are retired increases the penetration of renewable energy by almost as much as a doubling in the pace of technological progress. This is a particular example of the more general point that the capital intensity of the energy system acts as a speedbump on the pace at which new energies can penetrate. To sum up, continued technological gains in renewables are a necessary condition to achieve a rapid decarbonisation of the power sector, but they are unlikely to be sufficient on their own.

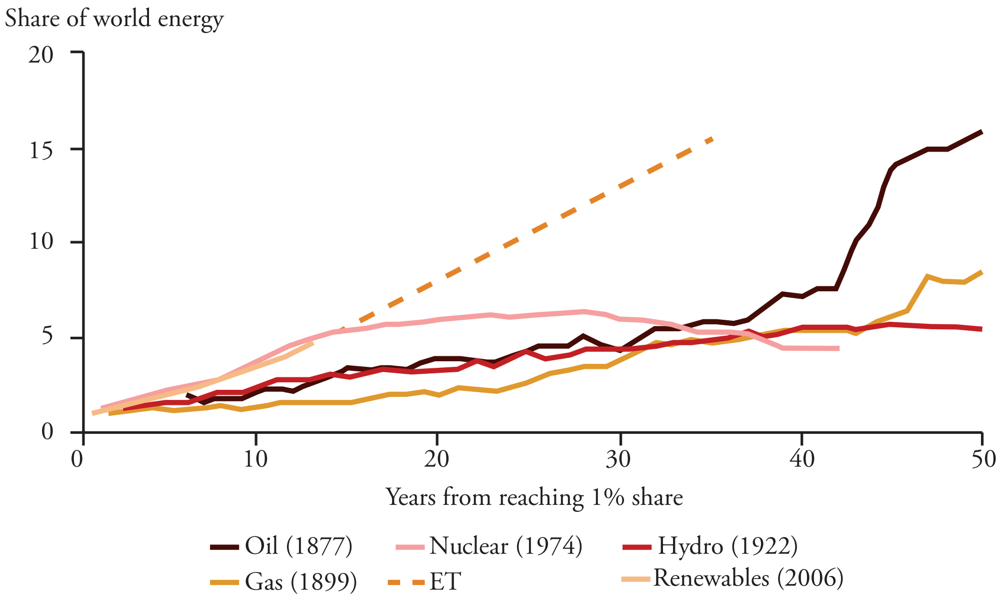
Figure 4 puts this point into a broader historical perspective. The key point to take away from this chart is the time it took for new energies to penetrate the energy system. This Figure shows the share of different energy sources, starting at the point when each one of these fuels provided 1% of world energy and considers how that share increased over the subsequent 50 years. So, for oil, the chart starts in 1877 when oil first accounted for 1% of world energy. For nuclear, it was 1974 — so in this case, we have not yet reached the end of the 50 years. This Figure 4 shows that it took almost 45 years for oil to increase its share from 1 to 10% of world energy. For natural gas, it took natural gas over 50 years. As mentioned before, the capital intensity of the energy system acts as a break on the speed at which new energies penetrate. Energy transitions in history have taken multiple decades (Fouquet, 2010).

In the case of renewable energy, the clock started ticking in 2006 when these energies achieved 1% of the global energy mix. So far, renewables have followed a path pretty similar to nuclear energy. What will happen next? The profile implied by the Evolving Transition scenario suggests that the share of renewables in world energy will increase from 1 to 10% in around 25 years. So, more quickly than any

Exhibit 4

Speed of penetration of new fuels in global energy system

(Percentage)



fuel ever seen in history, helped by policy support and sustained technological improvements.

However, this rapid growth of renewable energy is not enough to achieve the climate targets of the Paris Agreement. This rises the last question of this article.

7. FIFTH QUESTION: WHAT MORE NEEDS TO BE DONE TO ENSURE A RAPID TRANSITION TO A LOWER-CARBON ENERGY SYSTEM?

The Evolving Transition scenario is not consistent with Paris Agreement. The *BP Energy Outlook 2019* describes an alternative scenario that is broadly consistent with the Paris Agreement targets. This is called the Rapid Transition scenario. The idea behind this scenario is to consider a range of policy measures that can be applied in industry, transport, buildings and power to achieve a faster transition to a lower-carbon energy system.

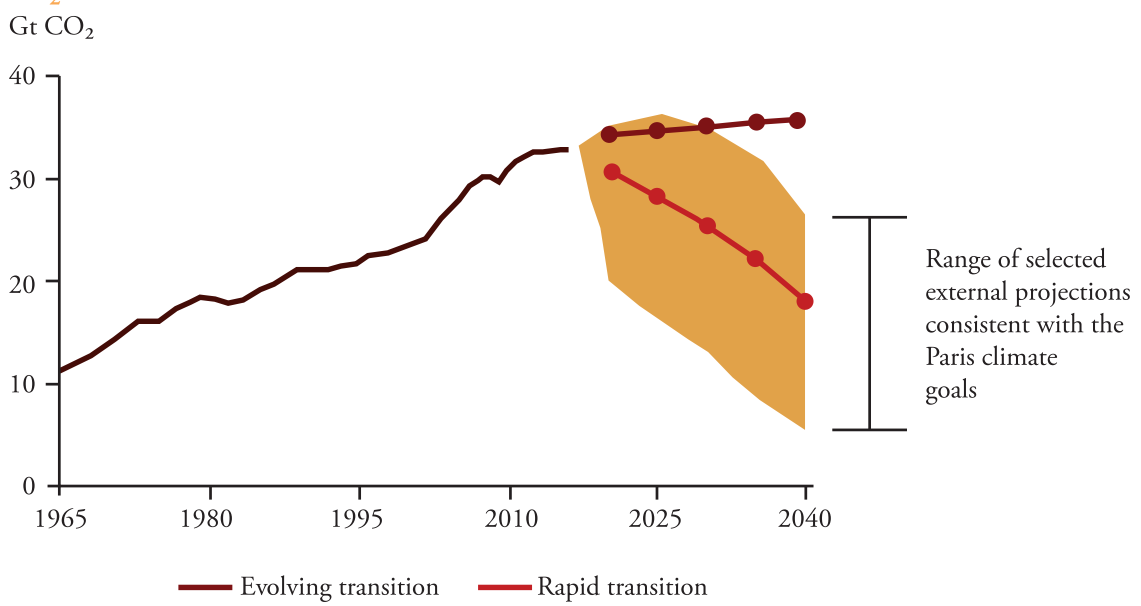
In this alternative scenario, carbon emissions from energy use fall by around 45% by 2040 compared to the Evolving Transition scenario. This reduction is in line with a sample of external projections which claim to be consistent with meeting the Paris climate goals. Figure 5 shows the path of carbon emissions in the Rapid Transition, the Evolving Transition, and a range of external projections consistent with the Paris climate goals.

This scenario has wide range of stretching measures across each sector, with the policies chosen so as to be broadly equivalent in terms of their implied costs and effort. The idea behind this strategy of multiple policy measures is that there is no silver bullet. A comprehensive set of policy measures is needed.

Carbon prices play a central role. This is particularly relevant for the power and industrial sectors, encouraging a switch into lower-carbon fuels and supporting investment in CCUS. In this scenario carbon prices reach $200 per tonne of CO_2 by 2040 in the OECD and $100 elsewhere. However, carbon prices are increased only gradually to avoid a premature scrapping of productive assets.

Exhibit 5

CO_2 emissions



This means there is a role, at least for a period, for targeted regulatory measures to help create the right incentives for new investments until carbon prices get to meaningful levels.

What is the role of the different sectors in this alternative scenario? Around 2/3 of the emissions reduction is due to the reduction in the carbon intensity of the power sector. Policies aimed at the power sector are central to achieving a material reduction in carbon emissions over the next 20 years. Much of the rest of the reduction (1/3) is due to reductions in buildings and industry. Its striking that the transport sector, despite an equally stringent set of measures being applied, accounts for only a small reduction in carbon emissions relative to the Evolving Transition scenario. For example, the number of electric cars in the Rapid Transition scenario is over 600 million in 2040 while in the Evolving Transition it is half of that number. Most of the low-hanging fruit in terms of reducing carbon emissions over the next 20 years is outside of the transport sector.

In absolute terms, the increased use of Carbon Capture Utilisation and Storage (CCUS) in the power and industrial sector –to around 4.5 Giga tonnes of CO_2 by 2040– accounts for around a quarter of the reduction in carbon emissions relative to current levels.

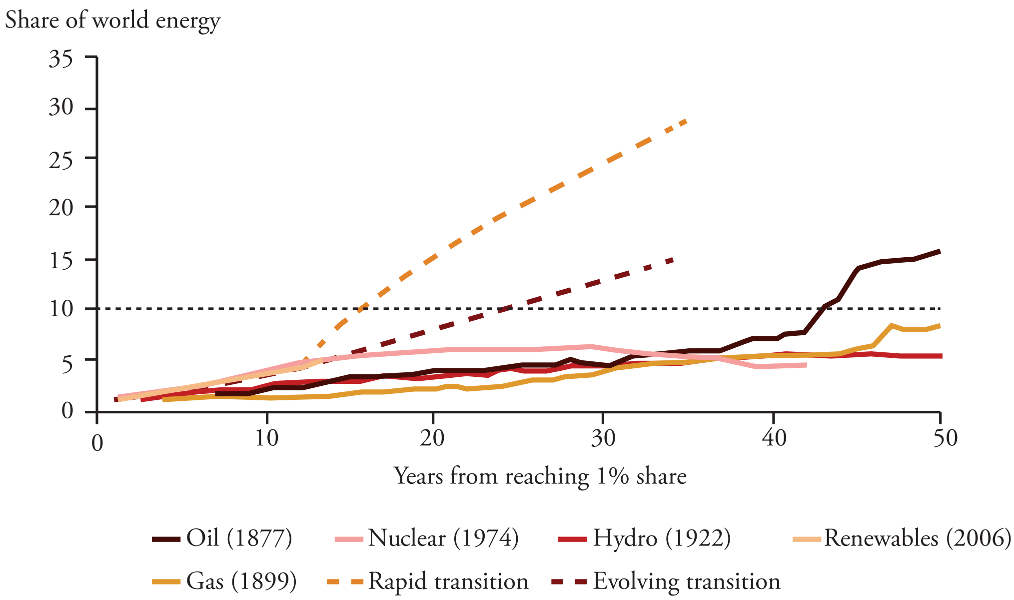
In this scenario, all of the growth in energy demand is met by increasing renewables, with their share of primary energy increasing to 30% by 2040. This brings back the question how fast can renewable energy grow. Figure 6 shows the speed of penetration of renewable energy in the energy system in the Evolving Transition and in the Rapid Transition. The growth of renewables is literally off the charts relative to anything seen in history, with renewables accelerating from 1% to 10% in just 15 years. This does not automatically suggest that this is impossible or implausible. However, to achieve a pathway consistent with Paris will require a speed of change and transition in the global energy system which is truly unprecedented.

Renewables accounts for around a 1/3 of global energy in 2040. This implies that other forms of energy need to provide the other 2/3. In this alternative, low-

Exhibit 6

Speed of penetration of new fuels in global energy system

(Percentage)



carbon scenario, oil and gas together account for almost 50% of primary energy in 2040. In the Rapid Transition scenario, oil demand falls to around 80 Mb/d by 2040. In contrast, the demand for natural gas actually increases over the next two decades, helped by the growing use of CCUS. Around 40% of natural gas consumption is used in conjunction with CCUS by 2040.

The main takeaways of this scenario are the following. First, the power sector is the lowest-hanging fruit in terms of carbon emissions. The power sector is key in that respect. Second, carbon prices are critical: they provide the correct incentives for producers, consumers, and innovators, but they have to be supplemented by targeted regulations, especially in the initial phases if carbon prices are increased only gradually. And third, many energies are likely to be required for many years.

Even if the world was to achieve everything envisaged in the Rapid Transition scenario, a significant level of CO_2 emissions from energy use would still remain in 2040. This alternative scenario represents a major step towards Paris, but it just a step. There is still a significant level of emissions remaining in 2040, concentrated in hard-to-abate processes and activities, particularly in transport and industry.

To achieve a net zero energy system in the second half of this century more things have to be done. A key development would be the need for an almost complete decarbonisation of the power sector, together with greater electrification of end-use activities. That in turn is likely to require: more renewables; CCUS to support gas and, perhaps, even coal; and energy storage and demand-side-response to help alleviate some of the growing intermittency issues associated with increased reliance on renewables. The International Energy Agency estimated that only 2/3 of final energy use has the technical potential to be electrified, highlighting the need for other low-carbon forms of energy and energy carriers, such as hydrogen and bioenergy. There will also be a need for accelerated gains in energy efficiency, including a substantial expansion of the circular economy. And, finally, a range of technologies for the storage and removal of carbon emissions, including negative emission technologies, such as land carbon. The road to Paris is long and challenging.

8. CONCLUSIONS

The global energy system is in transition. The obvious dimension of that transition in the need to shift to a lower carbon energy system. But that is only one dimension. The pattern of energy demand is also in transition, driven by growing prosperity in the developing world, as billions of people start to enjoy just a tiny fraction of the comforts and amenities that most people in developed countries take for granted. Meeting the dual challenge for more energy to support continued growth and prosperity, whilst reducing carbon emissions is the key challenge facing all of us. In this context, the *BP Energy Outlook 2019* explores some scenarios that could shape the energy transition in the next two decades. The main findings of the scenarios described in this document are the following.

First, in the Evolving Transition scenario, that describes the path of the energy system in 2017-2040 if policies, technology, and social preferences evolve in a speed and manner consistent with the recent past, energy demand increases by a third. In this context of higher demand, renewable technology penetrates the energy system faster than any other fuel in history, increasing by a factor of 5. However, this rapid growth is not enough to achieve the targets of the Paris Agreement and carbon emissions continue to grow.

Second, the world needs more energy. The Evolving Transition assumes that billions of people move from low to middle incomes. The emergence of a growing middle class in the developing world is the main force for economic growth in 2017-2040. However, in 2040 a significant share of world's population still live in countries in which increases in energy consumption tend to move hand-in-hand with pronounced increases in human development. This is the core of the dual challenge. The world needs simultaneously more energy to foster prosperity in less developed economies and less carbon emissions at a global level.

Third, an increase in trade disputes might have a material impact on the energy system due to a lower global growth and increased concerns of energy security. These two factors combined lead to a decrease in global energy demand of 4% compared to the Evolving Transition scenario, a sharp reduction in energy trade, and a different structure of international energy flows.

Fourth, non-combusted energy represents a significant share of the current and future demand for oil. The *Energy Outlook* explores the impact of a ban on all single-use plastics in an alternative scenario. This scenario is not likely, but shows that tighter regulation on plastic could have a significant impact on the pattern of oil demand growth. In particular, the growth of oil and other liquid fuels in this alternative scenario is reduced to around 4 Mb/d, compared with 10 in the Evolving Transition scenario.

Fifth, renewable technologies grow by a factor of 5 in the Evolving Transition scenario, accounting for around half of the increase in primary energy and around two-thirds of the growth in power generation in 2017-2040. However, this is not enough to be consistent with meeting the carbon targets of the Paris Agreement. The *BP Energy Outlook* develops an alternative scenario, the Rapid Transition, with a speed of reduction in carbon emissions over the next 20 years that is broadly consistent with the Paris Agreement. In this scenario, renewable energy grows by a factor of 8. The Paris Agreement requires a speed of transition which has no precedent in the history of energy.

What more needs to be done to ensure a rapid transition to a lower-carbon energy system? This is, probably, the most relevant question for policymakers and energy companies. The Rapid Transition scenario tries to answer this question. There are some takeaways of this scenario. First, power is the sector where it is easier to reduce carbon emissions over the next 20 years. The potential emission reduction in transport, industry and buildings is much lower. Second, carbon prices are a critical tool for achieving a low carbon energy system, but they have to be supplemented by targeted regulations at least in the short run. And third, many energies are likely to be required for many years. In this Rapid Transition scenario, oil and natural gas amount to 50% of the total primary energy consumed in 2040.

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