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ENERGY TRANSITION

A PUBLICATION OF THE **ECONOMIC RESEARCH** TEAM

ILLUSIVE PROGRESS

- **Improved energy efficiency over the last 30 years, but a stagnant energy mix**
  - To limit global warming to 1.5°C will require a 45% reduction in CO_2 emissions by 2030 according to the Intergovernmental Panel on Climate Change
  - Two driving forces will be essential to achieving this goal: an increase in the share of renewable energies in the energy mix and an improvement in energy efficiency
  - Since 1990, there has been visible progress in efficiency, which has increased 48% worldwide and 167% in China ...
  - ...but progress in the global energy mix is nonetheless disappointing. In 1990, 86.7% of energy consumption came from fossil fuels. In 2017, it was still at 85.1%
  - 2017 was a disappointing year in terms of the energy transition. The growth in worldwide energy and coal consumption accelerated and CO_2 emissions increased ...
  - ... mainly due to the acceleration of global economic growth from 3.3% to 3.7% in 2017, fueled in large part by industrial activity

- **Which countries are the most advanced in relation to the energy transition?**
  - We have developed an energy transition index that is based on four main components: energy consumption per person, CO_2 emissions per person, the share of fossil energy in total energy consumption, and energy efficiency
  - According to our index, the most advanced countries in 2017 were Switzerland, Colombia and Sweden
    - Switzerland: Despite high primary energy consumption per capita, Switzerland's consumption of fossil fuels is only 50.5% and the country's energy efficiency (GDP per unit of energy) is among the highest in the world
    - Colombia: Colombia owes its second place to a per-capita primary energy consumption well below the world average and a significant role played by hydroelectricity, accounting for 30.4% of its energy mix
    - Sweden: Sweden has been a pioneer in the energy transition. In 2017, fossil fuels accounted for only 32.6% of primary energy consumption. These results were achieved through innovative and inclusive regulations

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INTRODUCTION

According to the latest forecasts of the International Energy Agency[1] (IEA), by 2040 the world's population will have grown by 1.7 billion and the need for energy will have increased by over 25%. If no efforts to improve efficiency are made by then, this need could increase by 50% according to the same source. Supplying energy to the growing population while limiting CO_2 emissions – the main cause of global warming – is one of the biggest challenges of our century. It is for this reason that the signatory countries of the Paris Agreement undertook at the COP21[2] in 2015 to reduce their CO_2 emissions in order to keep global warming below 2°C compared with the pre-industrial era, and even to strengthen efforts to limit the increase in temperatures to 1.5°C[3]. This second objective would lead to a 45% reduction in CO_2 emissions by 2030 (relative to 2010) and to carbon neutrality by 2045-2055, meaning that the amount of CO_2 absorbed each year would be equivalent to the amount of CO_2 emitted[4].

Reconciling the rise in energy consumption with the reduction of CO_2 emissions calls for a true transformation of the global energy system. Improving energy efficiency and the adoption of energy sources that emit less CO_2 are the two key factors to achieve this goal according to the IEA[5] (see Inset 1). The role played by public authorities will be essential in this respect.

In the first part of this study, we analyse developments in energy consumption, the energy mix and energy efficiency in recent years. In the second part, we present our EdR energy transition index, which identifies the most advanced countries in this area as well as the policies they have implemented. Switzerland, Colombia and Sweden are the top three countries according to our index.

INSET 1

According to the IEA, the two main contributors to the reduction of CO_2 emissions by 2040 will be:

- An improvement in the **energy mix**, i.e. a transition from the current model, based on the use of natural resources that emit greenhouse gases during their combustion and that are running out (coal, oil, natural gas), towards an energy system based on renewable and "zero-carbon" energies, which produce very little greenhouse gas (including hydroelectricity, solar, wind, tidal energy, geothermal energy, and biomass).
- Improved **energy efficiency**, i.e. producing more GDP for the same amount of energy used.

[1] According to the "New Policies Scenario" of the IEA, "World Energy Outlook 2018"
[2] 21st Conference of Parties of the UN Framework Convention on Climate Change.
[3] "Global Warming of 1.5 °C", Intergovernmental Panel on Climate Change IPCC Report, 8 October 2018.
[4] Methods that absorb CO_2 include natural processes that consist in eliminating soil artificialisation and increasing forests and natural wells in the oceans, as well as chemical technologies that make it possible, in particular, to capture and contain carbon on industrial sites.
[5] Energy Technology Perspectives 2017, IEA, 2017

PART I – A DISAPPOINTING 2017, BUT ENERGY EFFICIENCY HAVE BEEN INCREASING

1) THE YEAR 2017 STRAYED FROM THE TRAJECTORY ON CLIMATE OBJECTIVES

Primary Energy consumption[6] increased by 1.9% worldwide in 2017, compared with 1.1% on average between 2014 and 2016. Coal consumption rose for the first time in three years, after an average contraction of 1.4% a year between 2014 and 2016. CO_2 emissions increased by 1.3% in 2017, after holding steady in the previous three years and contrary to the commitment made at COP21 by the international community to reduce CO_2 emissions.

The energy situation in 2017 is not very encouraging at first glance. One factor explaining the growth in energy demand is the acceleration of global GDP in 2017, which grew by 3.7% after 3.3% in 2016 (see Chart 1). This upturn was generated primarily by industrial activity[7], which is more energy intensive than the services sector. According to the IEA, manufacturing industries consume on average 27% of the total energy of an economy, compared with 34% for transport, 19% for the residential sector and 14% for the service sector. Consequently, unlike emerging countries, developed countries, as the main actors in the tertiary sectors, have economic structures allowing them to limit their energy consumption.

The increase in fossil fuel consumption in 2017 stemmed primarily from a growing contribution from coal consumption, which emits almost twice as much CO_2 as natural gas[8] and one-third more than oil during combustion. Demand increased the most in Asia, by 1.3% year on year, and notably in the Philippines, Pakistan, Indonesia and Bangladesh.

We have analysed the change in coal intensity, i.e. the amount of energy from coal needed to produce a unit of GDP. While coal intensity continued to fall in 2017, the reduction in intensity was significantly lower than in the previous three years (see Chart 2). South Africa and China – countries with a very high coal intensity (118 and 89 tonnes of oil equivalent (oe) for a dollar of GDP, respectively, compared with an average of 32 tonnes of oe worldwide) – nevertheless continued in 2017 the sharp decline in coal intensity already under way for several years now.

Chart 1 : Increase in Energy Consumption in 2017

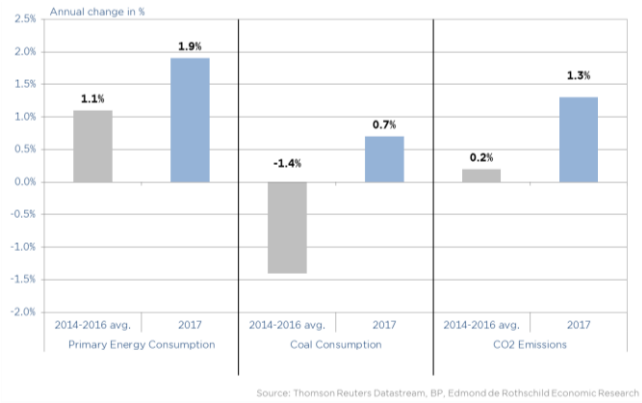
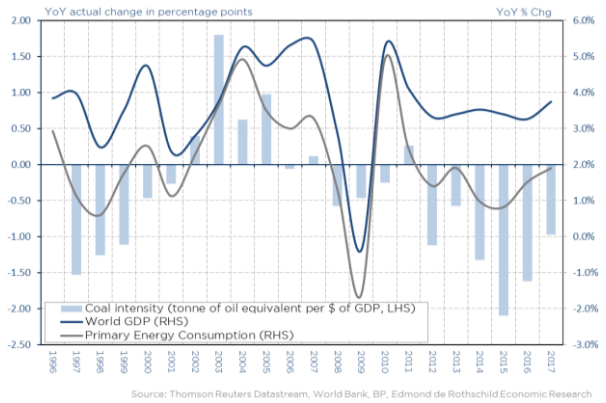


Chart 2 : Correlation between GDP growth and energy consumption growth



[6] We are referring here to primary consumption, in other words the consumption of energy that is not transformed or that comes from an initial transformation, for example, fuels such as coal, oil, natural gas, nuclear power, hydroelectricity, and other forms of renewable energy (as defined by the IEA).
[7] "The key man for global growth is Xi Jinping…and not Donald Trump", Mathilde Lemoine, January 2017
[8] "How much carbon dioxide is produced when different fuels are burned", US Energy Information Administration, 2018

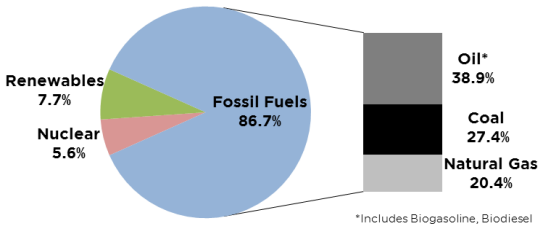
2) GREATER GAINS IN ENERGY EFFICIENCY IN RECENT YEARS, BUT FOSSIL FUEL SHARE STILL TOO HIGH

a) Improved energy intensity worldwide, but a disappointing trend in the energy mix

In a more retrospective way, energy consumption has slowed slightly since 2010, while energy efficiency has improved. But the share of renewable energy in primary energy consumption has changed very little.

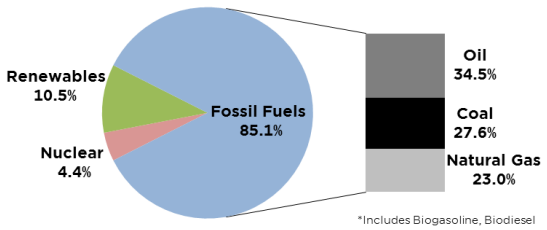
- **Primary energy consumption**: Global energy consumption increased by 2.4% a year on average between 2000 and 2009 and by 2.0% between 2010 and 2017. The European Union is the only region that has reduced its energy consumption, by an average of 0.1% per year since 2000, while consumption in Asia Pacific and the Middle East has increased by an annual 3.4% and 3.6%, respectively, since 2010, following growth of 5.5% between 2000 and 2009.
- **Energy intensity**: Energy intensity is the amount of energy used in a year (expressed in tonnes of oil equivalent) relative to one unit of GDP produced (in millions of constant dollars, Purchasing power parity). Significant decreases in energy intensity have been observed worldwide, falling 12.6% between 2010 and 2017 and 21.5% between 2000 and 2017, mainly thanks to developed countries. In our sample group, energy intensity has worsened in just eight out of 60 countries since 2000[9]. In 2017, Turkmenistan and Ukraine, as well as Canada and Russia, were particularly poorly ranked, consuming considerable amounts of energy per unit of GDP, partly because of their extreme climates and the long distances between urban areas. The high energy intensity of these countries is also a result of the low energy efficiency of buildings, the high fuel consumption of vehicles, unsuitable modes of transport, and low energy prices. In contrast, Ireland, Switzerland and the Philippines have a particularly low energy intensity.
- **The energy mix**: The trend in the energy mix has been disappointing. In 1990, 86.7% of the world's primary energy consumption came from fossil fuels (oil, coal, natural gas), 5.6% from nuclear energy and 7.7% from renewable energies. This global energy mix has evolved only marginally over the last thirty years. The percentages in 2017 were as follows: fossil fuels 85.1%, nuclear 4.4% and renewable energies 10.5%. The percentage of coal remained stable at 27.5% (see Charts 3 and 4).

Chart 3: World Energy Mix in 1990...



Sources: Thomson Reuters Datastream, BP, Edmond de Rothschild Economic Research

Chart 4: ...World Energy Mix in 2017



Sources: Thomson Reuters Datastream, BP, Edmond de Rothschild Economic Research

[9] Saudi Arabia, Iran, United Arab Emirates, Algeria, Brazil, Bangladesh, Kuwait and Thailand.

b) Have the largest energy consumers – China, the United States and the European Union – improved their energy intensity?

China, the United States and the European Union consumed 52% of the world's energy in 2017. Although China is the largest energy consumer in the world, with 3,132 million tonnes of oil equivalent (oe) consumed in 2017, or 23.2% of the world's energy, its per capita consumption (2,259 kg of oe) is only slightly higher than the world average. Americans, on the other hand, consumed three times more energy per person than the Chinese in 2017 (see Chart 7). The largest per capita users of energy are Saudi Arabia, Kuwait, Qatar and the United Arab Emirates, which consumed an average of 12,429 kg of oe per person.

China consumes less energy per capita than the United States and the European Union but its energy intensity (the amount of energy used per unit of GDP) remains higher. This is because the Chinese economy relies heavily on the industrial sector, which is energy intensive. However, the rapid development of the tertiary sector in China over the last 20 years and the transformation of the country's energy structure has led to a swift improvement in its energy intensity, which fell by more than twice the world average between 2010 and 2017 (-24.5% against -12.6%, see chart 5).

In Europe, both energy consumption per capita and energy intensity have decreased since the early 2000s. Between 2010 and 2017, intensity fell by 14.2% and per-capita consumption by 7.3%. While the energy used for one unit of GDP is particularly low in Switzerland, the European Union remains well ranked as well vis-à-vis the world. Within the EU, Lithuania, Ireland, Denmark, Italy and the United Kingdom contribute to improving the ratio, with France, Germany and Finland bringing up the rear (see chart 6).

Chart 5: Energy intensity has decreased in the world…

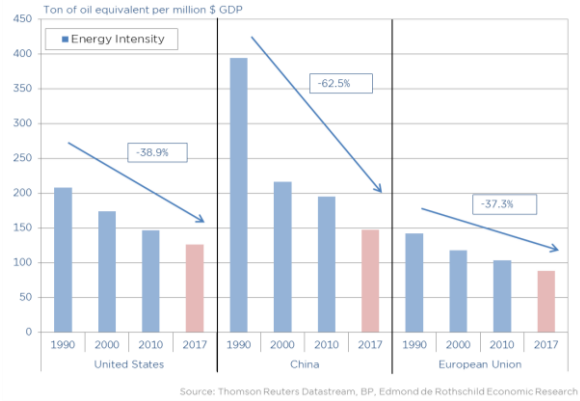


Chart 6: …as well as in Switzerland and in the EU

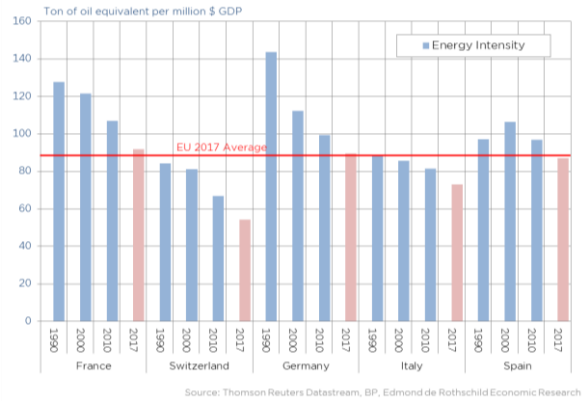
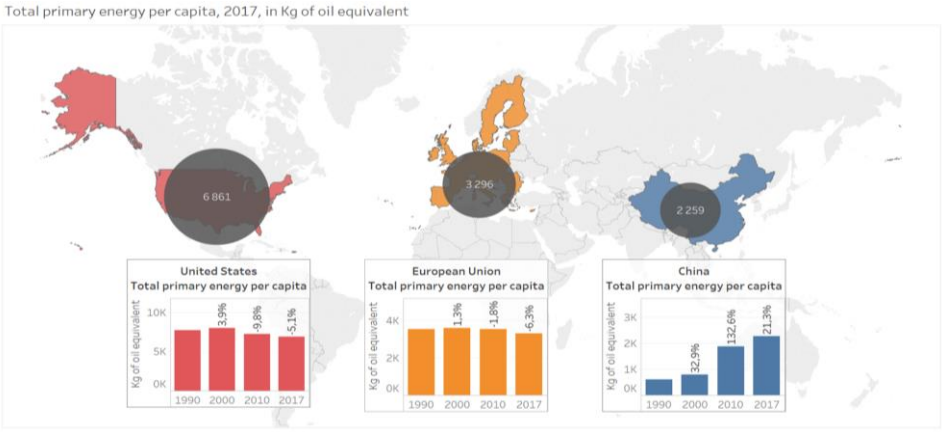


Chart 7 : Primary Energy Consumption per capita in the US, EU and China



Source: Thomson Reuters Datastream, BP, Edmond de Rothschild Economic Research

3) IS THE LIMITATION OF GLOBAL WARMING BELOW 2°C COMPATIBLE WITH CURRENT POTENTIAL GROWTH?

The IEA predicts that energy consumption will be 25% higher in 2040 than in 2010. The agency expects annual growth in energy consumption to slow from 1.9% a year between 1991 and 2017 to 0.5% a year between 2018 and 2040. But despite the strong correlation between growth in demand for primary energy and GDP (see Chart 2), this does not necessarily imply a slowdown in economic growth, but an improvement in energy efficiency might be possible (see Appendix 2 for details of the relationship), i.e. the ratio between GDP and energy consumption. If world economic growth maintains its long-term rate of 3.4% a year, a sharp acceleration in energy efficiency will be required. According to our estimates, this should increase by 2.4% a year, versus an average of 1.5% over the last 20 years. To disconnect energy consumption growth from GDP growth, countries will thus need to make considerable efforts in terms of energy productivity.

Energy efficiency is improved through the structural transformation of an economy towards services and industries that are less energy intensive, and through the electrification of production processes and the use of more efficient technologies in various sectors (industry, construction, services, transport)[10].

While many studies predict a slowdown in potential growth in the short and medium term[11], owing in particular to the implementation of policies to limit climate change (notably due to the higher energy costs they entail), the causal link between energy consumption and GDP is particularly complex and the empirical literature has failed to establish a clear direction or the existence of a causal link[12].

[10] "Are we decoupling energy consumption from economic growth?", European Environment Agency, 2010
[11] "European energy policy and the transition to a low-carbon economy", OECD, 2010
[12] "Re-assessing causality between energy consumption and economic growth", NCBI, 2018

PART II - OUR EDR ENERGY TRANSITION INDEX

1) WHICH COUNTRIES ARE THE MOST ADVANCED WITH REGARD TO THE ENERGY TRANSITION?

We have developed an energy transition index to assess the status of and progress made by countries in relation to the energy transition. The index has four main components for a sample of 60 countries[13]:

- per-capita primary energy consumption (in kilogrammes of oil equivalent)
- per-capita CO_2 emissions (in metric tonnes)
- fossil fuels as a percentage of total energy consumption
- energy (or productivity) efficiency, i.e. the GDP produced per unit of energy used (in PPP dollars per kg of oil equivalent)

The first component is primary energy consumption per capita (see Chart 1 in Appendix 1). The analysis is particularly interesting because of the differences observed: per-capita energy consumption is 100 times higher in Qatar than in Bangladesh, which is the country with the lowest per-capita primary energy consumption in our sample group.

- Energy consumption per capita in the four countries for which we have data in the Middle East (Saudi Arabia, Kuwait, Qatar, United Arab Emirates) is much higher than the average. However, their energy transition could accelerate in the coming years, since their margin for growth is large and their determination to reduce energy consumption is increasing. In the last ten years, per-capita consumption has decreased by an annual average of 1.6% in three of the four countries, while the figure has increased by 2.1% in Saudi Arabia.

- Canada and the United States are ranked just after the countries of the Middle East and Singapore. Despite the reduction observed since 2000 (-0.3% and -1.1% a year, respectively), per-capita primary energy consumption remains very high.

- Per-capita energy consumption remains low in emerging countries, but these last are making the biggest contribution to the increase in the world's energy demand, particularly because of their fast-growing economies, rapid urbanisation and growing populations.

The results of the second component, CO_2 emissions per capita, are similar to those of per-capita energy consumption, the latter being the main source of CO_2 emissions. Qatar, the United Arab Emirates and Kuwait are the lowest ranked in terms of per capita CO_2 emissions. However, Bangladesh, which emits very little CO_2 per person, has seen its CO_2 emissions increase by an annual 6.5% in the last ten years (compared with a worldwide increase of 0.3% a year), illustrating the relationship between CO_2 emissions and improved living standards.

Our third component compares the energy mix of countries. Fossil fuel consumption as a percentage of total energy consumption varies from 32% for Norway and Sweden, 50.5% for Switzerland and 52.0% for France to 100% for the Middle East countries. EU countries have made the greatest efforts in the last ten years to improve their energy mix, with the fossil energy percentage falling from 80.0% in 2006 to 74.4% in 2017. China has also improved its energy mix, with the fossil fuel component decreasing from 93.9% in 2006 to 86.3% in 2017.

The fourth component measures the energy efficiency of the sample countries. Energy efficiency is calculated by comparing a country's annual GDP with its annual energy consumption – the opposite of the energy intensity discussed above. Improving energy efficiency reduces not only energy consumption but domestic dependence on energy supplies from abroad. Ireland, the Philippines and

[13] British Petroleum database, which compiles government statistics from 60 countries.

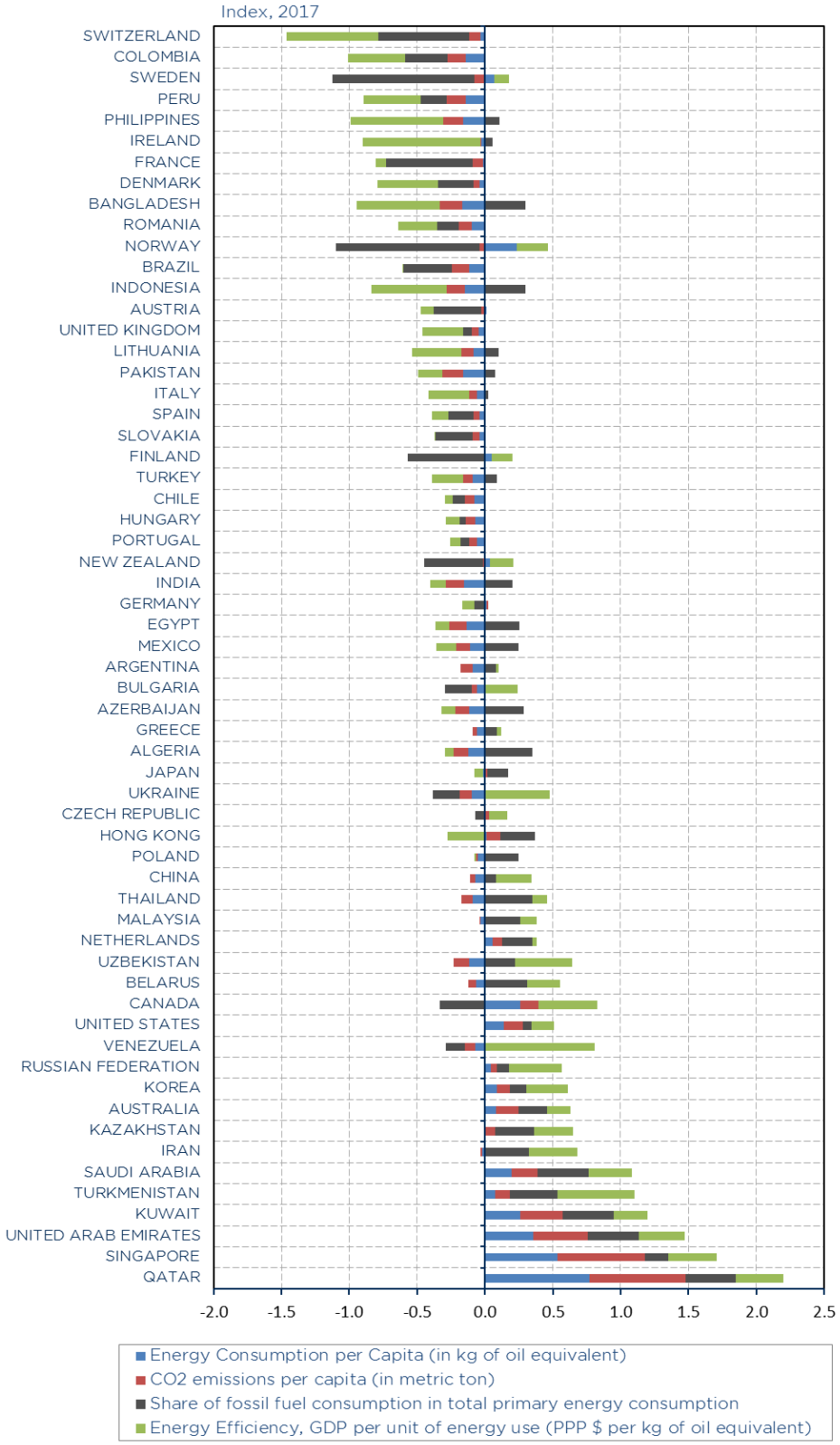
Switzerland produce far more GDP per unit of energy used than Turkmenistan, Canada and Ukraine, which are the lowest ranked countries in terms of energy efficiency.

In the design of our composite index, all the components were standardised according to the z-scores normalisation method (with a mean equal to 0 and variance equal to 1), to ensure their comparability. We then aggregated the results by weighting, taking into account the mutual correlations of the components.

Overall, our EdR energy transition index shows that Switzerland, Colombia and Sweden are the most advanced countries in our sample, while three countries in the Middle East – Qatar, United Arab Emirates and Kuwait – as well as Singapore still have efforts to make. This "ranking" must, however, be interpreted with caution, since the EdR index can take into account neither all countries nor all energy transition components. For example, our index does not take into account the "grey energy" or intrinsic energy[14] of the goods consumed in the various countries, i.e. the amount of energy consumed during the production cycle of a product, including the extraction of raw materials, processing, manufacturing and transportation. Developed countries thus improve their energy efficiency by offshoring energy-intensive activities, often to emerging countries.

[14] "Decoupling energy use and economic growth: Counter evidence from structural effects and embodied energy in trade", Vincent Moreau et François Vuille, 2016

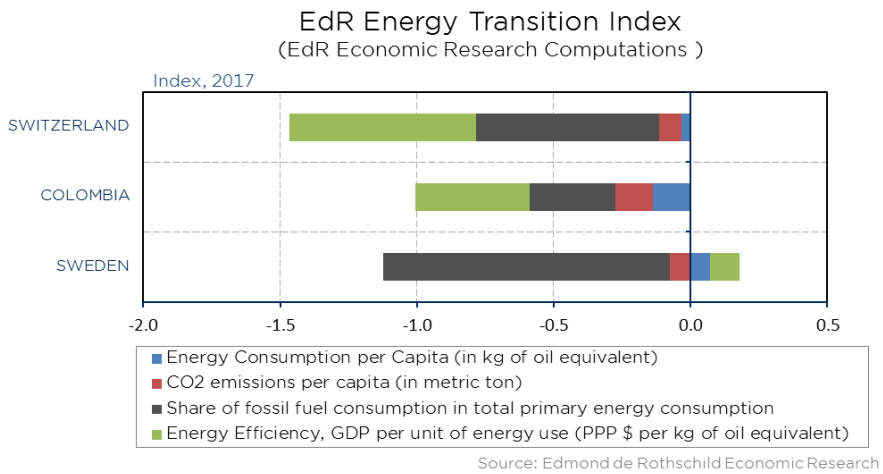
EdR Energy Transition Index
(EdR Economic Research Computations)



Methodology: Standardisation of the components according to the z-scores normalisation method and aggregation of the results by weighting, taking into account the mutual correlations of the components..

Source: Edmond de Rothschild Economic Research

2) A CLOSER LOOK AT OUR TOP-THREE COUNTRIES AND THE POLICIES THEY HAVE IMPLEMENTED



Conclusions:

- Reconciling the rise in energy consumption with the reduction of CO_2 emissions calls for a complete transformation of the global energy system. Improving energy efficiency and adopting less CO_2-emitting energy sources are two key components in this respect.
- While countries have made significant energy efficiency gains – a full 27.3% worldwide since 2000 – the improvement in the energy mix has been more timid. Fossil fuels still account for 85.1% of total primary consumption, compared with 86.7% in 1990.
- Our energy transition index, based on four components – per-capita primary energy consumption, per-capita CO_2 emissions, the share of fossil fuels in the energy mix and energy efficiency – has allowed us to determine the most advanced countries in terms of the energy transition: Switzerland, Colombia and Sweden.
- Although Switzerland, Colombia and Sweden benefit from natural resources favourable to renewable energies (including hydroelectricity and wind power), the regulations implemented by the public authorities have played an important role. The relevant authorities are not merely taxing fossil fuels and CO_2 emissions, but are also supporting the desired energy transition via
    - renewable energy subsidies or tax exemptions,
    - long-term support measures for companies seeking to innovate in renewable energy and energy efficiency,
    - extensive research and development programmes,
    - the inclusion of local authorities, businesses and households for a more effective application of the measures.

SWITZERLAND'S ENERGY TRANSITION

According to our EdR energy transition index, Switzerland finishes first in our ranking in 2017.

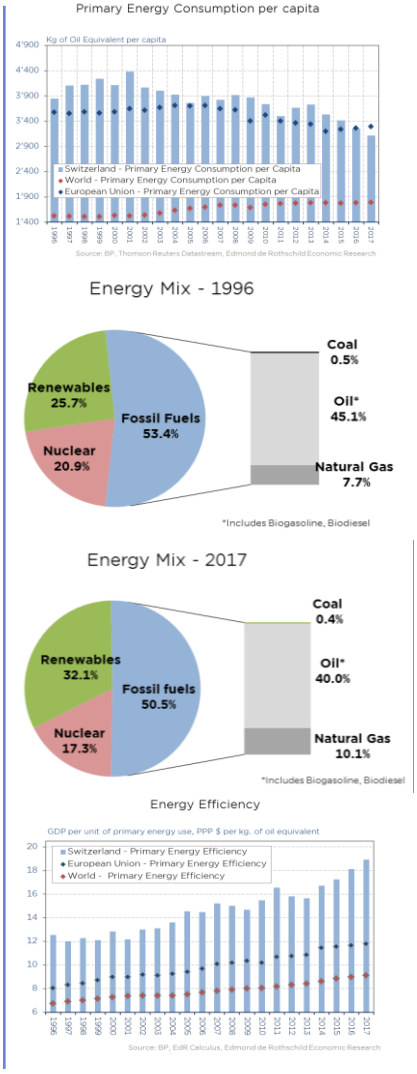
- The low share of fossil fuels in its energy mix (50.5% versus 85.1% worldwide) as well as the country's high energy efficiency ($18.4 of GDP per kg of oil equivalent versus $8.6 worldwide) make it an advanced country in terms of energy transition. In 2017, hydroelectricity and nuclear alone accounted for 45% of Switzerland's primary energy needs.
- The energy mix has not changed much in the last 20 years, but things could change in the coming years, as Switzerland is planning a gradual withdrawal from the nuclear sector following the accident at the Fukushima plant.
- However, Switzerland's per-capita primary energy consumption of 3,117 kg of oil equivalent in 2017 remains well above the world average of 1,794 kg.

Climate and energy objectives:

The Energy Act, which came into effect in 2018, aims to reduce average per-capita energy consumption by 16% by 2020 and 43% by 2035, compared with the 2000 level.

Regulations and public incentives implemented:

- 1977: An R&D programme in the energy field is introduced. Still applicable today, in 2015 it allocated 33.7 million Swiss francs for research in the field of energy efficiency and renewable energies and 33.3 million in 2018 for pilot projects in the same fields.
- 1991-1999: The Energy Act (LEne) requires grid operators to buy electricity generated using renewable sources from independent producers at a guaranteed price. The extra cost incurred by grid operators, corresponding to the difference between the guaranteed takeback price and the market price, is covered in part by a contribution from households and businesses.
- 2008: The CO_2 tax is implemented in Switzerland and is levied on fossil fuels. In 2018, it amounts to 96 francs per tonne of CO_2.
- 2008: To offset the financial risks of geothermal exploration projects, the government proposes to reimburse up to 60% of the total cost of prospecting, discovering and testing the resource.
- 2009: The Cost Price Compensation Programme (RPC) promotes renewable energy by covering the difference between the production price and the market price. This guarantees renewable electricity producers a price that covers production costs. This system is financed by a supplement billed to households and businesses (2.3 ct/kWh since 2018).
- 2010: The "Bâtiment" programme encourages property owners to rehabilitate old buildings (heating, insulation, etc.) via tax deductions. The programme is financed by cantonal contributions and part of the revenue from the CO_2 tax levied on fuels.
- 2011: The Federal Council decides not to renew the nuclear power stations in operation and to shut them down definitively once they are 50 years old (between 2019 and 2034).
- 2013: Launch of a "Technology Fund" encouraging innovations that limit greenhouse gases, promote renewable energy consumption and improve energy efficiency. The government can endorse loans to companies that innovate in this area.
- 2013: The "Coordinated Swiss Energy Research" action plan establishes eight interuniversity skills hubs in the field of energy research.
- 2018: the 2050 Energy Strategy, renewing and extending the majority of the above measures (RPC, Bâtiment).



Switzerland has managed to combine coercive regulations, such as taxes or the obligation for grid operators to buy renewable energy at a fixed rate, with incentives through the introduction of subsidies or tax exemptions that support the development of energy efficiency (the "Bâtiment" programme) or renewable energies. In addition, the country has invested substantially in innovation by promoting and funding extensive research and development programmes. Lastly, Switzerland has created a collective consciousness concerning environmental issues, effectively encouraging businesses and public authorities to play an active part in this area.

COLOMBIA'S ENERGY TRANSITION

Colombia owes its second place to a low per-capita primary energy consumption rate compared with other countries (869 kg of oe per person versus 1,794 kg worldwide and 3,296 kg in the European Union) as well as limited CO_2 emissions.

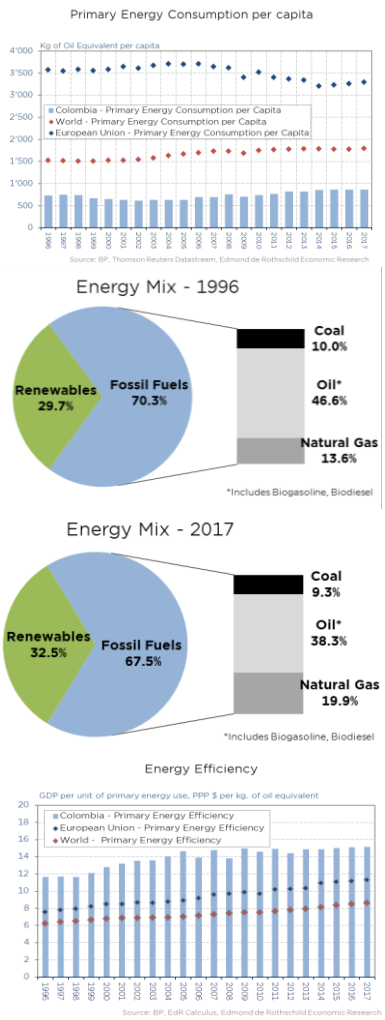
- The share of fossil fuels in Colombian primary consumption (67.5% in 2017) is well below the global average of 85.1%, owing to the country's extensive use of hydroelectricity, which accounts for 30.4% of its primary energy consumption.
- Colombia's energy intensity is also very good, with 15.2 dollars of GDP per unit of energy used in kg of oe.
- However the trend in the country's EdR index between 2011 and 2015 has deteriorated by 0.3 points due to an acceleration in per-capita primary energy consumption as well as an increase in the share of fossil fuels in the energy mix from 67.6% in 2011 to 73.6% in 2015. A major reform in 2014 has enabled the country to increase the share of renewable energy in its mix.

Climate and energy objectives:

In 2010, Colombia set the objective of increasing the share of renewable energy in its electricity mix to 3.5% and 6.5% for grid connected regions and 20% and 30% for non-connected regions for 2015 and 2020, respectively. In 2015, Colombia signed the Paris Agreement.

Regulations and public incentives implemented:

- 1993: Creation of a Ministry of the Environment with the objective of promoting the development of renewable energies. The law also makes it a requirement to hold an environmental license, particularly for the construction of dams and power stations or the laying of transport lines.
- 2000: The "Financial Support Fund for the Electrification of Non-Interconnected Areas" finances renewable electricity generation projects as well as local electricity distribution and the connection to the rural grid.
- 2001: An act is passed to promote the use of ethanol as a biofuel in transportation. A bioethanol target of 10% is set for cities with more than 500,000 inhabitants. In addition, ethanol for vehicles is exempted from the tax on petrol.
- 2004: A biofuel programme aims to stimulate the production and marketing of plant- or animal-based biofuels. The law exempts palm oil plantations and biodiesel.
- 2006: The Sustainable Urban Planning Act provides that after 2010 all public transport in metropolitan areas will run on clean fuels.
- 2009: A decree stipulates that from 2012 all new vehicles must be adapted to fuels containing up to 85% ethanol.
- 2014: The law provides for tax incentives to encourage private investment in renewable energy, establishes a special fund and creates the legal foundation for the development of projects related to renewable energies. Incentives include corporate tax deductions of up to 50% of the investment value for 5 years, exemption from VAT for renewable energy equipment and services; exemption from customs duties and accelerated depreciation.
- 2016: The Rational Use and Efficiency Programme aims to achieve a 9% improvement in energy efficiency in the transportation and industry sectors between 2017-2022.



Colombia is a country that is suffering the consequences of global warming, with water shortages and landslides in the mountains and rising sea levels and floods in coastal areas. Thanks to its topography, Colombia took the opportunity to develop hydroelectric power plants more than forty years ago. The country has also made considerable efforts in the field of energy transition in the transport sector, in particular by developing the use and production of biofuels. As Colombia continues to develop, energy demand will increase. Ongoing projects to further deploy hydropower could keep Colombia in a good position.

SWEDEN'S ENERGY TRANSITION

Sweden was ranked third by our energy transition index mainly because of its excellent energy mix. Sweden has been a pioneer in the energy transition.

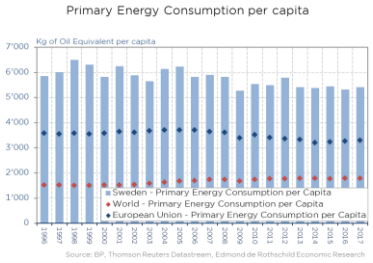
- In 2017, the country's fossil-fuel consumption level was only 32.6% versus 42.6% in 1996, the year of the first COP. Of the renewable energy consumption figure of 40.1% in 2017, 26.9% came from hydroelectric power.
- However, our index penalised Sweden for its high per-capita primary energy consumption (5,406 kg of oe, compared with 1,794 worldwide) and for its energy efficiency, which was slightly lower than the average of our sample. Sweden has nonetheless made considerable efforts in terms of energy efficiency, which has increased by 62.7% since 1996.

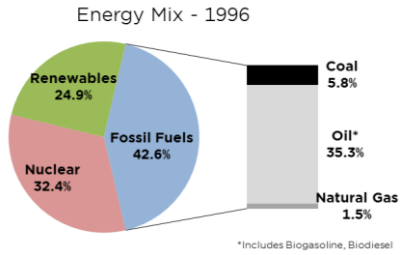
Climate and energy objectives:

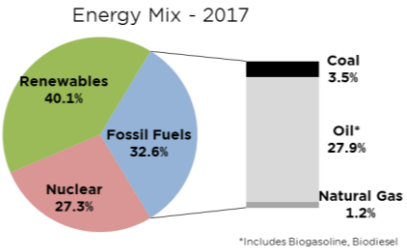
Sweden has committed to achieving carbon neutrality by 2045, to have a 50% share of renewable energy in its energy mix by 2020 and to increase its energy efficiency by 50% by 2030 (compared to 2005).

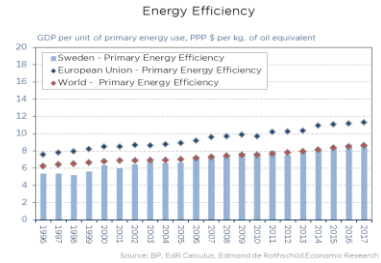
Regulations and public incentives implemented:

- In the early 1990s, public policies to improve the mix and energy efficiency combine incentives (through subsidies), the involvement of local authorities, and an influence on prices (via taxes).
- 1991: Establishment of a VAT on energy consumption, taxes on sulphide and nitrate emissions and the introduction of a carbon tax. These tax increases are accompanied by a decrease in income and corporate taxes. Some companies benefit from reduced carbon taxes according to their size, energy intensity and business sector. On average, the carbon tax came to €117 per tonne of CO_2 emitted for the tertiary and residential sectors and €67.4 per tonne for the industrial and agricultural sectors in 2015.
- 1991: Granting of subsidies to local authorities carrying out works on heating networks powered by biofuels and to households willing to connect to them. This measure also encourages the production of biofuels starting in the 2000s.
- 1996: Liberalisation of the energy market, with oversight in the hands of an independent agency.
- 1998: Creation of the Swedish Energy Agency, which has 14 regional offices in charge of providing advice and subsidies to municipalities, which in turn transfer them to companies and households while ensuring compliance with the rules. For households, subsidies relating to the renovation of housing amount to €11,000 per housing unit.
- 2006: Exemption from the annual vehicle tax for electric or hybrid vehicles and a tax reduction for vehicles running on natural gas. In 2007, subsidies of SEK 10,000 for the purchase of new vehicles with low carbon emissions are introduced.
- 2003: Sweden introduces Green Certificates (remodeled in 2012) to stimulate electricity generation from renewable sources. Renewable electricity producers receive a certificate for each MWh of energy produced, which can be sold on a dedicated market. Meanwhile, electricity suppliers are required to submit to a competent authority a certain number of green certificates in proportion to their sales (18% in 2010).
- 2016: Parliament signs an agreement to modernise Sweden's nuclear reactors. The aim is to limit rising energy costs and give renewable energies more time to develop. The agreement also promotes alternative sources of energy, emphasises the need to increase energy efficiency and gives an active role to industrialists and households.





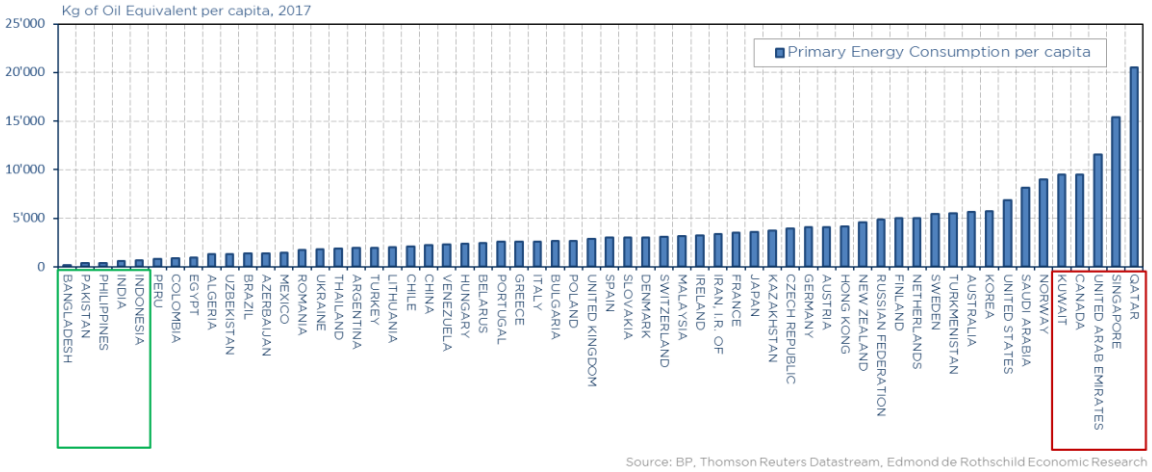




By implementing a wide range of government policies, combining subsidies and taxation and the involvement of local authorities, Sweden has rapidly developed its energy efficiency and increased the share of renewable energy in primary energy consumption. These policies were implemented effectively thanks to the collective will of political leaders to find solutions. It should be noted that Sweden's natural environment is favourable for natural resources, particularly for hydroelectric power and biomass.

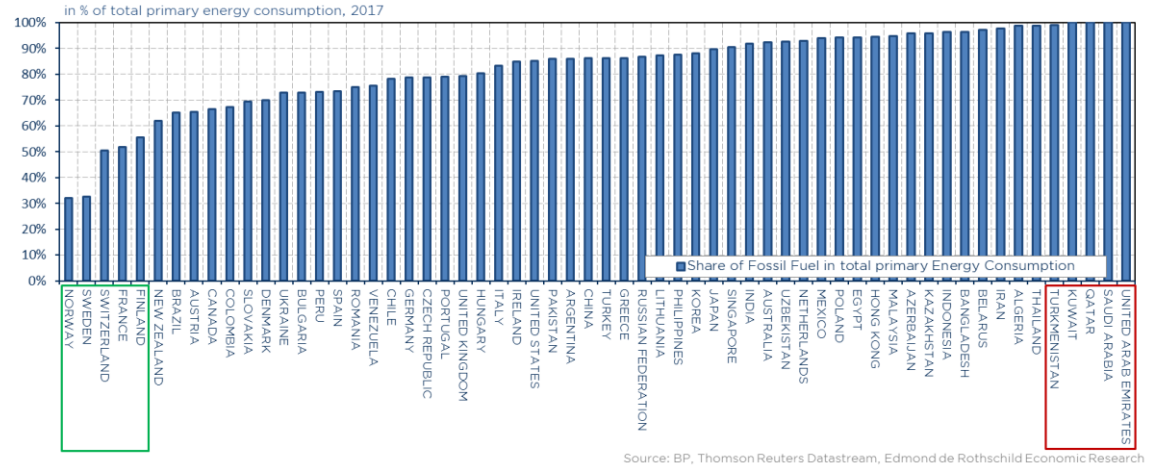
APPENDIX 1: COMPONENTS OF THE EDR ENERGY TRANSITION INDEX

Primary Energy Consumption per Capita



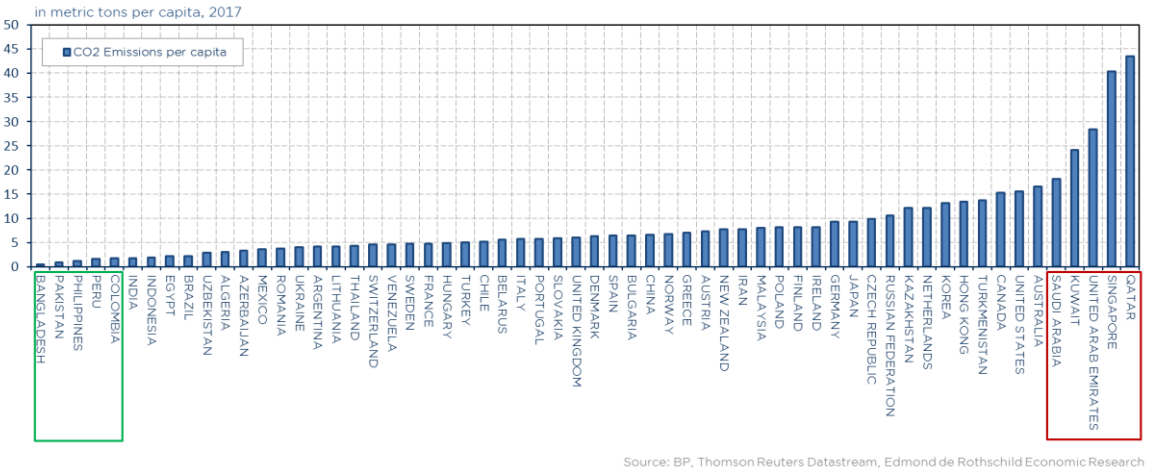
Source: BP, Thomson Reuters Datastream, Edmond de Rothschild Economic Research

Share of Fossil Fuel Consumption in total primary energy consumption

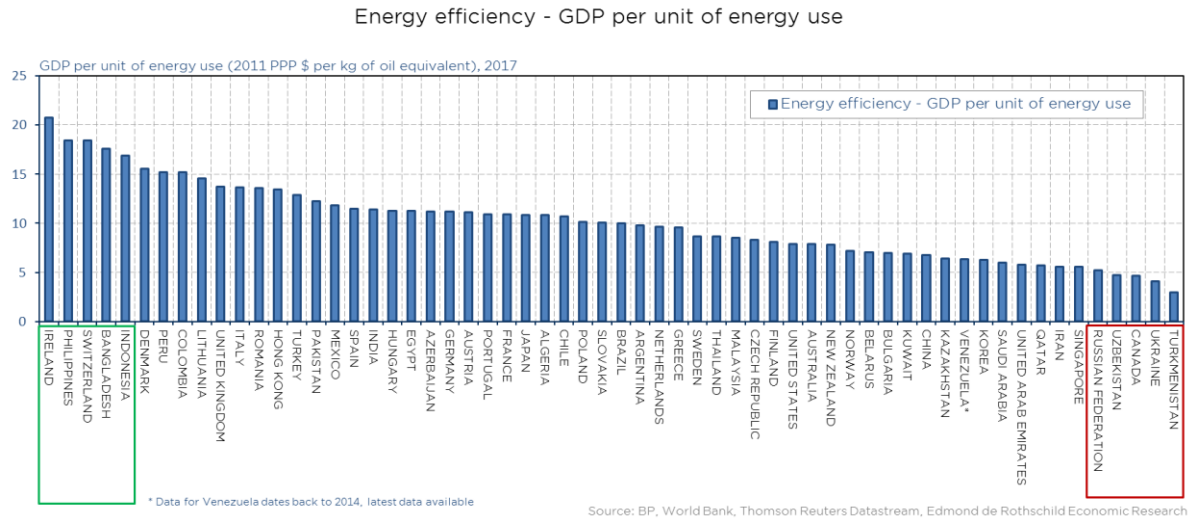


Source: BP, Thomson Reuters Datastream, Edmond de Rothschild Economic Research

Quantity of CO2 Emissions per capita



Source: BP, Thomson Reuters Datastream, Edmond de Rothschild Economic Research



APPENDIX 2 – RELATIONSHIP BETWEEN GDP, ENERGY CONSUMPTION AND EFFICIENCY

The relationship between GDP, energy consumption and energy efficiency can be established by the following equalities:

$$GDP = Energy\ cons. * \frac{GDP}{Energy\ cons.}$$

$$\frac{GDP}{Pop} = \frac{Energy\ cons.}{Pop} * \frac{GDP}{Energy\ cons.}$$

$$By\ developing\ this\ equation\ we\ obtain: \%\frac{GDP}{Pop} = \%\frac{Energy\ cons.}{Pop} + \%\frac{GDP}{Energy\ cons.}$$

Or,
GDP growth per capita = Growth in per-capita energy consumption + change in energy efficiency

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