Creating a Better Understanding of the Energy Transition

The most important key figures of a hard to predict transformation process

Mart Vos

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Why is this a relevant topic for me?

When I am asked about my job, I often describe myself as a consultant on a managerial level, with a focus on the energy transition. In this short description, I often trigger people by the term ‘energy transition’. From energy transition, this conversation can literally go into a million directions. From Paris Agreement to a Chinese building boom, from smart grids to artificial intelligence and from Tesla to Trump (I have this conversation regularly, and Trump comes up, surprisingly or not, quite often).

Normally, when I am not talking to oil and/or coal stakeholders, people are quite happy about this ‘energy transition’ and have normally read a few news articles about big solar parks being build, breakthroughs in geothermal energy, but also about how the U.S. lost its energy transition spirit and that the world is still doomed. When going a little bit deeper into the topic though, I often realize that, apart from, or maybe due to the wide variety of news articles, people don’t really know much about this transition, or whether this transition is even real. However, everyone agrees: it’s an important topic.

In a time of lobbying culture and fake news, it can be understood how people are uncertain what to believe. Especially when the topic is energy, undoubtedly the biggest market in the world, there is a huge conflict of interest issue. With many parties giving contrary information, it had been increasingly hard to find accurate information to create an objective opinion on, and that is a problem.

By having gone through the most reliable sources available, e.g. World Bank, CIA and autonomous intergovernmental organizations, I have collected data to show you the actual key statistics of this energy transition. In addition, I critically and comparatively went through 4 energy transition future scenarios, in order to make you, the reader, see different perspectives, trends and possible chances, so you can eventually make up your own mind.
> Key Energy Figures – Production and Consumption

*Who are the main players and what are the popular products?*
How to measure energy?

A common way to measure energy use for greater regions, like a country or the world, is by taking the sum of production and imports and subtracting exports and storage changes. This is referred to as the TPES or the Total Primary Energy Supply. The flowchart below gives a visual explanation of TPES. Because of energy losses, the global annual TPES is always higher than the total final consumption. When later in this report total consumption is going to be discussed, this will be the total consumption of TPES, not the total final consumption.

In order to calculate the global TPES, the sum of all countries individual TPES is needed. Because collecting this data is a time consuming process that takes more than a year, the most recent data when writing this report (April 2018) is over the year 2016 and shows that the total global TPES was 13783 Mtoe.

Total TPES worldwide: 13783 Mtoe (2016)
World total TPES supply by generation type

In 2016, the total worldwide TPES was 13783 million toe. To give you a better understanding of how much this is, the below calculation can be used. In the bottom left corner, the energy mix from 1971 to 2015 in Mtoe can be found\(^2\). In the bottom right corner the most recent worldwide energy mix, 2016\(^{13}\).

Calculation energy units:
1 Toe = amount of energy released by burning one tonne (100.000kg) of crude oil.
1 Mtoe = 1.000.000 burning tonne of crude oil (100bn kg of oil)
13.783 Mtoe = 13.783.000.000 burning tonne of crude oil
13.783 Mtoe = 160.296 TWh (Terawatt-hour)

World TPES from 1971 to 2015 by fuel (Mtoe)\(^2\)

Energy mix 2016\(^{13}\)

1. World includes international aviation and international marine bunkers.
2. In these graphs, peat and oil shale are aggregated with coal.
3. Includes geothermal, solar, wind, tide/wave/ocean, heat and other.
### Biggest producers of top 3 most used fuels (2016)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>% of world total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oil (32.7%)</strong></td>
<td></td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>13.5%</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>12.6%</td>
</tr>
<tr>
<td>United States</td>
<td>12.4%</td>
</tr>
<tr>
<td>Canada</td>
<td>5.1%</td>
</tr>
<tr>
<td>Islamic Rep. of Iran</td>
<td>4.6%</td>
</tr>
<tr>
<td>People's Rep. of China</td>
<td>4.6%</td>
</tr>
<tr>
<td>Iraq</td>
<td>4.4%</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>4.2%</td>
</tr>
<tr>
<td>Kuwait</td>
<td>3.7%</td>
</tr>
<tr>
<td>Brazil</td>
<td>3.1%</td>
</tr>
<tr>
<td>Rest of the world</td>
<td>31.8%</td>
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<tr>
<td><strong>World</strong></td>
<td>100.0%</td>
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<table>
<thead>
<tr>
<th><strong>Coal (28.0%)</strong></th>
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<tbody>
<tr>
<td>People's Rep. of China</td>
<td>44.6%</td>
</tr>
<tr>
<td>India</td>
<td>9.7%</td>
</tr>
<tr>
<td>United States</td>
<td>9.2%</td>
</tr>
<tr>
<td>Australia</td>
<td>6.9%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>6.3%</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>5.0%</td>
</tr>
<tr>
<td>South Africa</td>
<td>3.5%</td>
</tr>
<tr>
<td>Germany</td>
<td>2.4%</td>
</tr>
<tr>
<td>Poland</td>
<td>1.8%</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>1.3%</td>
</tr>
<tr>
<td>Rest of the world</td>
<td>9.3%</td>
</tr>
<tr>
<td><strong>World</strong></td>
<td>100.0%</td>
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</tbody>
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<table>
<thead>
<tr>
<th><strong>Natural Gas (22.4%)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>20.7%</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>17.8%</td>
</tr>
<tr>
<td>Islamic Rep. of Iran</td>
<td>5.3%</td>
</tr>
<tr>
<td>Canada</td>
<td>4.8%</td>
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<tr>
<td>Qatar</td>
<td>4.6%</td>
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<tr>
<td>People's Rep. of China</td>
<td>3.8%</td>
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<tr>
<td>Norway</td>
<td>3.3%</td>
</tr>
<tr>
<td>Algeria</td>
<td>2.5%</td>
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<tr>
<td>Saudi Arabia</td>
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<tr>
<td>Rest of the world</td>
<td>32.3%</td>
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<td><strong>World</strong></td>
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- **Saudi-Arabia** produces 10.5mln barrels of oil each day and exports 7.5mln barrels each day. Saudi-Arabia currently has a proven oil reserve of 266bn barrels, 22.3% of the world's total oil reserve, only Venezuela has more (302bn).
- In 2016, **China** and **India** together produced 54.3% of all the coal in the world, however because of their national energy demand, they only exported less than 1% of the total exported coal.
- In 2016 global coal exports dipped 7.1%. In this year **Australia** exported the most coal, 38.3% of the total export.
- **Norway** exports 95% of their gas, because they can power up their country for 98% using renewables (96% hydraulic and 2% wind energy). Norway is the 3rd exporter of gas in the world behind **Russia** and **Qatar** and 10th of oil.
TPES consumption by region

Changes in worldwide energy consumption:
- Asia and especially China are the main reasons for the global rise in energy consumption.
- 63% of Asia’s energy consumption comes from China.
- China’s share in the total energy consumption went up from 10,5% (1990) to 27,7% (2016). Europe’s share in that period went down from 20,8% to 13,5%.
- The total energy consumption went up from 1990 to 2016 by 61,1%.

Explanations for rise in Asian energy demand:
- With the rise of China’s GDP, a rise in national average energy consumption per capita occurred, going from 2.325KWh in 2007 to 4.293KWh in 2016.
- India’s GDP and energy consumption have also been rising: GDP in 2007 was $1.018, while GDP in 2016 was $1.709. India’s energy consumption per capita went from 543KWh (2007) to 801KWh (2015).
- Compared to Asia, the E.U. and the U.S. still have a substantially higher average in electricity consumption and GDP per capita; the E.U. 5.400KWh and $32.242 and the U.S. 12.071KWh and $57.638.
- Strongly focused on sufficient energy capacity, China and India are leading a rapid development in Solar energy.

Energy Consumption 2016

- Asia Pacific 42%
- North America 21%
- Europe and Eurasia 22%
- South and Central America 5%
- Middle East 7%
- Africa 3%

World TPES from 1990 to 2015 by region (Mtoe)

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Forecasted changes in global energy consumption

**Forecast in future energy demand**
- Expected annual rise in energy consumption is estimated to be slower than the past 25 years: **2.3% per year, 28% by 2040**.
- **Europe**, **US** and **Japan** are expected to continue focusing on energy efficiency.
- Because of the extreme rise of China’s GDP and changes in China’s regulations, China started pushing off cheap labour to cheaper Asian countries, e.g. India, Vietnam and Indonesia. An example of this process is the recycling of plastic that China is no longer doing.
- In **Southeast Asia** demand in energy is growing at twice the pace of China.
- The economic growth, population growth, high welfare and harsh living conditions including the scarcity of water, are the main reason for the change in energy demand in the **Middle East**.
- **Africa** accounts for 13% of the world’s population, but only 4% of its energy demand. This number is likely to rise because of the increasing population, urbanization and economic productivity.
- Africa is likely to utilize their energy resources better in the future. Currently they possess, compared to global reserve, reserves of coal 3.6%, reserves of natural gas 7.5% and reserves of oil 7.6%.
- Looking at high energy output from solar panels, solar could play an important role in Africa’s energy demand. An area of roughly **36,416 km²** in the Sahara (less than 0.4% of the Sahara) could supply the entire continent of Africa with energy.
> Predicting the Future Energy Mix

How to predict the biggest and most important market on this planet?
Difficulties of predicting the future energy mix

- Many institutions and companies make predictions, e.g.: BP, Shell, the Department of Energy and Climate Change (DECC), Bloomberg New Energy Finance (BNEF), Energy Information Administration (EIA), Organization of the Petroleum Exporting Countries (OPEC) and the International Energy Agency (IEA).
- There are many conflicts of interest in making predictions; traditional oil and gas companies have a lot of money and lobby/political power. Investors in renewable energy try to influence the crowd, too. Overall, there is much false information.
- Using the leverage cost of energy, it can be seen that renewables are the cheapest energy generation type at the moment. However, the geographic location, regulations and storage costs of renewables make this leverage cost of energy not an all-encompassing statistic.
- It is hard to predict future technology developments. While renewable generation solutions are plummeting in price, traditional generation types are also getting cheaper.
- Due to potential discoveries of new oil fields and the power of the OPEC countries, the oil price will likely remain unstable.
- Next to leverage cost of energy, payback periods of already done investments (e.g. a 2005 built coal plant) play an important role in predicting the energy mix.
- In the next pages we will look at the predictions for 25 years, from 4 different perspectives: EIA (USA based), OPEC (oil stakeholders) and 2 perspectives from the IEA (Europe based).
EIA, International Energy Outlook, 2017

Assumptions in International Energy Outlook:\(^{20}\):
- Population (+24\%), energy consumption (+28\%) and GDP (+63\%) are all expected to grow from 2015 to 2040.
- Technological developments in order to get shale gas and tight gas are the cause of the rise in natural gas.
- Renewables are the fastest-growing sources of generation over the period of 2015–2040, rising by an average of 2.8\% per year.
- India’s coal consumption will continue to grow, while China will steadily decline its coal consumption.
- Almost 80\% of the total increase in petroleum and other liquids consumption comes from China and India, as they experience a rapid industrial growth, causing an increased demand for transportation.
- The oil price will go up to $109 per barrel in 2040.

Criticisms:
- Big variance between EIA forecasts: projected change in energy consumption in the 2016 report was +48\% (2012 – 2040), compared to +28\% (2015 – 2040) in the 2017 report. This while the energy consumption from 2012 – 2015 only went up by 2.1\%\(^{21}\).
- The IEA has a high prediction error over the last 10 years (see figure on bottom right corner)\(^{34}\).
OPEC, World Oil Outlook 2040, 2017

Assumptions in World Oil Outlook 2040\textsuperscript{22}:
- Population (+26%), energy consumption (+35%) and GDP (+126%) are all expected to grow in the period from 2016 to 2040.
- GDP rise is anticipated to come from China and India, which combined are forecasted to represent 39% of the global GDP in 2040. In 2017 this was approximately 18.1\%.\textsuperscript{6}
- China and India’s individual GDP is estimated to grow from 15% to 23% (China) and 3% to 16% (India), in the period 2016 – 2040.
- The technological advances will not only benefit the renewables, but help to raise energy efficiency as a whole. For example, with batteries becoming cheaper, conventional ICE powered vehicles can take advantage by means of hybrid technologies.

Criticisms:
- OPEC does not forecast the future oil price. It’s hard to predict a demand without having a prediction for the price.
- OPEC is often not considered an objective party in predicting energy demands, because it consists of a group of oil exporting countries. However, in contrast with IEA, OPEC forecasts that for 2018 oil inventories will fall due to a lack of oil discoveries\textsuperscript{36}.\textsuperscript{36}
Future energy mix - Scenario 3


Assumptions in World Energy Outlook\(^\text{13}\):  
- Population (+23\%), energy consumption (+27\%) and GDP (+125\%) are all expected to grow during the period 2016 – 2040.  
- While road transportation sector will remain the biggest contributor to oil demand, it will no longer account for the biggest change in oil demand by sector. The petrochemical sector (e.g. plastic) will lead this growth until 2025. After 2025 aviation and shipping will take over the number 1 position.  
- The number of electronic cars would go from 3,2 million in 2016 to approximately 280 million in 2040\(^\text{26}\).  
- The US, followed by the Middle East, will continue having the biggest gas demands in 2040, this situation was the same in 2016.  
- Over the next three years, the U.S. will cover 80 percent of the world’s demand growth in oil.

Criticisms:  
- The IEA has always under-forecasted the role of renewables (see figure, bottom-right)\(^\text{21}\).  
- There are close similarities of IEA’s projections compared to projections of (biased) European fossil fuel industry (e.g. Shell and BP).
IEA, World Energy Outlook (Sustainable Development Scenario / SDS), 2018

Assumptions in World Energy Outlook\textsuperscript{13}:
- This scenario starts from a set of desired outcomes and considers what would be necessary to deliver them. Central to these outcomes is the achievement of an early peak in CO2 emissions and a subsequent rapid decline, consistent with the Paris Agreement.
- Population (+23\%) and energy consumption (+2.4\%) are both expected to grow (2016 – 2040). The growth of the GDP is unknown in this scenario.
- There will be 875 million plug-in vehicles and 3250 GW of installed solar PV capacity globally in 2040. At the end of 2017 these number were 3.2 million\textsuperscript{26} and approximately 400GW\textsuperscript{33}.
- In 2040 we will be twice as efficient with energy than we were in 2017 and global emission will drop by 46\%.

Criticisms:
- The scenario starts from a desired outcome, not from current policies or trends.
- In addition to countries’ self formulated pledges in the Paris Agreement, the Climate Change Performance Index measures how well countries are doing regarding their current performance. Right now only a few countries are on their way to prevent the dangerous impacts of climate change (see bottom right corner)\textsuperscript{35}.
## Comparing 4 scenarios 2016 – 2040

<table>
<thead>
<tr>
<th></th>
<th>EIA</th>
<th>OPEC</th>
<th>IEA (NPS)</th>
<th>IEA (SDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in population</td>
<td>+24%</td>
<td>+26%</td>
<td>+23%</td>
<td>+23%</td>
</tr>
<tr>
<td>Change in energy demand</td>
<td>+28%</td>
<td>+35%</td>
<td>+27%</td>
<td>+2%</td>
</tr>
<tr>
<td>Change in GDP</td>
<td>+63%</td>
<td>+126%</td>
<td>+125%</td>
<td>N/A</td>
</tr>
<tr>
<td>Change in Oil consumption</td>
<td>+17%</td>
<td>+16%</td>
<td>+10%</td>
<td>-25%</td>
</tr>
<tr>
<td>Change in Gas consumption</td>
<td>+43%</td>
<td>+57%</td>
<td>+45%</td>
<td>+15%</td>
</tr>
<tr>
<td>Change in Coal consumption</td>
<td>+2%</td>
<td>+11%</td>
<td>+5%</td>
<td>-53%</td>
</tr>
<tr>
<td>Change in Renewables cons.</td>
<td>+74%</td>
<td>+75%</td>
<td>+86%</td>
<td>+115%</td>
</tr>
<tr>
<td>Change in Nuclear energy cons.</td>
<td>+43%</td>
<td>+76%</td>
<td>+47%</td>
<td>+105%</td>
</tr>
<tr>
<td>Most important stakeholder(s)/members of the organization</td>
<td>A principal agency of the U.S. Federal Statistical System</td>
<td>Saudi Arabia, Nigeria, Venezuela, Iraq, Iran, UAE</td>
<td>Most of Europe, U.S., Mexico, Japan, South Korea, Oceania</td>
<td>Most of Europe, U.S., Mexico, Japan, South Korea, Oceania</td>
</tr>
<tr>
<td>Change in Co2 Emissions</td>
<td>+16%</td>
<td>+22%</td>
<td>+5%</td>
<td>-46%</td>
</tr>
</tbody>
</table>
Key Takeaways

• The global energy consumption is still on the rise, but due to the increased focus on climate change and energy efficiency, the growth will decrease with an ultimate growth ranging between 25% and 35% by 2040.
• GDP and population are very important variables in order to understand and predict the energy market.
• The extreme rise in China’s energy demand during the last 10 years led to a country that has an increased focus on efficient and renewable energy solutions. These developments make China the most important player in the energy market and trendsetter in the energy transition.
• China’s GDP will likely continue to rise, causing China to refuse more cheap labour. In addition, new environmental policies in order to reduce smog will lead to more energy efficiency. These two factors in combination with a higher GDP will likely result in a stabilized, slowly growing, Chinese energy demand.
• Countries in South-East Asia and especially India are already taking over the cheap labour that China is refusing, leading to a new exponential rise in the energy demand for countries in this region.
• Capacity of energy will be a huge challenge in South-East Asia. Traditionally, this region used coal plants and reserves to get production up to demand. However, to what extent South-East Asia will use coal in the future will depend on the individual LCOE of energy sources, politics and storage capacity of renewables. However, it seems to be a certainty that this will be one of the most important developments regarding the changing energy mix.
• Because of the different interests on organizational, national and global levels, forecasting energy is an extremely complicated procedure, with a range of different outcomes
• In addition to conflict of interest, the constantly changing policies as well as technological developments in all sectors are a main reasons why the future energy mix is so hard to predict
• Although renewables are likely to be the fastest growing source of energy, they will likely not be bigger than one of the traditional energy sources, being oil, gas and coal, before 2040.
• Due to developments in the gas industry, gas will overtake coal as second biggest energy source before 2035.
• Forecasts of the most legitimate organizations have been more wrong than ever recently. In particular, the role of renewables is constantly under forecasted
• The sustainable scenario is only possible if we reach our peak in fossil fuels within the next 5 years. This is possible if countries start focusing more on their pledges in the Paris agreement.
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Calc1.
Africa accounts for 4% of the total energy demand (160296 TWh per year) = 0.04 x 160296 TWh per year = 6411.84 TWh
The conditions of the Sahara (dryness and hours of sun) are very comparable as the El Romero Solar PV Plant in the Atacama desert, Chile37. This plant is 2.8km2 and generates 493 GWh per year = 0.493 TWh 6411.84 / 0.493 = 13.006 Romero Solar Plants
13,006 x 2.8 = 36.416 km2 Sahara is 9,200,000 km2 36.416 is 0.396% (given that this power plant would use the same quality solar panel and use the same amount of distance between them and energy losses due to transportation excluded).
UMS Group is an international management consulting firm specialized in solutions for the Global Energy and Utility Industries. With this article we would like to give you the basic information needed to understand the energy transition better.

At UMS Group, we believe that understanding energy flows, trends, markets and policies is key in understanding the world as a whole. With 5 out of the 10 biggest companies worldwide being oil producers and suppliers (and 10 out of 10 rely on energy to do their business), it goes without saying that apart from the environmental issue we are facing, a developing energy market can completely change the world’s economy.

The fact that forecasts have never been as inaccurate as recently, shows that there are a lot of unknown and/or under or overestimated variables. And where this used to be an issue on a political scale or for very energy intensive companies, this topic is shifting more and more towards smaller organizations and even individuals.

Do you want to know whether the energy transition is relevant for you as an individual or your business, are you interested in the recent energy trends in your region, or do you just want to educate your staff around what changes will be relevant for them? There is a fair chance that with almost 30 years of experience in the energy market, we will be able to help you and your business!