Zombie Electricity Utilities: A world with falling demand for on-grid electricity consumption [1]

Manuel Pinho
School of International and Public Affairs
Columbia University
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"Toto, I've a feeling we're not in Kansas anymore."
The wizard of Oz

1. Introduction

Power systems used to be a dull subject, however that is not the case anymore. Examples of how they are being turned upside down are not in short supply.

Value destruction	Negative wholesale prices	Curtailment	Super expensive nuclear power	Record low prices solar	100% renewables	Renewables in Australia
12 of the largest EU utilities reduced the value of their assets by $ 30 billion in 2015 bringing total write downs in the sector to $ 104 billion since 2010.	During 126 hours in 2015 Germany´s power station operators had to pay customers willing to take their power – 9 $/ MWh on average.	In the Chinese provinces of Jilin, Gansu and Xinjiang wind curtailment rates reached 32, 39 and 32 % respectively	The UK Gov. agreed to guarantee a price of $ 115/ MWh over 35 years for electricity produced in the Hinkley Point C nuclear power plant	A Spanish company wins a bid in Chile to sell power from a 120 MW solar power plant at 29.1 $/ MWh	Portugal entirely powered by renewables for 4 days	Wind and solar capacity reached 43% in Southern Australia
EU	Germany	China	UK	Chile	Portugal	Australia

The table above illustrates **negative** developments (value destruction in the EU), lack of flexibility of power systems (negative wholesale prices in Germany and high curtailment rates in China), **debatable** policy choices (nuclear in the UK) and **positive** surprises (record low solar prices, 100% renewables during 4 days in Portugal and rapid growth of wind and solar in Australia.

The traditional utilities model is under challenge. A zombie, or living dead, company is a company unable to survive on its own and needs artificial

[1] Lecture delivered at Queensland Treasury, ESA Qd and Georgetown Law School in March 2017

support. It is often argued that a world with falling demand for on-grid electricity consumption is producing zombie utilities. Is that the case?

The table below shows **positive** and **negative** performances at the corporate level based on the stock market performance of a small sample of large utilities in the US and in the EU. Overall, utilities underperformed the stock market; in the EU, a group of large utilities is under strong pressure; however, both in the US and the EU there are utilities that have adapted timely their business model and recorded a strong performance.

		Market cap	% 5 years % change in stock price
US	Duke Energy	55 billion $	27
	Con Edison	23 billion $	33
	Next Era Energy	60 billion $	165
	America Electric	31 billion $	68
	Dow Jones		57
EU			
Germany	E.On	14 billion E	-63
	RWE	8.4 billion E	-63
France	EDF	21.8 billion E	-58
	Ngie	40 billion E	-40
Italy		43 billion E	44
Spain	Iberdrola	41.4 billion E	42
Denmark	Dong Energy	17.1 billion E	--
Portugal	EDP	10.4 billion E	27
	Euro Stoxx 50		31

In China, the largest and fastest growing power market in the world, the largest utilities are state owned and there is no reliable data on their financial condition. However, the deceleration of electricity demand, the strong decline in the **capacity fact**or of thermal generators and very high **curtailmen**t of renewable energies indicate that the power system in China is also facing challenges.

Power systems are changing very fast and **there is no blueprint for success**, neither at the policymaking or corporate level.

2. My personal experience

I will start by describing how I got involved with energy policy given that it is related, although indirectly, with the subject of this lecture.

I have been involved with energy policy for 12 years, firstly as a policy maker and subsequently as an academic.

As a policy maker, I was responsible for the energy portfolio when I served as Minister of Economy and Innovation of my country in 2005- 2009. My policy making experience had 2 dimensions, at the European and domestic levels.

At the domestic level, I was involved in the full ownership unbundling of regulated assets, the creation of a regional electricity market involving Portugal and Spain and, above all, in developing an ambitious renewable energies program, the main objectives of which were the following:

- Achieving energy security (imports represented 30% of energy consumption)
- Creating a generation portfolio of 30% thermal, 30% hydro, 30% wind and 10% other sources
- Introducing an auction system to grant licenses to build new hydro projects and install wind capacity

That program has delivered important results. Portugal is one of the countries in the world with the highest contribution of variable renewables to power generation. Renewables sources account for 50% of power generation. To put this in perspective, this is the target that California set for 2030.

The table below shows how little Denmark and Portugal stand out. It is interesting to note that the key for Denmark´s success is wind power and in the case of Portugal it is a combination of wind and hydropower with pump storage. Both countries operate deregulated power systems and are integrated in regional markets with good interconnection capacity.

Rank	Country	% of electricity from renewable sources	Population (million)	% wind	% solar PV
1	Norway	99	5	1.5	--
2	Iceland	85	.3	--	--
3	Austria	70	8.5	5.8	1.1
4	Sweden	63	9.5	7.3	--
5	Canada	59	35.1	3.4	--
6	Portugal	50	10.5	22.9	1.1
7	Denmark	49	5.6	40.6	1.8

Source: Renewables 2016, Global Status Report

Portugal met during 4 days 100% of domestic consumption from renewable sources, which the Guardian ranked as the 3rd most important science achievement of 2016. Although the 1st reverse auction for wind generation is usually attributed to Brazil in 2008 actually it is not the case, it took place in Portugal in 2006.

Both countries achieved a large penetration of renewables with a small contribution of distributed generation. Given how technology has progressed, their example is difficult to replicate. **This confirms that there is no blueprint for success.**

3. The age of accelerations: the role of technology, markets and policies

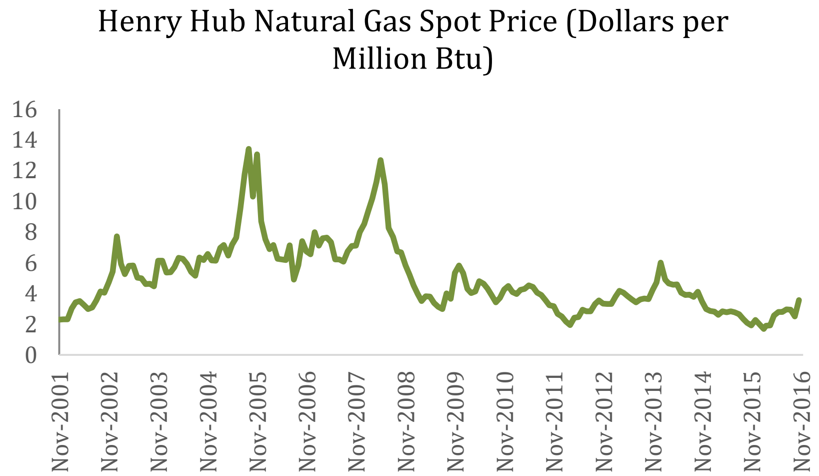
We live in an age of accelerations, i.e. extremely rapid transformations in many areas, among them the energy system. The energy system is changing in many aspects, all along from the contribution of energy sources, prices, trade flows and the configuration of power systems. Power systems are changing and the traditional utilities model is under pressure.

The main driving forces of the global acceleration are a combination of markets and technological change. Policies are important and will remain so, however they are less important than in the past and they are often self-defeating.

This can be illustrated with the example of the objectives of the new US administration: fostering coal and mitigating support to renewable energies.

a. US coal industry ("Putting coal country back to work")

The near death of the US coal industry is predominately due to ultra- cheap natural gas, not to climate policies. Repealing the Clean Power Plan may delay the adoption of measures to control pollution and emissions from coal, however it will not change the coal/ natural gas relative price on an energy basis that explains why the share of natural gas in power production in the US rose by 17 p.p. since 2008.



b. Renewable energies ("Wind power kills all the birds")

The main federal subsidy to wind power is the PTC that was extended in December 2015 with bi- partisan support with the provision that it would be phased out in 8 years. Indeed, the bill provides for continuation of the prior credit to 2020 and for a gradual step down in 2021- 25.

Let us assume that the CAPEX of a wind turbine is $ 1.500 MW, the NPV of the PTC (paid for the 1st 10 years) is 13 $/ MWH, a turbine has a 32% load factor and the project a 6% WACC. The break-even price of a PPA would be 58 $/ MWh, i.e. the LCOE (71 $/ MWH) minus the PTC subsidy (13 $/ MWh).

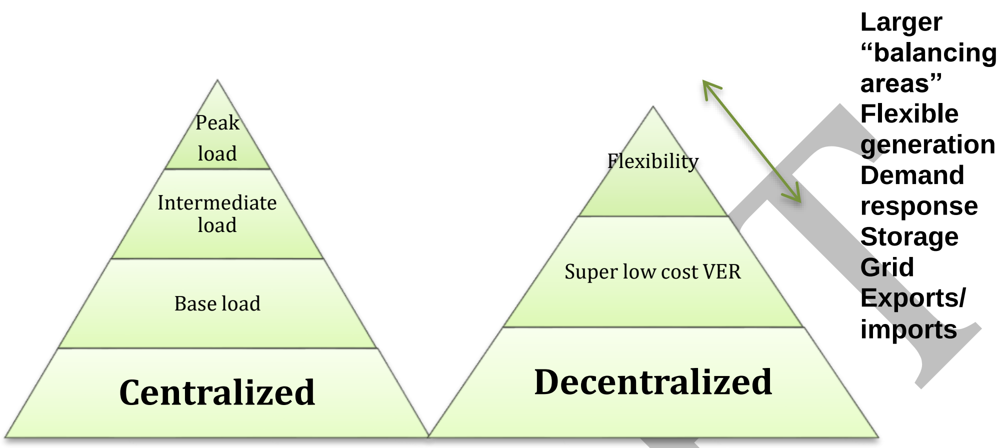
		Only CAPEX	CAPEX+ LOAD FACTOR
CAPEX	1500 $/MW	1070 $/ MW	1250 $/ MWh
WACC	6%		
FIXED O&M	70 $/ MW		
LOAD FACTOR	32%		36%
LCOE	71 $/ MWh	58 $/ MWH	58 $/ MWH
PTC subsidy	13 $/ MWh	0	
PPA= LCOE- subsidy	58 $/ MWh		

Now, imagine that the PTC is fully scrapped. Then, the wind developer needs CAPEX to fall from $ 1.500 MW to $ 1.070 MW (around 30%) to achieve a LCOE of 58$/ MWh. As we will see later this is in line with projections for the decline in the cost of wind power.

4. The “new power system”

The traditional electricity system was centralized and based on cheap base load power (coal, hydro, nuclear) complemented with more expensive capacity to meet peak load (usually gas peak turbines with low fixed costs and high variable costs).

In contrast, the emerging electricity system is seemingly decentralized and based on “super low cost renewables” complemented with flexible capacity from different sources (demand response, storage, natural gas, imports, etc.).



The transformation of electricity systems is the result of the combined effect of

- Structural change in demand patterns (slowdown in electricity consumption)
- Super low cost VRE
- Distributed energy
- Policies (climate awareness).

It creates challenges at several levels,

- How power grids are designed,
- Regulation and
- The electricity business.

5. Structural change in demand patterns

In middle and high-income countries electricity consumption is growing slower than expected, or is flat. For example, in Germany, electricity consumption reached a peak in 2007, in China the growth rate of electricity consumption declined abruptly. In the US it declined in 5 of the last 10 years.

There is no single reason to explain this deceleration.

- Overall, GDP growth did not fully recover from the 2008 world financial crisis in many countries.

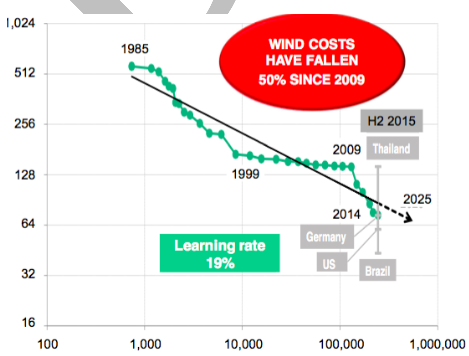
- In Europe, retail prices have increased as a result of taxes levied on electricity production and the pass through of subsidies to renewable energies.
- China entered a “new normal” of slower GDP growth entailing a smaller contribution of energy intensive industries and focus on the development of the services sector.
- Demand management programs are being developed in many countries with increasing success as a result of high retail prices, smart grids and metering and the increasing use of big data and analytics.
- Decentralized generation (defined as power generation at the point of consumption and demand response) is developing fast as a result of rapidly declining costs and a favorable regulatory environment. In an increasing number of countries the cost of solar has already reached “socket parity”. [2]

6. Super low cost variable renewable energies

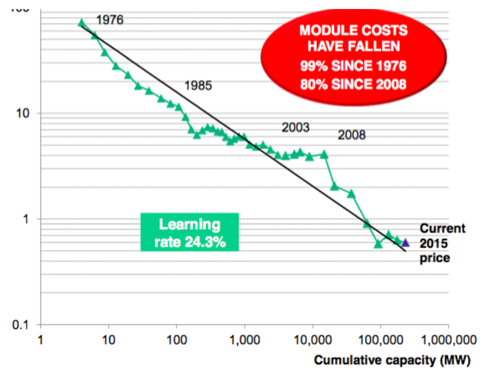
There are 2 types of renewable energies. Some resources (wind and solar) cannot be called upon when desired; they are variable (VRE). Other resources (hydro, biomass) can be controlled to a larger extent and called to meet fluctuations in demand. Renewable energies accounted for 23% of world electricity supply in 2014. VRE, for their part, account only for only 4% of electricity generation.

Given their high cost, VRE have been supported by different types of mechanisms. In Europe, FIT are the norm while in the US there is a very large number of support mechanisms, the most important of which are RES, the PTC for wind and the ITC for solar. This means that in Europe off market payments are incorporated in retail prices while in the US they are financed by the budget.

However, government incentives will be sooner or later phased out given that the cost of VER declined precipitously. Figures from BNEF show that wind costs have fallen by 50% since 2008 and module costs by 80% since 2008.



Note: Pricing data has been inflation corrected to 2014. We assume the debt ratio of 70%, cost of debt (bps to LIBOR) of 175, cost of equity of 8% Source: Bloomberg New Energy Finance



Note: Prices are in real (2015) USD. 'Current price' is $0.61/W Source: Bloomberg New Energy Finance, Maycock

[2] http://www.treehugger.com/renewable-energy/42-of-50-biggest-us-cities-rooftop-solar-now-cheaper-grid.html

This declining trend will continue and the cost of solar seems to follow Moore´s law [3] (solar modules are built from microprocessors), VER will be increasingly driven by the market and will depend less on government support, the major uncertainty is how fast costs will continue to decline.

IRENA [4] estimates conservatively that in 2017- 2025 the weighted average LCOE of solar PV will decline by 59%, CSP by 37- 43%, wind onshore by 26% and wind offshore by 35% and admits that faster reductions are possible.

	LCOE $/ MWh		
	2015	2025	**Δ%**
Solar PV	130	60	-59
Onshore wind	70	50	-26
Offshore wind	180	120	-35

Source IRENA

At the same time, Lazard projects a rapid decline in the cost of storage. [5]

7. VRE change the load profile

The rapid growth of low cost VER changes the load profile and the economics of the electricity business in different ways. I will use 2 well-known figures to illustrate how solar PV and wind power change the load profile.

a. Solar PV

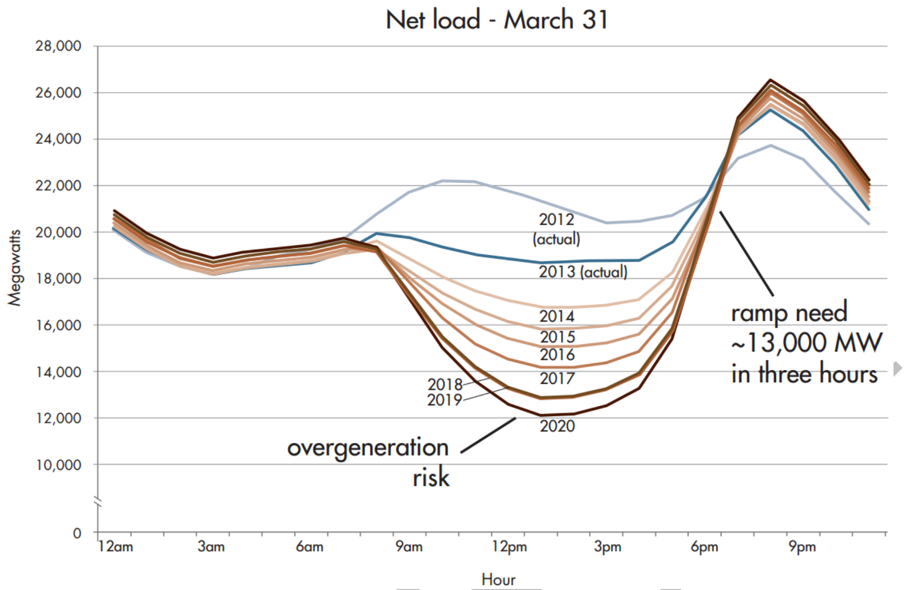
[3] Smaller, cheaper, faster, does Moore´s law apply to solar cells, Scientific America, 2016 https://blogs.scientificamerican.com/guest-blog/smaller-cheaper-faster-does-moores-law-apply-to-solar-cells/

[4] The power to change: wind and solar cost reductions, IRENA, 2016 http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf

[5] Levelized cost of storage 2.0 https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf

In 2013 the California ISO produced the well known “duck curve” [6] that shows how net load (load- VER generation) is projected to change on March 31 of each year between 2012 and 2020 as a result of higher penetration of solar PV.

This was the first time that a major ISO recognized that solar was not anymore a niche technology. [7]



The figure above shows that in 2012 (small VER penetration) the net load curve exhibited 2 peaks, around 9 AM- 12:00 AM and 7:00 PM- 9:00 PM. Generation was ramped up by around 4Gw in the morning peak and by 2.5 GW in the late afternoon peak with flexible generators with low fixed costs and high variable costs. Therefore, electricity prices were higher, producing a so-called “peak premium”.

In 2013, the ramp up of solar “shaved” thermal peak generation in the 9 AM-12:00 AM peak.

Fast forward to 2019. Assuming that solar PV will continue to grow, the California ISO study shows 3 effects:

Thermal generation will have to be ramped down rapidly by 7 GW between 9:00 AM and 12:00 AM;

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[6]Fast facts, California ISO https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

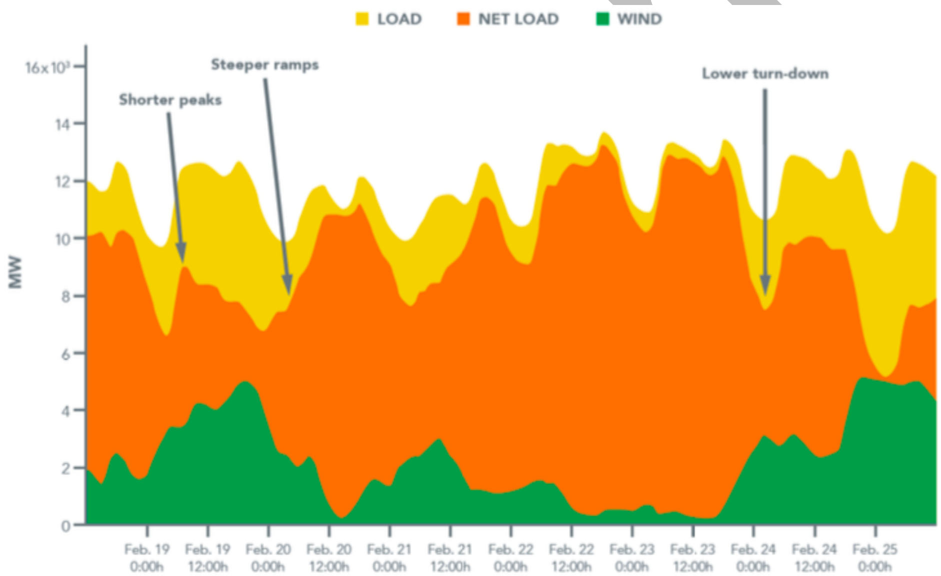
[7] Denholm, P. et al, Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart, NREL, 2015 http://www.nrel.gov/docs/fy16osti/65023.pdf

Some over- generation may take place by 12:00 AM, when some VER generation may be curtailed.
Between around 2:00 PM and 9:00 PM thermal generation will have to be ramped up rapidly by 12 GW.

The main result is that the system will need more flexibility, that the capacity factor of thermal generation will decline, potentially creating stranded assets, and that the peak premium around 12:00 AM is eliminated.

b. Wind

Flexibility is the capacity of a power system to respond to changes in demand and supply. The well-known figure below [8] illustrates how the large-scale introduction of wind power also leads to the need for greater flexibility and changes the load profile.



The yellow area represents demand, the green wind power production and the orange net load that must be met by the remaining generators. It shows:

- Shorter peaks: Periods when generation is supplied at the higher level. This reduces the capacity factor of thermal power plants and their capacity to recover costs;
- Steeper ramps: Higher rate of increase of thermal generation when wind power production fall as and at the same time demand increases.
- Lower turndowns: Operation of thermal generators at a low level when load is low and wind production is high.

8. Distributed energy

[8] Cochran, et al, Flexibility in 21st Century Power Systems http://www.nrel.gov/docs/fy14osti/61721.pdf

Distributed energy is a disruptive force that can be defined as energy technologies placed at the energy load and it includes 3 main types [9]:

- Energy extractors: technologies that reduce/ shift the load, such as energy efficiency and demand management.
- Energy technologies, such as solar PV;
- Distributed storage.

I will illustrate distributed energy with an example.

- I will be away from home for 6 weeks and when I go back to NYC I will be confronted with an expensive electricity bill because it includes many charges that do not depend on the electricity I consume. [10]This does not make any sense

- Sooner or later, I will install a **solar panel** in my rooftop and I will produce electricity at a price lower than 170 $/ MWh, the average **retail price** of electricity in NYC. I understand that ¼ of the houses in Queensland already have solar panels.

- I will not worry too much with the upfront payment because there are plenty of companies willing to finance the cost of installation if I agree to share the savings. There is a lot of **competition and financial innovation.**

- Solar energy makes sense given that **module costs** declined by more than 80% in the last 10 years and other costs (so- called **balance of system costs)** are also declining fast. New York is one among more than 50 cities in the US where it is possible to produce **rooftop solar electricity at a cost lower than retail price, i.e. it reached "socket parity" (**although factoring in subsidies).

- I will consume the electricity that I produce when I will be at home and will sell the surplus when I am away because new grids (called the **"smart grids**") now allow electricity to **flow in 2 directions**. [11]

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[9] Distributed energy, a disruptive force, BCG, 2014

https://www.bcgperspectives.com/content/articles/energy_environment_distributed_energy_disruptive_force/

[10] https://www.nyseg.com/MediaLibrary/2/5/Content%20Management/NYSEG/SuppliersPartners/PDFs%20and%20Docs/N%20Electric%20Rate%20Summary.pdf

[11] https://www.eia.gov/electricity/monthly/update/archive/february2017/

- "**Net metering"** will allow me to sell back electricity at the retail price. [12]This will be credited in a special account that will entitle me to use for free the surplus of electricity that I do not consume.

- Of course, this will be much easier when the **cost of batteries** will be competitive and that should not take too long. Industry participants expect that the cost of lithium batteries will fall by 50% in the next 5 years [13] and there are other very promising alternatives. [14]

- In addition to this I will sign a contract with my electricity provider where I commit to tell in advance when I can save electricity, for example when will be away from home, to turn off the air conditioning at specific hours of the day, etc. This is called **"demand response"**.[15] It will be very easy to communicate with my electricity provider because we are connected through an app that I installed on my IPhone.

- The meter I have at home will send information to my electricity provider every 15 minutes. This will allow it to use that information to create an offer better tailored to my specific needs. The system that allows it to bundle the information of millions of clients is called "**Big data and analytics"**.

- All in all, I will be much better off.

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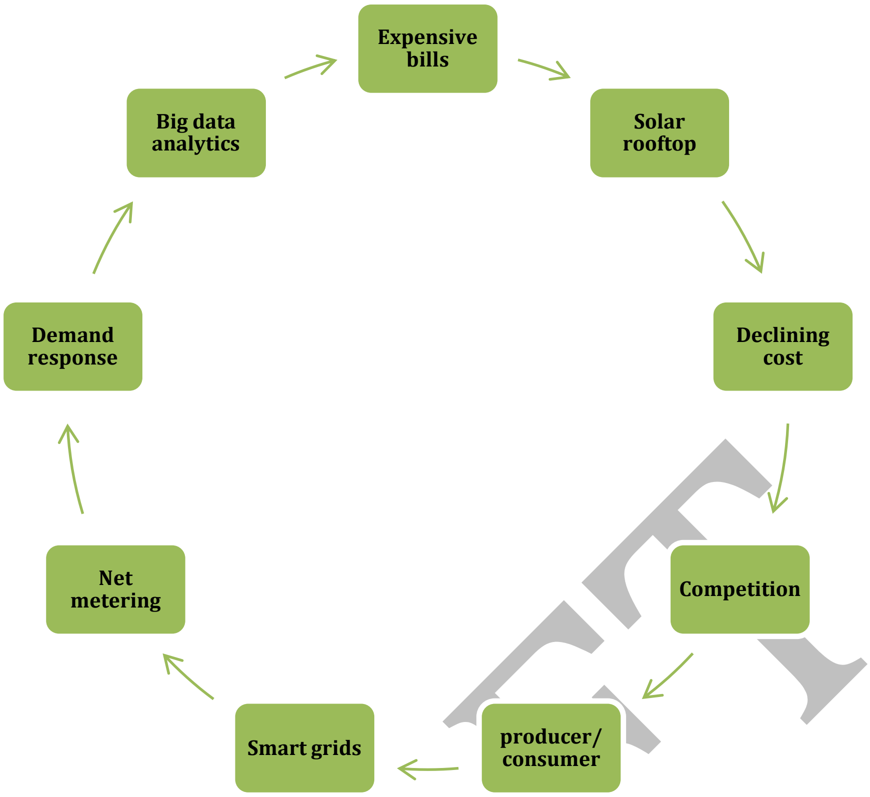
[12] Straight talk about net metering, Edison Institute, 2016
http://www.eei.org/issuesandpolicy/generation/NetMetering/Documents/Straight%20Talk%20About%20Net%20Metering.pdf

[13]Levelized costs of storage, Lazard, 2016
https://www.lazard.com/media/2391/lazards-levelized-cost-of-storage-analysis-10.pdf

[14] http://rameznaam.com/2015/10/14/how-cheap-can-energy-storage-get/

[15] Capers, P. et al, Demand response in US electricity markets, Orlando Lawerence Berkely Laboratory, 2016
https://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/Demand_Response_in_U.S._Electricity_Markets_-__Empirical_Evidence.pdf

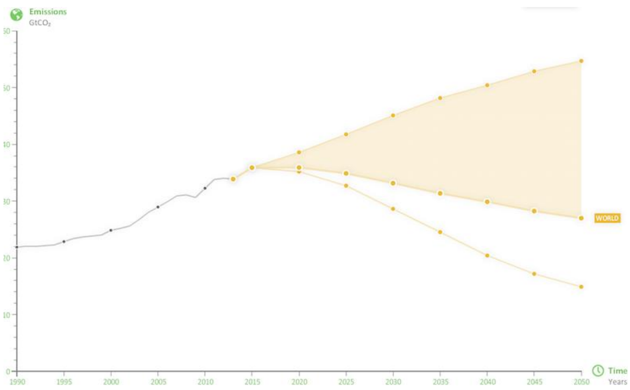


9. Climate awareness

No climate policy is serious without a rapid increase of VRE. Climate awareness increased, as witnessed by Paris COP21, which is to a large extent an energy deal. 150 countries in the world have specific policies to develop VER and in the INDC´s 106 countries stressed out that VER were a priority and 74 included specific development targets.

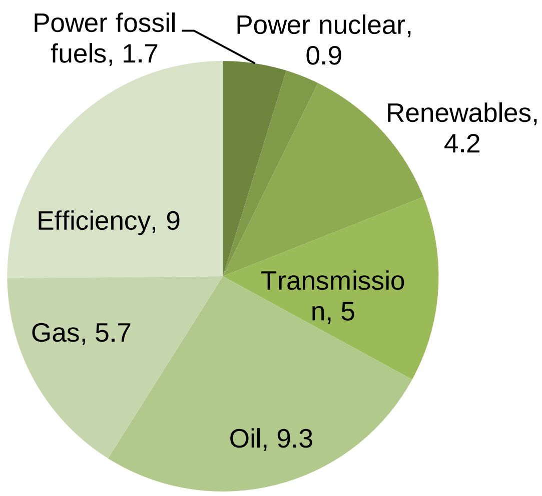
The rapid deployment of renewable energies and the improvement of energy efficiency are the 2 most powerful instruments to achieve a CO2 trajectory consistent with the 2° C target. The figure below is based on the IEA´s World Technology Perspectives simulator[16] and it shows a scenario where CO2 emissions would reach 55 GT/ year in 2050 if left unchecked when a decline to 15 GT is needed to reach the 2° C target. The shaded area illustrates the paramount contribution expected from end- use energy efficiency gains (36%) and from renewable energies (33%).

[16] http://www.iea.org/etp/explore/

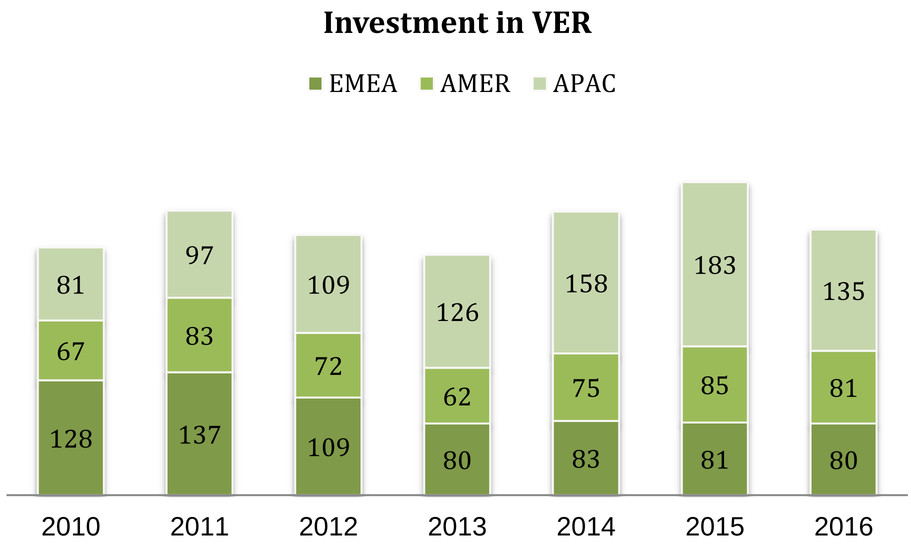


Source, IEA, Energy Technology Perspectives

Achieving the INDC´s submitted to Paris- COP 21 will require an investment of 36 trillion $ in the energy sector, of which $ 4.2 trillion in renewables (280 million $/ year).



2015 was a record year for investment in VER, the first time that it was higher both than in oil and gas and in thermal generation (including nuclear). It is remarkable that this took place in an environment of super low prices of fossil fuels. For the 4th consecutive year, Asia (notably China) was by far the largest investor. The decline by 18% recorded in 2016 is to a large extent the result of a decline in unit costs.



BNEF [17] shares the view that 2017 may be a more difficult year for several reasons, including uncertainty in the US and the slowdown in energy consumption in the China.

10. The impact on the traditional utility model (scissors effect)

The traditional utilities model is under pressure as a result of a so-called "scissors effect" whereby some revenue streams fall while at the same time that costs increase. [18]

In the EU, for example, this led to massive value destruction in the utilities sector. 12 of the largest EU utilities reportedly [19] reduced the value of their assets by$ 30 billion in 2015 bringing total write downs in the sector to $ 104 billion since 2010. The largest casualties were Eon and RWE (Germany), Engie and EDF (France).

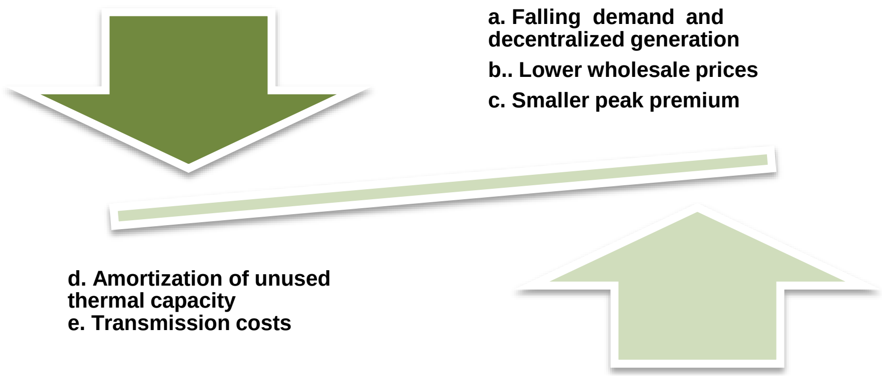
The "scissors effect" has 3 main (structural) causes:

- Firstly, flat or slow growth of electricity demand;
- Secondly, rapid increase of variable renewable energy sources at the expense of conventional thermal generation;
- Thirdly, growing importance of final consumers and decentralized energy resources

[17] https://about.bnef.com/blog/10-renewable-energy-predictions-2017/

[18] This term was originally coined by David Robinson in a 2015 report for the Oxford Institute for Energy Studies https://www.oxfordenergy.org/wpcms/wp-content/uploads/2015/08/EL-14.pdf

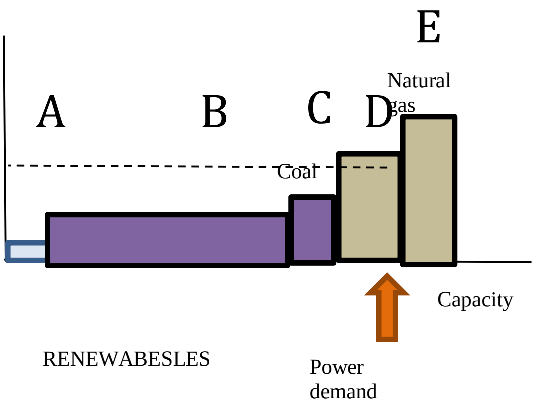
[19] https://www.ft.com/content/5b2dd030-1e93-11e6-b286-cddde55ca122

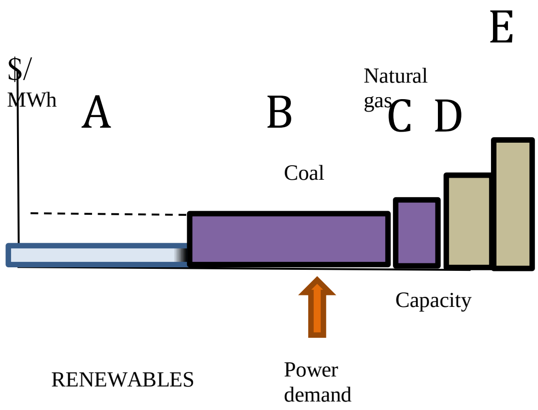


a. Lower wholesale prices

The economics of VER is different from that of thermal generation given that the former have high fixed costs and very low variable costs, i.e. zero marginal cost.
In a competitive market where the price is set by the generator with the highest marginal cost VER run first given that their marginal cost is zero.
The large-scale introduction of VRE reduces, other things being equal, wholesale prices- the so- called “order of merit effect”.
The figure below illustrates a competitive market with 5 generators (1 wind and 4 thermal) where the price is determined by the generator with the highest marginal cost. The VRE has zero marginal cost, in contrast to the 4 thermal generators.
On the left hand side, the penetration of VRE is low; generator “D” sets the wholesale price P1. On the right hand side the penetration of VRE increased and given its marginal cost is zero it will run first. Generator “B” will set a lower price P2 than before. Generators C, D and E will not produce and their amortization will be difficult, if not impossible. [20]

[20] https://www.cleanenergywire.org/factsheets/setting-power-price-merit-order-effect

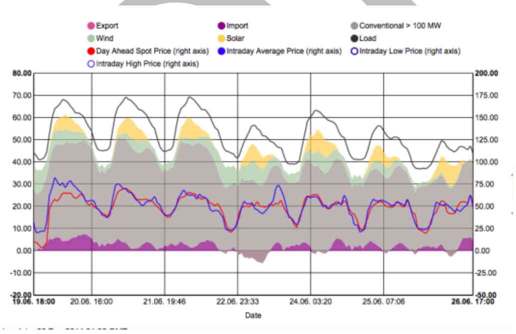


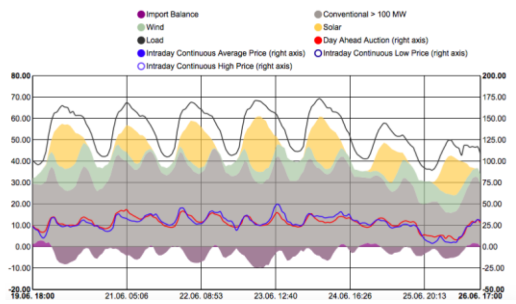


b. Lower peak premium

Power demand (load) and prices vary during the day and the year.
When demand is higher (peak periods), usually during the middle of the day and early in the evening, prices are higher (because they are set by flexible generators, usually peak turbines, with low fixed costs, low efficiency, and high variable costs).
In a conventional power system, utilities tend to recover capital costs with the infra- marginal profit made in peak periods. However, solar power is produced during one of the periods of the day when load is higher and this will reduce the wholesale peak premium given that they have zero marginal costs.

The figure below illustrates the order of merit effect and the fall of the peak premium in Germany in the same summer week of 2012 and 2016. It shows a strong increase in solar power during peak periods, a marked decline of wholesale prices and increase in exports. During that specific week there were no negative wholesale prices, which are a manifestation of inflexibility of the power market in Germany.





Source: Fraunhofer

c. Amortization of unused thermal capacity

The capacity factor of thermal generators is lowered as a result of VER running first and lower demand for on grid electricity consumption. This tends to create stranded assets. A few countries have been using “capacity payments" as a tool to secure reserves and avoid utilities shutting down unprofitable thermal generators, effectively killing liberalized markets. [21]

d. Transmission costs

The grid is expensive and will require large investments in the future.

The problem of the grid in the age of solar power is a mismatch between expenditure and revenue that ultimately may produce "zombie grids".

The cost of the grid typically does not depend on the quantity energy flows through the system. Grids need to invest more to maintain power lines and substations, for allowing connection to VER generation and to transform the grid from a one- way system to one where power flows in 2 directions.

In contrast, revenues are a percentage of the electricity bill and tend to decline as power demand decelerates and self-generation increases. This is compounded by arrangements in many countries to support solar energy (net metering) [22] that configure hidden subsidies.

11. Conclusion

The energy transformation is a fascinating topic. Overall, developments are positive:

Moderate growth of energy demand,
Declining energy intensity,
More abundant and cheaper resources, notably of unconventional oil and natural gas,
Rapidly falling cost of renewable energies and
CO2 emissions are flat for 3 consecutive years.

Power systems are changing fast although many uncertainties remain.

The traditional electricity system was centralized and based on cheap base load power (coal, hydro, nuclear) complemented with more expensive capacity to meet peak load (usually gas peak turbines with low fixed costs and high variable costs).
Although many uncertainties remain, the emerging electricity system is increasingly decentralized and based on "super low cost renewables" complemented with flexible capacity from different sources (demand response, storage, natural gas, imports, etc.).

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21 https://www.bcgperspectives.com/content/articles/energy_environment_sustainability_death_europes_liberalized_power_market/

22 http://www.eei.org/issuesandpolicy/generation/NetMetering/Documents/Straight%20Talk%20About%20Net%20Metering.pdf

This will force a revolution in the way power grids are designed and regulated and in the electricity business.

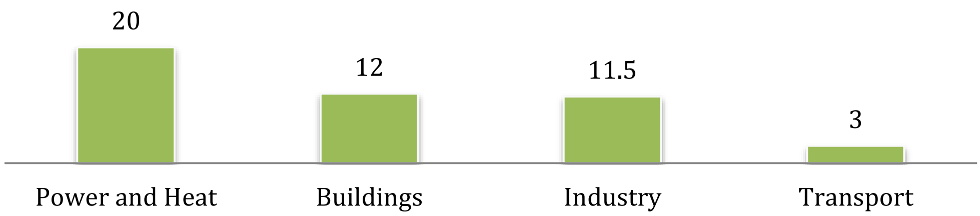
Utilities will need to make strategic choices and update their business model at the same time that system design and regulation need to be adapted. Inaction and wrong choices may have heavy costs.

I have described the general trends. The big uncertainty is whether the transformation of electricity systems will be linear and gradual or nonlinear and rapid. This makes a lot of difference.

Usually, energy transformations are slow, however this is may be not the case. There are other precedents. For example it took only 8 years for natural gas to gain a 17 p.p. market share to coal in electricity generation in the US leaving this industry in near death and in Germany it took less than 20 years for wind and solar gaining a market share above 30%.

The power sector has been leading the development of renewable energies, however this can change rapidly. The speed at which VRE and digital technology will penetrate the other sectors (buildings, industry and transport) will determine to a large extent the future of power systems.

World share of renewables by sector



Source: IEA

Basic concepts

Balancing area: Geographical area under supervision of a balancing authority
Balancing authority: Authority in charge of balancing demand and supply
Capacity factor: Average number of hours of a generator compared to its nameplate capacity
Capacity payments: Remuneration to generation availability
Curtailment: Reduction in the output of a generator from what it could otherwise produce.
Demand response: System that "provides an opportunity for consumers to play a significant role in the operation of the electric grid by reducing

or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives” (DOE).

Distributed energy: Energy technologies placed at the energy load

Feed in tariff: Renewables price support mechanism typically used in Europe

Flexibility: capacity of a power system to respond to changes in demand and supply.

LCOE: Breakeven cost of electricity on a NPV basis

Net load: Load minus VRE generation

Net metering: System that allows consumers who generate some or all of their own electricity to use that electricity anytime, instead of when it is generated.

Peak demand: Periods of the day with highest electricity demand

PPA: Legal contract between a electricity generator and a buyer, in most cases the seller is organized as an SPV

PTC: inflation-adjusted per-kilowatt-hour (kWh) tax credit for wind electricity generation in the US

Stranded assets: Investments that are not able to meet a viable economic return due to a combination of technology, regulatory and/or market changes.

Turndown: load range that is possible while remaining in low emissions mode.

Wholesale energy prices: Usually day ahead and intra-day electricity markets

VRE: Wind and solar power

Zombie companies: Company unable to survive on its own and needs artificial support.