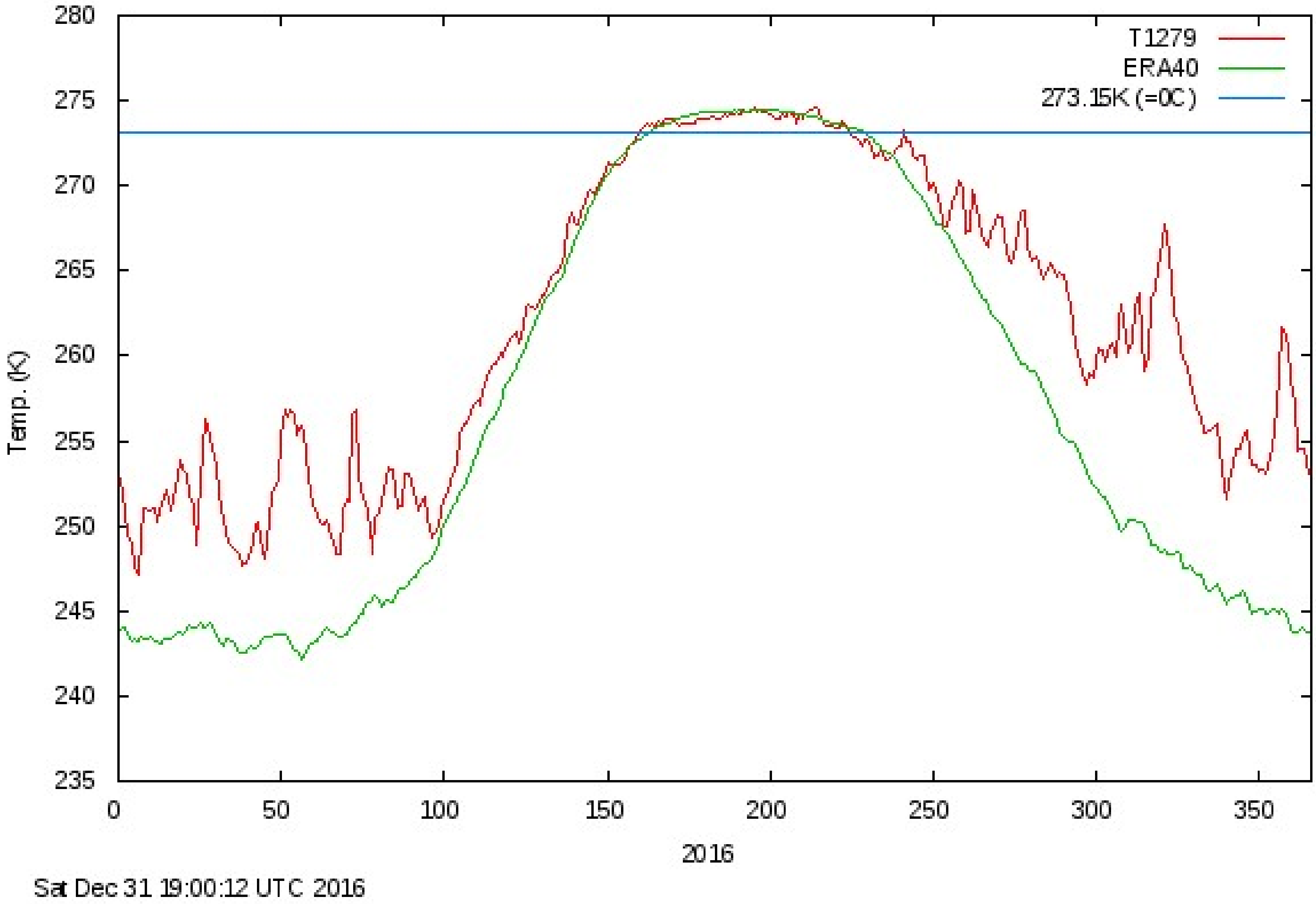
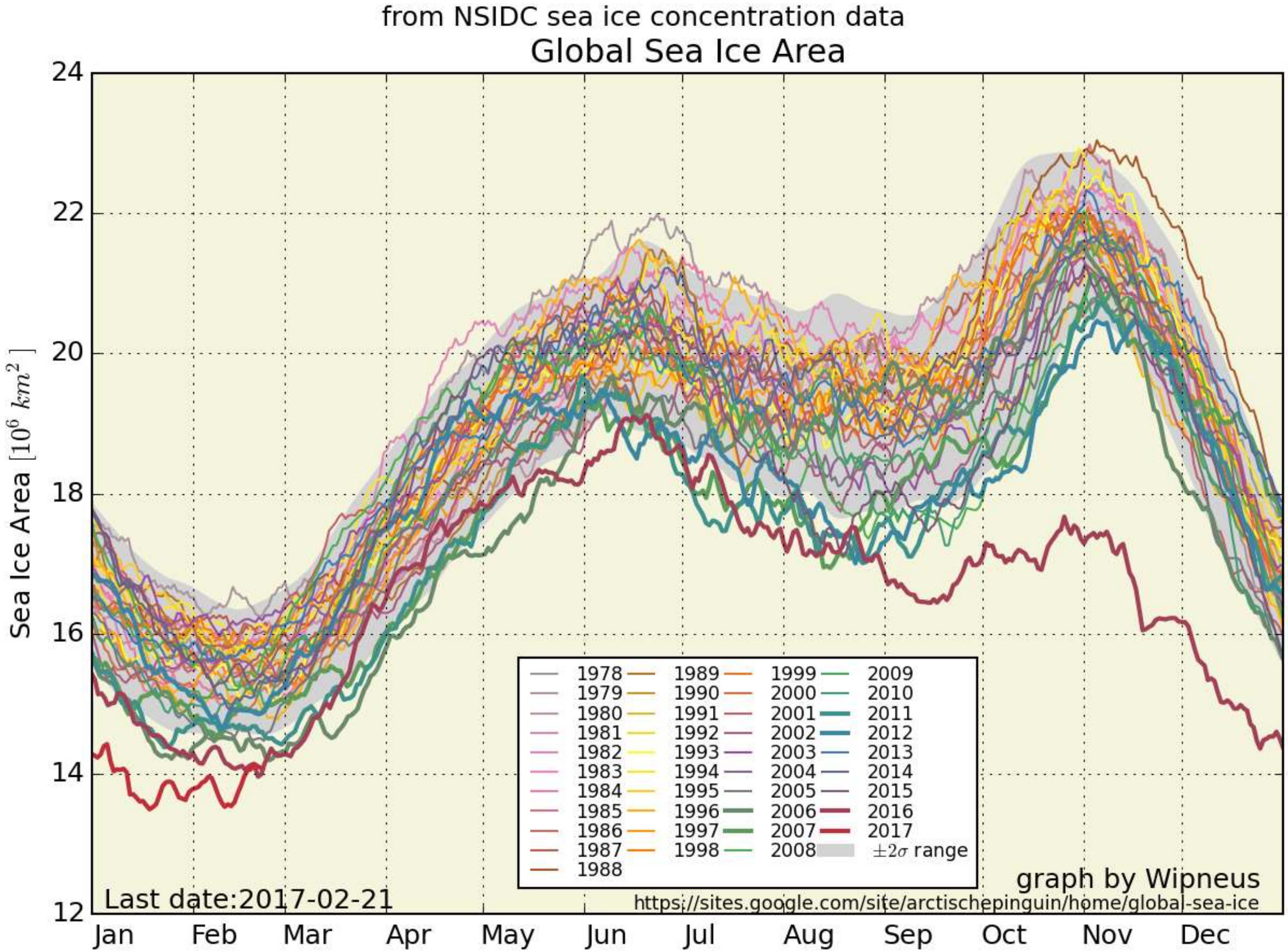

ENERGY : THE CLASH OF NATIONS
Prof. Damien ERNST



Red curve: temperature in the Artic in 2016. Green curve: Average temperature in the Artic over the period 1958-2002.


from NSIDC sea ice concentration data
Global Sea Ice Area
Sea Ice Area $[10^6\ km^2]$
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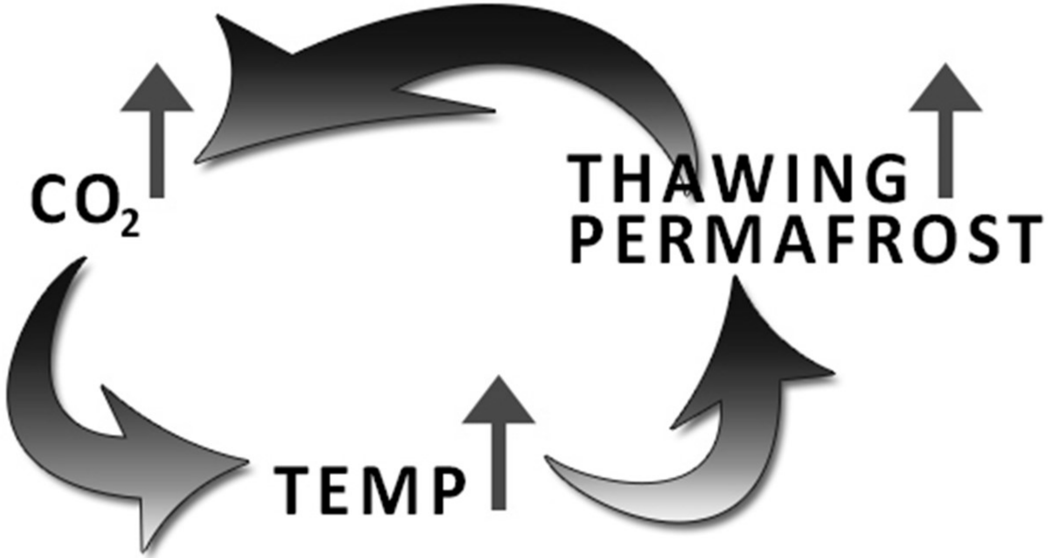
$\pm 2\sigma$ range
Last date:2017-02-21
graph by Wipneus
https://sites.google.com/site/arctischepinguin/home/global-sea-ice

The fear of climate tipping points

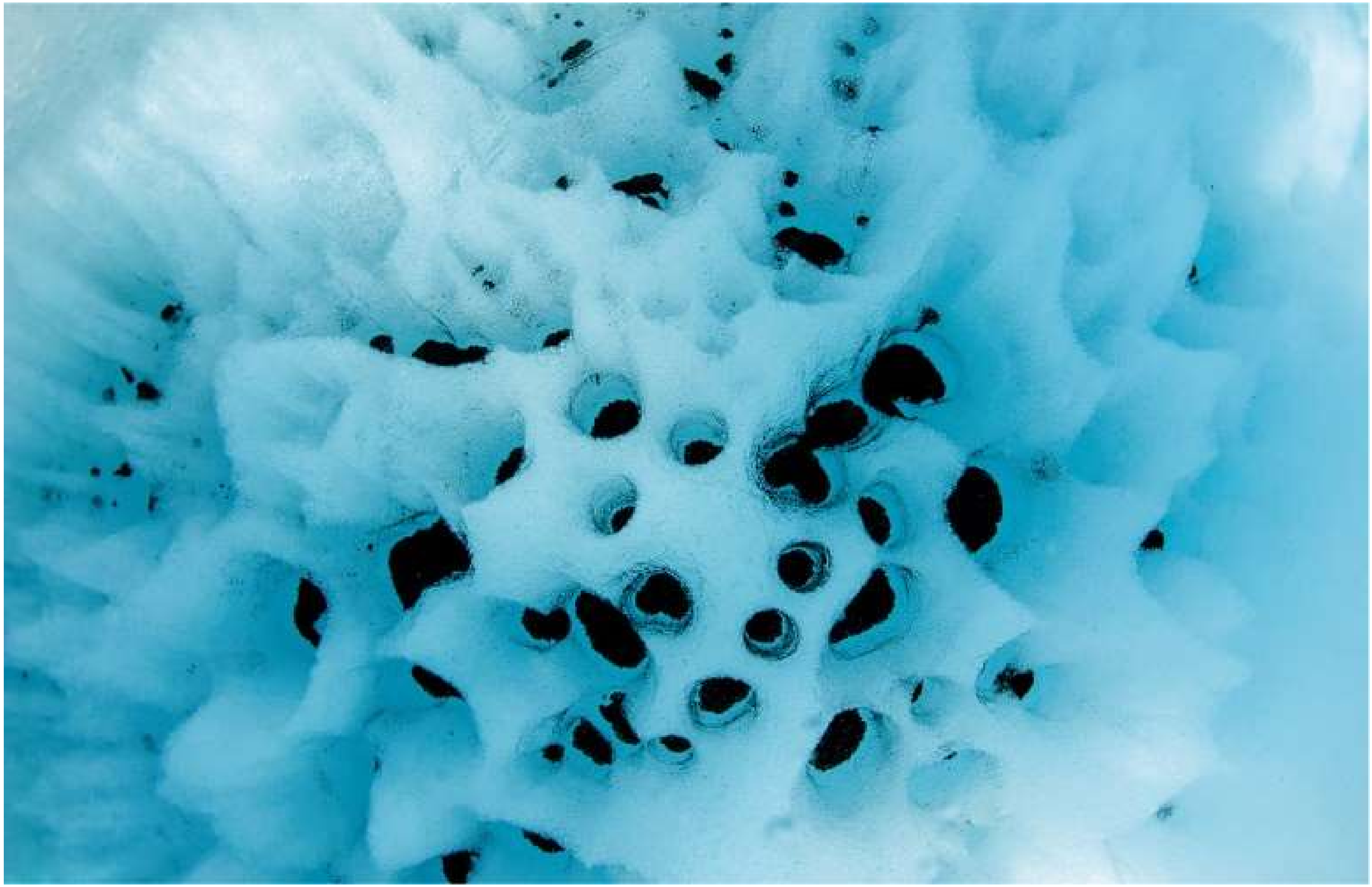
Example 1: When sea ice shrinks it leaves areas of dark ocean that absorb more heat, which in turn causes further shrinkage, and so on in a spiral.

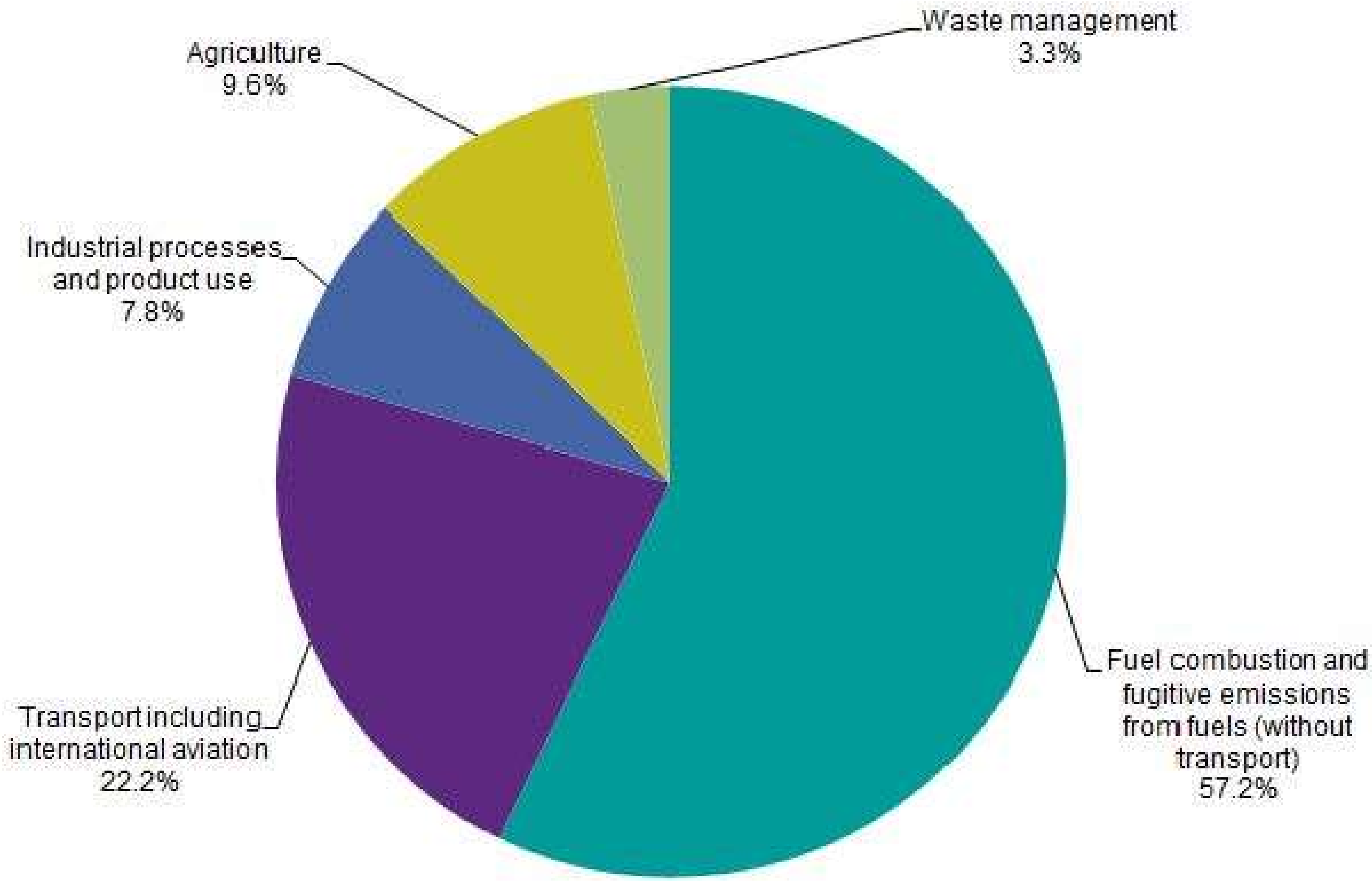
Example 2:



Methane bubble in Siberia.

Example 3: Growth of finger-width cryoconite cones holding black microbial gunk that accelerates melting if the Greenland ice sheet.





Greenhouse gas emissions, by source sector, EU-28, 2013 (% of total)

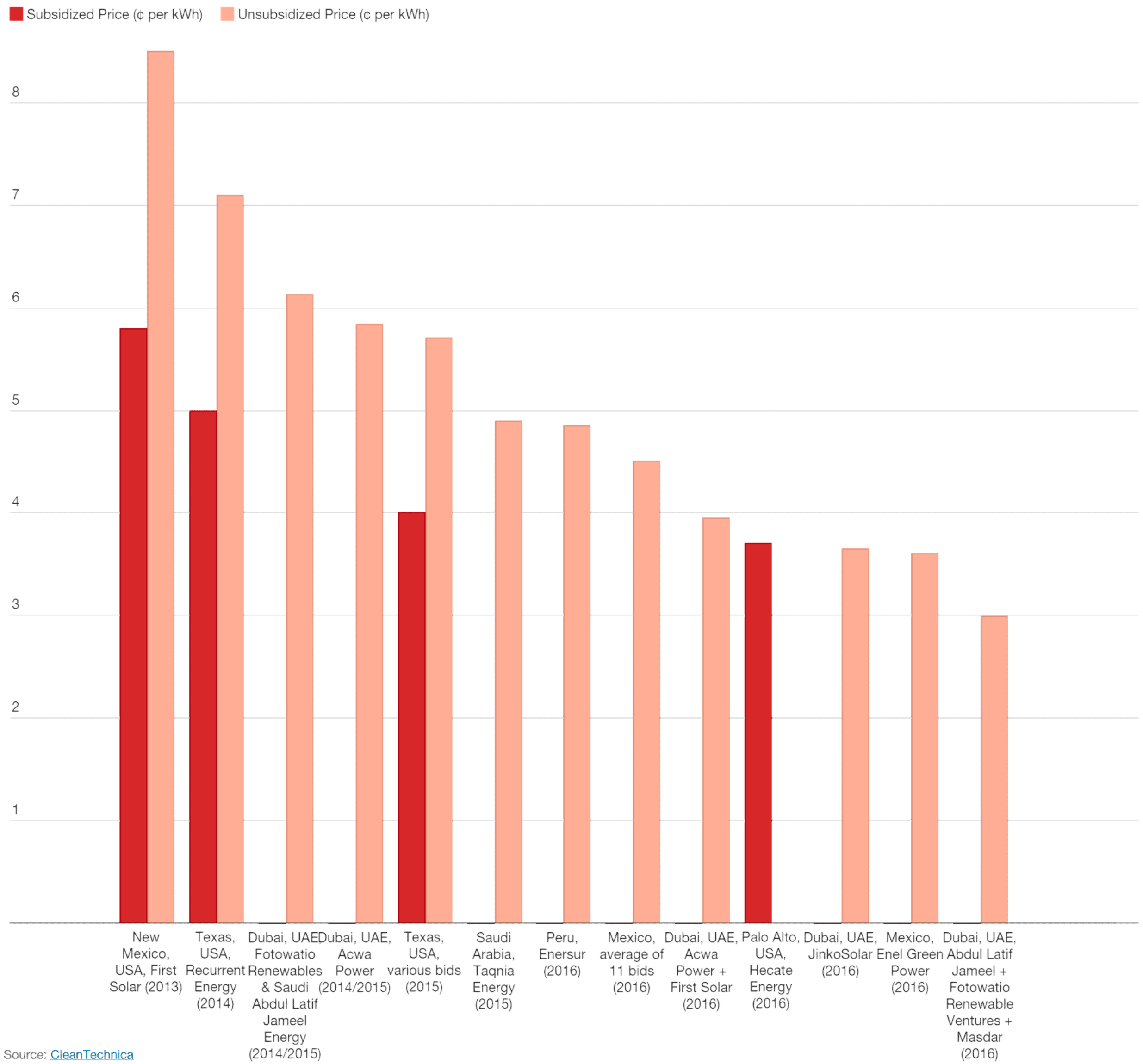
Nuclear power. Costs in 2016: 60€/MWh-120€/MWh.

Wind energy. Cost in 2016: 25 €/MWh-140€/MWh.

Solar energy. Cost in 2016: 26 €/MWh-130€/MWh.

Low Solar Bids (2013–2016)

Prices agreed to under 20- and 25-year power purchase agreements. Note that the low bids in Texas are actually lower than the amounts represented in the chart... but exact figures have not been revealed.



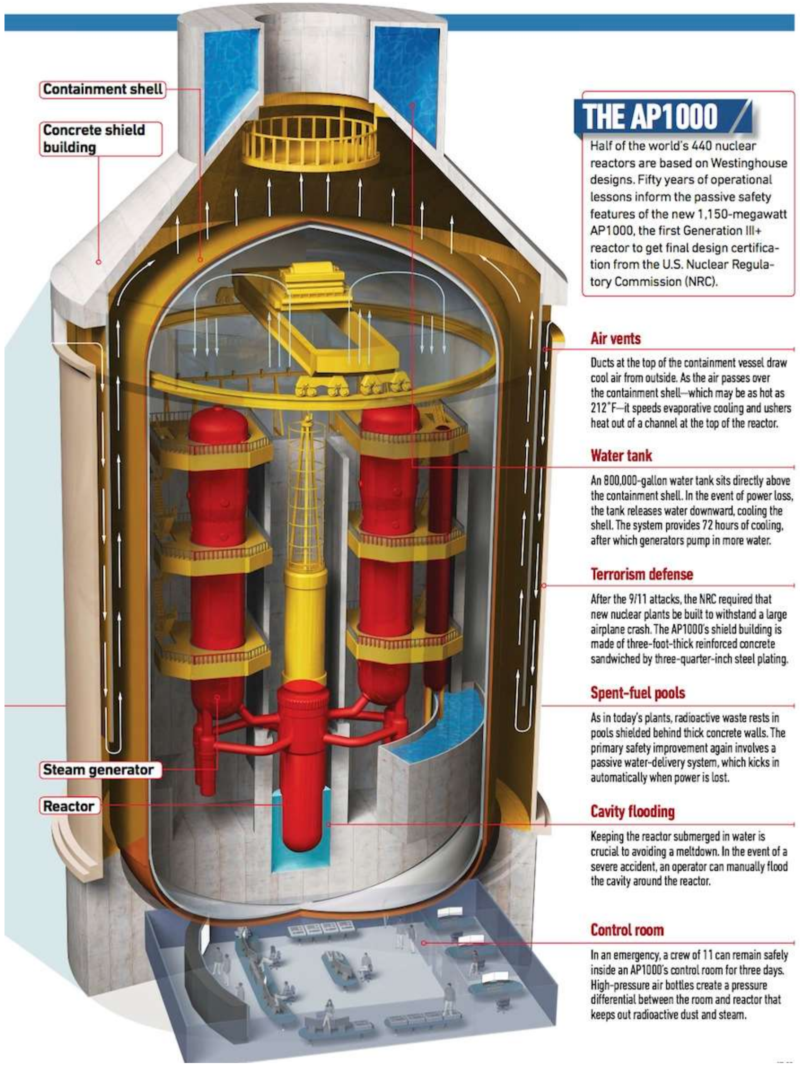
Source: CleanTechnica

Final energy consumption in Belgium: **150 kWh/person/day**

Yearly energy consumption : $150 \times 365 \times 11 \times 10^6 \simeq$ **600 TWh**

Electricity consumption : **80 TWh**

How to generate 600 TWh of energy every year ?



69 AP1000 nuclear reactors (designed and sold by Westinghouse/Toshiba).

Price tag: in the range of €200 billion.

Note: GDP Belgium in 2015 : €400 billion

Russia's Rosatom signs $10 billion worth of deals at AtomExpo

01 June 2016

Rosatom estimates that the "economic potential" of agreements and memoranda signed at AtomExpo 2016 is as much as $10 billion. Its director general, Sergey Kirienko, said yesterday that about 30 documents had been signed during the three-day annual conference and exhibition the Russian state nuclear corporation is hosting in Moscow this week.

Among countries inking the latest agreements with Russia's nuclear industry are Bolivia, Indonesia, Kenya, Nigeria, Tanzania and Zambia, he said. Of negotiations held by Rosatom subsidiaries, he highlighted those between Tenex, the uranium products and enrichment services provider, with energy companies from Europe and South America.

The raft of agreements signed by Rosatom and its subsidiaries at the Moscow conference cover fuel, finance, research, human resources and international cooperation in the development of nuclear power.

In addition to those agreements, delegates at the event also witnessed the signing of practical arrangements on cooperation between the International Atomic Energy Agency (IAEA) and the Regional Network for Education in Nuclear Technology, or STAR-NET.

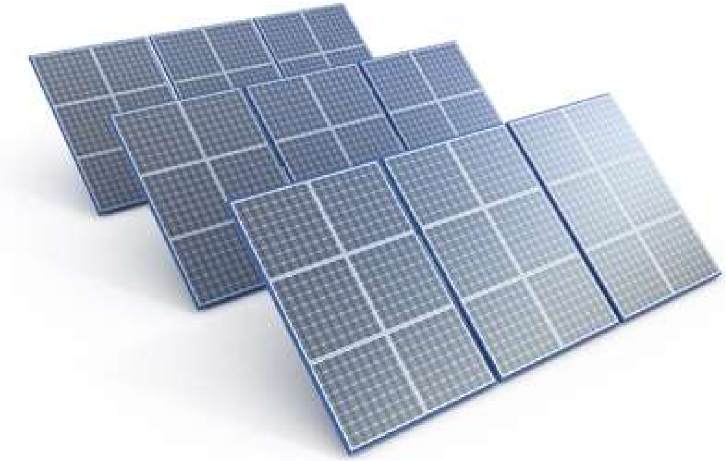
According to the IAEA's website, the STAR-NET initiative "seals collaboration" between educational institutions and nuclear industry-oriented training centres in Armenia, Azerbaijan, Belarus, Kazakhstan, Russia and Ukraine. It adds that the STAR-NET network involves interested stakeholders of non-profit, non-governmental and

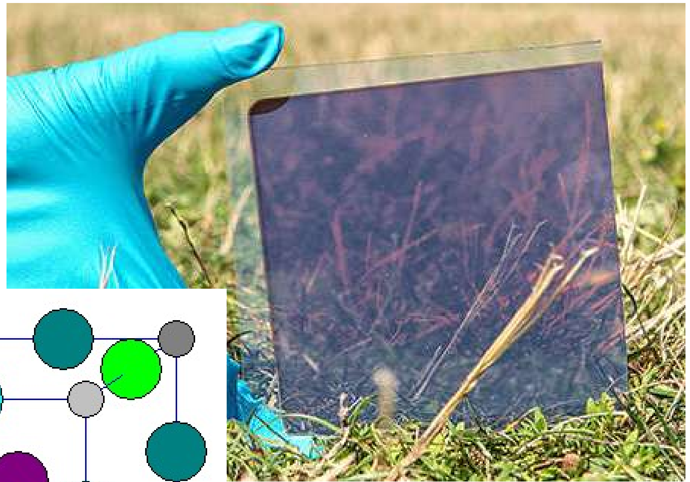
WNA Links

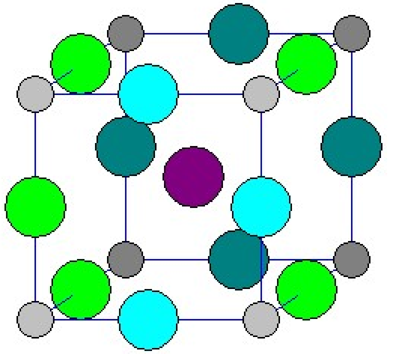
- Cooperation in Nuclear Power
- Nuclear Power in Russia
- Russia's Nuclear Fuel Cycle

Related Links

- Rosatom State Corporation
- Techsnabexport (Tenex)
- TVEL







Perovskite $CaTiO_3$

3424 km^2 of PV panels. This corresponds to an installed capacity of 685 GW or around 200 times the installed PV capacity in Belgium in 2016.

Price tag: in the range of €600 billion.

Table: **Best Solar Panel Manufacturers 2015 – Global ranking by volume, US market share & EnergySage quality ranking**

2015 Rank	Company	Change from 2014*	EnergySage quality ranking	Headquarters
1	Trina Solar	–	Standard	China
2	JA Solar	↑3	Standard	China
3	Hanwha Q Cells	↑6	Standard	South Korea
4	Canadian Solar	↓1	N/A	Canada
5	First Solar	↑3	Standard	USA
6	Jinko Solar	-↑	Standard	China
7	Yingli Solar	-↑	Standard	China
8	Motech Solar	-↑	N/A	Taiwan
9	NeoSolar	-↑	Standard	Taiwan
10	SunPower	–	Premium	USA

30220 Enercon-126 wind turbines = 229,071 MW of installed wind capacity, around 100 times more than the wind capacity currently operational in Belgium in 2016. This would correspond to wind farms covering 17,180 km^2 of land.

Price tag: in the range of €300 billion.

World's most powerful wind turbine selected for Belgium's largest offshore wind park. The V-164-8.4 MW

What about storage needs?

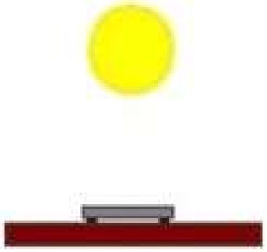
Power Produced = Power Consumed
+ Power Stored
+ Power Wasted

Storage needs for daily fluctuations : Computation of storage under the following assumptions: (i) all the energy (600 TWh/year) is generated by PV panels (ii) the load will be constant (iii) PV sources generate a constant power from 7 am till 7 pm and no power outside those hours. (iv) Efficiency of 1 for storage.

Storage capacity needed: 600÷365÷2= 0.82 TWh = 820,000,000 kWh

The Tesla Powerwall 2: capacity of 14 kWh => 58,571,428 Powerwalls would be needed.

Manufacturing price of around €200/kwh. Price tag in the range of €160 billion



Average solar irradiance figures (in kWh/day/m^2) in Belgium

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.9	1.5	2.5	3.7	4.8	5.0	4.9	4.3	2.9	1.8	1.0	0.7

Storage needs for interseasonal fluctuations: Solar irradiance during the six sunniest months of the year is three times higher than during the other months of the year => Storage needs: 150 TWh**. Price tag: €3000 billion.**

Other solutions: (i) Oversize the PV installations and throw power away during the sunny period **(ii)** Transform electricity into hydrogen that has a storage cost of around €2/kWh

Lithium mine in the Atacama desert, Chile

Country	Production	Reserves[note 1]
Argentina	3,800	2,000,000
Australia	13,400	1,500,000
Brazil	160	48,000
Canada (2010)	480	180,000
Chile	11,700	7,500,000
People's Republic of China	2,200	3,200,000
Portugal	300	60,000
Zimbabwe	900	23,000
World total	**32,500**	**14,000,000**

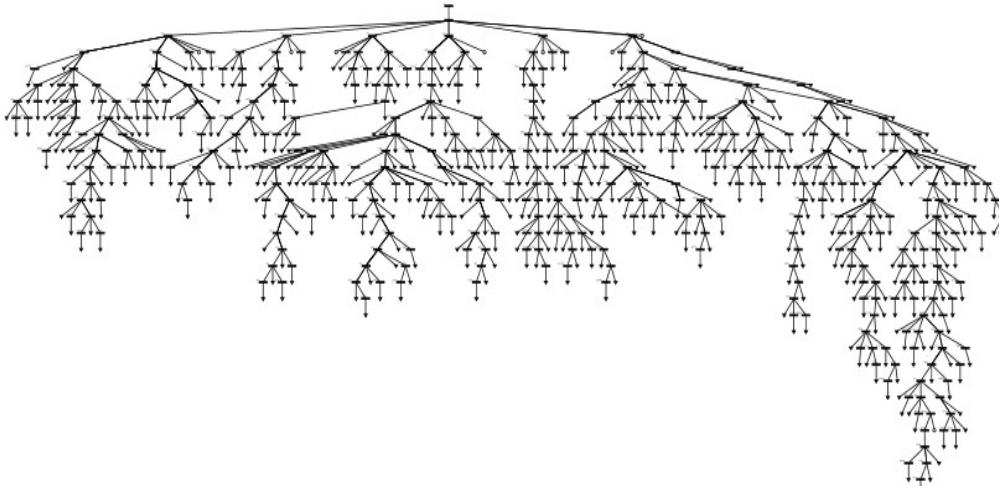
Lithium: yearly production by countries and proven reserves.

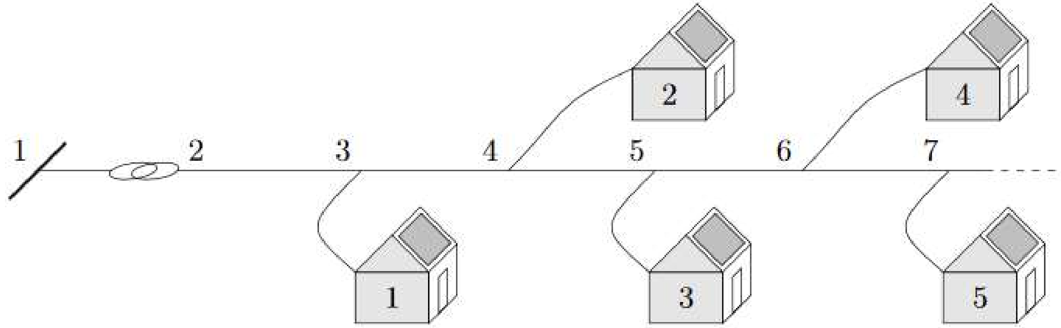
1 kg of Lithium needed for 10 kwh. 14 million tons of proven reserve. That corresponds to a potential storage capacity of 140 TWh.

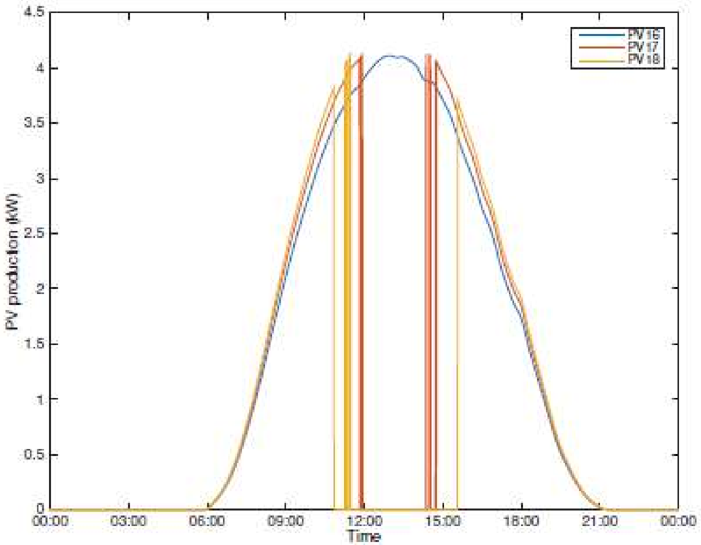
Equivalent to 12h of worldwide energy consumption (155,000 TWh).

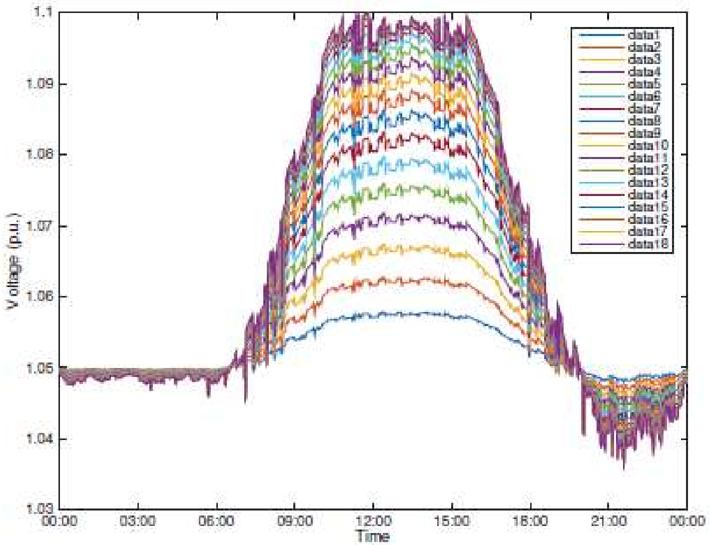
Equivalent to the storage capacity of 1.75 billion of Tesla cars.

Distribution networks and renewables: challenges



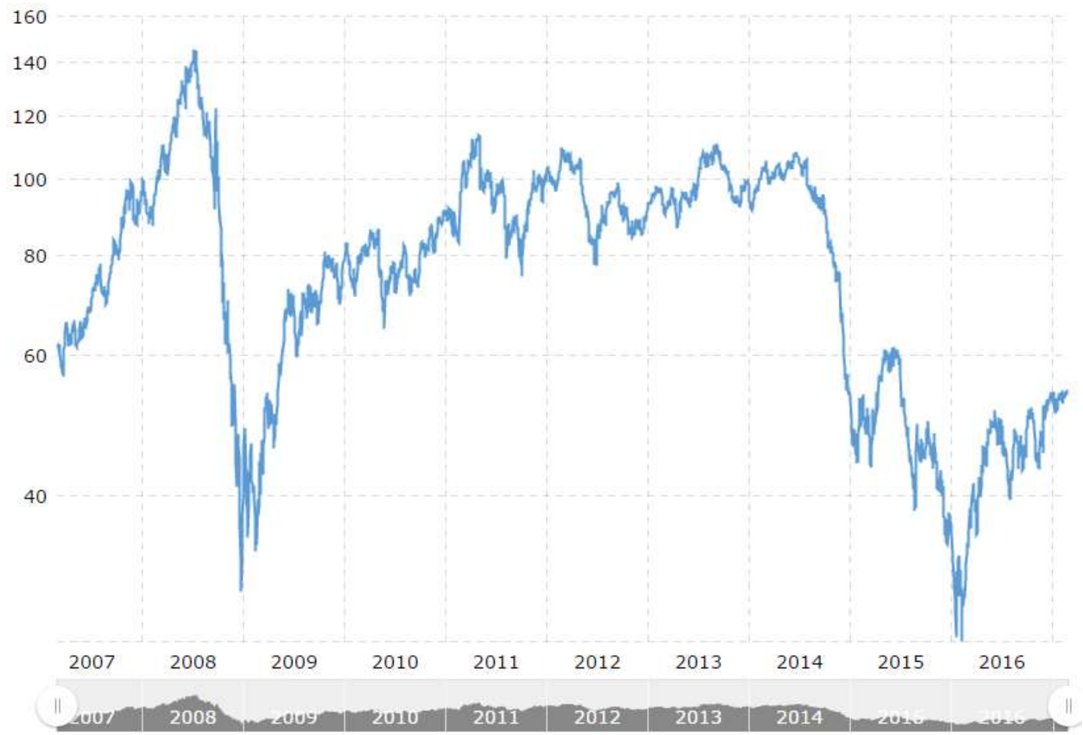






Forget the energy transition: let us go back to fossil fuels

Reason #1. Gas/oil is cheap and is poised to stay cheap with the shale revolution.



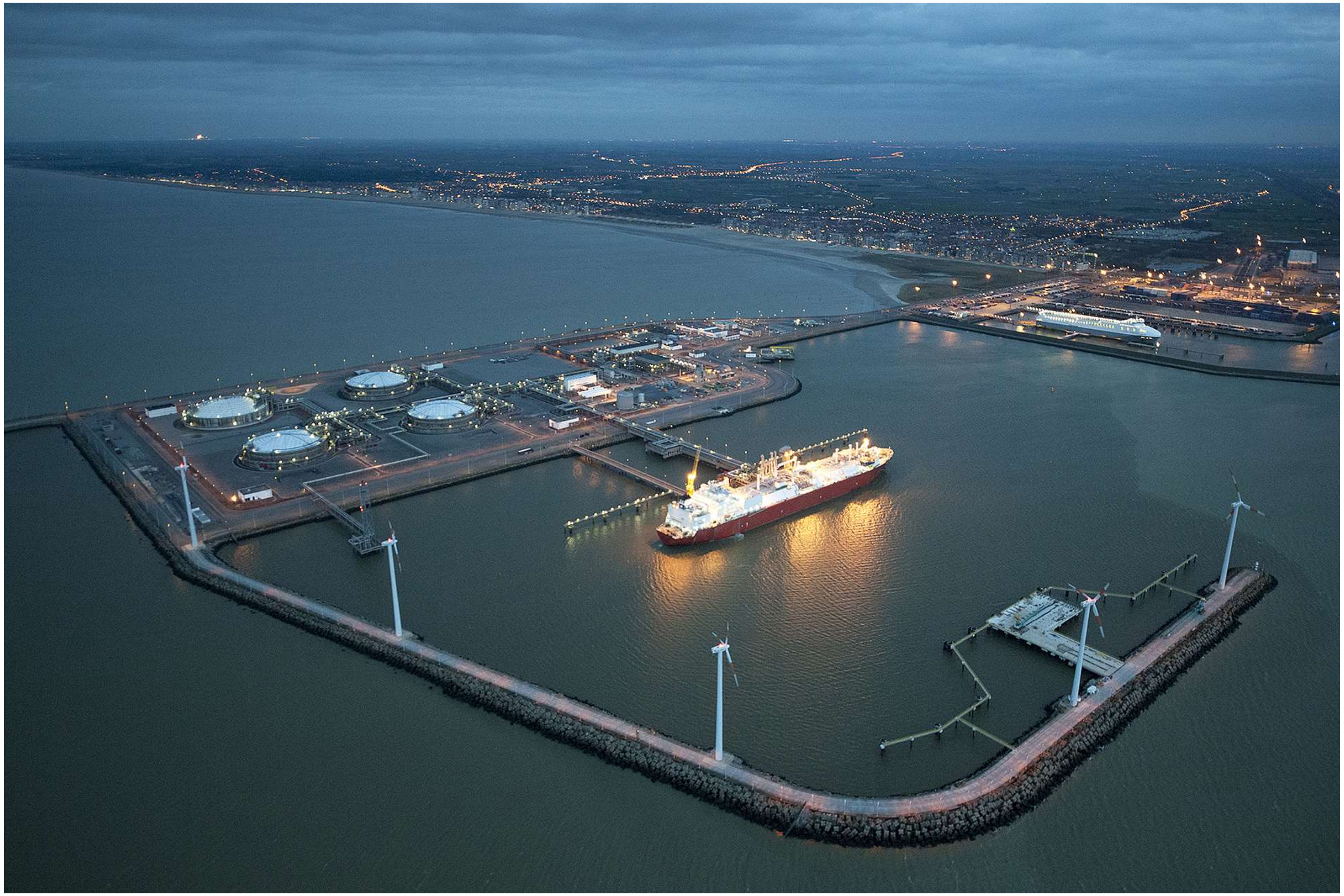
Price barrel of oil in \$. 1 barrel of oil = 1.62 MWh. If price of oil is equal to \$60, then 1 MWh of oil energy costs: 37 \$/MWh.

Leaner and meaner: US shale greater threat to OPEC after oil price war

Wednesday, 30 Nov 2016 | 3:09 AM ET

REUTERS

Reason #2. With the rise of liquefied natural gas (LNG), we do not have to depend anymore on Russia for our gas supply.



The LNG terminal in Zeebrugge.

Reason #3. Renewable energy will kill the EU industry

Chemical industry guarded about its European future

By Frédéric Simon | EurActiv.com   Nov 28, 2014 (updated: Jul 20, 2016)

Solvay CEO: 'Europe needs to react'

"The key factor which explains this loss of competitiveness is access to energy – both as a feedstock and as a source of energy. It means we are investing less because of this gap in competitiveness," said Jean-Pierre Clamadieu, CEFIC President and CEO of Solvay, who was presenting the report in Brussels last week.

ENERGY & ENVIRONMENT | GREEN COLUMN

High Energy Costs Plaguing Europe

By STANLEY REED DEC. 26, 2012

LONDON — On Dec. 19, Voestalpine, an Austrian maker of high-quality steel for the auto industry, announced that it would build a plant in North America that would employ natural gas to reduce iron ore to a kind of raw iron that would then be used in the company's European blast furnaces.

Reason #4. There is plentiful of coal. Let us burn it. Even if it generates lots of CO_2, we are anyhow too late to avoid climate warming (except if it is an hoax 😉).

Proved recoverable coal reserves: 1000 billions of tons = 8,141,000 TWh

Worldwide energy consumption per year: 155,000 TWh

Coal could cover all our energy needs for more than 50 years.

Price per ton of coal in $. 1 ton of coal = 8.14 MWh. If price of coal is equal to 100$/ton, then 1 MWh of coal costs: 12 $/MWh.

Wait....

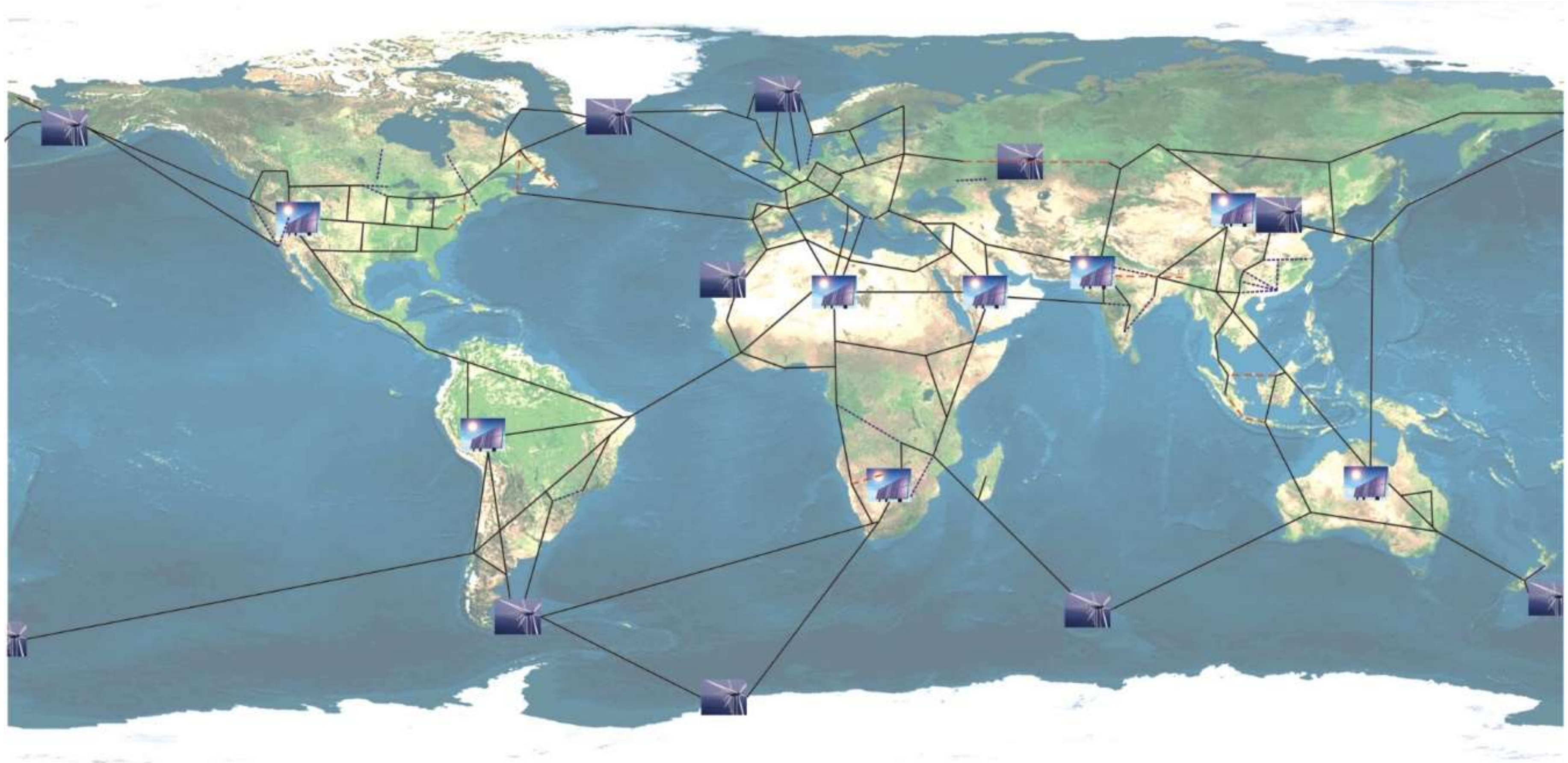
1. In good locations, renewable energy is becoming the cheapest way to produce electricity. In $/MWh of energy, it becomes also cheaper than oil.

2. Importing fossil fuels is also supporting terrorism, dictatures, while investing into renewables boosts the local economy.

3. Be carefull about shale oil/gas. Production prices may go up in a near future, once the best shale oil ressources have been exploited (the U-curve curse). Production may also brutally stop due to environmental constraints.

Shale oil field in the Permian bassin (Texas, USA)

A global grid for the provision of cheap renewable energy



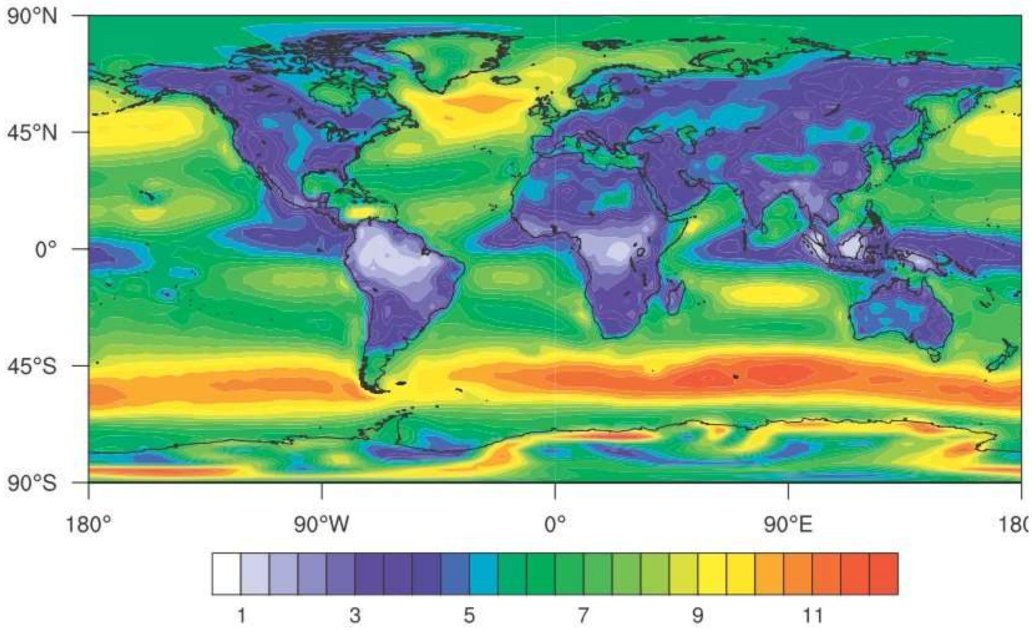
More at: http://blogs.ulg.ac.be/damien-ernst/tedx-talk-the-global-grid-for-empowering-renewable-energy/

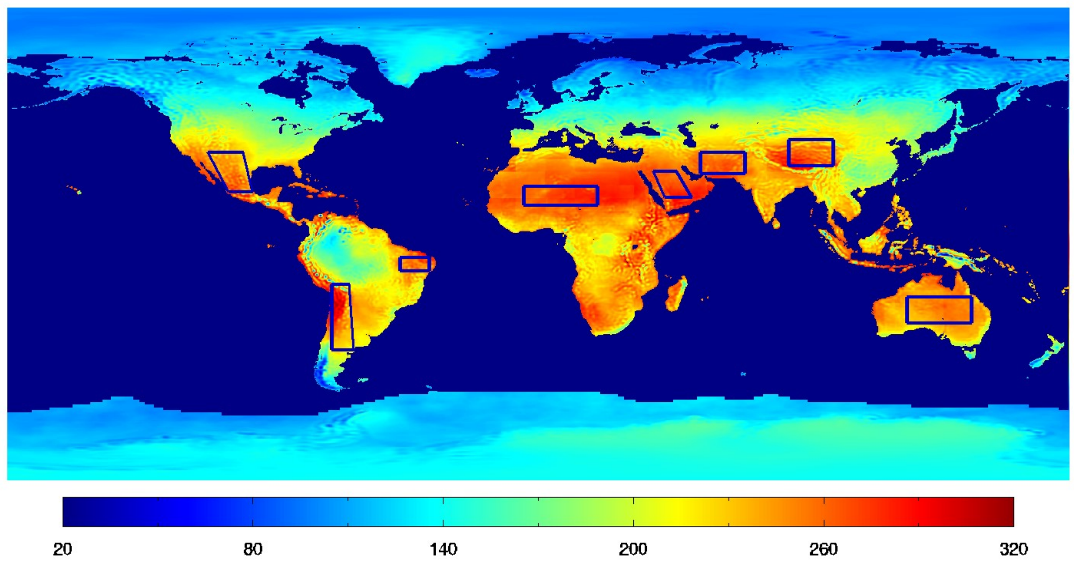
Why a global supergrid?

1. In many countries, you have only a limited number of prime locations for harvesting renewable energy

2. Intermittency of renewable energy sources

3. Tapping into rich veins of renewable energy sources



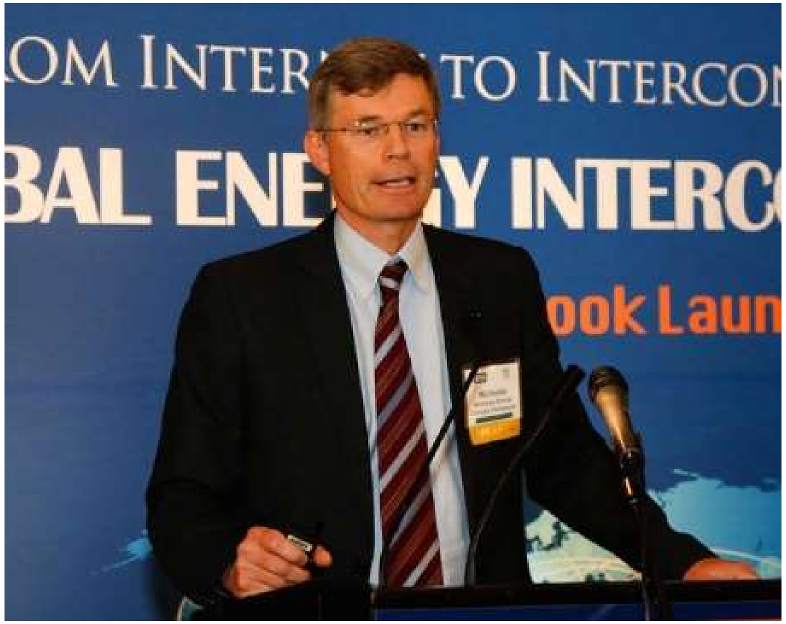


A future element of the global grid? An undersea cable between Morocco and Belgium. With such a project, Northern Europe would get access to cheap Moroccan PV energy, even during the winter.

Around 3000 km length of undersea cable

The cable could be connected on the Belgium side at the Doel nuclear power plant, which is closing in 2025, and which is located near the coast. This would allow for the reusing of the existing electrical infrastructure in Belgium (very difficult to build new lines in Belgium due to NIMBY issues).

Picture taken at the COP22 in Marrakech (November 2016), when exiting my airplane.



« *Humans are not good at global negotiations. But humans are a species of builders. So let us build this Global electrical grid* » Nicholas Dunlop, Chairman of the Climate Parliament, November 2016, COP22

CHINA POWER

China's $50 Trillion Plan for a Global Energy Grid

Plus, Scarborough Shoal, Nepal-China military ties, and myth-busting about China's economy. Friday China links.

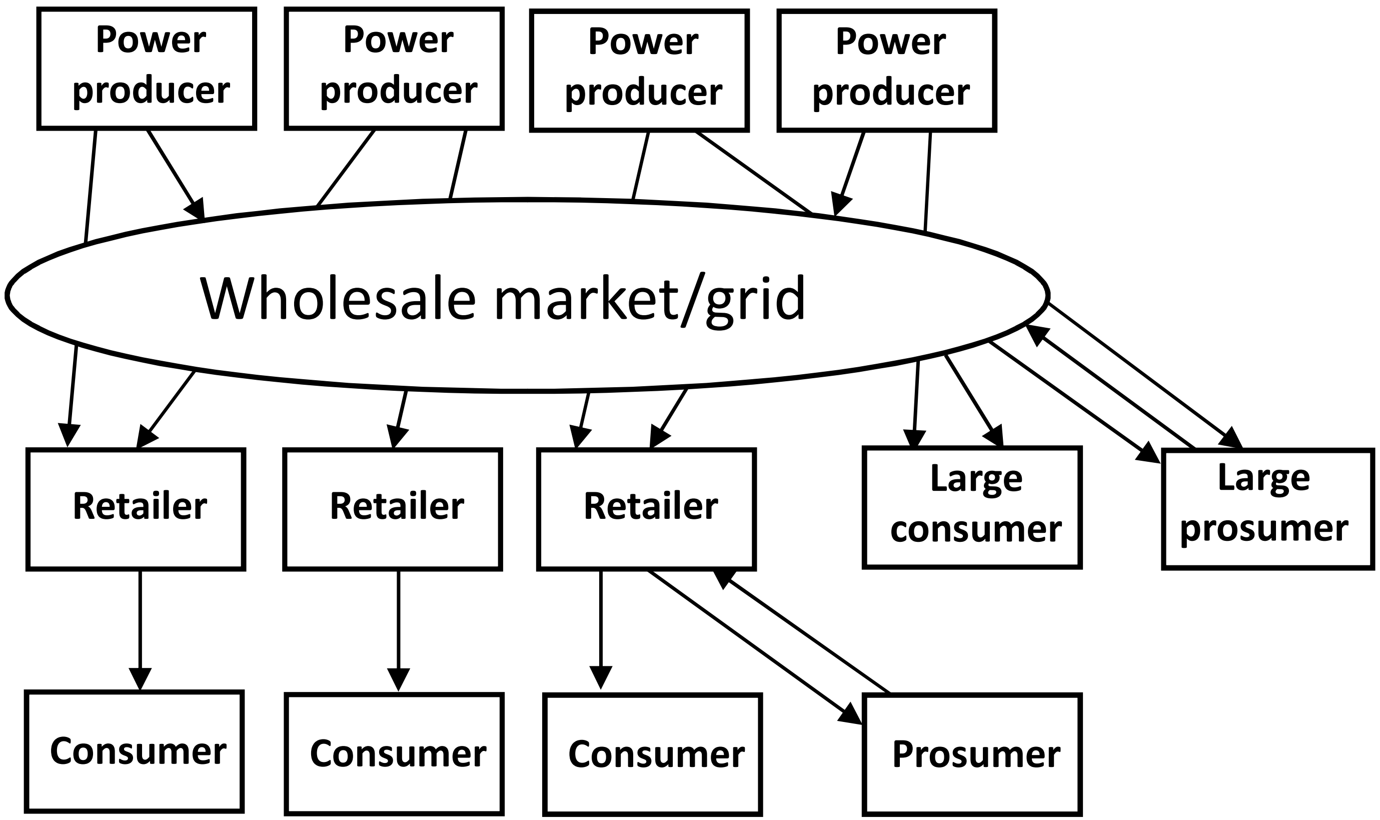
By Shannon Tiezzi
April 01, 2016

Image Credit: Shanghai solar panels image via Shutterstock.com

Your Friday roundup of China links…

China's State Grid Corp. has unveiled an ambitious blueprint for creating a global electricity network. As *Wall Street Journal* reports, on Wednesday State Grid chairman Liu Zhenya outlined the $50 trillion plan, which calls for long-range transmission lines to create a world grid that heavily incorporates wind and solar energy from the Arctic and the Equator regions, respectively. The project could come on line by 2050, but State Grid wants to begin pilot projects in the next 10 years. *WSJ* explains the plan:

> *In the near term, the focus will be on long-range interconnection domestically and on developing battery and other technology needed for better transmission of renewable power resources.*



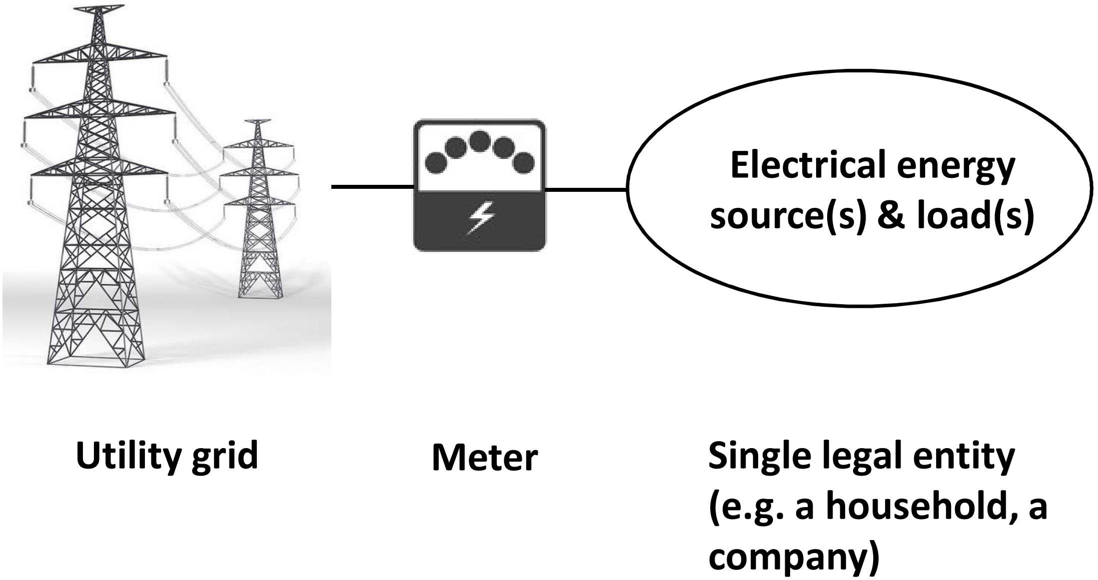
→ Electrical energy sales

Uber-like models for electricity: a definition

Electrical energy consumed by loads that does not go (only) through the electrical energy sale channels defined by →

Microgrids: the most popular uber-like model

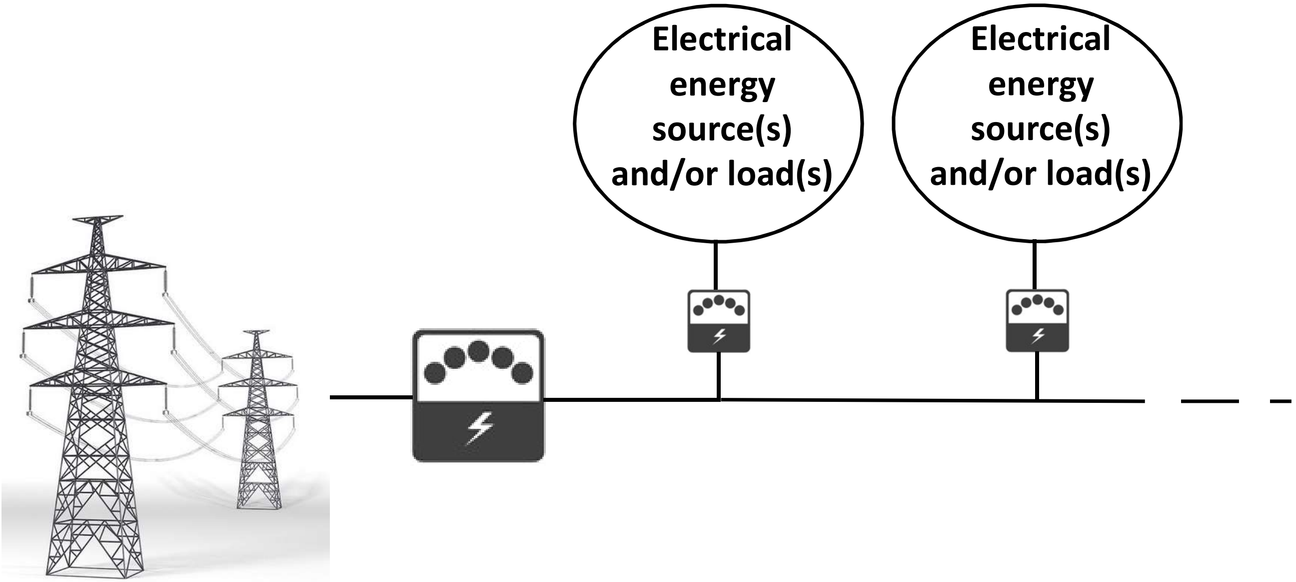
A **microgrid** is an electrical system that includes one or multiple loads, as well as one or several distributed energy sources, that are operated in parallel with the broader utility grid.



The single-user microgrid

1. Legal.
2. Popularised by PV panels and batteries.
3. Possibility to have a microgrid fully disconnected from the utility grid.

The multi-user microgrid



Utility grid

Money paid for energy and transmission/ distribution and tariffs only based on this meter

Several legal entities. Submetering

1. Regulatory framework may not allow for the creation of multi-user microgrids.
2. Often more cost-efficient than the single-user microgrid (e.g. economy of scale in generation and storage, easier to get higher self-consumption at the multi-user level).

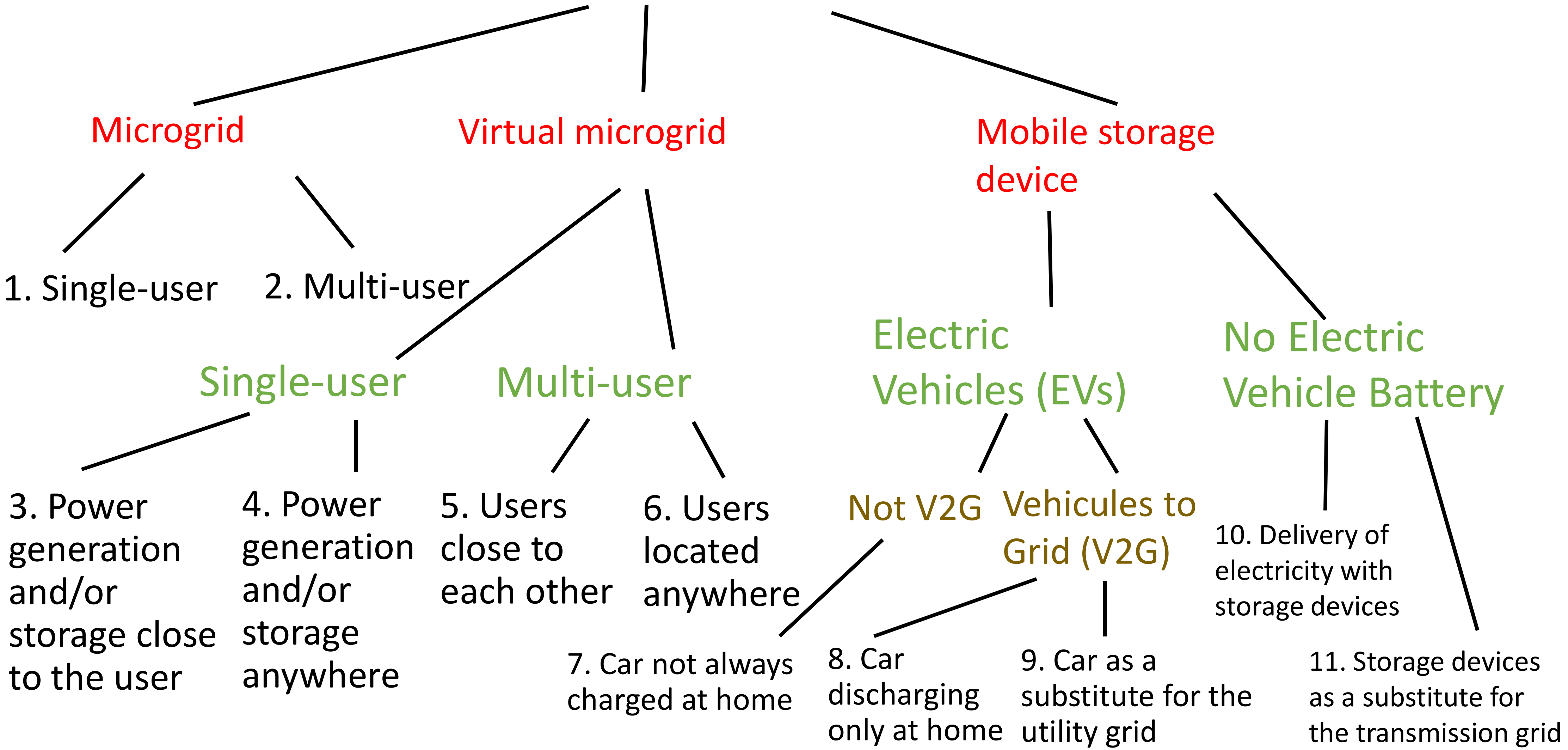
Why microgrids?

1. Financial reasons: (i) Price paid for generating electricity locally is lower than price paid for buying electricity from the utility grid (ii) Hedging against high electricity prices.

2. Technical reasons: (i) Microgrids – especially multi-user ones – are a great way for integrating renewables into the grid and developing active network management schemes (ii) Security of supply, especially if the microgrids can be operated in an autonomous way.

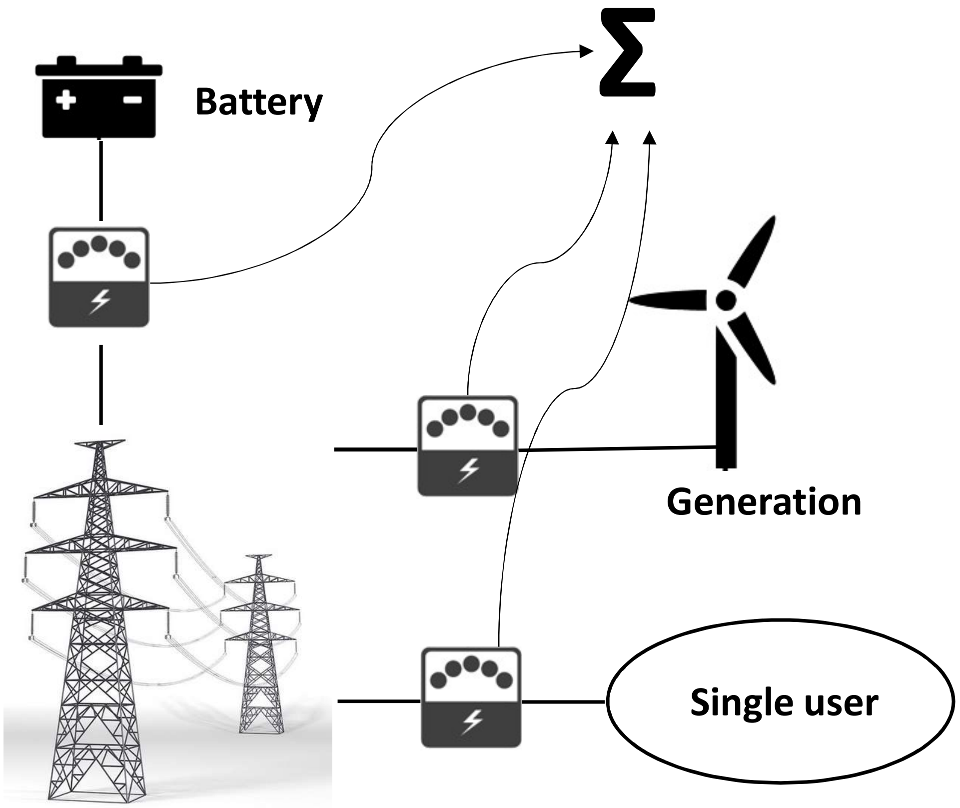
3. Societal reasons: (i) Local jobs (ii) Energy that belongs to the people.

A taxonomy for uber-like models for electricity

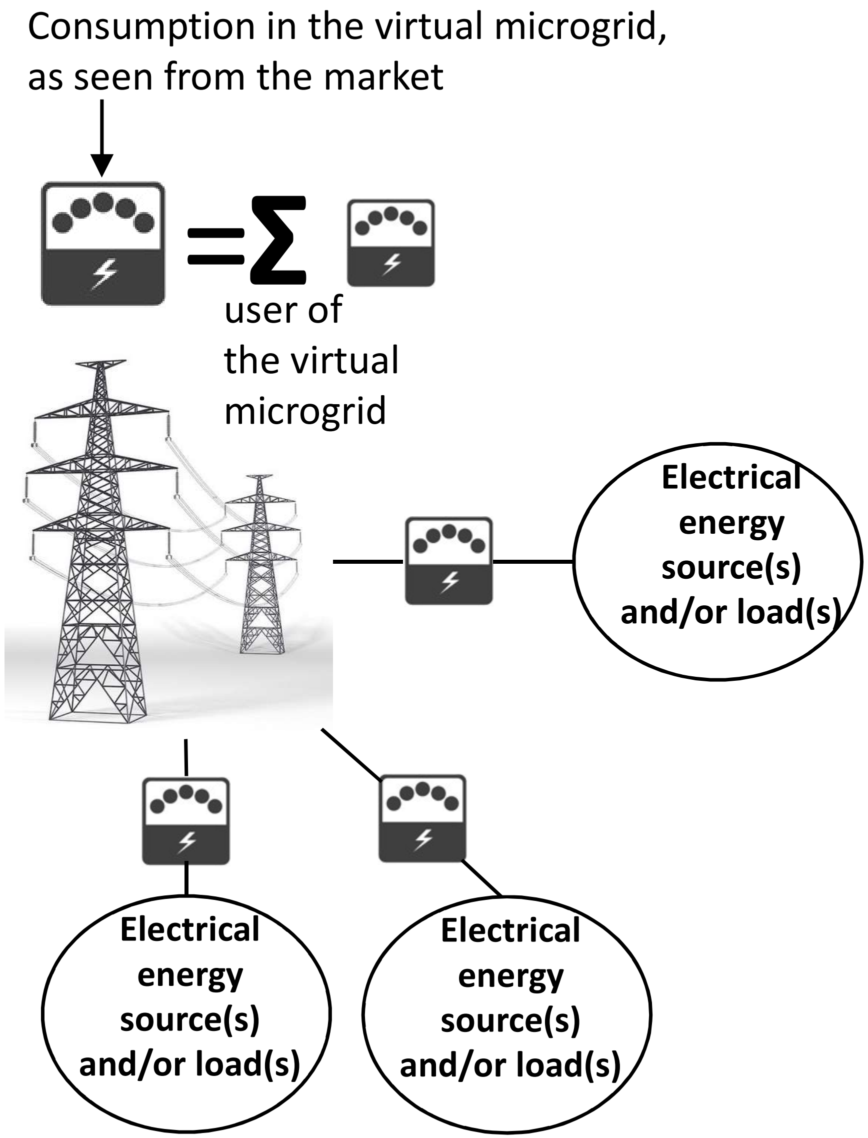


Model 3 and 4: The single-user virtual microgrid

From the market point of view, the consumption of the 'single user' is equal to the sum of the consumption measured by the three meters, for every market period.



1. If the user is located close to generation/storage (Model 3), it may have beneficial effects on the network to increase self-consumption in the virtual microgrid.
2. Model 3 tested in Belgium. Known as E-Cloud. Big storage generation/storage devices in an E-Cloud but they are divided up among several single users.
3. Standard regulations do not allow for the creation of virtual microgrids.



Model 5 and 6:The multi-user virtual microgrid

1. May be very helpful to integrate renewables if users are located close to each other (Model 5).

2. Difficult to have multi-user virtual microgrids that can operate in an autonomous way.

3. Easier to create a multi-user virtual microgrid in one area of a network than a multi-user microgrid. In a multi-user microgrid, one single potential user may block the creation of the microgrid.

Model 5 (not 6) authorized in France?

A piece of French regulation « authorizing » the creation of multi-user virtual microgrids for which all the users are connected to the same low-voltage feeder (Model 5):

Ordonnance n° 2016-1019 du 27 juillet 2016 relative à l'autoconsommation d'électricité

NOR: DEVR1615431R

ELI: https://www.legifrance.gouv.fr/eli/ordonnance/2016/7/27/DEVR1615431R/jo/texte

Alias: https://www.legifrance.gouv.fr/eli/ordonnance/2016/7/27/2016-1019/jo/texte

« Chapitre V

« L'autoconsommation

« Art. L. 315-1.-Une opération d'autoconsommation est le fait pour un producteur, dit autoproducteur, de consommer lui-même tout ou partie de l'électricité produite par son installation.

« Art. L. 315-2.-L'opération d'autoconsommation est collective lorsque la fourniture d'électricité est effectuée entre un ou plusieurs producteurs et un ou plusieurs consommateurs finals liés entre eux au sein d'une personne morale et dont les points de soutirage et d'injection sont situés sur une même antenne basse tension du réseau public de distribution.

« Art. L. 315-3.-La Commission de régulation de l'énergie établit des tarifs d'utilisation des réseaux publics de distribution d'électricité spécifiques pour les consommateurs participants à des opérations d'autoconsommation, lorsque la puissance installée de l'installation de production qui les alimente est inférieure à 100 kilowatts.

« Art. L. 315-4.-La personne morale mentionnée à l'article L. 315-2 organisatrice d'une opération d'autoconsommation collective indique au gestionnaire de réseau public de distribution compétent la répartition de la production autoconsommée entre les consommateurs finals concernés.

« Lorsqu'un consommateur participant à une opération d'autoconsommation collective fait appel à un fournisseur pour compléter son alimentation en électricité, le gestionnaire du réseau public de distribution d'électricité concerné établit les index de consommation de l'électricité relevant de ce fournisseur en prenant en compte la répartition mentionnée à l'alinéa précédent.

PS: Sorry for those of you who do not speak French

Model 7: EV – Car not always charged at home

A few comments on how this model could affect the electrical industry:

1. May help domestic microgrids with PV and batteries to go fully off grid. How? During a sunny period the owner of the (good-sized) domestic microgrid would charge its EV at home. Otherwise, he would charge it at another location. This would help the fully off-grid microgrid to handle the inter-seasonal fluctuations of PV energy.

2. The EVs could be charged immediately adjacent to renewable generation units where electricity costs may be much lower than retailing cost for electricity. Two numbers: retail price for electricity in Belgium: 250 €/MWh. Cost of PV energy in Belgium: less than 100 €/MWh.
May also help to avoid problems on distribution networks caused by renewables.

An App-based Algorithmic Approach for Harvesting Local and Renewable Energy Using Electric Vehicles

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Keywords: Multi-agent System, Electric Vehicles, Renewable Energy

Abstract: The emergence of electric vehicles (EVs), combined with the rise of renewable energy production capacities, will strongly impact the way electricity is produced, distributed and consumed in the very near future. This position paper focuses on the problem of optimizing charging strategies for a fleet of EVs in the context where a significant amount of electricity is generated by (distributed) renewable energy. It exposes how a mobile application may offer an efficient solution for addressing this problem. This app can play two main roles. Firstly, it would incite and help people to play a more active role in the energy sector by allowing photovoltaic (PV) panel owners to sell their electrical production directly to consumers, here the EVs' agents. Secondly, it would help distribution system operators (DSOs) or transmission system operators (TSOs) to modulate more efficiently the load by allowing them to influence EV charging behaviour in real time. Finally, the present paper advocates for the introduction of a two-sided market-type model between EV drivers and electricity producers.

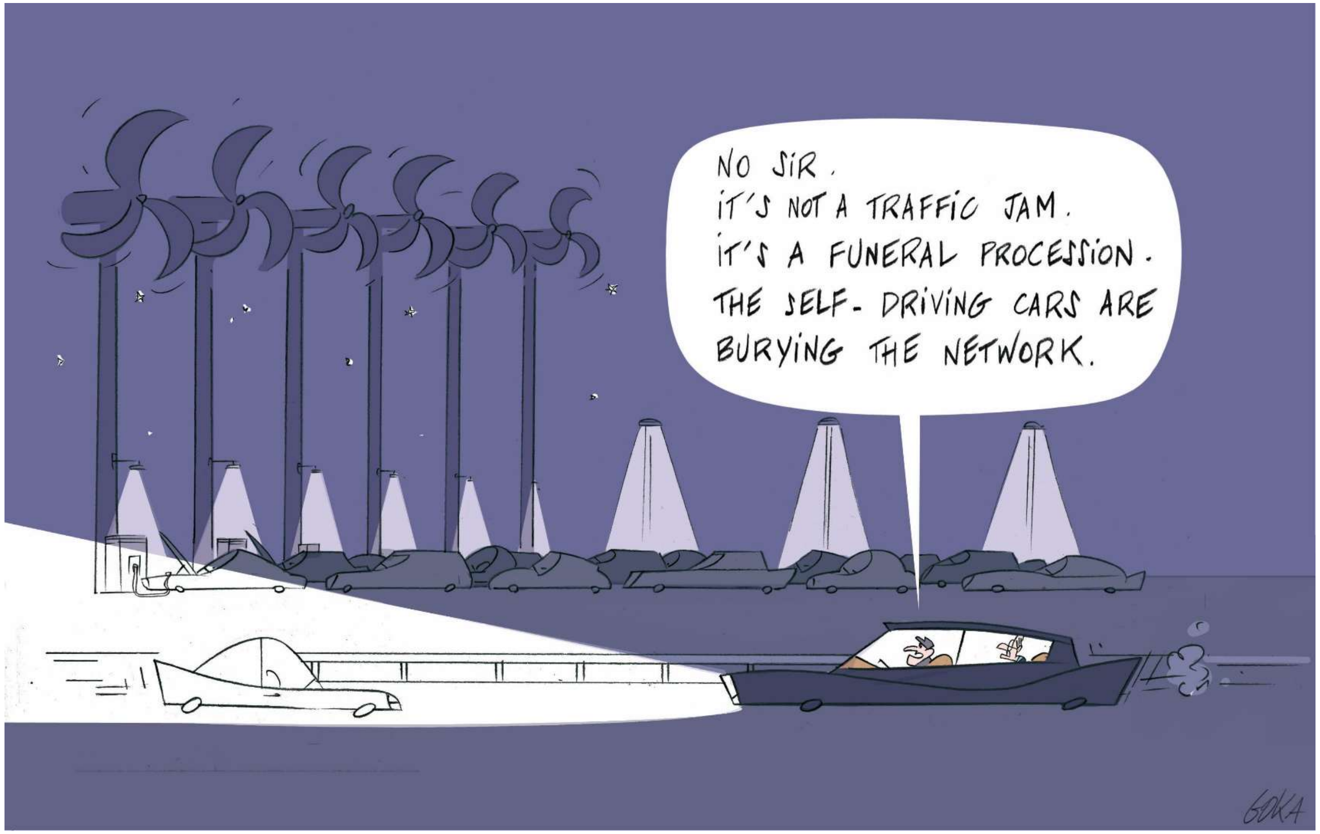
Model 8: V2G – Vehicle discharging only at home

1. Could allow for the creation of fully off-grid microgrids that do not have their own generation capacities.

2. Self-driving EVs could, during the night, autonomously bring back electricity to the house. This electricity could be stored in the batteries of the house.

Model 9: V2G – Car as a substitute for the utility grid

EV charging could be carried out next to electricity sources at a cheap price. Afterwards, EVs could directly sell their electricity (without using the grid) to any electricity consumer at a higher price. As such, they will act as a true competitor for the utility grid.



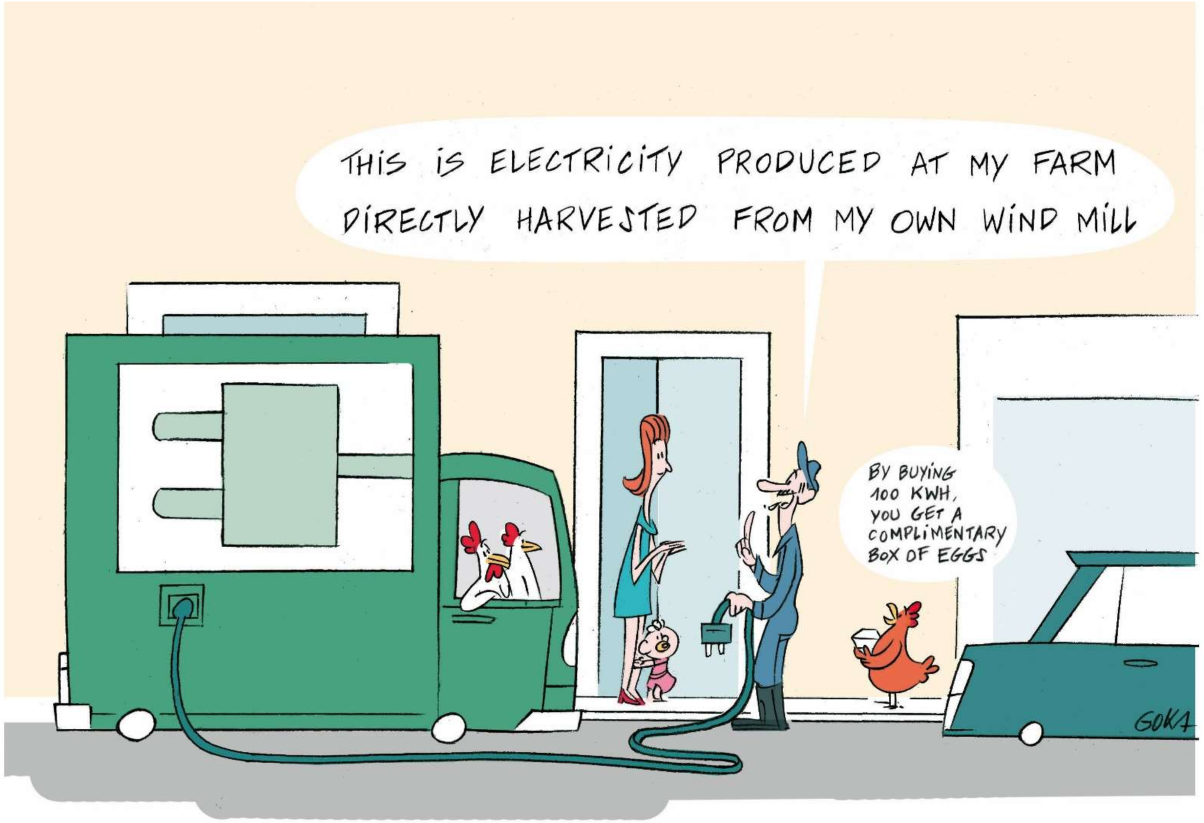
Model 9 may become very successful with the rise of self-driving cars for two main reasons:

1. No one will be needed to drive the car to collect electricity and deliver it to the electricity consumer.

2. Fleets of self-driving cars will not be used during the night to transport passengers. Using them during the night as a substitute for the electrical network will therefore accrue very little additional capital costs.

Model 10: No EV battery. Delivery of electricity using storage devices

1. Many producers of electrical energy could start delivering electricity directly to home batteries through the use of mobile batteries.
2. Delivery system may be significantly cheaper than the cost of running distribution networks in rural areas.
3. Biggest competitor of Model 10: Model 9.

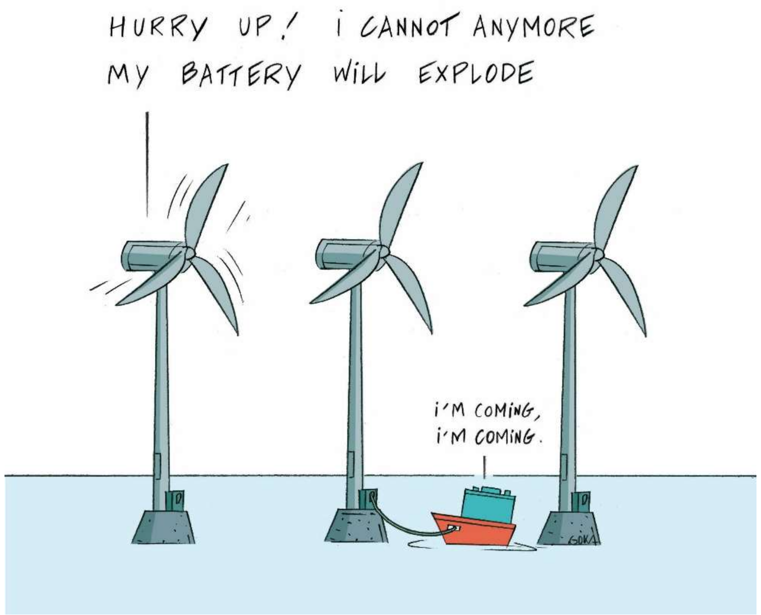


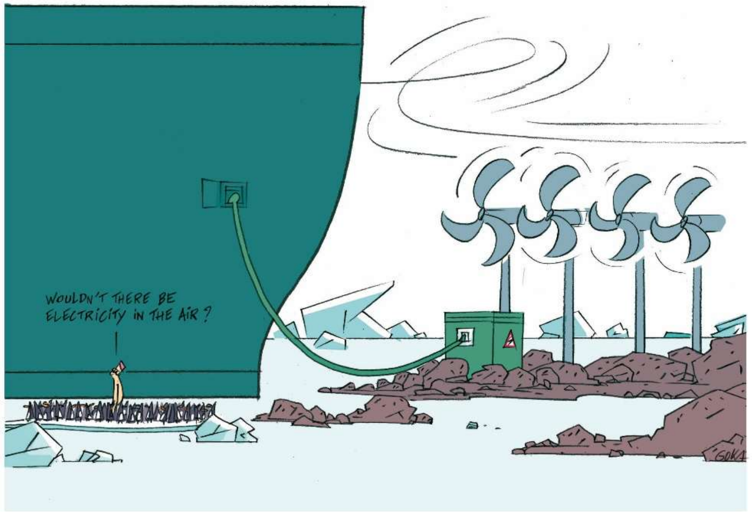
Model 11: No EV battery. Storage devices as a substitute for the transmission grid

1. The off-shore grid could be replaced by a system of boats with batteries.

2. Renewable energy collected at remote locations, such as the East coast of Greenland for example, where there is ample wind, could be brought back to consumption centres with using large ships full of batteries. Model is competitive with undersea cables once cost of batteries drops below 50 €/kWh.

3. Model 11 could be combined with a model based on electricity distribution with batteries.



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Watch a French version of this conference :

https://www.youtube.com/watch?v=QP2230dhYbg