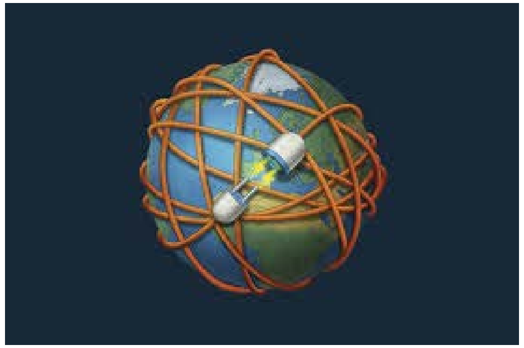
The Global Grid



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Energy needs of the planet: a few numbers

Yearly world energy consumption (2016): 155,000 TWh

Average energy needs per person per day: 56 kwh

Energy consumption the US: around 250 kwh/person/day

How to generate 155,000 TWh of green energy in a country with the same weather conditions as in Belgium?

7.8 million Enercon-126 wind turbines. This corresponds to a wind farm covering a land surface of 5.9 million km^2.

Data: Maximum power of an Enercon-126 wind turbine = 7.58 MW, load factor= 30%. A wind farm can collect around 3 W/m^2 in Belgium. Size of India 3,287 million km^2.

884,703 km^2 of PhotoVoltaic (PV) panels. This corresponds to an installed capacity of 176,940 GW.

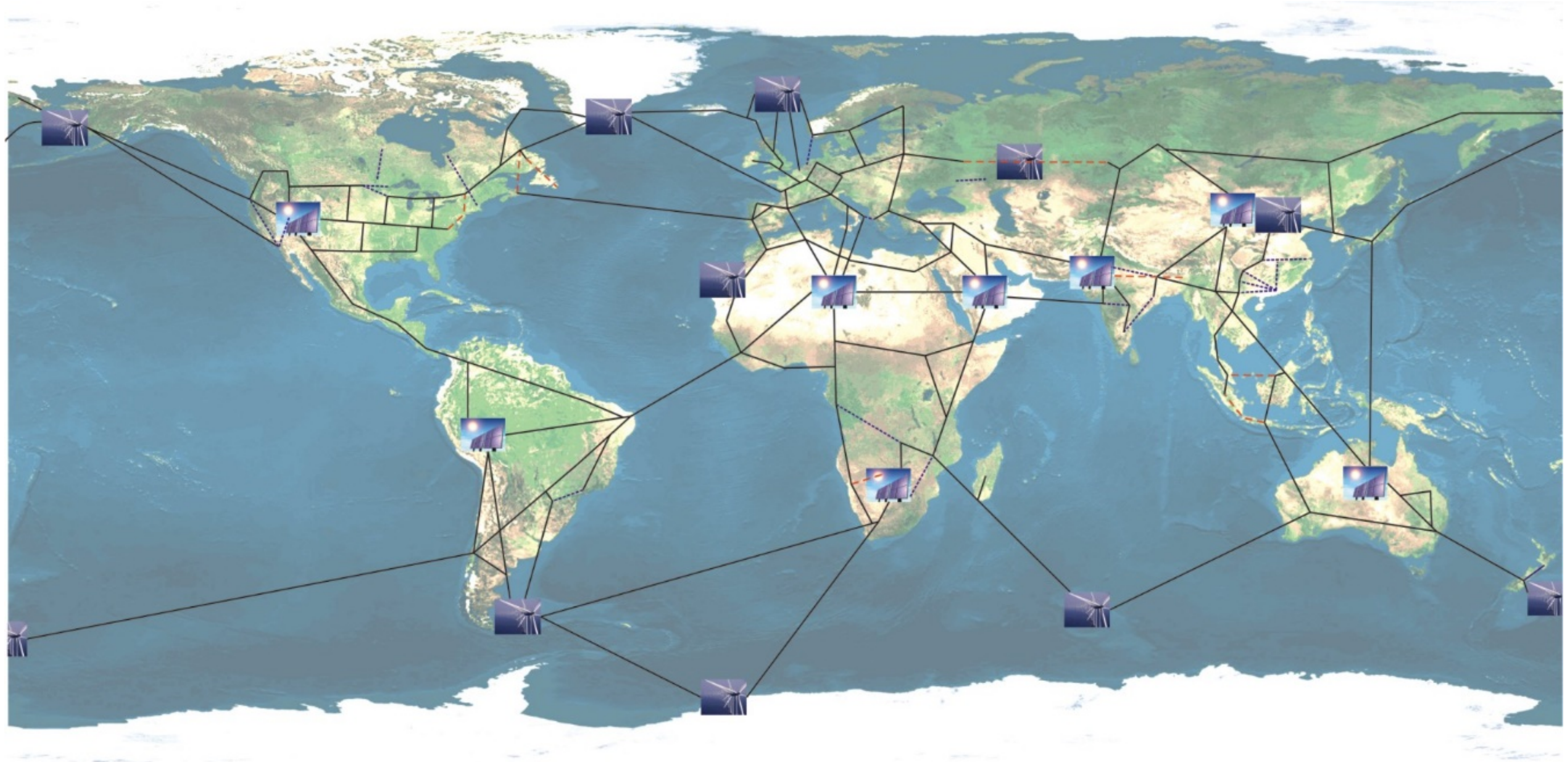
Data: Solar irradiance = 100 W/m^2. Efficiency of PV panels 20%. Load factor of PV panels: 10%. Size of France: 643 801 km^2

What about storage needs?

15 billion of Tesla Powerwall 2 batteries would be needed for addressing the storage needs for daily fluctuations of PVs.
Price tag: $90,000 billion.
Problem of interseasonal fluctuations of PV much worse in terms of storage needs.

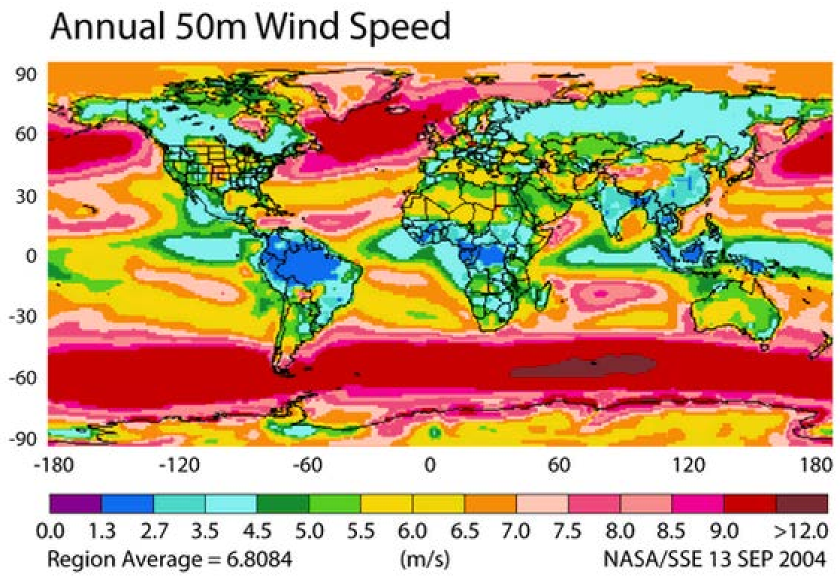
Data: We compute the storage needs caused by daily fluctuations of PV installations by assuming that all the energy - 155000 TWh/year - is generated by PV panels. We make the following assumptions: (i) The load will be constant (ii) PV sources generate a constant power from 7 am until 7 pm and no power outside those hours. (iii) Efficiency of 1 for storage (iv) Storage capacity of a Tesla Powerwall 2: 14 kwh (v) Price of a Tesla Powerwall 2 with installation: $6000 (vi) World GDP in 2014: $77,868 billion.

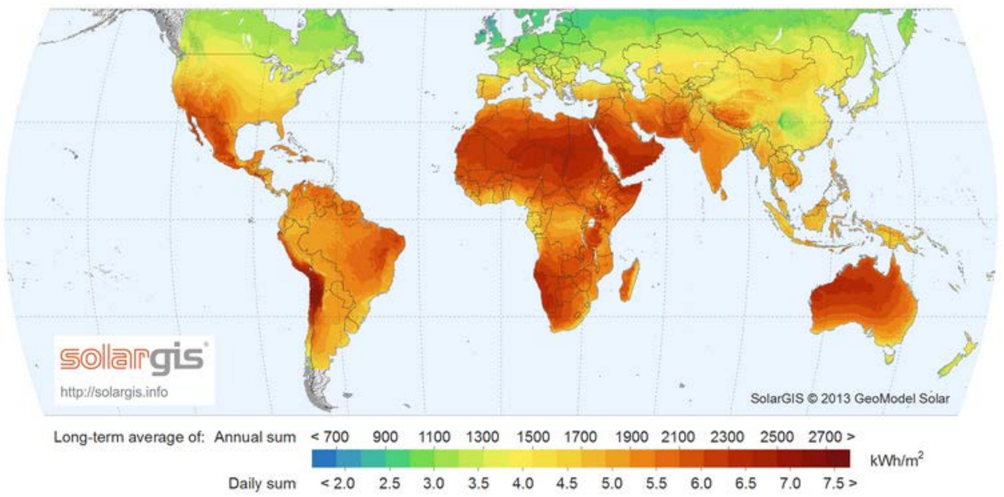
Why a global (green) grid network?



A global (green) grid is an electrical network spanning the whole planet and connecting together the world's consumers and producers of electricity. Its backbone would be made of (very long) High Voltage Direct Current (HVDC) links.

With respect to examples previously studied, a global green grid could:





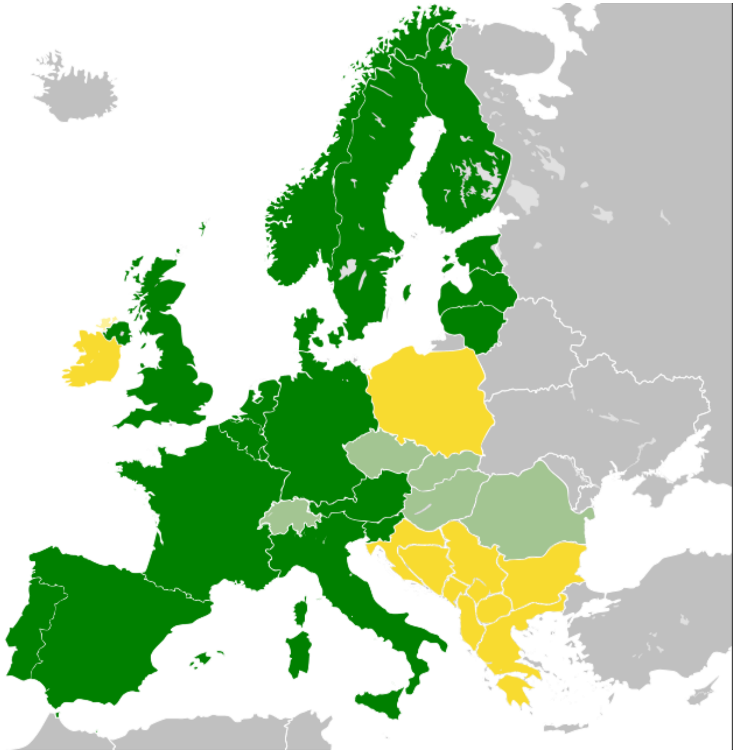
1. Reduce the number of windmills to be installed by a factor of 4 to 6 (power of a windmill is a cubic function of the wind speed)

2. Reduce the number of PV panels to be installed by a factor of 2 to 3.

3. Reduce the storage needs to almost zero (natural smoothing of the daily/seasonal variation of the load/green energy production at planet level)

Global grid and global market for energy: a process in the making

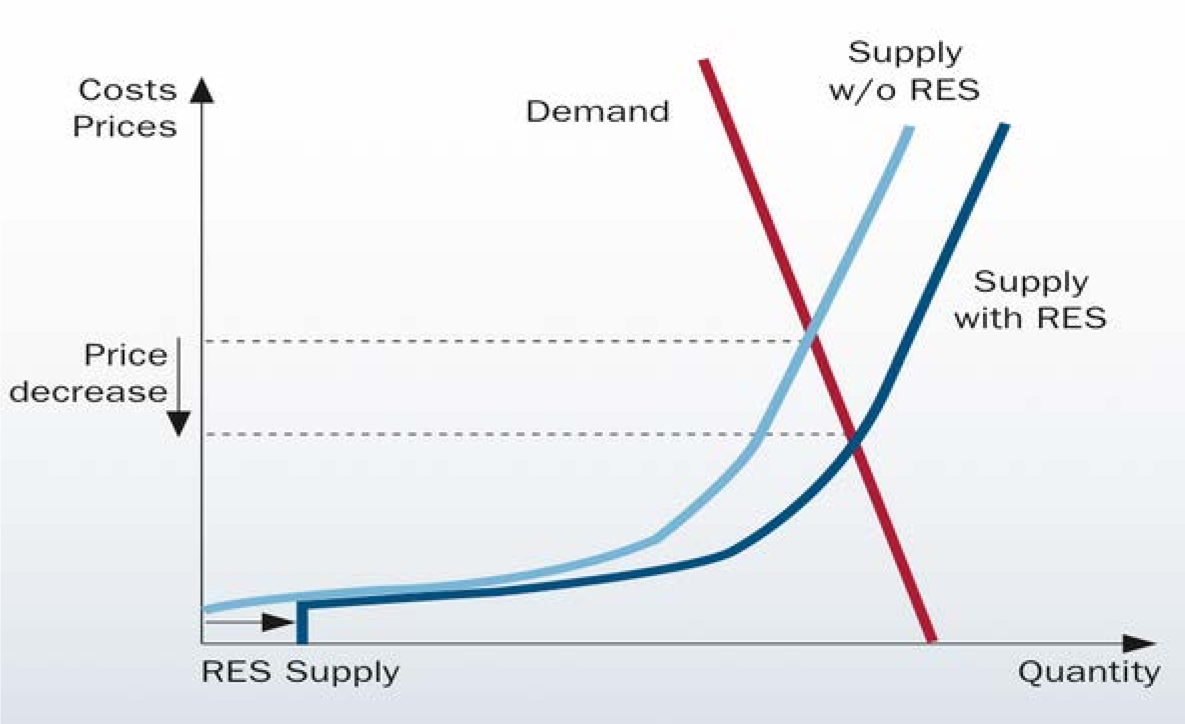
Year 1884. Pearl Street Station and its DC electrical network served 508 customers and a total of 10,164 lamps. Considered as being the first electrical network.



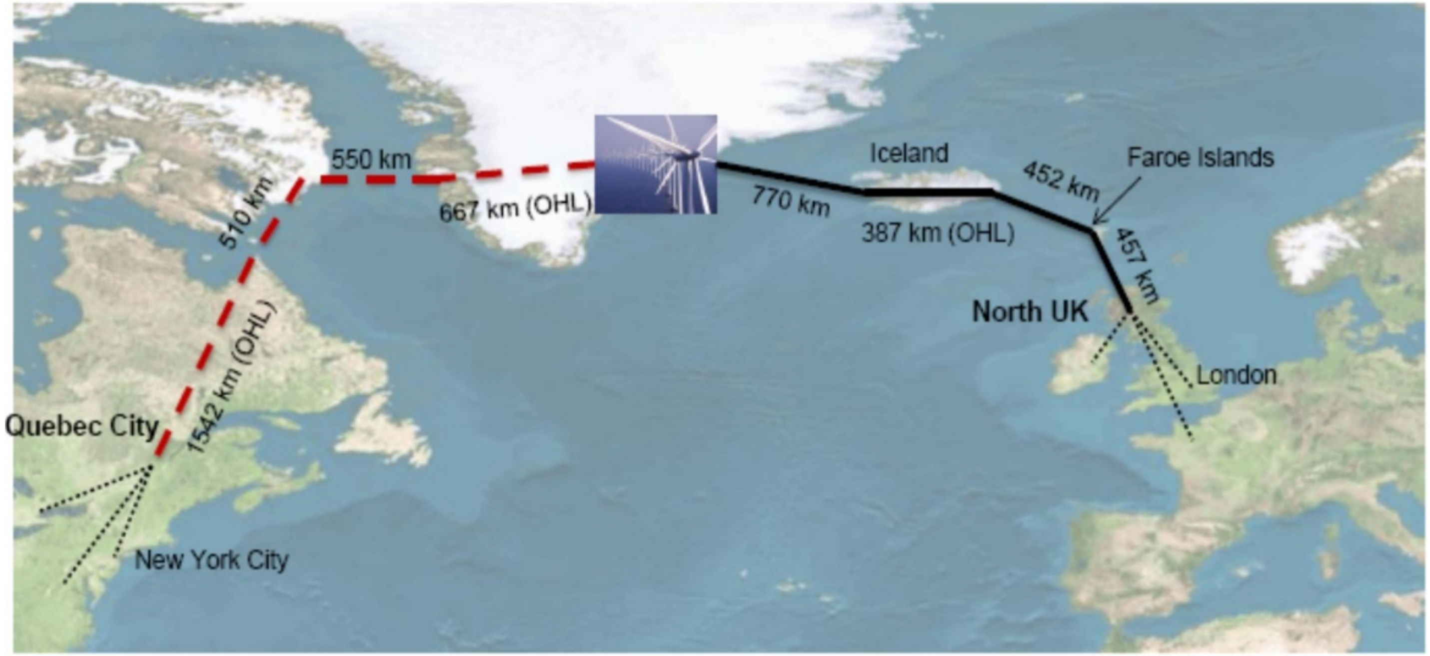
Year 2016. Dark green: Countries forming the **EU day-ahead electricity market** - Light green: Joining soon Yellow: Nothing decided yet but likely to join. Trading of electricity also possible between the EU and, e.g., Morocco, Turkey and Ukraine.

Barriers to the emergence of a global grid

<u>**Barrier #1**</u> **Disfunctioning electricity markets**. Wholesale markets for electricity do not give the right investment signals to private investors to develop this global grid infrastructure in a non-subsidized way. Main reason: when a high-percentage of energy is produced by zero marginal cost electricity sources, electricity market prices drop.



The figure illustrates the price decrease in electricity caused by a supply in renewable energy.
Underlying question: How to create a non-subsidised (worldwide) electricity market that synthesizes a price signal that will foster investment in renewable energy?



Example: Building a 5 GW wind farm on the East coast of Greenland as well as the grid infrastructure for bringing this energy to Europe would lead to wind energy that is much cheaper than that generated by wind farms in mainland Europe.
However, no investor will ever make such an investment with existing electricity market designs and national subsidy policies for renewable energy.

A strategy to overcome **barrier #1**

Stop subsidizing renewable energy production and instead force retailers to sell a certain percentage of renewable energy that could come from any country in the world.

Additional advantage: with current subsidy policies and market designs, taxpayers of one country can end up subsidizing renewable energy that is subsequently bought at a very cheap price by other countries.

Barrier #2 **The geopolitical fear.** Many countries dream of energy independance and do not want to be at the mercy of foreign powers for their renewable energy supply as they have been with oil, gas, etc.

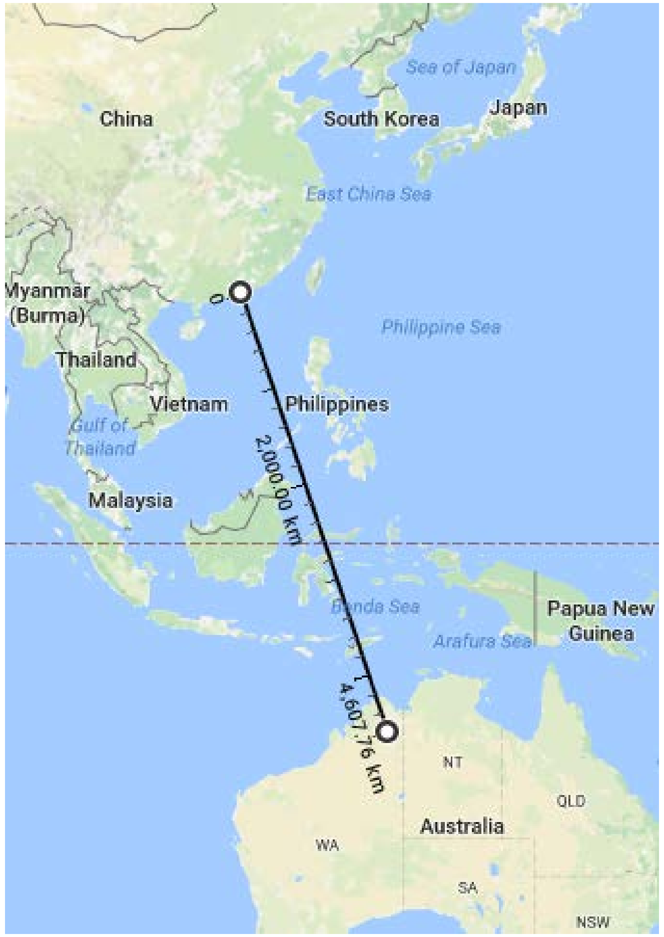
Proven Reserves (millions of barrels)	U.S. EIA (start of 2015)[1]		OPEC (end of 2015)[2]	
Country	Rank	Reserves	Rank	Reserves
Venezuela (see: Oil reserves in Venezuela)	1	298,350	1	300,878
Saudi Arabia (see: Oil reserves in Saudi Arabia)	2	268,289	2	266,455
Iran (see: Oil reserves in Iran)	4	157,800	3	158,400
Iraq (see: Oil reserves in Iraq)	5	144,211	4	142,503
Kuwait (see: Oil reserves in Kuwait)	6	104,000	5	101,500
UAE (see: Oil reserves in the United Arab Emirates)	7	97,800	6	97,800
Russia (see: Oil reserves in Russia)	8	80,000	7	80,000
Libya (see: Oil reserves in Libya)	9	48,363	8	48,363
Nigeria (see: Oil reserves in Nigeria)	11	37,070	9	37,062
United States (see: Oil reserves in the United States)	10	39,933	10	36,685

Strategies to overcome **barrier #2**

1. Diversify supply of renewable energy. Contrary to oil supplies, there are many places in the world with abundant renewable energy sources.
2. Make sure that the design/control of the large interconnections and the investments are such that countries cannot gain an excess of geopolitical power in this global grid environment.

<u>Barrier #3</u> The technological fears.

(i) No real experience in the building gigantic HVDC links.



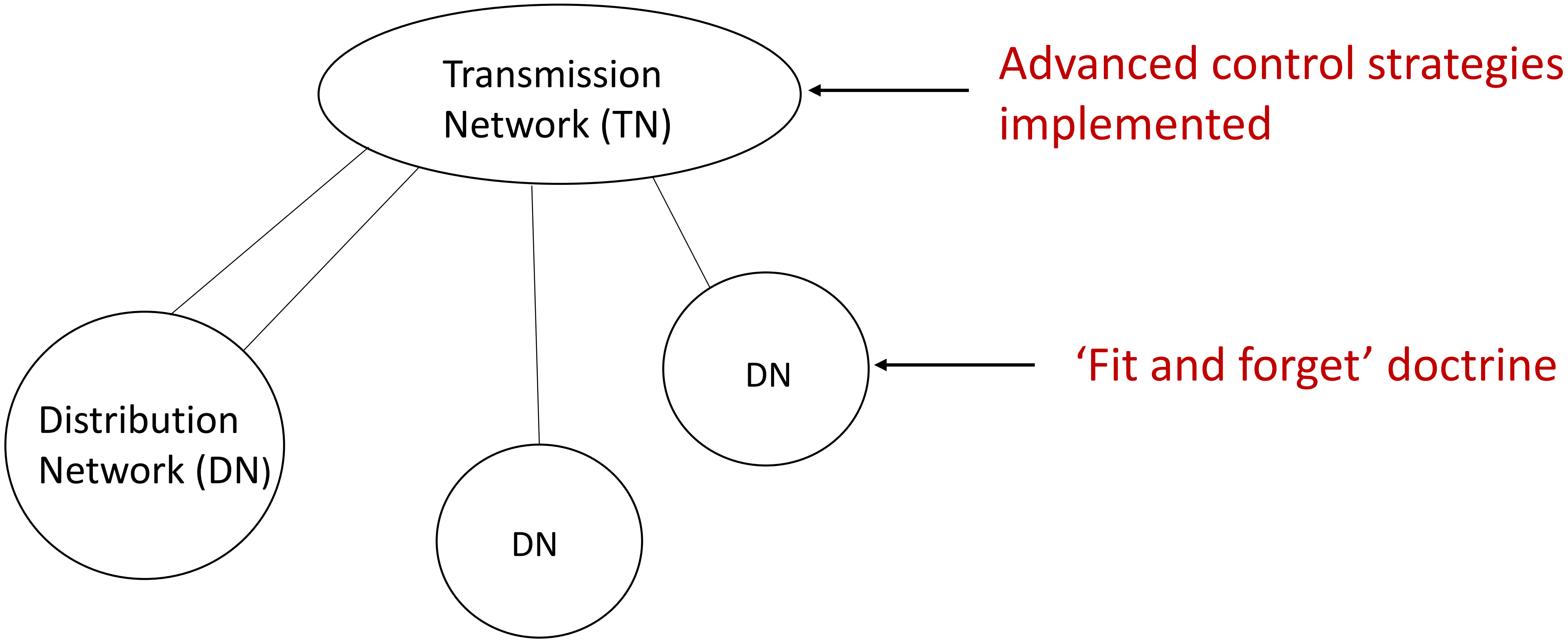
Building an electrical connection between China and the Australian deserts could help China to get access to cheap PV energy, *especially during its winter*.

The length of the interconnection would be around 4,600 km. If operated at 1000 kV, the electrical losses for sending the power to China would be less than 15%.

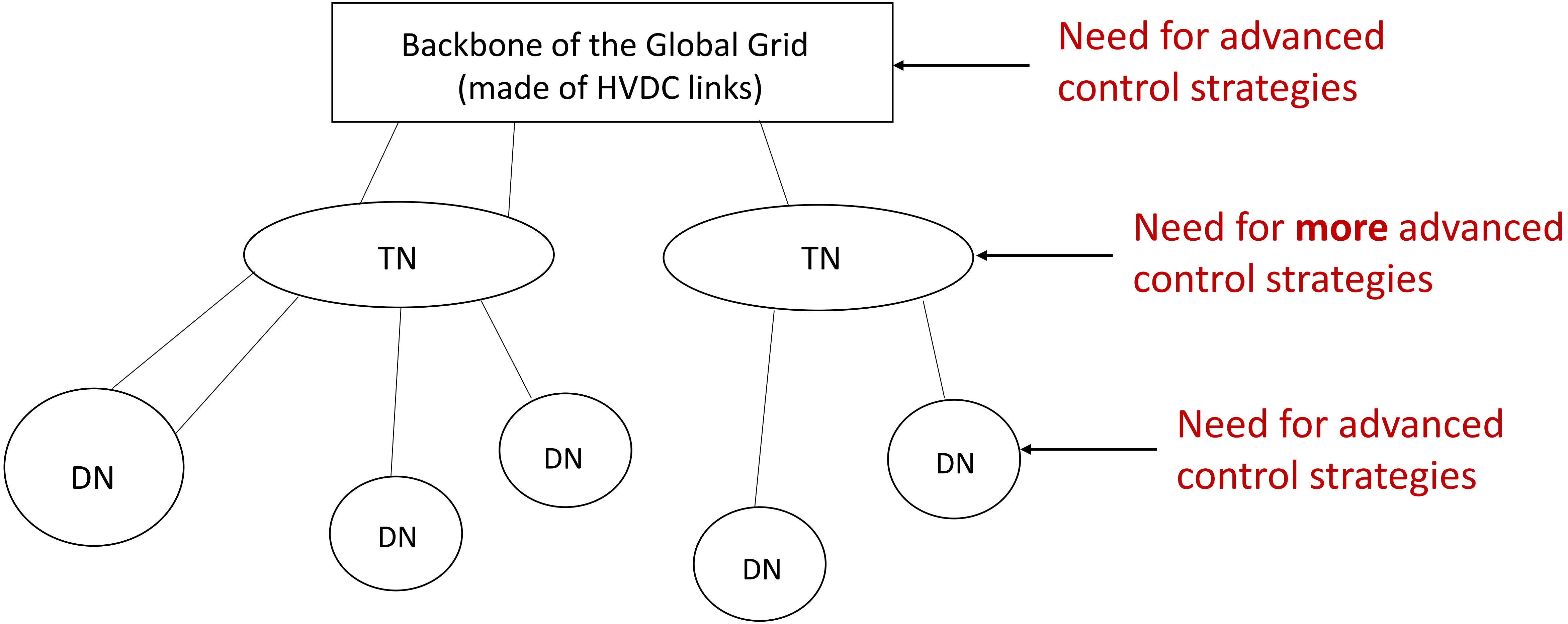
The longest undersea cable in operation right now is the NorNed, which connects Norway to the Netherlands. It has a length of 580 km and is operated at ±450 kV.

(i) Complexity of operating/controlling a global electrical grid.

The grid before the quest for renewable energy:



The grid as it is becoming:



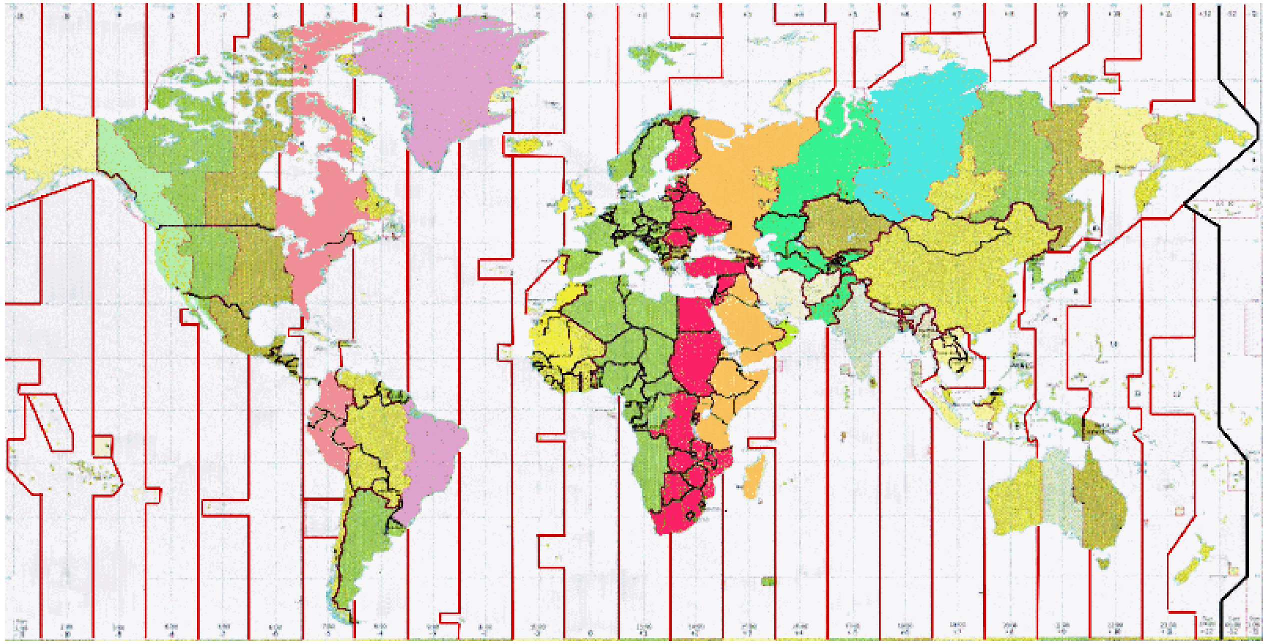
Supporting flagship projects for accelerating the building of the global grid.

A few more flagship projects:

Project #1: Harvesting wind energy in the southern part of South America, which is very windy, and using this to supply the consumption centers on the continent.

A wind farm in the southern part of South America can generate 13 W/m^2, against 3 W/m^2 in mainland Europe. The total consumption of electricity in Brazil, which is around 500 TWh/year, could be generated by covering the red area on this map with wind mills.

Project #2: An electrical connection between the middle East and China for smoothing out the daily PV fluctuations.



Five time zones separate the Middle East and East China.

[A] At around midday in the Middle East it could start sending its excess of solar energy production to East China, where the evening had begun.

[B] East China would send its excess of solar energy to the Middle Eastern to meet the morning surge in demand.

Project #3: 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 3000km 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).

More about the Global Grid at:

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