The Global Grid

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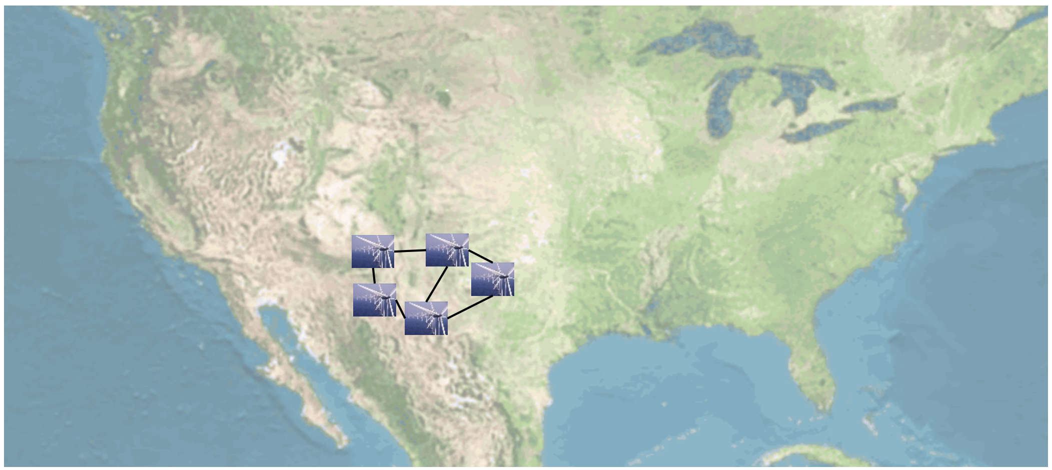
Towards a 100% Renewable Energy Future

Paris agreement on climate change:

- EU to reduce greenhouse gas emissions (GHG) at least 40% from 1990 levels in 2030
- US to reduce CO2 emissions by 32% from 2005 levels by 2030
- China committed to peak GHG by 2030, with the intention begin to cap even earlier (2020)
- Studies for a 100% RES* energy production

*RES: Renewable Energy Sources

Interconnecting RES increases reliability in supply



- Interconnection of 19 wind farms in Midwest-US
- Area of 850 x 850 km

- “On average, 33% of yearly averaged wind power can be used with the same reliability as a conventional power plant.”

(Archer and Jacobson, 2007)

Interconnections decrease the need for balancing power

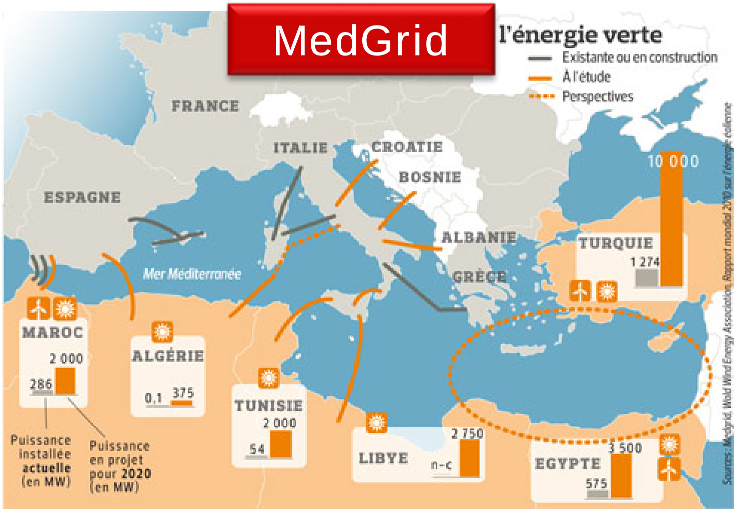
- Fully renewable European system

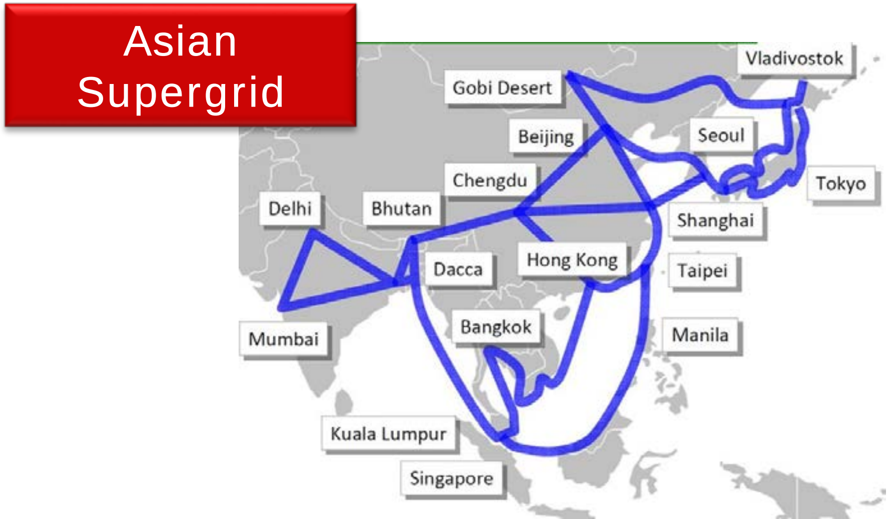
- Interconnector capacities 5.7x larger
  reduce by 38% the need for balancing energy (~32 GW)

- 32 GW less balancing power (~32 nuclear power plants)

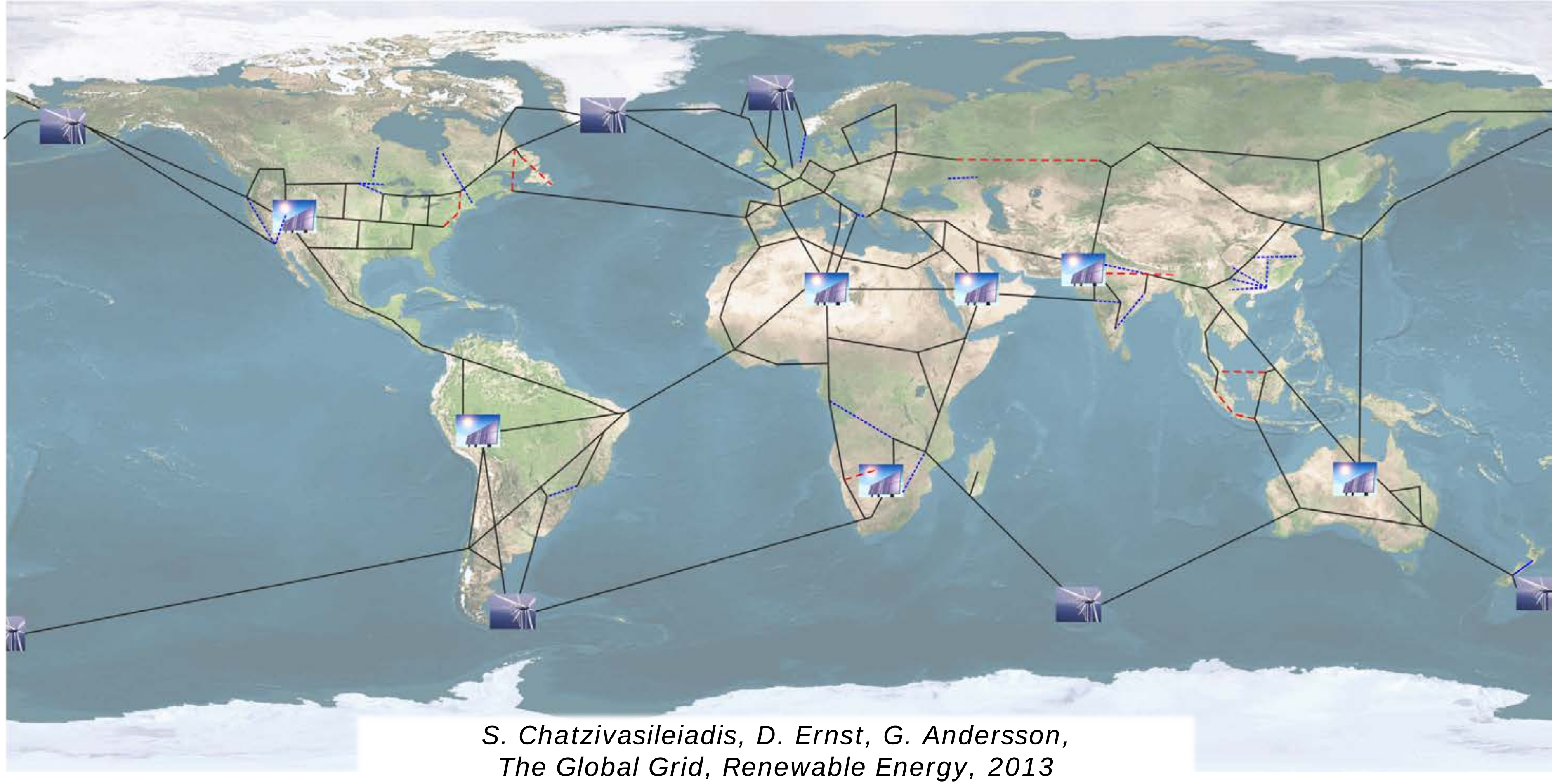
Becker et al (2014)

Cheap RES production over long transmission lines and Supergrids



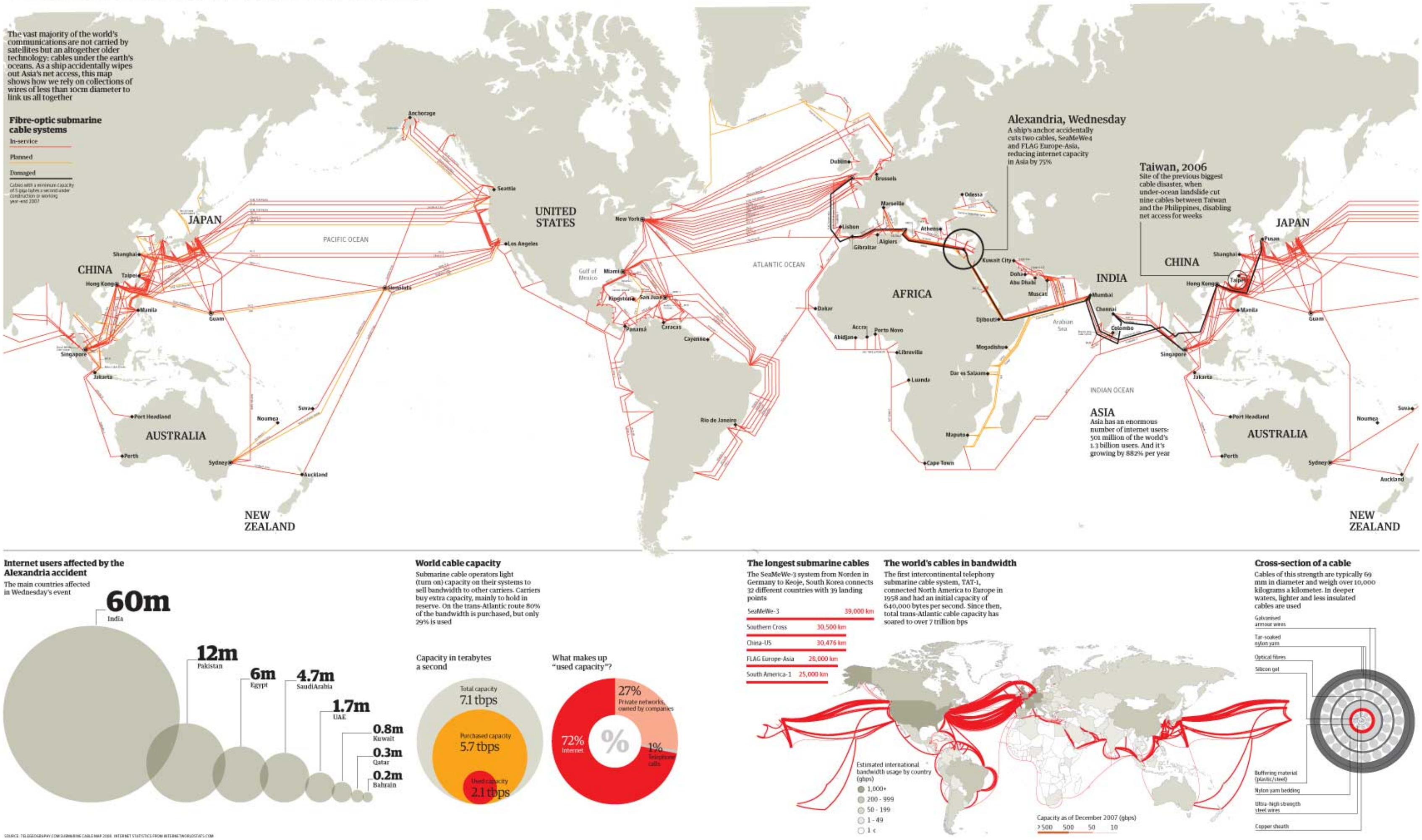


The Global Grid

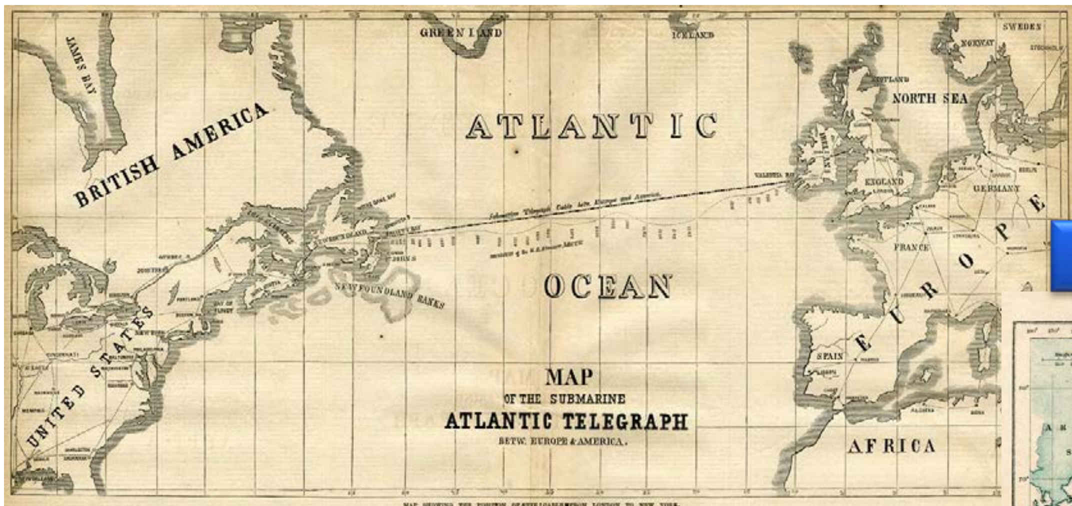


S. Chatzivasileiadis, D. Ernst, G. Andersson,
The Global Grid, Renewable Energy, 2013

The internet's undersea world

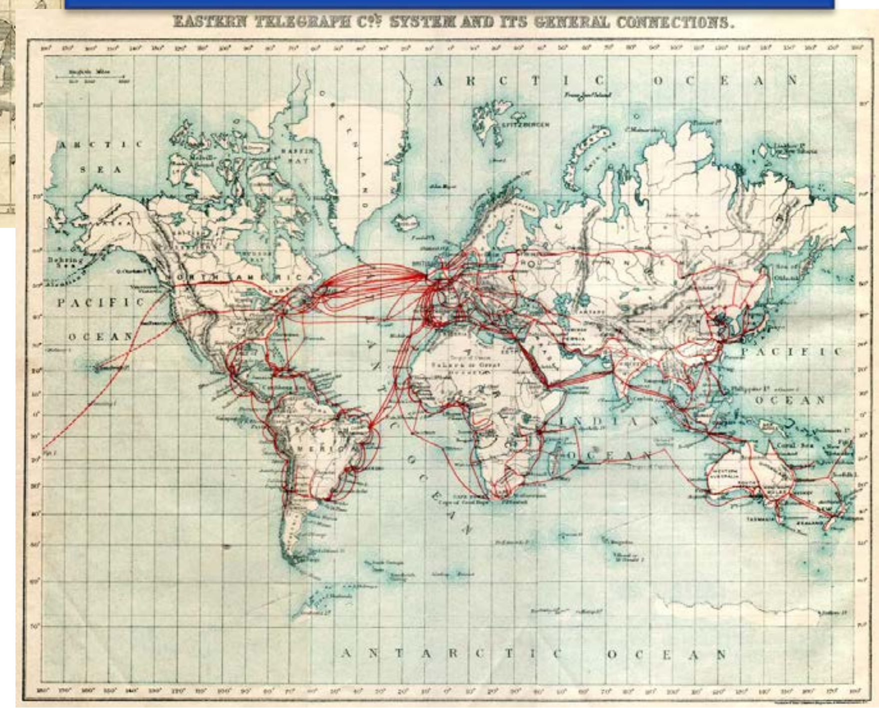


Telegraph 1866-1901



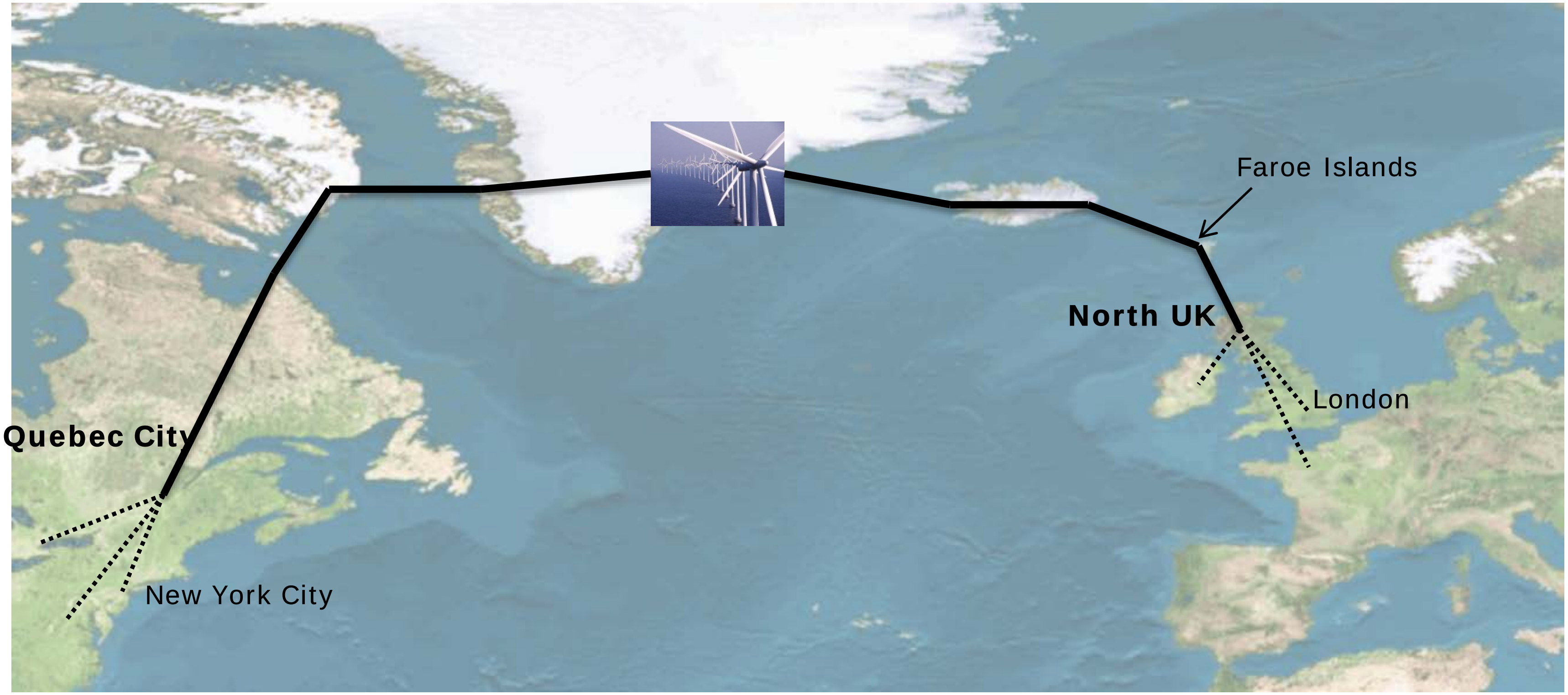
1866: First successful submarine cable

1901: Global Telegraphy Network



A Possible First Step: Wind Farm in Greenland

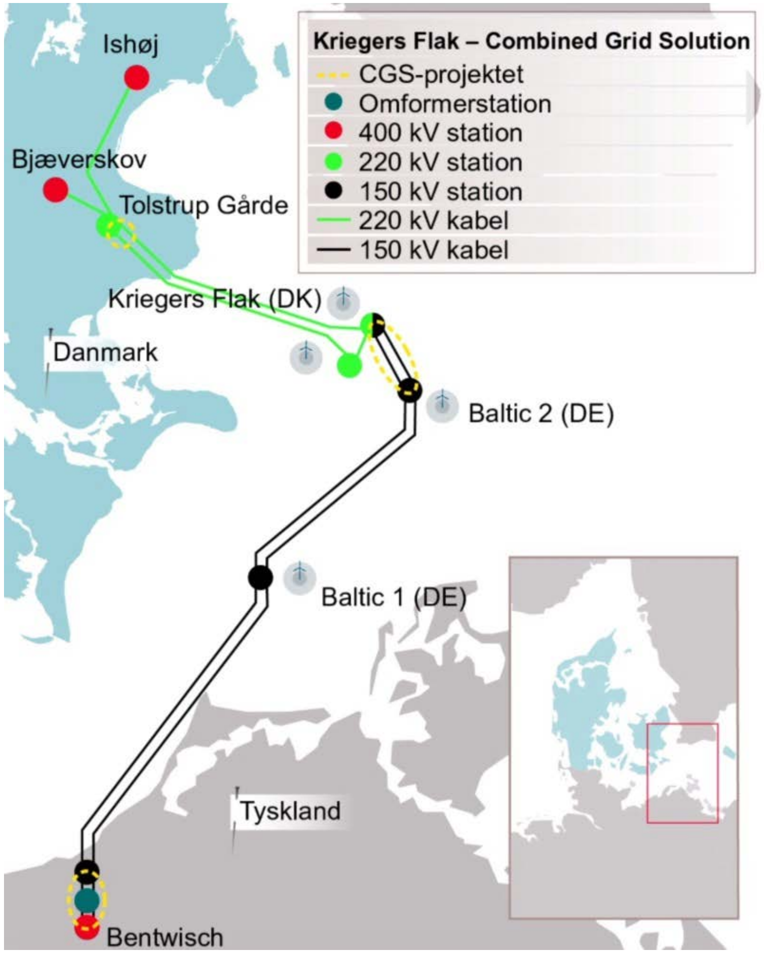
- High winds ~9.0 m/s
- Shallow waters



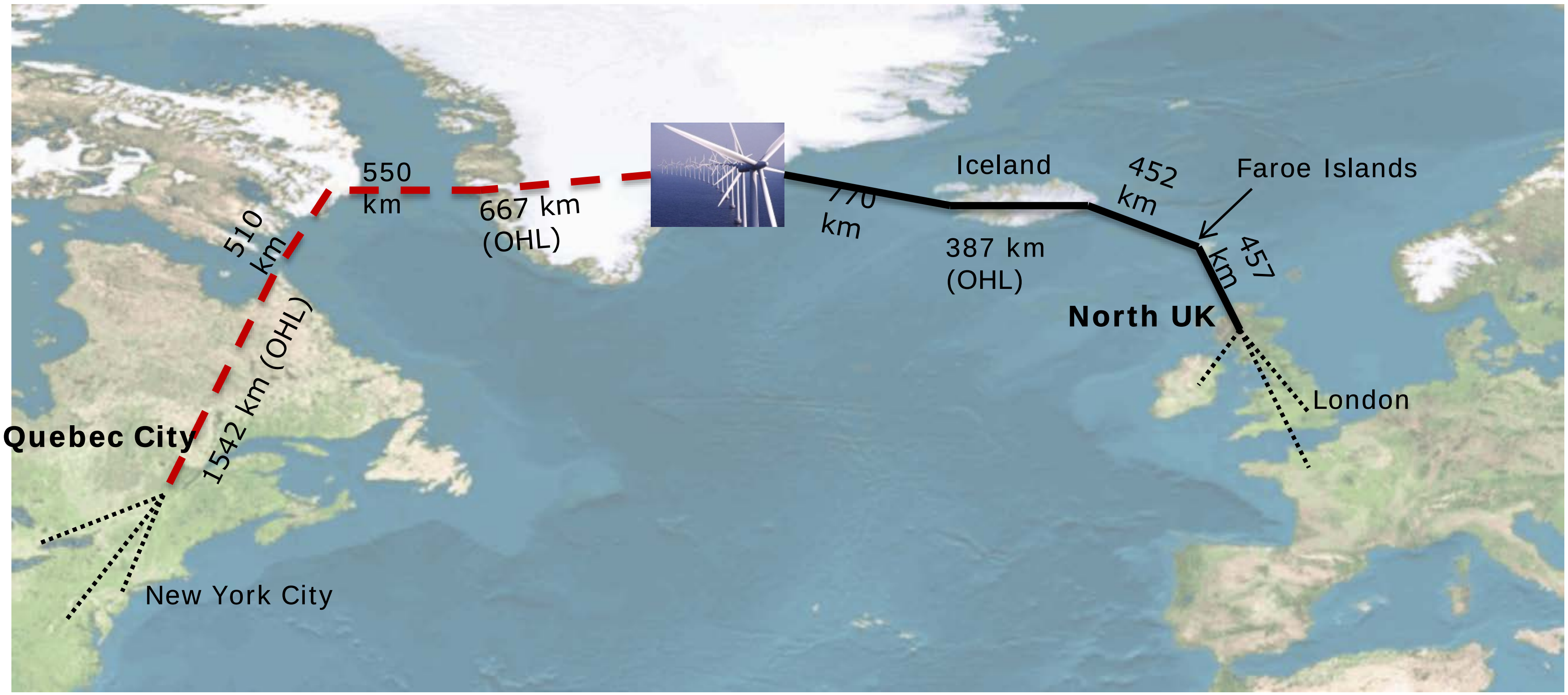
- Sell wind power always at peak prices
- Trade electricity with the remaining line capacity

Kriegers Flak

- Denmark – Germany: AC+HVDC
- **First interconnection in the world** that integrates off-shore wind farms along its path
- 400 MW Back-to-Back HVDC
- Wind Farm Kriegers Flak (DK) : 600 MW
- Wind Farm Baltic (DE) : 336 MW

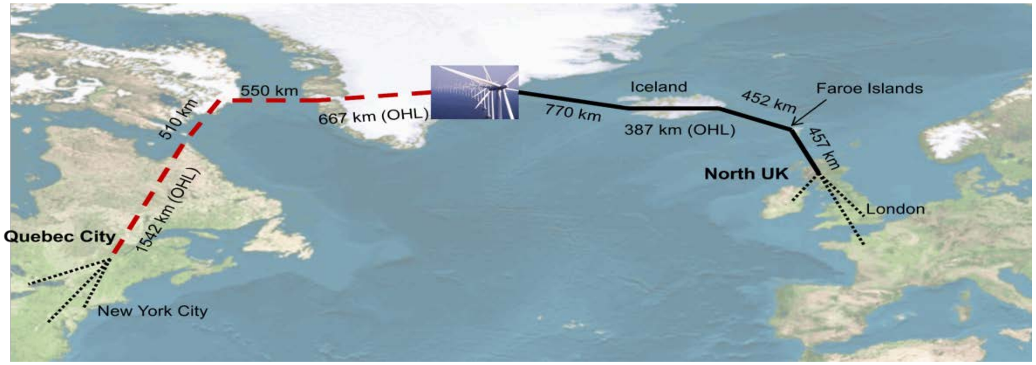


Wind Farm in Greenland



- Greenland – North UK: 2066 km (81% Cable)
- Greenland – Quebec: 3269 km (32% Cable)

Wind Farm in Greenland (3 GW)



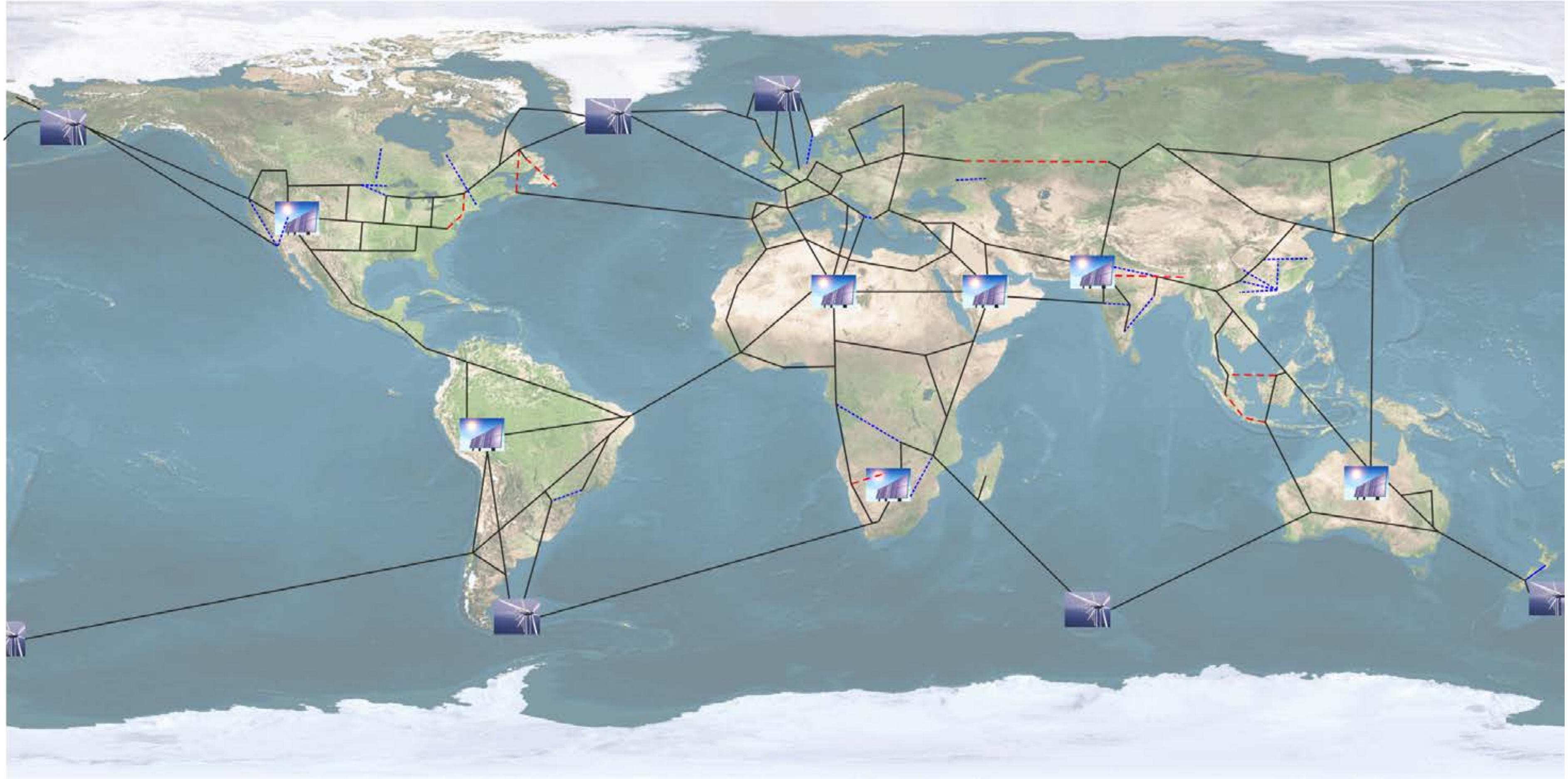
Transmission Route: Europe – USA over Greenland
Total Cable Energy Capacity: 20 TWh / year

	Wind Production (sell at peak prices)	Electricity Trade** (USA ←→ Europe)	
Utilization (% of total time)	~10 TWh (40%)	~6 TWh (30%)	~10 TWh (50%)
Profits Increase	7% – 12%*	24% – 27%	39% – 42%

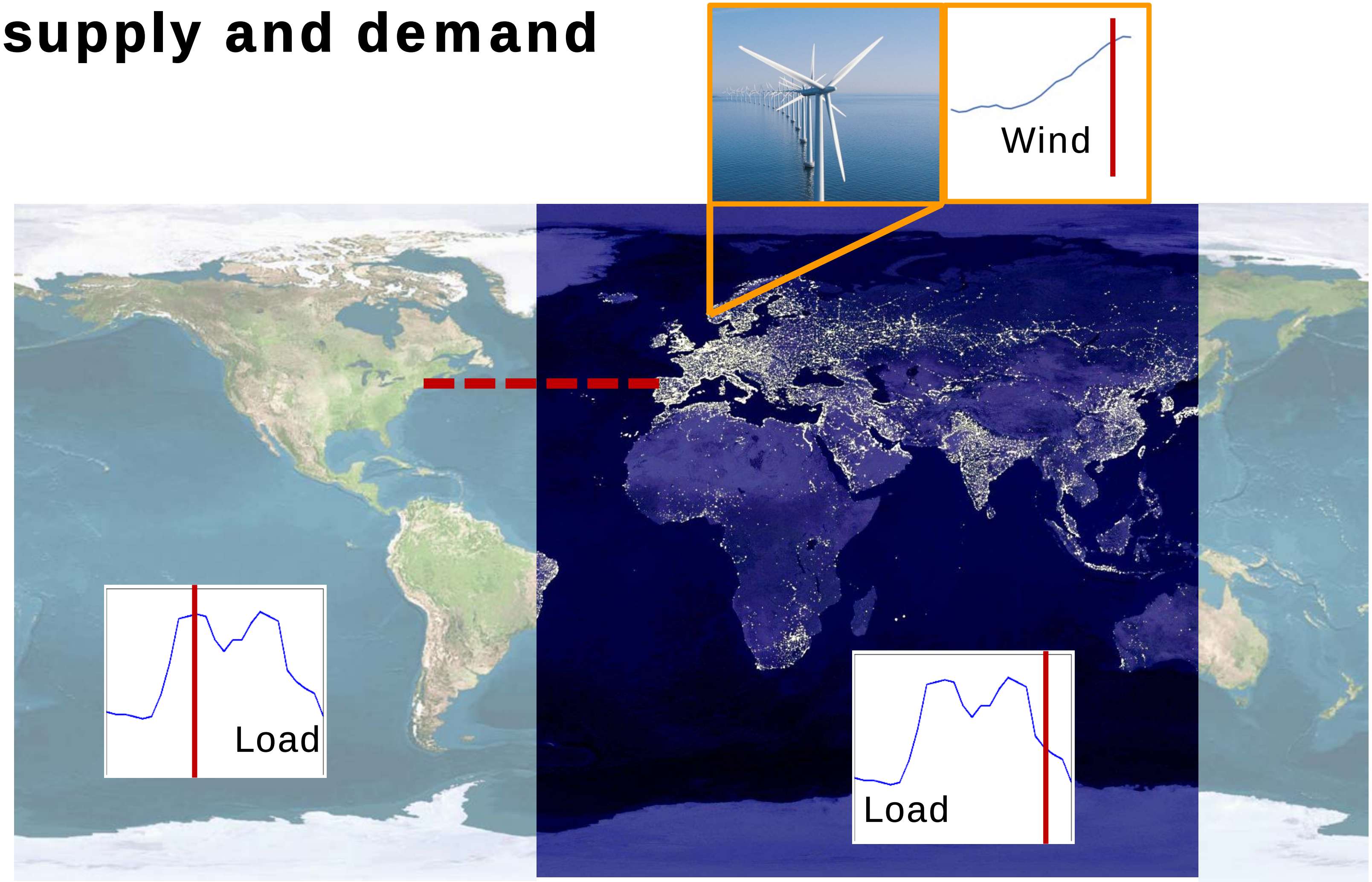
Both options result *independently* to a profitable operation

*Assumption: off-peak-price/peak-price = 50%
**Real Data for 2012: PJM (USA), EPEX (Germany)

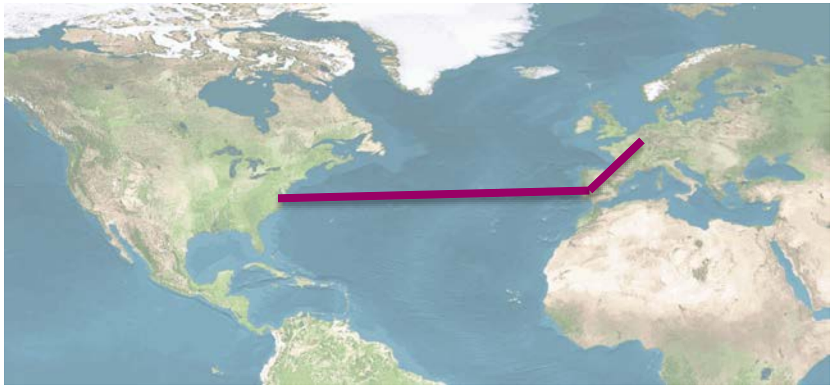
The Global Grid



Smoothing out electricity supply and demand



Electricity trade USA – Germany



- Real price data for 2012
  - EPEX in Germany
  - PJM in the USA
- Losses for an 8000 km route
- Investing in the interconnection (5500 km long cable)

- Amortization period
  - 18-35 years for cable utilization 50% or more

- Costs per delivered kWh
  - Except for the most expensive RES generators, it is more economical for the US to import RES power from Europe than operate its own conventional power plants

Additional Benefits

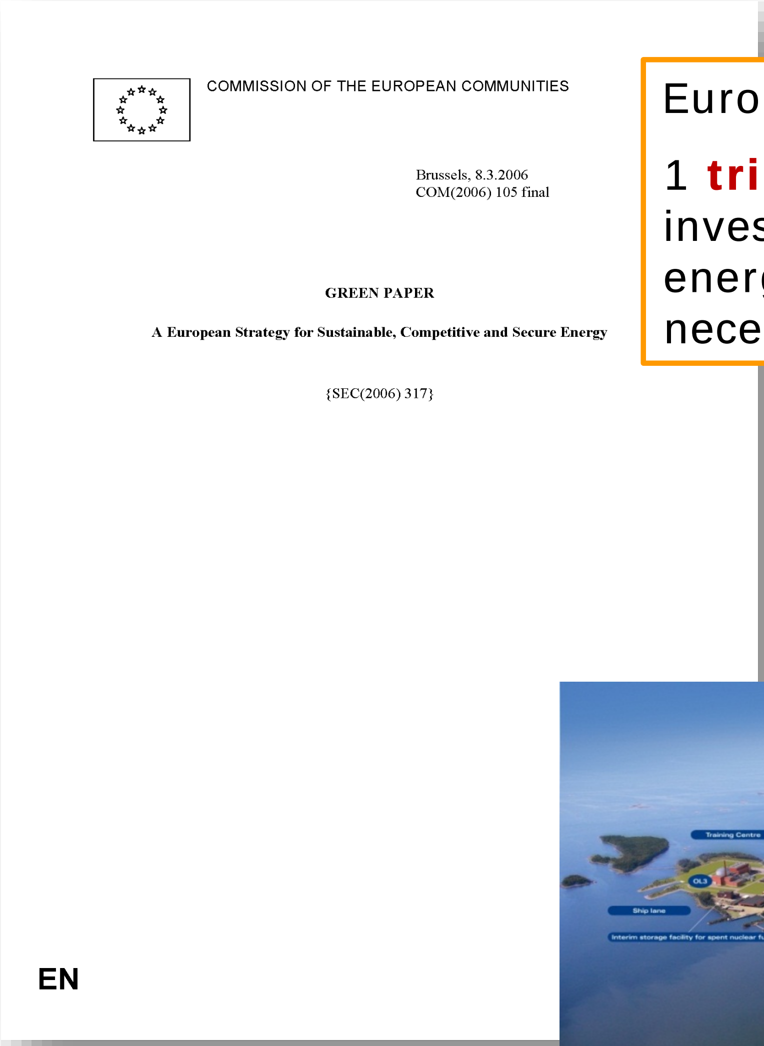
- Less need for bulk storage
- Lower volatility of electricity prices
- Enhance security of supply, by increasing the diversification of energy sources
- Boost developing economies and reduce their GHG emissions

Investments

- Costs are the biggest concern for the Global Grid

- Investment costs are estimated in the range of billions of dollars for each interconnection

- *However:* this is in line with the costs of other energy infrastructure projects


COMMISSION OF THE EUROPEAN COMMUNITIES

Brussels, 8.3.2006
COM(2006) 105 final

GREEN PAPER

A European Strategy for Sustainable, Competitive and Secure Energy

{SEC(2006) 317}

EN

Europe:

1 **trillion** Euros in investments for energy infrastructure necessary

North-Sea Grid

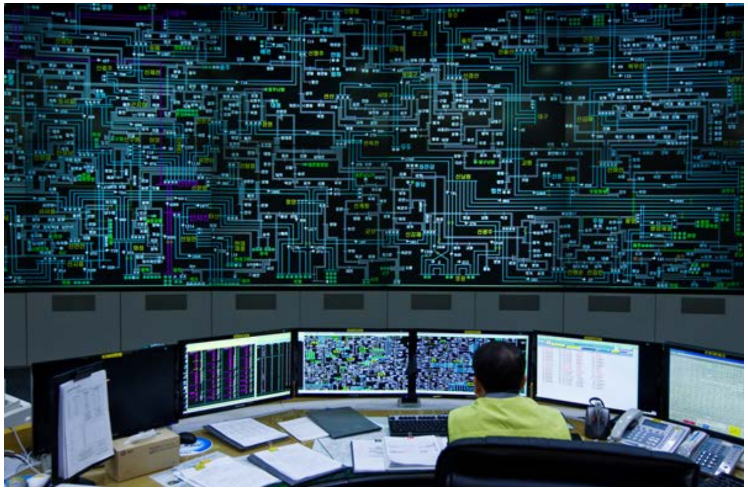
Offshore grid scenario 3: Wind-driven approach (blue = changes to base case, red = existing, pink = under construction, green = planned)

Estimated Costs:
~ €70-90 billion until 2030

Olkiluoto, Finland: 4th Gen. Nuclear Power Plant; *Cost: $4.1 US billion*

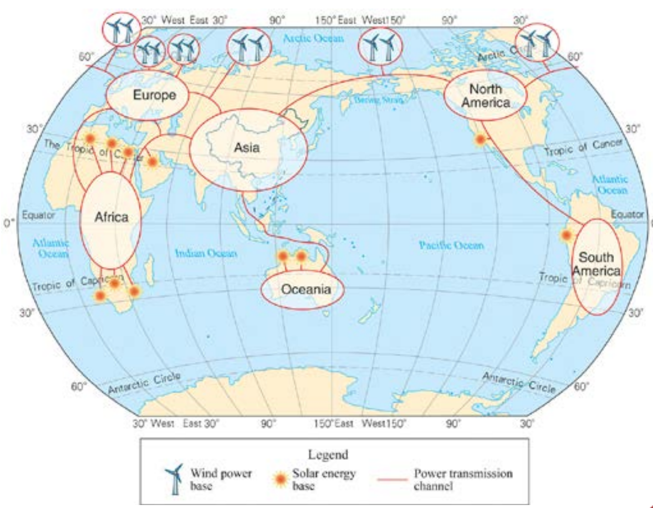
Operation

- Coupling regional markets to a *Global Power Market*
- Global Power Exchange
- Electricity as global commodity
- Increase competition within each region
- Establish competition among the lines



Cigre WG C1.35:
Feasibility Analysis of the Global Grid

- Zhenya Liu, CEO of the State Grid Corporation of China
- Book on “Global Energy Interconnection”, Elsevier 2015
- GEIDCO: Global Energy Interconnection Development and Cooperation
  - About 250 experts working on the vision



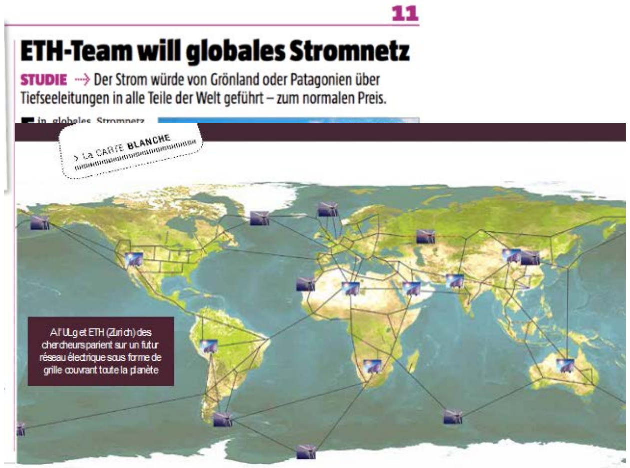
- Cigre C1.35 Working Group: “Global Electricity Network Feasibility Study” → **this session!**
- A group of about 20 international experts from industry and academia taking a deeper look in the vision

Convenor: Jun Yu, SGCC

Secretary: Gerald Sanchis, RTE France

Global Grid in the News (only a selection)

Articles in Newspapers & Magazines



TEDx Talk by Prof. Damien Ernst

World Trade Forum on
International Trade of Electricity

IEEE Spectrum, August 2015
“Let’s build a globe-spanning Supergrid”

Challenges

Political and Regulatory

- Security of supply
  - Similar problems for gas and oil
  - But: electricity cannot be stored
    - For importing country: no long-term reserves
    - For exporting country: RES not exported = economic loss

- Cost of electricity differs due to differing environmental policies

Technical

- Power Systems Security → Global Blackouts?

Conclusions

- A Global Electricity Grid is technically feasible and can potentially be economically competitive

- Several opportunities emerge:
  - Reduction of balancing power to more than 50%
  - International trade
  - Global Electricity Market

- Several challenges still exist

- Alternatives:
  - Global Power-to-Gas network
  - Microgrids

- Further need to examine in detail different aspects of the Global Grid

Thank you!

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