BIPV:Responsibility of building in the future

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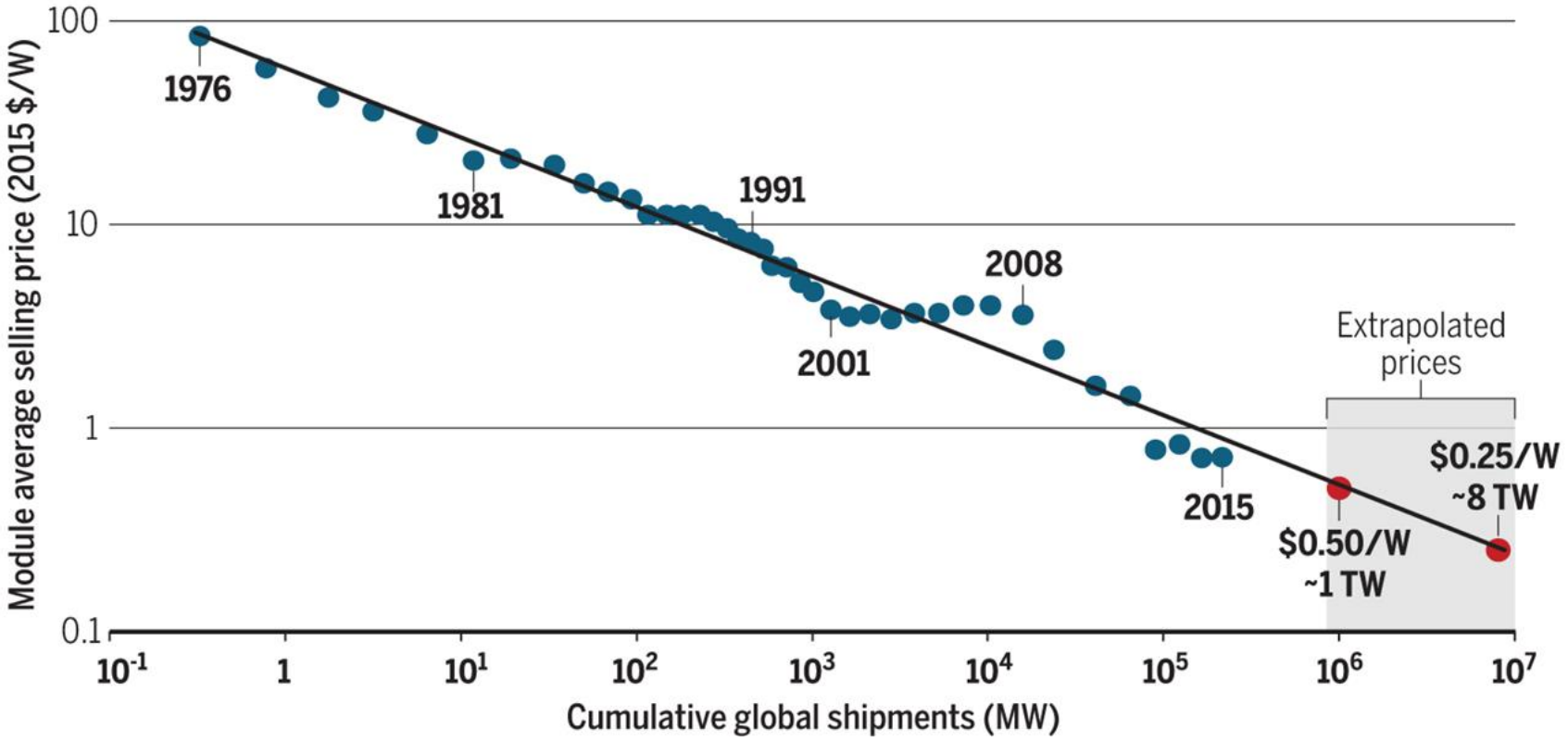
Low carbon energy future

- China will reach the carbon neutral by 2060
- The future structure of low carbon energy in China
  - Hydraulic, wind, solar, nuclear power will be the major zero carbon energy
  - Hydr. 380GW, generate 1500 TWh, Will be 450GW, 1800TWh
  - Nuclear 50GW, generate 350TWh, Will be 250GW, 1800TWh
  - Wind power 200GW, 400TWh,
  - Solar power 200GW, 200TWh
  - Zero carbon power 2550TWh, about 35% of total electricity
  - There will be 11000~12000TWh power with zero carbon power more than 7500 TWh, To reach this target, wind and solar power should be more than 4000 TWh, The installation should be more than 3000GW, 7 times as current installation

The cost of PV module has went down rapidly

PV module experience curve

Historically, module prices have decreased as a function of cumulative global shipments (blue dots reflect historical data, red dots reflect extrapolated prices for 1 TW and 8 TW based on the historical trend line). See supplementary materials for data sources.



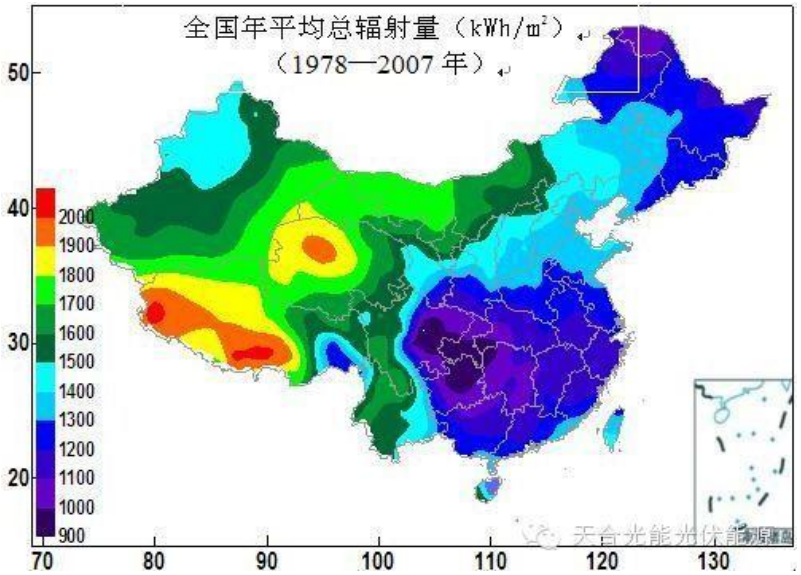
Haegel, Nancy M., et al. "Terawatt-scale photovoltaics: Trajectories and challenges." *Science* 356.6334 (2017): 141-143.

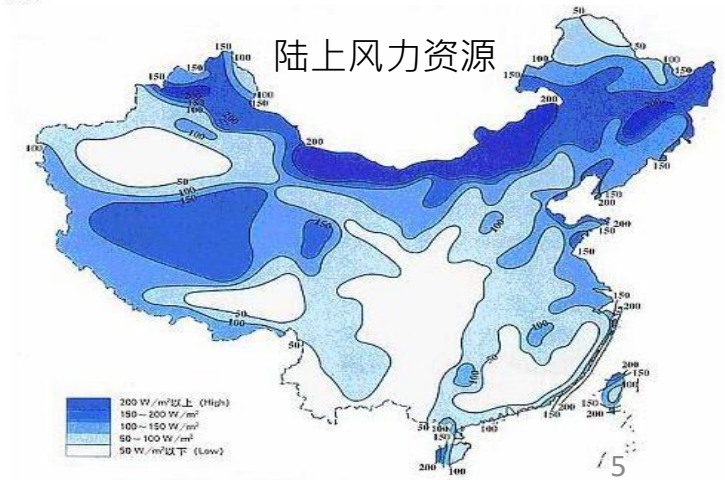
The cost of wind power & solar power reach the same level of coal power

- Take the PV as example：
  - Year 2000：module 40RMB/W，85%，connection 5RMB/W，other 2RMB/W
  - Year 2020：module 1.3RMB/W，25%，connection 2RMB/W，other 2 RMB/W
  - Major part of cost has been changed from module to the connection and others
  - In many cases the PV power can be cheaper than coal power
    - Coal: initial cost 8RMB/W，10 years depreciation，annual run 5000 hr，depr. 0.16RMB/kWh，total cost 0.46RMB/kWh
    - PV power : initial cost 5.3RMB/W，10 years depreciation，annual run 1200hr，total cost 0.44RMB/kWh
- The bottleneck for PV power has changed from high cost of the module into：
  - Space for installation
  - Cost of connection
  - Unmatching between source and load, due to the undetermined PV power

Centralized or distributed for PV power?

- Most of Chinese land does receive solar well, The solar at Tibet is about 1.5~2 times as at the east
- We need 2000GW solar power, if 100W/m2, it needs 20 billion m2 space, that is 20K square km land
- Where we put these PV? On the west？
- There are 20 billion m2 roof on rural and urban buildings can be used to install PV





Centralized or distributed for PV?

- As the PV power generated on the west has to be combined with hydraulic or thermal power to become stable power so to be able to transported from the west to the east, the ratio PV:thermal=1:1.5
- For distributed PV on the east, the daily shape is very closed with the daily load, so the requirement of pitch peak can be reduced, cost for long distance transportation can also be saved
- To reach the high ratio of zero carbon power, distributed PV should be the major part
- West Tibet：high density, long distance trans, multi-loop, base development.
- Building surface： low density, local use, less loop, ready for installation
- As far as the low cost of PV module, building surface appears advantage
- Suitable ratio: Central system on West **1/3, Distributed on East 2/3**

Building becomes the important resource

- The resource for renewable energy：space
- Building surface should be regarded as the important resource
- Zero energy, negative energy ？ Or high rate of surface used?
  - The capacity of PV power installed is dependent on the shape of building, the function of building and etc. It is not related on the power capacity the building required
  - The evaluation should not be according to the ratio the power generated and the power the building needed
  - If the surface resource is not well used it is a kind of resource waste regardless how much the building needs
  - Green building evaluation should take the surface use rate as one item for energy
- The challenge for Architects
  - Create new shape of buildings that have more surfaces for PV
  - Integrate PV with building fabric, make better buildings and reduce the cost

The influence of PV to building performance

- Light pollution by PV?
  - PV surface try to absorb solar radiation and convert the radiation into power. The remind part will be released as heat. PV surface trys to reflect solar as less as possible. Through surface treatment, the reflect ratio of PV surface should not be higher than normal building surface decorative materials
- The thermal effect of PV to buildings？
  - Comparing with normal building surface materials, PV receive same among of solar radiation, but 20% has been converted into electricity, so that the surface heat reduced
  - In winter, PV reduces 20% of surface heat gain. However if the U value of the roof is large enough, the indoor heat gain due to solar can reduce less than 5% only.
  - In summer the PV receive 20% of solar radiation on the roof, so to reduce the internal heat gain
  - Conclusion：Put PV on building surface will improve building thermal performance

The way of connection and consumption is the key issue

- Low cost connection, local consumption should be the key for develop distributed PV energy
- If convert the PV output into AC and then send it to the grid, the building receives power from the grid, it will be high cost and high lost
- Building should play the role as a “flexible plant” or “flexible load”
  - If PV provides more than 40% power in the grid, as the PV output changes with solar simultaneously, same capacity of flexible power plant is needed to balance.
  - If building could be the virtual power plant and undertaken the task, it could be great contribution to power system

Consumption of PV power

- Consume locally first
- Stored locally to adjust
- Prevent impact to grid

- In urban area, BIPV could only provide 30%-70% electricity consumption
- Try to coordinate relationship between PV and electricity demand with local batteries
- Connecting to smart charging piles to charge electric vehicles is the best application of PV power
- The DC micro-grid in the building reduces conversion links and improves flexible adjustment capabilities
- Replace back-up electricity generator and fire-fighting backup power source by batteries inside buildings

Building’s role in low carbon energy system

- The huge peak-to-valley difference on the electric load side of the city is largely due to the way of building electricity consumption

- The random variation of wind and PV power does not match the day and night variation of the load, which requires a huge flexible power to balance. This determines the proportion of fossil thermal power in the power system

- Change rigid power consumption to flexible power consumption. Building could operate partial load with demand response mode, with batteries and external smart charging piles. This mode could make building from “**Trouble Maker**” to “**Virtual flexible power plant**”, and make contribution for power system to receive wind and PV electricity

Conclusion: building's role in low carbon energy system

- **Energy generation**: Make full use of external surface to install PV
- **Energy storage**: distributed storage with battery
- **Flexible load**: real time consume/supply electricity according to the relative relationship between power generation and load, to relieve power supply and demand contradiction

- **Technology**: from rigid AC distribution to flexible DC micro-grid
- **Policy:** electricity price mechanism taking full consideration of contribution from active load adjustment

- **Four revolutions and one cooperation of energy** :
  - Revolution in supply, demand, technology and policy
  - International cooperation

Thanks for your attention!

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