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Clean energy development in China

--the real potential and real challenge

December 04, Tsinghua University

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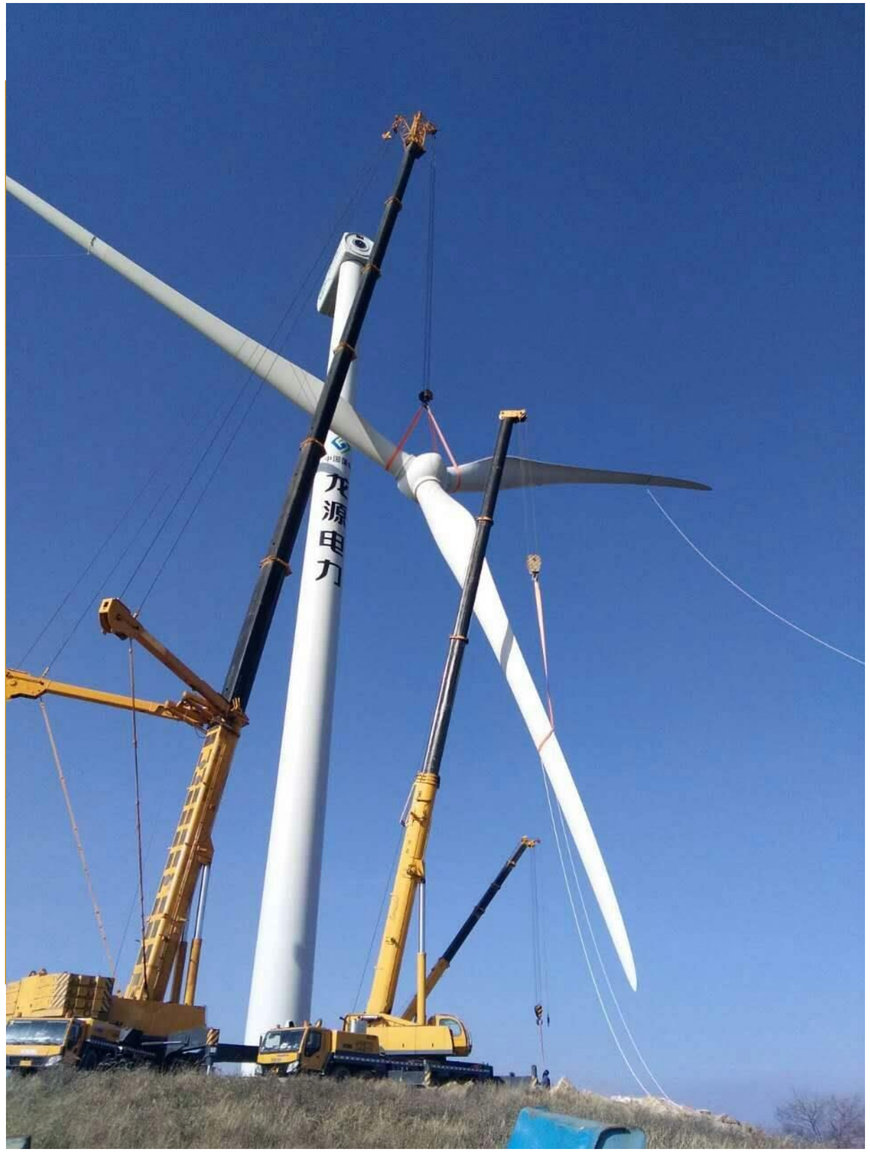
School of Environment

Beijing Normal University



Today’s Topics

1 The resource potential and development status of China’s CE

2 Renewability of biomass energy in China

3 MFA/LCA/EA of wind power development in China

Pre-talk questions

- Why for clean production and recycling?
- What’s the difference between the concepts of clean energy, renewable energy, non-fossil energy?
- Do you think or believe clean energy will play a big role in future energy mix in China as well as at worldwide?

Changes of focus for sustainable development in China

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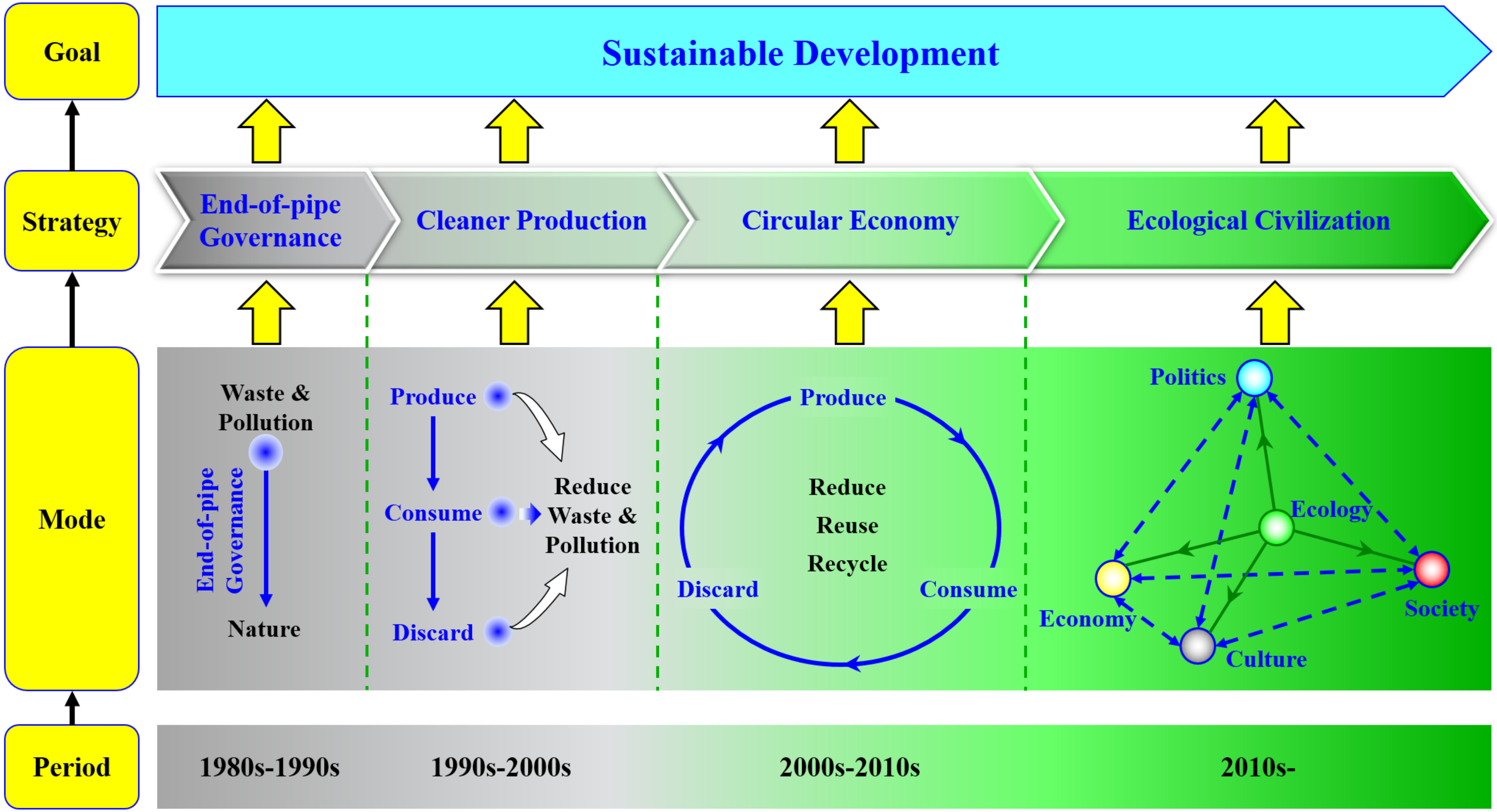
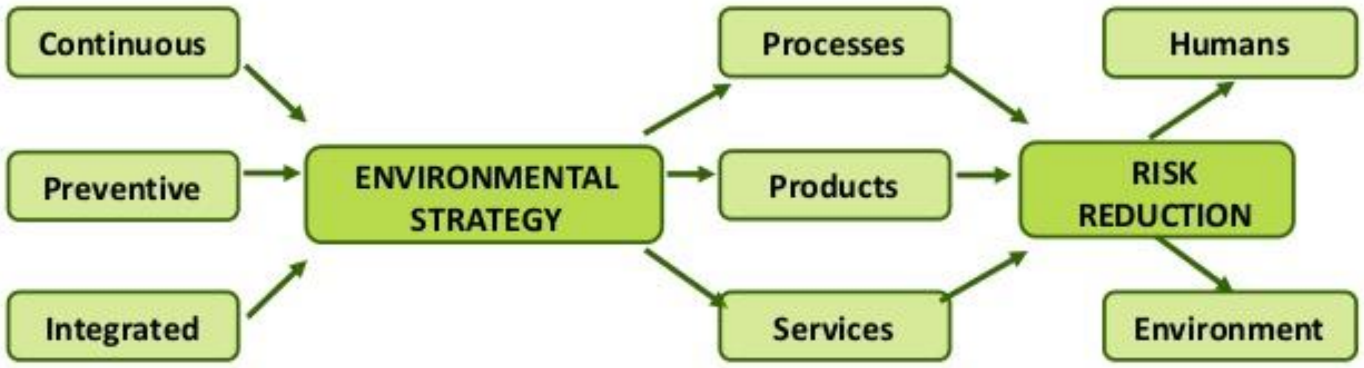


Xu, 2019

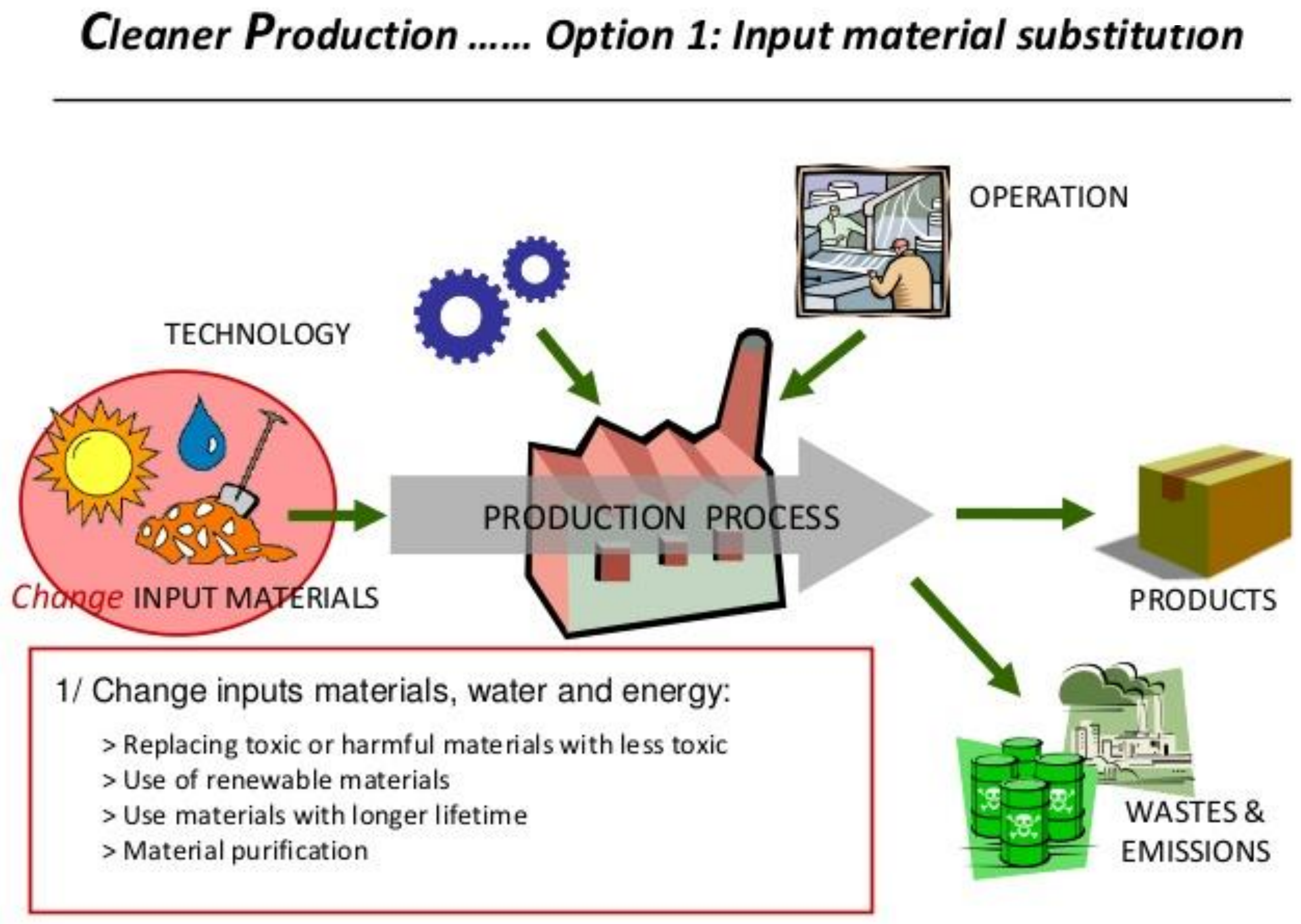
Cleaner production and clean energy

Cleaner Production …… Definition by UNEP

" Cleaner Production is the continuous application of an integrated, preventive environmental strategy towards processes, products and services in order to increase overall efficiency and reduce damage and risks for humans and the environment."



Cleaner production and clean energy



The resource potential and development status of China's CE

Clean energy family

Hydroenergy

Wind Energy

Solar Energy

Biomass Energy

Geothermal Energy

Nuclear energy

The resource potential estimation

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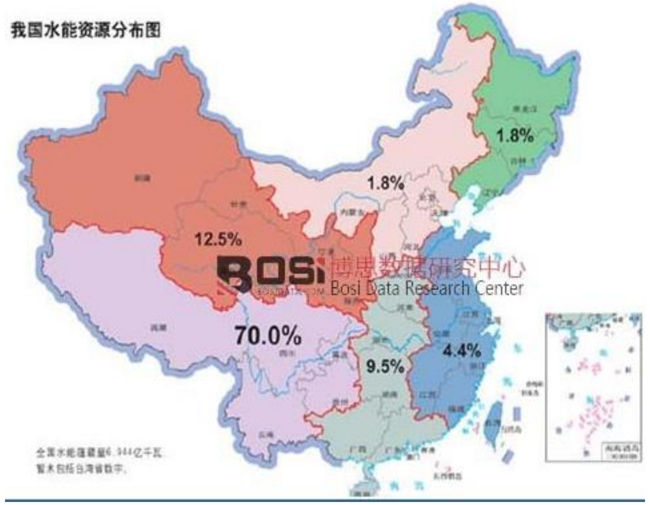
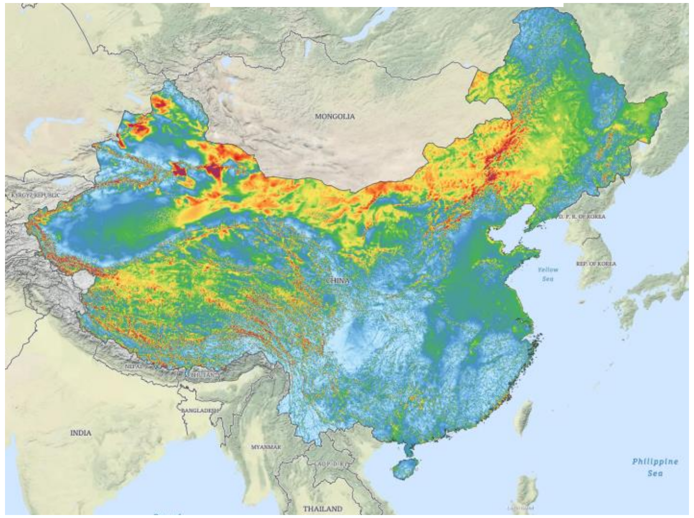
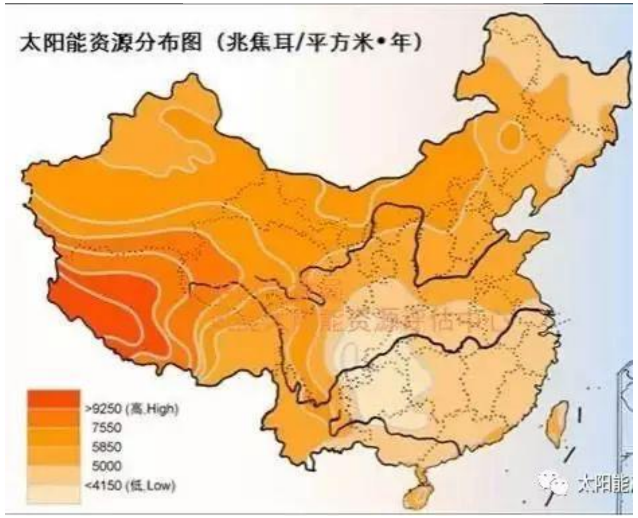
Hydro energy resource



Wind resource



Solar resource



Type	Technical exploitation capacity (GW)	Explored capacity (GW)	Proportion
Hydro power	660	350（by 2017）	53.0%
Wind power	3500	198	5.7%
PV power	2200	190	8.6%
Biomass power	460（Mtce）	22（Mtce）	6.1%

12 th-13th FYP clean energy development goals

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	2010	12th FYP target	2015	Rate	13th FYP target	2018	Rate by 2018
Hydropower (GW)	216.06	290	319.54	110.2%	340	350	102.9%
Wind power (GW)	31	100	129	129.0%	210	198	94.3%
PV power (MW)	0.8	21	43.18	205.6%	105	190	181.0%
Biomass power (GW)	5.5	13	10.3	79.2%	15	17.84	118.9%
Solar thermal power (MW)					500	200	40%
Nuclear power (GW)					45	44.6	99%

Main policy initiatives

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Year	Incentive policy	Issuing authority	Main influences
2005	Notice on the relevant requirements of wind power construction management	National Development and Reform Commission	Localization rate of wind power equipment is asked to reach more than 70%; the wind farm, which does not meet the requirements of the equipment localization rate, is not allowed to build
2006	Renewable energy law	The National People's Congress	It provides a legal framework for the development of wind power in China and establishes a relatively complete legal framework for renewable energy.
2007	Medium and long-term development plan for renewable energy	National Development and Reform Commission	Strive to make renewable energy consumption in 2010 reach 10% of total energy consumption, to reach 15% in 2020.
2008	Renewable energy development plan for “11th Five-Year"	National Development and Reform Commission	In the 11th Five-Year period, the new wind power installed capacity is planned to reach 9 million kilowatts; by 2010, the total installed capacity of wind power is planned to reach 10 million kilowatts.
2009	Notice on canceling the localization rate of procurement equipment for wind power project	National Development and Reform Commission	Cancel procurement requirement on 70% localization rate.
2009	Renewable Energy Law Amendment Act	The National People's Congress	National finance sets up a renewable energy development fund.
2013	Wind power development "12th Five-Year" planning	National Energy Administration	By 2015, the wind power installed capacity is planned to reach 100 million kilowatts, the annual generating capacity is planned to reach 190 billion kWh, and the proportion of wind power in total electricity generation is planned to exceed 3%.
2016	Notice on promoting electric energy storage to participate in peak service of "Three North" area	National Energy Administration	Energy storage facilities are planned to be an important mean of peak shaving.
2016	Notice of the 2016 national wind power development and construction plan	National Energy Administration	No new project is arranged to the "three north area", which has serious abandoning wind problem.
2016	Management measures of full guaranteed acquisition of renewable energy generation	National Energy Administration	The annual electricity generation of the renewable energy grid power generation project is divided into two parts: the indemnification purchase electricity and the market transaction electricity.
2016	Opinions on promoting coordinated development of electric power in Northeast China	National Energy Administration	Accelerate the construction of power transmission channel, control the scale and construction rhythm of wind power.
2016	Wind power development "13th Five-Year" planning	National Energy Administration	By the end of 2020, the national wind power generation capacity is planned to reach 420 billion kWh, accounting for about 6% of the total power generation.
2017	Opinions on deepening the reform of the price mechanism in an all-round way	National Development and Reform Commission	By 2020, the electricity price of wind power is equivalent to that of coal-fired power generation.

Hydropower

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- China is sitting in the world's first place in terms of both installed and generation capacity.
- In 2018, China has registered an installed hydraulic capacity of 352 GW of electricity, and an annual grid power generation capacity of 1232.93 TWh of electricity, accounting for 17.6% of the total electricity generated in the country.

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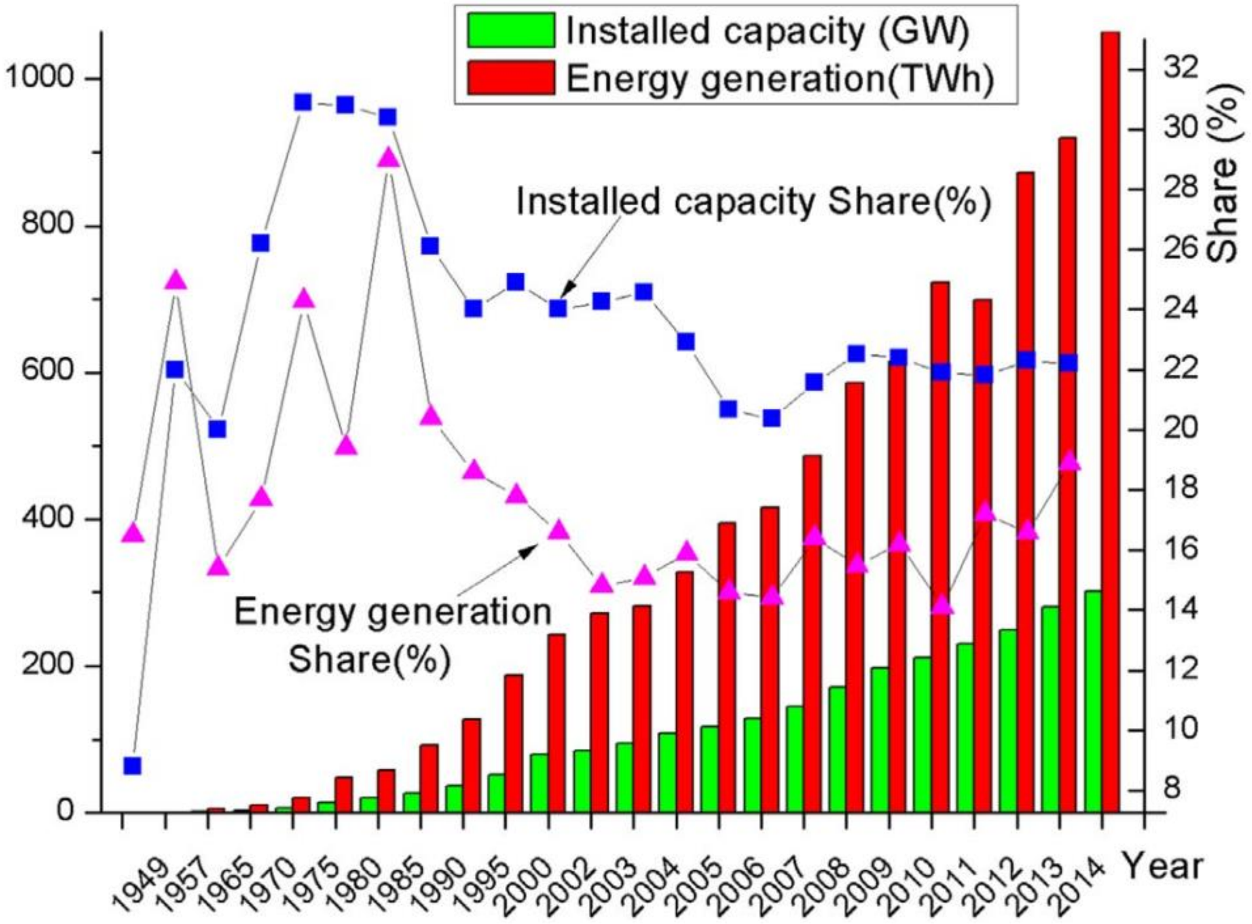
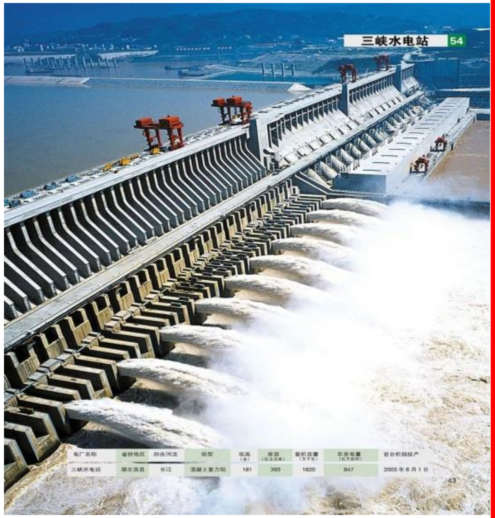


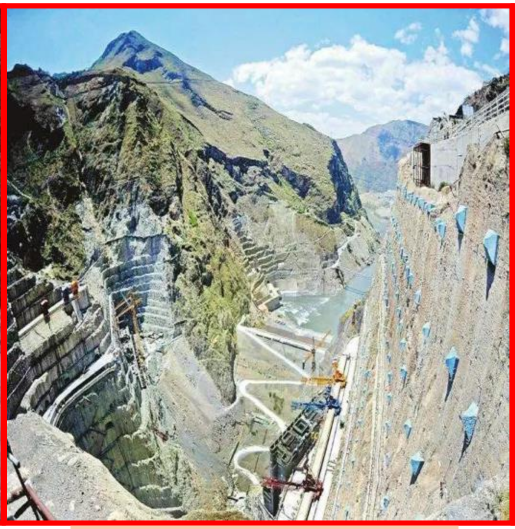
Hydropower stations(Top 10)



Three Gorge, 22,500 MW


Xiluodu, 13,860 MW


Baihetan,16,000MW


Wudongde,12,000MW


Xiangjiaba,7,750MW

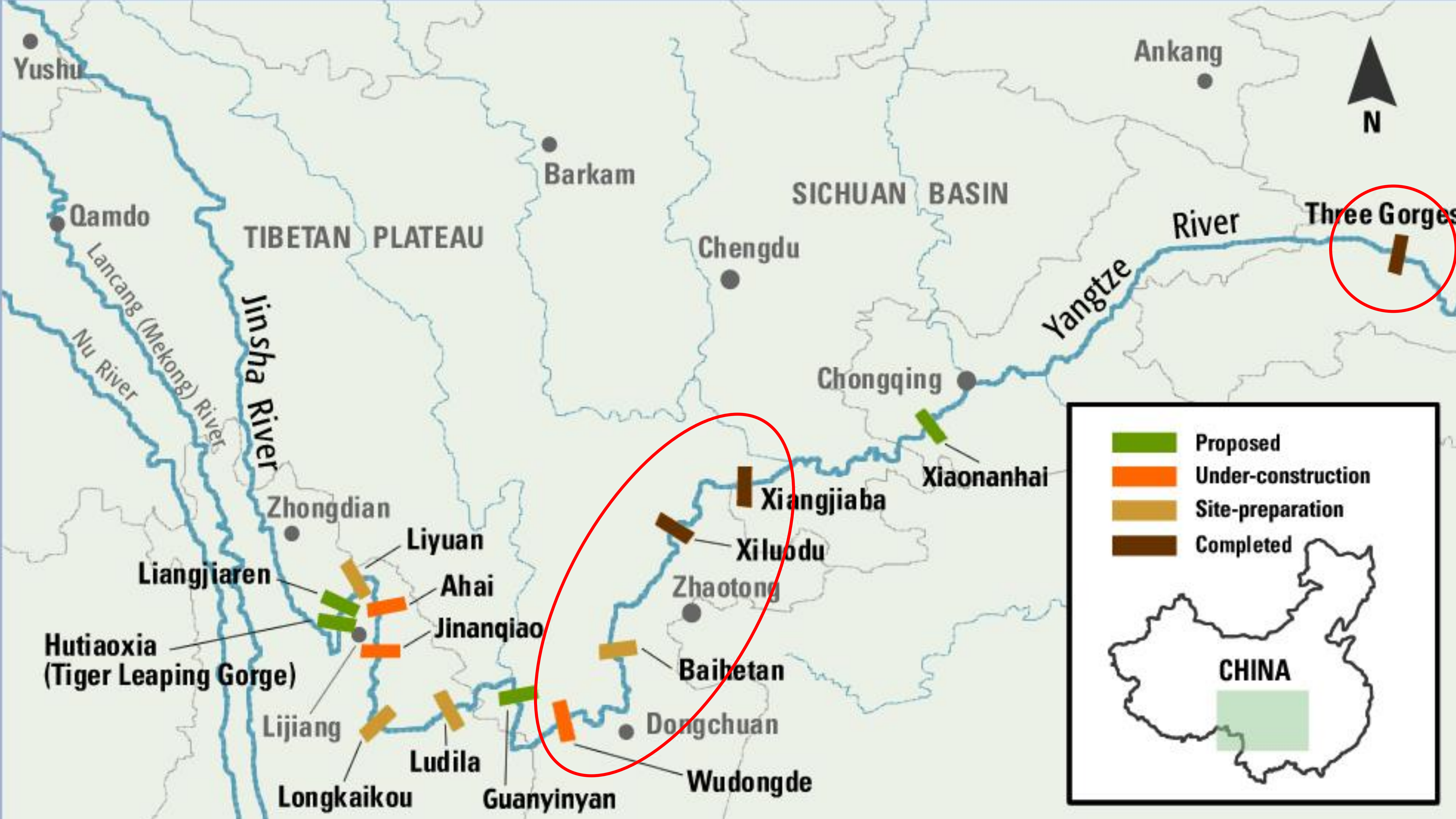

Longtan,6,300MW


Nuojiadu,5,850MW


Jinping ,4,800MW


Xiaowan ,4,200MW


Laxiwa ,4,200MW


Yushu
Ankang
N
Barkam
SICHUAN BASIN
Qamdo
TIBETAN PLATEAU
Chengdu
Three Gorges
River
Yangtze
Lancang (Mekong) River
Nu River
Jinsha River
Chongqing
Xiaonanhai
Proposed
Under-construction
Site-preparation
Completed
Xiangjiaba
Zhongdian
Xiluodu
Liyuan
Liangjiaren
Ahai
Zhaotong
Jinanqiao
Hutiaoxia
(Tiger Leaping Gorge)
Baihetan
CHINA
Lijiang
Dongchuan
Ludila
Wudongde
Longkaikou
Guanyinyan

Challenges

- **Hydropower curtailment**

Imbalance of supply and demand and grimly consumption situation of water power

- **Low efficiency of pumped storage power station**

Affected by overcapacity, thermal power, and other causes of power peaking in the utilization rate of decreasing storage

- **Negative impact on the environment**

Regional ecosystem

- **Lowing economic return**

Mountainous, difficult and higher cost to construct

- **Resettlement difficulties**

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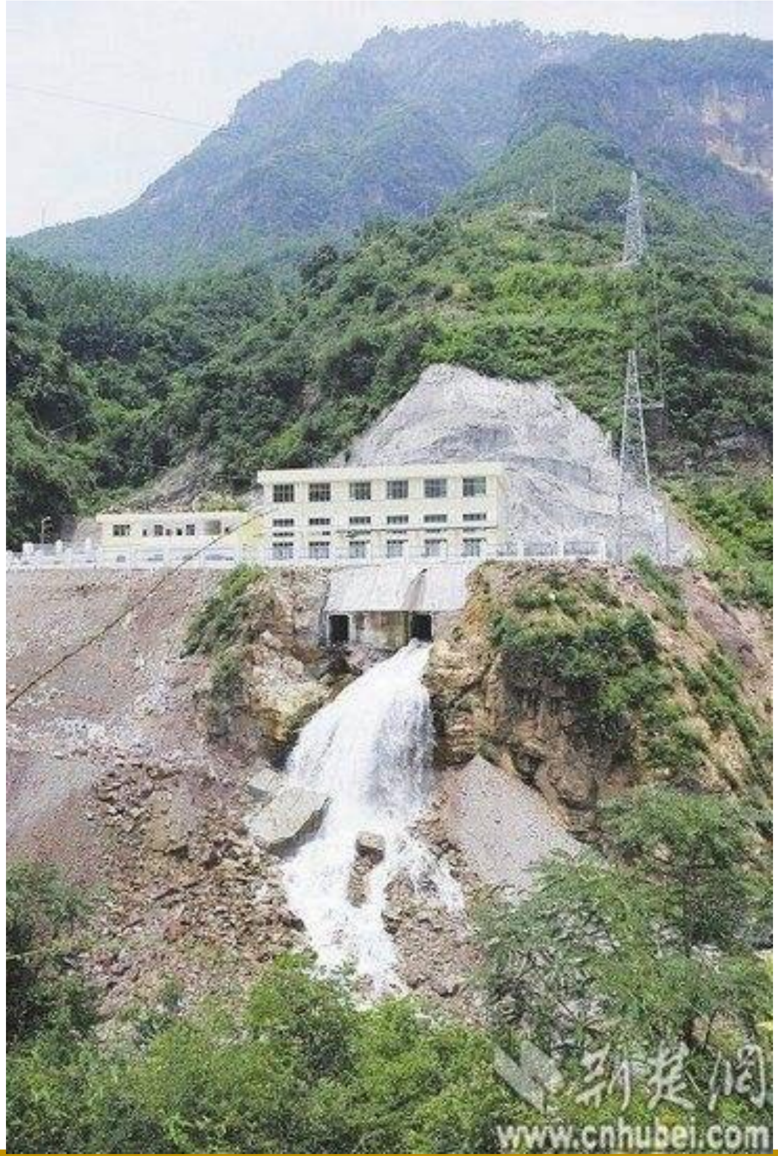
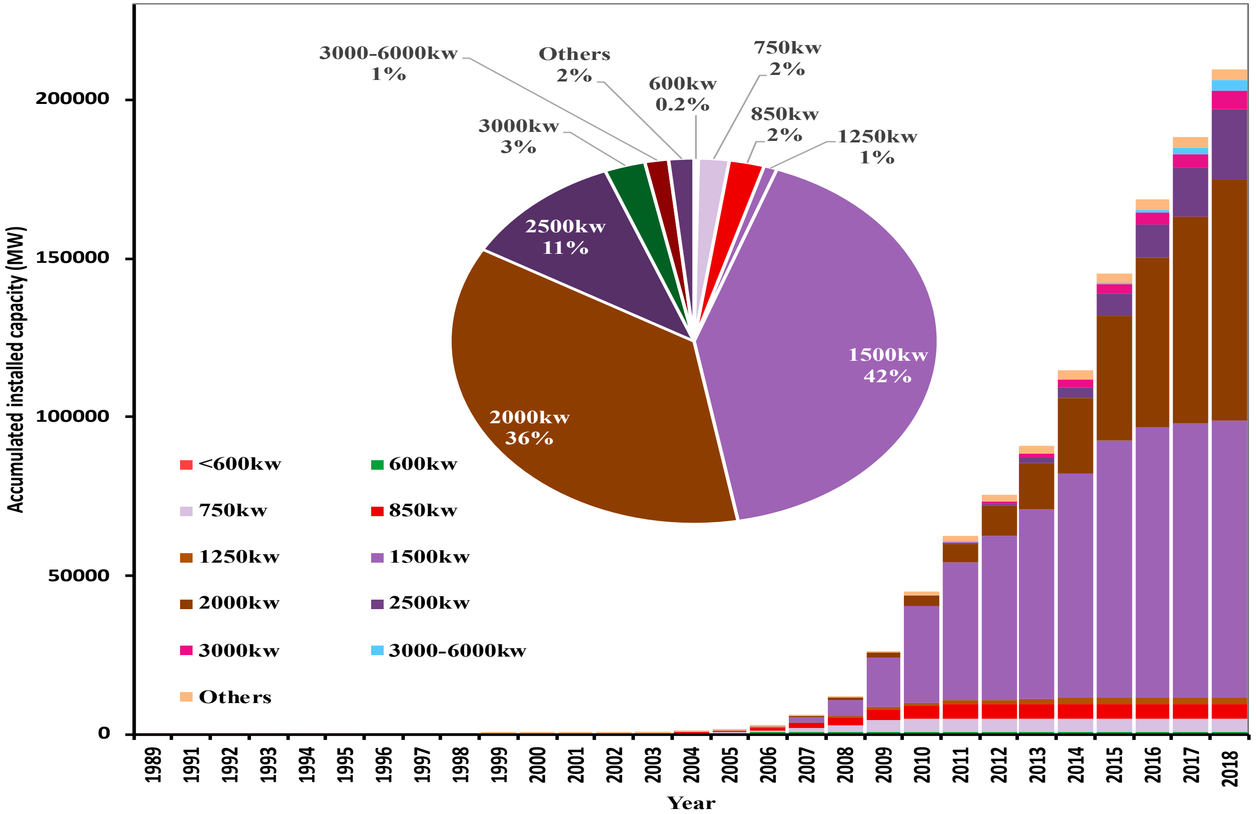
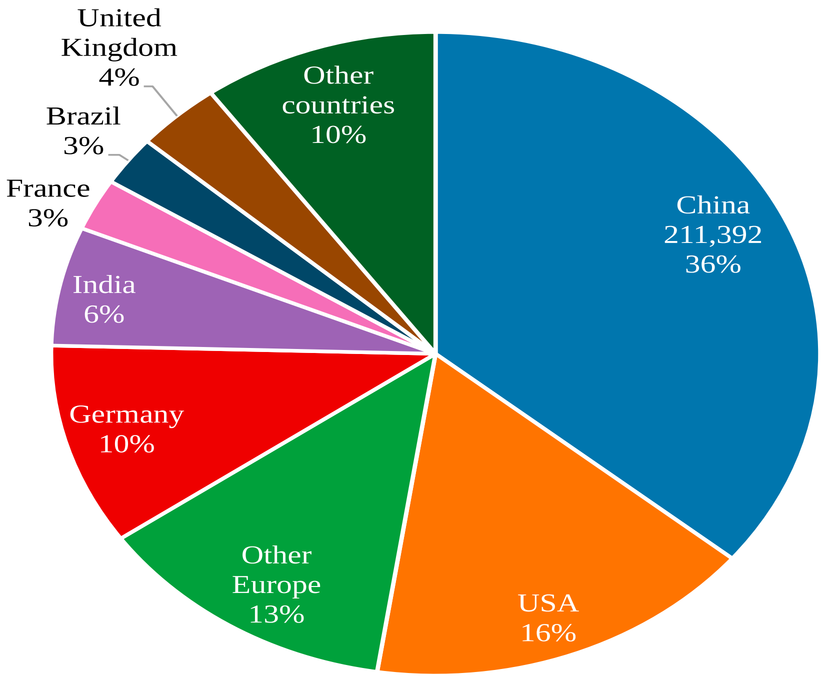


Wind power



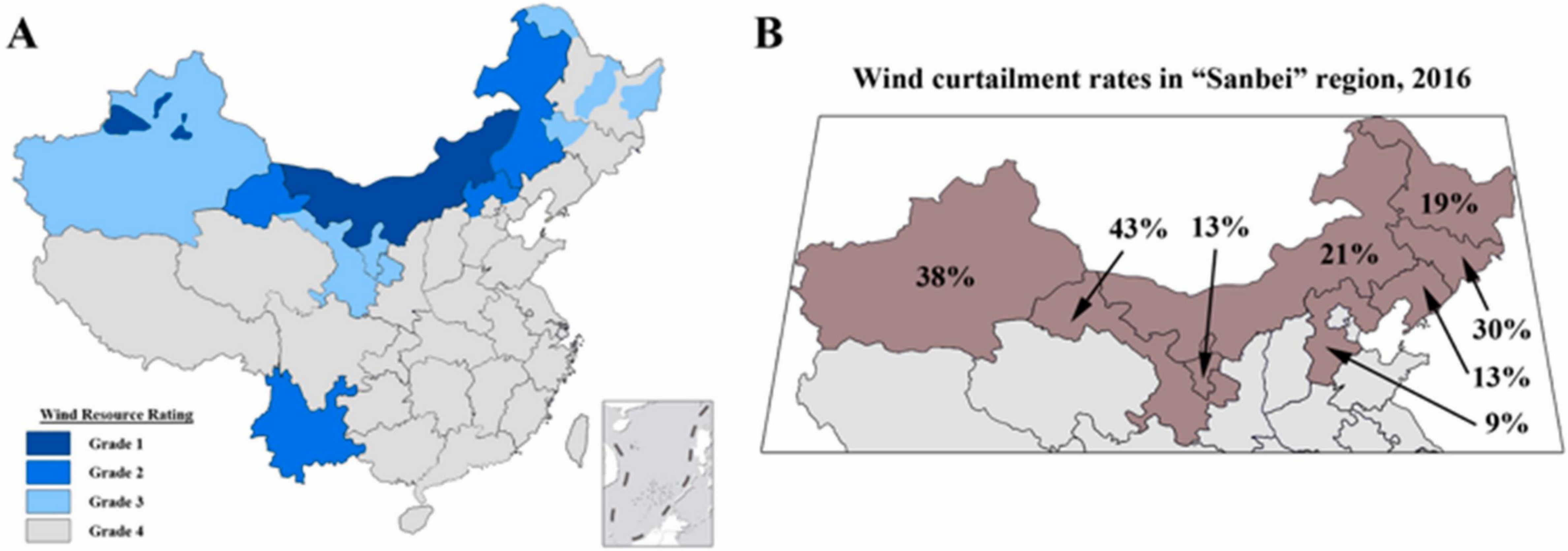
Accumulated installed capacity of wind power in China



Structure of the accumulated wind power installed capacity in 2018

- Accumulated installed capacity increased from 1.27GW in 2006 to 211GW in 2018, with **166 times** increase.
- Dominant wind turbine size updated quickly with the wind turbine size enlargement.
- By 2018, China has become the world's largest wind power market, accounting for **36%** of the total.

Wind power curtailment



Wind energy resources and curtailment rates in the Sanbei region

Solar power

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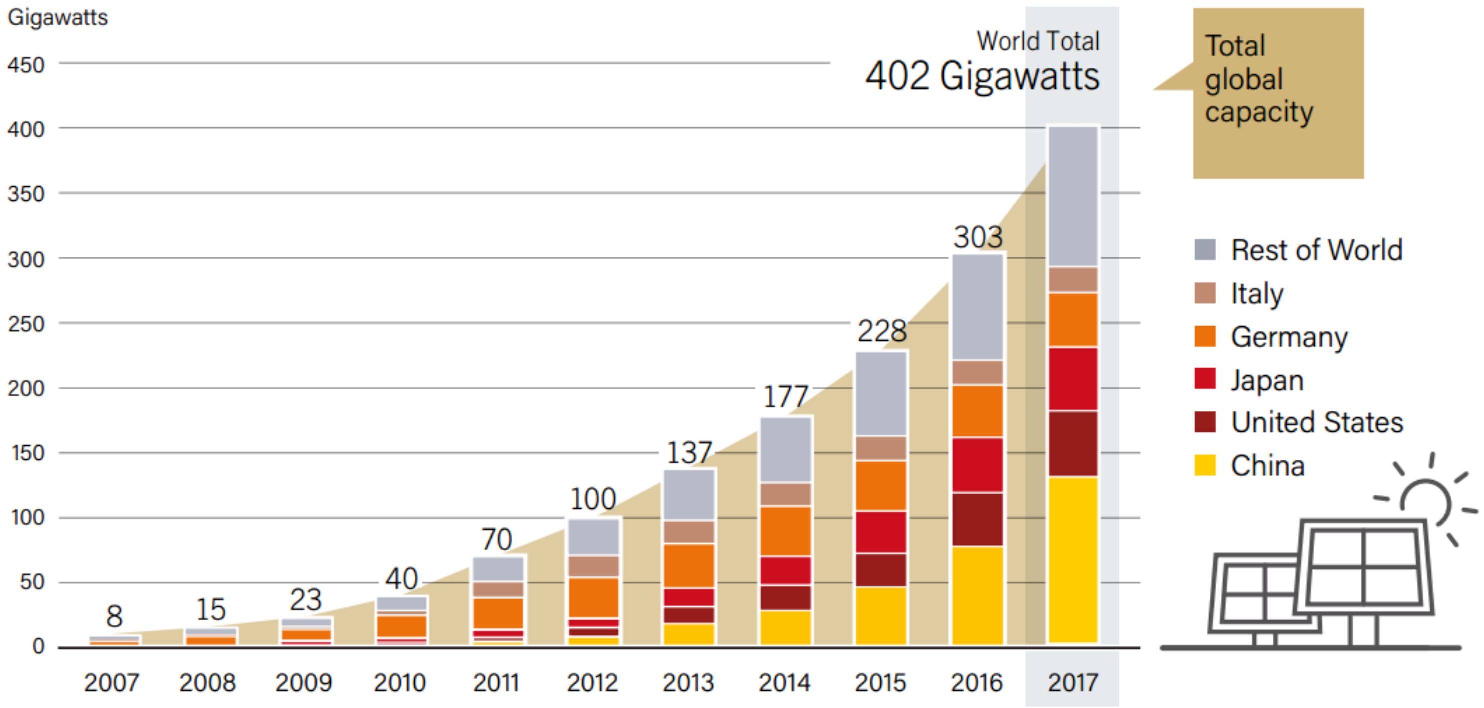
- China enjoys a fast growth of its solar photovoltaic industry since 2004
- China has kept first place in the world since 2007 in terms of production of photovoltaic cells.



- Ever since March 2009, particularly during 2011–2015, a series of incentives, including direct subsidies for solar PV installations, a national FIT scheme, among others, have been implemented by the government

Solar power

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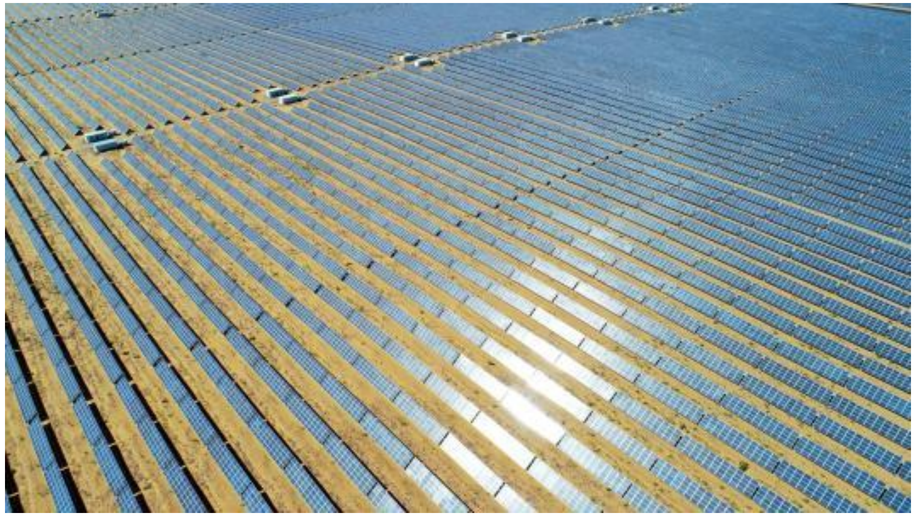
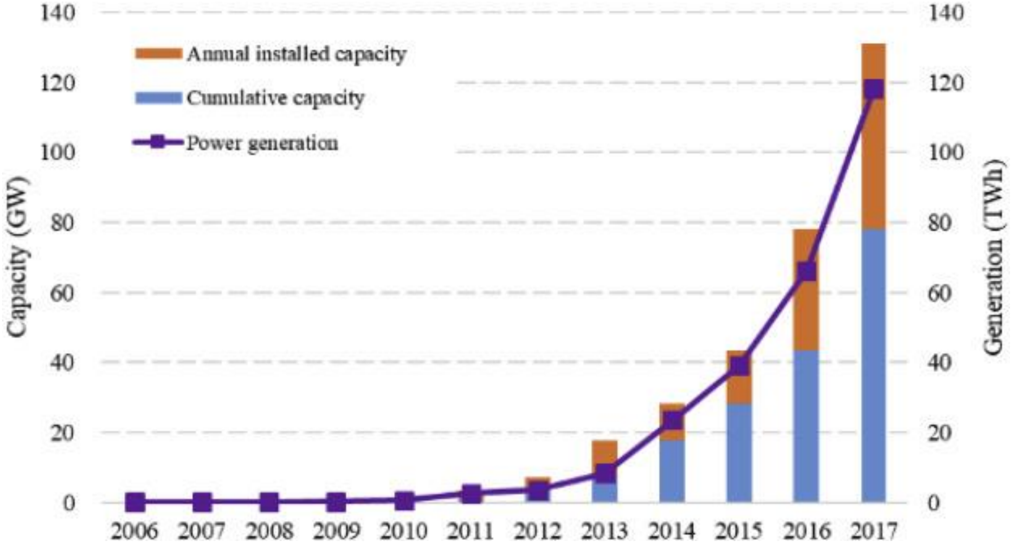
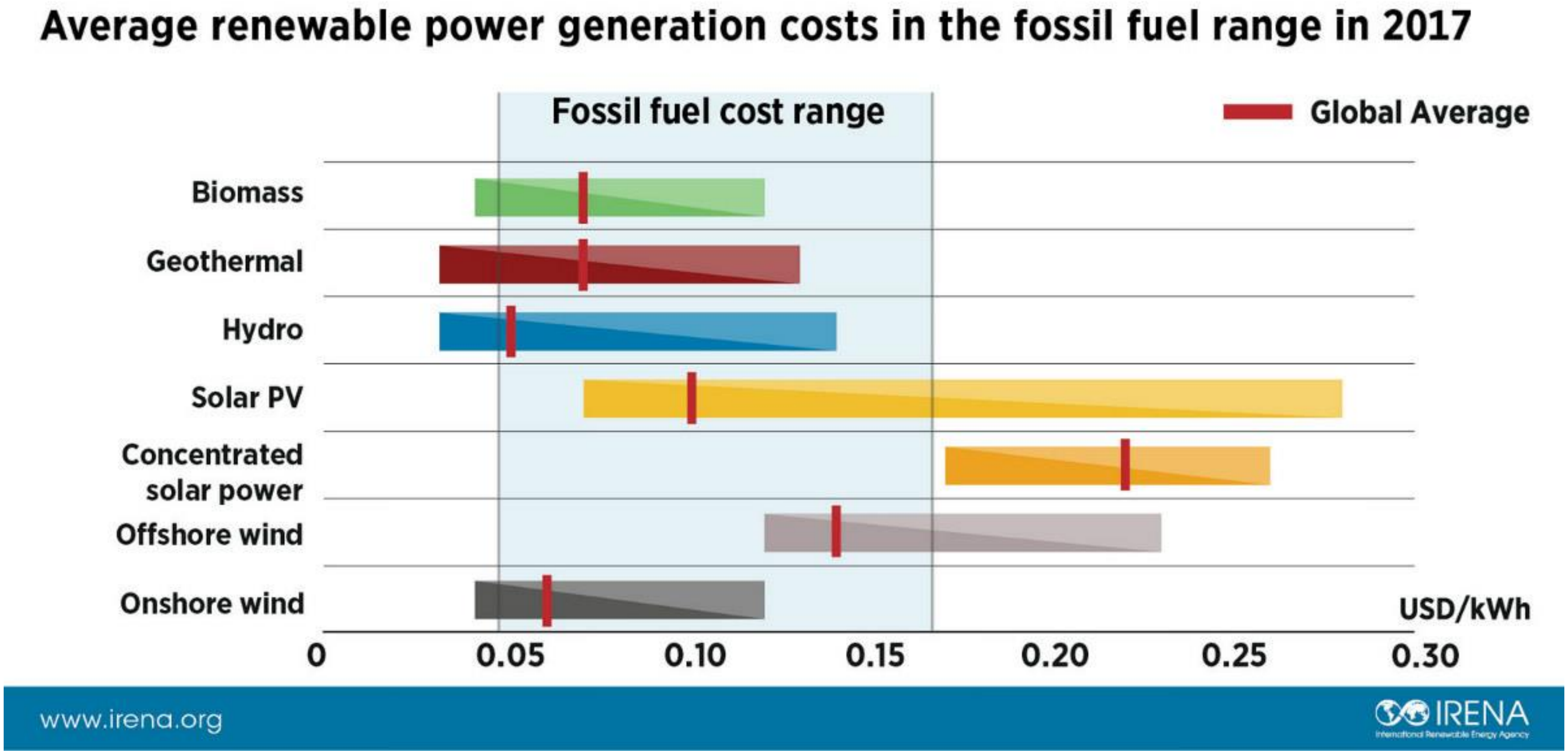


- China's solar PV accumulated installed capacity reached 131 GW by the end of 2017, including 100.6 GW of large-scale PV and 30.5 GW of distributed PV, resulting in a 1310-fold increase in capacity from 0.1 GW in 2006 to 53 GW in 2017.
- Solar power generation increased from 0.1 TWh in 2006 to 118.2 TWh in 2017, accounting for 1.67% of total power generation.

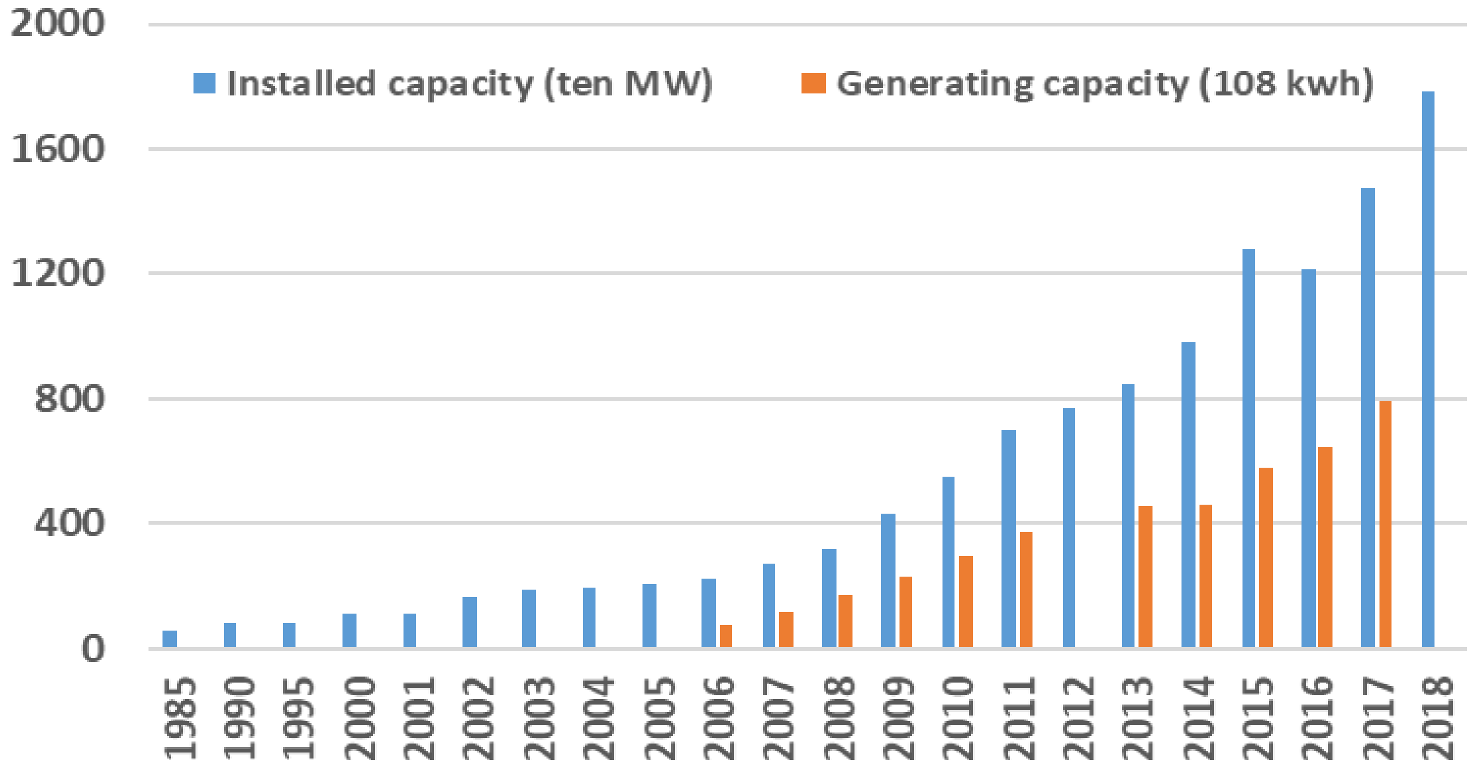


Growth of solar power in China between 2006 and 2017

Economic cost



Biomass power



Installed capacity and generating capacity of biomass power in China

Data source: China Electricity Statistical Yearbook

Nuclear power

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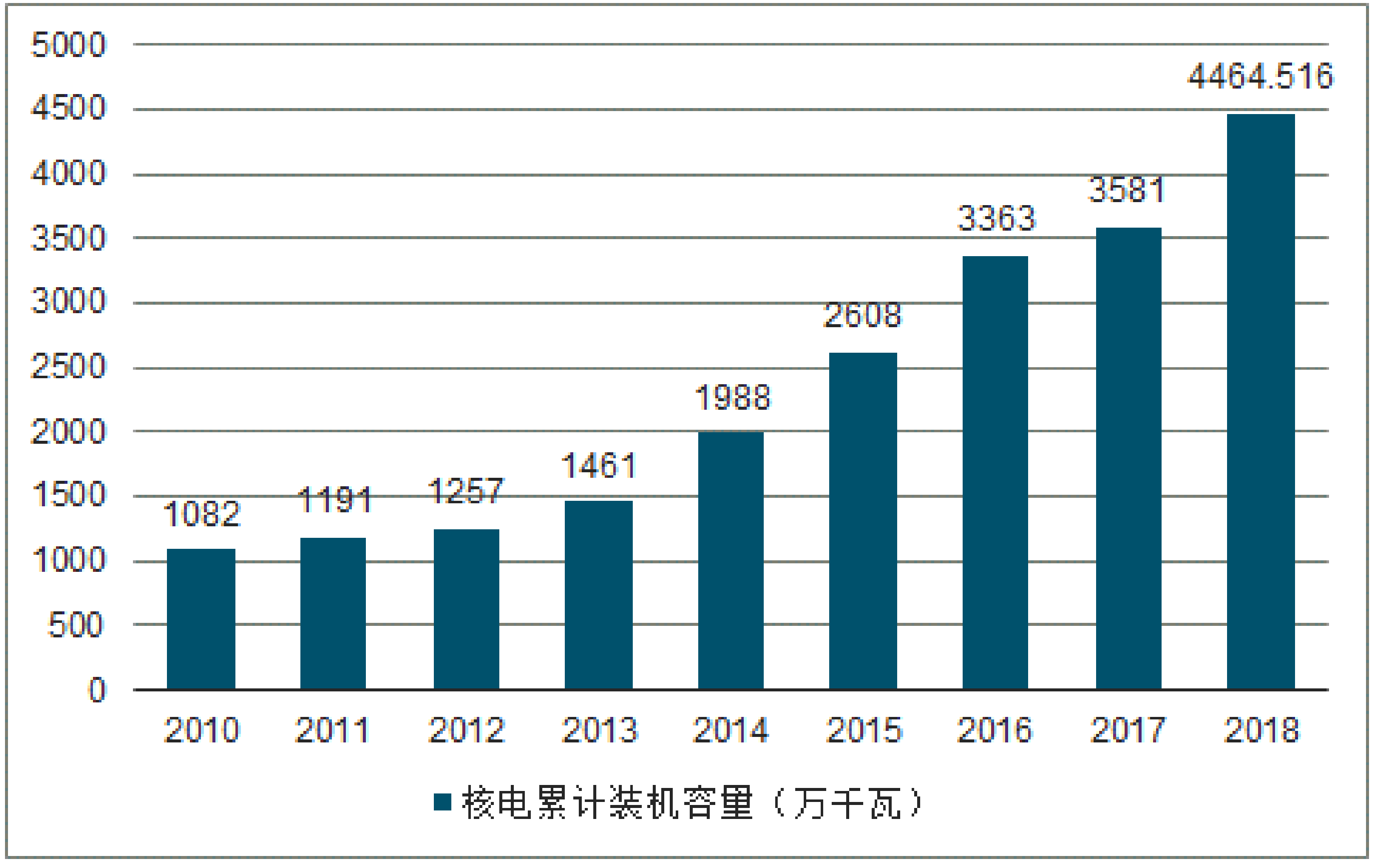
44.6 GW



Source: The Radioactive Safety Center of the Ministry of Environmental Protection

Data source: China Electricity Statistical Yearbook

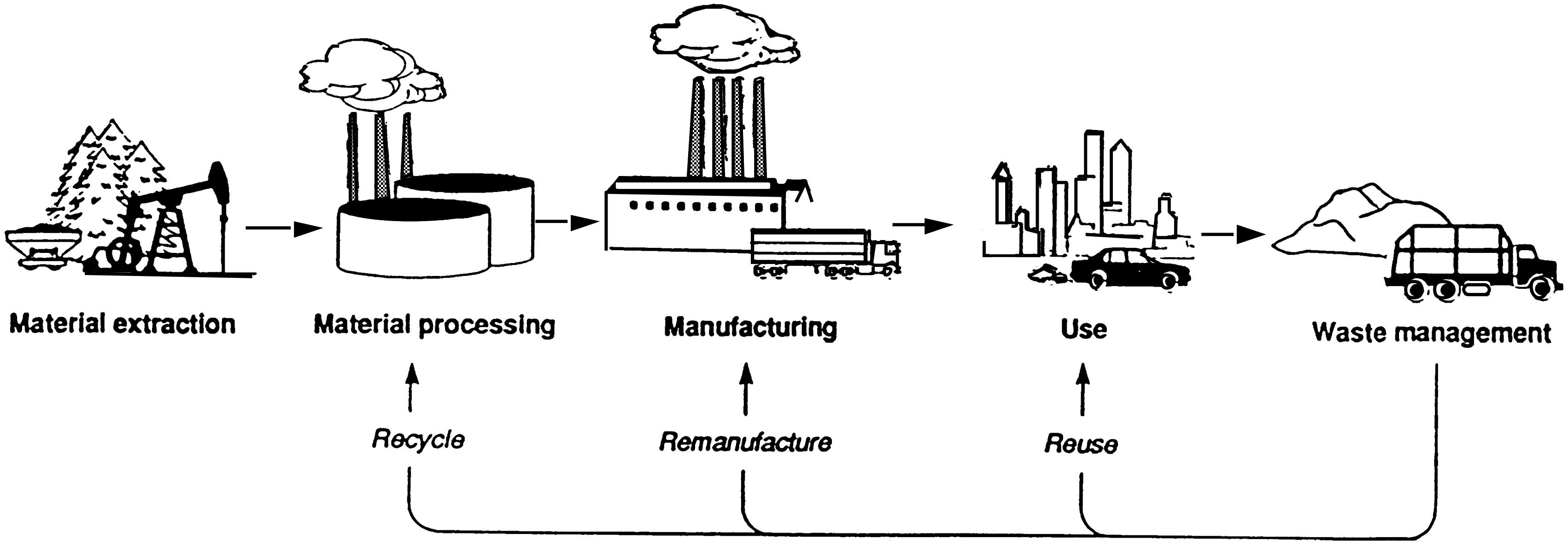
Discussions

- What's do you think the possible resources impacts derived from the development of CE?
- What's do you think the possible environmental impacts derived from the development of CE?
- What's do you think the possible ecological impacts derived from the development of CE?

Renewability of biomass energy in China

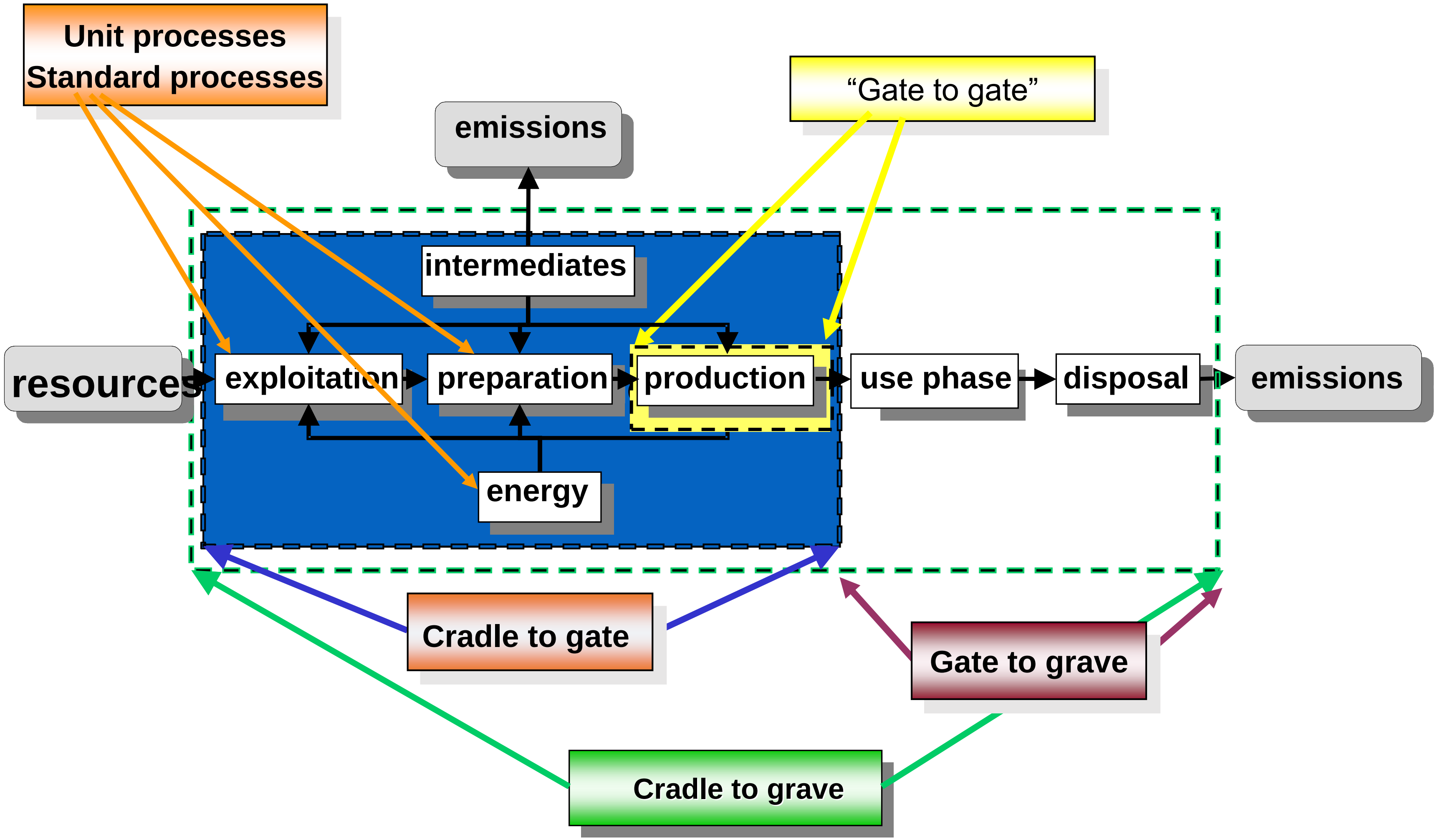
Life cycle thinking

- Consider the entire life cycle of a product when evaluating its environmental impacts
  - raw material extraction → processing → manufacturing → transport → use → recycle/reuse → disposal



US Office of Technology Assessment (1992)

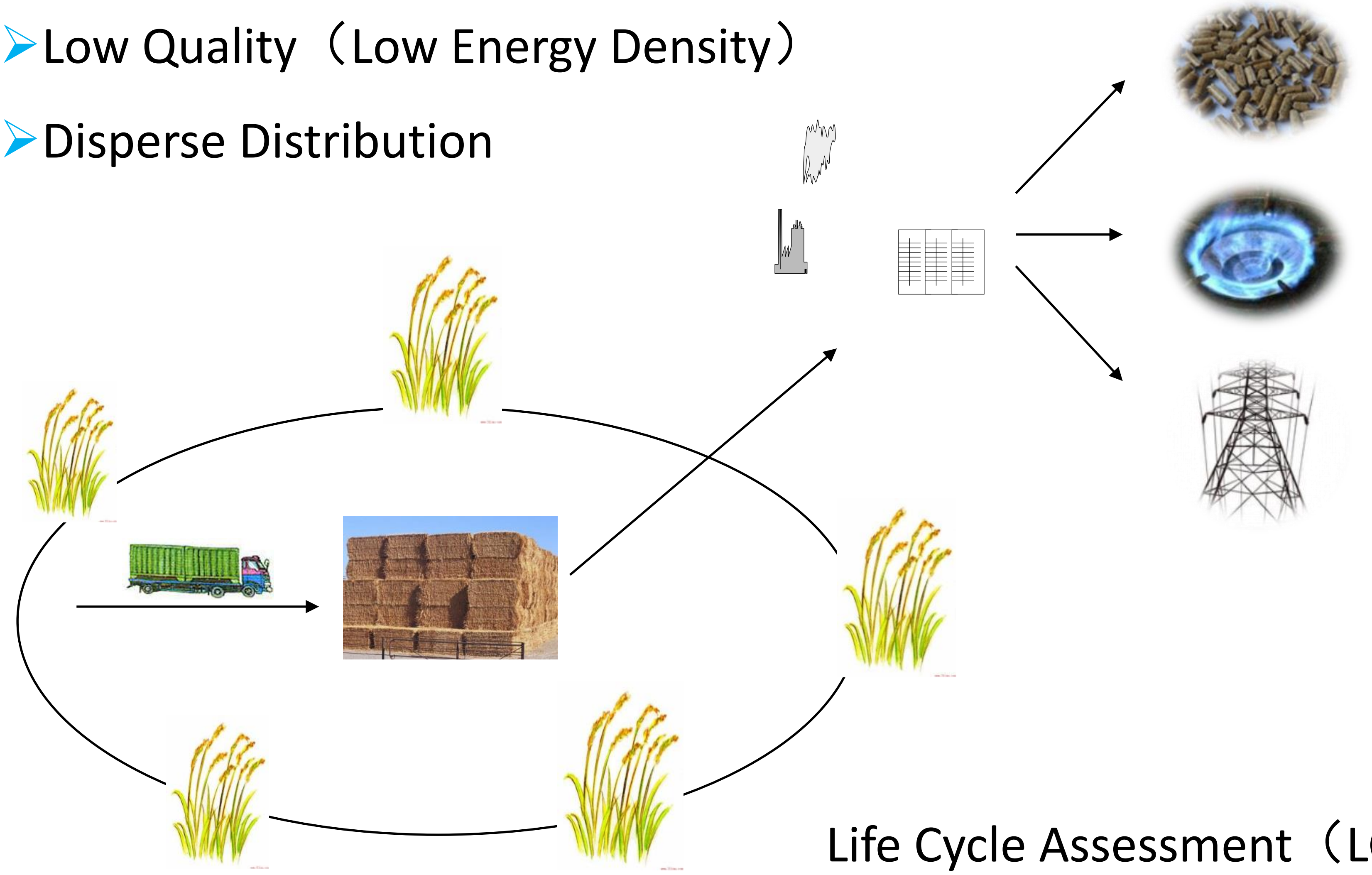
LCA method



Unit processes
Standard processes
emissions
"Gate to gate"
intermediates
resources
exploitation
preparation
production
use phase
disposal
emissions
energy
Cradle to gate
Gate to grave
Cradle to grave

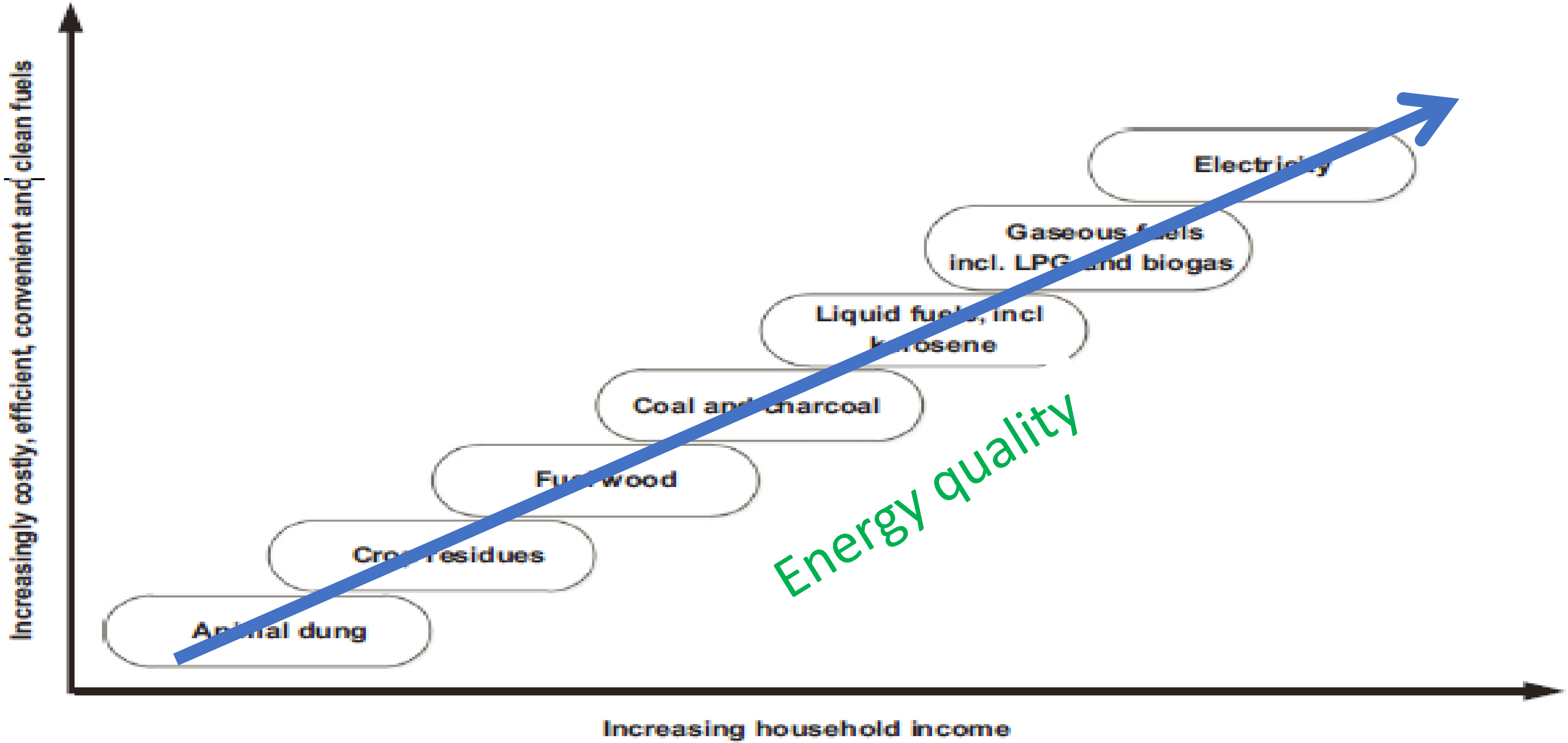
Renewability analysis

- Low Quality（Low Energy Density）
- Disperse Distribution



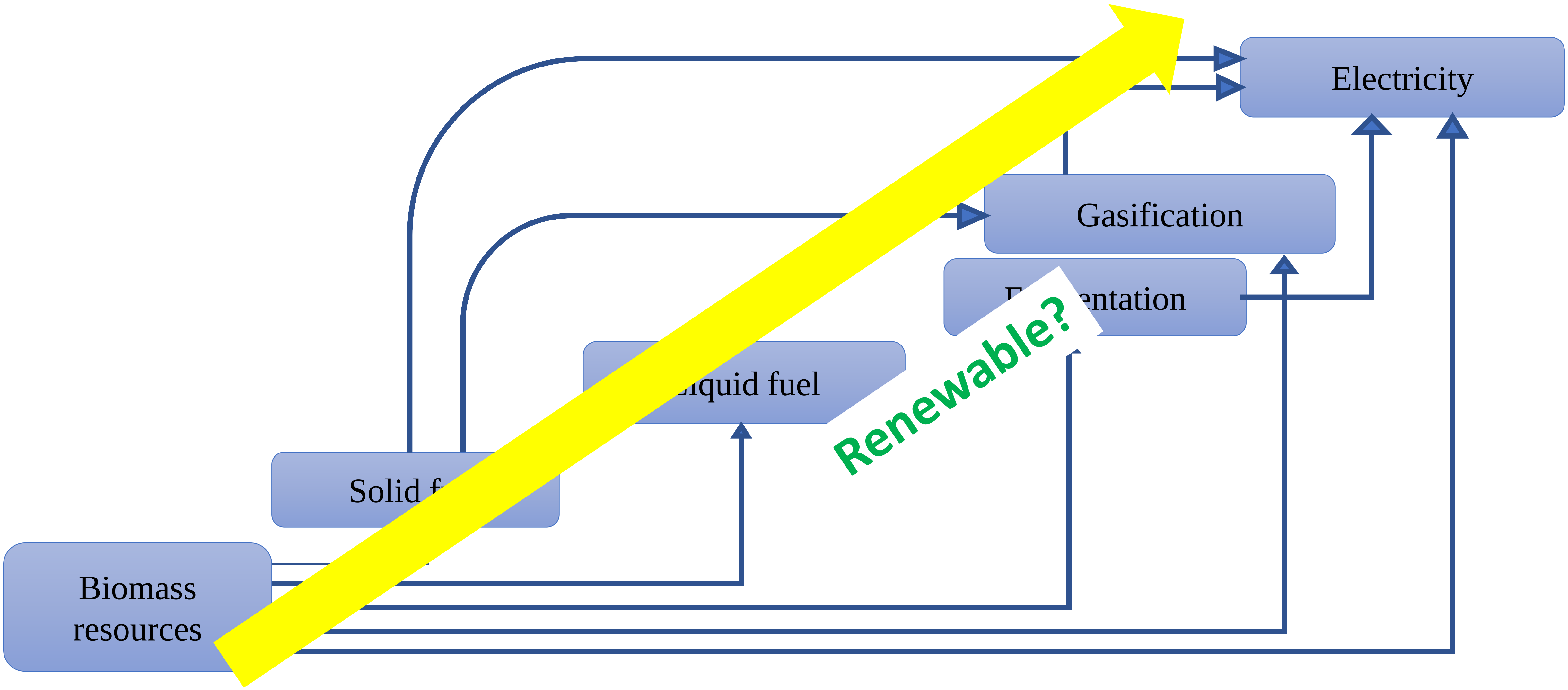
Life Cycle Assessment（LCA)

Energy quality

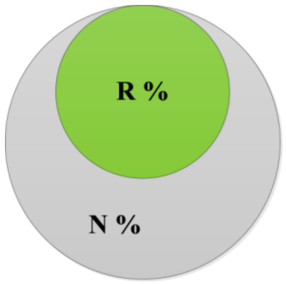


Energy ladder ranks fuels from ‘worst’ to ‘best’ in terms of cost, cleanliness, convenience or energy intensity etc. (quality) (Gosens et al. 2013).

Industrial processes

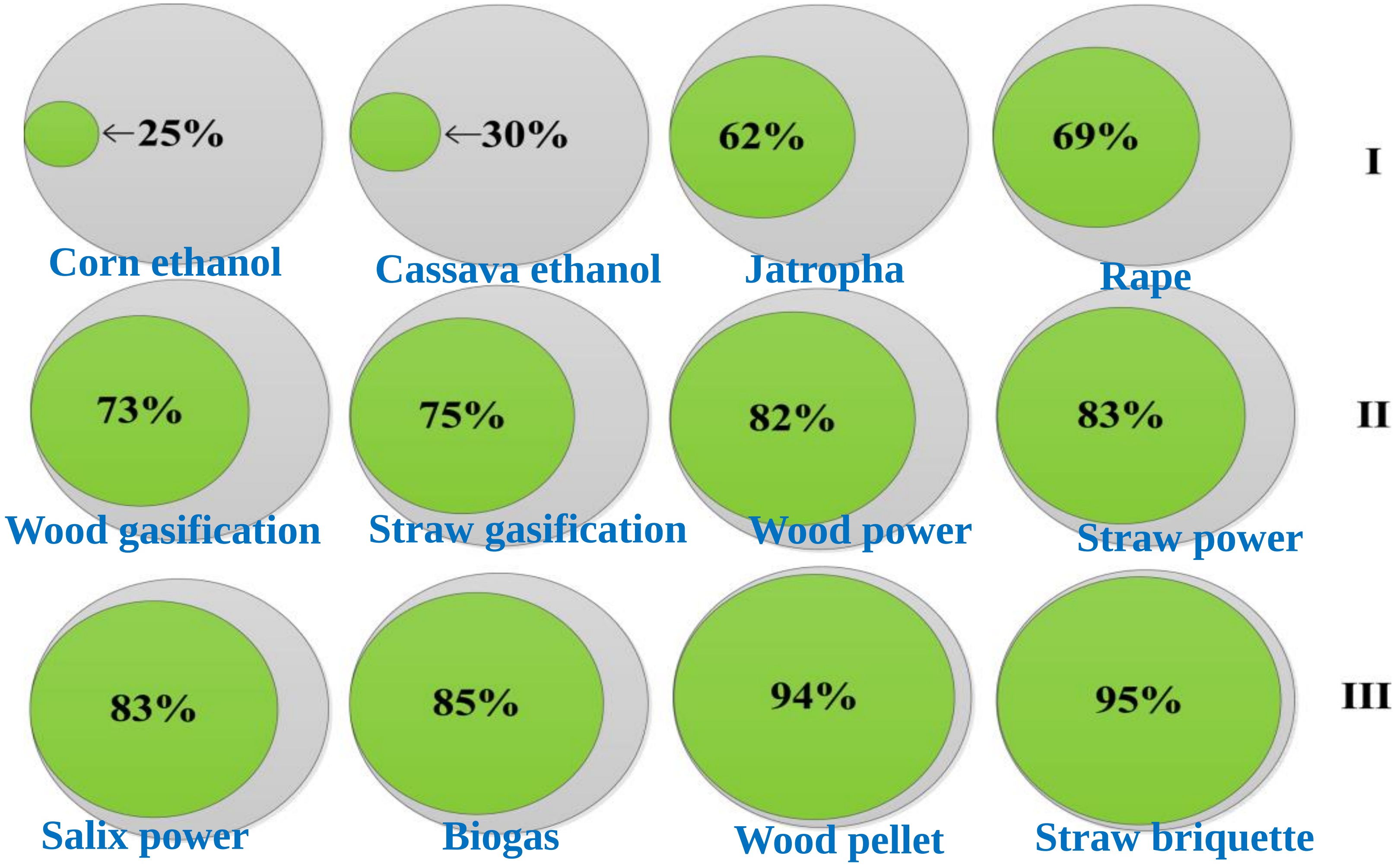


Renewability analysis



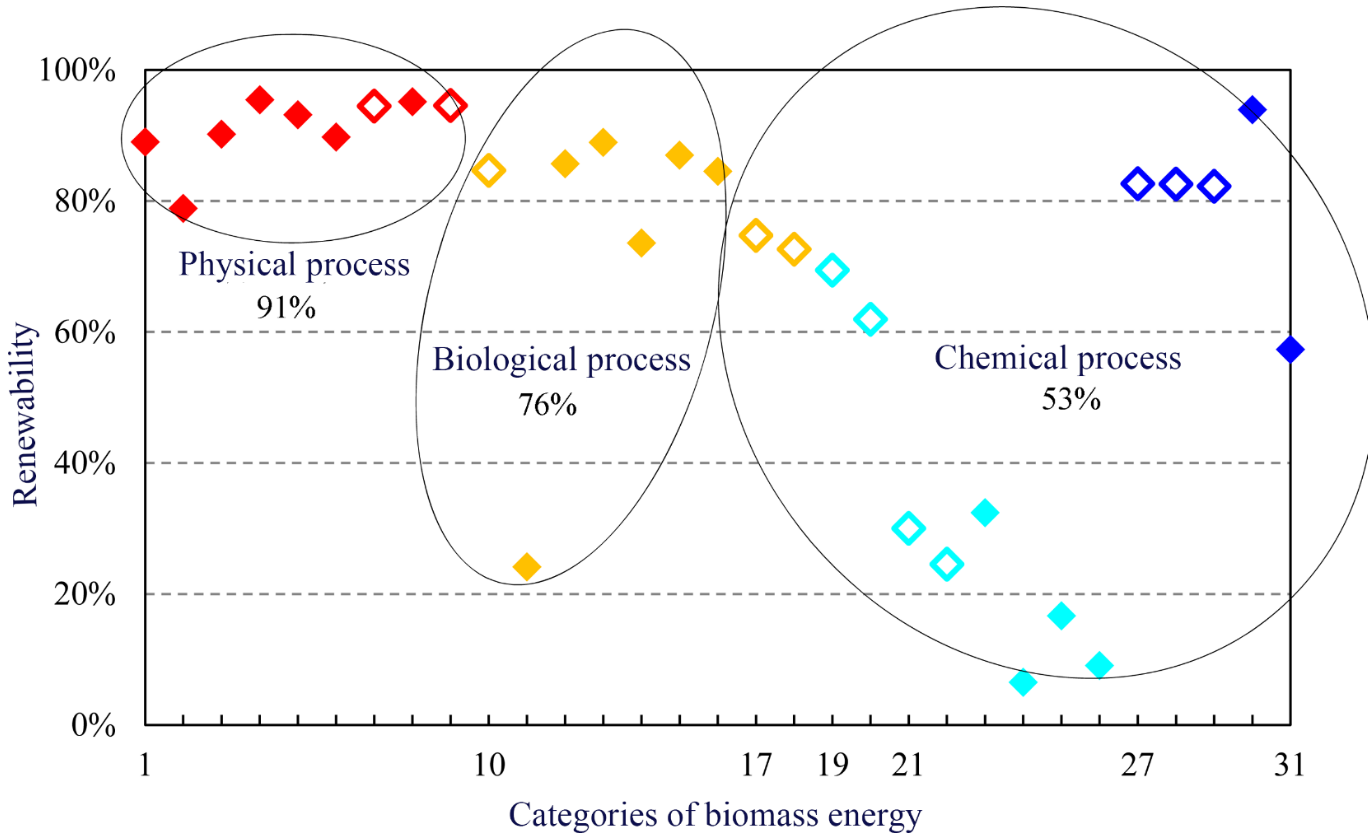
R%—energy output provided by renewable resources

N%—energy output provided by non-renewable resources



Renewability analysis

- In terms of different energy forms, solid fuel has the highest renewability, while liquefaction and gasification processes are relatively complex;
- The poor renewability indicates that in the process of improving energy quality, energy cost increases and system renewability decreases;
- From different transformation processes, the physical process (compression molding) is the most renewable, and the biological process (household) is the best.



MFA/LCA/EA of wind power development in China

Wind power is material intensive

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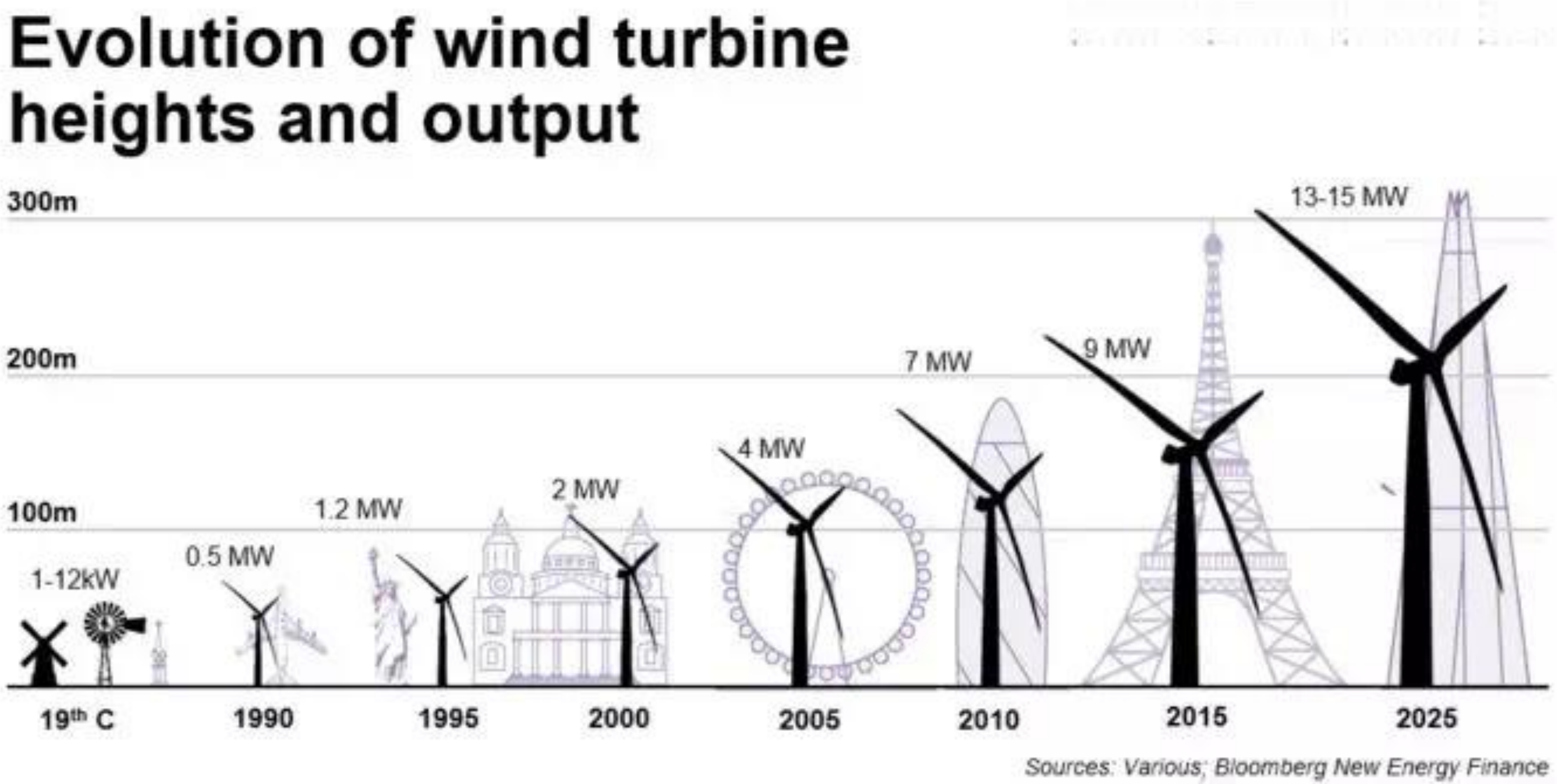

MFA is essential

PNAS

Integrated life-cycle assessment of electricity-supply scenarios confirms global environmental benefit of low-carbon technologies

Edgar G. Hertwich[a], Thomas Gibon[a,1], Evert A. Bouman[a], Anders Arvesen[a], Sangwon Suh[b], Garvin A. Heath[c], Joseph D. Bergesen[b], Andrea Ramirez[d], Mabel I. Vega[e], and Lei Shi[f]

[a]Industrial Ecology Programme, Department of Energy and Process Engineering, Norwegian University of Science and Technology, 7491 Trondheim, Norway; [b]Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106; [c]Technology Systems and Sustainability Analysis Group, Strategic Energy Analysis Center, National Renewable Energy Laboratory, Golden, CO 80401; [d]Energy and Resources, Copernicus Institute of Sustainable Development, Utrecht University, 3584 CD, Utrecht, The Netherlands; [e]Department of Chemical Engineering, University of Concepción, Casilla 160-C, Concepción, Chile; and [f]School of Environment, Tsinghua University, Beijing 100084, China

change mitigation and presents an opportunity to address pollution resulting from fossil-fuel combustion. Generally, renewable technologies require higher initial investments in infrastructure than fossil-based power systems. To assess the tradeoffs of increased up-front emissions and reduced operational emissions, we present, to our knowledge, the first global, integrated life-cycle assessment (LCA) of long-term, wide-scale implementation of electricity generation from renewable sources (i.e., photovoltaic and solar thermal, wind, and hydropower) and of carbon dioxide capture and storage for fossil power generation. We compare emissions causing particulate matter exposure, freshwater ecotoxicity, freshwater eutrophication, and climate change for the climate-change-mitigation (BLUE Map) and business-as-usual (Baseline) scenarios of the International Energy Agency up to 2050. We use a vintage stock model to conduct an LCA of newly installed capacity year-by-year for each region, thus accounting for changes in the energy mix used to manufacture future power plants. Under the Baseline scenario, emissions of air and water pollutants more than double whereas the low-carbon technologies introduced in the BLUE Map scenario allow a doubling of electricity supply while stabilizing or even reducing pollution. Material requirements per unit generation for low-carbon technologies can be higher than for conventional fossil generation: 11–40 times more copper for photovoltaic systems and 6–14 times more iron for wind power plants. However, only two years of current global copper and one year of iron production will suffice to build a low-carbon energy system capable of supplying the world's electricity needs in 2050.

PNAS

CrossMark
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Global socioeconomic material stocks rise 23-fold over the 20th century and require half of annual resource use

Fridolin Krausmann[a,1], Dominik Wiedenhofer[a], Christian Lauk[a], Willi Haas[a], Hiroki Tanikawa[b], Tomer Fishman[b,c], Alessio Miatto[b], Heinz Schandl[d], and Helmut Haberl[a]

[a]Institute of Social Ecology Vienna, Alpen-Adria University, A-1070 Vienna, Austria; [b]Graduate School of Environmental Studies, Nagoya University, Chikusa-ku, Nagoya 464-8601, Japan; [c]Center for Industrial Ecology, School of Forestry and Environmental Studies, Yale University, New Haven, CT 06511; and [d]Commonwealth Scientific and Industrial Research Organization, Black Mountain Laboratories, Acton, 2601 ACT, Australia

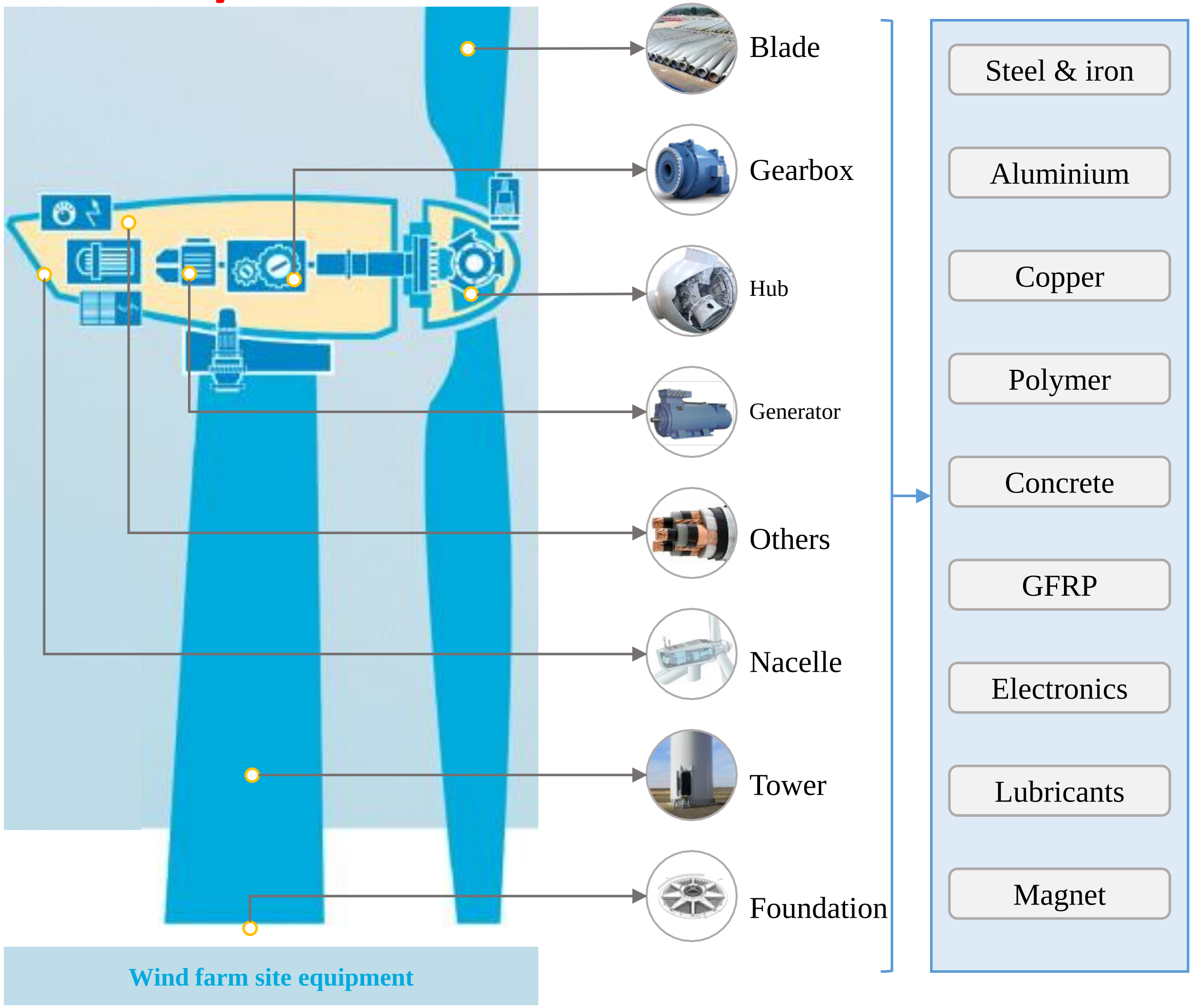
Human-made material stocks accumulating in buildings, infrastructure, and machinery play a crucial but underappreciated role in shaping the use of material and energy resources. Building, maintaining, and in particular operating in-use stocks of materials require raw materials and energy. Material stocks create long-term path-dependencies because of their longevity. Fostering a transition toward environmentally sustainable patterns of resource use requires a more complete understanding of stock-flow relations.

Significance

A large part of all primary materials extracted globally accumulates in stocks of manufactured capital, including in buildings, infrastructure, machinery, and equipment. These in-use stocks of materials provide important services for society and the economy and drive long-term demand for materials and energy. Configuration and quantity of stocks determine future waste flows and recycling potential and are key to closing material loops and reducing waste and emissions in a circular economy. A better understanding of in-use material stocks and their dynamics is essential for sustainable development. We present a comprehensive estimate of global in-use material stocks and of related material flows, including a full assessment of uncertainties for the 20th century as we analyze changes in stock-flow relations.

Renewable energy infrastructure requires much more material than traditional energy.

Wind turbine components



Conceptual figure of the material intensity split model

High-resolution wind turbine database

Top10 Manufacture
26 Series
102 Types

Domestic & imported
Geared & Direct Drive

金风科技 GOLDWIND
上海电气 SHANGHAI ELECTRIC
sinovel 华锐风电
联合动力 United Power
ENVISION 远景能源
XEMC 湘电风能
WIND POWER HEAG 华仪风能
Vestas
SIEMENS 西门子
Gamesa

W1250-64
W1250-70
W2000-105
W2000-99
W2000-93
W2000-87
W3600-122
W3600-116
W5000
GW115/2.0MW
SL3000/90
SL3000/100
SL3000/105
SL3000/113
SL3000/118
GW43/600
GW48/750
GW87/1500
GW62/1200
UP1500-77
UP1500-82
UP1500-86
UP3000
V52-850kw
XE72-2000
XE/DD115
XE/DD128
77/1500kw
MWT100/2.5WM
EN15-82
100/2500
90/2500
87/1500
87/1500
87/1500
V82-1.65
V90-3.0MW
V100-3MW
V52
V80
V52-850kw

Material in-flow

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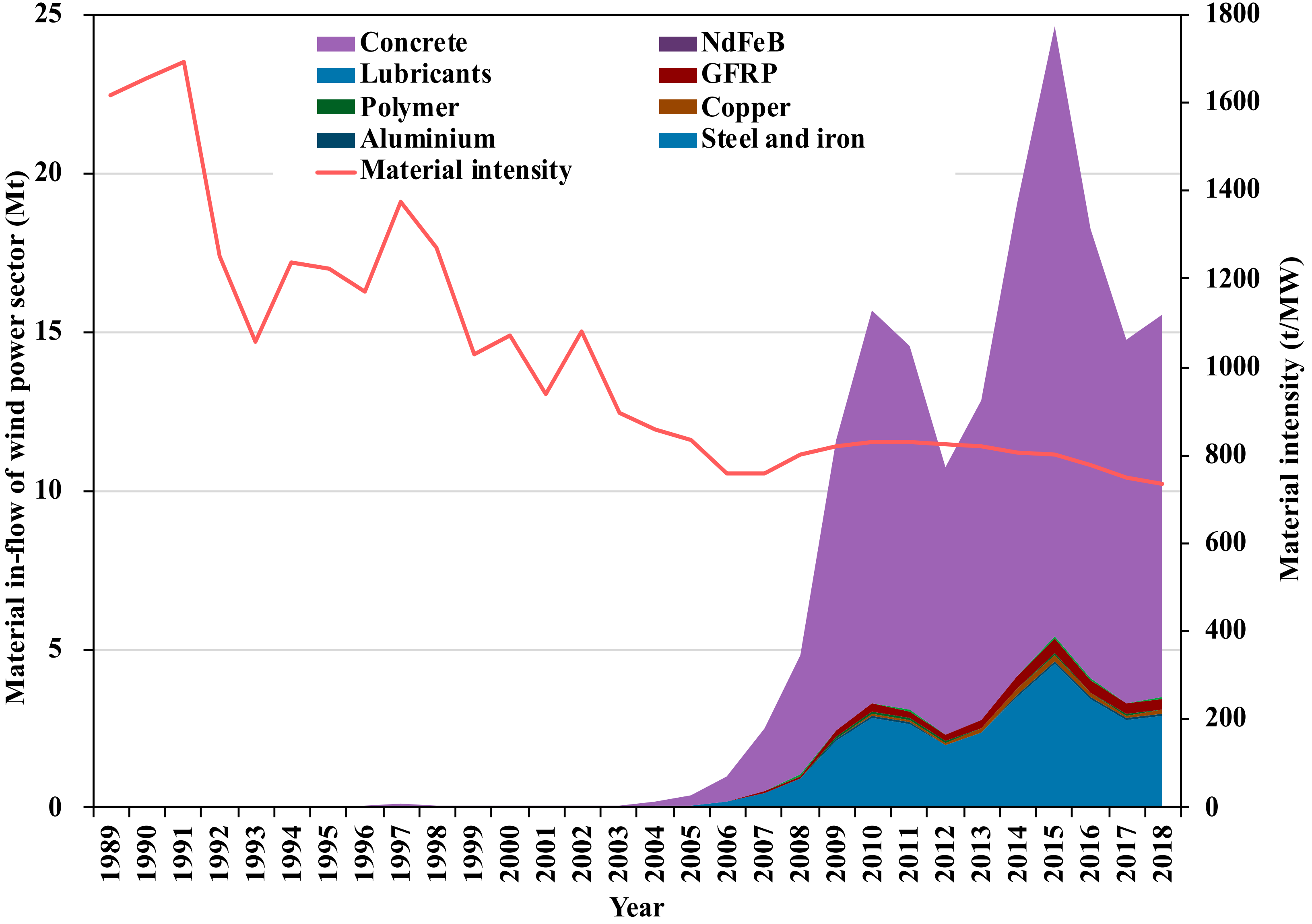

Material in-use stock

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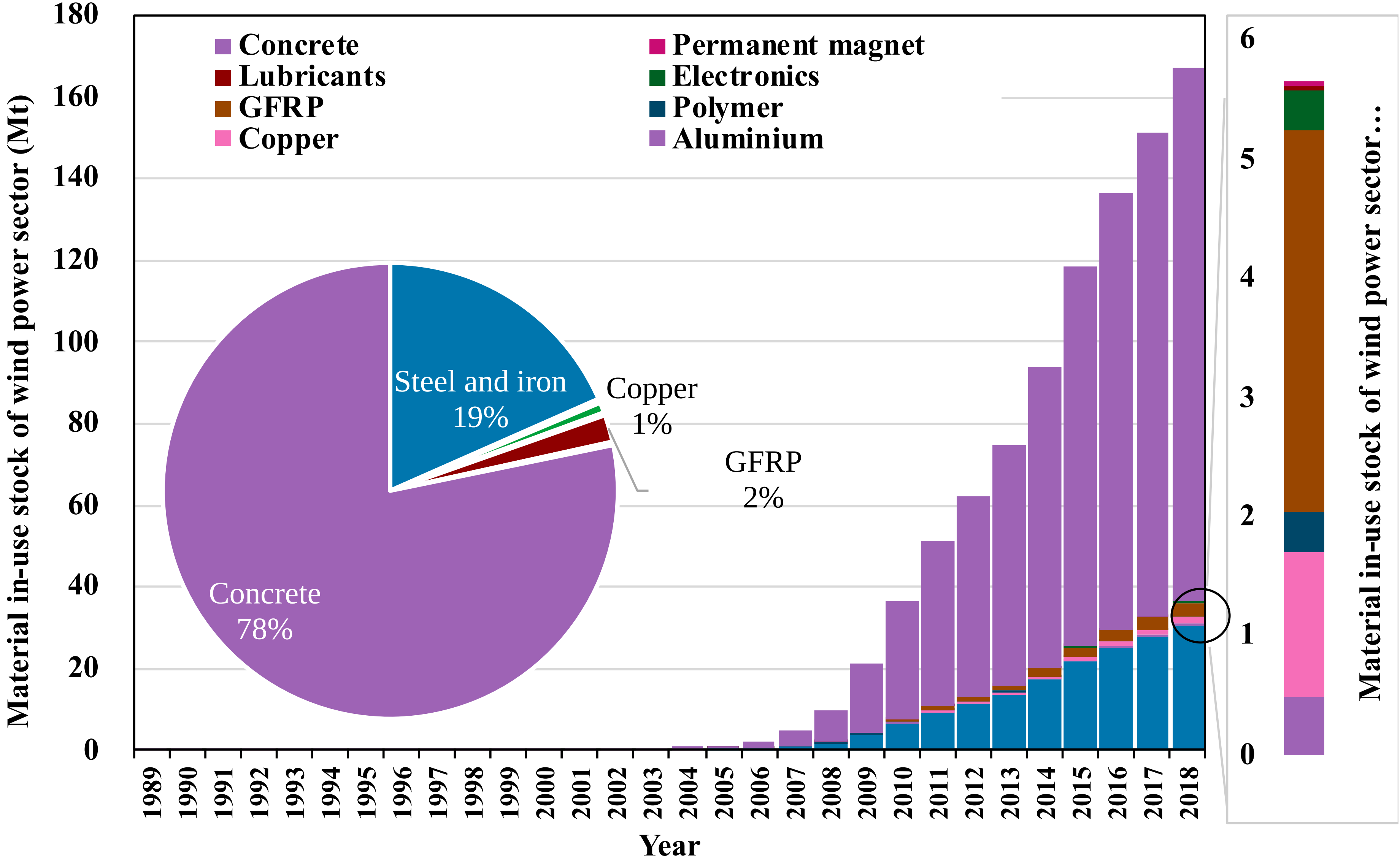

Spatial distribution of material in-use stock

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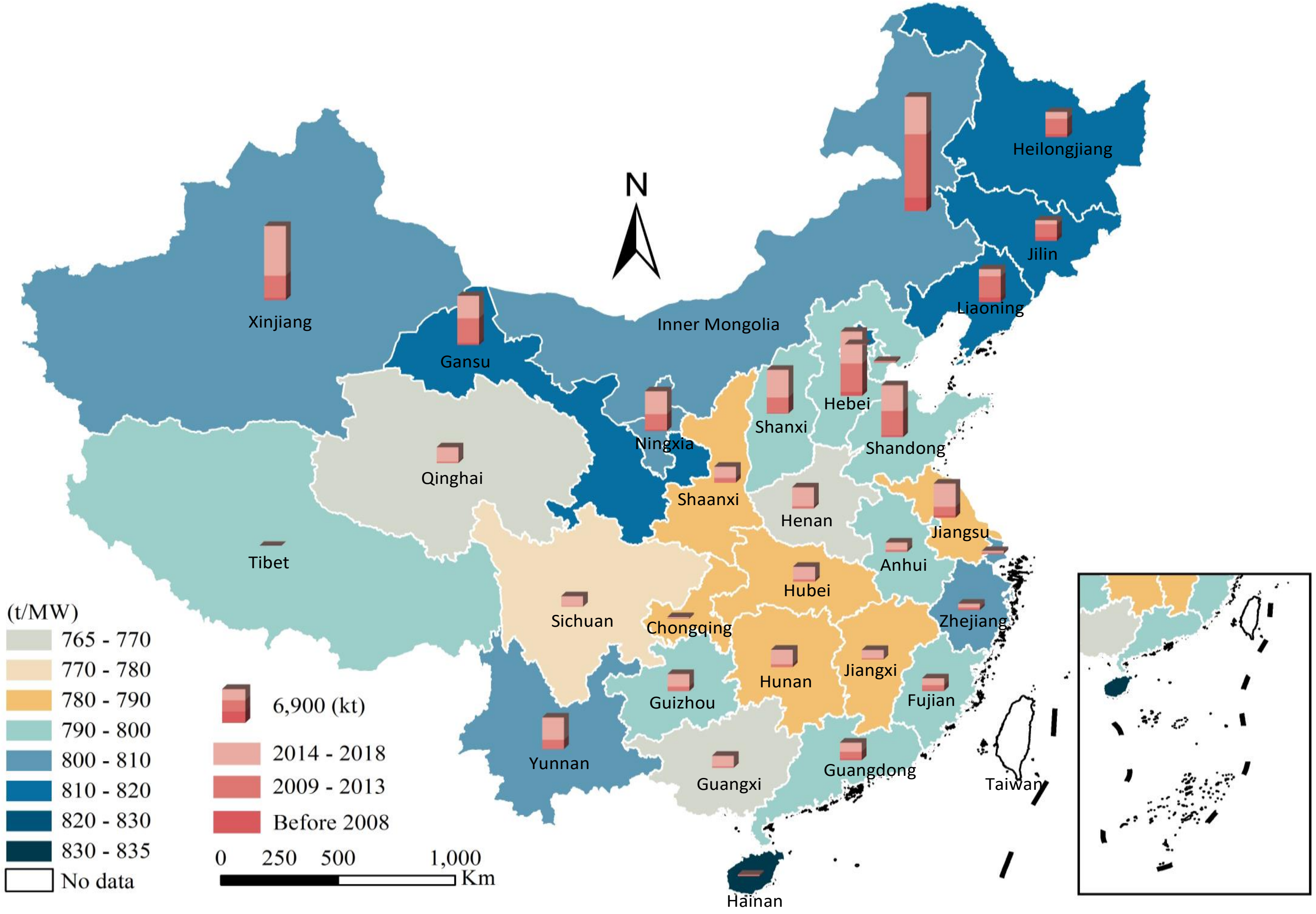

Material stock efficiency

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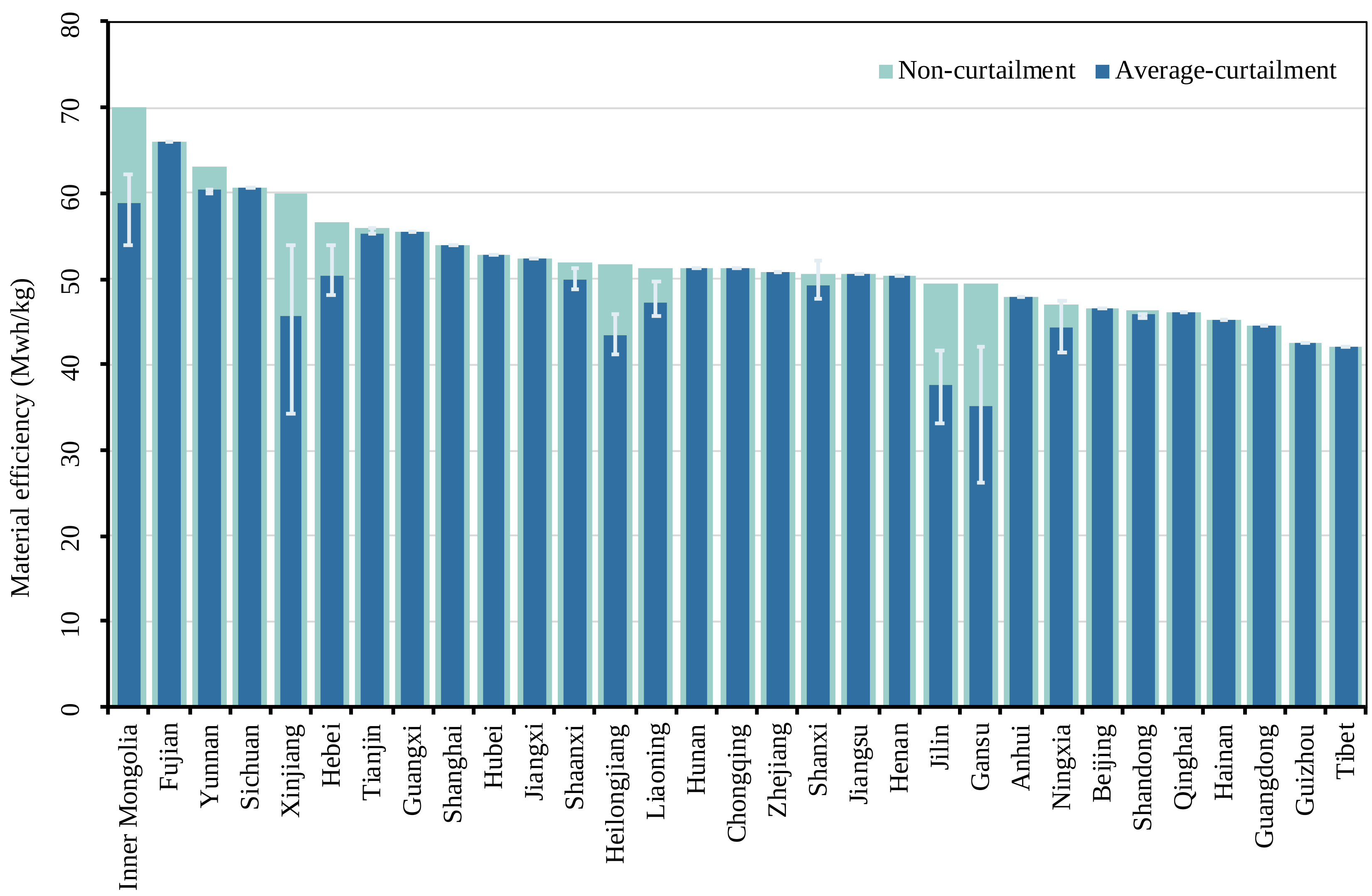

Wind turbine blade waste of China

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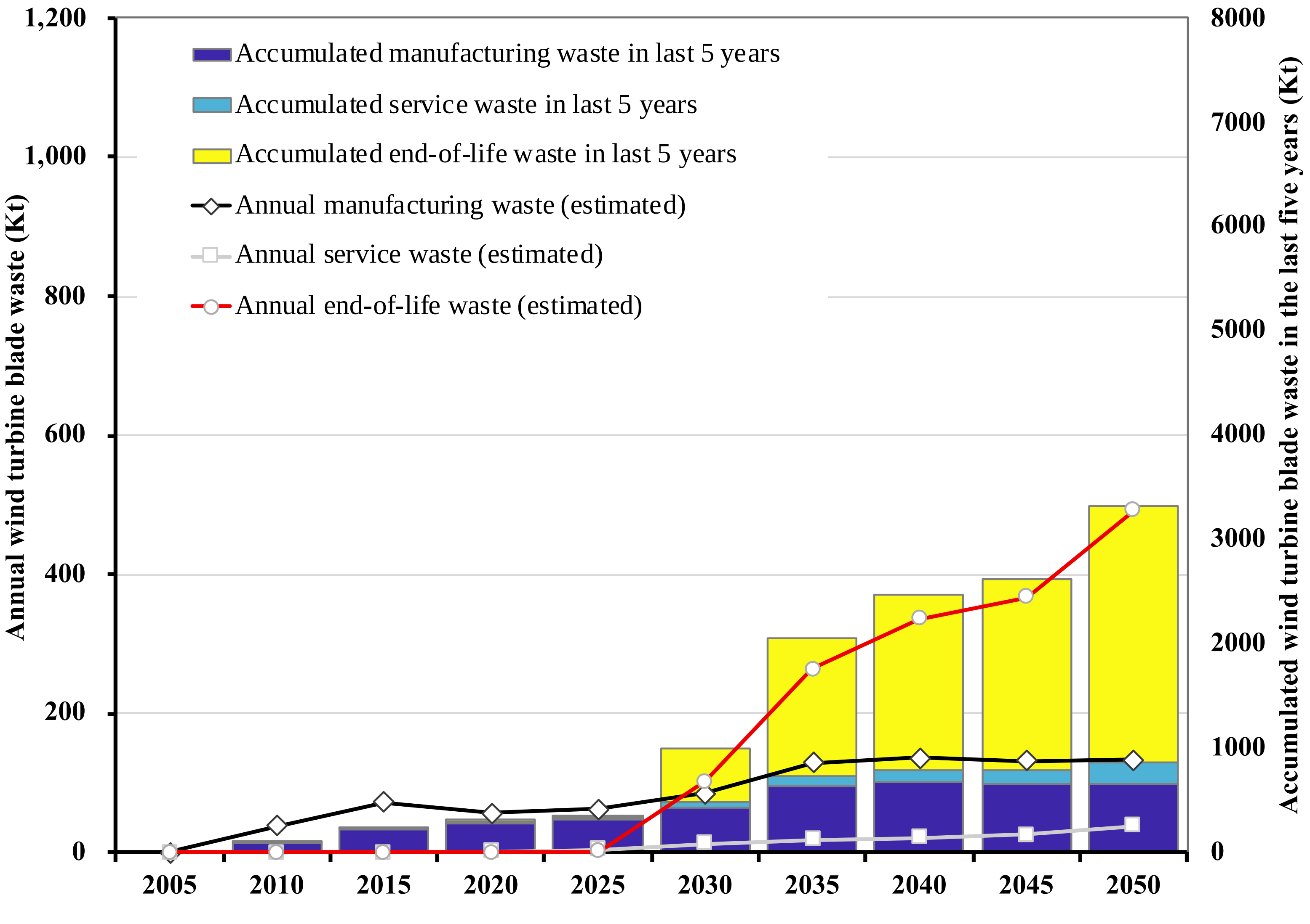

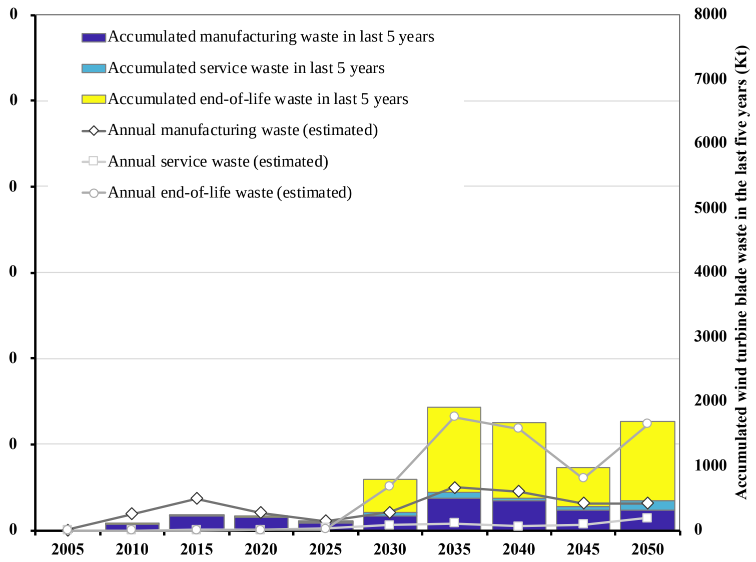

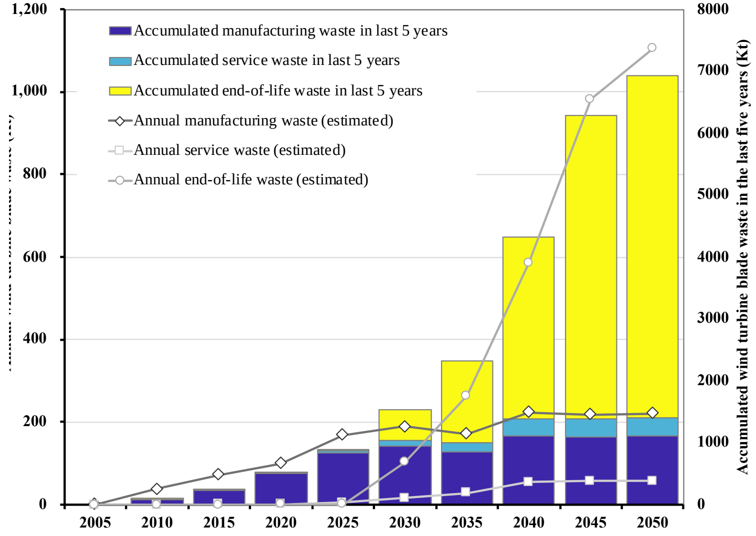

Patterns of blade waste in each region

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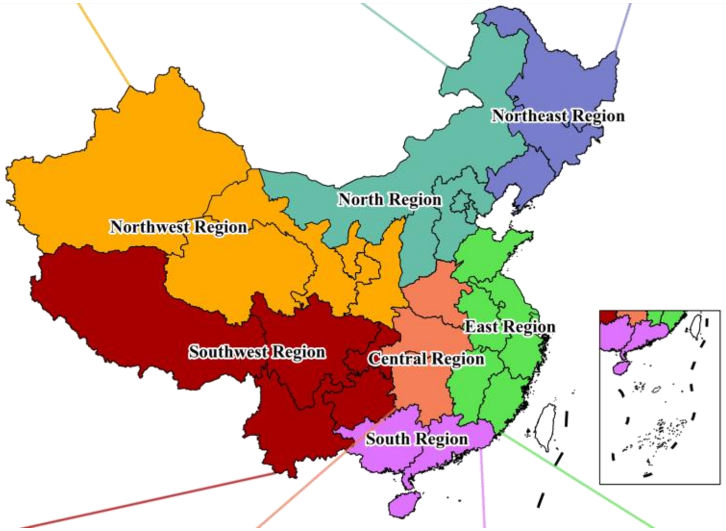

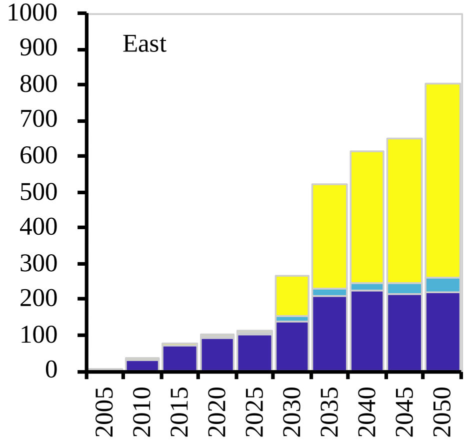

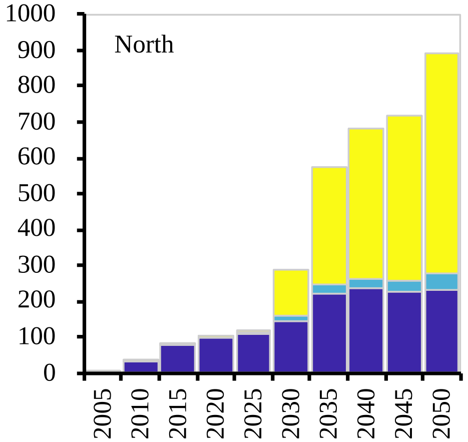

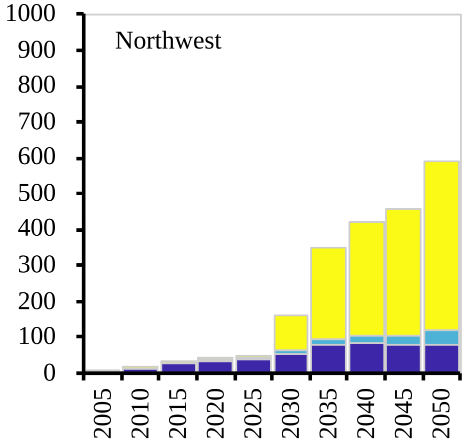

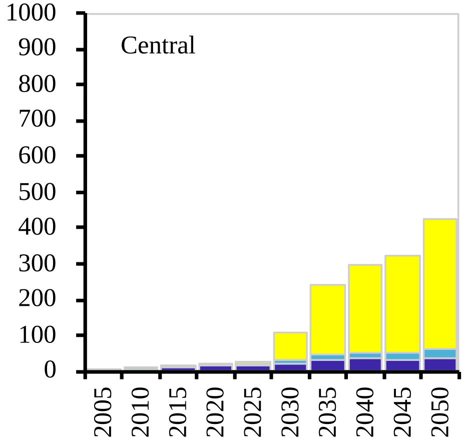

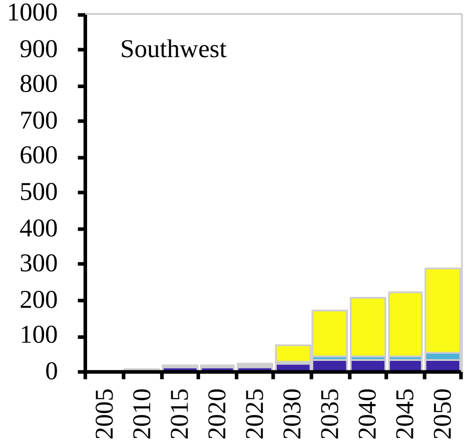

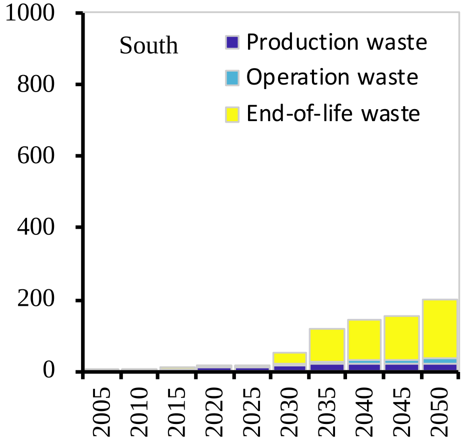

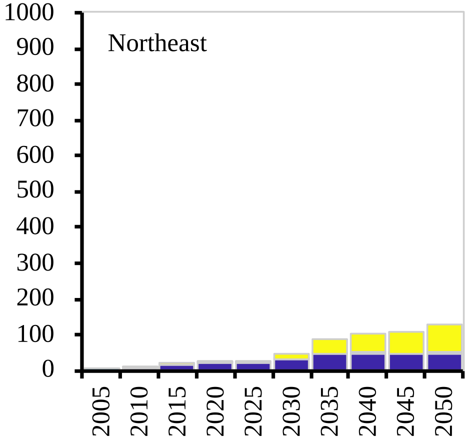

Blade waste in each province

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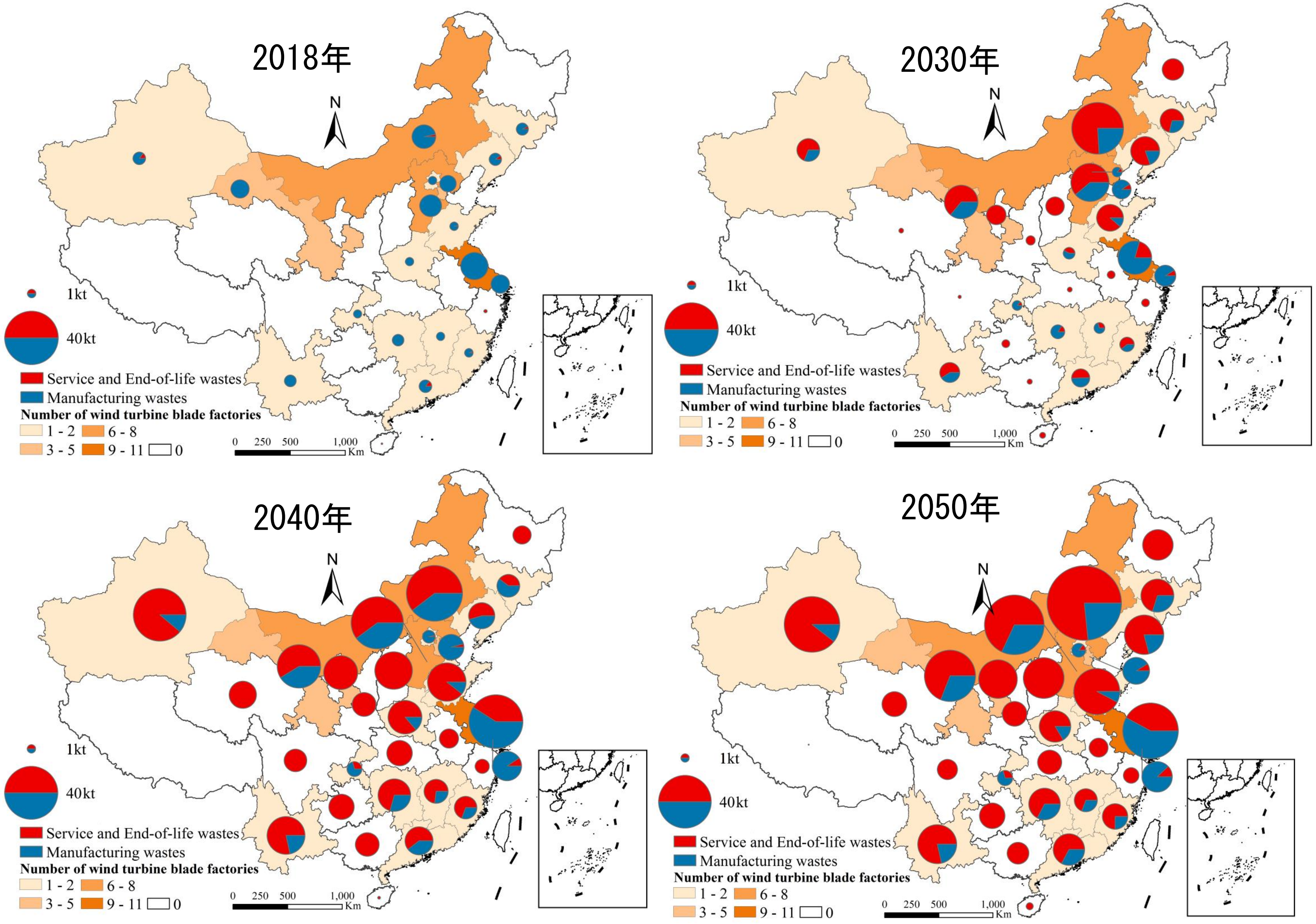
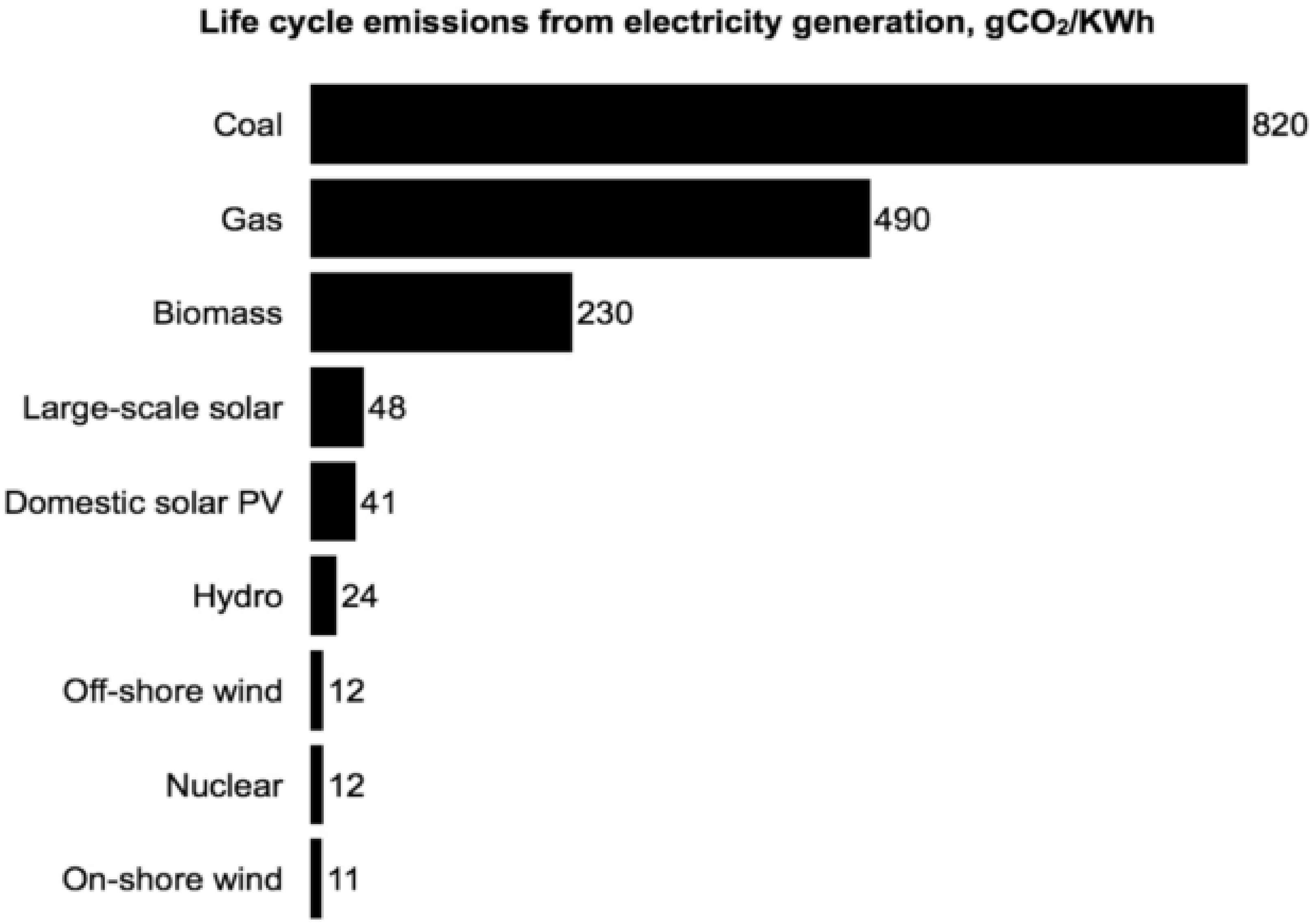


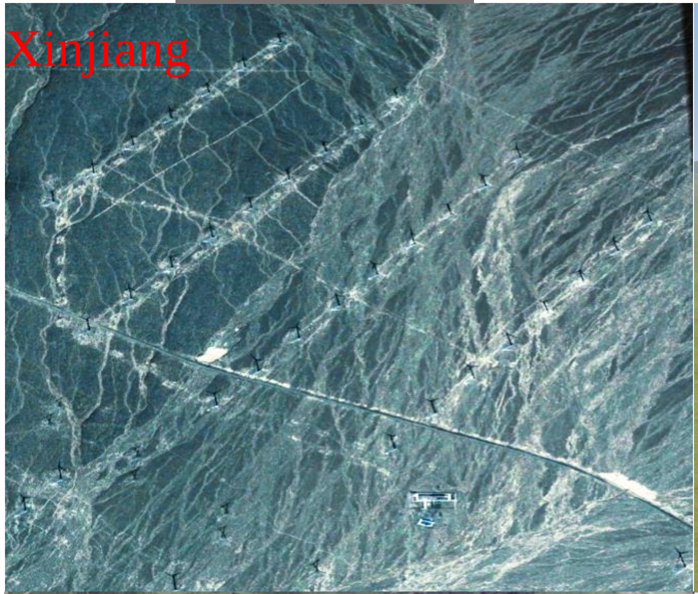
Life cycle emissions of CE



Comparison between plain and mountain

Distribution | Road | Platform

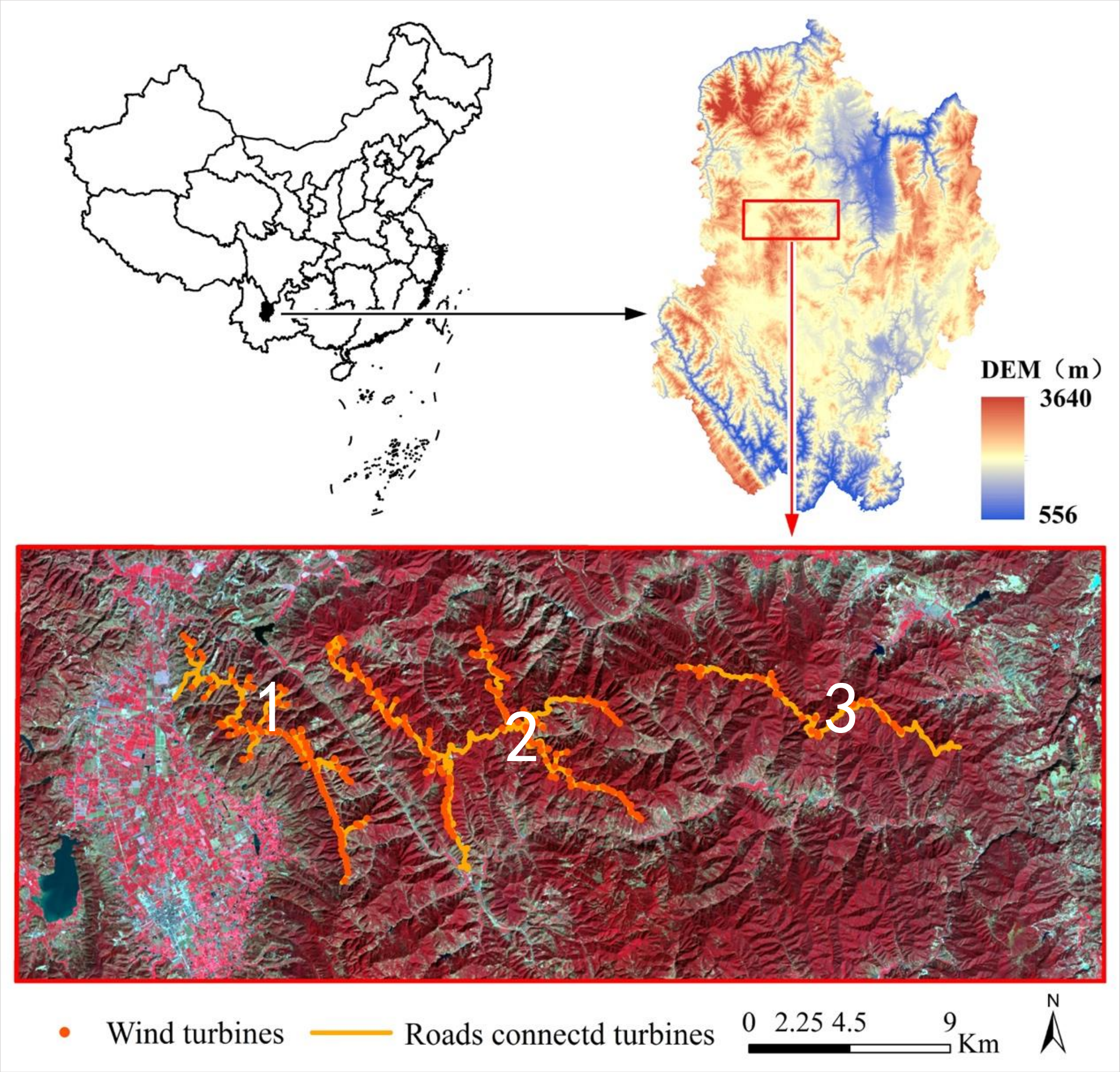
Plain



Mountain

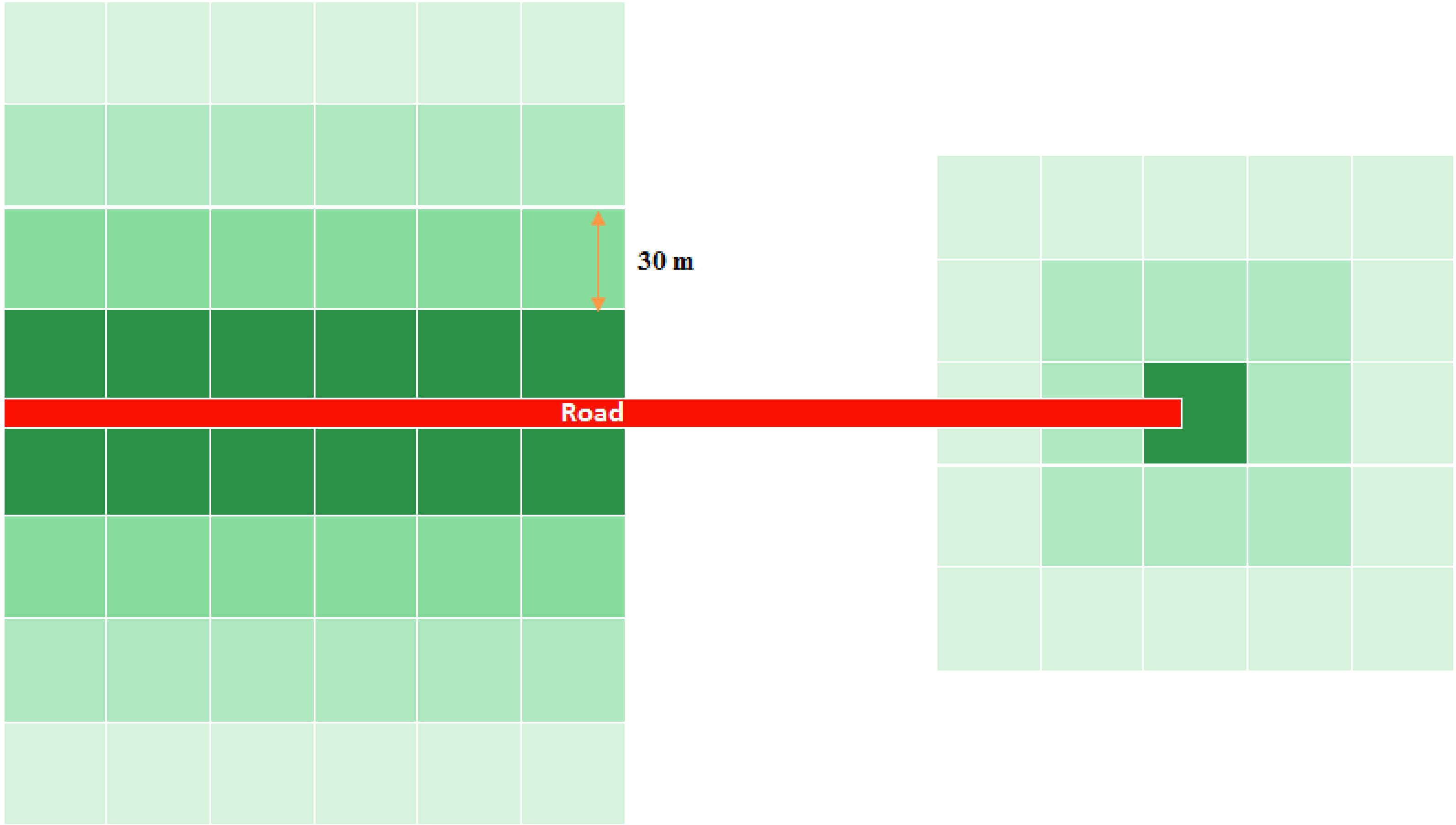
Construction process

Case area



Wind farm	Construction	Altitude (m)	Road (km)	Turbines	Installed capacity (MW)
NO.1	2010-2011	1997-2621	49.56	87	130.5
NO.2	2014	2350-2704	72.38	113	169.5
NO.3	2014	2256-2547	26.61	25	50

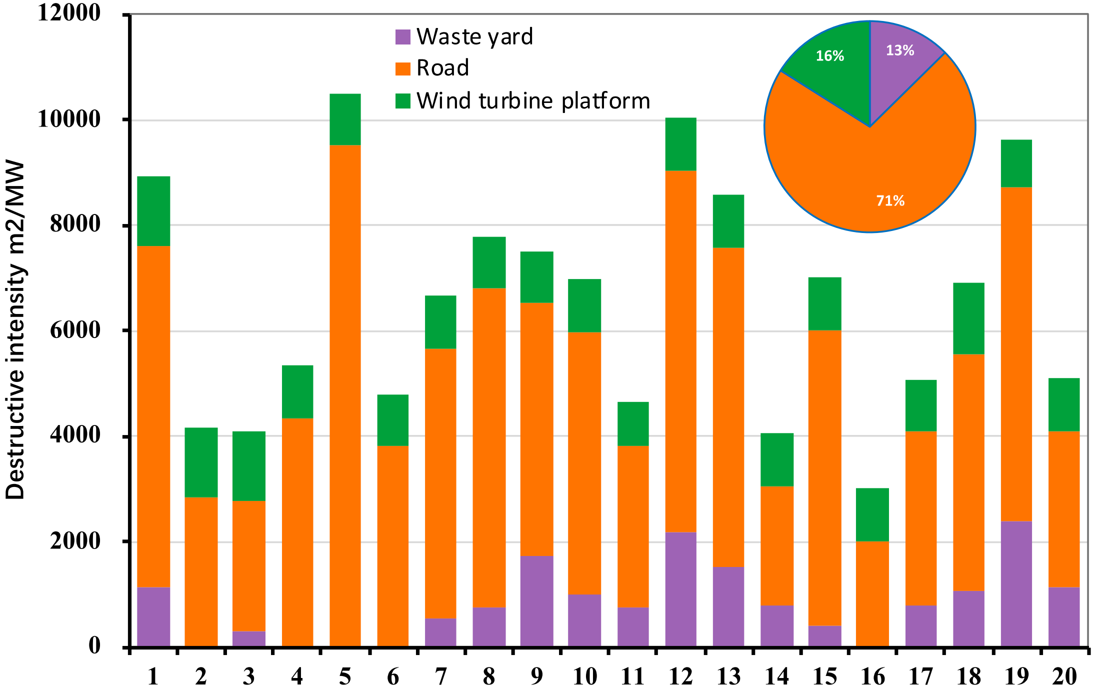
Schematic diagram



Land use change intensity

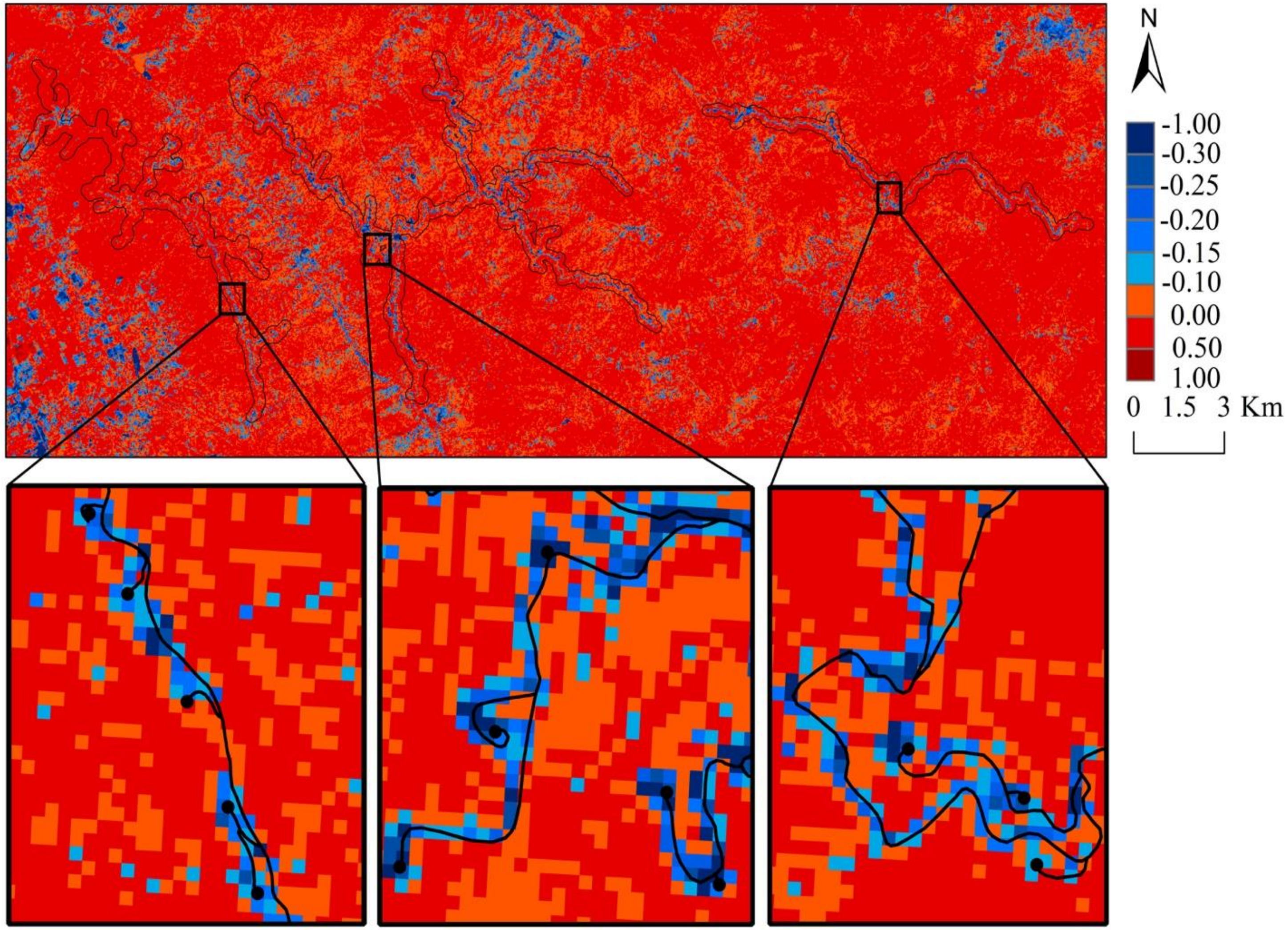
Road
R_i： 0.61m/kW

Platform
P_i:1m^2/kW



A 50MW wind farm would occupy approximately 42 standard football fields

2010-2017 △NDVI



NDVI changes of different buffers

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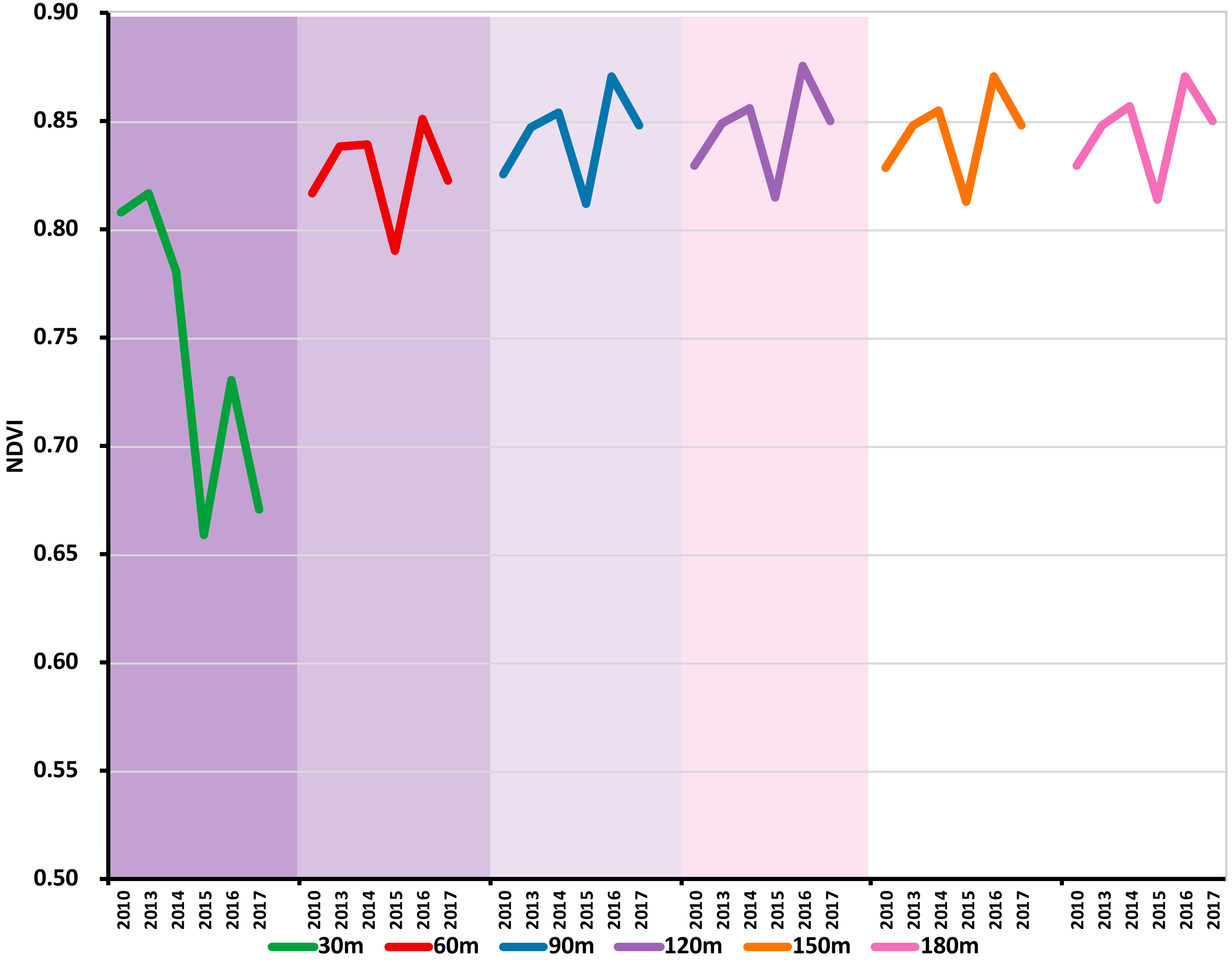
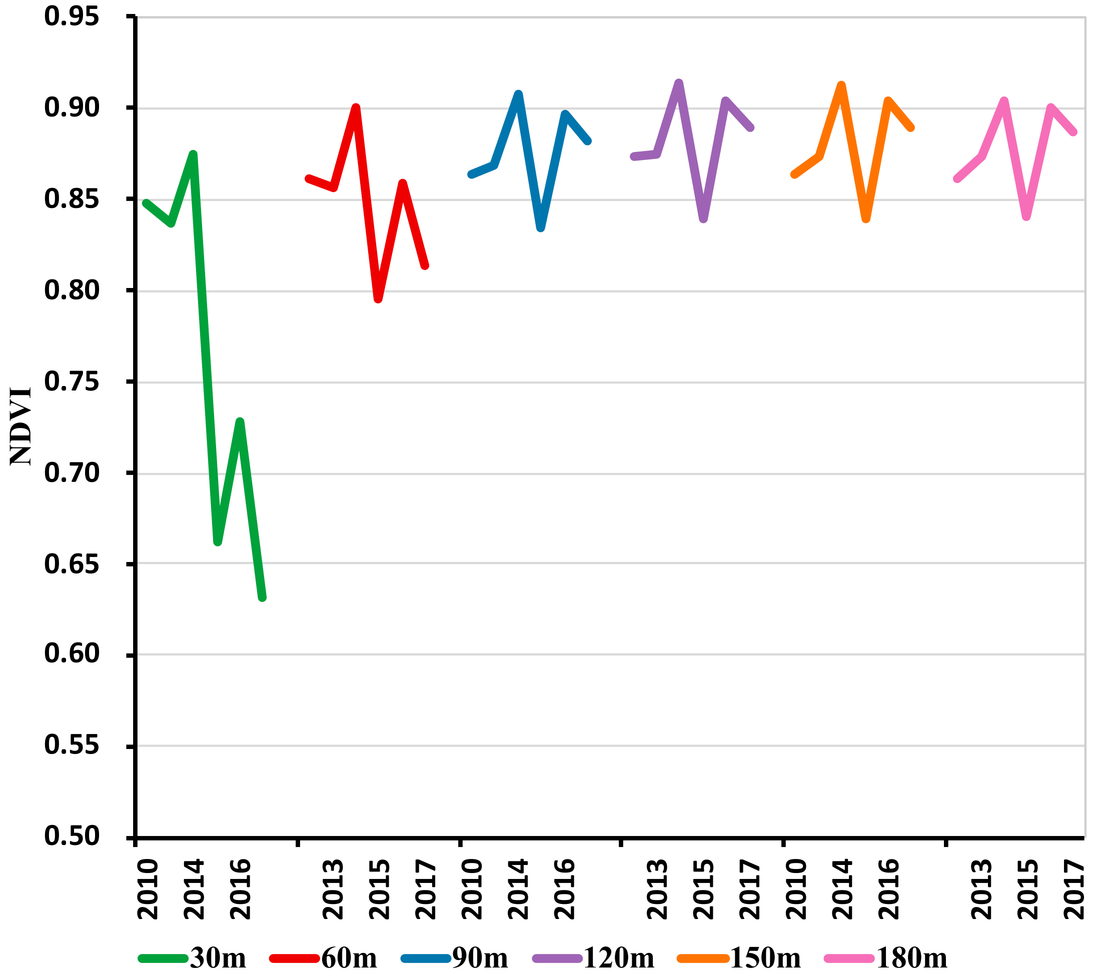


Road



Wind turbine platform

NDVI changes with time

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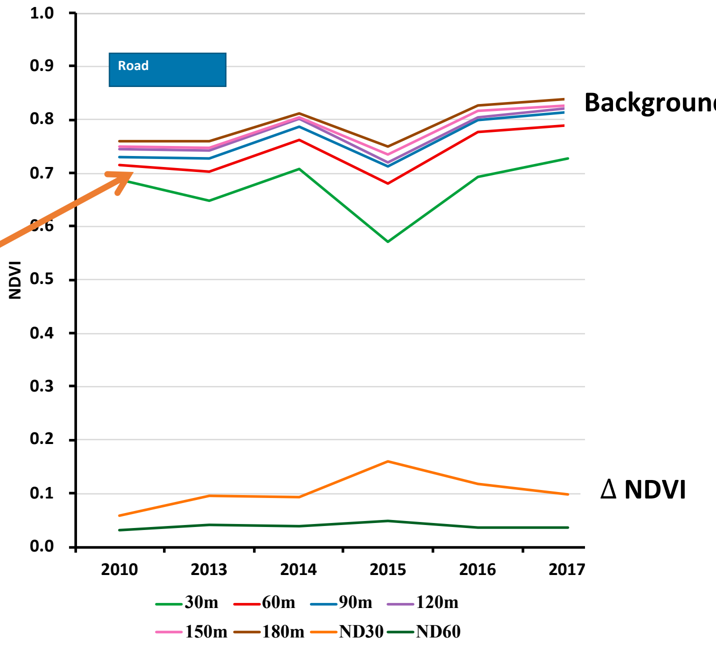
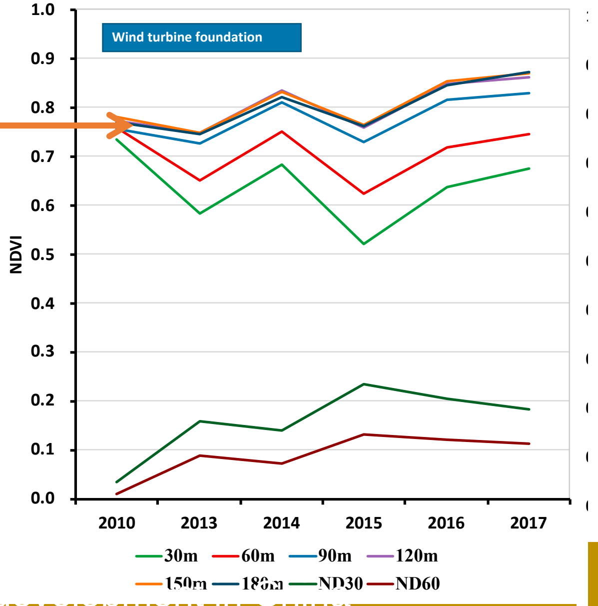




Δ NDVI=Background NDVI - Construction area NDVI

Wind power construction decreased the resilience.

Make the construction area more sensitive

Wind farm changed the surface temperature


Impacts of wind farms on surface air temperatures

Somnath Baidya Roy[1] and Justin J. Traiteur

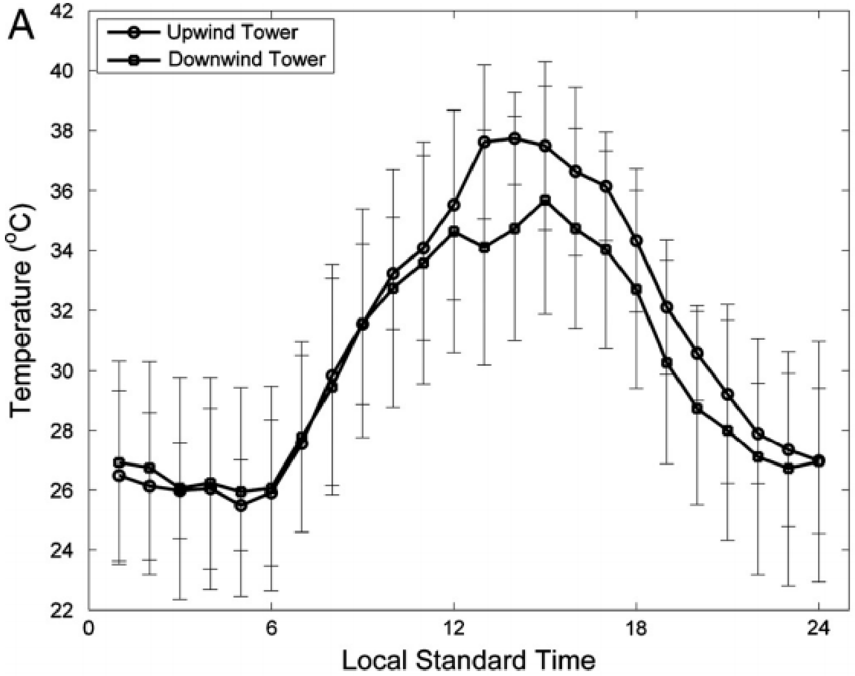
Department of Atmospheric Sciences, University of Illinois, 105 South Gregory Street, Urbana, IL 61820

Edited* by Stephen H. Schneider, Stanford University, Stanford, CA, and approved August 13, 2010 (received for review January 15, 2010)

Utility-scale large wind farms are rapidly growing in size and numbers all over the world. Data from a meteorological field campaign show that such wind farms can significantly affect near-surface air temperatures. These effects result from enhanced vertical mixing due to turbulence generated by wind turbine rotors. The impacts of wind farms on local weather can be minimized by changing rotor design or by siting wind farms in regions with high natural turbulence. Using a 25-y-long climate dataset, we identified such regions in the world. Many of these regions, such as the Midwest and Great Plains in the United States, are also rich in wind resources, making them ideal candidates for low-impact wind farms.

impact assessment | regional climate model | sustainable energy | wind energy | wind power potential

Wind power is one of the fastest growing energy sources in



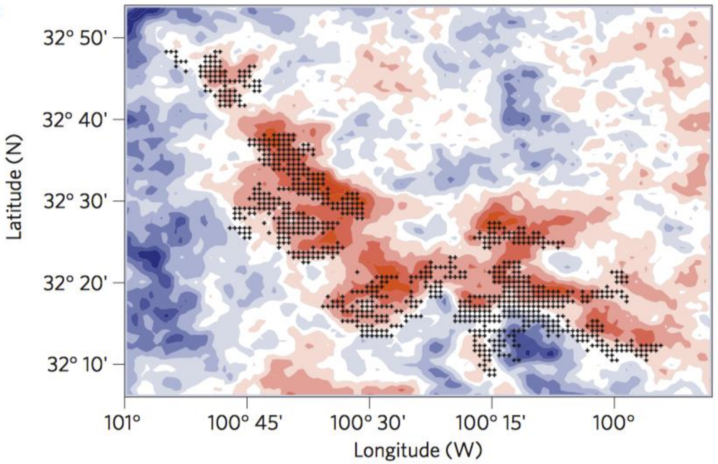

nature climate change

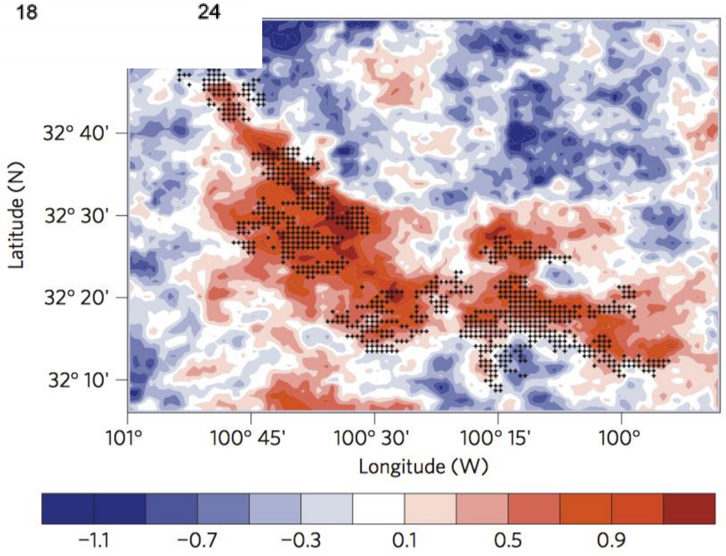
LETTERS

PUBLISHED ONLINE: 29 APRIL 2012 | DOI: 10.1038/NCLIMATE1505

Impacts of wind farms on land surface temperature

Liming Zhou[1]*, Yuhong Tian[2], Somnath Baidya Roy[3], Chris Thorncroft[1], Lance F. Bos and Yuanlong Hu[4]





Wind power impacts the ecosystem

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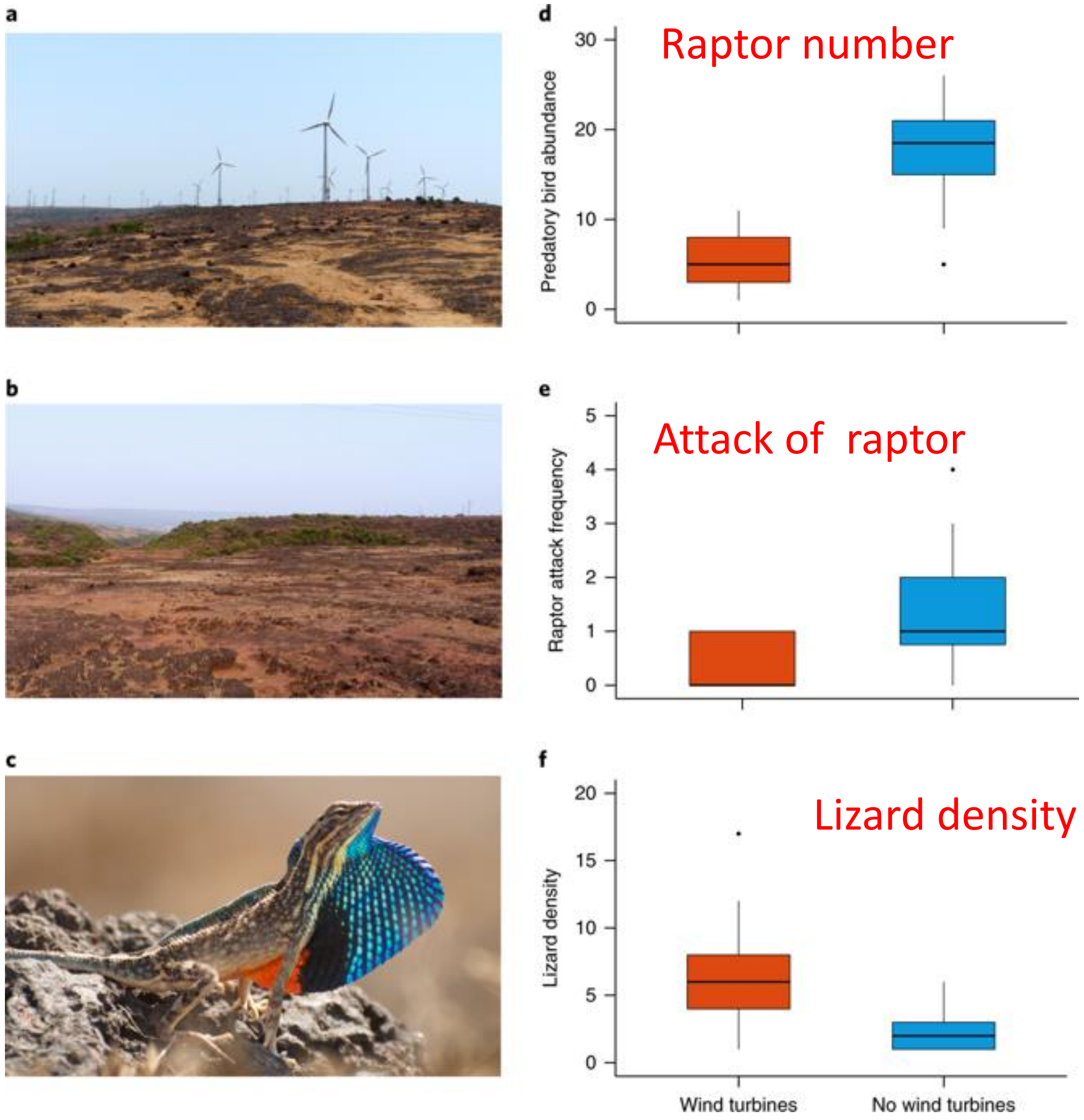
BRIEF COMMUNICATION
https://doi.org/10.1038/s41559-018-0707-z
nature ecology & evolution

Wind farms have cascading impacts on ecosystems across trophic levels

Maria Thaker[1,3*], Amod Zambre[1,2,3] and Harshal Bhosale[1]



Killing bird?

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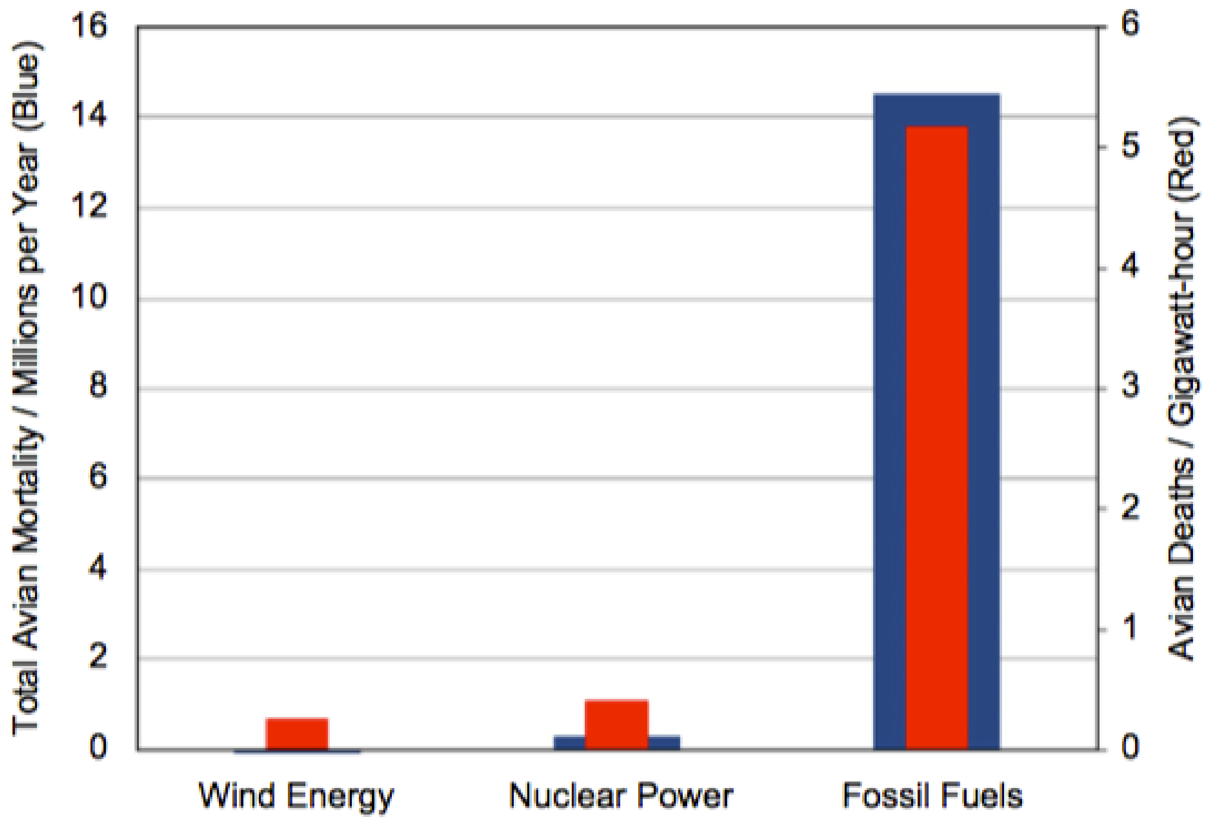

Fig. 1. Estimated avian mortality for wind, fossil-fuel, and nuclear energy per year. (Readers are invited to view the online version of the article to decipher the references to color.)

Sovacool B K. Contextualizing avian mortality: A preliminary appraisal of bird and bat fatalities from wind, fossil-fuel, and nuclear electricity[J]. Energy Policy, 2009, 37(6): 2241-2248.

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Thank You

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