A comparison of solar and wind energy development between western China and the western US

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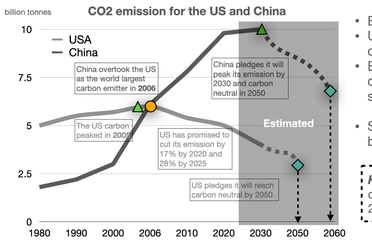
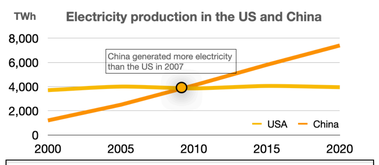
Introduction





Both countries are the world's largest electricity generators

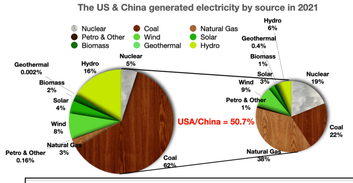
- Both China and the US are pursuing carbon neutrality targets
- US and China are the largest electricity generators and consumers
- Both countries are the world's largest emitters. The two countries combined share 42%+ of total carbon emission since 2017

→ *"Why China and the US"*

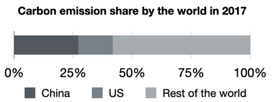
- Solar and wind energy are selected as the research targets because they have the best potential in the future

→ *"Why solar and wind"*

Key purpose: To evaluate the performance of solar and wind energy development in each western state/province in the US and China in 2020



Both countries are the world's largest electricity consumers



Both countries are the world largest emitters

*Western/National = West %	
Area	West% = **31.8%** (3.1 million KM^2)
Population	West% = **21.9%** (308 million)
GDP per capita	West% = **78.3%** ($9,825)
Area	West% = **31.8%** (3.1 million KM^2)
Population	West% = **21.5%** (71.4 million)
GDP per capita	West% = **101.5%** ($70,153)

Yellow-shaded areas are selected western areas in both countries

- Western regions are important for both countries' carbon neutrality goals and renewable energy development
- Based on the definition, there are **12** provinces in western China and **11** states in the western US
- Both western regions share Similarities in solar and wind resources, area, and population ratio

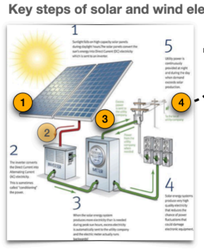
→ *"Why western areas"*

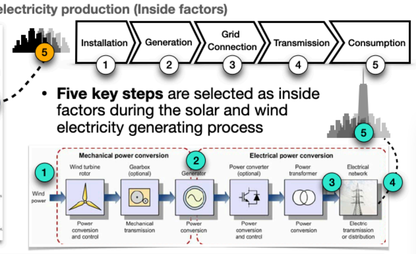
Literature Review

- Total covered **50+** academic articles and industry reports
- Among them, **18** are related to China's renewable energy, from which there are only **4** regional studies focused in western China; **15** are related to the US renewable energy, but only **6** are focused in the western US
- Total covered **50+** academic articles and industry reports
- The rest **17+** are general studies regarding renewable energy or solar and wind development status in other countries
- **4** articles are considered as the reference methodology for this research, Wang et al. (2020) used a multidimensional assessment approach to conduct regional renewable energy development in China. However, it is an assessment of renewable energy overall in 32 provinces of China from 2008 to 2014 to explore the improvement. However, this research primarily focuses on solar and wind development
- **Research gap**: **Limited articles or reports compare two western regions directly regarding solar and wind energy development**

Methodology

Key steps of solar and wind electricity production (Inside factors)





The above graphs show the key steps during the solar and wind electricity generation process

- ***Key Assumptions:* all weights are identical (W/V=1)** as there is no evidence to assume which factor plays a more important role than the other
- **Normalization:** to re-scale different factors' value (in different units) within the same range, to make them add-able and calculate-able
  - **Electricity deficit:** $N_{Consumption} = 1 - D$
    A deficit is not a positive indicator, so that's why we need to find its negative value
  - **Other factors:** $N = (X - X_{min})/(X_{max} - X_{min})$

Factors calculation:

Outside Factors

$Ne = Vgdp * Ngdp + Vincome * Nincome$

$Ns = VRebate * NRebate + VNet\ Metering * NNet\ Metering + VPPtax * NPPtax + VCtax * NCtax + Vincome * Nincome$

Inside Factors

$Ni = V5\text{-}year\%ins\text{-}wind * N5\text{-}year\%ins\text{-}wind + V5\text{-}year\%ins\text{-}solar * N5\text{-}year\%ins\text{-}wind + Vcwind * Ncwind + Vcsolar * Ncsolar$

$Ng = V\%\_Gwind * N\%\_Gwind + V\%\_Gsolar * N\%\_Gsolar$

$Ngc = Vcurtail\text{-}wind * Ncurtail\text{-}wind + Vcurtail\text{-}solar * Ncurtail\text{-}solar$

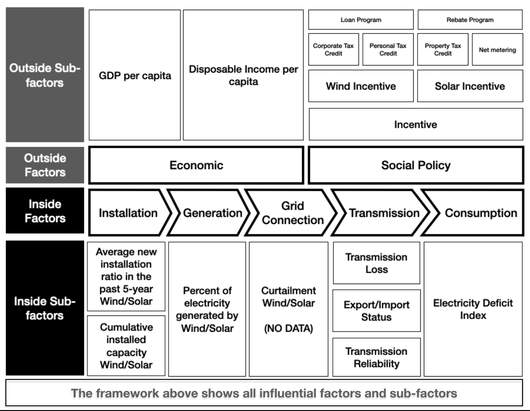
$Nt = Vtrans\_loss * Ntrans\_loss + Vtrans\_Reliability * Ntrans\_Reliability + Vexport\_import * Nexport\_import$

$Nc = Vconsumption * Nconsumption$

Final score's calculation:

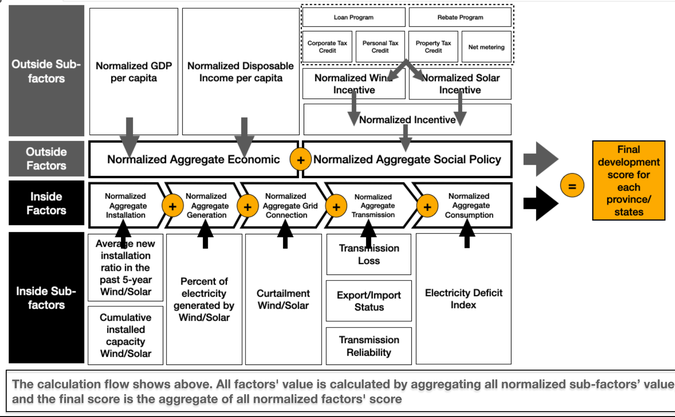
$Nscore = \sum Wx * Nx\ (W>0;\ N>=0)$

- **Economics and social policy are selected as two outside factors**
- The sub-factors of economics are **GDP per capita** and **disposable income per capita**
- The sub-factors of social policy is the **incentive**, including **Loan Programs, Rebate Programs, Corporate Tax Credits, Personal Tax Credits, Property Tax Credits, and Net metering**



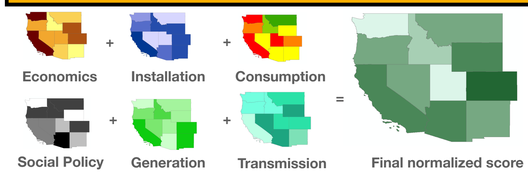
The framework above shows all influential factors and sub-factors

W represents the weight of factors, V represents the widget of sub-factors, N represents a normalized score

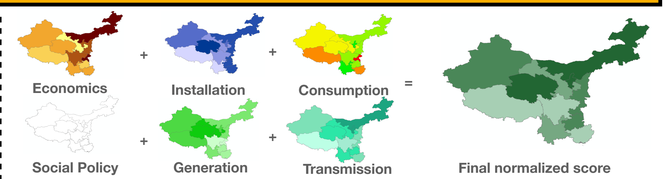


The calculation flow shows above. All factors' value is calculated by aggregating all normalized sub-factors' value, and the final score is the aggregate of all normalized factors' score

Normalized Results



The darker color is, the higher the index is for each factor's result and the final normalized result. The **top three performers** in the western US are **Colorado, Arizona, and Wyoming**

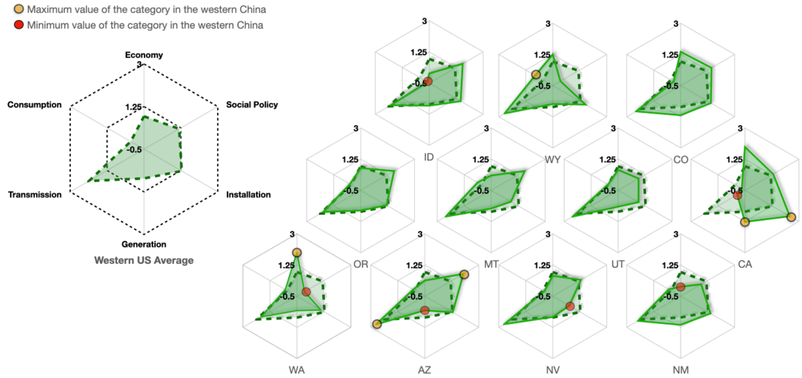


The **top three performers** in western China are **Inner Mongolia, Qinghai, and Ningxia**

Results & Framework Application

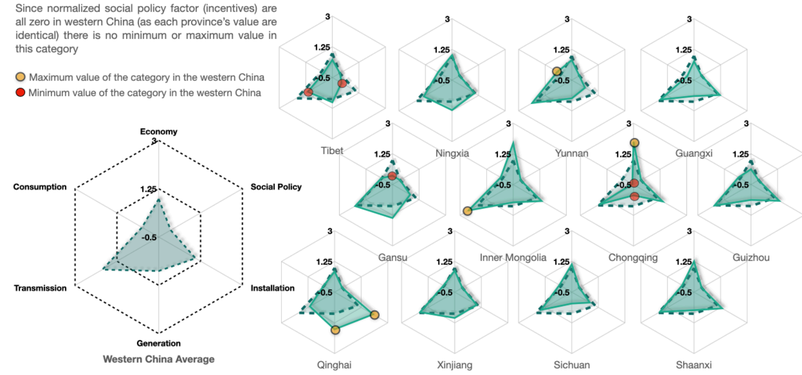
Vertical comparison: within each western region

Vertical comparison: the US

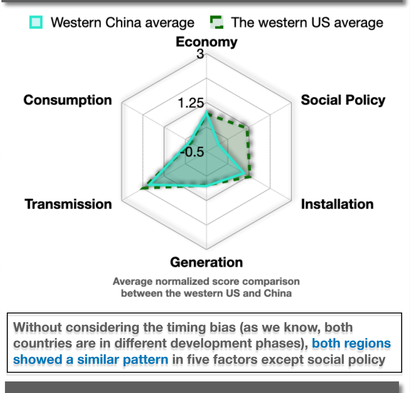


Vertical comparison: China

Since normalized social policy factor (incentives) are all zero in western China (as each province's value are identical) there is no minimum or maximum value in this category



Average comparison: between the two average



Average normalized score comparison between the western US and China

Without considering the timing bias (as we know, both countries are in different development phases), **both regions showed a similar pattern** in five factors except social policy

Horizontal comparison: between two regions

Each province in China can pair with each state **with the same regional ranking** as a long-term target

Province/States	Normalized Score	Ranking
Guangxi	3.86	10
Xinjiang	4.67	6
Tibet	2.71	12
Gansu	4.26	8
Shaanxi	5.17	4
Yunnan	4.11	9
Chongqing	4.81	5
Sichuan	3.75	11
Qinghai	6.48	2
Ningxia	5.83	3
Guizhou	4.34	7
Inner Mongolia	6.49	1
Western Average	4.71	-
Western STD	1.09	-
California	6.65	4
Washington	5.38	10
Oregon	6.33	5
Idaho	5.62	9
Montana	6.11	6
Nevada	5.91	8
New Mexico	5.96	7
Arizona	6.91	2
Utah	5.33	11
Colorado	7.88	1
Wyoming	6.66	3
Western Average	6.25	-
Western STD	0.72	-

Table 4 Ranking and normalized score for the western US and western China

Conclusion

- This study **designed a framework** to assess two comparable regions' solar and wind development statuses. Development biases can be limited by using the normalized value
- Normalized value can also provide convenience to different index different factors
- **This framework can be applied to other renewable energy assessments** if needed
- In this study, the **top three performers** in the western US are **Colorado, Arizona, and Wyoming**; in western China, they are **Inner Mongolia, Qinghai, and Ningxia**
- Western China, at the current stage, **performed as well as** the western US, except for the availability of solar and wind incentives
- Economically, China should only build girds to transfer green electricity from west to east. They should be consumed at the local level. Thus, **Western China should build more load centers such as industrial parks**, given that western China has a great foundation of chemical industries and natural resources.
- **Western China can build more "zero" emission parks** after Ordos' "zero" emission parks have been tested successfully.
- The western US should upgrade its current grid system

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