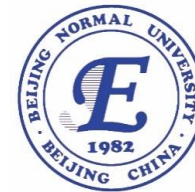# 煤炭产区公正能源转型评价
Evaluation of just energy transition in coal regions

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Agora能源转型论坛、博众智合能源转型
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背景Background

- 碳中和时代煤炭产区面临经济社会全方位挑战，其公正平稳转型涉及能源、经济、社会、生态环境等多方面的协调发展，需要用科学的煤炭产区公正能源转型评价指标体系加以客观分析。
- In the era of carbon neutrality, the economy and society of coal regions face extensive impacts, and their just energy transition involves coordinated development of energy, economy, society, environment and other aspects. It is necessary to establish a scientific evaluation index system for just energy transition of coal regions.

评价目标
Evaluation objective

01 系统、客观地衡量煤炭产区的转型进展，对比各地区之间的差异
Systematically and objectively measure the transition progress of coal regions

02 揭示转型过程中经济发展、社会公正、环境保护等各要素的不均衡现象，识别转型过程中的薄弱环节
Reveals the unbalanced situation of various elements such as economic development, social justice……

03 为政策制定者调整策略，优化资源配置，科学决策提供支持
Providing support for policymakers to adjust strategies, optimize resource allocation, and make scientific decisions

案例区域概况
Case area overview

选择中国和欧洲6个典型煤炭产区开展公正能源转型评价：

- Select 6 typical coal regions in China and Europe to conduct a just energy transition evaluation:

中国山西省
Shanxi, China

- 中国最大的煤炭供应基地，2023年煤炭产量占中国的29%，50%以上的煤炭、70%左右的焦炭以及1/3以上的电力外送其他省份。
- China's largest coal supply base, coal production in 2023 accounted for 29% of China, more than 50% of coal, about 70% of coke and more than 1/3 of the electricity sent to other provinces.

波兰贝尔哈托夫
Bełchatów, Poland

- 是波兰及欧洲最大的褐煤产区。贝尔哈托夫发电厂是欧洲最大的褐煤发电厂，其发电量约占波兰总发电量的13.3%，占波兰褐煤发电量的近72%。
- Bełchatów is the largest lignite coal field in Poland and in Europe. The Bełchatów power plant is still the largest lignite power plant in Europe, accounting for about 13.3% of Poland's total electricity generation.

波兰上西里西亚
Upper Silesia, Poland

- 是波兰最大的煤炭开采区，也是波兰和欧洲最大的硬煤产区之一，占波兰硬煤资源的80.05%，截至2022年仍有17座煤矿在运营。
- Upper Silesia is the largest coal mining area in Poland, accounting for 80.05% of Poland's hard coal resources, with 17 mines still in operation as of 2022.

案例区域概况
Case area overview

德国卢萨提亚 Lusatia, Germany

- 拥有丰富的褐煤资源，煤炭开采历史长达数百年，褐煤发电为德国提供了相当比例的电力，在德国能源供应体系中占据重要地位。
- Lignite power generation in Lusatia provides a significant proportion of Germany's electricity and plays an important role in the German energy supply system.

德国北莱茵-威斯特法伦州 North Rhine-Westphalia(NRW), Germany

- 鲁尔煤田和莱茵兰煤田是德国最大的两个煤炭基地。目前北威州的煤炭开采量在德国仍占有一定比例，但随着能源转型的推进，煤炭产业也在逐渐调整。
- The Ruhr coalfield and the Rhineland coalfield are the two largest coal bases in Germany. Coal mining in NRW still accounts for a certain proportion in Germany.
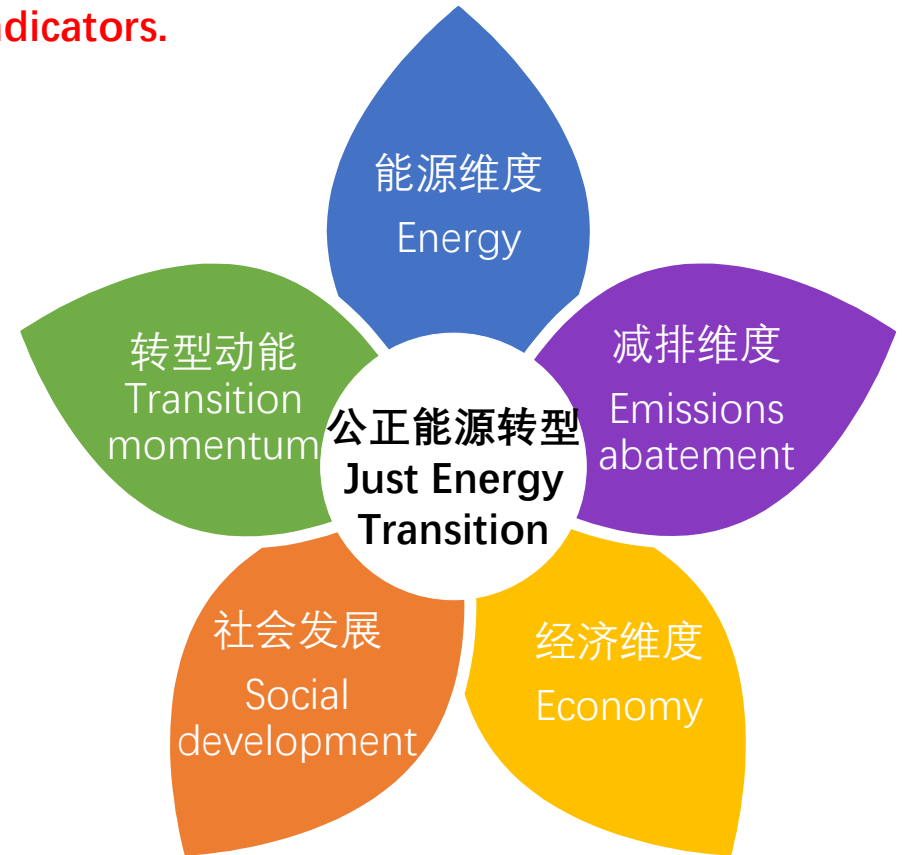
英国南威尔士 South Wales, United Kingdom

- 是英国的主要采煤区，也曾是世界上主要的采煤区之一。目前南威尔士已基本退煤，能源结构中主要是天然气。
- South Wales is a major coal-mining region in the UK. At present, South Wales has basically withdrawn coal, and the energy mix is mainly natural gas.

评价指标体系构建
Evaluation index system construction

- 本研究借鉴国内外权威机构提出的能源转型相关评估指标体系，结合煤炭产区的自身特点，咨询相关领域专家，构建了一套煤炭产区公正能源转型评价指标体系，用以测度和比较各地区公正能源转型的成效。

- This study draws on the energy transition-related evaluation index systems proposed by authoritative institutions, combines the unique characteristics of coal regions, consults experts in relevant fields, and constructs a just energy transition evaluation index system for coal regions.
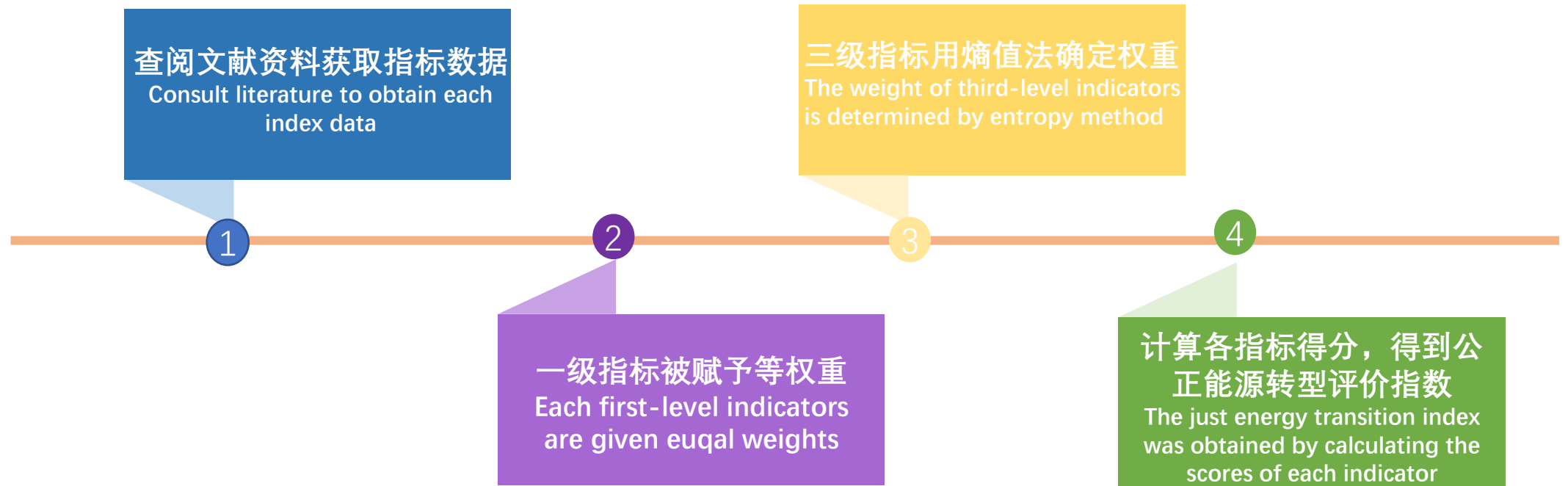
一级指标涵盖5个维度，二级指标15个，三级指标36个

The evaluation index system includes 5 dimensions/first-level indicators, 15 second-level indicators, and 36 third-level indicators.

能源维度
Energy

减排维度
Emissions abatement

转型动能
Transition momentum

公正能源转型
Just Energy Transition

社会发展
Social development

经济维度
Economy

评价指标体系构建
Evaluation index system construction

- 采用主、客观赋权相结合的方法。首先，采用主观赋权法对5个一级指标各赋予20%的权重；然后，对二、三级指标采用客观赋权方法，即熵值法，进行赋权。

- Each first-level indicator is given a weight of 20%. Then, the entropy method is applied to assign weights to the second and third-level indicators

查阅文献资料获取指标数据
Consult literature to obtain each index data

三级指标用熵值法确定权重
The weight of third-level indicators is determined by entropy method

① ② ③ ④

一级指标被赋予等权重
Each first-level indicators are given euqal weights

计算各指标得分，得到公正能源转型评价指数
The just energy transition index was obtained by calculating the scores of each indicator

评价指标体系构建
Evaluation index system construction

煤炭产区公正能源转型评价指标体系及指标权重
Evaluation index system and the indicator weights

一级指标 Primary index	二级指标 Secondary index	三级指标 Three-level index	权重 Weight
能源维度 Energy (20%)	煤炭生产与消费 Coal production and consumption	能源生产中煤炭占比 Share of coal in primary energy production	2.09%
		一次能源消费中煤炭占比 Share of coal in primary energy consumption	1.73%
		供暖用能中煤炭占比 Share of coal in heating energy consumption	2.85%
	可再生能源发展 Renewable energy development	电力生产中可再生能源占比 Share of renewable energy in total electricity production	3.33%
		新增风力装机年均增速（5年平均增速） Average annual growth rate of additional wind power capacity (average of the past 5 years)	1.20%
		新增光伏装机年均增速（5年平均增速） Average annual growth rate of additional solar power capacity (average of the past 5 years)	2.13%
	能源结构与效率 Energy structure and efficiency	燃煤发电装机容量占比 Share of coal-fired power capacity in total power capacity	2.26%
		单位GDP能耗水平 Energy consumption per unit of GDP	1.86%
		终端用能电气化程度 Electrification of end-use energy	2.55%

评价指标体系构建
Evaluation index system construction

| 一级指标 Primary index	二级指标 Secondary index	三级指标 Three-level index	权重 Weight
减排维度 Emissions abatement (20%)	碳排放 Carbon emissions	碳强度 Carbon intensity	9.10%
	空气质量 Air quality	PM$_{2.5}$年均浓度 Annual average concentration of PM$_{2.5}$	7.83%
		SO$_2$年均浓度SO$_2$ Annual average concentration of SO$_2$	3.07%
经济维度 Economy (20%)	经济发展 Economic development	人均GDP Per capita GDP	5.21%
		GDP增长率（最近5年平均值） GDP Growth rate (Recent 5-year average)	2.88%
		经济增长与能源消耗的脱钩指数（最近5年平均值）Decoupling index of economic growth and energy consumption (recent 5-year average)	5.31%
	产业结构 Economic structure	服务业占GDP比重 Contribution of service sector to GDP	3.75%
		采矿业增加值对经济的贡献 Contribution of mining industry to the economic growth	2.85%

评价指标体系构建
Evaluation index system construction

一级指标 Primary index	二级指标 Secondary index	三级指标 Three-level index	权重 Weight
社会发展 Social development (20%)	就业 Employment	直接煤炭行业就业占比 Share of direct coal industry of employment	1.57%
		当地居民失业率 Unemployment rate	0.63%
	社会保障 Social Security	居民养老保障水平 Pension coverage level of retirees	2.28%
		居民医保参保水平 Participating in public health insurance	0.75%
	收入 Income	居民收入水平 Residents' income	4.93%
		居民收入公平性 Income equity of residents	2.19%
	科研教育 Scientific research and education	居民受教育程度 Education level of residents	2.31%
		教育科研能力 (高等教育机构密度) Education, science, and research capacity	3.92%
	医疗健康 Medical and health	医疗资源水平 Level of medical resources	0.44%
		居民健康水平 Residents' health	0.99%

一级指标 Primary index	二级指标 Secondary index	三级指标 Three-level index	权重 Weight
转型动能 Transition momentum (20%)	政策支持 Policy support	碳中和目标 Carbon neutrality target	2.27%
		碳中和政策方案 Action plans	1.49%
		碳定价机制 Carbon pricing mechanism	3.13%
	投资 Investment	研发投入/投资 R&D investment	3.01%
		外商直接投资占GDP比重 FDI as a share of GDP	3.49%
	营商环境 Business environment	政商关系 Government-business relationship	0.51%
		公路交通发展水平 Road transport development	2.72%
		铁路交通发展水平 Railway transport development	2.61%
		人均物流水平 Per capita logistics	0.78%

能源维度评价结果
Evaluation results of energy

- 英国南威尔士得分最高，德国卢萨提亚和北威州次之，山西省得分总体上略高于波兰的上西里西亚和贝尔哈托夫。

- South Wales scored the highest, followed by Lusatia and NRW. Shanxi generally scores higher than that of Upper Silesia and Bełchatów.

- 南威尔士的能源系统已经基本摆脱煤炭，而波兰上西里西亚和贝尔哈托夫以及山西省的能源生产和消费中，煤炭依然占有相当比例。山西省近年来可再生能源发展迅速，终端用能的电气化水平也大幅提升。

- The energy system in South Wales has largely freed itself from coal, while in Poland's Upper Silesia and Bełchatów, as well as in Shanxi, coal still accounts for a significant proportion of energy system. In recent years, Shanxi has seen rapid development in renewable energy and a significant increase in the level of electrification in end-use energy.
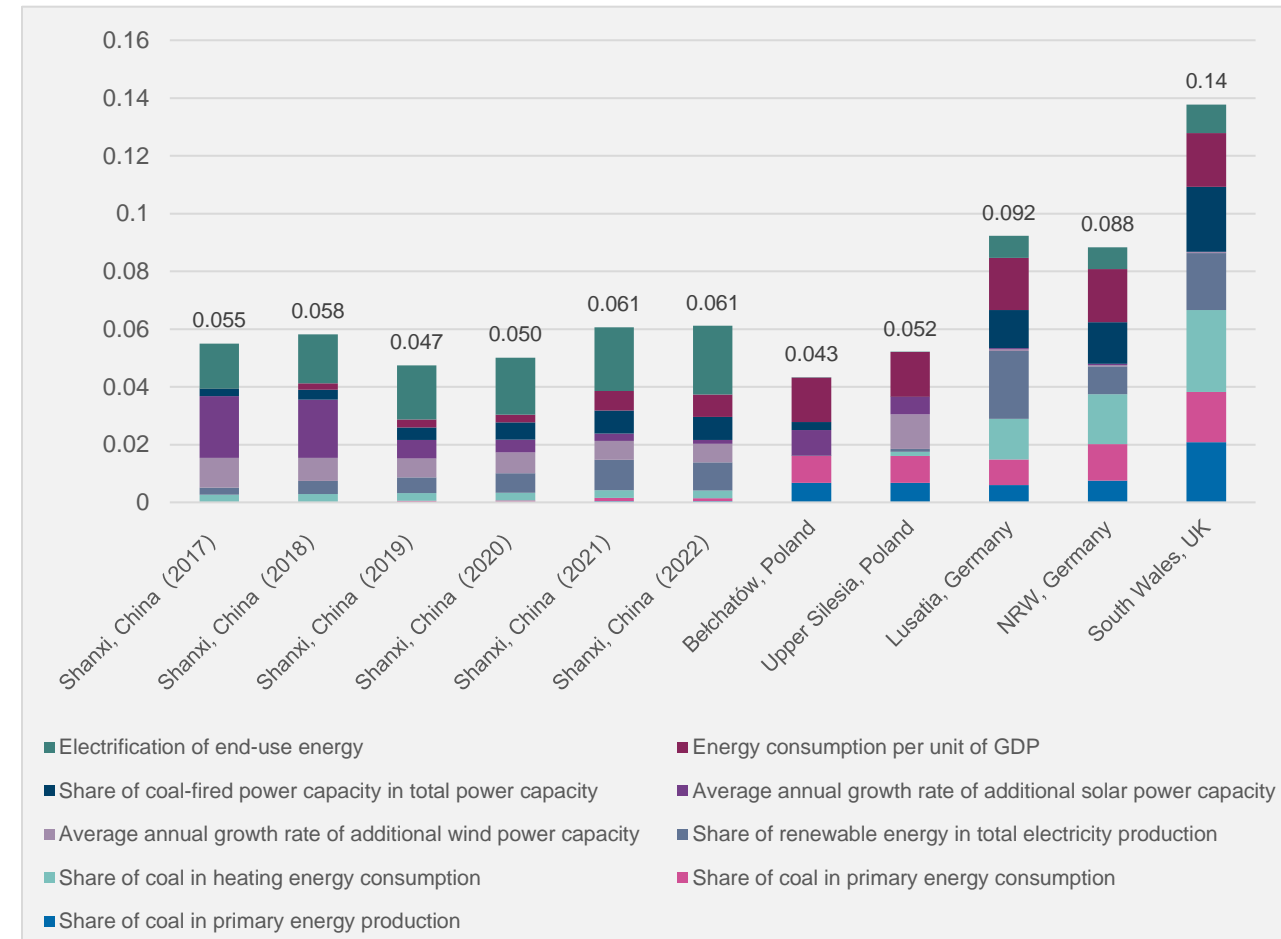
中—欧各煤炭产区的能源维度得分对比
Energy dimension scores of coal regions in China and Europe

- 山西省落后于欧洲各煤炭产区：

- Shanxi lags behind European coal regions:

  ➤ 2022年山西省$PM_{2.5}$和SO_2年均浓度在各煤炭产区中最高。

  ➤ In 2022, Shanxi had the highest annual average concentrations of $PM_{2.5}$ and SO_2 among various coal regions.

  ➤ 山西省能源消费对于煤炭依赖较大，由此产生的温室气体排放量较大，碳强度更高。

  ➤ Shanxi's energy consumption is highly dependent on coal, resulting in a larger volume of greenhouse gas emissions and higher carbon intensity.

  ➤ 山西省的碳减排与环境治理水平在快速提升。

  ➤ Shanxi's level of carbon emission reduction and environmental governance is rapidly improving.
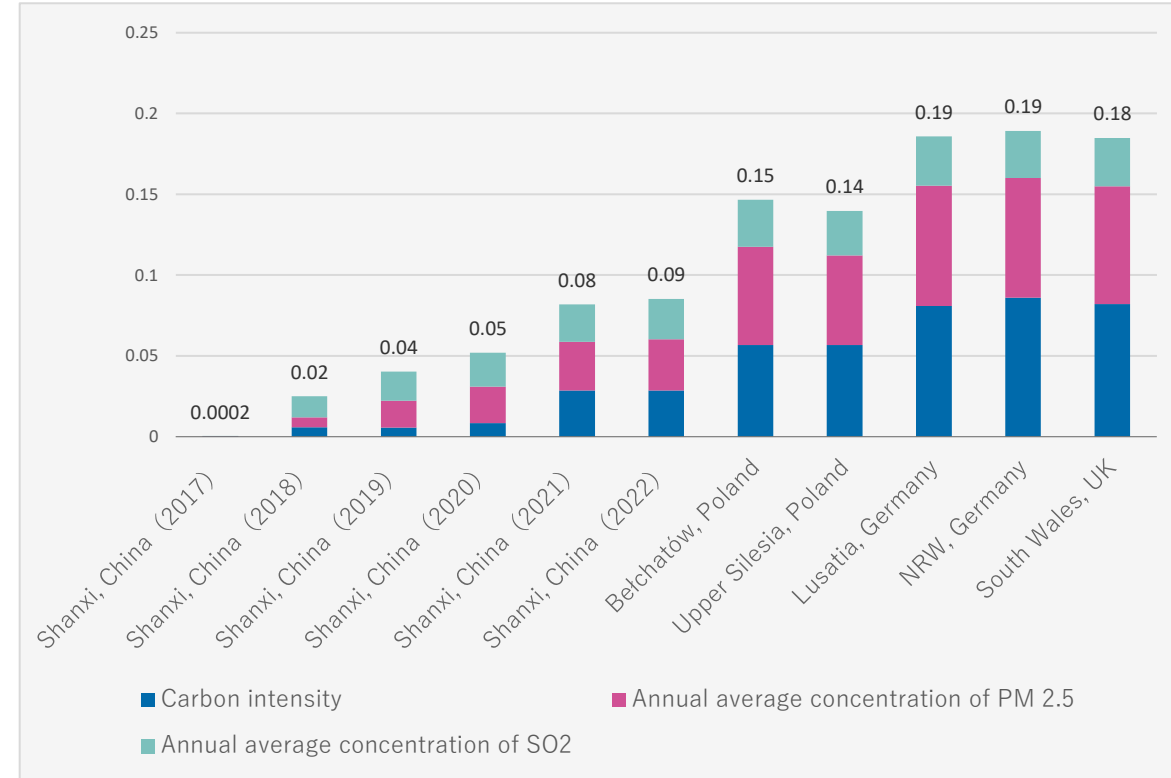
中—欧各煤炭产区的减排维度得分对比

Emissions abatement dimension scores of coal regions in China and Europe

经济维度评价结果
Evaluation results of economy

- 德国的北威州、卢萨提亚以及英国的南威尔士得分位列前三，中国山西省与波兰的上西里西亚和贝尔哈托夫总体水平接近。

- The economic system in NRW, Lusatia, and South Wales rank in the top three, while Shanxi and Upper Silesia and Bełchatów score lower.

  - ➤ 英国和德国案例区的经济发展已经基本摆脱了对煤炭的依赖，采矿业对经济的贡献度较低。山西省、波兰的贝尔哈托夫和上西里西亚，现阶段经济与能源消费尚未脱钩，采矿业占经济比重较大，服务业占比低。

  - ➤ The economic development in the UK and German case study areas has largely freed itself from dependence on coal. In contrast, Shanxi, Bełchatów, and Upper Silesia have not yet decoupled their economies from energy consumption; the mining industry still accounts for a significant proportion of their economies, and the service sector has a lower share.

  - ➤ 山西省经济深受采矿业影响。新冠疫情等因素导致全国能源需求增长，2021-2022年山西省GDP增速高，但对煤炭采掘业的依赖有所增长。

  - ➤ The economy in Shanxi relies on mining industry. The COVID-19 pandemic and other factors have led to an increase in energy demand across the country, and Shanxi has a high GDP growth rate in 2021-2022, but its dependence on the coal industry has increased.
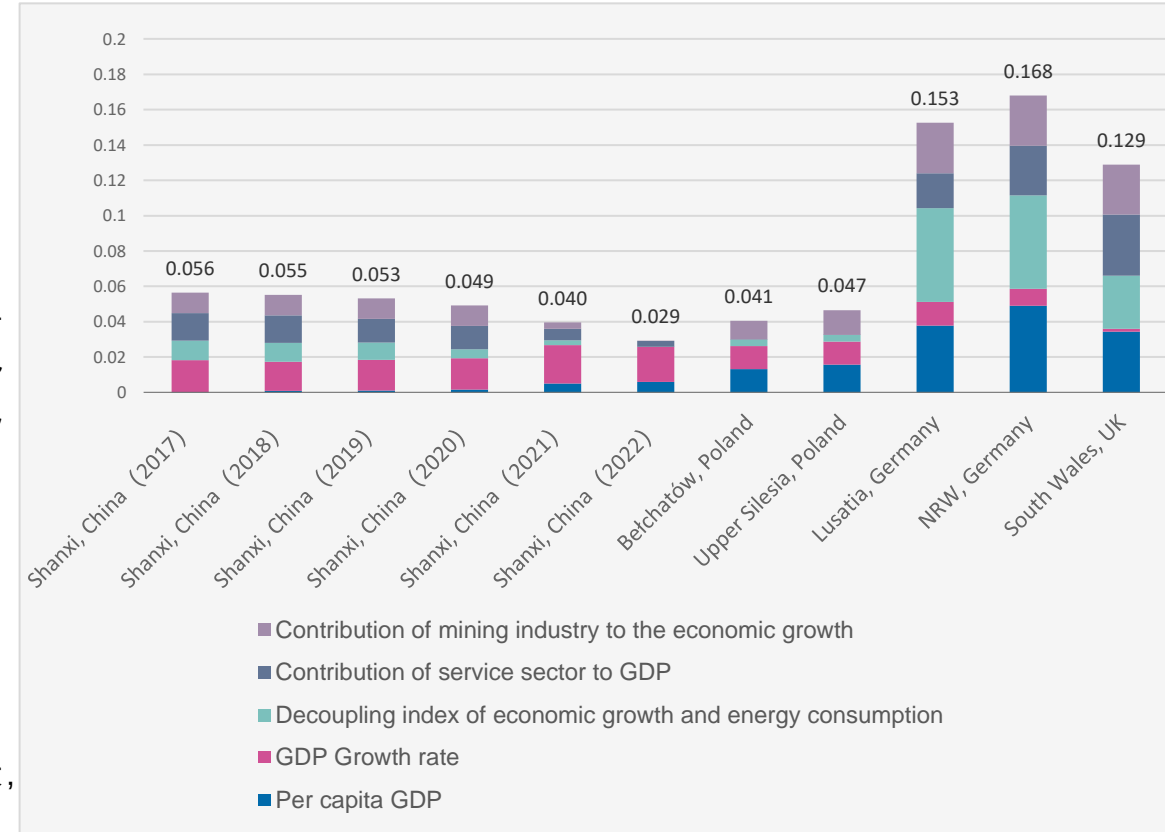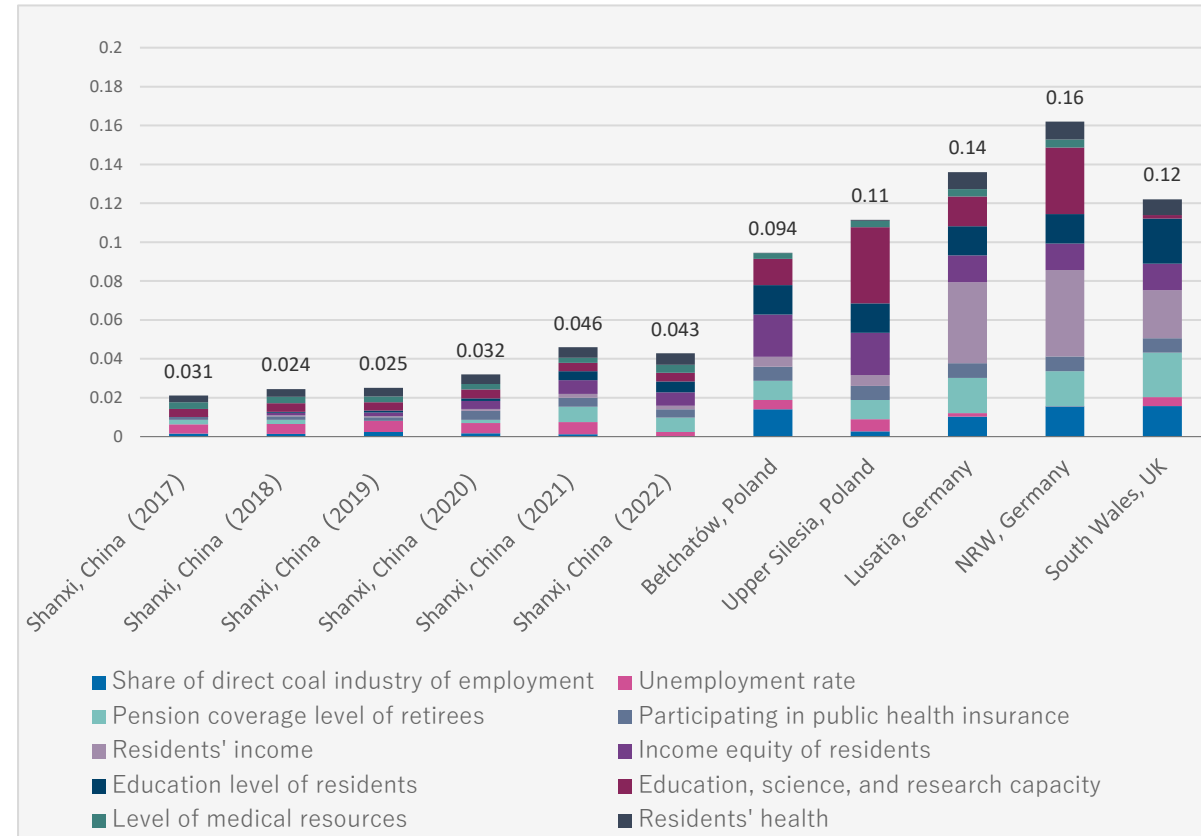

中—欧各煤炭产区的经济维度得分对比
Economy dimension scores of coal regions in China and Europe

社会发展评价结果
Evaluation results of social development

- 得分最高的是德国北威州和卢萨提亚，其次是英国南威尔士，山西省得分靠后。

- The highest score is achieved by NRW, followed by Lusatia, and then South Wales, with Shanxi ranking lower.

  - ➤ 山西的居民收入水平与欧洲煤炭产区有差距。山西省的煤炭行业直接就业人数占比较高，在养老保障方面也弱于欧洲。

  - ➤ The main reason is the disparity in the income level of residents in Shanxi compared to European coal regions. The direct employment proportion in the coal industry in Shanxi is relatively high, and in terms of pension security, Shanxi is also weaker than Europe.

  - ➤ 山西省的社会公正水平总体呈现改善态势，主要得益于山西省近年来在就业、社会保障、收入和教育医疗方面逐步改善。

  - ➤ The overall level of social justice in Shanxi has shown an improving trend, mainly thanks to the gradual improvements in employment, social security, income, and education and healthcare in Shanxi in recent years.

中—欧各煤炭产区的社会发展维度得分对比
Social development dimension scores of coal regions in China and Europe

转型动能评价结果
Evaluation results of transition momentum

- 得分最高的是德国的北威州和卢萨提亚。

- The highest scores go to NRW and Lusatia in Germany.

- 波兰表现较好，这主要受益由于其良好的公路、铁路交通条件以及快速增长的外来直接投资。

- Poland performs relatively well, mainly benefiting from its good road and railway transportation conditions as well as rapidly increasing foreign direct investment.

- 山西省的转型动能持续提升，尤其是自2020年提出碳达峰碳中和目标后，出台了碳达峰碳中和1+N政策体系，对转型的驱动力大幅提升。

- The momentum for transformation in Shanxi continues to improve, especially after the carbon peak and carbon neutrality goals were proposed in 2020, a carbon peak and carbon neutrality 1+N policy system has been introduced, significantly enhancing the driving force for transformation.
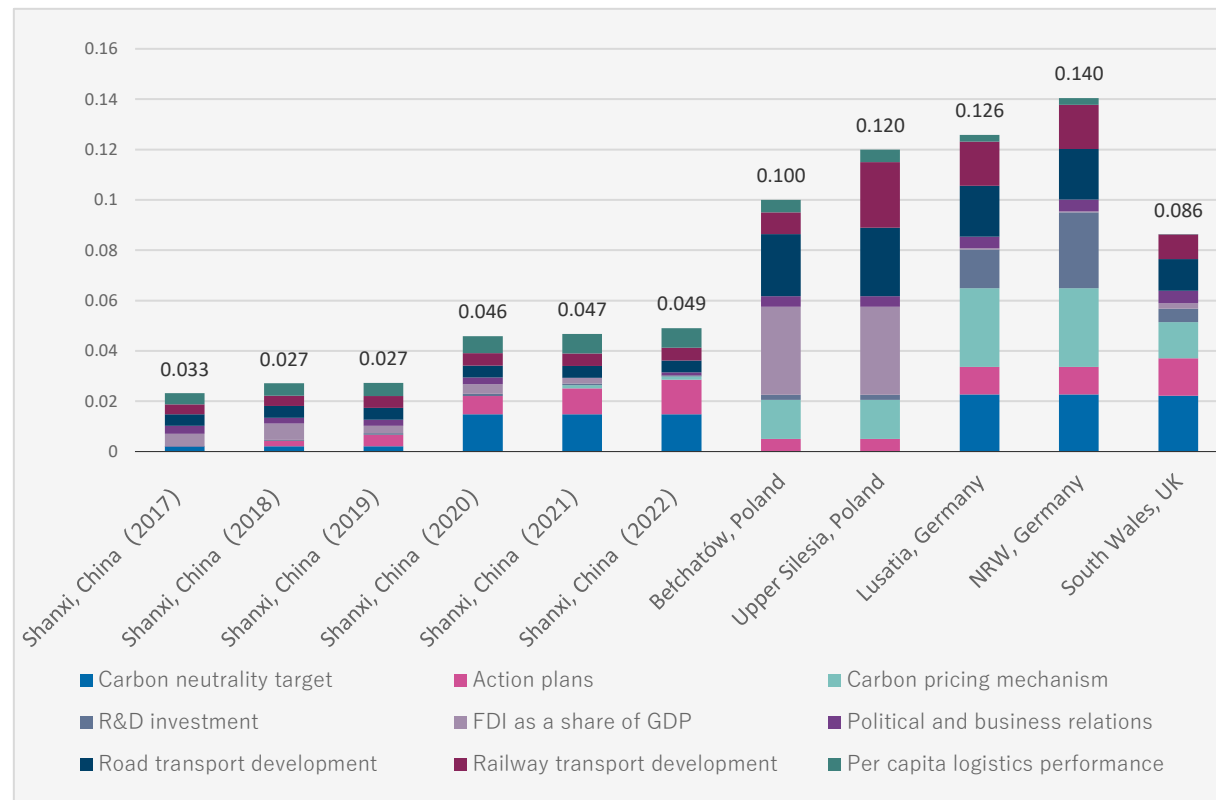
中—欧各煤炭产区的转型动能得分对比
Transition momentum dimension scores of coal regions in China and Europe

综合评价结果
Comprehensive evaluation result

- 总得分最高的是德国北威州，其次是德国卢萨提亚，再次是英国南威尔士，然后是波兰的上西里西亚、贝尔哈托夫和中国山西省。

- NRW ranked the first, followed by Lusatia, South Wales, and subsequently Upper Silesia, Bełchatów, and Shanxi.

- 山西省和上西里西亚及贝尔哈托夫的转型依然处于早期阶段，退煤进度、社会保障、经济韧性等都较英、德两国的煤炭产区存在差距，将在未来更快速的能源转型过程中面临挑战。

- Shanxi, Upper Silesia and Bełchatów in Poland are in their early transition stage. There are gaps in coal phase-out progress, social security, and economic resilience compared to coal regions in the UK and Germany. They will face challenges in the future.
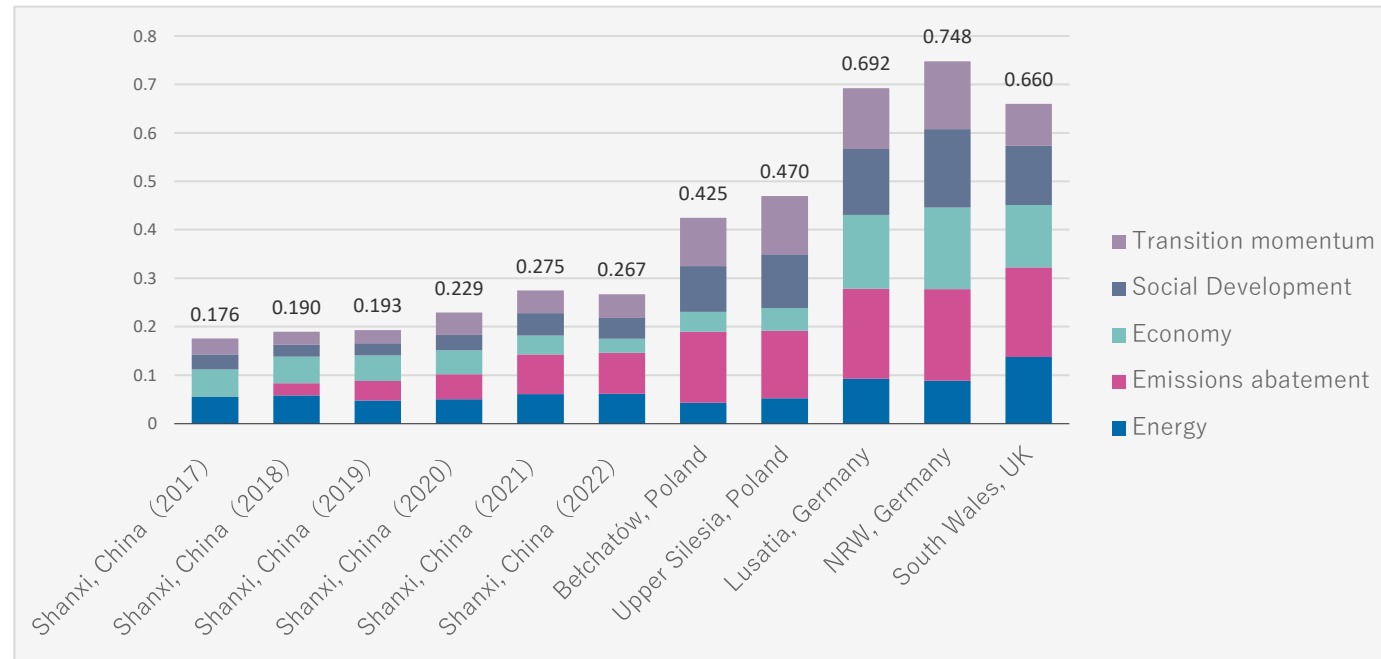

中—欧各煤炭产区公正转型综合评价得分
Comprehensive evaluation of just energy transition of coal regions

综合评价结果
Comprehensive evaluation result

- 中国山西与波兰的贝尔哈托夫和上西里西亚面临相似的挑战：
- Shanxi Province and Bełchatów and Upper Silesia in Poland are faced with similar situation：
  - ➤ 能源、经济、社会发展等维度上的评价得分较低。The energy, economic, and social development scores are relatively low.
  - ➤ 退煤进程还处于早期探索阶段，煤炭依然是能源结构的主体；The coal phase-out process is still in the early exploratory stage, with coal remaining the mainstay of the energy structure.
  - ➤ 经济对煤炭产业依赖度高，产业多样化不足； The economy has a high dependency on the coal industry, and there is a lack of industrial diversification.
  - ➤ 就业机会集中在能源领域，公共服务和社会福利体系较弱，社会发展和保障水平不足。Employment opportunities are concentrated in the energy sector, and the public service and social welfare systems are weak, with insufficient levels of social development and security.


Shanxi,China（2022）

Bełchatów,Poland

Upper Silesia, Poland
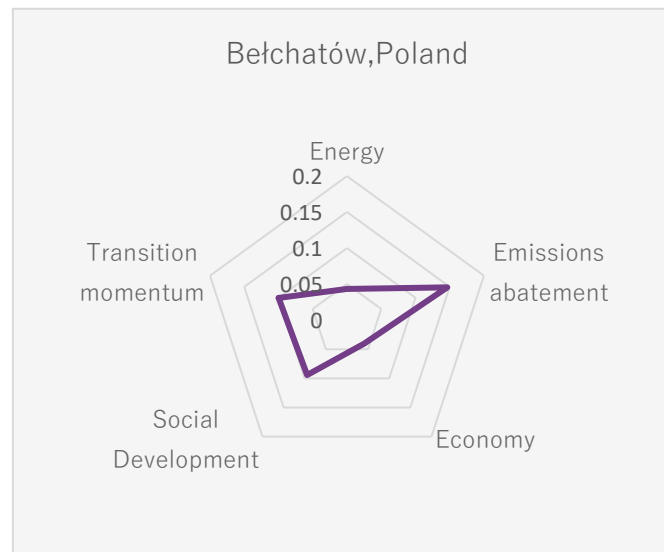
综合评价结果
Comprehensive evaluation result

- 英国南威尔士和德国的卢萨提亚、北威州在碳减排和环境治理、社会发展和经济发展等维度上评价得分较高：经济和社会发展已经基本摆脱煤炭，具有较强的经济韧性和良好的社会福利保障水平，碳减排和环境治理成效显著。

- South Wales in the UK and Lusatia and NRW in Germany exhibit similar performances, as they all achieve high scores in dimensions such as carbon emission reduction, environmental governance, social development, and economic development: Their economic and social development has largely moved away from reliance on coal, demonstrating strong economic resilience and a high social welfare level, with significant achievements in carbon emission reduction and environmental governance.

Lusatia, Germany

NRW, Germany

South Wales, UK
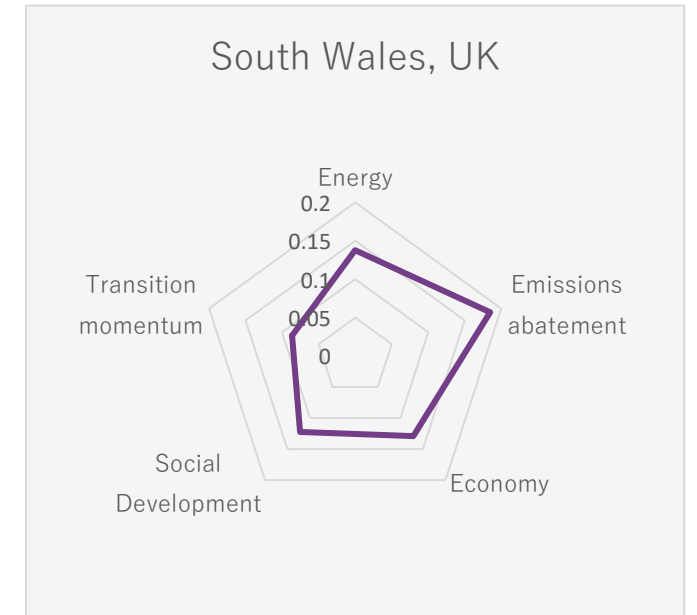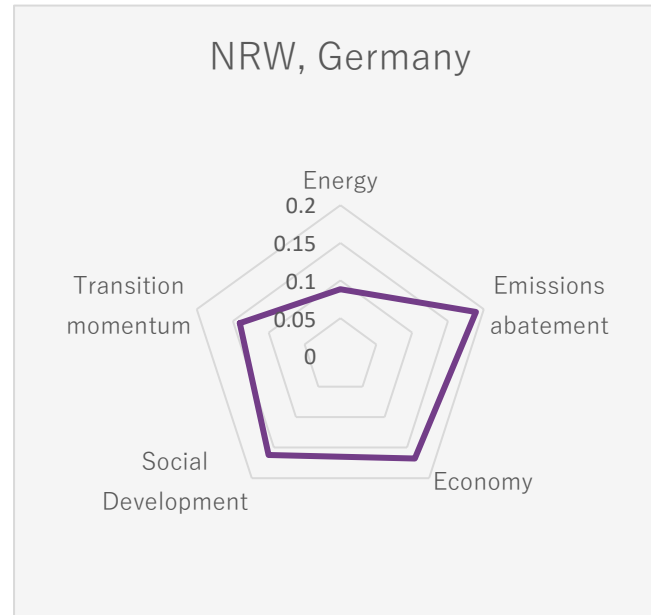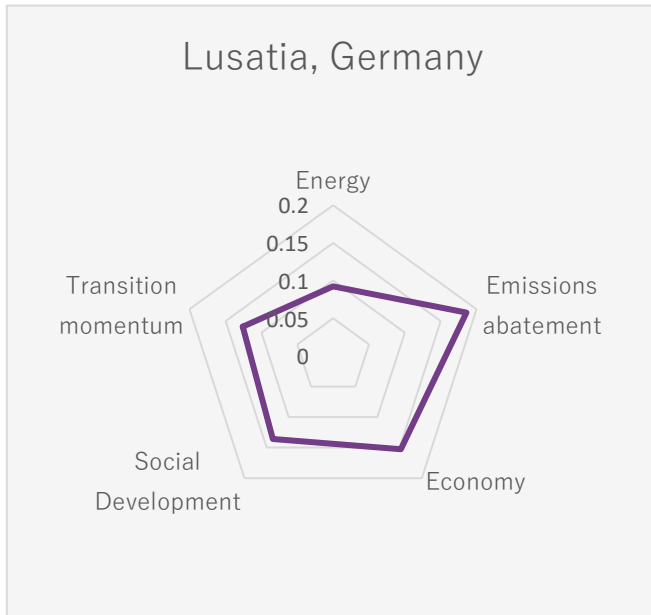
主要发现Key findings

1. **英国和德国的案例区处于退煤转型中后期阶段，公正能源转型水平较高，中国山西和波兰案例区仍然处于退煤转型早期阶段，面临较大挑战**
   The case study areas in the UK and Germany are in the middle and late stage of coal withdrawal transition, and the level of just energy transition is relatively higher, while the case study areas in China and Poland are still in the early stage of coal withdrawal transition, facing greater challenges

- 英国的彻底退煤进展迅速，2024年9月英国关闭了最后一座燃煤发电厂。

- 德国通过稳健政策逐步推进转型，计划到2038年逐步淘汰燃煤发电。

- 山西和波兰的两个案例区对煤炭的依赖度较高，煤炭在能源生产和消费中仍占较高比例，煤炭产业对地区生产总值和就业的贡献较大。

- UK has almost completely phased out coal, with the last coal-fired power plant being closed in September 2024.

- Germany is advancing the transition through solid policies, with plans to phase out coal-fired power generation by 2038.

- Shanxi and the two case study areas in Poland have a high dependency on coal, with coal still accounting for a significant proportion in energy production and consumption, and the coal industry contributing substantially to regional gross domestic product and employment.

主要发现Key findings

2. 各煤炭产区转型的驱动力与路径不同
The driving forces and pathways for the transformation of coal-producing regions vary

英国：市场主导
UK: Market dominance

- 英国退煤的最初驱动因素是成本和市场。煤炭在英国比德国更早退出历史舞台。退煤的快速推进伴随着对社会公正转型关注不足的问题。
- The initial drivers of UK coal withdrawal were cost and market. The rapid advance of coal withdrawal has been accompanied by insufficient attention to social justice transformation.

德国：市场+政策平衡
Germany: Market+Policy balance

- 卢萨蒂亚退煤最初由德国统一后的政治经济变化推动，北威州最初是由市场推动，而目前更多受应对气候变化政策影响。并逐渐重视煤炭产区的公正转型。
- Withdrawal of coal in Lusatia was initially driven by the political and economic changes following German reunification, and in NRW it is more influenced by climate policy. Germany has paid more attention to the just transition of coal regions.

波兰：市场+外部支持
Poland: Market+External support

- 波兰的能源转型受到欧盟碳减排政策的直接影响：欧盟的碳排放交易体系施加了高额的碳排放成本；同时波兰的转型也得到欧盟公正转型机制的支持。
- Poland's energy transition is directly encouraged and supported by the EU: EUETS imposes high costs on carbon emissions; Poland's transition is as also supported by the EU's Just Transition Mechanism.

中国：国家战略和政策驱动
China: National strategy and Policy-driven

- 山西的能源转型以政策驱动为核心，表现为"碳达峰、碳中和"目标的强力推进和地方政府的积极响应。山西面临双重挑战：既要保障国家能源安全，又要实现经济与能源的脱钩。
- Shanxi's energy transition is driven by the strong promotion of the "carbon peak, carbon neutrality" goal and the positive response of local governments. Shanxi faces a double challenge: to safeguard national energy security, but also to achieve economic and energy decoupling.

主要发现Key findings

3. 在山西省推进公正的能源转型，要利用好现有的优势：政策支持力度大，可再生能源、电气化水平进步显著 To promote a just energy transition in Shanxi requires making good use of advantages: strong policy support, renewable energy and electrification

01

- 山西省在中国2020年提出"30·60碳达峰碳中和目标"后，转型动能中的"碳中和目标"和"碳中和政策方案"指标得分快速上升。

- After Shanxi put forward the "30·60 carbon peak carbon neutral target" in China in 2020, the index scores of "carbon neutral target" and "carbon neutral policy plan" have risen rapidly

02

- 山西省近年来可再生能源发展迅速，能源结构显著优化，新增风电和新增光伏装机增速远高于欧洲的煤炭产区。

- Renewable energy in Shanxi has developed rapidly, and the growth of installed wind power and photovoltaic capacity surpasses most of the coal regions in the Europe.

03

- 山西省终端用能电气化水平超过欧洲的煤炭产区，因为山西省电网基础设施较完善、电力供应覆盖广且稳定，以及近年来大力推进"电能替代"政策。

- Shanxi is also ahead of the coal regions in terms of end-use electrification, due to its better grid infrastructure, extensive and stable power supply coverage, and the "electricity substitution" policy

主要发现Key findings

4. 山西省转型关键：聚焦社会发展与经济可持续性
Key issues in Shanxi's just energy transition: Focusing on social development and economic sustainability

01
- 经济增长与能源消耗尚未脱钩，经济对煤炭产业依赖较高。
- Economic growth and energy consumption have not been decoupled, and the economy is highly dependent on the coal industry.

02
- 采矿业增加值占比偏高，产业结构单一。
- The mining industry accounts for a high proportion of added value and has a simple industrial structure.

关键挑战
Critical Challenges

04
- 直接煤炭行业就业占比高，劳动力市场对煤炭行业的波动敏感。
- The coal industry accounts for a high proportion of direct employment, and the labor market is sensitive to fluctuations in the coal industry.

03
- 居民可支配收入水平较低，社会福利和生活质量需持续改善。
- Residents' disposable income and social welfare should be continuously improved.