



MLJC Intelligence™
Global Electricity – The Map of Divergence and What It Reveals
About Energy Transition
全球电力结构 —— 一张地图揭示的分化与能源转型真相

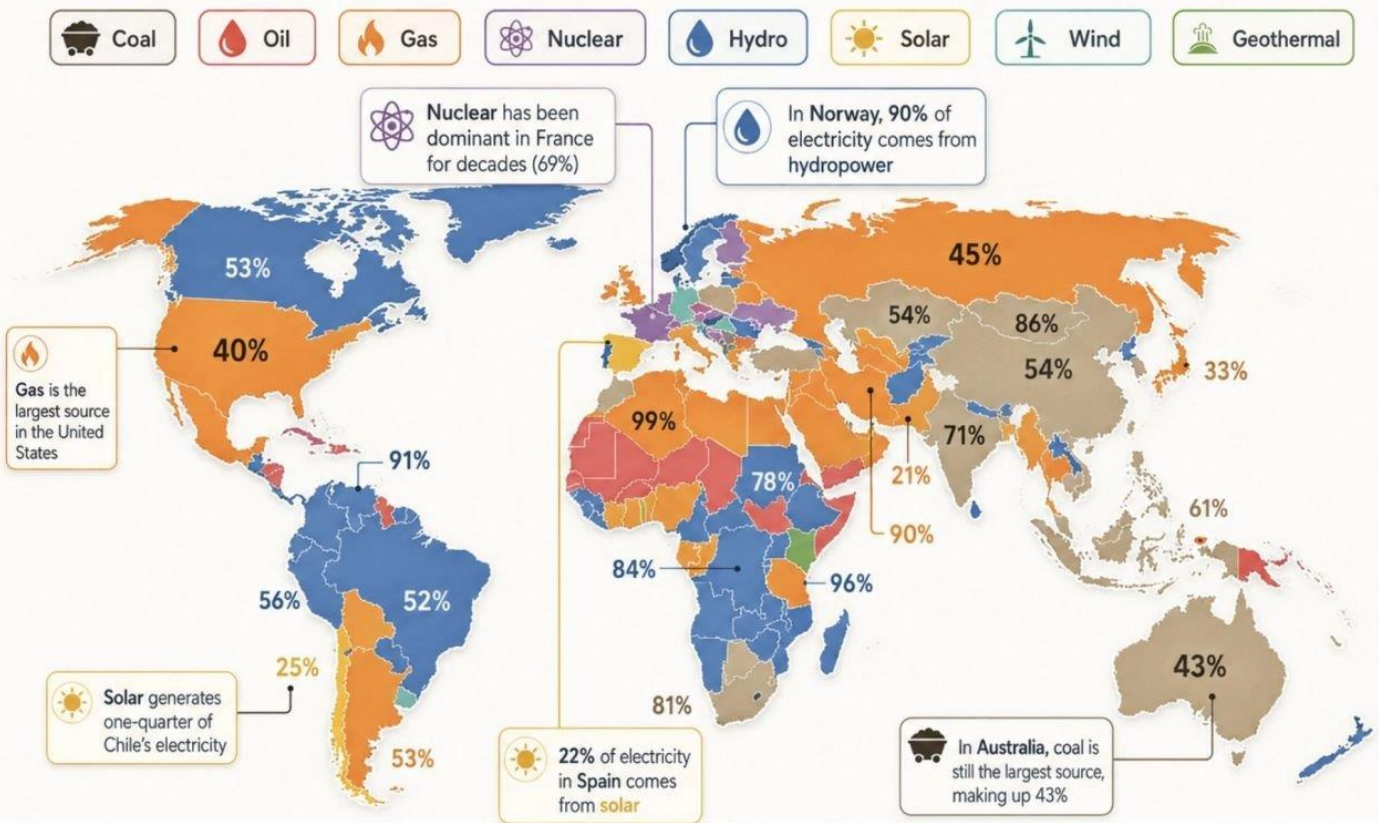
ENGLISH | 中文

Ref No : MLJC/GE/TMDAWIRAET/2026-10/05/15.58
Date : 05 October 2026

MLJC | Global Electricity — The Map of Divergence and What It Reveals About
Energy Transition

What is the largest source of electricity? ⚡

The source that generated the most electricity in 2024/25, by country.
Labels show the share of generation coming from the largest source.



Source: Our World in Data

Executive Signal

A global map of electricity generation, published by Our World in Data, tells a story that is both simple and misleading. The dominant source of power in each country falls into one of eight categories — coal, oil, gas, nuclear, hydro, solar, wind, or geothermal. The visual impression is one of diversity: gas in the United States, nuclear in France, hydropower in Norway, solar in Chile, wind in Denmark, coal in Australia and China.

The headline summary from a casual reader is often: "the energy transition is underway, but uneven."

That is correct, but incomplete. A deeper reading reveals three structural facts:

- 1. Fossil fuels remain the single-largest source of electricity in most major economies — including the United States (gas, 53%), China (coal, 54%), and India (coal, 72%).
- 2. Technological and resource lock-in is more powerful than policy ambition — countries tend to stay on their historical energy paths.
- 3. The outliers are as important as the averages — South Africa and Mongolia are "carrying the flag for king coal" at 83% and 91%, respectively, while Norway (90% hydro), France (69% nuclear), and Chile (25% solar) illustrate how resource endowment and policy history can create radically different energy systems.

The map is not a report card. It is a baseline for understanding the structural inertia of global electricity systems — and the magnitude of the challenge facing any attempt to decarbonise them.

What Happened

Our World in Data, a research publication based at the University of Oxford, compiled country-level data on electricity generation sources for 2024/25. The visualisation assigns each country a dominant source and the corresponding share of generation.

Key observations from the map:

Country	Dominant Source	Share of Generation
United States	Gas	53%
China	Coal	54%
India	Coal	72%
France	Nuclear	69%
Norway	Hydro	90%
South Africa	Coal	83%
Mongolia	Coal	91%
Australia	Coal	43%
Chile	Solar	25%
Denmark	Wind	56%
Spain	Solar	22%
Brazil	Hydro	61%
Germany	Wind	31%

The map also includes smaller but notable figures: nuclear in Finland (45%), Poland's coal (71%), and Japan's gas (78%).

Market Evidence

1. Fossil fuel dominance remains intact at scale

The United States, China, India, and Australia — four of the world's largest economies — all rely on fossil fuels as their dominant electricity source. Combined, these economies account for over 45% of global electricity demand. Their energy mixes are not shifting rapidly; they are shifting gradually, at rates that remain below Paris-aligned trajectories.

2. Resource endowment explains more than policy

Norway's 90% hydro share reflects geography, not just environmental ambition. Similarly, France's 69% nuclear share is a legacy of the post-1970s "Messmer Plan," which was driven by energy security concerns — not climate policy. Chile's 25% solar share reflects the Atacama Desert's exceptional solar radiation, not merely policy leadership.

3. Coal remains resilient in specific contexts

South Africa (83%) and Mongolia (91%) are extreme cases. South Africa's Eskom, the state-owned utility, has been unable to transition due to a combination of coal resource abundance, apartheid-era industrial policy, and a constrained fiscal position. Mongolia's coal dominance reflects its vast coal reserves and lack of alternative infrastructure.

4. Nuclear: stable but not expanding

France (69%), Finland (45%), and Sweden (32%) demonstrate that nuclear can provide clean baseload power. However, new nuclear construction remains slow and capital-intensive — with few countries actively expanding their nuclear fleets.

5. Renewables: high shares in small systems

Denmark (wind, 56%) and Chile (solar, 25%) achieve high renewable shares, but these are relatively small electricity systems (Denmark: ~34 TWh annually; Chile: ~85 TWh). Scaling these shares to larger systems — China, the US, India — presents grid integration challenges that are not yet fully solved.

Structural Interpretation

MLJC Assessment — Causal Hypothesis

The map reveals that electricity systems are path-dependent — not in a deterministic sense, but in a structural sense. Once a country builds a power system around a particular fuel source, the sunk costs, infrastructure, workforce, and regulatory framework create self-reinforcing inertia.

Three mechanisms drive this:

1. Capital stock lock-in

Coal and gas plants have lifespans of 40–60 years. Once built, their capital costs are sunk. Running them — even at reduced capacity — is often cheaper than early retirement, particularly in countries with limited fiscal space.

2. Institutional lock-in

Utilities, regulators, and labour unions have developed expertise, political influence, and vested interests around specific technologies. Transitioning away from coal, for example, is not merely a technical challenge — it is a political and social challenge.

3. Resource lock-in

Countries with abundant domestic coal (Australia, India, South Africa, Mongolia, China) face a different political economy than countries with limited domestic fossil fuel resources. Import substitution is a powerful driver of energy policy. The countries achieving high renewable shares are those that either: (a) had no fossil fuel resource to begin with; (b) had exceptional renewable resource endowments; or (c) made deliberate policy choices over multiple decades.

Transmission Mechanism to Markets

Electricity mix → Marginal cost of power generation → Wholesale electricity prices → Industrial competitiveness → Investment in energy-intensive sectors → CO₂ pricing and compliance costs → Capital allocation across energy assets

1. Fossil-fuel-dependent economies — China, India, South Africa, Australia — face a rising carbon compliance burden as EU CBAM and other border carbon adjustments scale up. Their electricity costs are likely to become less competitive relative to lower-carbon systems.

2. Nuclear-dominant systems — France — enjoy a stable, low-carbon baseload that provides predictable electricity pricing. However, they face future cost uncertainty as reactor fleets age and replacement costs remain opaque.

3. Renewable-heavy systems — Denmark, Chile, Norway — achieve low marginal cost electricity but face grid stability and storage costs that are not captured in the headline share.

4. Coal-dominant systems — South Africa, Mongolia — face structural vulnerability to both carbon pricing and coal supply disruptions. Their electricity systems are not transitioning rapidly, which creates both risk and investment opportunity.

Market Mispricing

A substantial portion of market commentary treats the transition to renewables as linear and inevitable — an extrapolation of current trends. The map suggests otherwise.

The mispricing risks are:

1. Underestimating the persistence of fossil fuels

If policy does not accelerate materially — and if technological breakthroughs in storage do not materialise — fossil fuels will remain a dominant electricity source for longer than current consensus pricing implies. This is a risk for carbon credit markets, and an opportunity for fossil-fuel asset holders.

2. Overestimating the speed of grid integration

High renewable shares in small systems (Denmark, Chile) are not directly scalable to large systems without significant grid storage investment. Markets may be underpricing the cost — and timeline — of this integration.

3. Overlooking nuclear as a transitional anchor

France's nuclear fleet, while aging, provides reliable clean baseload. Markets may be underestimating nuclear's role in energy security, particularly in Europe's post-gas-shock environment.

Scenario Analysis

[MLJC subjective probability assessment, not a statistical model]

Scenario Key Drivers Outcome

Base Case (Highest probability)
Renewables grow gradually; gas and coal decline slowly; nuclear fleet ages without rapid replacement; storage costs continue to fall but not dramatically. Electricity mix remains diversified; fossil fuels remain dominant in Asia and the US; Europe accelerates its renewable buildout; carbon pricing pressures emerge gradually.

Policy Acceleration (Lower probability)
Stronger carbon pricing; EU CBAM expands; China accelerates its grid storage investment; nuclear technology breakthroughs. Fossil fuels decline faster; renewables and nuclear expand; electricity costs converge across regions.

Policy/Technological Delay (Material tail risk)
Carbon pricing stalls; storage costs remain high; grid integration proves more difficult than expected; nuclear retirement accelerates without replacement. Fossil fuels persist longer than consensus; carbon compliance costs create trade friction; electricity costs diverge between regions.

What to Watch — Monitor Logic

Variable Current Signal Direction Why It Matters

US gas share of generation 53% Stable
Largest single market; shifts alter global gas prices

China coal share 54% Gradually declining at ~1-2%/year
Key signal for global coal demand and CO₂

India coal share 72% Rising?
India's industrialisation has been coal-powered; any deviation is significant

France nuclear share 69% Aging; replacement uncertain
Security of French baseload affects European power prices

South Africa/Mongolia coal share 83% / 91% Stable
Extreme cases of coal dependence; transition barriers are structural, not policy-led

Battery storage costs Declining ~15%/year
Continuing Key enabler for high renewable shares in large systems

EU CBAM pricing \$50-100/tonne CO₂
Rising Directly affects fossil-fuel-dependent economies' export costs

Falsification Conditions

We would revise our base-case view if:

1. Battery storage costs fall by more than 50% in three years, enabling grid-scale storage at a cost that makes renewable intermittency cost-competitive with fossil baseload.
2. Nuclear technology (SMRs or new generation designs) reaches commercial viability in a Western country, with credible cost and timeline projections.
3. China's coal share falls below 45% within five years, signalling a structural break in the world's largest electricity system.
4. Carbon pricing reaches \$150/tonne in the EU and \$75/tonne in China, materially altering the marginal cost calculus for coal and gas generation.

MLJC Assessment

The Our World in Data electricity map is a valuable diagnostic — but it is not a trajectory. It tells us where the world stands, not where it is going.

The structural reality is that electricity systems are inertial. Countries do not change their dominant power source quickly. The capital stock, institutional frameworks, and resource endowments that define current patterns were built over decades — and will take decades to transform.

The map also reveals that the energy transition is not a single global phenomenon. It is a set of country-specific phenomena, each shaped by resource endowments, policy history, and economic structure. Solar in Chile, nuclear in France, hydro in Norway, and coal in South Africa and Mongolia are not comparable cases; they are divergent outcomes of different structural conditions.

For institutional investors, the key signal is not "which country is winning the transition." It is which countries have the institutional capacity to manage their electricity transition — and which will be locked into their current path for longer than markets expect.

South Africa and Mongolia carry the flag for coal not because they are backward, but because their electricity systems were built around coal, and the conditions for transition — fiscal space, policy clarity, infrastructure investment — have not yet materialised. That is not a judgment. It is a structural observation.

Beyond the Signal

A map is a snapshot. It captures a moment, but it cannot capture the forces that are already moving the moment forward.

The countries that dominate the electricity map today — the United States, China, India, France — will dominate it tomorrow as well. But the composition of that dominance will change. Slowly. Imperceptibly at first. Then, perhaps, suddenly.

The question is not whether the transition will happen. It is whether the transition will be managed or chaotic.

A managed transition requires foresight, investment, and institutional capacity. A chaotic transition is what happens when policy lags infrastructure, and infrastructure lags economics, and economics lags reality.

South Africa and Mongolia are not symbols of failure. They are symbols of institutional inertia — the tendency of large systems to continue doing what they have always done, until external pressure forces a change.

That pressure is coming. It is already here in the form of carbon pricing, trade policy, and technological displacement. The question is whether the systems will adapt — or wait until adaptation is no longer a choice.

In the language of energy, a system that does not change is not stable.

It is storing pressure.



MLJC Intelligence™

Global Electricity – The Map of Divergence and What It Reveals About Energy Transition

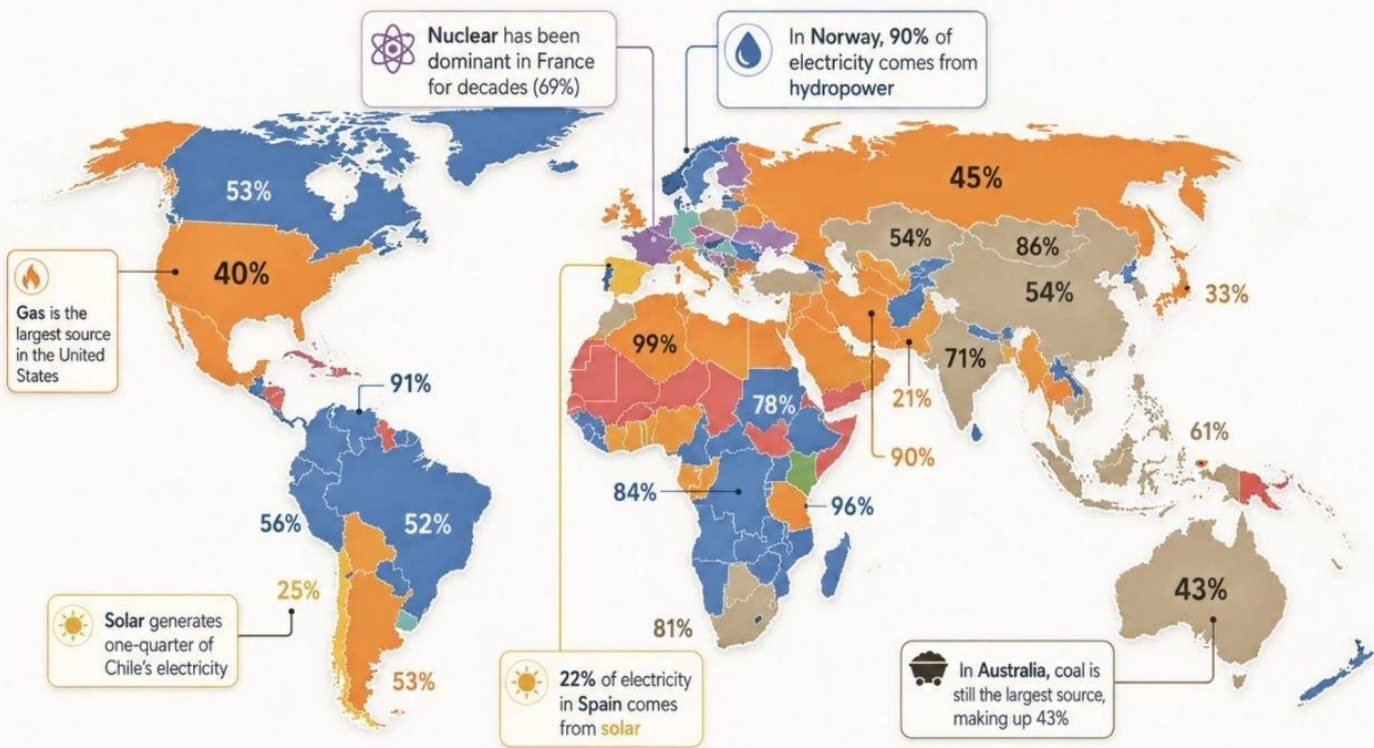
全球电力结构 —— 一张地图揭示的分化与能源转型真相

MLJC | 全球电力结构 —— 一张地图揭示的分化与能源转型真相

What is the largest source of electricity? ⚡

The source that generated the most electricity in 2024/25, by country.

Labels show the share of generation coming from the largest source.



Source: Our World in Data

Executive Signal

Our World in Data 发布的一张全球电力来源地图，讲述了一个既简单又容易被误读的故事。每个国家的主要电力来源落在八个类别之一——煤、油、气、核能、水电、太阳能、风能或地热。视觉印象是多元化的：美国以天然气为主，法国以核能为主，挪威以水电为主，智利以太阳能为主，丹麦以风能为主，澳大利亚和中国以煤炭为主。

普通读者最常见的总结是：“能源转型正在推进，但不均衡。”

这个说法正确，但不完整。更深层的解读揭示了三个结构性事实：

1. 化石燃料仍然是大多数主要经济体的最大电力来源——包括美国（天然气，53%）、中国（煤炭，54%）和印度（煤炭，72%）。
2. 技术和资源的路径锁定比政策意愿更强大——各国倾向于停留在其历史能源路径上。
3. 极端值同样重要——南非和蒙古以83%和91%的煤炭占比“扛起煤电大旗”，而挪威（水电90%）、法国（核电69%）、智利（太阳能25%）则展示了资源禀赋和政策历史如何能够创造出截然不同的电力系统。

这张地图不是成绩单。它是理解全球电力系统结构性惯性的基线——以及任何试图使其脱碳所面临挑战的规模。

What Happened

牛津大学旗下研究机构 Our World in Data 汇编了2024/25年度各国电力来源数据。该可视化图表为每个国家分配一个主要来源及其相应占比。

地图中的关键数据：

国家	主要来源	占比
美国	天然气	53%
中国	煤炭	54%
印度	煤炭	72%
法国	核能	69%
挪威	水电	90%
南非	煤炭	83%
蒙古	煤炭	91%
澳大利亚	煤炭	43%
智利	太阳能	25%
丹麦	风能	56%
西班牙	太阳能	22%
巴西	水电	61%
德国	风能	31%

地图中还包含一些规模较小但值得注意的数据：芬兰核能占比45%、波兰煤炭占比71%、日本天然气占比78%。

Market Evidence

1. 化石燃料在大规模上仍然占据主导地位

美国、中国、印度和澳大利亚——全球四个最大的经济体——全部依赖化石燃料作为其主要电力来源。这些经济体合计占全球电力需求的45%以上。它们的能源结构变化不是快速的，而是渐进的，变化速度仍低于巴黎协定对齐的轨迹。

2. 资源禀赋的解释力超过政策
挪威90%的水电占比反映的是地理条件，而不仅仅是环境雄心。同样，法国69%的核能占比是1970年代后“梅斯梅尔计划”的遗留产物，由能源安全关切驱动，而非气候政策。智利25%的太阳能占比反映的是阿塔卡马沙漠独特的太阳能辐射条件，而不仅仅是政策领导力。

3. 煤炭在特定背景下仍然具有韧性
南非（83%）和蒙古（91%）是极端案例。南非的国有电力公司Eskom因煤炭资源丰富、种族隔离时代的产业政策以及有限的财政空间，一直无法实现转型。蒙古的煤炭主导地位反映了其巨大的煤炭储量和缺乏替代基础设施。

4. 核能：稳定但未扩张

法国（69%）、芬兰（45%）和瑞典（32%）表明核能可以提供清洁基荷电力。然而，新建核电站仍然缓慢且资本密集——积极扩张核能机组的国家寥寥无几。

5. 可再生能源：在小系统中占比高

丹麦（风能，56%）和智利（太阳能，25%）实现了较高的可再生能源占比，但这些都是相对较小的电力系统（丹麦约34 TWh/年；智利约85 TWh/年）。将这些占比推广到更大的系统——中国、美国、印度——面临尚未完全解决的电网整合挑战。

Structural Interpretation

MLJC Assessment — Causal Hypothesis

张地图揭示的是，电力系统具有这路径依赖性——不是决定论意义上的，而是结构性的。一旦一个国家围绕某种燃料来源建设了电力系统，沉没成本、基础设施、劳动力和监管框架就形成了自我强化的惯性。



三种机制驱动这一现象：

1. 资本存量锁定

煤电厂和气电厂的寿命为40至60年。一旦建成，其资本成本已经沉没。即使以较低容量运行，通常也比提前退役更便宜——特别是在财政空间有限的国家。

2. 制度锁定

公用事业公司、监管机构和工会已围绕特定技术形成了专业知识、政治影响力和既得利益。从煤炭转型不仅是技术挑战，更是政治和社会挑战。

3. 资源锁定

拥有丰富国内煤炭资源的国家（澳大利亚、印度、南非、蒙古、中国）面临与国内化石燃料资源有限的国家不同的政治经济学。进口替代是能源政策的强大驱动力。

实现高可再生能源占比的国家，要么：（a）本来就没有化石燃料资源；（b）拥有特殊的可再生能源资源禀赋；要么（c）在数十年间做出了深思熟虑的政策选择。

Transmission Mechanism to Markets

电力结构 → 发电边际成本 → 批发电价 → 工业竞争力 → 能源密集型产业投资 → 碳定价与合规成本 → 能源资产的资本配置

1. 化石燃料依赖型经济体——中国、印度、南非、澳大利亚——面临不断上升的碳合规负担，随着欧盟碳边境调节机制（CBAM）和其他边境碳调节措施的扩大，其电力成本相对于低碳系统可能变得竞争力下降。

2. 核能主导型系统——法国——享有稳定、低碳的基荷电力，提供可预测的电价。然而，随着反应堆机组老化和替代成本仍然不透明，它们面临未来成本不确定性。

3. 可再生能源比重高的系统——丹麦、智利、挪威——实现了低边际成本电力，但面临电网稳定性和储能成本，这些未被其头条占比所反映。

4. 煤炭主导型系统——南非、蒙古——面临对碳定价和煤炭供应中断的结构性脆弱性。它们的电力系统转型缓慢，这同时创造风险和投资机会。

Market Mispricing

大量市场评论将可再生能源转型视为线性和必然的——即对当前趋势的外推。这张地图表明并非如此。

被误定价的风险包括：

- 1. 低估化石燃料的持续性
如果政策没有实质性地加速——如果储能技术的突破没有实现——化石燃料将在比当前共识定价所暗示的更长时间内保持主导电力来源。这对碳信用市场是风险，对化石燃料资产持有者是机会。
- 2. 高估电网整合的速度
小系统（丹麦、智利）中的高可再生能源占比不能直接扩展到大型系统，而没有大量的电网储能投资。市场可能低估了这一整合的成本和时间表。
- 3. 忽视核能作为过渡期支柱的作用
法国的核机组虽然老化，但提供了可靠的清洁基荷电力。市场可能低估了核能在能源安全中的作用，特别是在欧洲后天然气危机环境中。

Scenario Analysis

[MLJC 主观概率评估，非统计模型]

情景 关键驱动因素 结果

基准情景（最高概率） 可再生能源逐步增长；天然气和煤炭缓慢下降；核机组老化但无快速替代；储能成本继续下降但非剧烈。 电力结构保持多元化；化石燃料在亚洲和美国仍占主导；欧洲加速可再生能源建设；碳定价压力逐步显现。

政策加速情景（较低概率） 更强力的碳定价；欧盟CBAM扩大；中国加速电网储能投资；核技术取得突破。 化石燃料下降加快；可再生能源和核能扩张；各地区电力成本趋同。

政策/技术延迟情景（重大尾部风险） 碳定价停滞；储能成本仍高；电网整合证明比预期更困难；核机组退役加速而无替代。化石燃料持续时间超出共识；碳合规成本造成贸易摩擦；各地区电力成本分化。

What to Watch — Monitor Logic

变量 当前信号 方向 重要性

美国天然气发电占比 53% 稳定
最大单一市场；占比变化影响全球气价

中国煤炭发电占比 54% 逐步下降（约1-2%/年） 全球煤炭需求和CO₂的关键信号

印度煤炭发电占比 72% 上升中？
印度的工业化一直以煤电为基础；任何偏离都意义重大

法国核电占比 69% 老化；替代不确定 法国基荷安全影响欧洲电价

南非/蒙古煤炭占比 83% / 91%
稳定 煤炭依赖的极端案例；转型障碍是结构性的，非政策性的

电池储能成本 约下降15%/年 持续 大型系统中高可再生能源占比的关键赋能因素

欧盟CBAM碳价 \$50-100/吨CO₂
上升 直接影化石燃料依赖型经济体的出口成本

Falsification Conditions

在以下情况下，我们将修正基准判断：

- 1. 电池储能成本在三年内下降超过50%，使电网规模储能的成本能够使可再生能源的间歇性与化石基荷电力具有成本竞争力。
- 2. 核技术（SMR或新一代设计）在一个西方国家达到商业可行性，并附有可信的成本和时间表预测。
- 3. 中国的煤炭占比在五年内降至45%以下，标志着全球最大电力系统的结构性断裂。
- 4. 碳定价在欧盟达到75/吨CO₂，实质性改变煤电和气电的边际成本计算。

MLJC Assessment

Our World in Data 的电力地图是一个有价值的诊断工具——但它不是一条轨迹。它告诉我们世界现在在哪里，而不是将要去哪里。

结构性现实是：电力系统具有惯性。各国不会快速改变其主要电力来源。构成当前格局的资本存量、制度框架和资源禀赋是数十年间建立起来的——也将需要数十年才能转变。

这张地图还揭示出，能源转型不是一个单一的全球现象。它是一组国别特定现象，每一个都由资源禀赋、政策历史和经济结构所塑造。智利的太阳能、法国的核能、挪威的水电、南非和蒙古的煤炭，都不是可比较的案例；它们是不同的结构性条件下的不同结果。

对于机构投资者而言，关键信号不是“哪个国家在转型中领先”。而是哪些国家具备管理其电力转型的制度能力——以及哪些国家将在其当前路径上被锁定比市场预期更长的时间。

南非和蒙古扛起煤电大旗，不是因为它们落后，而是因为它们的电力系统是围绕煤炭建设的，而转型的条件——财政空间、政策清晰度、基础设施投资——尚未成熟。这不是一种评判，而是一个结构性观察。

Beyond the Signal

地图是一张快照。它捕捉了一个瞬间，但无法捕捉已经在推动这个瞬间向前移动的力量。

今天主导电力地图的国家——美国、中国、印度、法国——明天仍将主导。但主导地位的构成将会改变。缓慢地。起初难以察觉。然后，也许，突然。

问题不在于转型是否会到来。问题在于转型将是可控的还是混乱的。

可控的转型需要远见、投资和制度能力。混乱的转型发生在政策落后于基础设施、基础设施落后于经济学、经济学落后于现实的时候。

南非和蒙古不是失败的象征。它们是制度惯性的象征——大型系统倾向于继续做它们一直在做的事情，直到外部压力迫使其改变。

这种压力正在到来。它已经以碳定价、贸易政策和技术替代的形式存在。问题在于这些系统是主动适应——还是等到适应不再是选择。

在能源的语言中，一个不变的系统并非稳定。它是在积蓄压力。