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RISKS TO THE ENERGY TRANSITION

AUGUST 2023

WHY THE TRANSITION IS FAILING

The definition of insanity is continuing to do the same thing, even when it is not working. Rising carbon emissions, missed clean energy deployment targets, and growing organized resistance are clear evidence that our current energy transition strategy is failing. Yet the models we use to guide policies and planning tell us to continue deploying more wind, solar, and energy efficiency. In fact, none of the models used by the principal modeling organizations, whose models create the consensus for the world's climate policy, can reproduce what is actually happening in the real world.

Unfortunately, these mainstream energy transition models, because they are derived from capacity addition models, prioritize cost optimization and overlook critical factors related to the feasibility of building massive amounts of new clean energy infrastructure, including socio-political, cultural, commercial, and financial aspects. For example, although all the renewable energy projects needed for the energy transition will require project developers and a project development process, existing models contain no explicit representation of this process or how real-world constraints and risks drive project development outcomes. The projects in these models just instantly appear in the year that they are needed.

Another consequence of this omission in these models is that all 'available land' is presumed to be 'developable', when in fact much of that land is not attractive or amenable to project development, and where it is, few of the projects ultimately make it to operation. These omissions lead to greatly overstating the potential for deployment and create a dangerous gap between the decarbonization pathways proposed and the real world of project development. This, in turn, leads to ill-informed policy targets and inadequate implementation plans.

Terra Praxis is a non-profit organization that exists to de-risk the energy transition. Powered by philanthropy, Terra Praxis is innovating transformative climate change solutions for the difficult-to-decarbonize sectors of coal-for-power, industrial heat, and heavy transport. Terra Praxis shines a light on risks to the global energy transition that threaten the deployment of clean energy at speed and scale. With this clear-eyed perspective, Terra Praxis designs and innovates scalable solutions in response to these challenges. We lead deep engagement with industry, governments, regulators, academic institutions, energy systems modelers, and other non-governmental organizations to diversify and expand the range of tools available for deep decarbonization.

By studying and understanding the real risks to the clean energy transition, we can guide decisionmakers to develop and implement risk-informed strategies which will increase our chances of successfully achieving Net Zero by 2050. By considering their advantages in the context of their risks, each of the zero-carbon energy technologies can contribute in a different way to achieving large-scale rapid decarbonization. This new way of modeling will enable us to reduce the likelihood of failing to decarbonize by creating a portfolio of solutions that do not all share the same risks. For example, a renewables new build strategy complemented with a strategy that repurposes existing coal plants and other energy-intensive infrastructure with emissions-free power, heat, and steam enables large-scale clean energy supply while hedging the risks of public opposition to renewable greenfield projects, which also require new interconnections, and extensive transmission buildout.

This brief report, based on work done by the Terra Praxis team since 2018, summarizes analysis of the risks to the clean energy transition in the United States, United Kingdom, Germany, and Japan, and outlines the immediate risks that must be anticipated and mitigated to ensure progress toward a Net Zero future. It also sets out how, by diversifying the portfolio of emissions-free technologies, aligning targets with feasibility analysis, and implementing risk-informed strategies, we can mitigate the key risks and help drive a successful transition.

RISKS TO THE CLEAN ENERGY TRANSITION

Land

There is a fundamental mismatch between what we consider available land for power projects in energy transition models and what is considered developable land by project developers. As shown in **Figure 1**, the project development process begins once all practically available land is identified (i.e., site assessment). Several critical milestones—which are not currently factored into mainstream energy transition models—need to be achieved before a project is built, and each milestone has several associated risk factors. Any one of these risk factors can cause a project to fail. For jurisdictions with poor wind and solar resources that plan on decarbonizing with renewables and green hydrogen, it is important to note how much land will be needed, and how difficult it will be to secure rights to the land (or sea) and successfully develop enough capacity for economy-wide decarbonization.

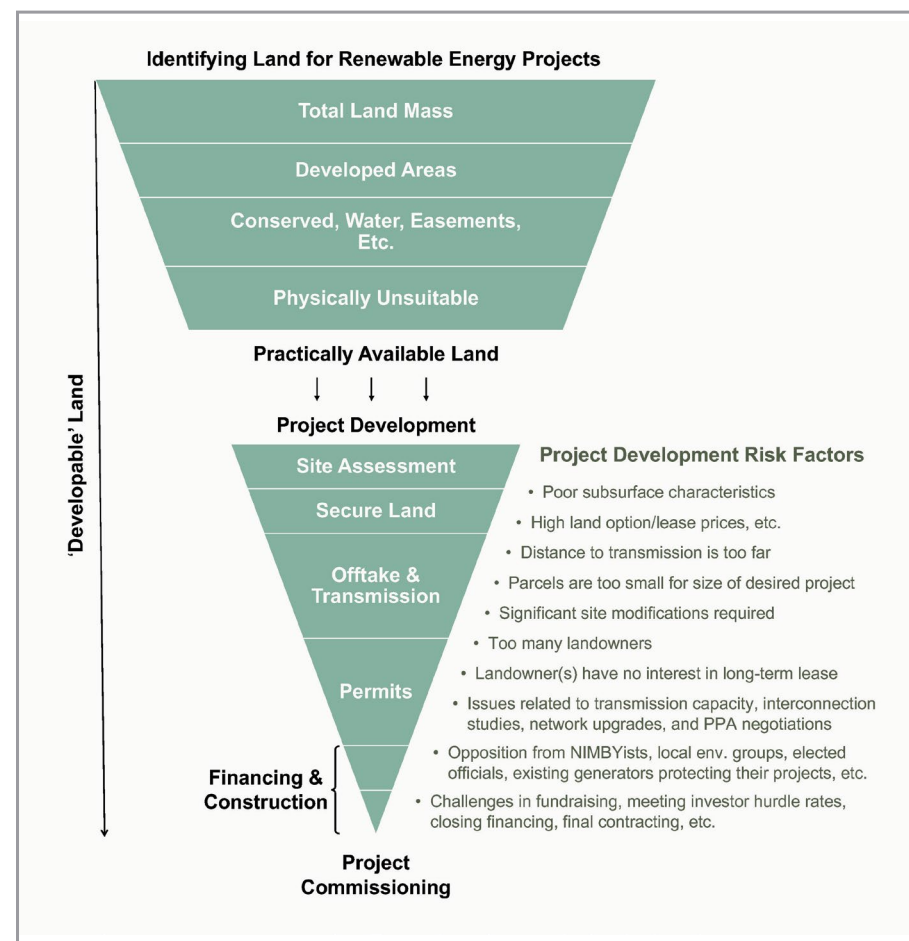


Figure 1. Project Development Risk Factors

For example, **Figure 2**, showing two maps, represents in colored outlines the total area that would be required for each energy resource if used to generate enough hydrogen to supply current oil consumption in the UK and Japan, respectively.

The UK is a high-income country with high energy use per capita and high population density. The area required to supply the UK's current oil consumption with hydrogen from solar would be 26,090 km². To produce the same amount of hydrogen instead with offshore wind would require an area of 136,120 km²—which would take up most of the North Sea. The pink outline shows the size of a single continuous wind farm to produce this much hydrogen. If the UK were to produce the same amount of hydrogen for liquid fuels substitution using Gigafactories or production platforms with advanced heat sources, the land area required is dramatically smaller—only 55 km²—illustrated by the barely visible green shape.

Japan is a particularly striking example as it is mountainous and densely populated, with very little land available for the large solar farms that would be required for solar-generated hydrogen and similar geographic constraints facing onshore wind. As Figure 2 shows, the solar task is simply not viable—the area required for the 63,170 km² projects to supply the solar-generated hydrogen equivalent to Japan's current consumption of oil-based liquid fuels does not appear feasible. Japan's offshore wind resources are limited by the extent of the shallow continental shelf. Even floating offshore wind turbines must be anchored to the seabed, so water thousands of meters deep will never be suitable.

We do not map a projection for global comparisons, because in practice the hydrogen production locations would be in multiple locations. We have to assume that if countries are planning massive investments in clean energy that they will want—as far as possible—to control those investments. However, the numbers are striking. For example, if solar PV were to replace all global oil using hydrogen, 770,900 km²—an area similar to the size of Turkey—would have to be covered with solar panels. If offshore wind were to replace global oil with hydrogen, an even larger area of 8,380,000 km² would be required—about the size of Brazil (8,460,000 km²). If the production platforms described in this report, powered by advanced heat sources, were to do the same job—only 3,414 km² would be needed, equal to a square of 58 kilometers per side.

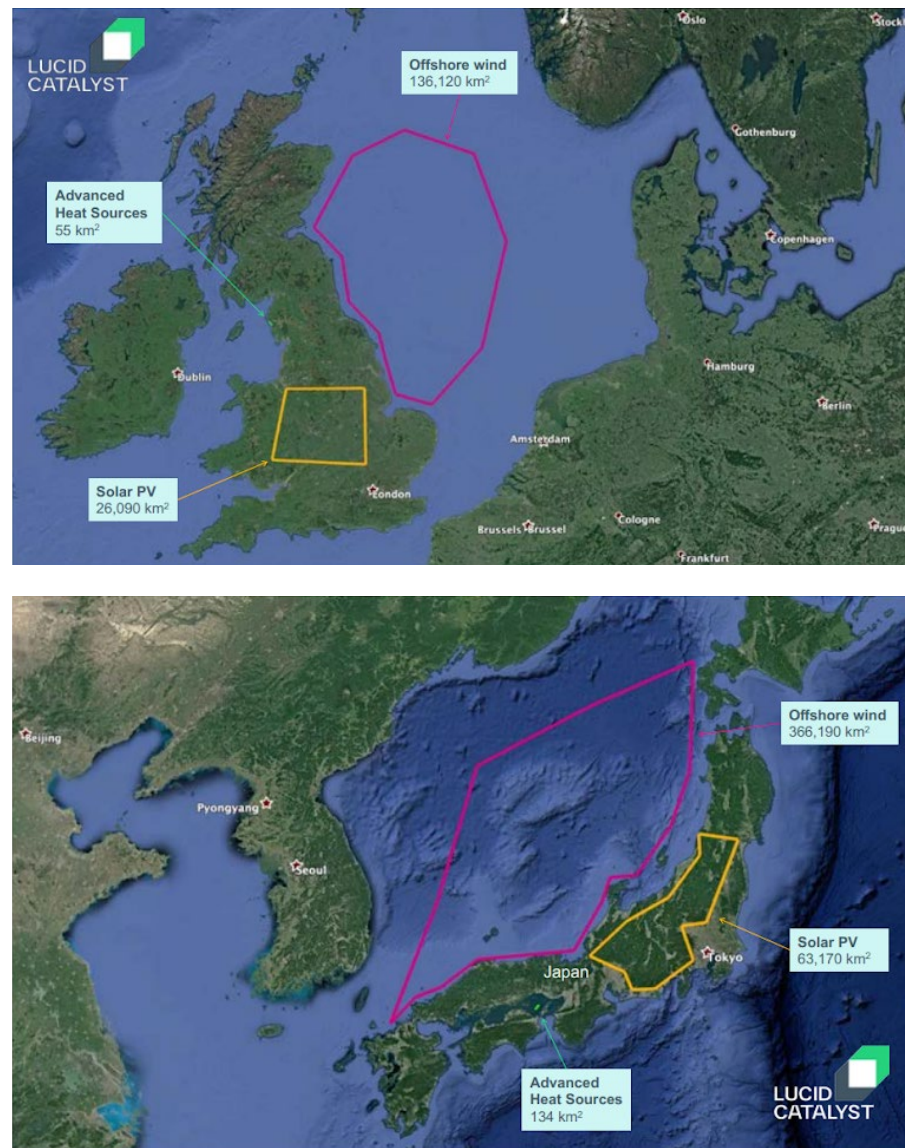


Figure 2. Area that would be required to supply UK's (top) and Japan's (bottom) current oil consumption with hydrogen from wind, solar, or advanced heat sources

Transmission

Transmission fundamentally governs power project development. Without available capacity to interconnect a project, developers will not invest in development. Transmission must be built first, and due to the need to obtain approvals across multiple geographical and governmental jurisdictions, building transmission typically takes much longer than power projects. This makes transmission development a risky endeavor. Further, because of lower capacity factors, transmission dedicated to wind and solar is substantially more expensive on a per unit energy basis: approximately twice as much will be required per TWh of wind, and approximately four times as much per TWh of grid scale solar. If enough transmission cannot be built in a timely manner (i.e., at an unprecedented rate), there simply is no practical path to delivering enough clean energy for pathways that depend on these resources.

Public Support/Opposition

Public opposition to renewable power projects is becoming better organized and more frequent. For example, **Figure 3** shows the growth of public opposition to wind energy development in Iowa over time. A growing proportion of opposition is being led by the environmental and conservation communities and others interested in protecting an area's rural character and/or viewshed. Public opposition tends to increase as more projects are deployed in a given area. It will also play a critical role in the build out of transmission as well.

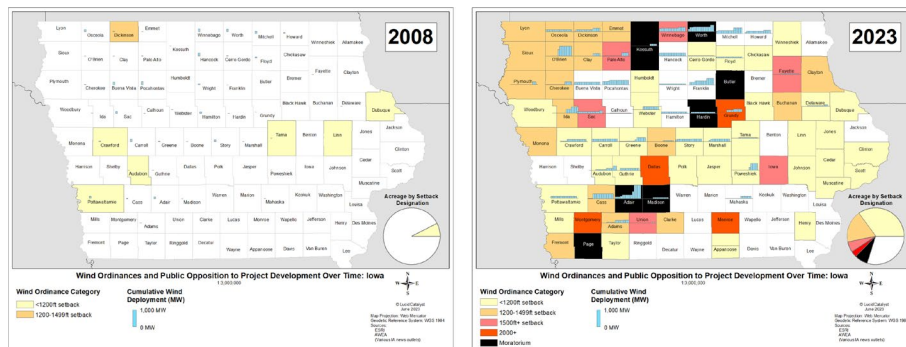


Figure 3. Public opposition to wind energy development in Iowa from 2008 to 2023

Escalation of Non-Hardware Project Costs & Risks

Fortunately, solar and wind hardware costs have enjoyed a remarkable decline over the past decade. However, it is likely that non-hardware project costs and risks will escalate as more projects are developed in a given area. In addition, increased project development costs and risks must be paid with project developers' risk capital, which is more expensive and harder to raise than the low-cost capital that models assume will provide the long-term financing for projects. Project developers typically look for factors like low land cost, large parcels in close proximity to planned or existing transmission, landowners who are willing to sign long-term land leases, good solar or wind resources, the need for few right-of-way approvals to interconnect the project, clear public support, favorable energy market environment, etc. Nearly all these essential developer criteria get worse as more projects are deployed in an area.

As more land is converted for projects, land costs increase, projects are pushed further from transmission, project capacity factors get worse (as the good sites are taken), the public is less supportive, etc. All these conditions occur simultaneously, compounding project risk and thus cost. Energy models often show increasing deployment over time, as in a 'hockey stick' growth curve. The real factors that affect large-scale project deployment suggest that an 'S-curve' (as shown in **Figure 4**), is more likely.

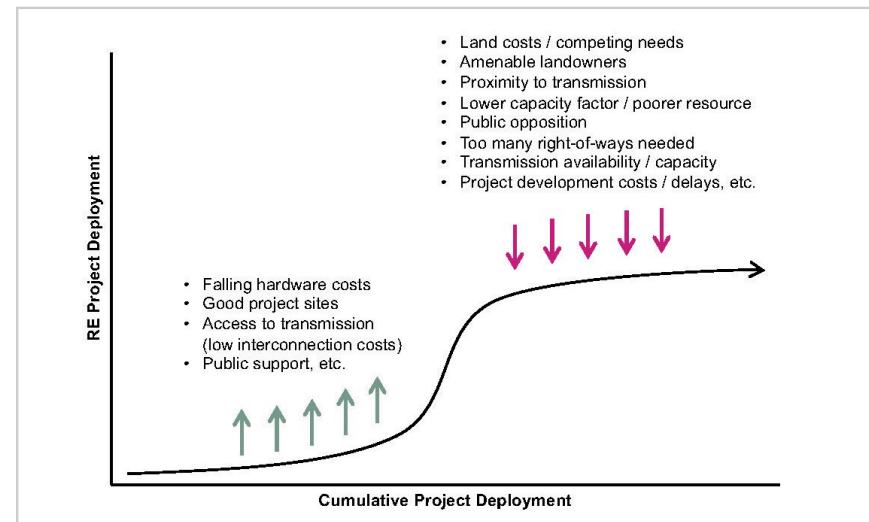


Figure 4. The project development S-curve

Timing & Logistics

The sequencing and time-sensitivity of the massive, simultaneous infrastructure build out in every country that is required for decarbonization presents an unprecedented logistical challenge. The challenge is not only to build enough infrastructure for clean electricity generation, but to also build the infrastructure needed to electrify other sectors such as heat and transport. Most potential projects do not make it all the way through the project development process, which means that commissioning a gigawatt of solar requires several gigawatts to reach the late-stage development. This will necessarily require more developers overall, more development capital, and more human resources dedicated to other parts of the process (e.g., permitting, interconnection studies, engineers, financiers, etc.).

Beyond the Power Sector

Seventy-five percent of primary energy use is outside the power sector (e.g., data centers, steel, cement, aviation, marine shipping). The amount of generation capacity required to develop emissions-free substitute fuels and to decarbonize other carbon-intensive sectors of the economy will require a staggering amount of emissions-free energy.

The scale of investment required, necessary deployment rates, willingness of the public to bear these costs, and available land for development are major hurdles to the energy transition. In many locations, deployment rates for renewables are far below what is necessary to achieve renewables-intensive 2050 decarbonization targets. Advocates for these strategies point to this shortfall and say we need to redouble our efforts. But it would be prudent to consider how the current sluggish levels of deployment may actually be evidence of how difficult large-scale renewables deployment is becoming even though we are just at the beginning of the build-up needed for the energy transition. If it is difficult now, at the beginning, it is only going to get more difficult due to the best sites being taken already, lack of transmission, escalation of development risks and cost, and growing public opposition.

The magnitude of the project development challenges requires energy models that expand beyond simple cost optimization to represent and advance feasible solutions and drive policy and investment in large-scale decarbonization.

TERRA PRAXIS CONCLUSIONS

1. Interrogate for Feasibility: Modeling needs to include feasibility, or else we are set up for failure. Private foundations, which directly and indirectly drive a lot of energy transition modeling, can demand that real issues of feasibility be rigorously included in modeling results before funding modeling projects and the policies that are based on them. A modeling Code of Conduct may be necessary.

2. Reality Check: Land availability and public acceptance are only likely to get more difficult—and we need to at least triple generation and transmission capacity in the next 27 years. Resource availability in models should be based on real developable land, including physical conditions, restrictions, and other factors that drive availability for the front end of the development process. The time required to develop power projects and transmission projects needs to be accurately modeled, and the fact that investments in power project development will not start until transmission exists should be a requirement for all models. Funding for modeling or policies based on modeling need to meet these basic ‘reality checks’.

3. Repurpose Assets: Leverage as much of the existing infrastructure as possible. Advanced heat sources—advanced fission, fusion, and geothermal—can be used to repower coal plant facilities and other energy-intensive infrastructure, requiring far less incremental transmission, land use, and inter-state connectivity. Given the likelihood that we are living in the ‘transmission constrained scenario,’ we need to invest aggressively in decarbonization pathways that make optimal use of precious existing sites already connected to the grid.

4. Diversify Pathways: It is highly likely that building clean power projects will become increasingly risky in the 2030s and further into the 2040s. This could lead to a situation where we have gone ‘all in’ on pathways that require very extensive deployment of new greenfield projects, but we are stalled long before we reach the required new clean supply. Therefore, we need mainstream scenarios that also explore and support the deployment of technologies with high power density, capacity factor, and reliability, and that do not have the same constraints and risks.

Climate strategies that enable the repurposing of existing infrastructure to run on emissions-free energy and produce emissions-free fuel are a practical, achievable, scalable, and equitable way to reach a carbon-negative economy and put the world on a fast path to growth and decarbonization by 2050.

TERRA PRAXIS SOLUTIONS

Based on the insights gained from our empirical risk analysis, Terra Praxis has outlined a strategic roadmap for achieving our vision for rapidly and cost-effectively repowering the global economy with emissions-free power, heat, and steam. Terra Praxis' key programs of work include:

- 1 Transforming Modeling:** Build and disseminate new global decarbonization modeling methods to establish feasibility guardrails around infrastructure build assumptions and diversify clean energy options.
- 2 Catalyzing Market Demand:** Facilitate a buyers' group of major industrial energy users that signals massive market demand for terawatts of emissions-free energy services in the 2030 timeframe.
- 3 Accelerating Pre-Development:** Develop digital solutions for swift and cost-effective licensing, permitting, and fleet-wide feasibility studies to lower development risk and stimulate investment.
- 4 Accelerating Deployment:** Define requirements for a standardized product design and delivery system that enables fast, low-cost, repeatable, reliable, and scalable deployment.
- 5 Activating Finance:** Leverage buyers' demand signal to engage investors, governments, international finance institutions and Multilateral Development Banks in financing deployment.
- 6 Leading the Change:** Lead a consortium of leading industry, government, academia, regulators, and nonprofits to execute an integrated strategy across key activities to achieve speed, scale, and impact.

LEARN MORE

You can find out more about our work and impact at terrapraxis.org and by reading our latest [Annual Review and publications](#).

Key Publications on Energy Transition Risks

May 2023 Terra Praxis' Climate Solution Brief: [Repowering the Global Coal Fleet by 2050](#).

July 2022 Terra Praxis informs a report published by LucidCatalyst & ClearPath: [Hawkeye State Headwinds: A Case Study of Local Opposition & Siting Challenges for Large Scale Wind Development In Iowa](#).

October 2022 Terra Praxis informs a report published by Clean Air Task Force & Environmental Defense Fund: [Growing the Grid: A Plan to Accelerate California's Clean Energy Transition](#).

POWERED BY PHILANTHROPY, WE DESIGN
TRANSFORMATIVE STRATEGIES TO ADDRESS
THE GREATEST RISKS TO THE ENERGY
TRANSITION — MAPPING UNCHARTED
DECARBONIZATION TERRITORY

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