

Harnessing Wind Power: A Socio-Technical Assemblage of Wind Energy in Thailand

Prasert Rangkla

Faculty of Sociology and Anthropology, Thammasat University, Bangkok, Thailand

Email: prasertr@tu.ac.th

Received: September 8, 2025

Revised: February 26, 2026

Accepted: May 4, 2026

Abstract

This article examines wind power development in Thailand as a contingent socio-technical assemblage. Rather than adopting a teleological or technocentric perspective, it highlights how renewable energy prospects emerge from the entanglement of sociopolitical and material conditions. Drawing on qualitative research conducted at the edge of the Korat Highlands, the study analyzes how wind energy projects are constituted through knowledge practices, institutional reforms, and material infrastructures. These projects become investible through processes of long-term measurement, data processing, and capacity factor calculation. Such practices intersect with regulatory changes that enabled private generation under power purchase agreements, supported by feed-in tariffs and subsidies. Technological advances—particularly the deployment of IEC Class 3 turbines—have extended feasibility into low-wind contexts. Yet turbine production and installation remain materially dependent on fossil fuel and other extractive resources. By foregrounding these socio-material entanglements, this article demonstrates that wind power development emerges from the interdependence of knowledge, socio-political processes, and material elements. The intensive material and energy demand of such projects is closely tied to extractive industries, contributing to cumulative energy systems. The intertwined relationship between fossil fuels and renewables challenges deterministic narratives of energy transition framed as straightforward “substitution.”

Keywords: socio-technical assemblage, wind energy, renewable energy, entanglement

Introduction

On February 12, 2013, then-Prime Minister Yingluck Shinawatra traveled by helicopter to Ban Sub Plu School, landing on its football field to preside over the opening ceremony of the West Huay Bong 2 (WHB2) and West Huay Bong 3 (WHB3) wind power projects in Dan Khun Thot district, Nakhon Ratchasima province. She declared:

The project is a source of pride for Thailand in producing the largest amount of electricity from wind in the ASEAN region... The production of electricity from wind power will be one way to realize Thailand’s renewable energy promotion plan. It is expected that the volume of electricity from wind power will increase to 1,200 megawatts in the next eight years (Matichon Daily, 2013: 14).

The grand opening in 2013 signaled the Thai government’s intention to pursue rapid expansion in renewable energy. Advanced energy technologies—wind turbines in this case study—were envisioned as pivotal instruments for the expansion of renewable energy. More emphasis is currently being placed

on technological innovation, based on the premise that transitioning away from fossil fuels is essential for addressing climate change. This perspective reflects the techno-economic model of energy transition. Within this tradition, it is assumed that innovation dynamics and active efforts to develop low-carbon energy systems will significantly accelerate the transition process, ultimately making a global energy transition achievable in the future (Bromley, 2016; Kern and Rogge, 2016; Sovacool and Geels, 2016). Similarly, Thailand's promotion of renewable energy has emphasized the substitution of particular technological artifacts and energy supply systems as the primary pathway toward energy transition.

Although the imperative for a large-scale transition toward sustainability is widely recognized, the techno-economic rationale has been criticized for its speculative and teleological assumptions. Arnulf Grubler once observed that "a new solution does not evolve in a vacuum but interacts with existing practices and technologies" (Grubler, 1996: 37). He and his colleagues later argued that "an encompassing sustainability transition will require changes that are systemic, large-scale, and often provide few immediate adoption benefits" (Grubler et al., 2016: 24). Beyond questions of temporality, social science scholars have also challenged technological determinism for its underlying logical limitations and reductionist assumptions (Günel, 2022; Lawhon and Murphy, 2011). By foregrounding technology, the techno-economic analysis renders social actors and their interests less visible, while presenting outcomes as anticipated. Consequently, readers are left without a sense of how these changes occurred, by whose agency, and whether energy systems necessarily emerge from technological innovation.

Recent scholarship underscores that energy systems are not solely about resources or technologies but are deeply intertwined with social, political, and cultural structures. The socio-technical perspective (Bridge, 2018) highlights that energy is both a social product and a force shaping social life and processes. Accordingly, studying energy requires analytical frameworks that extend beyond the physical or technical to encompass spatial and temporal interactions. This perspective has become the epistemological foundation for contemporary social science research on energy. Building on this trend, the present article situates wind power development in Thailand as energy technologies embedded within particular contexts, shaped by the entanglement of material and social features across a broad landscape. In challenging the binary separation between the social and the material, the analysis engages with what Simone Abram and colleagues describe as "the relationship between electricity's material properties and its manifestations in social and political worlds" (Abram et al., 2019: 6).

This article draws on qualitative research conducted between October 2023 and August 2025 as part of the project, *Socio-technical Entanglement and Dynamics of Wind Energy Infrastructure in the Korat Highland, Thailand*. The study examines the development of wind energy projects located on the western edge of the Korat Highlands, a region that hosted, in 2024, more than 80 percent of Thailand's operational wind turbines. Empirical data for this article were collected through field visits to the research sites. The historical development of wind energy in Thailand was examined through news reports, current affairs magazines, and energy-related websites. To investigate the dynamics of project development, the researcher conducted semi-structured interviews with personnel from wind energy companies, including executives, project managers, and operational staff. Interviews were also conducted with local public servants and community members. Pseudonyms are used where necessary to protect the identities of participants. The collected data were analyzed through the perspective of sociotechnical entanglement.

The article argues that wind energy in Thailand is becoming investable through assemblages that bring together measurement and calculative practices, institutional and policy reconfigurations, and diverse combinations of material and resource inputs. Moreover, the study demonstrates that wind energy development is embedded within cumulative, rather than substitutive, energy systems. This perspective challenges deterministic “substitution” narratives of energy transition by foregrounding the interdependent relations between fossil fuels and renewables within global supply chains.

Sociotechnical Entanglement

The study of energy has conventionally been framed through the lens of technological advancement, with the aim of propelling societies toward modernization. Within this paradigm, technological progress is frequently equated with social progress (Nader, 1981). Such a perspective has tended to narrow the field of energy studies to questions of engineering knowledge and technical expertise. Electricity, in this framework, is often construed as neutral knowledge, detached from socio-political contexts.

The division between technological and social knowledge is deeply entrenched within academic disciplines. As Timothy Mitchell (2011) argues, modern scientific modes of knowledge production cultivate a systematic separation of nature from society, positioning the natural world as distinct from the social realm of beliefs, desires, and political power. Even when power plant projects encounter opposition or criticism regarding their social and environmental impacts, these public debates seldom penetrate the domain of technical and engineering decision making.

Contemporary scholarship increasingly calls for the study of energy as a sociotechnical entanglement (Abram et al., 2019; Boyer, 2014; Coleman, 2017; Leach et al., 2010; Middleton and Ketelsen, 2022), thereby moving beyond dichotomous framings that cast energy and electricity as either technological or social phenomena. Processes of production, distribution, and consumption are more accurately understood as hybrid systems composed of interwoven social and natural elements. From this perspective, technology is not merely an “instrument” deployed for energy planning and production but is intrinsically embedded within society—both emerging from it and shaping its dynamics.

Therefore, the study of energy entails close attention to the entanglements among material components, infrastructures, politics, and forms of knowledge. Energy should not be reduced to technologies and infrastructures alone. To understand energy requires, as Abram et al. (2019: 6) emphasize, “a refusal to separate objects from society, and instead to engage with the relations between electricity as object and electricity in social and political worlds.”

The energy research in social sciences in the 2010s challenged the teleological assumption that technologies certainly lead to predetermined outcomes. Instead, technological deployments generate multiple, contingent, and unpredictable consequences. Energy scholars, therefore, “do not primarily aim to explain the functional operation or ultimate objectives of energy projects, but rather to explore the origins and emergent forms of energy systems and projects” (Günel, 2022: 695). This approach arises from recognition that social change is not determined by instruments or technological progress alone, but rather is constituted through interactions among diverse elements.

Building on the idea that energy emerges through assemblages of resources, recent scholarship increasingly highlights its political dimensions, showing how multiple elements come together to constitute energy and shape its possible futures. Adopting a sociotechnical entanglement perspective, this

article underscores how wind energy projects are formed through the interplay of knowledge production, material objects, infrastructures, political arrangement. The recognition of the relations between objects and society points to the need for empirical investigation into the conditions that make wind energy projects possible in Thailand. This study therefore traces the origins and development of wind power as shaped by the assemblage of material-technological elements and emergent processes.

Reassessing Wind Energy Potential

The feasibility of utilizing wind energy in Thailand has long been subject to skepticism. Much of the country experiences low wind speeds, insufficient for electricity generation using conventional wind turbine technology. In addition, wind speed varies significantly by time of day and across seasons, further diminishing the attractiveness of wind energy development. Early assessments by state agencies such as the Electricity Generating Authority of Thailand (EGAT) and the Department of Alternative Energy Development and Efficiency (DEDE) identified the country's most promising wind resources along the southern coastline. These agencies commissioned energy researchers from various universities to study locations including Laem Phromthep in Phuket province, Sathing Phra district in Songkhla province, and Hua Sai district in Nakhon Si Thammarat province.

Prior to 2012, all operational wind energy initiatives in Thailand were small-scale pilot projects aimed at data collection and research, with installed capacities ranging from 0.05 to 2.5 megawatts. Several agencies erected wind measurement towers to collect wind speed data—for example, DEDE in Ranot district, Songkhla province, and EGAT in Laem Phromthep, Phuket province, and Sikhiu district, Nakhon Ratchasima province. However, these datasets proved inadequate for supporting large-scale project developments (van den Akker, 2018).

By the late 2000s, both established Thai energy firms and new market entrants had begun to explore opportunities in the Korat Highlands. A shift in perception regarding the region's wind potential was, according to Somsak, a key informant, catalyzed by "the arrival of a German man with a Thai wife." Somsak accompanied this couple during an initial site survey for wind speed measurement. The foreign developer was a staff member of ProVentum International (PVI), a Germany-based multinational specializing in wind energy project development. In 2007, PVI established a Thai subsidiary, PVI Thailand, to undertake feasibility studies, project planning, and development. Between 2009 and 2011, PVI Thailand operated a wind measurement tower in Wa Tabae subdistrict, Thap Sakae district, Chaiyaphum province, systematically collecting data over a 28-month period.

The findings from PVI Thailand's study redirected the trajectory of wind energy development in Thailand. The report concluded that the edge of the Korat Highlands had substantial potential for wind power generation. Although the wind speed data and measurement results were not publicly disclosed, they indicated that the border area between Chaiyaphum and Nakhon Ratchasima provinces experienced consistent wind throughout the year. At 100 meters above ground level, combined with the area's elevation of 300-400 meters above sea level, wind turbines would effectively operate at more than 400-500 meters above sea level.

Technical assessments confirmed that turbines at this elevation could achieve commercially viable wind energy production. PVI Thailand, however, did not directly develop the project. Instead, it transferred the project feasibility to the Electricity Generating Public Company (EGCO), which subsequently developed it under Theppana Wind Farm Company Limited. In return, PVI Thailand received a 10 percent

share in the project—later sold back to EGCO. EGCO oversaw the project's construction, engaging a Thai contractor and a Chinese wind turbine manufacturer under an engineering, procurement, and construction (EPC) contract.

The installation of PVI Thailand's wind measurement tower also attracted attention from other developers. Wind Energy Holding (WEH), which had pioneered wind energy projects in Khao Kho, Phetchabun province, installed its own measurement towers in the area. WEH eventually developed the Huay Bong 2 (WHB2) and Huay Bong 3 (WHB3) projects in Huay Bong subdistrict, Dan Khun Thot district, Nakhon Ratchasima province, both of which were officially inaugurated in 2013, as noted earlier. The German company's technical assessment effectively placed the edge of the Korat Highlands on the map for wind energy investment. The early projects of EGCO and WEH were, in this sense, sequential outcomes of this German-led expertise.

Measurement and the Economization of Wind

The pioneering wind energy projects in Thailand underscore the central role of wind speed measurement in transforming a natural phenomenon into a commercially viable resource. My own introduction to this concept came during a meeting with the director of the Forest Industry Organization (FIO) in Dan Khun Thot. I learned that a wind energy company had surveyed the FIO's forest plantation, marking sites for 13 wind turbines, delineating blade rotation radiance, and mapping connecting roads. The director explained that the site had been chosen after wind measurement towers confirmed the area's potential for wind power development.

Wind speed data, managers of wind energy project emphasize, is fundamental in determining the viability of a wind power site. Industry practice requires the installation of wind measurement towers for at least two years to ensure robust technical assessment. These tall steel structures are anchored to concrete foundations and stabilized by cables. Digital data loggers placed at different heights record wind speed—measured in meters per second (m/s)—continuously, day and night.

According to one project manager, tower placement is informed by global wind speed maps, which range from free sources such as the World Bank's database to proprietary, subscription-based products. Some databases integrate geographical information system (GIS) platforms, offering real-time readings, historical records, and near-term forecasts. While such maps provide macro-scale guidance, on-site measurement remains essential for confirming feasibility. Extended monitoring—sometimes up to five years—allows companies to analyze temporal variability: the number of productive hours per day, differences between day and night wind speeds, and seasonal fluctuations. This long-term data enables developers to process raw wind speed measurements into performance metrics that render wind economically legible.

A critical derived metric is the capacity factor (CF)—the ratio of actual electricity generated to the maximum possible output at full capacity. In the Korat Highlands, CF values typically range from 20 to 25 percent, meaning turbines produce, on average, one-fifth to one-quarter of their installed capacity over a year. This figure can be used to estimate total electricity production: multiplying CF by installed capacity yields annual generation in kilowatt-hours (kWh). Summing across all turbines gives project-level output, which, when multiplied by the electricity purchase price, generates a revenue forecast. Such forecasts form the basis for investment appraisal, enabling projections of profit margins,

debt repayment schedules, and overall financial viability.

For project developers, this process integrates technical feasibility with commercial assessment. Wind energy does not exist as a ready-made commodity but is produced through “processes of measurement, framing, and calculation” (Asdal, 2008). Latour (2010) similarly describes how environmental phenomena are transformed into “objects of fact” with economic and social value. Through wind speed measurement and subsequent data processing, wind is reconstituted as *natural capital*—a quantifiable, tradable resource that can be incorporated into national energy systems.

This calculative transformation also shapes perceptions of wind’s utility. As Sullivan (2018) notes, assigning numerical value to environmental processes reinforces their treatment as economic goods to be optimized for maximum benefit. In the context of wind power development, the appearance of natural wind as a resource coincides with the creation of the infrastructure and analytical tools required to exploit it. This aligns with concept of “calculative devices” (Çalışkan and Callon, 2009; Callon and Muniesa, 2005) — sociotechnical arrangements that translate intangible phenomena into measurable outputs capable of supporting investment decisions.

Without such measurement and calculation, large-scale wind power projects would be nearly impossible to develop. The transformation of atmospheric movement into a dataset, a financial model, and ultimately, a capital asset is what enables turbines to be built and electricity to be sold to the state grid. These processes show that wind power development is not solely a technical exercise in turbine installation but a multifaceted socio-technical process involving scientific instrumentation, economic modeling, and institutional certification.

The case of the Korat Highlands illustrates the layered nature of this transformation. First, wind is made visible and legible through long-term measurement. Second, it is converted into numerical indicators—such as capacity factor—that enable predictive modeling. Third, it is inscribed into financial forecasts that justify infrastructure investment. At each stage, the tools and practices of measurement are not merely neutral instruments but active agents in creating wind as a resource.

In sum, wind energy projects depend on a complex interplay between environmental processes, measurement technologies, and market-oriented calculation. Wind speed towers and their associated dataset function both as engineering instruments and as devices that produce wind as a viable economic good. By translating natural variability into stable, calculable, and monetizable figures, these projects embody the central logic of contemporary renewable energy development: the fusion of environmental knowledge with financial rationality. The transition from moving air to grid-connected electricity is therefore as much a product of data and calculation as it is of blades and generators.

Policy Shift and Institutional Reconfiguration

Prior to the 2000s, renewable energy development in Thailand progressed slowly. Although a 1997 Cabinet resolution approved electricity purchases from small power producers (SPPs) using non-conventional energy sources (plants with capacities of 10-90 MW), few private companies initially participated. Renewable energy investment gained momentum in the mid-2000s following a 2006 directive issued by the National Energy Policy Council (NEPC), requiring the Electricity Generating Authority of Thailand (EGAT) to formalize renewable electricity purchasing regulations. In 2007, EGAT announced a renewable energy procurement target of 530 MW, including 115 MW from wind power projects. As the transmission system operator and sole electricity purchaser, EGAT invited project proposals but initially

received only a limited number of submissions, partly due to high turbine costs, capital-intensive investment requirements, and limited access to bank financing. Additional constraints stemmed from inadequate grid infrastructure, particularly the shortage of high-voltage substations. Consequently, the earliest renewable energy projects were largely developed by companies with close connections to EGAT executives, whose personal networks facilitated access to grid connections and project approvals.

The deployment of renewable energy projects, including wind power technologies, expanded substantially during the mid-2010s following Thailand's policy shift toward renewable energy promotion. The Alternative Energy Development Plan (AEDP) 2015 established a target of increasing the share of renewable energy to 30 percent of final energy consumption by 2036. With respect to electricity generation, the AEDP set a target for renewable energy to account for 20 percent of national electricity demand, projected at 326,116 GWh in 2036 (EPPO and DEDE 2015). During the second half of the 2010s, Thailand witnessed a rapid increase in renewable energy projects across the country. In the wind energy sector, seventeen additional projects successfully passed the state selection process. Construction of these small- and medium-scale projects was subsequently completed, and they commenced commercial electricity generation.

The implementation of AEDP 2015 was deeply embedded in at least three forms of institutional reconfiguration. Renewable energy markets were consequently constituted through substantial changes in the rules, regulations, and actors involved in Thailand's national power system. First, the Thai government initiated a foundational transformation in the structure of electricity generation. It gradually loosened the state's monopoly over electricity production, previously justified under the rationale of national energy security, by granting licenses to private firms to generate electricity and sell it to the national grid. This model, commonly referred to as a public-private partnership (PPP), significantly altered governance arrangements and exchange relations within the energy sector. Although PPP arrangements had previously been applied to fossil-fuel power plants since the 1990s, similar institutional mechanisms were later extended to promote private-sector participation in renewable energy development during the 2010s. As new market actors, private energy companies became state partners through bilateral power purchase agreements (PPAs). Wind energy projects in Thailand therefore emerged within a changing institutional landscape governing electricity production and investment.

Second, the Thai government introduced feed-in tariffs (FiTs), a price-support mechanism designed to accelerate renewable energy deployment. Although the costs of renewable energy technologies declined over time, these projects continued to require substantial upfront investment. Governments worldwide therefore adopted attractive electricity purchasing schemes to offset high production costs and incentivize private-sector investment. These measures included guaranteed grid access throughout the contractual period, long-term power purchase agreements, and fixed electricity purchase rates over the duration of the contracts. In Thailand, the FiT mechanism proved highly effective in attracting private energy firms to invest in renewable energy projects, including the wind energy developments examined in this study.

Finally, the government introduced additional financial incentives to encourage electricity generation from alternative energy sources. One particularly lucrative mechanism was the "add-on cost" incentive, which provided an additional payment per unit of electricity generated above the base purchase price. For example, wind energy projects received an additional 3.50 baht (approximately USD 0.12) per kWh for a period of ten years following commercial operation. The add-on scheme was discontinued for new projects after 2015 (Osborne, 2012; Department of Alternative Energy Development and Efficiency,

n.d.). In addition, wind energy companies utilized privileges granted by the Board of Investment (BOI) to reduce development costs. Key benefits included exemptions from import duties on machinery and equipment—often amounting to up to 30 percent of project costs—as well as corporate income tax holidays lasting up to eight years.

Wind energy projects in Thailand have therefore emerged within a shifting political and institutional landscape governing electricity production. The Thai government has played a central role in strengthening the renewable energy sector through regulatory restructuring, market liberalization, and the provision of diverse financial incentives. These policy interventions not only encouraged private-sector participation but also reconfigured the institutional relationships between the state, energy firms, and infrastructure networks. In this sense, the development of wind energy in Thailand illustrates how state-led institutional transformation can actively construct markets for decarbonizing energy technologies, thereby advancing pathways toward energy sustainability (Johnstone and Newell, 2018).

Capital Intensity and Institutional Incentives

High capital expenditure constituted a major barrier to the expansion of wind energy projects in Thailand during the 2010s. The development of wind energy requires substantial financial investment, as project developers must purchase and import turbine equipment and technical expertise from abroad, followed by the construction and installation of the entire system prior to the commencement of electricity generation. For instance, Wind Energy Holding's (WEH) first two wind projects, constructed between 2011 and 2013, required a total investment of approximately US\$ 421 million. According to one company engineer, the average price of a wind turbine during that period was approximately US\$ 3.87 million.

The introduction of feed-in tariffs (FiTs) and other financial support mechanisms proved highly significant in facilitating the growth of Thailand's renewable energy industry. These lucrative contractual arrangements convinced private companies that investment in renewable energy was both commercially feasible and financially worthwhile. In particular, the fixed electricity purchase rates offered through the FiT scheme during the early 2010s were perceived as highly attractive by private investors. The adder cost mechanism further strengthened expectations regarding the profitability of project development. All project owners applied for these incentives and support measures, which substantially improved project feasibility and financial management capacity. These schemes, therefore, played a crucial role in attracting private-sector investment into commercial wind energy projects. A bond solicitation document issued by Wind Energy Holding Public Company Limited stated that "the company has significant revenue from the adder cost." This incentive enabled project owners to sell electricity at substantially higher unit prices. As one executive from a wind energy company explained:

The adder increased our selling price from 4.35 baht (14.5 cents) per unit to 7.85 baht (26.2 cents) during peak hours (9:00 AM-10:00 PM), and from 2.48 baht (8.2 cents) to 5.98 baht (19.9 cents) during off-peak hours (10:00 PM-9:00 AM). The wind speed in this area is modest, with a capacity factor of only 25 percent; some superior locations achieve 28-30 percent. The actual electricity production does not fully match our installed capacity, so the adder is essential for maintaining financial sustainability (Executive [Pseudonym], 2024).

This testimony demonstrates that the adder functioned as a crucial institutional mechanism for fostering private investment by enhancing the commercial viability of wind energy projects despite their high upfront costs. Revenues generated through the adder scheme also facilitated debt repayment, with some projects able to repay loans before the end of the 10-year support period. For example, a company representative from Wind Energy Holding Public Company Limited noted,

Our first two wind projects, totaling 180 megawatts (90 turbines), began operation in 2012 and 2013. The fixed-electricity purchase rate and the 10-year adder (until 2022 and 2023) enabled us to fully repay our loans within six years. Currently, our primary expenses relate to only operation and maintenance (Company Representative [Pseudonym], 2024).

Class 3 Turbine Technologies

All wind energy projects in the study area are privately owned. These companies independently assess local wind potential, plan and design the projects, procure and import equipment, oversee construction, and manage electricity generation. The wind turbines in the Korat Highlands come from four major manufacturers: Siemens Gamesa Renewable Energy (SGRN), a Spanish–German joint venture; General Electric (United States); Vestas (Denmark); and Goldwind (China). Each manufacturer supplies multiple turbine models, meaning a single company operating several projects may employ different turbine types.

Despite the region's low and inconsistent wind speeds, wind energy development in the Korat Highlands has been enabled by the technical capabilities of modern turbine designs. All turbines installed are engineered for electricity generation in low-wind areas—defined as those with average wind speeds below 7.5 m/s—and are classified by the International Electrotechnical Commission (IEC) as Class 3 turbines. The IEC categorizes turbines according to the average wind speed for which they are designed: Class 1 for 8.5–10 m/s, Class 2 for 7.5–8.5 m/s, and Class 3—introduced in the early 2010s—for speeds under 7.5 m/s. Before 2000, most turbines installed worldwide were Class 1 or Class 2.

Class 3 turbines outperform earlier designs in low-wind contexts. They incorporate taller towers, larger foundations, longer blades, and bigger nacelles, enabling them to capture more kinetic energy and withstand high-altitude wind conditions. Whereas Class 1 towers ranged from 45 to 80 m in height, Class 3 towers reach 100–160 m. Their blade diameter, which determines the swept area, has increased from 45–60 m for Class 1 turbines to 90–140 m for Class 3 turbines—more than doubling the collection area for wind energy.

Taller towers reduce turbulence caused by ground-level obstacles, while longer blades intercept greater wind volumes. These design features allow Class 3 turbines to begin generating electricity at wind speeds as low as three to four m/s, well below the operating threshold of older models. Their full power capacity is also substantially greater: in the 1980s, a typical Class 1 turbine produced about 100 kW, whereas a modern Class 3 turbine with a 138 m rotor can reach an installed capacity of 4 MW (4,000 kW). These advancements enable viable projects in areas previously deemed unsuitable due to low wind potential.

These technological advancements are often associated with broader societal expectations that innovation can significantly contribute to social transformation, particularly through the transition toward sustainable energy systems. However, this article argues that the expansion of wind turbine scale and generating capacity should not be understood merely as a linear process of technological progress.

Rather, it is necessary to examine how these technological developments are embedded within material relations involving land, infrastructure, state policies, financial investment, and local communities. By tracing the socio-material conditions that enable wind energy development in the Korat Highlands, this study further questions whether the expansion of renewable energy infrastructures necessarily produces the forms of social and environmental transformation commonly anticipated in dominant energy transition discourses.

Material Interdependence

Wind turbine technology is widely perceived as a clean energy solution with minimal environmental impact. However, despite its “green” label, its production and deployment remain materially complex, relying on diverse components, techniques, and resources—many of which are rooted in the extractive industries and fossil fuel that renewable energy seeks to replace. Each turbine embodies an intricate assemblage of materials and energy inputs. As the expansion of wind energy drives demand for more turbines, it becomes essential to examine the material conditions shaping these projects and the transformations they produce. This section considers the principal components of a wind turbine—rotor blades, tower, nacelle, and foundational infrastructure—together with the logistical and material demands of project construction.

Although the scale of turbine blades is difficult to grasp in situ, their size becomes striking when laid out for repair or replacement. At one blade yard visit, the longest blade measured 68.5 meters—roughly the length of five articulated trucks placed end to end. Each turbine has three blades attached to a central hub. The blade set converts wind power into mechanical energy, with a pitch system adjusting blade angles to optimize wind capture. Aerodynamically shaped, with a rounded leading edge similar to an airplane wing, the blades are designed to be lightweight yet strong enough to withstand substantial wind forces. Their form reflects technological advancements derived from aviation engineering.

Early blade production used balsa wood—sourced primarily from Ecuador—as a core, sheathed in fiberglass for reinforcement. Each large blade weighed 15-18 tons. However, growing demand for balsa spurred deforestation, monopolistic trading practices, and conflicts in logging areas (The Economist, 2021). Wood scarcity drove blade manufacturers to adopt composite carbon-fiber and polyester materials, achieving comparable performance. Wind energy technicians also point that petrochemical-based coatings are also applied to prevent blades’ surface corrosion. Modern blade materialities underscore how the sector depends upon fossil fuel-derived substances.

The tower, supporting both blades and nacelle, is a hollow steel cylinder weighing 150-250 tons, typically equipped with a spiral staircase and lift for maintenance. Manufacturers in China produce these towers in segmented sections, which are shipped to deep-sea ports in Thailand and subsequently transported inland by specialized trucks. Recently, some projects in the Korat Highlands have utilized locally-produced pre-cast concrete for the lower tower sections. A factory producing pre-cast concrete sections is located in the study area. These components are utilized for the lower sections of the turbine towers, while imported steel pipes are employed for the upper segments. This hybrid construction method contributes to reducing overall project costs.

Beneath the tower rests a massive reinforced concrete foundation, pendulum-shaped and measuring approximately 5-6 meters in depth and 18-24 meters in width, with an estimated weight of

300-500 tons. The base is constructed from reinforced steel bars and high-strength cement. The foundation pour requires precise coordination, as large volumes of ready-mixed concrete must be placed continuously over a period of 8-14 hours to maintain structural integrity and avoid cold joints. On average, 400-700 cubic meters of concrete are required, with the exact volume varying according to the foundation's dimensions and the specific turbine model. This process necessitates the presence of a nearby batching plant and the mobilization of dozens of concrete trucks, which often operate through extended shifts, including nighttime hours.

The nacelle, situated behind the blades, houses the turbine's mechanical systems, including a lubrication system akin to that of a car engine. Its core component is the generator, which converts mechanical rotation into electrical energy. Many generators rely on powerful permanent magnets produced from heavy rare earth elements (HREEs), such as neodymium, dysprosium, and terbium. HREEs play a critical role in enhancing industrial processes and have been described as the spice of industry, signifying their indispensability for the green energy transition. Dysprosium is essential for manufacturing permanent magnets capable of maintaining the constant magnetic fields required in wind turbine generators and electric vehicles. A significant portion of these HREEs is sourced from northern Myanmar. However, increasing evidence indicates that mining for dysprosium and terbium in the region has resulted in severe consequences, including loss of life, environmental degradation, and governance challenges (Global Witness, 2024).

The construction phase of wind energy projects transforms the surrounding landscape into a hub of industrial activity. Wind project construction entails substantial civil works, including new roads and transmission systems. Turbines are often sited in dispersed locations, sometimes within agricultural land distant from existing infrastructure. Access roads, built to stringent specifications, must support the heavy loads of cranes, hydraulic lifts, and transport trucks. In many projects, electrical cables are buried beneath these roads, connecting turbines to substations.

The development of wind energy projects thus reveals the deep material interdependencies between “clean” energy infrastructure and conventional industrial elements. The construction of wind turbine towers and foundations requires substantial quantities of steel and cement, both of which are highly energy-intensive materials. Steel production entails processes such as sheet stamping and component assembly, while cement manufacturing involves the operation of high-temperature kilns for clinker production. These kilns typically rely on fossil fuels, particularly coal and petroleum coke. The increasing demand for cement and steel would then generate more greenhouse gas emissions. The transportation, installation, and ongoing maintenance of turbines are further dependent on heavy machinery powered predominantly by diesel fuel. In addition, the manufacture of turbine blades involves the use of composite materials and protective coatings derived from petrochemicals.

These material linkages exemplify what historian Jean-Baptiste Fressoz (2024) describes as a “symbiotic relationship” between new and existing energy systems. Rather than representing an absolute break from fossil fuels, wind power projects often accumulate atop existing infrastructures, drawing upon and reinforcing them. The continued reliance on primary materials, such as wood, stone, minerals, cement, and fossil fuels, challenges the narrative of a straightforward energy transition.

Indeed, wind turbines have advanced not through independence from these resources, but through their integration. Far from displacing conventional fuels, renewable energy technologies may, in practice, intensify their use—by creating additional demand for materials and industrial processes tied to fossil

energy. The expansion of wind energy thus contributes to the cumulative growth of energy consumption, in which different energy sources are intertwined as much as they compete.

What emerges is not an “epic struggle” between renewable and fossil energy systems, but rather a mutually reinforcing relationship. Fossil fuels remain integral to the construction, deployment, and maintenance of wind energy infrastructure. Rather than representing a straightforward substitution of fossil fuels, these projects underscore trajectories of energy interdependence and the complex interlinkages shaping the region’s energy transitions. This reality complicates prevailing aspirations for a complete energy transition and indicates that future pathways will require navigating—and perhaps rethinking—these persistent material entanglements.

Conclusion

This study demonstrates that wind energy development in Thailand exemplifies the complex socio-technical dynamics which characterize contemporary energy transitions globally. Rather than representing the straightforward adoption of technologies, wind power materializes through the entangled interactions of technological innovation, institutional arrangements, and intricately interconnected material infrastructures. Institutional reconfigurations in state—private sector relations represent a pivotal dimension of wind energy development in Thailand. By revealing how wind is rendered economically viable through measurement, calculative practices, and supportive policies, this research highlights the processes by which renewable energy is produced as a socio-technical and financial assemblage.

The material realities of turbine manufacturing and installation challenge dominant narratives of a clean break from fossil fuels, illustrating instead a symbiotic relationship that intensifies cumulative energy demand. The production of wind turbines is highly dependent on fossil fuels and a range of materials, including wood, steel, stone, minerals, machinery, oil, coal, and petrochemical derivatives. This interdependence transcends the conventional dichotomy between fossil fuels and renewable energy. Electricity generation from wind turbines remains intrinsically linked to these industrial resources and petrochemical composites, which continue to serve essential functions in renewable energy projects. Consequently, the expansion of renewable energy infrastructure, rather than supplanting fossil fuels as is often presumed, in practice, may contribute to an increased demand for conventional energy sources (Fresso, 2024).

The findings on sociotechnical assemblages and symbiotic energy dynamics problematize simplistic representations of turbines as inherently transformative technologies and challenge linear models of transition. They point instead to the need for more nuanced understandings of how renewable technologies are embedded within socio-economic landscapes and interdependent with established industrial systems. By situating Thailand’s Korat Highlands within broader global energy debates, this article contributes to social science scholarship on energy transitions by illustrating the interconnected roles of knowledge, politics, and materiality in shaping renewable energy pathways. It underscores the importance of rethinking assumptions of substitution and demonstrates the analytical value of socio-technical perspectives for capturing the relational dynamics that characterize energy transitions across diverse geopolitical contexts.

Acknowledgements

This research was supported by a research grant from the Faculty of Sociology and Anthropology, Thammasat University SOCANTH 02/2566

References

- Abram, S., Winthereik, B. R., and Yarrow, T. (2019). Current thinking—An introduction. In S. Abram, B. R. Winthereik, and T. Yarrow (Eds.), **Electrifying anthropology: Exploring electrical practices and infrastructures** (pp. 3-23). London: Bloomsbury Publishing.
- Asdal, K. (2018). Enacting things through numbers: Taking nature into accounting. *Geoforum*, **39**(1), 123-132.
- Boyer, D. (2014). Energopower: An introduction. *Anthropological Quarterly*, **87**(2), 309-333. <https://doi.org/10.1353/anq.2014.0020>
- Bridge, G. (2018). The map is not the territory: A sympathetic critique of energy research's spatial turn. *Energy Research & Social Science*, **36**(11-20).
- Bridge, G., Bouzarovski, S., Bradshaw, M., and Eyre, N. (2013). Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy*, **53**, 331-340.
- Bromley, P. S. (2016). Extraordinary interventions: Toward a framework for rapid transition and deep emission reductions in the energy space. *Energy Research & Social Science*, **22**, 165-171.
- Çalışkan, K. and Callon, M. (2009). Economization, part 1: Shifting attention from the economy towards processes of economization. *Economy and Society*, **38**(3), 369-398.
- Callon, M. and Muniesa, F. (2005). Economic markets as calculative collective devices. *Organization Studies*, **26**(8), 1229-1250.
- Coleman, L. (2017). **A moral technology: Electrification as political ritual in New Delhi**. Ithaca: Cornell University Press.
- Department of Alternative Energy Development and Efficiency Ministry of Energy of Thailand. (n.d.). **Manual for the development and investment in renewable energy, Volume 1: Electricity from wind power**.
- EPPO (Energy Policy and Planning Office) and DEDE (Department of Alternative Energy Development and Energy Efficiency). (2015). **Thailand's main energy regulatory framework: Thailand integrated energy blueprint**.
- Frantal, B., Pasqualetti, M. J., and Van der Horst, D. (2014). New trends and challenges for energy geographies: Introduction to the special issue. *Moravian Geographical Reports*, **22**, 2-6.
- Fresso, J. B. (2024). **More and more and more: An all-consuming history of energy**. Penguin Books.
- Global Witness. (2024). **Fueling the future, poisoning the present: Myanmar's rare earth boom**. Retrieved from <https://globalwitness.org/en/campaigns/transition-minerals/fuelling-the-future-poisoning-the-present-myanmars-rare-earth-boom/>
- Grubler, A. (1996). Time for a change: On the patterns of diffusion of innovation. *Daedalus*, **125**(3), 19-42.
- Grubler, A., Wilson, C., and Nemet, G. (2016). Apples, oranges, and consistent comparisons of the temporal dynamics of energy transitions. *Energy Research & Social Science*, **22**, 18-25.
- Günel, G. (2022). Accumulation: Exploring the materiality of energy infrastructure. In M. H. Bruun, A. Wahlberg, R. Douglas-Jones, C. Hasse, K. Hoeyer, D. B. Kristensen, and B. R. Winthereik (Eds.), **The Palgrave handbook of the anthropology of technology** (pp. 689-702). Singapore: Palgrave Macmillan.
- Johnstone, P. and Newell, P. (2018). Sustainability transitions and the state. *Environmental Innovation and Societal Transitions*, **27**, 72-82.
- Kern F. and Rogge K. S. (2016). The pace of governed energy transitions: Agency, international dynamics and the global Paris agreement accelerating decarbonisation processes? *Energy Research and Social Science* **22**, 13-17.
- Latour, B. (2010). **On the modern cult of the factish gods**. Duke University Press.
- Lawhon, M. and Murphy, J. T. (2011). Socio-technical regimes and sustainability transitions: Insights from political ecology. *Progress in Human Geography*, **36**(3), 354-378.

- Leach, M., Scoones, I., and Stirling, A. (2010). **Dynamic sustainabilities: Technology, environment, and social justice**. Abingdon: Earthscan.
- Matichon Daily. (2013, February 13). **Yingluck opens Korat wind power plant**. Matichon Daily.
- Middleton, C. and Ketelsen, T. (2022). **Pathways to a sustainable and just transformation of the Mekong Region's electricity sector**. Bangkok and Perth: Center for Social Development Studies, Faculty of Political Science, Chulalongkorn University and the Australia-Mekong Partnership for Environmental Resources and Energy System.
- Mitchell, T. (2011). **Carbon Democracy: Political power in the age of oil**. London: Verso.
- Nader, L. (1981). Barriers to thinking new about energy. **Physics Today**, 34(2), 99-104.
- Osborne, C. (2012). Thailand's renewable energy adder rates. **Asian Power**. <https://asian-power.com/power-utility/commentary/thailand%25E2%2580%2599s-renewable-energy-adder-rates>.
- Richardson, T. and Weszkalnys, G. (2014). Introduction: Resource materialities. **Anthropological Quarterly**, 87(1), 5-30.
- Sovacool B. K. and Geels F. W. (2016). Further reflections on the temporality of energy transitions: A response to critics. **Energy Research & Social Science** 22, 232-237.
- Sullivan, S. (2018). Making nature investable: From legibility to leverageability in fabricating 'nature' as 'natural capital.' **Science & Technology Studies**, 31(3), 47-76.
- The Economist. (2021). **The wind-power boom set off a scramble for balsa wood in Ecuador**. <https://www.economist.com/the-americas/2021/01/30/the-wind-power-boom-set-off-a-scramble-for-balsa-wood-in-ecuador>.
- Van den Akker, J. (2018). **Theppana Wind Power Project, Thailand: Pioneering private sector utility-scale wind power**. Retrieved from https://www.cif.org/sites/cif_enc/files/knowledge-documents/thailand_2_pages_dtp1.pdf

Interviews

- Executive (Pseudonym). (2004, February). **Interview**. Wind Energy Company's executive who provided insights on wind energy pricing structures and project financial feasibility. Nakhon Ratchasima.
- Company Representative (Pseudonym). (2024, May). **Interview**. Wind Energy Holding Public Company Limited's representative who provided data on project financial returns and debt repayment. Nakhon Ratchasima.