

Addressing Global Energy Transition Challenges with Modular TSTM Solutions

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Abstract

The global energy transition faces severe bottlenecks due to inadequate grid infrastructure and limited seasonal storage capacity, leading to massive curtailments of renewable energy. In China, 6.2% of wind and 6.1% of solar energy were curtailed in 2025 – equivalent to around 1,210 TWh (Bloomberg, 2025). In Europe, 50–100 TWh are curtailed annually, while 1,700 GW of clean energy are still awaiting grid connection approval (EuroNews, 2025). Redispatch measures in just seven EU countries resulted in €7.2 billion in losses in 2024 alone. In the US, more than 2,600 GW of renewable energy projects – representing over 6,800 TWh/year – remain stalled in interconnection queues (LBNL, 2025).

This paper proposes a dual-solution architecture using the Tubular Storage Tank Module (TSTM): (1) TSTM for land-based seasonal storage to capture curtailed renewables, and (2) TSTM for maritime gas logistics to enable flexible, geopolitically independent transport. TSTM achieve a full-cycle efficiency of 55–58%, cost <10 €/kWh, and a 40+ year lifespan, while TSTM avoids energy-intensive liquefaction, leverages existing ship fleets, and supports multigas transport (CH₄, Bio-CNG, H₂, ammonia). These modular systems address systemic inefficiencies, enhance grid stability, and unlock renewable energy potential, aligning with global decarbonization goals. We call for pilot projects in high-curtailment zones to validate this approach.

1. Introduction

The global shift to renewable energy, driven by climate targets, is increasingly constrained by systemic bottlenecks in grid infrastructure and seasonal storage capacity. Wind and solar power, though abundant, are intermittent and seasonally variable, resulting in large-scale curtailment—clean energy that goes unused due to inadequate grid integration or storage options.

This paper highlights these challenges across China, the USA, and Europe, where more than **12,500 TWh** of renewable energy potential remains curtailed or delayed annually. In response, we propose a

modular solution based on the **Tubular Storage Tank Module (TSTM)** system—offering both land-based seasonal storage and maritime gas logistics. These innovations, detailed in patent filings from **27 May 2025** and **2 June 2025**, present scalable, cost-efficient, and geopolitically resilient pathways to accelerate the energy transition.

Building on a prior AI-supported meta-evaluation of the TSTM concept for European deployment (Dzikowski, 2025), this paper extends the architecture to global and offshore applications.

2. Global Challenges in the Energy Transition

The global energy transition is increasingly constrained by a 'generation-first, storage-last' approach, resulting not only in energy losses, grid instability, and blocked renewable projects, but also in

deeper systemic challenges. Supply chain disruptions and persistently rising, supply-constrained material costs — linked to the structural increase in energy prices — are slowing the deployment of critical infrastructure. Public resistance is growing against the unchecked expansion of wind and solar installations, particularly in densely populated regions. Meanwhile, soaring electricity prices in Europa — exceeding **€1,000/MWh** during recent winter peaks — expose the vulnerabilities of a renewables-dominant system without sufficient storage capacity. Recent blackouts in Portugal and Spain further underscore the reliability risks of such unbalanced grids. These factors collectively highlight the urgent need for scalable, modular storage solutions to stabilize grids, secure supply chains, and maintain public trust in the energy transition.

Another fundamental weakness of the current energy transition strategy is becoming increasingly evident: the massive yet uncoordinated expansion of variable renewables is progressing in parallel with the phase-out of stable, dispatchable generation capacity. This structural imbalance reveals a critical physical contradiction: solar energy peaks during daylight hours, when demand is moderate, but delivers no output during evening and nighttime hours — precisely when demand often surges.

This intrinsic mismatch between generation and consumption underscores a key reality: cost-effective, large-scale energy storage is not optional — it is essential for the viability of the energy transition.

TransnetBW (2024) has already highlighted this issue. Energy Secretary Chris Wright echoed these concerns before the House Energy and Commerce Committee on June 10, 2025, noting that at 4:00 a.m., solar contributed 0% and wind only 2% to total power supply (Forbes Breaking News, 2025).

As Vaclav Smil (2024) extensively documents, energy transitions are inherently slow and complex, governed by physical, technical, economic, and material constraints. Without corresponding storage capacity, achieving large-scale, on-demand renewable supply remains highly improbable within the politically prescribed timeframes. Grid expansions alone cannot compensate for the systemic gap between variable generation and real-time demand.

2.1 China: Hidden Curtailment Crisis

China, despite being a global leader in renewable energy deployment, faces persistent curtailment challenges. In 2025, 6.2% of wind and 6.1% of solar generation were curtailed, equivalent to approximately 1,210 TWh of lost renewable energy — nearly 12% of national electricity production. While massive investments in ultra-high-voltage (UHV) transmission infrastructure are underway, they cannot resolve the fundamental limitation: electricity must be consumed at the same time it is

generated. Without sufficient storage, structural mismatches between generation and demand remain inevitable. A striking example is Gansu Province, where wind curtailment has exceeded 50% since 2016 due to lack of local demand and limited grid flexibility. This underscores the critical need for large-scale, cost-effective storage solutions to fully utilize China's renewable energy potential. (Bloomberg, BJX, NEA, 2025).

2.2 USA: Interconnection Queue Paralysis

In the USA, 2,600 GW of renewable projects — potentially generating over 6,823 TWh/year — are stuck in interconnection queues due to grid constraints. The lack of a national seasonal storage strategy and slow grid buildout (lagging by decades) continues to hinder progress (LBNL, PJM, 2025). Moreover, the aging and fragmented grid infrastructure is increasingly unable to maintain stable operation under growing renewable penetration. Recent large-scale blackouts in states like California and Texas highlight the systemic risks: grid congestion, limited flexibility, and lack of sufficient storage have led to widespread outages during peak demand periods and extreme weather events. Without scalable, modular storage solutions, these vulnerabilities will only intensify as renewable deployment accelerates.

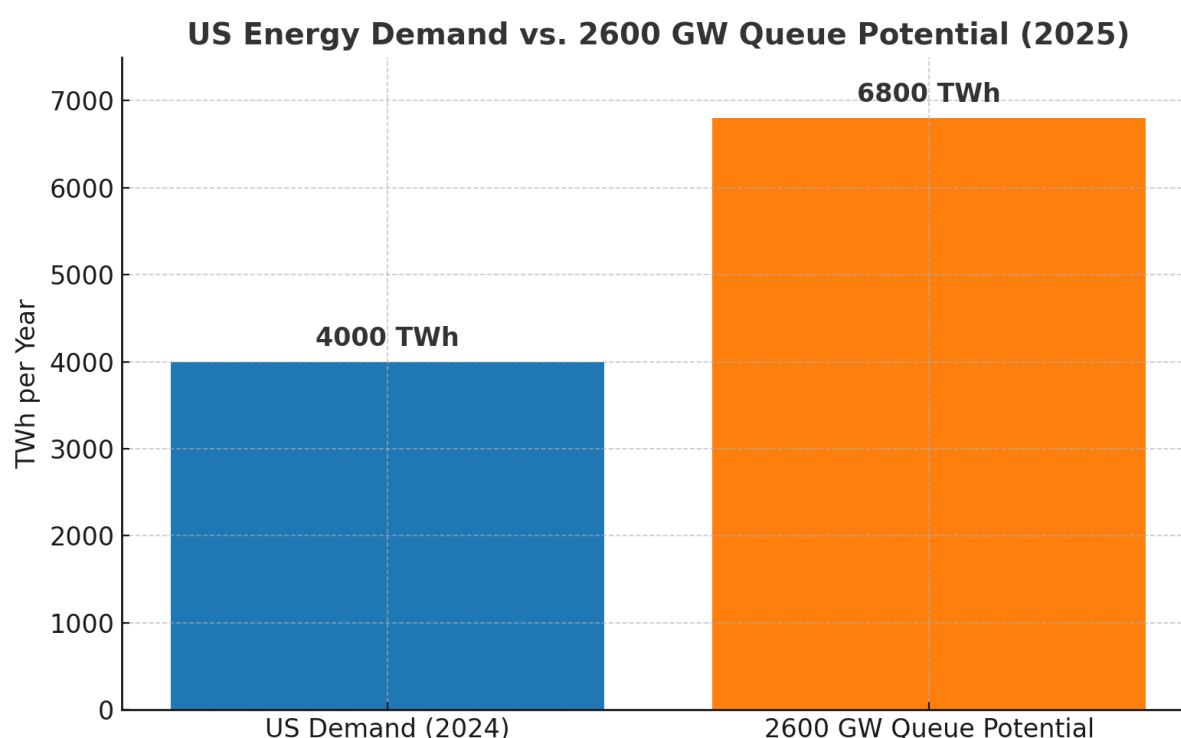


Fig.1 Conceptual illustration of the systemic mismatch between current US electricity demand and the renewable generation potential blocked in interconnection queues due to grid and storage bottlenecks.

2.3 Europe: The Winter Paradox

Europe faces a “winter paradox,” where renewable generation drops significantly during the winter months, precisely when energy demand peaks. This seasonal imbalance highlights the structural vulnerability of a system dominated by variable renewables without sufficient storage.

Curtailment losses remain substantial: **50–100 TWh** are curtailed annually across the EU, with **Germany alone losing over 20 TWh**, including more than **24% of its offshore wind production**

(Fraunhofer, Agora, 2023). This situation is expected to worsen as offshore wind capacity rapidly expands, especially in the North Sea and Baltic regions, without parallel development of seasonal storage infrastructure.

In addition to curtailment, **redispatch interventions**—necessary to stabilize the grid amid transmission bottlenecks—have become increasingly costly. In **2024**, redispatch costs in just **seven EU countries** amounted to **€7.2 billion** (EuroNews, 2025). Simultaneously, more than **1,700 GW** of clean energy projects remain queued for grid connection approval, reflecting a massive backlog that further slows down the decarbonization process.

Together, these factors expose the limits of current expansion strategies and underscore the urgent need for **large-scale, cost-effective seasonal storage** to bridge the temporal gap between summer generation surpluses and winter demand peaks.

In Northern Europe, the seasonal imbalance is particularly severe. From October to February, solar generation is minimal, with daylight hours often limited to 8 hours or less. Extended "dark periods" of up to 16 hours are common, and during these months, wind output frequently drops as well, leading to prolonged low-generation periods. Moreover, even during daytime hours, the actual output of solar installations is far below nominal capacity: due to low sun angles and persistent cloud cover, effective generation typically ranges between 5% and 30% of installed capacity. These seasonal patterns create persistent gaps between renewable supply and demand, underscoring the need for reliable, large-scale storage to maintain grid stability.

3. Proposed Solutions: The TSTM Architecture

While CH₄ (methane) is often politically framed as a "fossil" fuel, it remains — from a purely physical and systems-engineering perspective — the only viable large-scale energy carrier for seasonal storage at present. Unlike highly energy-intensive pathways such as power-to-gas (P2G) or green hydrogen (H₂), CH₄ is abundantly available as a mature energy carrier and requires no energy-expensive synthesis processes. This fact alone positions methane as the only immediately scalable option for enabling an efficient and durable energy system during and beyond the transition phase. Without such pragmatic solutions, the energy transition risks systemic collapse — as Vaclav Smil (2024) warns, "ignoring physical realities in favor of political wishful thinking will ultimately derail progress." The TSTM architecture is deliberately designed to leverage this pragmatic path: it utilizes existing CH₄ streams while remaining compatible with future renewable methane (bio-CNG, synthetic CH₄) where available.

3.1 TSTM: Stationary Seasonal Storage for Grids

TSTM (Tubular Storage Tank Modules) are modular, land- and sea-based high-pressure storage systems designed to capture excess renewable energy and make it seasonally available. Unlike centralized storage concepts, TSTM can be strategically deployed at grid-critical locations—exactly where the risks of transmission bottlenecks and restrictions are highest. By absorbing energy that would otherwise be lost due to local grid overloads, TSTM help stabilize the grid and enable a higher share of renewable energies without the need for massive new transmission infrastructure.

Key features include:

- **Modular Design:** Stackable, land-based units co-located with generation (e.g., wind farms) or demand centers (e.g., industrial clusters).
- **Flexible Siting:** Suitable for brownfields, old power plant sites, or ports.

- **Technical Specs:** Full-cycle efficiency of 55–58%, storage loss <0.1%/month, CAPEX <10 €/kWh, lifespan >40 years.
- **Multigas Compatibility:** Supports CH₄, Bio-CNG, synthetic methane (SNG), H₂ blends, and ammonia.
- **Impact:** Reduces curtailment by recovering 55–58% of wasted energy, stabilizes grids, and supports sector coupling (electricity, heat, transport), and supports sector coupling (electricity, heat, transport) **while reducing dependency on costly grid reinforcements.**

The methane used in TSTM systems is sourced from existing gas flows already present in the European and global energy system. During spring and summer months — when gas networks are typically underutilized — surplus renewable electricity powers compressors that extract and store methane at high pressure in the TSTM infrastructure. Alternatively, methane can be supplied via mobile gas tankers, further enhancing flexibility and location independence. This approach leverages current infrastructure without requiring new fossil gas exploration, while remaining fully compatible with renewable methane sources such as biomethane or synthetic methane in the future.

3.2 TSTM-M: Maritime Modular Gas Logistics Layer

TSTM-M extends the TSTM concept to maritime transport, offering a "floating gas battery" for flexible, geopolitically independent gas logistics. In stationary grid applications, TSTM modules primarily capture surplus renewable electricity for seasonal storage. In maritime applications (TSTM-M), the modules are additionally filled with methane as an energy vector, leveraging both surplus renewable power and existing methane supply for flexible energy transport and distribution. Where available, offshore wind power can be used locally to drive compression processes, further increasing system efficiency and renewable integration.



Fig. 2 Conceptual illustration of a maritime TSTM-M "floating gas battery," integrating offshore wind power with flexible energy storage and transport.

Enabling Enhanced Gas Extraction

Beyond its role as a flexible storage and transport solution, TSTM-M also enables significant improvements in gas field utilization. By providing mobile, modular storage capacity, TSTM-M can decouple extraction rates from fixed pipeline capacities. Multiple injection and withdrawal nodes along existing pipelines, or entirely pipeless gas extraction at previously undeveloped fields, become technically and economically feasible. This novel capability — detailed in the patent application filed on 02 June 2025 — offers a pathway to increase gas production rates, reduce flaring, and unlock stranded reserves, while simultaneously supporting energy transition goals through flexible infrastructure.

Key features include:

- **Avoids Liquefaction:** Eliminates the need for LNG, avoiding 85–90% energy losses from liquefaction and regasification.
- **Existing Infrastructure:** Uses existing ship fleets (e.g., MPP, RoRo, container ships) with minimal retrofitting.
- **Multigas Support:** Compatible with CH₄, Bio-CNG, SNG, H₂, and ammonia.
- **Logistics Chain:** Subsea Access Nodes → Floating Production Units → Ship-to-Ship Transfer (STST) → Floating Storage → Port/Rail Delivery.
- **Use Cases:**
 - North Sea (e.g., Troll A, Baltic Pipe): Flexible gas export.
 - Gulf of Mexico: Offshore wind-to-gas integration.
 - Middle East: Reduces LNG dependency.
 - ASEAN: Floating import capacity for islands.
 - Africa: Offshore monetization without LNG mega-projects.
- **Impact:** Enables market arbitrage, enhances resilience against geopolitical risks, and decouples gas transport from fixed pipelines.

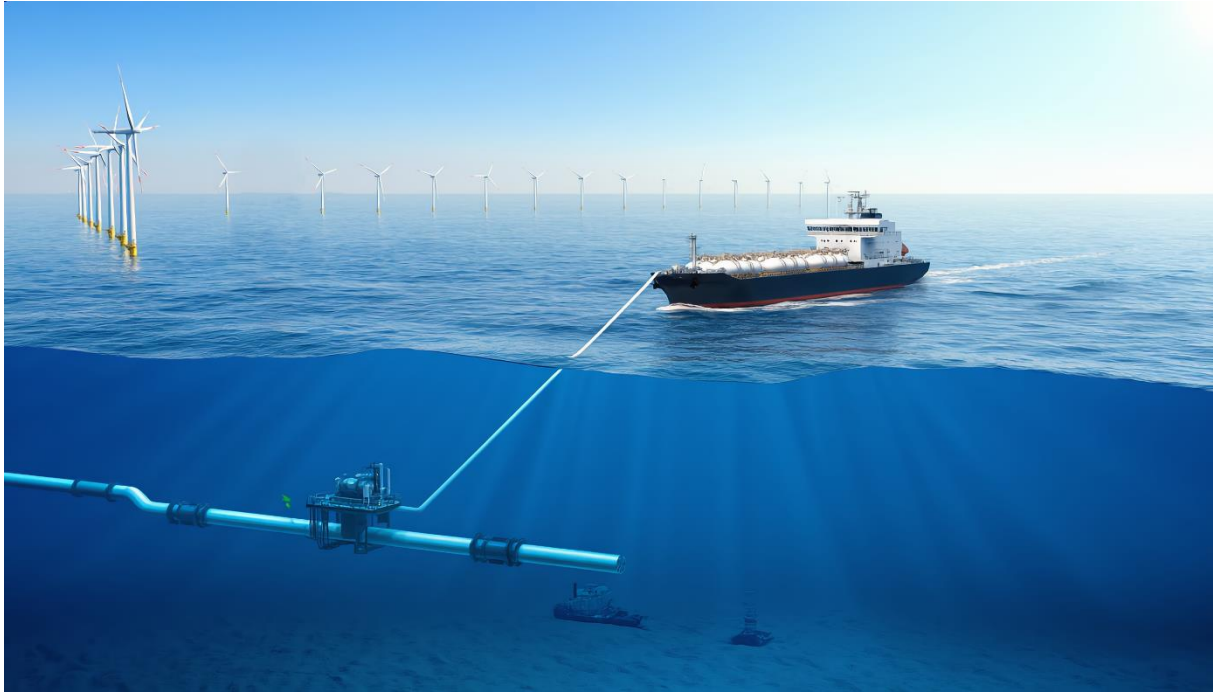


Fig. 3 Conceptual illustration of a flexible subsea-to-ship TSTM-M logistics chain. Subsea access nodes enable direct coupling of offshore gas extraction with floating storage and maritime transport, bypassing fixed pipeline constraints and integrating offshore wind power into the energy chain.

4. Technical and Economic Benefits

The TSTM architecture offers significant advantages over conventional solutions like LNG, hydrogen, and lithium-ion batteries:

- **Efficiency:** TSTM systems achieve 55–58% full-cycle efficiency, compared to 25–30% for Power-to-H₂ and 35–40% for LNG.
- **Cost:** CAPEX of <10 €/kWh (TSTM) versus >250 €/kWh for Li-ion batteries and >500 €/kWh for hydrogen systems.
- **Scalability:** Modular design allows flexible scaling from small to TWh-scale installations.
- **Geopolitical Flexibility:** TSTM reduces dependency on LNG infrastructure and fixed pipelines, enabling dynamic market access.
- **Environmental Impact:** Avoids energy-intensive liquefaction (saving 85–90% energy compared to LNG) and uses recyclable steel, minimizing the carbon footprint.
- **Compared to lithium-ion batteries** — which are optimized for short-term grid balancing and not for seasonal storage — TSTM offers an order-of-magnitude cost advantage for long-duration, multi-month energy storage.

5. Implementation Scenarios

1. Grid-critical zones first (TSTM land-based)

→ **Deployment in regions with high curtailment and grid bottlenecks**

→ e.g. Northern Germany, Denmark, Netherlands, parts of UK, East China, California

- Targeted installations near wind clusters and industrial demand centers
- **Goal:** Immediate reduction of curtailment and redispatch costs

2. Integration with offshore wind hubs (TSTM-M maritime)

- Deployment at key offshore hubs
- e.g. North Sea, Baltic Sea, Gulf of Mexico, Asia (Taiwan Strait, South China Sea)
- Combine with floating compression powered by offshore wind
- **Goal:** Enable flexible gas transport, relieve pipeline dependence, monetize surplus offshore wind

3. Pipeless gas field development

- TSTM-M as enabler for economic extraction of currently stranded gas fields
- **Regions:** North Africa, Eastern Mediterranean, South America (Guyana Basin), Arctic marginal fields
- **Goal:** Unlock reserves without full pipeline build-out

4. Combined land + maritime architecture

- Build integrated corridors → land-based TSTM + maritime TSTM-M + flexible nodes
- **Example:** Norway → Germany/NL → Central Europe → reduce LNG dependence, optimize grid-balancing

5. Scalability pathway

- Modular roll-out → begin with MW-scale pilot → scale to multi-GWh
- Manufacturing can leverage existing pipeline industry supply chains
- **Goal:** Industrial scaling within 3–5 years

5.1 TSTM Deployment

TSTM systems can be strategically deployed in high-curtailment zones to absorb surplus renewable energy, stabilize grids, and defer costly grid reinforcements. Deployment prioritizes regions with structural renewable surpluses, transmission bottlenecks, and seasonal imbalances. Both land-based (stationary) and maritime (TSTM-M) modules can be adapted to local conditions.

Deployment Pathway:

Germany:

In Germany, curtailment already exceeds 20 TWh/year, with offshore wind farms frequently forced to reduce output due to grid congestion. A cluster of land-based TSTM modules (e.g. 100,000 m³ total volume) sited near offshore wind hubs — such as in Lower Saxony or Schleswig-Holstein — could store approximately 250 GWh of energy. Such a deployment could recover a substantial share of currently curtailed wind energy, while reducing redispatch costs and local grid overloads. Moreover, co-siting with industrial clusters enables direct use of stored energy in power, heat, or transport applications.

China:

China faces over 1,200 TWh/year of renewable curtailment, with provinces such as Gansu exhibiting extreme mismatch between generation and local demand. Large-scale TSTM clusters (e.g. 1,000,000 m³ total volume, storing ~2.5 TWh) can be deployed near major renewable generation zones and at key UHV grid nodes. TSTM provides a flexible buffer that complements grid expansion efforts and helps balance China's rapidly growing renewable fleet. Integration with existing gas networks further enhances flexibility and scalability.

United States:

The US faces a severe grid integration challenge, with over 2,600 GW of renewable projects stuck in

interconnection queues — representing more than 6,800 TWh/year of potential generation. Key regions such as Texas (ERCOT), California (CAISO), and Midcontinent (MISO) already experience frequent grid congestion and renewable curtailment. Land-based TSTM clusters deployed near major wind and solar hubs — such as West Texas or the California Central Valley — can absorb surplus generation and provide long-duration balancing. TSTM also offers a pathway to reduce dependence on long-distance transmission investments, which often face permitting and public acceptance hurdles in the US market.

United Kingdom:

The UK's ambitious offshore wind expansion — targeting 50 GW installed capacity by 2030 — already stresses grid infrastructure in regions such as East Anglia, Yorkshire, and Scotland. Curtailment of offshore wind is rising sharply due to limited onshore transmission capacity and temporal demand mismatch. Coastal TSTM clusters can provide local buffering for offshore wind, while maritime TSTM-M modules can enable flexible energy transport to demand centers or export markets. This approach aligns with the UK's strategy of developing flexible, distributed storage to complement its expanding renewable portfolio.

General Impact:

TSTM deployment enables cost-effective energy balancing without the need for massive new transmission infrastructure. Its modular nature allows gradual scaling — from local demonstration projects to full-scale regional storage hubs — aligned with renewable buildout. This approach addresses one of the key barriers to deeper renewable penetration: the lack of seasonally capable, geographically flexible storage.

5.2 TSTM-M Deployment

Maritime TSTM-M modules offer unique flexibility for offshore energy hubs, enabling storage and transport of energy without relying on fixed pipeline or grid capacity. They allow decoupling of production rates from existing infrastructure constraints and open new pathways for energy export, market arbitrage, and pipeless field development.

Deployment Pathway:

North Sea (Troll A and other platforms):

Existing offshore gas platforms such as Troll A face export limitations due to saturated pipeline networks. Side take-off using TSTM-M modules allows incremental gas extraction and export — increasing platform utilization by 10–20% without requiring costly new pipelines. The modular nature of TSTM-M enables staged deployment, matching platform capacities and market demand. Additionally, TSTM-M can integrate with nearby offshore wind farms to use renewable electricity for compression, enhancing the renewable share of exported energy.

Gulf of Mexico:

The Gulf of Mexico combines significant offshore gas potential with emerging offshore wind development. TSTM-M modules can serve as a flexible interface between offshore production and onshore or international markets, bypassing grid bottlenecks and optimizing logistics. Co-location with offshore wind allows renewable-powered compression, aligning with US policy goals for clean energy integration. TSTM-M also enables pipeless development of smaller or marginal gas fields in the region.

Baltic Sea (offshore wind integration via existing pipeline infrastructure): The Baltic Sea is experiencing a significant increase in offshore wind energy development. Plans call for the addition of several dozen gigawatts of new capacity in the coming decades. Many of these projects face

significant challenges regarding onshore grid connection and transmission capacity. TSTM-M offers a complementary pathway: existing subsea pipeline infrastructure — including underutilized or currently idle gas pipelines — can be repurposed as transport corridors for compressed gas derived from offshore wind power. Local offshore wind energy can drive compression processes to convert excess electricity into storable energy, which can then be transported flexibly by ship. Examples include pipelines such as Baltic Pipe or Nord Stream, which could be adapted for this purpose. This approach enables faster deployment of offshore wind, reduces dependence on new high-voltage grid infrastructure, and provides an economically attractive reuse for stranded pipeline assets.

General Impact:

Maritime TSTM-M deployment complements land-based TSTM systems by providing mobile, scalable storage and transport capacity. It enhances flexibility, supports energy export diversification, and enables economic recovery of resources that would otherwise remain stranded due to infrastructure constraints.

5.2 Business Case**Troll A: Unlocking Additional Production with Floating TSTM-M Platforms**

One of the most promising applications of TSTM-M technology lies in enhancing the export flexibility of existing large offshore gas platforms such as Troll A. Currently, production from Troll A is constrained by the fixed capacity of existing export pipelines (Troll Gas Pipelines I & II). Building new pipelines is economically and politically challenging, with long permitting cycles.

By deploying multiple floating TSTM-M platforms near Troll A and connecting them via side-tap points to the existing production lines, Equinor can significantly increase effective offtake capacity without major new infrastructure. These platforms can store compressed gas temporarily and enable flexible, just-in-time export via maritime transport.

Such an architecture offers several economic advantages:

- Increases total production and monetization of reserves without pipeline investment
- Allows better management of seasonal market demand and price arbitrage
- Enables integration with offshore wind-powered compression (e.g. from Hywind Tampen), enhancing ESG profile
- Accelerates tie-in of smaller nearby fields (Fram, Byrding, etc.) using floating storage as intermediate offtake
- Extends the economic life of Troll A and associated infrastructure

In summary, floating TSTM-M platforms offer a scalable and capital-efficient path for Equinor to unlock additional value from the Troll area, positioning the company as a pioneer in flexible, future-proof gas logistics.



Fig. 4 Conceptual illustration of the Business Case Troll A: deployment of floating TSTM-M platforms for flexible gas storage and transport. The architecture enables incremental offtake from existing offshore infrastructure like Troll A, enhancing export capacity without new pipelines and supporting integration with renewable-powered compression (e.g., Hywind Tampen).

5.3 Saudi Arabia – Unlocking Gas Without LNG

Saudi Arabia possesses one of the world’s largest untapped gas reserves — more than **200 trillion cubic feet of methane** — yet exports virtually none of it. This vast resource remains largely underutilized due to the Kingdom’s lack of LNG infrastructure and export pipelines. Unlike oil, which transformed Saudi Arabia in the 20th century, natural gas has remained a domestic resource — consumed locally or flared.

The **TSTM architecture** offers a radically different path forward: enabling compressed natural gas (CNG) storage and export without relying on expensive, centralized LNG terminals. This solution is not only **cost-effective** and **fast to deploy** but also geopolitically independent — requiring no foreign pipelines or liquefaction technology.

Desert Hydrogen Without Water

Saudi Arabia’s hydrogen ambitions face a critical challenge: **water scarcity**. Electrolysis for green hydrogen requires large-scale desalination, which consumes both energy and capital. In contrast, TSTM allows for **pyrolytic conversion** of methane into **clean hydrogen and solid carbon** — without water input and without CO₂ emissions. This process — dubbed “**desert hydrogen**” — leverages solar and wind power to compress methane, store it at 250–500 bar, and use it flexibly for hydrogen production, power generation, or gas operations. (Dzikowski, R. 2025)

“Desert hydrogen doesn’t need water – just sunlight, wind, and methane.”

Strategic Export Advantage

TSTM enables modular gas export via maritime CNG, bypassing the need for LNG megaprojects. Pilot deployments can begin by **2028** with export volumes of ~3.65 Bcm/year (36.5 TWh), scaling up to **~100 TWh/year by 2030**, generating potential revenues of **\$2.5–4.0 billion** annually (based on \$25–40/MWh market prices).

Export Hubs: Yanbu, Dammam, and NEOM offer ideal locations for containerized gas export using multipurpose vessels, RoRo ships, or customized barges.

Business Opportunities:

- TSTM container leasing
- Mobile solar-fueled energy hubs
- Desert-based fueling infrastructure

“This is not just a technology — it’s a platform for economic reinvention.”

Economic and Technical Comparison

System	Initial Investment	Construction Time	Break-even	Scale-up Speed
TSTM-CNG	~\$250–400 million	6–24 months	< 3 years	Modular, fast
LNG	>\$10 billion	6–10 years	>10 years	Slow, centralized

With abundant solar energy and methane resources, Saudi Arabia is uniquely positioned to pioneer **maritime TSTM-CNG logistics**, redefine gas export standards, and become a **global leader in compressed gas innovation** — without relying on legacy LNG infrastructure.

“What Dammam No. 7 was to oil, TSTM may be to methane.”

6. Conclusion and Call to Action

The global energy transition is increasingly bottlenecked by inadequate grid and storage infrastructure, leading to massive renewable energy losses. Moreover, the further expansion of planned renewable capacity is already being severely constrained — as clearly demonstrated by the United States, where over 2,600 GW of projects remain blocked in interconnection queues due to infrastructure limitations. Without scalable, flexible storage solutions, these bottlenecks will increasingly stall the energy transition globally.

The TSTM architecture — land-based TSTM modules for seasonal grid storage, and maritime TSTM-M modules for flexible energy transport — offers a modular, scalable, and geopolitically adaptable pathway to address these challenges. TSTM can decouple renewable energy growth from grid expansion constraints, enable faster offshore wind integration, and unlock stranded gas infrastructure for productive use.

We call for pilot projects in key high-curtailment zones and strategic energy hubs — including the North Sea, Baltic Sea, United Kingdom, United States (ERCOT, CAISO), Gulf of Mexico, and China — to validate and demonstrate the potential of TSTM systems. We invite collaboration from energy researchers, grid operators, offshore wind developers, gas network operators, and maritime logistics providers.

For inquiries and collaboration opportunities, please contact the author at rich@desert.solar.

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