Prioritizing Capacity vs Integration: The Steps to 100% Clean Energy

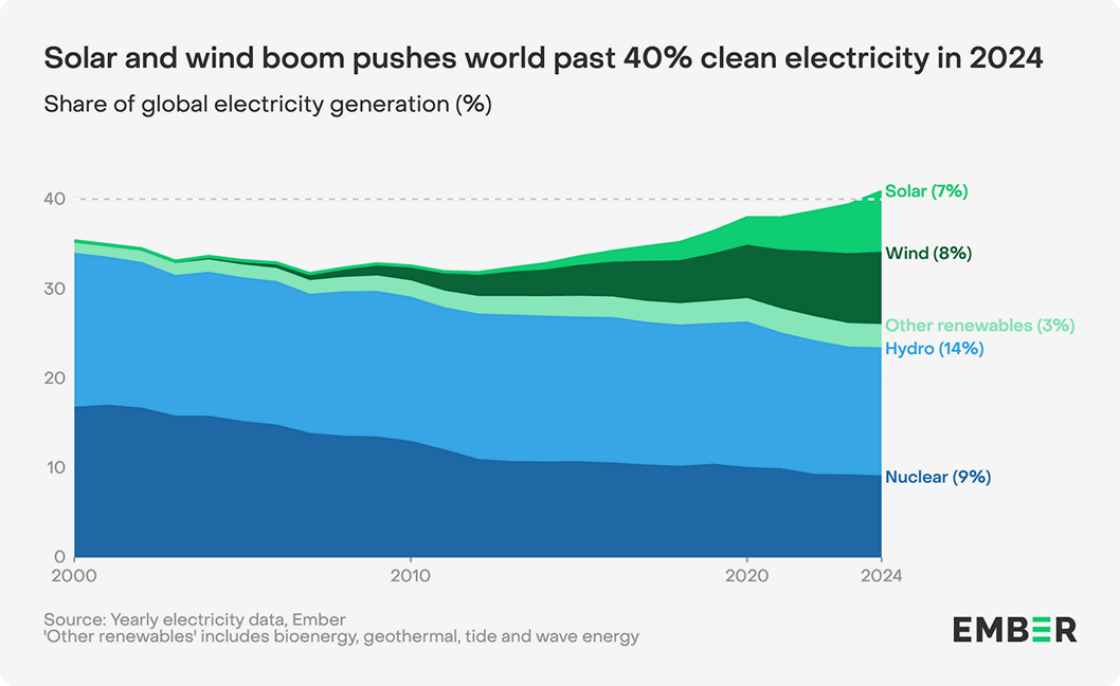
Over the past 15 years, companies have voluntarily set goals for renewable energy and taken action to achieve those goals to help decarbonize our world. The impact has been significant: those companies have signed contracts that backed the development of over 200 gigawatts of added renewable energy generation capacity (enough to power over 90 million households globally).

As we look to the next decade, should companies still focus on building more solar and wind farms with attention paid to additionality? Or should they shift to supporting batteries or adopting new target setting methodologies like hourly matching (aka 24/7 carbon free energy)?

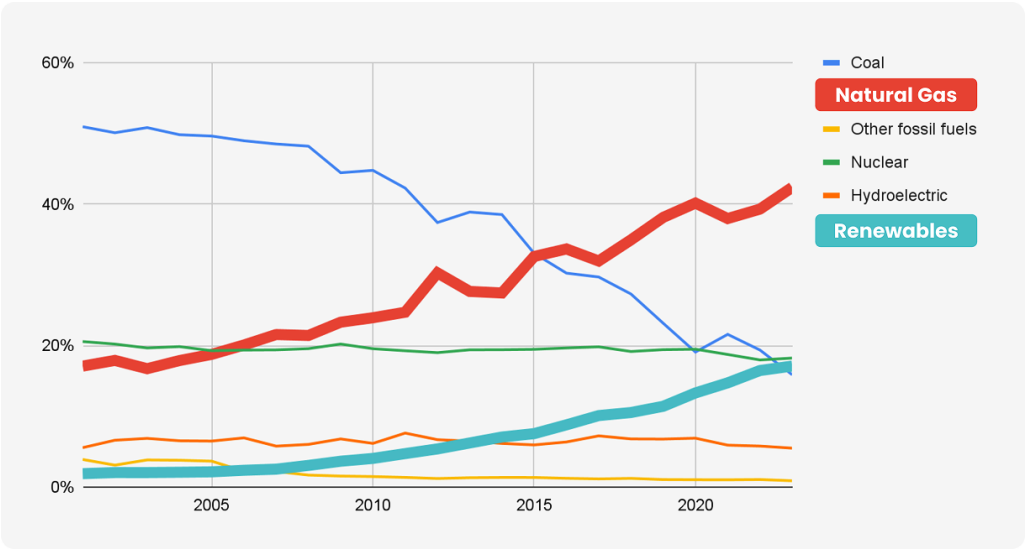
To answer that question, we should look at what grids need, how grids move from fossil fuels to clean energy (both reliable and variable), and how companies can best accelerate the transition. After all, this is a team sport with many players and moving pieces.

How clean is the grid right now?

Solar and wind surpassed 15% of global electricity generation in 2024, a major milestone in the energy transition. Clean power, which includes hydropower and nuclear, now accounts for more than 40% of global electricity. Source



In the U.S., solar and wind are growing, but so is natural gas. While we celebrate these milestones, it's important to remember that the transition to clean power is not automatic, nor is it moving fast enough to minimize the worst effects of climate change. Explore what this looks like for each U.S. state here.



Not all forms of clean energy are the same

Some clean energy sources, like geothermal or nuclear, can reliably produce the same volume of clean energy for all 8,760 hours in a year. Others like solar and wind are considered variable renewable energy (VRE) sources, since they depend on the weather and production fluctuates hour-to-hour and season-to-season.

While grid operators have always managed variability in demand, solar and wind present a new challenge: variable renewable energy supply. If we want to increase the percentage of electricity generation from solar and wind, we need to think about more than just how to build as many projects as possible—we need to think about how to manage and reduce variability.

A 2024 IEA report on integrating solar and wind puts this succinctly:

> Variability will require increasing the flexibility of the entire power system, by leveraging dispatchable generation, grid enhancements, increased storage and demand response. Successful integration maximizes the amount of energy that can be sourced securely and affordably, minimizes costly system stability measures, and reduces dependency on fossil fuels.

Because of VREs, the path to 100% clean electricity will be faster and cheaper, but the priorities for grid operators shift by necessity as VREs make up a greater and greater percentage of electricity supply.

Six phases of the transition

The same IEA report lays out six phases of variable renewable energy integration that can be put into two buckets:

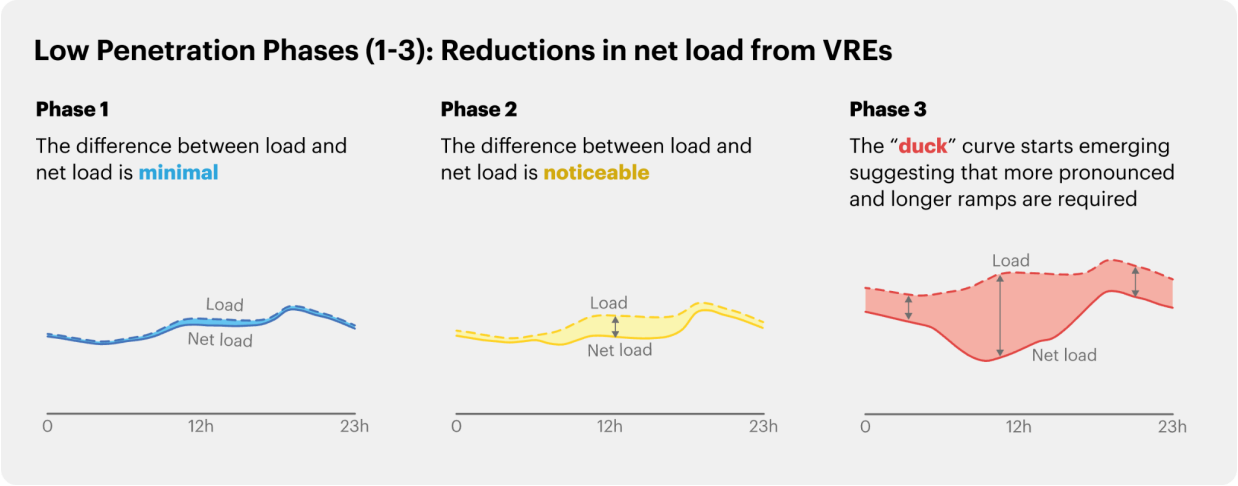
1. **Low penetration of VREs** (phases 1-3): VREs have a relatively low impact on grid reliability or how the grid is run. The priority is to build as much clean, cheap wind and solar as possible.
2. **High penetration of VREs** (phases 4-6): VREs have a growing influence on reliability and how the grid is run. It becomes just as important to integrate that power—firming it, shifting it across time and space, and making sure it replaces fossil generation hour by hour.

Stage 1: Low Penetration (0% → 35% Variable Renewable Generation)

In this early stage, every new megawatt of solar or wind is valuable. Fossil fuels still dominate, and the grid is far from saturated with clean energy. The priorities are:

- **Build baby, build:** Build as much wind or solar, as fast as you can. All of it helps.
- **Do what is easy first**: Regions should lean into what they have the most resources for. Texas began with wind because of its strong nighttime wind patterns and land availability. California started with solar, taking advantage of abundant sun and supportive policies.
- **Pay attention to integration as you ramp**: As you get closer to 35% (the point at which VREs start to determine the operation pattern of the grid), it becomes more critical to ramp up investments in transmission and technologies like battery energy storage systems (BESSs) as an integration strategy.

Progress can be seen as the growing difference between **load** (electricity usage) and **net load** (electricity usage minus electricity supply from VREs) – graphic from IEA's report:



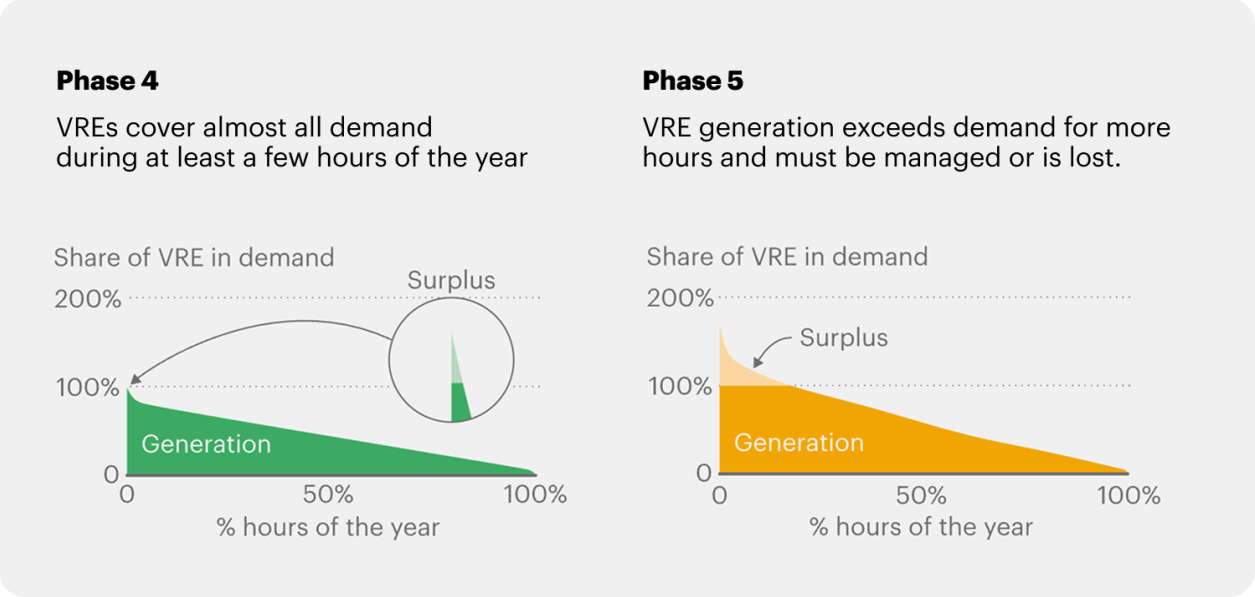
The goal in this stage is for the grid to run on >90% clean energy for at least a few hours each year. 45 out of 50 US states are in this phase, with 25 states still not yet achieving 10% of generation from VREs.

How corporate action and reporting standards can help:

- Priority number one is capacity expansion; integration needs are less of priority as there's little risk of curtailment or oversupply.
- The current scope 2 accounting standards, based on annual matching of supply and demand and with minimal geography constraints, have allowed buyers to use instruments like power purchase agreements (PPAs) to support capacity expansion.
- Changes being considered right now around requiring hourly matching RECs (or even painting it as the highest impact action) will likely depress, not incentivize use of long-term contracts like PPAs.
- Emphasizing hourly matching (aka 24/7 carbon-free energy) at this point is premature—**adding more capacity to enable the next clean megawatt-hour is what matters most**.

Stage 2: High Penetration (>35% Variable Renewable Generation)

Phase 4-5: Surplus generation starts to appear, at first in a few hours a year and eventually in a few hours for many days of the year → keep building new capacity as you work on optimizing and integrating.



As variable renewables climb above 35% of annual electricity generation, new challenges emerge. Certain hours or seasons begin to have **surplus generation**. Some clean energy may be curtailed, while fossil fuels still dominate evenings and cloudy or windless days.

Integration strategies start to matter and will become a bottleneck. It's time to invest more in:

- **Optimal additions to the generation mix** as wind tends to peak at night or in winter and solar peaks during midday. Blending them, where possible, smooths the overall VRE supply curve and reduces the need for storage or overbuilding.
- **Short-duration storage** (e.g., 4-hour batteries) to shift solar to the evening.
- **Grid-enhancing technologies** and **regional transmission** to move power larger distances from where it's windy or sunny to where it's not.
- **Flexible demand** (e.g., smart EV charging or industrial / residential demand response).

Capacity building is still critical. Many of the remaining fossil plants are running most of the time. The goal is now to run the grid on >90% clean electricity for **more hours** across **more days** of the year.

In phase 4, where surplus is still rare on an hourly basis, hourly matching for corporate action should still not be a primary sustainability requirement. More emissions are avoided for each dollar spent enabling new capacity than those spent micromanaging the timing of each megawatt-hour (especially in regions that are still heavily reliant on fossil fuels).

In phase 5, it makes sense for companies with renewable energy targets to start considering the hourly matching of electricity usage with renewable electricity supply, but they should proceed with caution.

Hourly matching presents both added challenges but also new risks of diminished impact compared to annual matching unless companies seek to match >90% of hours and/or can clear new barriers to continue using long-term forward contracts that enable new projects. Some companies with loads on cleaner grids may choose to instead focus on decarbonizing dirtier grids elsewhere.

It's also worth noting that corporate reporting standards do little to incentivize or reward investments in technologies and actions that balance VREs and better integrate them into the overall grid. More work needs to be done to fully leverage corporate climate actions in these later phases.

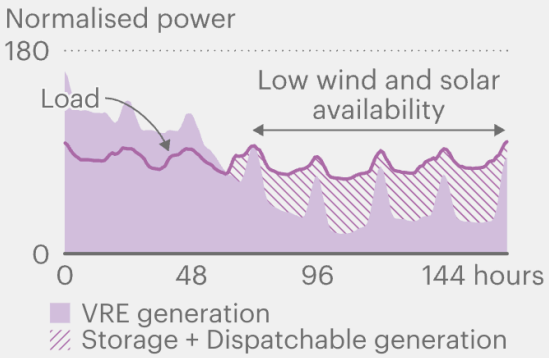
Phase 6: Beyond 60% Variable Renewable Generation

Clean energy is on the hook for reliability and resource adequacy. Firming, shifting, and diversifying VREs and the grid to reach full decarbonization is a must.

Phase 6

VREs become the primary source of generation. Periods of low VRE availability (short or long) need to be compensated for by shifting generation and/or demand.

The graph shows a span of 6 days and how excess VRE generation was stored for days of lower generation.



Beyond 60%, running a grid on clean energy is no longer about volume—it's about **firmness, reliability, and resilience**. Periods of surplus and periods of low VRE availability are met with flexibility in shifting demand and supply in both time and space.

- Every remaining fossil hour becomes harder and more expensive to eliminate.
- Seasonal mismatches become critical (e.g., long winter lulls with low solar output).
- **Long-duration storage, long-range transmission**, and **zero-carbon firm resources** like geothermal and nuclear become essential.

The clean energy system must be designed to run well **even during the worst week of the year**, not just the average hour. Grid planning must now fully account for the most extreme variability.

Just as in Phase 5, hourly matching corporate actions may be more impactful than annual matching when targets are >90% of hours and PPAs and other long-term contracts are still used.

Two Competing Caveats

We don't need to fully replace every fossil MWh with one from clean energy. Fossil systems waste a lot of energy as heat; electric systems are far more efficient. This is sometimes called the "primary energy fallacy".

But we'll need more electricity overall, thanks to electrification of our world (cars, buildings, industry) and other energy-hungry solutions to climate and human development challenges (AI, water desalination, carbon removal, etc). That's Jevons Paradox at work.

Renewable Energy Deployment is a Journey

In the early stages, **capacity expansion** gives the biggest emissions reduction bang for the buck. The cheapest, fastest new megawatt-hour does the most good. But as the grid matures, it's not just about how much clean energy we have—but how well we **integrate** and match demand with clean supply.

To maximize the impact of corporate climate action, greenhouse gas standards and programs like GHG Protocol and SBTi should recognize and reward companies doing the most impactful things to decarbonize our world. We should avoid imposing hourly matching rules well before the grid needs to focus on integration, especially when those rules may constrain the build-out of new clean energy. And we must be ready to invest in integration when the time is right.

Because reaching 100% clean energy won't just take more action—it will take **more strategic action**.

A downloadable copy of this essay is available at ever.green/papers/phases.
