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Power and resources

Transformational Innovation Opportunities (TRIO): Power and resources

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- The UBS Chief Investment Office believes there are three transformational innovation opportunities (TRIOs) that will drive equity markets in the coming decade: *Artificial intelligence*, *Power and resources*, and *Longevity*.
- *Power and resources* focuses on opportunities related to power infrastructure and industrial technology—parts of the value chain that are essential to facilitate the energy transition, develop AI, expand energy infrastructure, and satisfy rising electricity demand. We see the best investment prospects at present in the electrification value chain, which is supported by growth in electricity demand, data center capex, and vital investment in aging power grids.
- We forecast around USD 3.0tr in combined annual investment by the end of the decade in power generation, energy storage, grid infrastructure, data centers, and transportation and industry. For our stock picks, investors should see our new "Power and resources" Equity Preference List, which highlights companies we believe are best positioned to capitalize on the aforementioned tailwinds.

Source: Shutterstock

Nathaniel Gabriel, CFA, CIO Equity Strategist, Materials & Industrials, contributed to this report prior to his leave.

CIO recently introduced its Global Equity Framework, which utilizes a combination of three principal perspectives to identify investment opportunities: macroeconomic, structural, and company-specific. The structural element enhances the traditional equity research process by focusing on what we call transformational innovation opportunities (TRIOs)—three trends we expect to have an outsized influence on equity markets in the coming years. These include *Artificial intelligence*, *Power and resources*, and *Longevity*.

Power and resources represents various sectors and themes enabled by an evolution of industrial technology. Our long-term investment ideas highlight a series of opportunities within those themes that could help companies increase revenues at higher-than-GDP growth rates and are buoyed by the interplay of technological advancement and resource scarcity. This includes opportunities ranging from the energy transition (in which BloombergNEF estimates USD 1.8tr was invested in 2023), such as lower-carbon technology, to critical materials and providers of efficiencies in resource consumption.

For the *Power and resources* theme, we see the biggest opportunity today in electrification. A confluence of environmental, technological, and regulatory forces is driving a global shift toward electricity. Specifically, electricity use is set to grow amid burgeoning demand from AI data centers, the building of megaprojects, and the electrification of heating, industry, and transport. This segment should also benefit from a grid infrastructure upgrade cycle, the increased cost competitiveness of renewable power, global decarbonization goals, and supportive legislative measures.

Our ten predictions about *Power and resources*

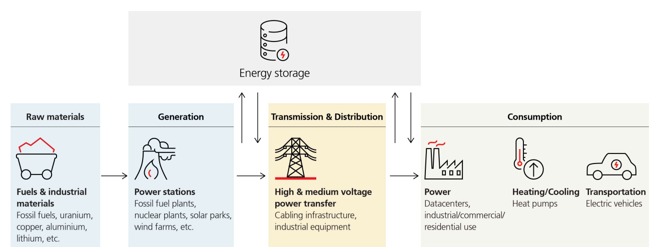
1. The accelerating electrification of our economy, transportation, industries, and households (or in other words: the energy transition) will require an **enormous amount of investment—we project USD 3.0tr in annual spending by 2030**—and offer attractive investment opportunities.
2. **Electricity consumption is set to accelerate, driven by new technologies such as artificial intelligence, data centers**, and the crypto sector in many regions, particularly in the developed world.
3. **Electricity consumption should also rise amid increased electrification** of transport (e.g., electric vehicles), heating (e.g., heat pumps), and across industries and households.
4. **Renewable technologies** (especially solar and wind energy) will likely continue to **grow rapidly** and play a central role in the global power generation mix of the future, leading to a rising share of the global electricity mix.
5. While traditional **large natural gas power plants** should continue to play a major role regionally, the **power generation mix of the future will employ smaller power plants,** requiring more electrical equipment.
6. **Transmission (high voltage) and distribution (medium voltage)** will experience **one of the highest growth rates** in electricity grid investments in the coming years.
7. **Electrical equipment,** such as substations, switchgear, transformers, and circuit breakers, **will drive a significant increase in investment** to meet rising electricity demand.
8. Innovations in **nuclear technology** (e.g., small nuclear reactors, nuclear fusion) and **emerging technologies** (e.g., batteries and hydrogen) **will play an important role** in the energy mix of the future.
9. **Demand for natural resources** (copper, aluminum, etc.) will increase, requiring the identification and commercialization of new supplies.
10. **Electrification should increase efficiency, reduce pollution, and lower carbon emissions.** It should also increase the standard of living globally, particularly in emerging markets.

The electricity system explained

Value chain

To identify the most prominent opportunities, we find it useful to follow electricity along its path from generation to consumption. Figure 1 illustrates the electrification value chain, where electric power flows from generation facilities through transmission and distribution grids before it is consumed in various applications.

Figure 1 - The electrification value chain



Source: UBS

Note: See Figure 17 in the appendix for a broader view of the value chain

Raw materials

The entire value chain begins with the essential raw materials required for electricity generation (coal, natural gas, uranium, etc.) and the materials needed for electrification (copper, aluminum, lithium, etc.).

Generation

The second step in the value chain involves power generation plants, which capture the energy of their fuel and transform it into electricity, with technology varying by energy source. Thermal power stations utilize the thermal energy released by the combustion of fossil fuels, biomass, or hydrogen. Nuclear plants harness the kinetic, thermal, and radiation energy produced by the splitting of large atomic nuclei. Hydroelectric plants and wind turbines convert the mechanical energy of water and wind, respectively, while solar panels absorb radiation from the sun. Table 1 shows the contribution to global electricity generation of the leading power sources, along with their emissions impact.

Table 1 - Characteristics of the main power production technologies

Energy source	2010 generation share (%)	2023 generation share (%)	2030E (STEPS) generation share (%)	Emissions CO2e (g/kWh)
Oil	4.5%	2.5%	1.0%	1080
Natural Gas	22.4%	21.9%	18.4%	490
Coal	40.3%	35.7%	24.6%	820
Nuclear	12.8%	9.3%	8.7%	12
Hydroelectric	16.1%	14.2%	12.9%	24
RES (ex. Hydro)	3.5%	16.0%	34.0%	
Wind	1.6%	7.8%	13.4%	11
Solar	0.1%	5.4%	17.2%	48
Geothermal	0.3%	0.3%	0.4%	38
Biomass	1.4%	2.4%	2.9%	230
Others	0.4%	0.4%	0.4%	n/a

Source: Statistical Review of World Energy 2024, IPCC AR5 Annex III (2014), IEA (https://www.iea.org/statistics, all rights reserved), UBS, Nov 2024.

Note: Emission figures represent median lifecycle emissions, incl. albedo effect. RES = renewable energy source. STEPS: Stated Policies Scenario used by the International Energy Agency. CO2e = Carbon Dioxide Equivalent.

Transmission and distribution

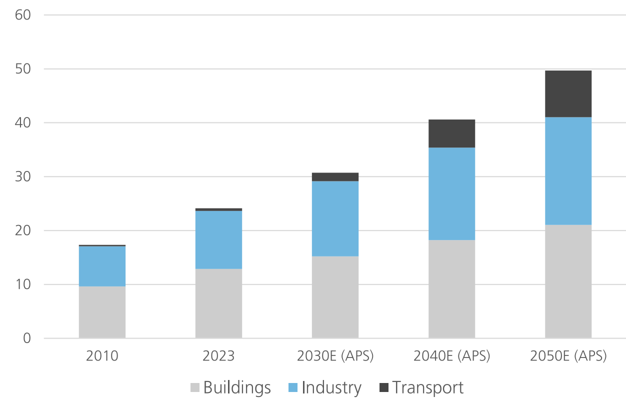
After electricity is generated, the transmission and distribution networks come into play. These consist of power lines that move electricity from production facilities to consumers. The transmission grid involves the long-distance transfer of electricity from power plants to local substations via overhead and underground power lines. Subsequently, the distribution network connects the local substation to individual consumers. Various voltage levels are employed throughout the process to minimize power losses, with transformers adjusting the voltage at each step. Along the path of power delivery, electrical equipment —such as switchgear, circuit breakers, and capacitors— facilitate energy transfer, stabilize the network, and prevent outages.

Consumption

In the final stage, electricity is consumed in buildings, transportation, or industrial applications (see Figure 2 for the global consumption split). Notably, heating, ventilation, and air-conditioning (HVAC) constitutes one of the most electricity-intensive applications, spurring demand across the residential, commercial, and industrial categories (EIA Annual Energy Outlook 2023, US MECS 2018). In recent years, an increasingly important driver of power demand has been AI data centers, which, according to EPRI, already represent around 4% of total US electricity consumption (up over 50% since 2020) and around 3% in Europe.

Figure 2 - Global electricity consumption, split by segment

In TWh. Future consumption according to the IEA Announced Pledges Scenario (APS)



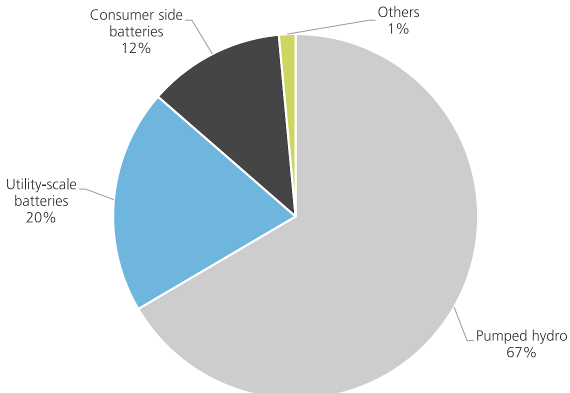
Source: IEA World Energy Outlook (2024), https://www.iea.org/statistics. All rights reserved. UBS

Electricity market and energy storage

While the transmission grid allows producers and consumers to be geographically independent, its proper function requires that power produced and consumed are equal at all times so voltage and frequency remain stable. Therefore, from a grid perspective (i.e., without accounting for environmental impact), large fossil fuel and nuclear plants with predictable generation profiles have an advantage over renewable energy sources, as they have limited dependence on prevailing weather and can avoid intraday deviations in grid frequency.

Energy storage is one method to reduce this volatility and avoid destabilization of the grid. Energy is stored during times of excess production and discharged when production alone is insufficient. Electricity can be stored using various technologies, though there are trade-offs among cost, energy density, storage duration, and response time. As Figure 3 shows, the market is dominated by pumped hydro, which is already effectively used to balance the grid, and battery storage. With the latter's total installed capacity almost doubling in 2023, future improvements in their technology, along with their utilization in combination with smart meters, could provide an additional reliable method for grid stabilization. While the scale of energy storage is quite small relative to overall energy infrastructure today, these solutions will be needed to accommodate intermittency, presenting a long-term opportunity.

Figure 3 - Global installed storage capacity
In %



Source: IEA - Batteries and Secure Energy Transitions (2024). https://www.iea.org/statistics. All rights reserved. UBS

1. Prediction: The accelerating electrification of our economy, transportation, industries, and households (or in other words: the energy transition) will require an **enormous amount of investment—we project USD 3.0tr in annual spending by 2030**—and offer attractive investment opportunities.

By 2030, we project total annual spending globally of USD 3.0tr, up from USD 2.0tr in 2023, spanning power generation, energy storage, power grids, and end-use consumption. Table 2 depicts the composition of the investments in each step of the value chain. In our "Power and resources" Equity Preference List (EPL), we identify companies with strong fundamentals along the value chain that we believe are well-positioned to benefit from this increase in investment. Our stock picks fall primarily on the electrical equipment, utility, raw material, and grid services categories.

We expect higher electricity demand to drive investments across the entire value chain. However, as shown in Table 2, the highest growth within the larger segments is projected in transmission and distribution, data centers, transport, and, from a low base, energy storage. These have higher growth rates than those for the power generation segment for several reasons:

- **Replacement capital expenditures (capex) should be a significant driver in developed markets.** Until a few years ago, there was a decade of underinvestment in the grid. Consequently, developed markets have pending grid upgrades, and we expect replacement capex to be a key driver moving forward. In the US, for instance, replacing old infrastructure will likely be equally important as expansion capex and investment in grid hardening and resilience, all accounting on average for around 30% of grid capex, according to Edison Electric Institute (e.g., 33% of transmission spending is replacement capex and 28% of distribution spending). Grid hardening and resilience are, for instance, investments in equipment that operates in extreme heat or underground distribution lines. The remaining spending is related to advanced technology, including management systems (e.g., sensors, energy software, real-time system management) to better balance electricity supply and demand, and the rest to others (not specified) (source: EEI Financial Analysis and Business Analytics 2023 surveys).
- **New build in emerging markets (EM).** In emerging markets, the grid is relatively young, with approximately 40% being less than ten years old (source: IEA Electricity Grids and Secure Energy Transitions based on Global Transmission Report (2023)). In these regions, grid buildout will likely be the most important driver in the coming decades.
- **The nature of generation is changing.** The share of renewable energy is growing worldwide, while smaller electricity generation plants will likely lead to more investments in new electrification equipment, upgrades to the existing grid, and storage infrastructure.
- **The way electricity is consumed is also changing.** The growth in large AI data centers and electric vehicle (EV) charging hubs will require more medium-voltage equipment, a segment we particularly favor and expect to see high single-digit growth in the coming years.
- **The renovation market drives electrification demand in buildings.** For the low-voltage market (consumer consumption), we see less growth compared to transmission and distribution, but it remains an attractive segment. The low-voltage market relies on the more cyclical new-build market, which grows in tandem with GDP over the long term, and the renovation sector, where we anticipate acceleration and increased investments in electrification equipment.

In summary, due to a combination of underinvestment and changes in the nature of electricity generation and consumption, we see several factors that will drive faster growth in electrification equipment than in generation.

As shown in Table 2—excluding data center equipment—UBS estimates that total annual spending will reach USD 3.0tr by 2030. In comparison, the IEA projects investments in the same segments to exceed USD 4tr, while IRENA forecasts that investments in the renewable power generation market alone will reach USD 1.5tr by the end of the decade. While the primary drivers of these requirements are similar, the significant gap between the figures is noteworthy. The main difference in the projections arises from the perspective under which they are calculated. The estimates from these agencies serve more as progress tracking toward achieving decarbonization and energy transition goals, rather than as realistic market forecasts. They are based on the necessary spending to align with global targets set at COP28 to achieve the "Net Zero Emissions by 2050 Scenario," which aims to limit the global temperature rise to 1.5 °C (with at least a 50% probability).

As a result, the respective assumptions rely on rapid growth in renewable power generation, an immediate decline in fossil fuel demand, and substantial spending on energy efficiency improvements, which are expected to triple between 2023 and 2030. While spending at these levels may be essential for achieving climate goals, it is important to highlight their purpose and distinguish them from expected market approximations. In regard to the *Power and resources* TRIO, if the estimates by the IEA and IRENA prove directionally more accurate, and if spending is in fact higher than we expect by the end of the decade, the investment opportunity we foresee would be even greater.

Table 2 - The electrification market opportunity
Estimated annual investments along the value chain

Market segment	2023 annual investments (USD bn)	2030E annual investment needs (USD bn)	Expected annual growth rate
Power generation (across all technologies)	908	1125	3.1%
Energy storage	41	102	13.9%
Transmission & Distribution grid	331	623	9.5%
Consumption			
Buildings	350	476	4.5%
Industry	47	67	5.1%
Transport	229	397	8.2%
Data centers	68	191	15.9%

Source: IEA, https://www.iea.org/statistics.

Electrification opportunity set

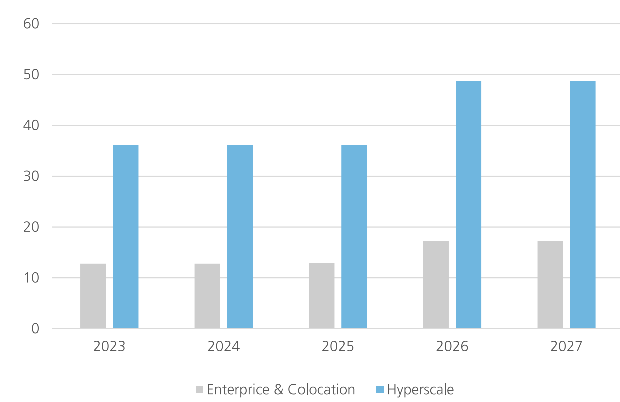
In this section, we highlight the key investment opportunities across the electrification value chain and emphasize the segments where we see the biggest opportunity (see Figure 17 for an illustrative overview of the investment universe).

2. Prediction: Electricity consumption is set to accelerate, driven by new technologies such as artificial intelligence, data centers, and the crypto sector in many regions, particularly in the developed world.

Data center investment a catalyst

Data centers have always been heavy users of power and electrical equipment, but the aggregate scale and per-rack power densities are accelerating significantly thanks to the rise in popularity of generative artificial intelligence (genAI). A major driver is the shift from CPUs (serial processing) to GPUs (parallel processing), which are better suited to AI processes but consume significantly more energy. For example, in a year, a single NVIDIA GB200 GPU can consume roughly the same amount of power as an average US household, and just one server rack can include 36 CPUs and 72 GPUs. In the US, electricity demand from data centers has grown 50% since 2020, now accounting for 4% of the country's consumption, while in Europe, although lower, it represents a considerable level of 2.8%. The Electric Power Research Institute projects data centers may use up to 9% of all electricity generated in the US by 2030, while the IEA notes that global data center consumption could more than double by 2026 relative to the 2022 base of 460 TWh.

Figure 4 - Average rack density
Estimated values for 2024-2027. In kW/rack.

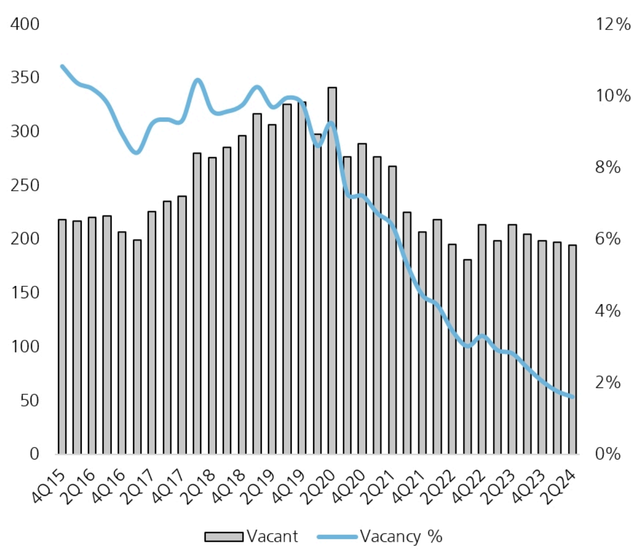


Source: Jones Lang LaSalle Data Centers 2024 Global Outlook

To frame the opportunity, we trace the path of electricity and heat through a typical data center. A transformer first receives medium-voltage three-phase power from the grid and steps it down to a lower voltage, where it passes through complex switchgear and an uninterruptible power supply (UPS) for backup power. From there, electricity is routed along busways through various switches and power distribution units (PDUs) until it arrives at the server rack.

The chips and facility generate significant heat, yet the data center must strictly maintain a low-humidity temperature of 73-75°F (23-24°C). To this end, roughly 40% of a data center's power consumption is used for cooling. The cooling of a modern hyperscale facility can require transferring the equivalent of the heat required to melt 40,000 tons of ice per day. Most data centers today are air-cooled, but liquid cooling can handle rack densities an order of magnitude higher.

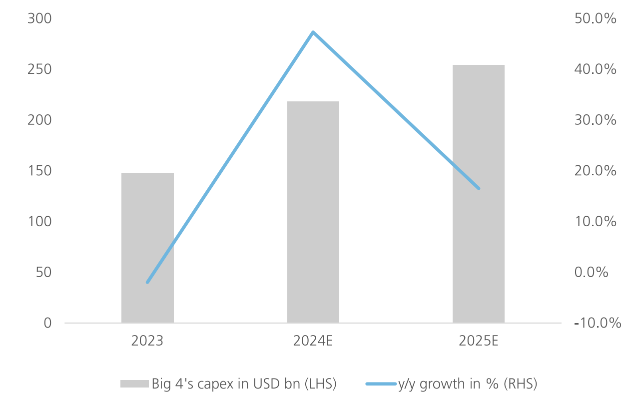
Figure 5 - US data center vacancy
lhs: MW, rhs: % of total



Source: Data Centre Hawk

We believe air cooling will always play a role but expect the fastest growth in direct-to-chip liquid cooling solutions. Highly efficient immersion cooling holds promise, but we expect adoption to be in niche circumstances for now, given the challenges associated with system design and the toxicity of PFAS chemicals in the coolant.

Figure 6 - Data center capex by major AI companies is expected to grow significantly in the coming years
Big four (Amazon, Microsoft, Meta, Alphabet) hyperscaler capex in USD bn (lhs) and y/y growth in % (rhs)



Source: Bloomberg, Factset, UBS as of Oct 2024

The existing data center footprint is quickly filling up, with vacancy rates in the US now in the low single digits. Major tech companies see leadership in AI as an imperative and are likely to continue spending on capacity expansion to the extent supply constraints allow. UBS anticipates more than 45% year-over-year growth in capex from the "big four" (Amazon, Microsoft, Meta, and Alphabet), followed by 15% in 2025 (topping USD 250bn). We anticipate 20-25% growth in the short term and 10-15% growth in the medium term for the data center end market. We see transmission and distribution electric equipment, non-residential HVAC, and select non-regulated utilities as the primary beneficiaries.

3. Prediction: Electricity consumption should also rise amid increased electrification of transport (e.g., electric vehicles), heating (e.g., heat pumps), and across industries and households.

Global energy demand has steadily increased, with an annual growth rate of about 1.4% over the past decade. But electricity consumption is growing at a faster pace, recording a 2.5% per annum rise during the same period, according to the Energy Institute Statistical Review of World Energy. Electricity growth is poised to accelerate to a 3.4% annual rate from 2024 to 2026, per the IEA, with expectations of even faster growth beyond that window as large projects come online. At the same time, global climate mitigation efforts and decarbonization goals are expected to drive this trend in the longer term, with the

IEA Announced Pledges Scenario projecting more than a doubling of electricity's share in total energy consumption by 2050.

The OECD forecasts that global GDP will nearly double by 2060, suggesting rapid growth in both total energy and electricity demand in particular as economies expand. This trend mirrors the strong increase seen over the past six decades, primarily driven by non-OECD countries since the turn of the millennium. More people mean more households, transportation, and infrastructure, leading to higher energy needs. Urbanization and efforts to supply energy to underserved regions—about 1 in 10 people in the world lack access to electricity, according to the IEA—should also contribute to energy demand in the coming years and decades.

While consumption in emerging markets is growing fastest, developed market demand is expected to be on the rise as well, fueled by a variety of technological, industrial, and socio-economic factors. Technological innovation has led to new energy-intensive devices, and the reshoring of industrial activities in sectors such as semiconductor and battery production has added to energy needs regionally. The shift toward electrification in transportation, industrial, commercial, and residential applications—including an increased penetration of electric vehicles and the transition from fossil fuels to electric heating solutions—further amplifies this trend. Although advancements in energy efficiency can help to partially offset demand surges, the overall trajectory of increasing electricity consumption should continue, driven by these diverse and powerful factors. Alongside the need for decarbonization, energy affordability and security of supply will be major factors determining the pace of change.

Numerous industries play important roles in electrification

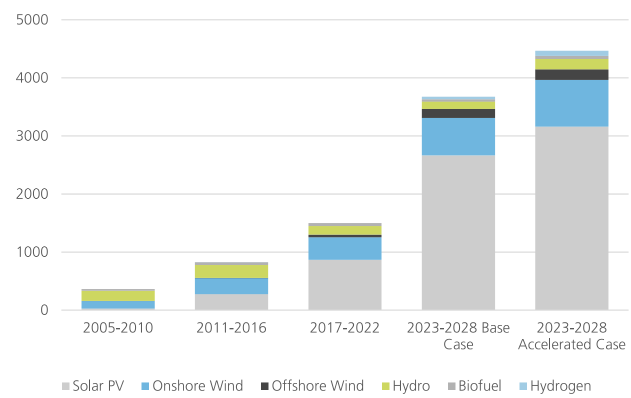
4. Prediction: Renewable technologies (especially solar and wind energy) will likely continue to **grow rapidly** and play a central role in the global power generation mix of the future, leading to a rising share of the global electricity mix.

Renewables

The development of renewable energy generation is key for advancing the world's decarbonization goals. The category includes hydroelectric, wind (onshore and offshore), solar, biofuel, geothermal, and ocean wave/tidal, though wind and solar are the most straightforward to deploy and scale. Government incentives backing the COP28 commitment to triple renewable capacity and significant deflation in equipment costs are aligning to support strong growth in wind and solar capacity.

Figure 7 - Growth in renewable capacity

In GW



Source: IEA Renewables Forecast 2023 https://www.iea.org/statistics. All rights reserved. UBS

Note: IEA Accelerated Case: projections aligned with achieving the COP28 energy goals. IEA Base Case: projections assuming more moderate progress compared to the COP28 goals

Despite the strong trajectory in renewable capacity, within an equities context, we advise investors to be selective in their participation, focusing on specific segments rather than the entire value chain, for several reasons. Challenging fundamentals persist across different pockets of renewables sector representation in public markets. Development of renewables projects is limited by substantial land requirements, financing rates, long queues to obtain access to transmission (five-year median wait in the US), required upgrades to grid management software, and more. Equipment makers face significant competition and geopolitical headwinds. According to the IEA, China alone will be able to supply the entire global market for solar PV modules, one-third of the global market for electrolyzers, and 90% of the world's EV battery demands in 2030. Tariffs, while providing short-term protection, risk further exacerbating structural oversupply issues in the long term.

From a bottom-up standpoint, we also see challenges in wind as major turbine manufacturers have struggled to fulfill sizable warranty obligations due to manufacturing defects. Operational restructuring and pricing discipline are beginning to stabilize turbine manufacturer fundamentals, but more progress is needed.

Despite these challenges, we see renewables growing most rapidly as a result of economics, with wind and solar remaining very cost competitive. For equity investors, we prefer the wind segment, but non-solar-panel equipment like racks and wiring harnesses are also interesting.

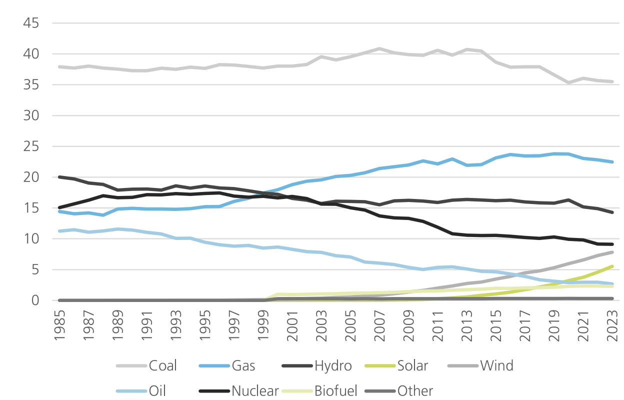
5. Prediction: While traditional **large natural gas power plants** should continue to play a major role regionally, the **power generation mix of the future will employ smaller power plants,** requiring more electrical equipment.

Fossil fuels and generators

Fossil fuels still account for more than 60% of global electricity generation. Growth in electricity consumption (amplified by electrification) and limitations on renewables' applicability are likely to keep fossil fuel demand on an uptrend over the next seven to ten years before alternative sources meaningfully "bend the curve."

Figure 8 - Global share of electricity generation

In %



Source: Energy Institute Statistical Review of World Energy (2024)

Fossil-fuel-based power generation plays a key role in the supply and stabilization of the energy grid. Coal, natural gas, and nuclear typically serve as sources of baseload or intermediate energy, while more flexible natural gas aeroderivative turbines or diesel generators serve to satisfy peak load demand. Baseload power is necessary to match electricity supply and demand and preserve stable electricity characteristics across the grid. Natural gas is seen as an intermediate step toward decarbonization in some developed regions, as it emits the least CO2 among fossil fuel types, whereas many emerging markets are likely to bypass this step in favor of renewables. Generators and microgrids—ideally clean ones—are increasingly important for residential use given the frequency of climate events. They are also critical for industrial and commercial facility uptime. Data centers, for example, typically install enough on-site diesel capacity to run the entire facility at full output if need be.

While not directly a driver of structural change in the power value chain, supply by fossil fuel plants will continue to play an important role in meeting electricity demand, offering resilience and facilitating the integration of cleaner solutions. For equity investors, we favor the gas-turbine segment of fossil-fueled generation, as natural gas generation is expected to grow rapidly.

6. Prediction: Transmission (high voltage) and distribution (medium voltage) will experience **one of the highest growth rates** in electricity grid investments in the coming years.

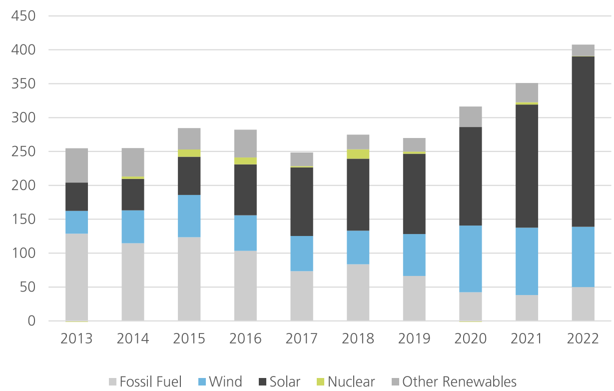
Grid equipment (high and medium voltage)

Even if the IEA's timeframe is ambitious, the direction and magnitude of spending is likely to be substantial, as rising electricity demand will require incremental investment in the power transmission and distribution grid. However, it is not the only driver of our constructive demand outlook. The integration of renewable energy generation (often in remote locations), the growth in cross-country transmission capacity, and the linkage of new power customers will require heavy investment in network infrastructure.

Renewable sources (including hydropower) already generate 21% of all electricity in the US and 44% in European Union, respectively, up from 13% and 27% ten years ago (EIA, Eurostat). Additionally, more than 85% of all capacity additions are attributed to renewable generation. The share of renewables in electricity production is rising, impacting the grid in two main ways: It requires the buildout of additional cabling infrastructure, and introduces instability in the grid's frequency.

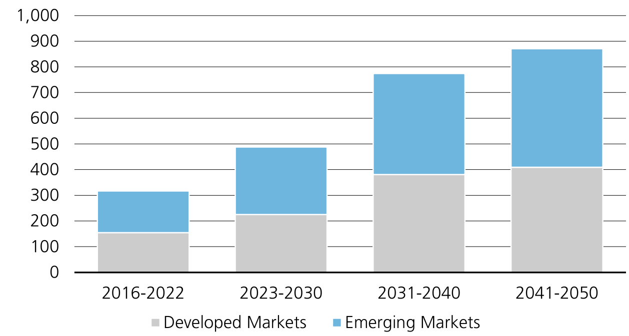
In practice, grid balancing is facilitated by transmission systems operators, which request electricity from generation facilities based on a marginal cost schedule and match it with downstream demand. This is still a fairly manual process, but modernizing the grid with sensors, digital technologies, and load management software will be vital to ease the workload and reduce inefficiencies. Illustrating the complexities of renewables and energy storage, digital technology investment comprises around one-fifth of total grid spend.

Figure 9 - Global electricity generation capacity additions
In GW



Source: BloombergNEF, UBS

Figure 10 - Average annual grid investment estimates under announced pledge scenario
In USD bn



Source: IEA, https://www.iea.org/statistics. All rights reserved. UBS

At the same time, the need to expand network infrastructure poses a troublesome bottleneck for renewable installations. In the US, the waiting time between connection request and commercial operation rose from a median of two years in 2000-2007 to five years for projects built in 2023 (Rand et al. (2022), Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection). In addition, siting and permitting of high-voltage transmission lines require navigating an exceedingly complex web of authorities, though provisions of the Inflation Reduction Act aim to speed the process. In Europe, where renewables permitting can take up to 10 years, the grid must also accommodate the increase in cross-border transmission capacity, with the European Commission targeting a total of 180GW by 2030, up from the 93GW in 2023.

Meanwhile, growth requirements aside, existing infrastructure in advanced economies is approaching the end of its lifecycle, which typically lasts 50 to 60 years. Around 40% of Europe's distribution grids are over 40 years old, while 70% of transmission lines in the US are over 25 years old (per EU Commission and US DoE, respectively). The transmission grid is younger than the distribution grid on average; however, there is a significant differential in construction lead time to consider. Transmission lines require an average of eight to ten years (for underground and overhead lines, respectively), while low-voltage distribution lines average only one year (IEA).

Based on the aforementioned factors, UBS anticipates 8-12% annual growth in grid investment spending through the end of the decade.

In the transmission and distribution category, we believe utility spending trends favor manufacturers of complex transformers, insulated switchgear, relays, high-voltage switches and breakers, substation automation solutions, cabling, monitoring devices, and grid management software. Participating companies have robust backlogs (with accretive pricing embedded) and strong visibility to utility capex plans, providing runway for margin expansion in the coming years.

We believe spending on transmission and distribution will represent the majority of global grid investment in both developed and emerging economies. Utilities will also need to invest in new generation capacity and squeeze the most from the existing footprint, supporting providers of gas, wind, hydro, and steam turbines, as well as maintenance/services and DCS automation.

7. Prediction: Electrical equipment, such as substations, switchgear, transformers, and circuit breakers, **will drive a significant increase in investment** to meet rising electricity demand.

Power distribution and conditioning equipment (medium and low voltage)

As electricity approaches the point of use, numerous additional layers of equipment are required to step down the voltage on premise, route it along the proper channels, and protect delicate componentry. Demand in this category is driven by many end markets undergoing electrification (several of which are discussed in later sections) and a sizable backlog of megaprojects fueled by fiscal support, leading to structurally higher top-line growth rates and smoothing bumps caused by timing on any single project.

Key beneficiaries include manufacturers of transformers, switchgear, power distribution units (PDUs), uninterruptible power supplies (UPSs), enclosures, connectors, wiring solutions, control devices, and more.

As mentioned in the previous chapter, particularly in advanced economies, much of the equipment is often outdated. Transformers, for instance, are a crucial part of the grid and have a lifespan of 30 to 40 years. The same applies to circuit breakers and other switchgear in substations. Underground or subsea cables have a longer lifespan, typically designed for 40 years, with newer versions lasting up to 50 years. Overhead transmission lines have the longest lifespan, lasting up to 60 years. These numbers are indicative, as servicing and maintenance can extend their lifespan (source: IEA, Electricity Grids and Secure Energy Transitions, October 2023). Considering the age of the equipment we described earlier, it is evident that significant grid components will need replacement and require ongoing service and maintenance capital expenditures. We therefore believe this presents a structural growth opportunity for firms in this sector.

Electric vehicle infrastructure

Though sales growth rates in any single country may vary year to year based on incentives, consumer preferences, and geopolitical developments, global electric vehicle adoption is steadily increasing.

The rise of electric vehicles is supportive for power and resources companies in numerous ways. Simply adding a single EV and a level 2 charger can increase a household's electricity load by 40% and necessitate electric panel replacement. EVs themselves include significantly more power electronics, including inverters, converters, batteries, charging components, and six times more minerals by weight than conventional cars.

The buildout of public charging infrastructure is another tailwind, as chargers have high content of electric componentry (enclosures, AC/DC converters, cables, connectors, etc.) and increase load on the grid. Indeed, a lack of available grid capacity is frequently the barrier to building EV charging stations. In 2021, the US set a goal of building 500,000 chargers by 2030, allocating USD 7.5bn of funding (though deployment has been exceedingly slow to date). The EU has built more than 570,000 chargers, while China has already topped 2.2 million.

Pacing factors throttle the speed of transformation

The growth of utilities, data centers, industrial plants, and other downstream electricity consumers typically depends on two key factors. First, they must secure the necessary power supply from grid interconnections. Second, they need to acquire the equipment required to connect and condition the electricity for use in sensitive, high-value components. In many cases, procuring these resources has limited the ability to capitalize on demand and keep expansion plans on schedule. The specific cause of bottlenecking has shifted over time, and we anticipate a rotating cast of gating factors going forward. Importantly, this is not necessarily undesirable—it can smooth the path of development, reduce the risk of overbuilding, and extend the duration of the tailwind from pent-up demand.

Electrical equipment represents one of the most significant constraints at present due to long-running underinvestment in manufacturing capacity and residual labor and supply chain issues caused by COVID-19. Electrical equipment markets historically grew slowly and exhibited little pricing power, so it had been decades since most manufacturers considered greenfield expansion. Moreover, labor shortages exacerbated shortfalls in production for intermediate components such as circuit breakers and leading-edge semiconductors. While conditions are gradually improving, customers still observe lead times of two to three years for three-phase transformers and 12-18 months for complex switchgear, which need to be installed at an early stage of a project's construction.

The major manufacturers of this high-voltage transmission, transformer, switchgear, and breakers are expanding production, spurring a steady drumbeat of public announcements. Even a major US steel manufacturer announced it would convert a tinplate mill into a transformer plant—a clear indication of asymmetric supply and demand, in our view. All considered, we believe key participants are likely to purposely undershoot current demand out of an abundance of caution about industry-wide capacity.

As clouds clear on the equipment side, we expect power generation capacity to become the next gateway. Demand from data centers, heat pumps, electric vehicles, and manufacturing facilities clashes with an increasingly strained grid, necessitating significant utility capex on generation and transmission infrastructure. For regulated utilities in the US, which must petition for higher customer rates to recover capex and are at risk of regulatory intervention if things go awry, the ability to service these customers may be many years away. Some utilities have even stopped accepting new service requests for large customers.

Sophisticated customers understand that a mosaic of solutions will be necessary to secure (ideally low carbon) power. This includes a mix of adjustments related to the grid's structure, such as power plant relocation, on-site generation, and microgrids. It also involves various mechanisms of power market function, including merchant power, power purchase agreements (PPAs), and take-or-pay contracts, while it may encompass the expansion of new forms of generation such as small modular nuclear reactors. This scramble for capacity is perhaps best exemplified by Microsoft's recent PPA to restart shuttered capacity at the Three Mile Island nuclear facility (the site of an infamous nuclear incident, albeit not the same reactor) and receive all output for 20 years. Customers' determination to source the long-term capacity they require, despite short-term constraints, represents another opportunity for *Power and resources*.

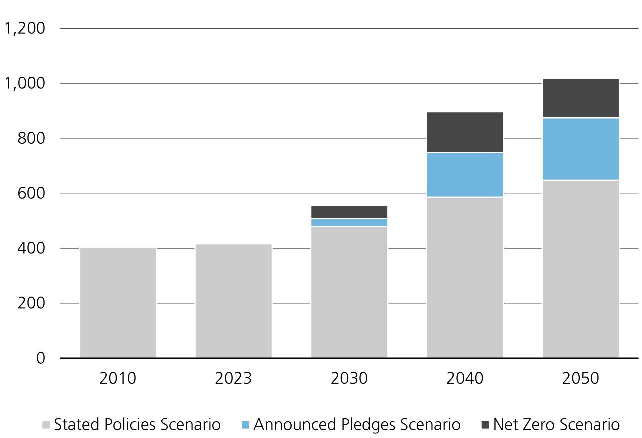
8. Prediction: Innovations in **nuclear technology** (e.g., small nuclear reactors, nuclear fusion) and **emerging technologies** (e.g., batteries and hydrogen) **will play an important role** in the energy mix of the future.

Nuclear

Nuclear plants generate emission-free electricity and are increasingly seen as a necessary contributor to a lower-carbon future. Illustrating this, the United Nations Climate Change Conference in 2023 (COP28) publicized a goal to triple global nuclear energy capacity by 2050. Per the World Nuclear Association, there are some 440 reactors in operation around the world today with an average age of 32 years, generating roughly 9% of electricity.

Figure 11 - Low-carbon electricity generation requires the installation of additional nuclear capacity

Global nuclear installed capacity estimates according to the different IEA scenarios, in GW



IEA World Energy Outlook (2024), https://www.iea.org/statistics. All rights reserved. UBS

Other than improvements to operating efficiency and passive safety systems, nuclear technology in the majority of the installed power plants has remained largely unchanged, making cost, environmental, and geopolitical concerns the primary gating factors for expansion. We expect greater utilization of existing nuclear plants as well as capacity growth in the coming years, supporting relevant utilities, producers of uranium and fuel rods, and nuclear plant automation providers.

Whereas traditional nuclear plants are highly bespoke endeavors, small modular reactors (SMRs) hold promise for providing 300MW or less of efficient on-site generation for steel mills, data centers, or other facilities. SMRs are intended to be highly standardized and manufactured at scale, lowering installation costs meaningfully. The idea is that smaller, self-contained, and standardized nuclear plants could be deployed faster, more economically, and on smaller sites. The International Atomic Energy Agency (IAEA) defines "small" as below 300MW. Contracts are beginning to flow, though deployment beyond pilot projects is likely to be in the 2030s at the earliest.

Nuclear fusion has been studied for over 50 years. But despite an understanding of the process, scientists have struggled to generate more energy than it took to start the fusion process. In December 2022, for a fraction of a second, the Lawrence Livermore Laboratory in California performed a fusion experiment that produced about 1.5 times more energy than it took to start the fusion process. Though certainly a promising breakthrough, we view commercial applications of nuclear fusion as realistically a decade away as an energy technology

For equity investors, investing in nuclear is more challenging. We prefer existing operators for expansion opportunities, while SMR players bear higher risks.

Battery storage

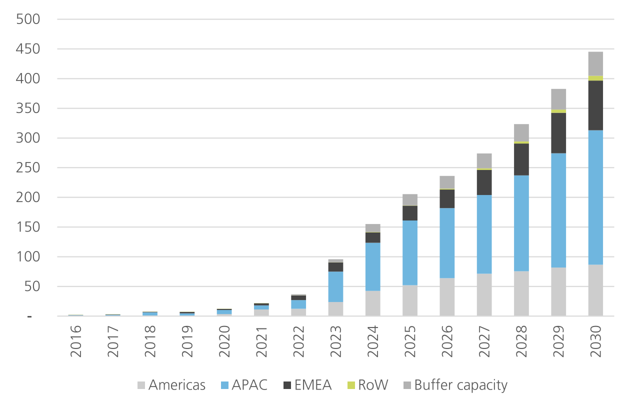
Homeowners with installed solar panels are likely familiar with residential energy storage units, which allow them to store surplus solar electricity for backup and avoid peak electricity pricing. Utility-scale battery storage can facilitate the integration of intermittent renewables as well as buffer supply/demand imbalances on the grid by reacting as quickly to changes or outages as a power plant.

Energy storage introduces logistical hurdles as grids were not optimized for energy storage, making integration, regulation, and grid planning more complex. Lithium-ion batteries have high energy density but degrade with time—they have a limited useful life of ~10 years—and are expensive when used as long-duration supply. Standard lithium-ion batteries provide only a few hours of power, though early-stage technologies such as flow batteries and metal-air batteries hold promise for greater longevity.

Battery manufacturers also face additional risks, including the availability of critical minerals and the manufacturing (over)capacity from competitors. Per BloombergNEF, in 2023, the production of new batteries (across both EVs and stationary storage) from China alone was roughly equivalent to total global demand, while the average cost of a two-hour storage system in China was down 43% y/y in early 2024. Even with government incentives in the US and Europe, it will be challenging for developed market battery manufacturers to compete.

Figure 12 - Installed energy storage capacity

Estimated values for 2024-2030. In GW

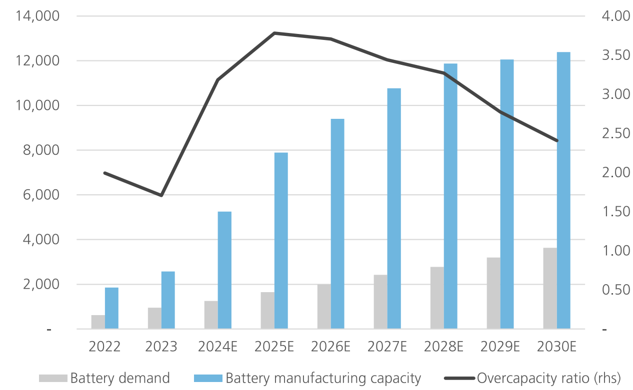


Source: BloombergNEF 1H24 Energy Storage Market Outlook

Nonetheless, as renewables deployment continues at a rapid clip, the stark shortfall in global energy storage capacity should continue to spur both policy support and investment. COP29 aims to seal a global pledge to increase installed energy storage capacity to 1,500GW by 2030, or 6x the 2022 level. Although we expect battery investments to grow rapidly, similar to solar panels, we believe this segment carries above-average risks.

Figure 13 - Battery manufacturing capacity far exceeds demand

In GWh



Source: BloombergNEF 2023 Global Battery Manufacturer Profile

Hydrogen

The present scalability of hydrogen is limited by market demand, with hydrogen being primarily used for oil refining, metal processing, and ammonia production for fertilizer. Other applications include hydrogen-powered vehicles, bunker fuel, feedstock for sustainable aviation fuel, green steelmaking, and the reduction of emissions from fossil fuel-based power plants.

Equally, the source of hydrogen also drives the longer-term demand potential. Currently, 96% of hydrogen is produced from fossil fuels (or so-called "grey" hydrogen). "Blue" hydrogen, produced from hydrocarbons, mainly natural gas, where CO2 is captured and not released in the atmosphere, also appears viable, as post-subsidies pricing can approach grey. Meanwhile, "green" hydrogen (produced by splitting water molecules in an electrolyzer powered by renewable energy) remains scarce and constrained by renewable capacity. It takes roughly 40-50kWh of electricity to produce 1kg of hydrogen. Requirements are immense; for example, the green hydrogen project at Saudi Arabia's NEOM requires 300km2 of land for wind and solar to produce 4GW of electricity. Therefore, green hydrogen should command a substantial premium, though this would be capped somewhat by European carbon tax levels.

Hydrogen is attractive as a means to decarbonize legacy fossil fuel infrastructure, power hard-to-abate sectors such as steelmaking, and in the case of green hydrogen, it can also function as transportable energy storage to alleviate power consistency concerns (e.g., in long-haul commercial vehicles or as feedstock to sustainable aviation). It therefore enjoys widespread policy support. The US Inflation Reduction Act includes a clean hydrogen tax credit for ten years, scaling from USD 0.60/kg to USD 3.00/kg depending on emissions. The EU has also pledged to produce 10mn and import 10mn tons of green hydrogen by 2030. The COP29 Hydrogen Declaration pending passage at the UN Climate Change Conference aims to harmonize global standards and may help resolve demand bottlenecks. Hydrogen could play an extensive role in the energy mix, but low-carbon forms of the fuel still remain expensive. This technology contains higher risks for investors, in our view.

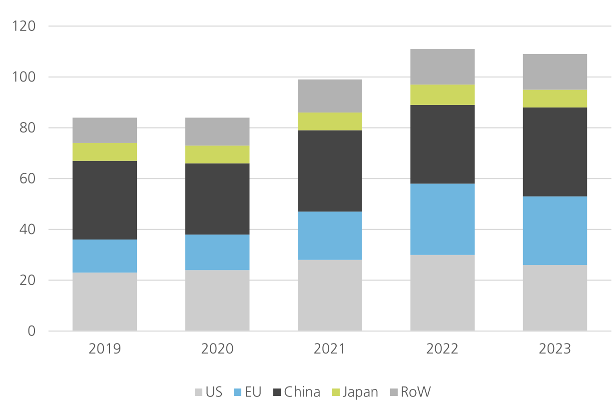
Heat pumps

Heating and cooling is the largest use of global energy consumption and is responsible for roughly 40% of CO2 emissions. Traditional air conditioning radiates heat to the outdoors, raising environmental temperatures and requiring more air conditioning, creating a vicious cycle.

Heat pumps running solely on (ideally renewably sourced) electricity are the most practical choice to achieve decarbonization targets. The IEA believes a tripling of the 2021 install base (~9%) has the potential to cut fossil fuel use in half by 2030. In brief, heat pumps use electricity to operate a reversible refrigerant circuit, which transfers existing heat from outdoors to indoors, or vice versa, to provide both heating and cooling.

Figure 14 - New heat pump sales

In GW



Source: IEA Clean Energy Market Monitor 2024, https://www.iea.org/statistics. All rights reserved. UBS

Heat pumps have pros and cons relative to traditional furnaces and air conditioners. The system can transfer more than three times the heat per unit of power and, as mentioned above, is emission-free if linked to green energy. However, the upfront cost of installation is high before incentives (~4x a natural gas furnace), making the value proposition less compelling when retail electricity prices exceed those of fossil fuels. To mitigate this, more than 30 countries currently offer incentives. Heat pumps also struggle to cope with especially high or low temperatures, limiting the range of latitudes and circumstances in which deployment is practical (though innovation is widening the bands).

We expect the install base of heat pumps to rise, albeit with year-to-year volatility. Residential heat pumps use approximately 5.5 MWh of electricity per year on average, implying ~550 TWh of electricity use on 2022 install base metrics. Rising adoption of heat pumps, in tandem with EVs and other needs, represent an added strain on the grid and additional impetus for renewables integration.

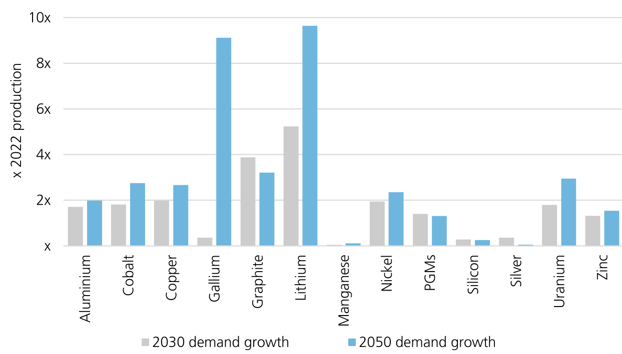
9. Prediction: Demand for natural resources (copper, aluminum, etc.) will increase, requiring the identification and commercialization of new supplies.

Raw materials

Natural resource markets (copper, aluminum, lithium, etc.) will likely tighten further as strong demand intersects with supply bottlenecks in production and processing and new projects become harder to identify and commercialize. Indeed, access to stable and accessible supplies of critical metals is key to the rapid deployment of transition energy technologies—especially those related to infrastructure and energy storage. In addition, AI data centers (and growth in electricity consumption) could lead to even higher metal demand than expected. If we assume copper intensity of around 65 metric tons (mt) per MW of data center capacity and 15% annual growth in data center installation between now and 2030, this could see incremental demand of about 100,000 metric tons of copper per year, according to UBS analysis. According to the IEA, global demand for some metals will rise by nearly 10 times versus 2022 production in the decades ahead.

Figure 15 - Demand for some metals is expected to 10x by 2050

Demand growth vs 2022 production



Source: IEA, https://www.iea.org/statistics. All rights reserved. US Geological Survey, UBS

So, with future technological solutions heavily dependent on raw material markets that are comparatively small or concentrated along the small chain, risks of minor shortages are likely to emerge and could cause severe dislocations. Copper is a good example: The IEA and S&P Global Market Intelligence estimate cumulative primary copper demand over the next 30 years will be around double the amount consumed in the previous 30 years. But such an increase in supply over such a short time has never been seen before. And even if copper prices remain at higher level, it takes a decade or more to build a greenfield mine and the cost to do so is significantly higher than in the past.

Another example is the aluminum supply chain. Guinea holds nearly a quarter of the world's known bauxite reserves (according to US geological survey), which is a critical raw material to produce alumina (and subsequently aluminum). Aluminum is a key material used in the construction of high-voltage power transmission lines. A disruption to shipping of bauxite saw its spot price rise almost 50% year over year. This highlights the issue at hand: If alumina producers face shortages of bauxite, a commodity that usually flies below the radar, this would quickly feed through downstream, exacerbating supply chain issues.

So, with such rapid growth in demand, we believe a new super cycle has emerged. Miners need to boost capex to raise supply, and government support is required to alleviate concentration risks along the supply chain. Some of these challenges are geopolitical, while others are more geological and climate related. On the geopolitical side, the supply of metals that are critical to the energy transition are a key risk to the West as processing is highly concentrated in China. Moreover, unlike previous booms, miners seem content to maintain recent capital discipline. As such, returns on mining and new production technologies, which could unlock ores not previously processed economically, could rise to levels not seen since the early 2000s.

10. Prediction: Electrification should increase efficiency, reduce pollution, and lower carbon emissions. It should also increase the standard of living globally, particularly in emerging markets.

Sustained regulatory and fiscal support is key

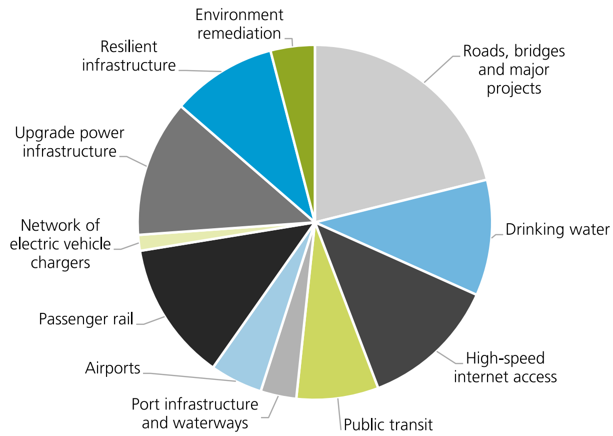
Governments around the world acknowledge the necessity of decarbonization to facilitate the energy transition, mitigate risks from climate events, and support economic growth. Consequently, they recognize the need to invest in energy infrastructure and grid resilience. The White House notes that power outages alone are a ~USD 70bn annual drag on the US economy. Moreover, the severity of damage from crises, such as the winter storm in Houston that halted power for days and fires sparked by power lines in California and Maui, lays bare the consequences of neglecting spending on resilience. To this end, significant funding has been made available to support public and private sector investment.

In the US, the Infrastructure Investment and Jobs Act (IIJA) of 2021 marked the largest investment in the country's history in clean energy infrastructure, allocating USD 65 billion to build transmission lines, support nuclear facilities, advance clean energy technology, weatherize building stock, incentivize domestic manufacturing of clean energy equipment, and build out a nationwide EV charging network. Subsequent announcements illustrate that this funding is being put to work and exhibiting the intended multiplier effect in private spending.

We believe the benefits of the IIJA will remain a tailwind for many years, with the tempo smoothed by labor constraints among municipal offices and construction contractors. Moreover, we do not anticipate a 'cliff' from the conclusion of IIJA support, given the implausibility of paring back sorely needed infrastructure investment when it is politically popular and supports employment.

Figure 16 - The Infrastructure Law will support a number of end markets

Spending share in each market under the Infrastructure Investment and Jobs Act (IIJA)



Source: The White House (whitehouse.gov)

Additional incentives to encourage industry development appear in other major US legislation as well. The Inflation Reduction Act (2022), built on the IIJA, appropriates nearly USD 400bn to incentivize the adoption of cleaner and more efficient vehicles, fuels, batteries, and residential appliances, as well as upgrade energy infrastructure. Blue and green hydrogen production, sustainable aviation fuel, electric vehicles, nuclear power, and heat pumps are significant beneficiaries as well. The CHIPS Act is primarily focused on research and development in the semiconductor industry but also supports the expansion of semiconductor manufacturing in the US. Semiconductor fabrication plants are heavy users of electricity and electrical equipment for stringent process control and temperature / humidity management.

In Europe, policy was initially guided by the Clean Energy for All Europeans package (2019), which promoted the reduction of building emissions and ramping renewable energy mix, and then the European Green Deal (2020), which set the target of carbon neutrality by 2050. Recognizing the need to speed progress toward EU climate neutrality by 2050, the Renewable Energy Directive was revised in 2023, setting a binding minimum renewable energy goal of 42.5% by 2030 and an 18-month time limit to embed most details into members' laws.

The EU Commission initiated a narrower Action Plan for Grids in late 2023, noting that EUR 584bn of incremental grid investment is needed to support electrification and outlining a 14-step proposal to improve capacity, automation, financing, and permitting. This is not binding from a legislative perspective but does assign responsibilities to task forces for implementation. In addition, threats to energy security from the Russia/Ukraine conflict prompted the REPowerEU plan, which mobilized nearly EUR 300bn to overcome dependency on fossil fuel.

China spent USD 676 billion on the energy transition in 2023 alone based on Bloomberg data, more than double of any other nation. Supplies of renewable equipment in China are surging, given significantly lower manufacturing costs than in the US or Europe. China has committed to 1.2TW of renewable capacity by 2030 and is well on the path to meeting that goal years ahead of schedule, which comes with sizable investment in high-voltage transmission as well.

Zooming out to a global level, the United Nations Climate Change Conference in 2023 (COP28) called on members to transition from fossil fuel energy sources "in a just, orderly, and equitable manner" and "accelerate efforts globally toward net zero emission energy systems… well before or by around mid-century." Per IEA tracking, 98 countries have made pledges to reach net zero via announcements (15), policy documents (56), or outright law (27) as of this writing, representing 86% of 2021 energy-linked emissions. These commitments are ambitious and enforcement mechanisms are limited, but any progress in this direction should be supportive for the industry participants facilitating the transition.

While pledges and policy are helpful, they also demonstrate the need for financing support and incentives to prod industry to make investments. The reversal of subsidy programs or even the perceived threat of reversal due to changing political priorities may introduce uncertainty into long-term planning and willingness to commit capital. Altering incentives can also affect return profiles for long-lived capital projects. As a result, the supportiveness of policy is a key swing factor influencing the timing and magnitude of the profit opportunity for participating companies.

Longer-Term Investment themes

In our Longer-Term Investment (LTI) research series, we have published several themes that directly or indirectly benefit from the developments described in this report, such as our *Energy transition(s)* or *Energy efficiency* themes. Scarce resources are not limited to the mining and power market; they also encompass our other long-term investment topics in the water and food sectors.

SI consideration

Clean electrification lies in the heart of the global decarbonization challenge. This is a two-step process: First, electrify everything and consolidate power needs away from direct fossil fuel use—think internal combustion engines and gas boilers. Second, rapidly modernize the grid—not only in terms of how it's powered, but also the flexibility to switch and manage shifting fuel sources, for example. Achieving both would be key to mitigating the high correlation between GDP growth and carbon emissions.

From an equity standpoint, investing directly in solution providers whose products and services may have clear alignment with the UN Sustainable Development Goals (SDGs). Under SDG 7: Affordable and Clean Energy, specific targets emphasize energy accessibility (and it's worth bearing in mind here that natural gas remains superior to biomass and coal), expanding renewable energy's share of total power generation, and energy efficiency. Investments into modern, sustainable energy infrastructure, including resource efficiency solutions such as carbon capture, utilization and storage, is a specified target under SDG 9: Industry, Innovation and Infrastructure. This is especially important for solutions targeting emerging markets, where the investment shortfall is the widest.

These investments may be aligned to an ESG thematic strategy. Investors seeking credible alignment to these SDGs may consider emerging sustainability data. A caveat, however, is that some investment opportunities and impact may stretch well beyond the SDGs and associated datasets —which, ultimately, were designed to be achieved by 2030.

Beyond the SDGs, investors prioritizing holistic sustainability and impact alignment may also consider life-cycle analyses and companies' operational sustainability to ensure holistic alignment. Systemic thinking is crucial. Over 60% of electricity consumed today remains powered by unabated fossil fuels—switching to an electric vehicle may have limited impact if your grid is burning coal.

Risk considerations

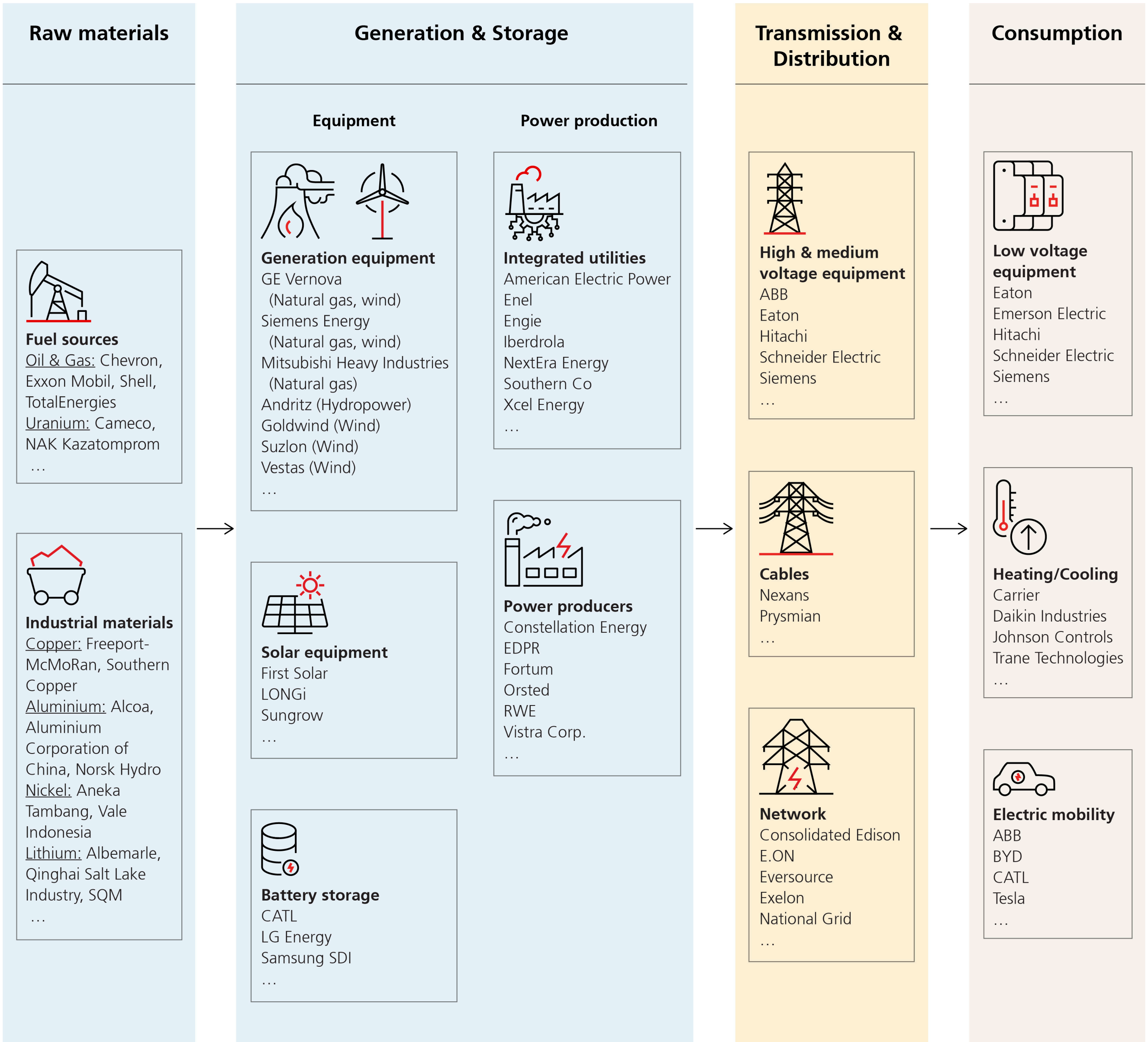
There are a number of risks to consider when investing in this theme. Regarding equipment, risks include lumpiness in customer projects or ordering patterns, the likely burndown of elevated backlogs as lead times decrease, challenges associated with matching manufacturing capacity to demand, and a potential mismatch between pricing and input costs during periods of high inflation. Grid service providers are also subject to the timing of project development and inflation.

Materials providers typically carry high volatility and can move quickly with small changes in sentiment or positioning, or new technology could render the underlying commodity unnecessary for a certain purpose. Utilities may face scrutiny from customers or regulators over pricing or adverse events, or an inability to meet customer demand. The broader theme involves risks associated with geopolitics, commodity prices, electricity prices, government policies, incentive changes, and other external factors.

The outcome of the US election, with Donald Trump set for a second term, suggests a neutral impact on energy sectors, in our view. Trump's focus on encouraging US fossil fuel production is unlikely to materially change US output trends. While he may recognize the economic gains from the 2022 Inflation Reduction Act, there could be some reductions in clean energy tax breaks, and he may introduce new import tariffs, which could slow renewable energy expansion at the margin.

Offsetting this impact is rising electricity demand from AI data centers and industrial activity reshoring, both of which are likely to continue to encourage renewable-, nuclear-, and natural gas-fueled electricity generation expansion. In short, Trump's policies could be slightly negative for renewable energy but somewhat supportive of traditional energy like oil and natural gas, leading to a neutral overall effect on the energy theme.

Figure 17 - The electrification value chain – illustrative with select companies



Source: Based on Factset business classification system (RBICS) and UBS analysis as of Nov 2024

Note: This is for educational purposes only. For investment ideas and our stock picks, see our companion report.

Appendix

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