GE VERNOVA

REACHING NET ZERO CARBON IN UNITED ARAB EMIRATES

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EXECUTIVE SUMMARY

GE Vernova has modelled a least-cost, credible pathway that results in 156.6 GW of renewable generation, decarbonized thermal generation, and energy storage by 2050.

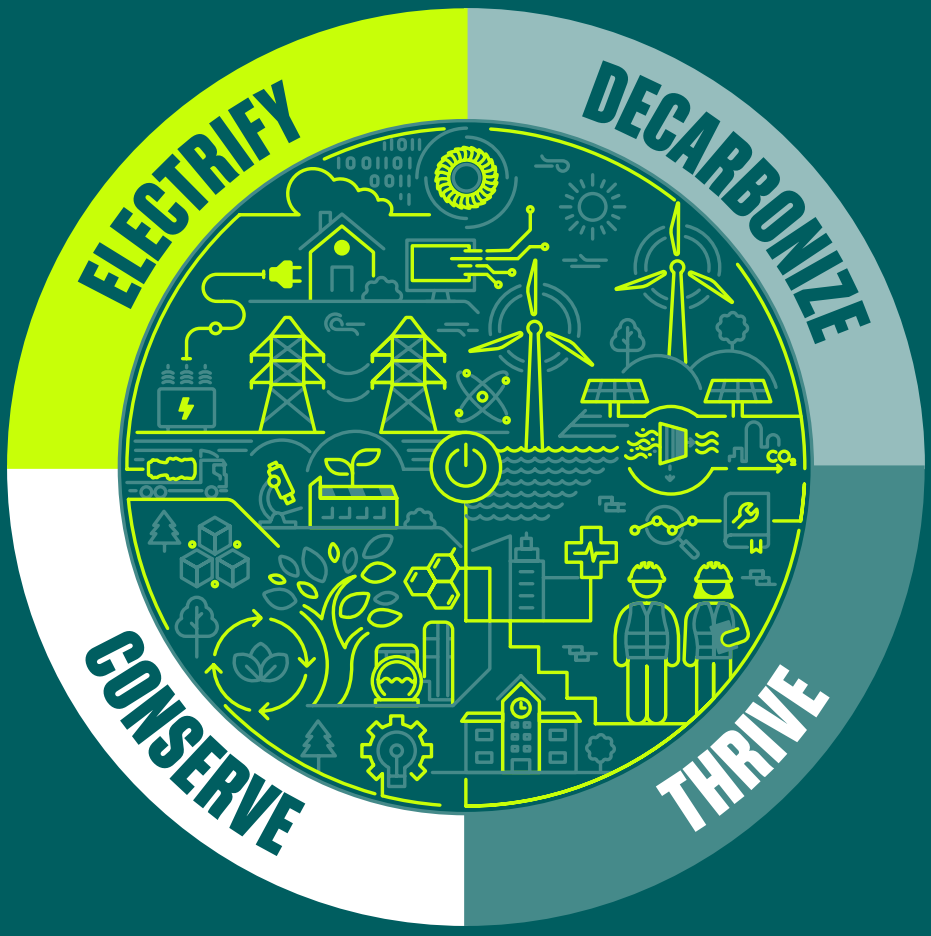
In the face of escalating global climate challenges, nations worldwide are increasingly embracing the imperative of transitioning towards net-zero carbon emissions. While many nations are working to do their part, the UAE is leading by example through the UAE Energy Strategy 2050, a strategic initiative to achieve net-zero emissions by 2050 established by the Ministry of Energy and Infrastructure (MOEI)[1].

Achieving this ambitious target requires action-focused analysis to inform decision makers on market mechanisms that will incentivize investment in the right generation technology. For this reason, GE Vernova studied the UAE's existing energy portfolio and has identified a potential technology investment scenario that could enable the country to meet their net-zero goals.

The UAE is projected to see a 78% growth in electricity demand by 2050. Factors contributing to this demand growth include increasing adoption of electric vehicles, transitioning desalination operations toward electricity-dependent reverse osmosis, and the overall growing electrification of industrial sectors. In order to meet this projected demand while achieving its zero-carbon goals, the UAE must invest in expanding its lower-carbon capacity.

This study presents one potential scenario that would enable the UAE to meet their projected demand and decarbonization goals. In this scenario, GE Vernova has modelled a least-cost, credible pathway that results in 156.6 GW of renewable generation, decarbonized thermal generation, and energy storage by 2050 with the following recommended capacity breakdown:

- 85 GW of solar PV
- 31 GW of open cycle gas turbines (OCGT) running on green hydrogen fuel
- 21 GW/84 GWh 4-hour battery energy storage systems (BESS) to balance the variability of solar
- 14 GW of combined cycle gas turbines (CCGTs) with carbon capture and storage (CCS)
- 5.6 GW of nuclear



INTRODUCTION

In 2023, the United Arab Emirates (UAE) led the fight against climate change as host of the 28th United Nations Climate Change Conference (COP28) in Dubai. In 2015, at COP21, the world came together to enact the Paris Agreement, an international treaty with the aim to limit global temperature rise to 1.5°C compared to pre-industrial levels[2]. According to the UN's Intergovernmental Panel on Climate Change (IPCC), achieving this will require a 43% reduction in global emissions by 2030[3]. This target date is quickly approaching.

While many nations are working to do their part, the UAE is leading by example through the UAE Energy Strategy 2050, a strategic initiative to achieve net-zero emissions by 2050 established by the Ministry of Energy and Infrastructure (MOEI)[4]. With over $40 billion invested in the electricity sector to date[5], the UAE has already made considerable progress toward achieving their target. This includes:

- Developing the 5.6 GW Barakah Nuclear Power Plant, which will prevent 21 million ton of CO_2 emissions annually
- Developing around 7 GW of solar PV
- Improving the generation and transmission efficiency of the energy system
- Initiating the decoupling of desalination and power generation through adoption of Reverse Osmosis (RO) technology

The UAE is looking to go further by adding 19.8 GW of renewable energy capacity by 2030. This would enable 30% of the total installed capacity in the UAE to be clean energy and reduce the grid emission factor from 0.556 $KgCO_2$/KWh in 2021 to 0.27 $KgCO_2$/KWh in 2030.

To facilitate discussion regarding the UAE's potential decarbonization pathways, GE Vernova studied how the electric sector could potentially achieve net-zero emissions.

METHODOLOGY & KEY ASSUMPTIONS

The UAE's electricity and water sector makes up more than 60% of the country's total carbon emissions[6] and plays a critical role in its future decarbonization strategy.

1. Decarbonize electric supply. UAE can shift its electric generation to lower carbon technologies such as renewables, nuclear, hydrogen and carbon capture and storage. Thus, consumers can plug in to a cleaner electric mix.

2. Plug it all in! UAE can decarbonize transportation and industrial applications by electrifying vehicles and major industrial sectors such as desalination.

This study presents a credible least-cost UAE investment pathway to meet decarbonization goals. Secondly, it serves to illustrate how power plants under this pathway could operate to meet demand in the future and how it may impact the grid.

The analysis has been conducted with a zonal model of the UAE. This model assumes that the UAE operates as a wholesale electricity market using least-cost security constrained unit commitment (SCUC) to serve load for each hour of the day.

UAE Electricity Transmission Zones

The model incorporates all existing, grid-serving, power plants on the UAE system, with electricity demand and generation capacity modelled in four separate utility zones as shown in Figure 1. These zones are meant to represent the separate utilities that operate within the country, including Emirates Water & Electricity Company (EWEC), Dubai Electricity & Water Authority (DEWA), Sharjah Electricity, Water, and Gas Authority (SEWA), and Etihad Water & Electricity (EWE). A simplified representation of the internal transmission capability between neighboring utilities has been considered using data from Abu Dhabi Transmission & Despatch Company (TRANSCO)[7]. While potential benefit exists from energy sharing with neighboring countries, based on recent data published by local utilities[8], imports and exports of electricity using interconnections with the Gulf Cooperation Council (GCC) have been excluded from this study due to low net trading volume.

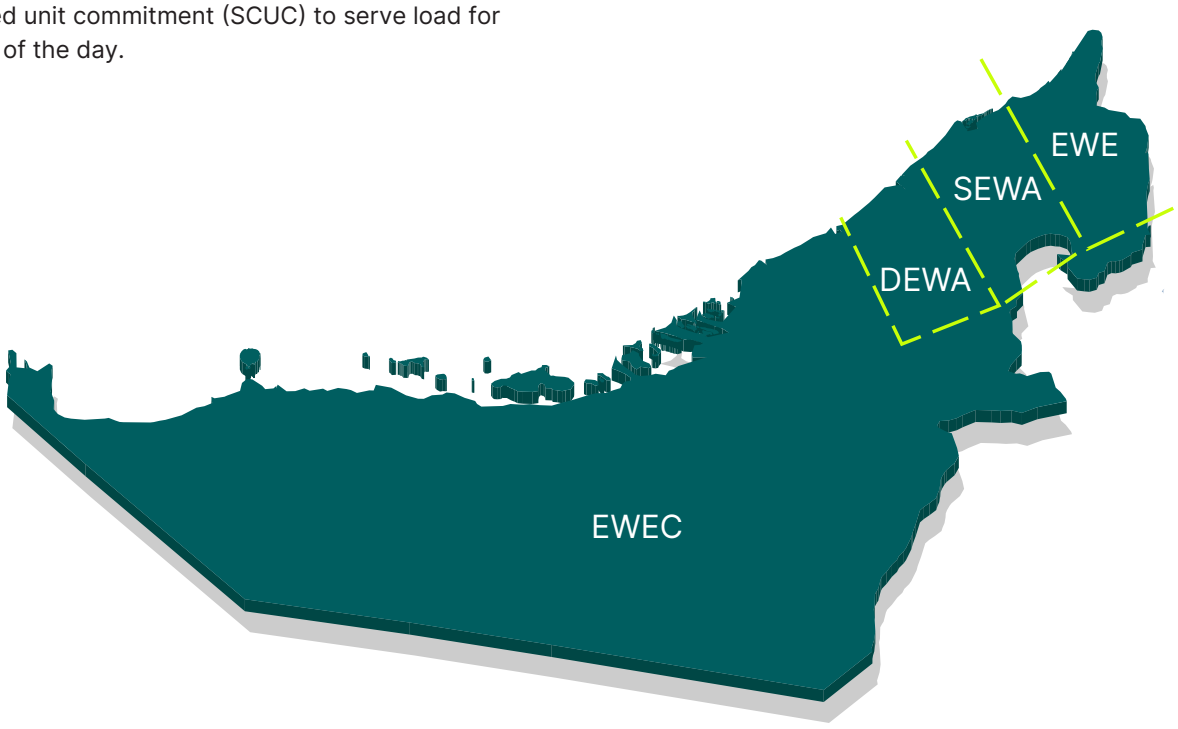


Figure 1 - UAE Utility Zones

Electricity Demand

The electricity demand forecast for the UAE uses a multi-variable regression analysis that considers historical electricity requirements published by utilities (both peak and energy), and both historical and future economic growth (GDP) and population published by Oxford Economics[9]. Therefore, future demand for 2023-2050 is primarily driven by forecasted GDP and population.

Demand for water desalination and light-duty vehicle electrification has also been incorporated as separate, but additional loads, and are described in the following sections of this report. In total, the combination of the regression analysis, water desalination, electric vehicles, and ADNOC and EMAL electrification results in a peak forecast for the UAE that grows from 34 GW in 2025 to 61 GW in 2050, and an energy forecast that grows from 187 TWh in 2025 to 332 TWh in 2050 – a 78% increase in load over the forecast period at a compound annual growth rate of 2.2%, shown in Figure 2.

Water Desalination

Water and power in the UAE are commonly cogenerated – waste steam from power generation is used for water production via thermal desalination. This method is energy intensive and can cause imbalances in demand, especially in the winter when electricity demand is low, but water demand remains high.

To reduce emissions from water production, while carbon capture is a potential solution, the consensus at EWEC is to decouple power and water production[10]. To achieve this, EWEC is rapidly expanding its Reverse Osmosis (RO) capacity, a desalination process that is both more energy efficient[11] and more economical[12] than Multi-Stage Flash Distillation (MSF) and Multi-effect distillation (MED). EWEC expects that, by 2030, 90% of its water production will use RO. While the decoupling of power and water is not specifically mentioned in the UAE Water Security Strategy 2036, following the lead of EWEC, our model assumes this decoupling, and a significant uptake in RO technology, occurs in all utilities by 2036.

Regarding the specific modelling method, energy required for desalination is reported by most utilities (EWEC, DEWA, SEWA) through annual statistical reports. In some instances, this data is reported on a plant level and others at the utility level. The model uses this data to estimate plant-specific desalination loads that are co-located with their specific generation resources. This relationship is conserved until 2030 in EWEC, and until 2036 for the remaining three regions, when the model assumes power and water decoupling, and moves to a zonal desalination electricity demand represented by new RO facilities. Energy consumption from desalination was quantified using reports from local utilities or, where limited data is available, estimated based on desalination capacity.

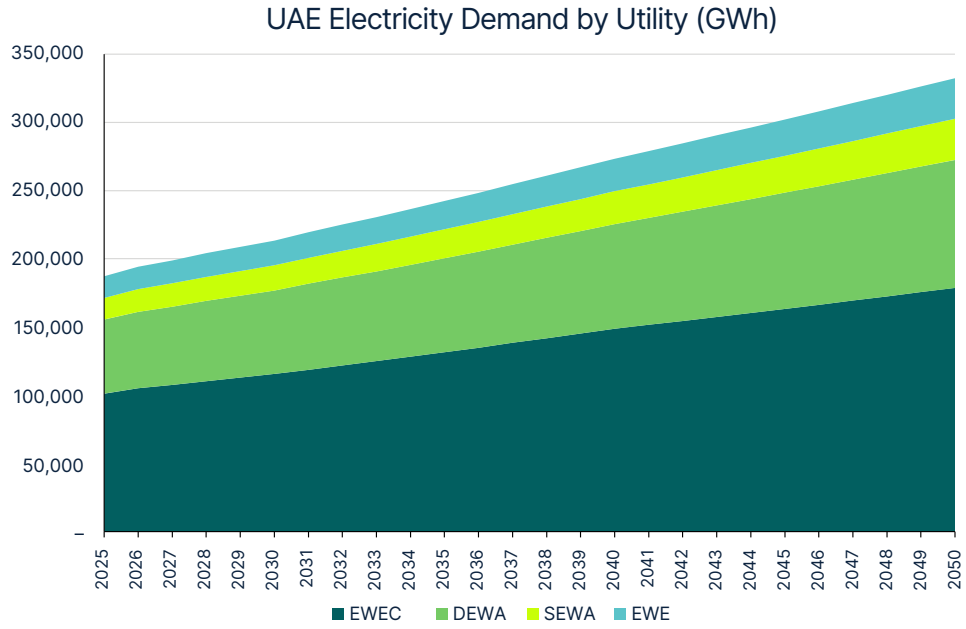


Figure 2 - UAE Utilities Forecasted Demand Growth

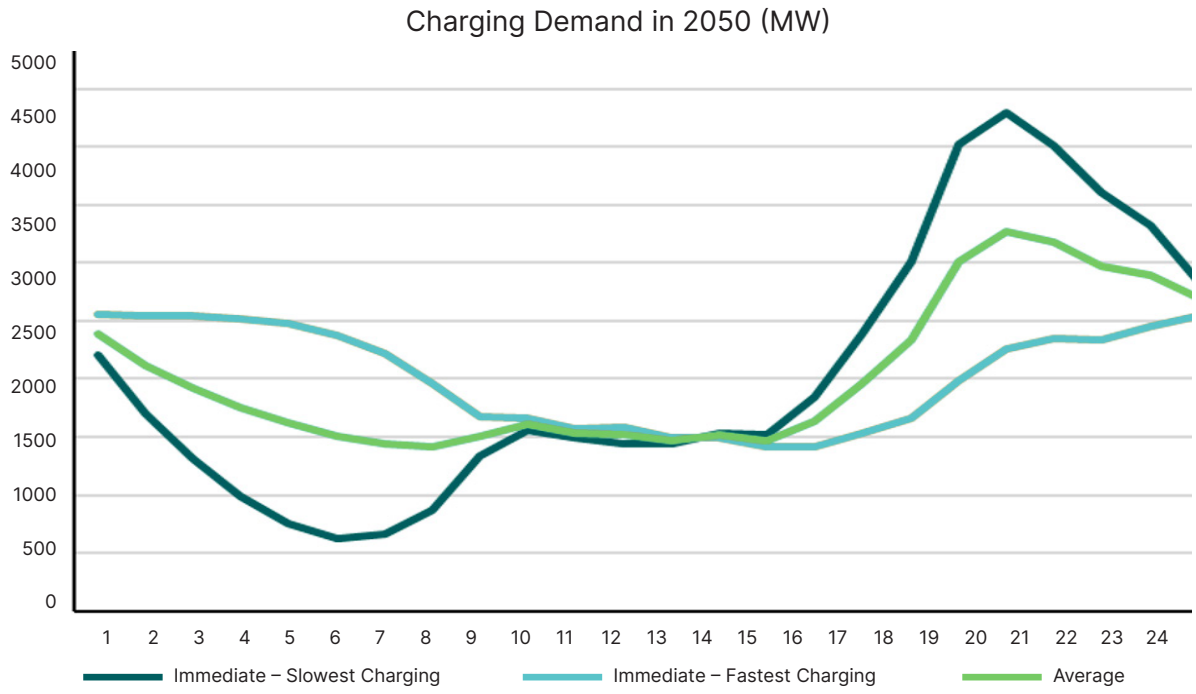


Figure 3 - 2050 Weekday Electric Vehicle Charging

Vehicle Electrification

As part of the Energy Strategy 2050, the UAE has announced Green Mobility[13] objectives that highlight their goals for electric vehicle adoption. These objectives lay out specific targets for both electric and hybrid vehicles and buses. For example, UAE expects the share of electric and hybrid vehicles to be 53% by 2050.

Since electric vehicle adoption will have a significant impact on electricity demand, GE Vernova used the Green Mobility data and available industry tools, to estimate this impact and incorporate it in the model.

Focusing on passenger vehicles only, thus excluding buses, GE Vernova used the Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite, available from the U.S. Department of Energy and developed with the U.S. National Renewable Energy Laboratory (NREL) and the California Energy Commission, to develop for EV charging demand. Given inputs for electric vehicle fleet size, adjusted for annual UAE vehicle projections, the tool provides hourly weekend and weekday charging profiles.

EVI-Pro provides multiple charging strategy options as an input to the tool, including “Immediate – as fast as possible” and “Immediate – as slow as possible (even spread).”[14] The assumption adopted for EV charging uses an average of both scenarios which can be shown in Figure 3, specifically for 2050. The demand from EVs is in addition to demand from the previously described regression model.

Fuel Price

According to the National Hydrogen strategy published by the MOEI[15], UAE plans to become a leading producer of hydrogen, with plans to produce 1.4 million tons per annum (MPTA) by 2031 and 15 MPTA by 2050. In the short term, hydrogen is expected to be exported to global markets and consumed locally in hard-to-abate sectors, like steel, aluminium, and other chemical processing sectors. However, as the price of hydrogen drops, we recognize that hydrogen can also play a key role in a net-zero power sector, specifically for open-cycle gas turbine (OCGT) units that provide dispatchable capacity at hours of peak demand net of solar generation.

Hydrogen prices are based on numbers reported in the Global Hydrogen Review 2022 published by the IEA[16]. It assumes a green hydrogen price of $1.5/kg by 2030 which drops to below $1/kg by 2050.

Oil prices used in the model are based on forecasted data from IHS Markit and is linked to Brent, FOB North Sea. Natural gas prices are also linked to the Brent, FOB North Sea pricing in the short term, with a shift to Henry Hub growth in the long term. This is driven by historical natural gas production in the Middle East being associated with oil production. However, UAE has made noteworthy progress toward building its own domestic gas supply.

Renewable Energy Resource

The hourly solar and wind generation profiles for the four different utility zones was modelled using NREL's geospatial and solar irradiance database[17]. The average capacity factor of the four utility profiles is 22% for solar and 17.7% for wind.

Lower carbon Technologies

Beyond 2030, all new capacity additions are assumed to be built based on economics, emissions targets, and a realistic level of build rate for the UAE. The candidates considered in this study are listed in Table 1.

Lower Carbon Technologies	Size (MW)
CCGT with CCUS	400
OCGT (H2 ready)	300
Wind	100
Solar	100
Battery (1-hour storage)	100
Battery (4-hour storage)	100
Nuclear SMR	300

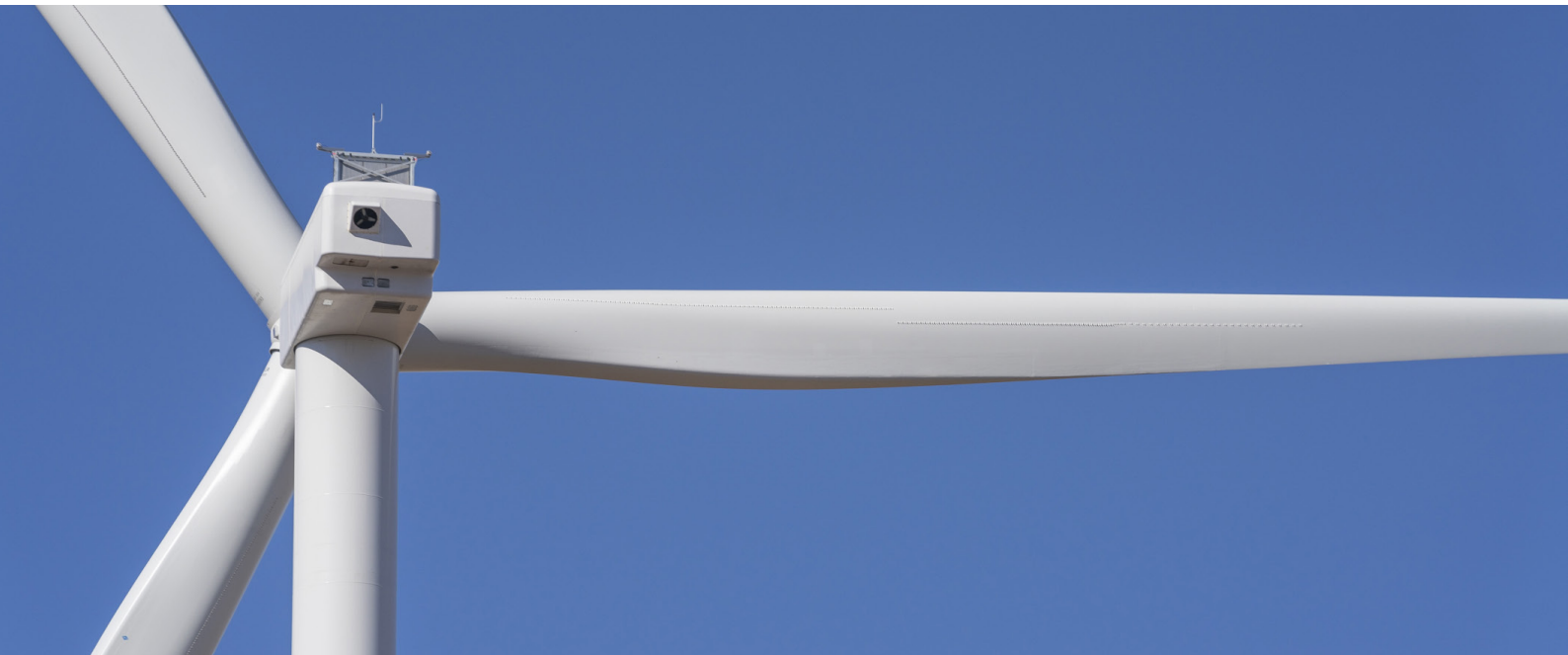
Table 1 - New Capacity Candidates

The model allows for new Combined Cycle Gas Turbine (CCGT) plants integrated with CCS and new Open Cycle Gas Turbine (OCGT) units capable of operating on hydrogen. We assume CCS will capture 95% of CO_2 emissions and that the combustion of hydrogen is CO_2 free using green hydrogen.

Further research on upcoming retirements of existing units has also been included. Beyond this research, existing capacity and built capacity are assumed to have a technical life of 25 years, after which they are retired and can be replaced. The exception is for nuclear capacity which is assumed to be online past the modeling horizon.

Given the operation of Barakah Nuclear Power Plant, we have researched the potential for additional nuclear generation within the UAE. Based on information from UAE's Emirate Nuclear Energy Corporation (ENEC)[18], we have determined that ENEC has additional potential sites in the UAE where nuclear power plants can be built.

The build and operation cost used to inform the analysis come from the Business, Energy & Industrial Strategy (BEIS)[19], Energy Information Administration (EIA)[20], and National Renewable Energy Laboratory (NREL)[21].



KEY FINDINGS

Our analysis shows that electricity demand would grow by approximately 78% by 2050 as a result of the electrification of desalination, light-duty transportation, and portions of industry such as EMAL and ADNOC offshore demand. This will require a total of 156.6 GW of renewable and low-carbon thermal generation and energy storage to meet the net-zero target by 2050 as shown in figure 4 and 5.

Generation Profile Findings

1. The UAE energy mix will be mainly dominated by solar energy. Driven by high solar yield, lowest-cost generation technology, and the availability of land, the UAE may deploy 85 GW of solar by 2050. This would enable the UAE to generate half of its electricity from solar energy coupled with long-duration energy storage. Increasing solar is critical to meeting the UAE's decarbonization targets, but it can create operational challenges if installed alone. Therefore, the system will also require flexible assets such as gas turbines and battery storage to smooth out the generation profile and fill the potential capacity gap when solar is not generating.
2. The UAE may upgrade or replace existing gas generation with carbon capture and storage. Given its vast network of oil and gas extraction facilities, carbon capture presents an opportunity for the UAE to maintain and decarbonize some of the existing fleet of gas generation. Our analysis shows that building ~14GW of combined cycle gas turbines with carbon capture and storage would potentially meet 23% of UAE's higher electric demand in 2050 running at a 70% yearly average capacity factor.
3. Energy storage and open cycle gas turbines are needed in a high renewable system to balance the variability of renewable power. With the deployment of 85 GW of solar, the UAE will require 31 GW of open cycle gas turbines running on green hydrogen fuel and 21 GW/84 GWh 4-hour battery storage to balance the variability of solar by 2050. As the share of solar increases in the system, 1-hr BESS will be needed to provide ancillary services and reduce the impact of curtailment in the short to medium term and 4-hr BESS will be needed for energy shifting towards the end of the horizon. In addition, the open cycle gas turbines would potentially meet 18% of electricity need running at a 21% yearly average capacity factor.

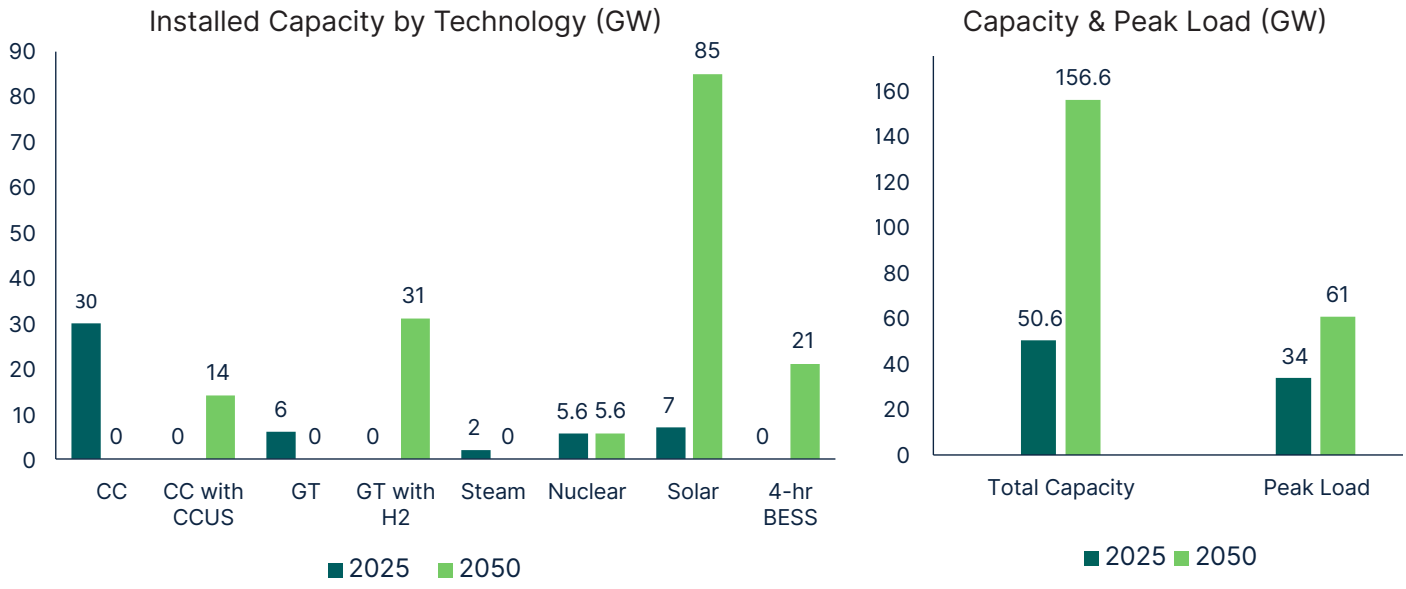


Figure 4 - UAE Peak Load and Installed Capacity in 2025 and 2050

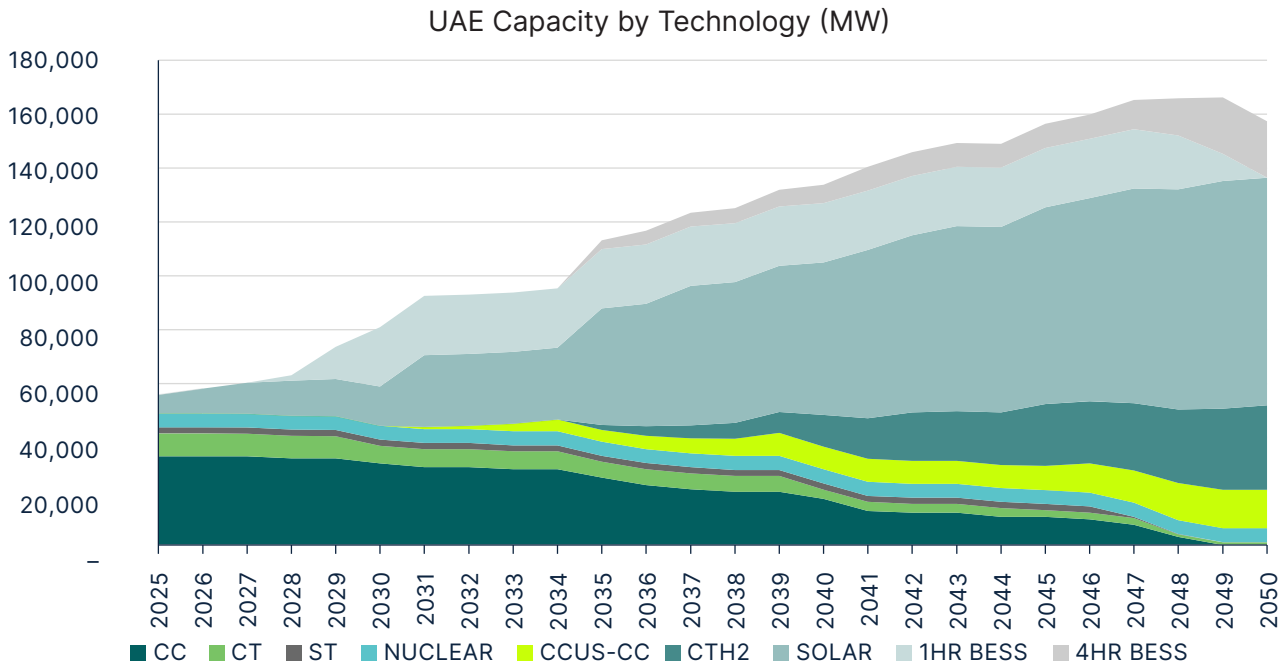


Figure 5 - UAE Annual Installed Capacity by Technology between 2025 and 2050

System Operation Findings

Figure 6 summarizes GE Vernova's simulated electric generation results for the year 2050. Despite a load increase of ~78%, integrating carbon capture and hydrogen as well as growing its fleet of solar, UAE could virtually eliminate carbon emissions from its electric sector as shown in Figure 7. In its simulations of UAE's electric grid, GE Vernova observed the following:

1. UAE's 2050 summer peak demand is more than double winter peak demand such that generators running in summer may be idle in winter. Figure 9 illustrates the seasonality of the UAE's electric demand. Higher air conditioning usage in the summer results in dramatically higher electric usage compared to winter. Building out electric generation to meet summer levels may thus mean that these resources are idle in winter. Such a seasonal profile favors resources with lower capital costs and higher operating costs. Hence, using existing gas units with hydrogen and carbon capture and storage is advantageous for this purpose.

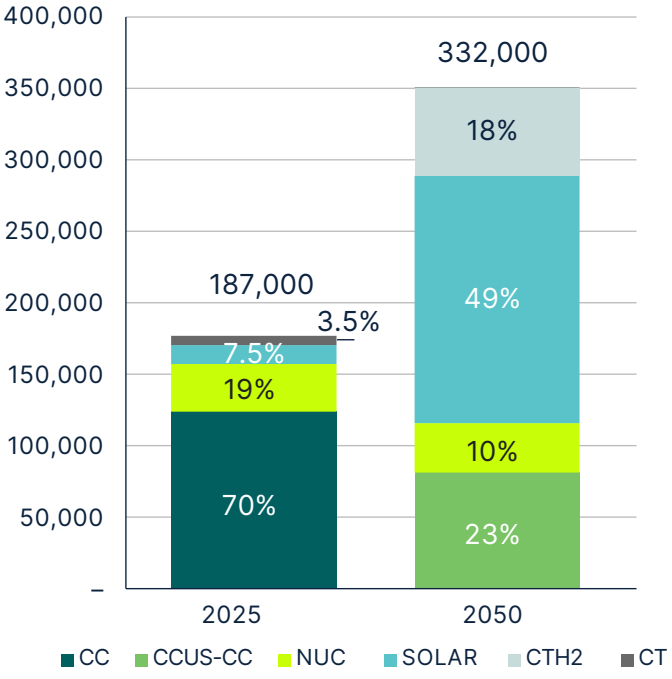


Figure 6 - UAE electricity generation in 2025 and 2050

2. Solar resources help meet mid-day demand, but not evening. Figure 8 illustrates an example week of generation in summer 2050. While a lot of UAE's daily needs can be met with baseload resources such as nuclear and CC-CCS, given that daily demand increases during daylight hours, solar generation is helpful for meeting such demand. However, without additional battery storage, solar creates what is commonly known as a "duck curve." This is when solar meets load during the day but forces all other generators to quickly respond as solar availability diminishes. In this study, batteries helped shift solar generation into the evening by charging during the day and discharging at night. Where there are additional evening gaps, especially in the summer when demand is high, quick-responding simple cycle units using hydrogen play a key role.

3. Electrifying desalination plants enables thermal generation flexibility. Today's desalination plants rely on thermal generation as its heat source. By increasing investment in electric-dependent reverse osmosis desalination, if thermal generators are not needed for electric demand, such as in winter, they then have the flexibility to turn off. This flexibility can help UAE economically bridge the gap between winter and summer demand levels.

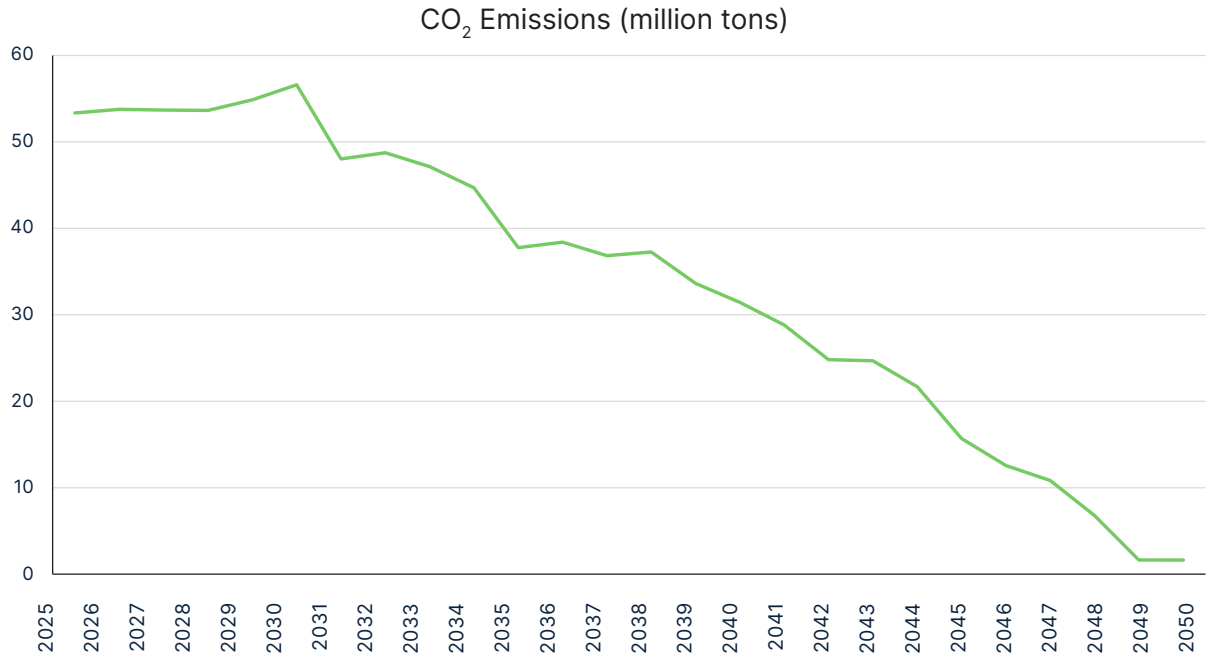


Figure 7 - UAE CO_2 Emissions

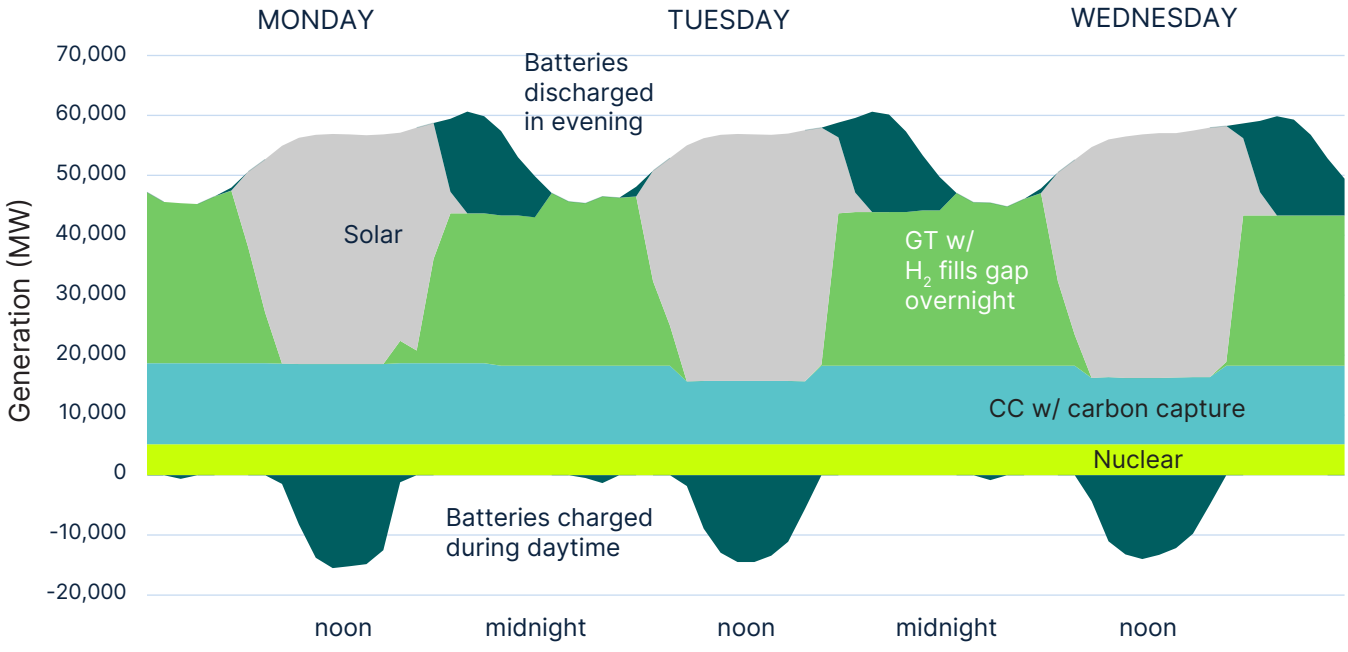


Figure 8 - Projected 2050 summer generation pattern in UAE

RECOMMENDATION

A combination of multiple electricity generation technologies with underlying supportive regulatory measures will be essential. Therefore, our key recommendations are:

- Enable and accelerate investments at the required scale and pace in all lower-carbon generation technologies (renewables, carbon capture and storage, hydrogen, and battery storage).
- Achieve full decoupling of the water and power sector to enhance system efficiency and improve system flexibility.
- Accelerate the deployment and permitting of flexible resources (battery storage and open cycle gas turbines) necessary to integrate 83 GW of solar capacity by 2050.

Overall, the United Arab Emirates must make tangible progress within this decade regarding the above key recommendations. GE Vernova, with its unique portfolio of generation and grid technologies, global project experience, comprehensive footprint and expertise is well positioned to support the UAE in achieving its net-zero goals. GE Vernova is privileged to work with its customers and stakeholders across the UAE to deliver reliable, affordable, secure, and resilient energy to help realize net-zero targets.

FUTURE STUDIES

The UAE is on a path leading to the decarbonization of its economy. The UAE Energy Strategy 2050 is a first step in the right direction, but there are many questions left to address. In this study, GE Vernova illustrated a feasible, potential pathway to decarbonizing UAE's electric sector that can also help decarbonize transportation, industrial activities, and desalination. Further studies should be conducted for a comprehensive and optimized path toward decarbonization.

1. Wind. Could wind energy help mitigate a UAE "duck curve?" The need for renewable generation into UAE's evening hours raised the question regarding whether alternative renewable technologies could be more optimal versus solar + batteries. As Figures 9 and 10 show, wind profiles are much more seasonally and diurnally constant versus solar profiles. Having a mix of both wind and solar can provide diversity benefits since wind produces electricity during both on and off-peak demand periods.
2. Demand-side management. What demand-side mechanisms could balance energy demand? Is it feasible to shift some of UAE's evening demand to daytime through demand-side management or economic signals?
3. Interconnections. Can UAE benefit from greater network interconnections? Network reinforcements within the country could help avoid bottlenecks associated with energy delivered from new carbon free resources. Connections to neighboring countries could provide operational flexibility to UAE, including helping to address potential "duck curves." The UAE could also potentially supply other GCC countries with UAE's decarbonized electricity during times of excess.
4. Evolving technology cost. How will the price of low-carbon solutions evolve? GE Vernova is aware that the price of low-carbon solutions is continuously evolving and is difficult to project (e.g. Small Modular Nuclear Reactors, CCS, BESS, H_2, etc.). Therefore, further analysis will be required to assess multiple price scenarios, including potential expansion of nuclear fleet.

GE Vernova welcomes the opportunity to discuss potential decarbonization pathways with stakeholders in the UAE system. It is only through diverse collaboration that initial strategies can be turned into actionable investments.

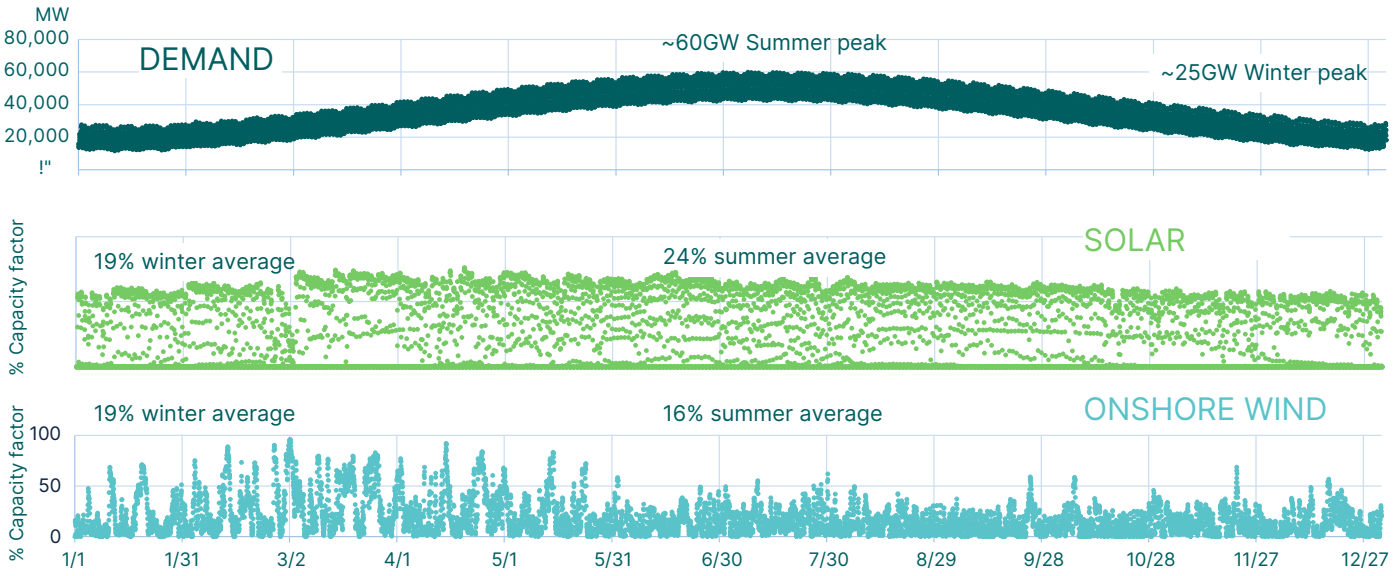


Figure 9 - Seasonal profiles of electric demand versus solar and wind resource availability

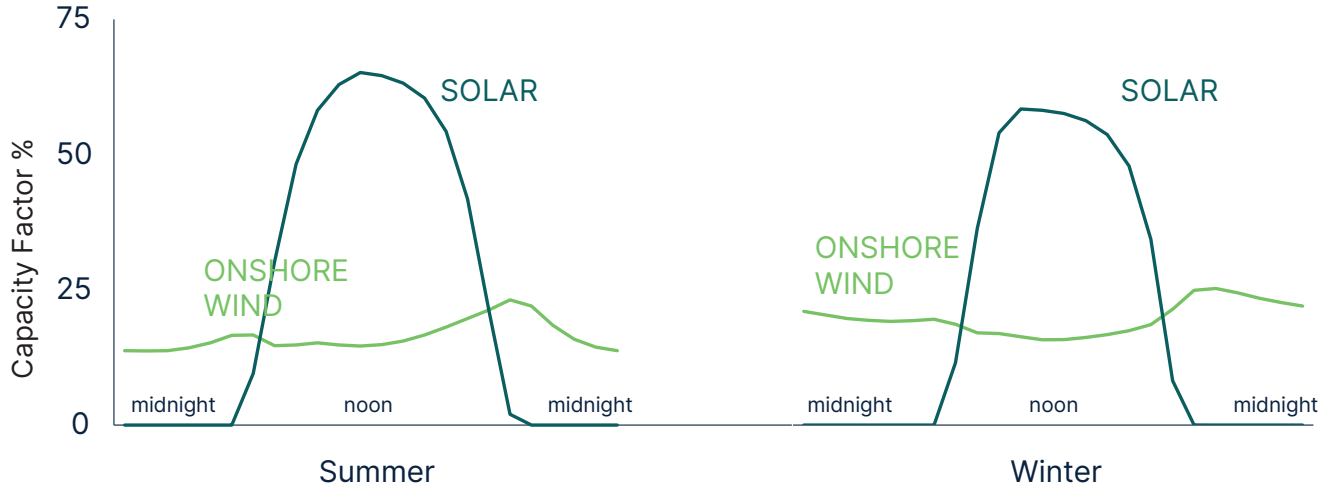


Figure 10 - Average wind and solar capacity factor per season

PROJECT TEAM

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FIGURES

FOOTNOTES

[1] https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/environment-and-energy/uae-energy-strategy-2050
[2] https://unfccc.int/process-and-meetings/the-paris-agreement
[3] https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/
[4] https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/environment-and-energy/uae-energy-strategy-2050
[5] https://u.ae/en/information-and-services/environment-and-energy/climate-change/theuaesresponsetoclimatechange
[6] https://www.moei.gov.ae/en/open-data/statistical-report
[7] https://www.transco.ae/documents/2019-E7YPS-2020-2026.pdf
[8] https://www.ewec.ae/en/media/statistical-reports
[9] https://www.oxfordeconomics.com/
[10] https://www.ewec.ae/en/media/press-release/ewec-announces-partners-develop-mirfa-2-reverse-osmosis-seawater-desalination
[11] https://www.sciencedirect.com/science/article/pii/S1876610214032871
[12] https://www.mdpi.com/2073-4441/13/21/3023#:~:text=Thermal%20desalination%20technologies%20are%20about,and%20USD%201.3%20million%2C%20respectively.
[13] https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/environment-and-energy/uae-energy-strategy-2050
[14] https://afdc.energy.gov/evi-pro-lite
[15] https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/environment-and-energy/national-hydrogen-strategy
[16] https://www.iea.org/reports/global-hydrogen-review-2022
[17] https://nsrdb.nrel.gov/data-sets/international-data
[18] https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/030322-uaes-enec-may-develop-more-nuclear-power-plants-locally-internationally-in-future
[19] http://www.gov.uk/government/publications/beis-electricity-generation-costs-2020
[20] https://www.eia.gov/outlooks/aeo/
[21] https://data.openei.org/submissions/5716

This paper contains forward-looking statements – that is, statements related to future events that by their nature address matters that are, to different degrees, uncertain. These forward-looking statements often address GE Vernova's expected future business and financial performance and financial condition, and the expected performance of its products, the impact of its services and the results they may generate or produce, often contain words such as "expect," "anticipate," "intend," "plan," "believe," "seek," "see," "will," "would," "estimate," "forecast," "target," "preliminary," or "range." Forward-looking statements by their nature address matters that are, to different degrees, uncertain, such as statements about planned and potential transactions, investments or projects and their expected results and the impacts of macroeconomic and market conditions and volatility on the Company's business operations, financial results and financial position and on the global supply chain and world economy.

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