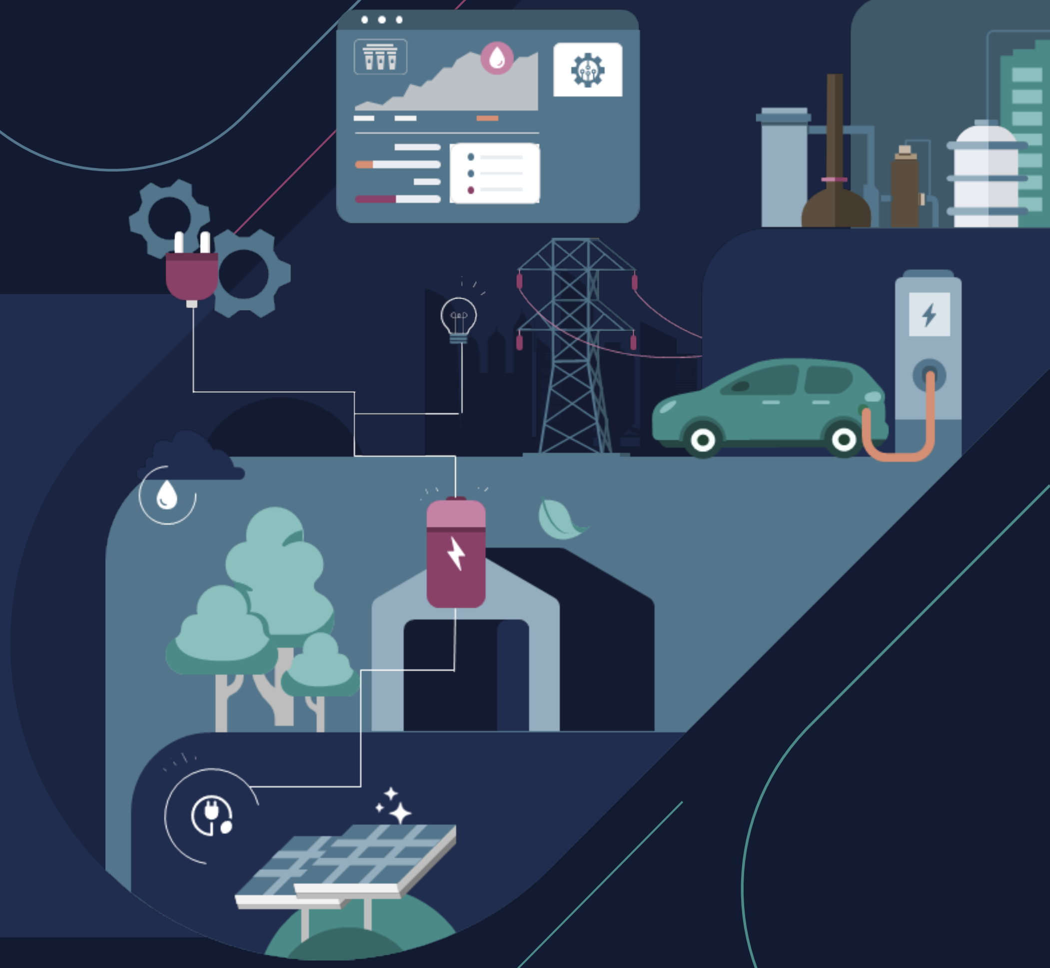
EWEC

EWEC's Decarbonisation Journey

November 2023



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Acronyms

Abbreviations	Definitions
AC	Alternating Current
CCUS	Carbon Capture, Utilisation, and Storage
CEST	Clean Energy Strategic Target
CO_2e	Carbon Dioxide Equivalent
DOE	Abu Dhabi Department of Energy
ETC	Energy Transitions Commission
ENEC	Emirates Nuclear Energy Corporation
EWEC	Emirates Water and Electricity Company
GW	Gigawatt
IEA	International Energy Agency
IT	Information Technology
kWh	Kilowatt-hour
LDC	Load Despatch Centre
MENA	Middle East and North Africa
MOCCAE	UAE Ministry of Climate Change and Environment
MTPA	Million Tonnes per Annum
MWh	Megawatt-hour
OCGT	Open Cycle Gas Turbine
OT	Operational Technology
PCOD	Project Commercial Operation Date
PV	Photovoltaic
P(W)PA	Power (Water) Purchase Agreements
RO	Reverse Osmosis
SFCR	Statement of Future Capacity Requirements
TRANSCO	Abu Dhabi Transmission and Despatch Company
TWh	Terawatt-hour
UAE	United Arab Emirates
VRE	Variable Renewable Energy

Executive Summary

In October 2021, the United Arab Emirates (UAE) announced its ambitious goal of achieving net-zero emissions by 2050. The nation is well-positioned for a rapid and effective transition to clean energy, thanks to political stability, low-cost capital and strong renewable resources.

Emirates Water and Electricity Company (EWEC) will play an important role in this journey. Responsible for supplying around 60 per cent of the UAE's utility power and desalinated water needs, we have already made some progress on the decarbonisation front, with 40 per cent lower power emissions intensity now than in 2019. However, the challenges ahead are technically complex and potentially costly unless technological breakthroughs make clean electricity options much more cost-effective than today.

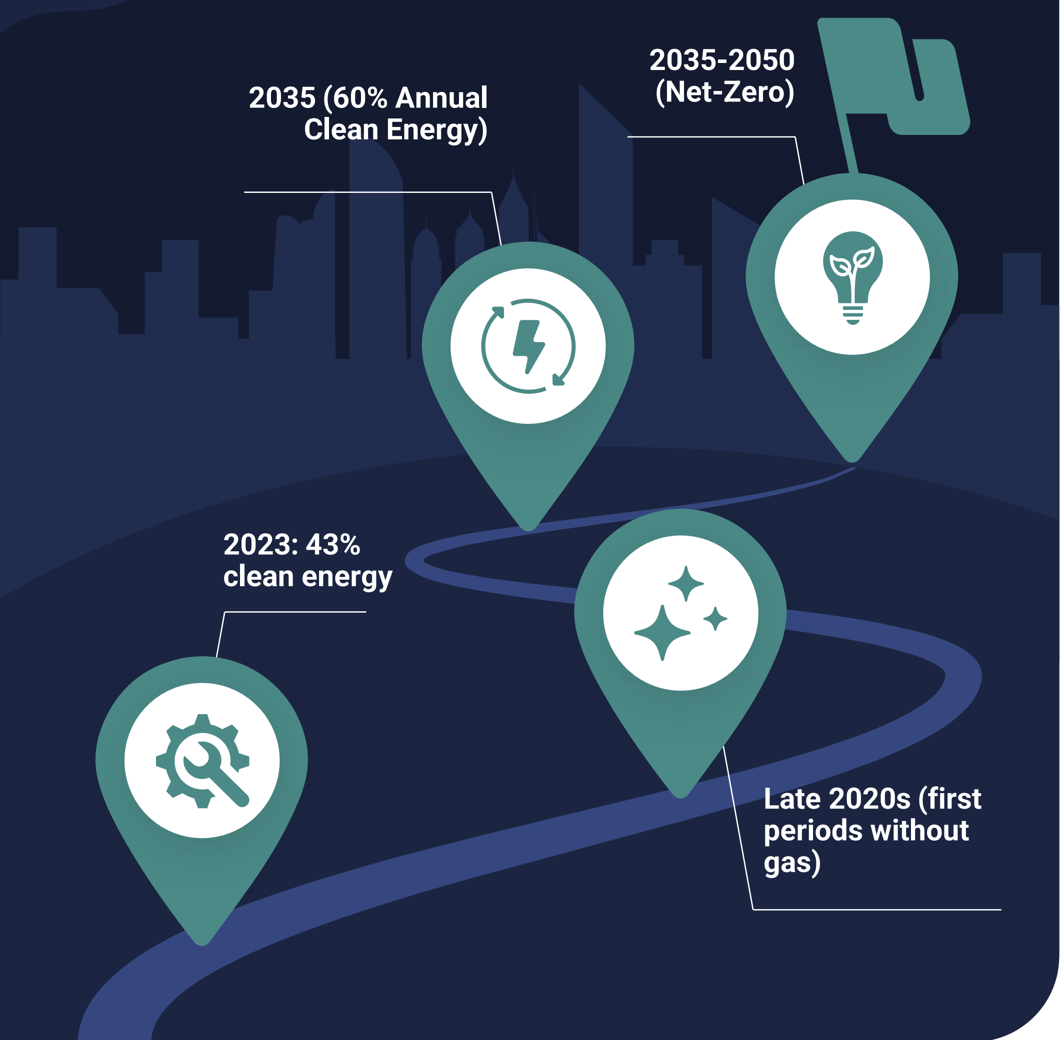
Since our first use of techno-economic optimisation tools in 2015, we have tuned our system planning process to better manage the complex trade-offs between security of supply, decarbonisation objectives, and affordability. This approach has been effective in identifying the generation investments needed for our interim target of 60 per cent annual clean energy by 2035. Yet, the first major test lies in the operational realm; we anticipate experiencing periods of 100 per cent instantaneous penetration of clean energy by the late 2020s. How well our control systems and operating procedures cope with increased supply-side fluctuations at this stage will determine our readiness for even more challenging milestones ahead.

As we push for deeper levels of decarbonisation, the landscape becomes fraught with uncertainties around the rate of electrification of other sectors, technological progress and policy development. Our marginal abatement cost, initially negative, is projected to increase substantially beyond around 55-60 per cent clean energy unless technology costs fall significantly. Furthermore, we need to make long-lived investments before knowing the eventual development of all possible technology pathways. This underscores the need for constant analysis of emerging technologies to minimise the risk of investing in assets that are surpassed by better options soon after.

Despite these complexities, we have a well-tested planning process and have proven institutional adaptability and foresight (Figure 1, overleaf). We have identified specific challenges that await us and are preparing to meet them head-on. As we approach the more challenging phases of our decarbonisation journey, we recognise our planning and operational processes may need to evolve to adapt to changing demands and emerging technologies.

The clarity of EWEC's mandate, coupled with a rigorous techno-economic approach to system planning, allows for immediate and longer-term steps to ensure decarbonisation while maintaining security of supply at least-cost to consumers. EWEC embraces its role in supporting strategic initiatives in the region and is fully aligned with the objectives set out by UAE leadership.

Figure 1: Summary of Progress & Next Steps

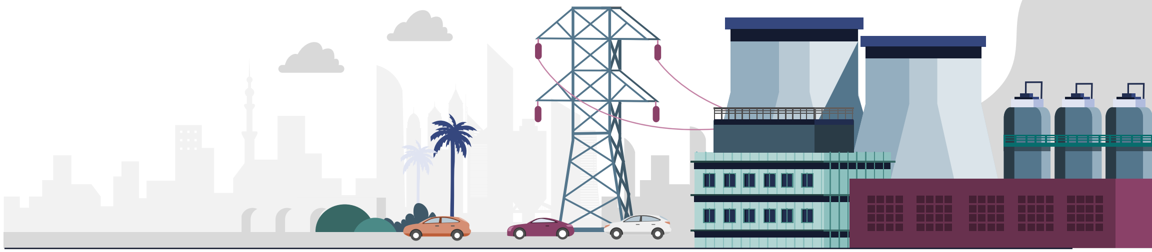


2023 (43 per cent clean energy): We've kick-started our transition with nuclear, PV and reverse osmosis (RO), reorganised sector planning functions; initiated a technology tracking function and evolved our techno-economic modelling process to minimise the cost of meeting security of supply and decarbonisation targets.

Late 2020s (first periods without gas): Our focus will be on finalising the RO rollout, procuring adequate battery storage to balance renewable variability, overhauling operating standards to ensure system stability with high clean energy penetration and enhancing our 2050 techno-economic modelling capabilities.

2035 (60 per cent Annual Clean Energy): We will need to scale up deployment of both renewables and bigger batteries for energy shifting and ensure comprehensive control and telemetry systems are in place to support sustained periods of 100 per cent clean energy.

2035-2050 (Net-Zero): Efforts will likely pivot towards platforms for demand-side response, extensive cross-border transmission networks, resilience planning overhauls and the integration of emergent technologies across the energy spectrum.



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Net-Zero 2050 – EWEC at the Heart of the Journey

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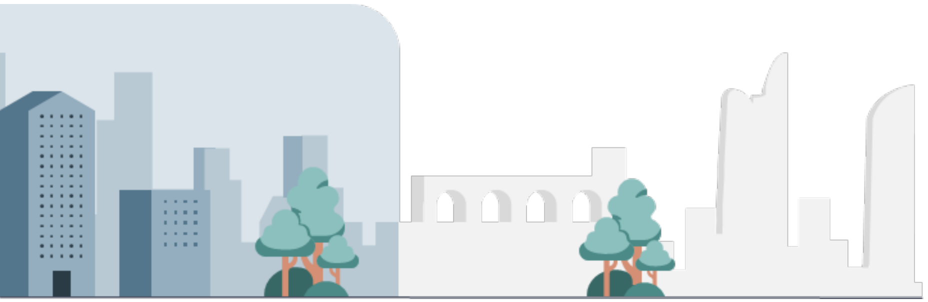
As the world grapples with climate change, the transition towards a decarbonised energy sector has become a global imperative. The UAE, a nation traditionally associated with a hydrocarbon-based economy, has risen to this challenge and committed to achieving net-zero carbon emissions by 2050.

The UAE's commitment to a net-zero future is not merely a response to the global climate crisis. It is a strategic move that capitalises on the country's strengths and aligns with its broader vision for sustainable development. As a major energy exporter with abundant renewable resources, the UAE is poised to play a leading role in the global energy transition from fossil fuels to green energy. Political stability and healthy public balance sheets from the recent hydrocarbon boom should continue to attract the low-cost funding essential for capex-heavy infrastructure. Abundant land, exceptional solar and decent wind resources comprise the remaining raw ingredients, while the country's approach of centrally planning the electricity system and directly contracting for the required services may side-step many of the inefficiencies ensnaring fossil-era electricity markets around the globe.



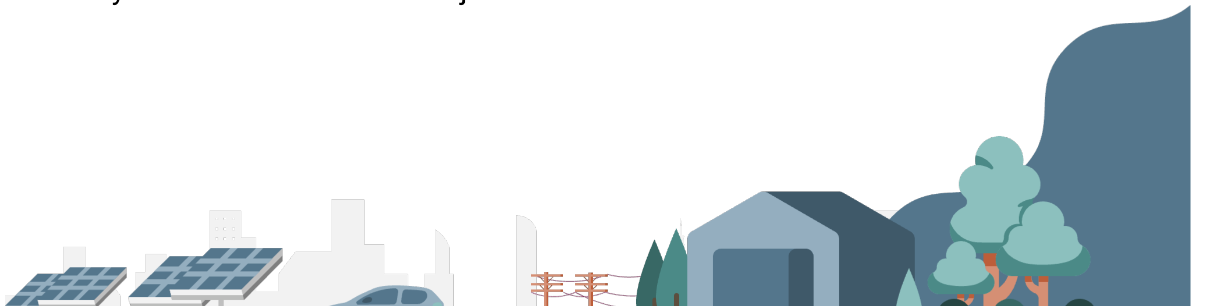
Do brownouts betray bad planning?

A recent spate of electricity shortages in rich, industrialised countries has quickened policymakers' focus on whether energy markets designed in the fossil-fuel era remain fit for purpose today. Whilst essential system services such as inertia and voltage support were implicitly bundled with energy from conventional generators, their displacement by renewables has seen energy markets schism into a complex web of subsidies, capacity mechanisms and a bewildering array of ancillary service products.

Central-planning models can avoid some of the confused price-signalling and investment paralysis seen in electricity markets globally, but may come with their own inefficiencies. They certainly suffer their share of electricity shortfalls too, albeit predominantly in developing countries that are racing to keep up with demand rather than in mature, low carbon systems.

In either case, the stigma of brownouts in rich countries might start to fade as consumers become more active participants in the supply-demand balance and the line between brownouts and demand-side-response begins to blur. Clean energy is a noble ambition for countries that can afford it, but the steep cost of maintaining reliability in a renewables-based system means that people may sometimes prefer to forgo consumption.

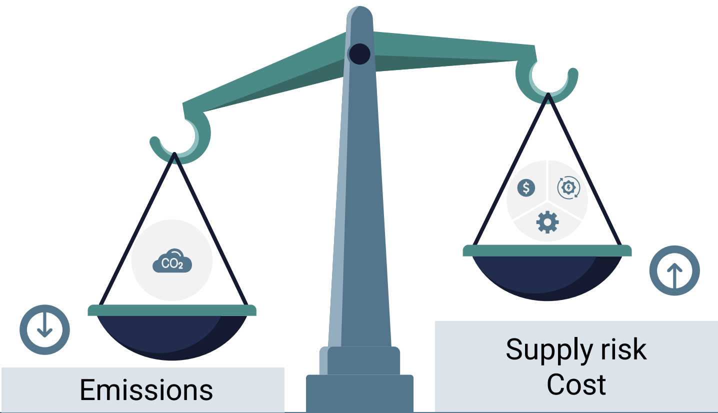
The power and water sector is a critical component of the UAE's decarbonisation efforts. Electricity currently comprises around 18 per cent of final energy consumption in the UAE and 20 per cent globally.[1,2] The electricity sector is expected to become much more significant as other hard-to-decarbonise sectors such as transport increasingly rely on electrification to reduce their emissions. For example, the IEA and ETC project that electricity's share worldwide will need to reach 50 to 70 per cent by 2050 to meet net-zero objectives.[3,4]



EWEC sits at the heart of the power and water sector in the UAE, with responsibility for managing around 60 per cent of the country's utility power production.[5] EWEC's mandate is to manage the energy trilemma by providing clean, reliable electricity and water at the lowest possible cost (Figure 2). This requires it to undertake everything from real-time operations to long-term planning and contracting new capacity and system services (see overleaf).

Balancing each of these three dimensions is a complex task, particularly in a rapidly evolving technology and regulatory landscape. When looking at infrastructure investments, rarely is there a single option that is simultaneously the most secure, affordable and sustainable. Instead, we look for combinations that collectively result in a system that achieves security and sustainability objectives at the lowest expected cost over the long run.

For instance, transitioning to cleaner energy sources reduces carbon emissions but may require significant additional expense. Similarly, ensuring security of supply might involve maintaining a certain level of fossil-fired power capacity or building grid support assets to mitigate the adverse impact of renewables. EWEC's role is to navigate these trade-offs and optimise the energy trilemma to deliver the best possible outcomes for the sector.



The rise of clean energy sources, which enables a reduction in carbon emissions, will require significant infrastructure investment and introduce many new security of supply risks.

Figure 2: Energy & Water Trilemma

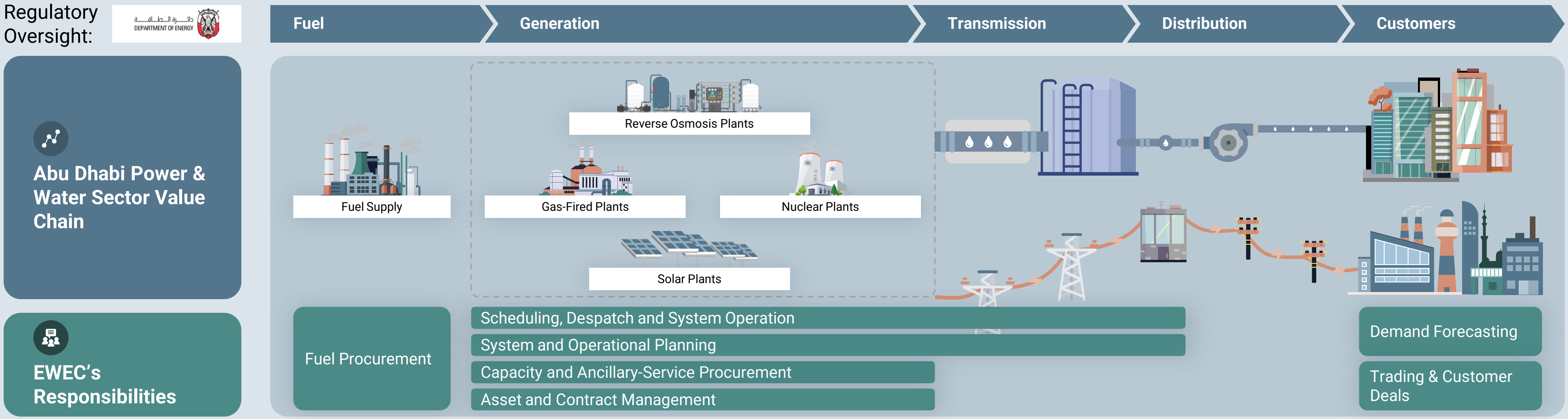
The Energy Trilemma

The three variables are interlinked and cannot be managed independently.

1. **Affordability – EWEC always plans for least-cost**
   Affordability involves optimising the mix of energy sources and infrastructure investments to deliver electricity and water at the lowest possible cost to consumers.

2. **Security – while ensuring security of supply**
   Security of supply is about ensuring that the power and water system can meet demand at all times, even during peak periods or when some supply sources are unavailable.

3. **Sustainability – and meeting decarbonisation objectives**
   EWEC is committed to supporting government objectives, including meeting the Clean Energy Strategic Targets to reduce carbon emissions.



Since its first use of techno-economic optimisation in 2015, EWEC has developed its system planning to co-optimise the competing components of the energy trilemma. We have established a process which enables us to build a comprehensive understanding of future power and water system operations at a granular level. We use specialist modelling software to holistically consider generation, water desalination and gas systems, and iteratively pair this with transmission planning software to ensure our recommendations are operable and meet our network and system operation code obligations.

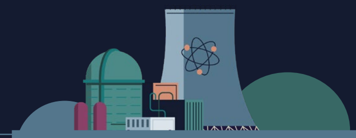
Importantly, our planning platform is scalable and can be readily adapted to future dynamics in EWEC's system, such as major changes in electrical load through integration with large customers or changes in regulatory policy. We can incorporate rapid changes in the cost of existing technologies or the eventual maturity of proto-technologies such as hydrogen or carbon capture. Our planning tools and processes are supported by a diverse team, including a graduate scheme to cultivate young UAE Nationals.

Moreover, EWEC is well supported by its regulator, the Department of Energy (DoE), who, among other things, is responsible for reviewing all of EWEC's planning recommendations. The DoE introduces supporting policies and reinforces the national vision, for instance, through the July 2022 establishment of the 2035 Clean Energy Strategic Target (CEST). This interim goal gives EWEC a clear planning mandate for one dimension of the trilemma by requiring it to serve 60 per cent of its electricity from clean sources by 2035, to be met alongside the other dimensions of security of supply and lowest possible cost.

The following sections critically examines the background and lessons learned from the progress achieved so far, before charting the outlook and processes underpinning the expected transition to 2035. The final section highlights the uncertainties associated with planning beyond 2035 and takes a critical look at EWEC's processes to ensure the best possible transition.

By 2035, 60% of our energy will come from clean sources

40% from nuclear

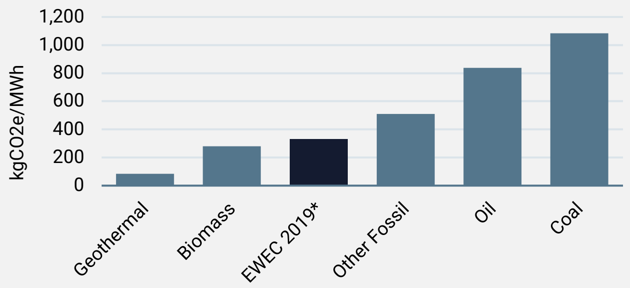


20% from renewables

1.1 EWEC's Progress between 2019-2023

The UAE is a major oil and gas economy with the seventh largest proven gas reserves.[6] Its power and water sector has benefited from a decades-long secure and stable supply of natural gas and invested heavily into gas-fired generation, leading to lower power emissions intensity than countries that relied on more carbon-intensive fuels such as oil or coal.

Figure 3: Estimated Carbon Intensity of Power Generation by Fuel Type c.f. EWEC 2019[7]

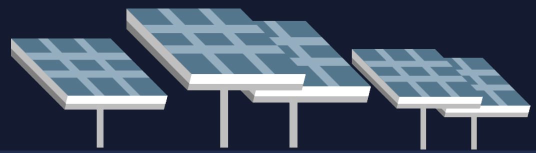


The UAE's power and water sectors are closely intertwined due to the energy-intensive processes needed to supply potable water in a desert environment. Historically, we produced power and desalinated water simultaneously in cogeneration (cogen) facilities to use less fuel than producing each output through standalone processes. However, the fact that both products are made with the same fuel clouds our intensity reporting. Based on our short run marginal cost allocation methodology, we estimate the power share of emissions in 2019 at 330 kgCO_2e/MWh; ignoring water production and allocating emissions entirely to power would yield 540 kgCO_2e/MWh.

Over recent years, Abu Dhabi has committed billions of dirhams to clean energy and water projects, recognising their economic, strategic and environmental benefits.

Al Dhafra Solar PV: Secured world's lowest tariff (at the time) for solar PV at 4.97 fils/kWh

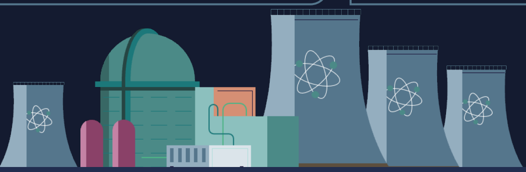
- **2.1 GW (DC)**
- **2.4 million** tonnes reduction in CO_2 emissions per year
- Provides **~160,000** households across the UAE with electricity



2023
Project commercial operation

Barakah Nuclear Energy Plant: Developed by ENEC, the first nuclear energy plant in the Arab world provided invaluable construction, regulation and operation experience. Conceived by the UAE Government[7] more than 15 years ago as a key strategy to reduce reliance on natural gas without the environmental impact of coal.

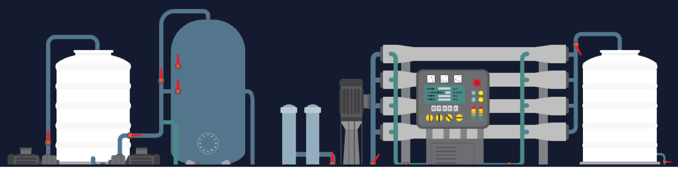
- **5.6 GW** Total capacity, with 1.4 GW reactors
- **21 million** tonnes of carbon footprint reduction per year when all units come online
- Provides **40%** of EWEC's electricity needs in 2025 when fully operational



2021
Unit 1 Commercial operation

Taweelah RO Facility: World's largest RO desalination plant (at time of construction) with a capacity of 910,000 m³/day

- Produces a tonne of desalinated water using the same energy as boiling a kettle for an hour.
- Provides **~350,000** households with water
- First major step on the way to **80% RO production by 2028**



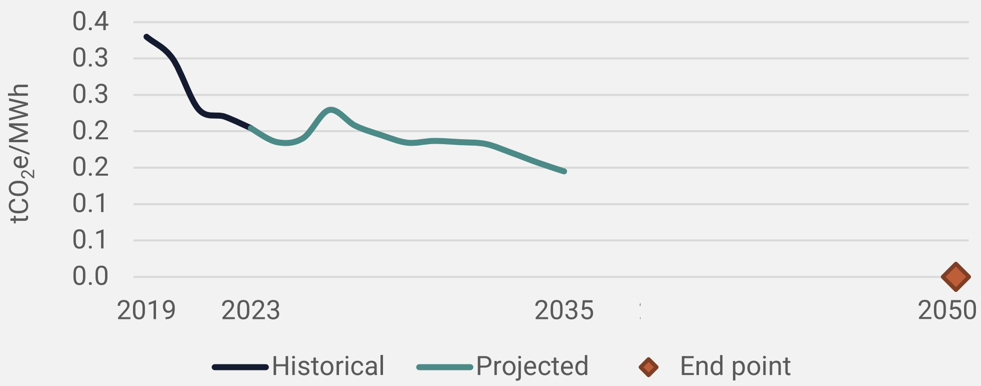
2023
Phase 2 commercial operation

1.2 How will the System Need to Evolve for 2035 and 2050 Targets?

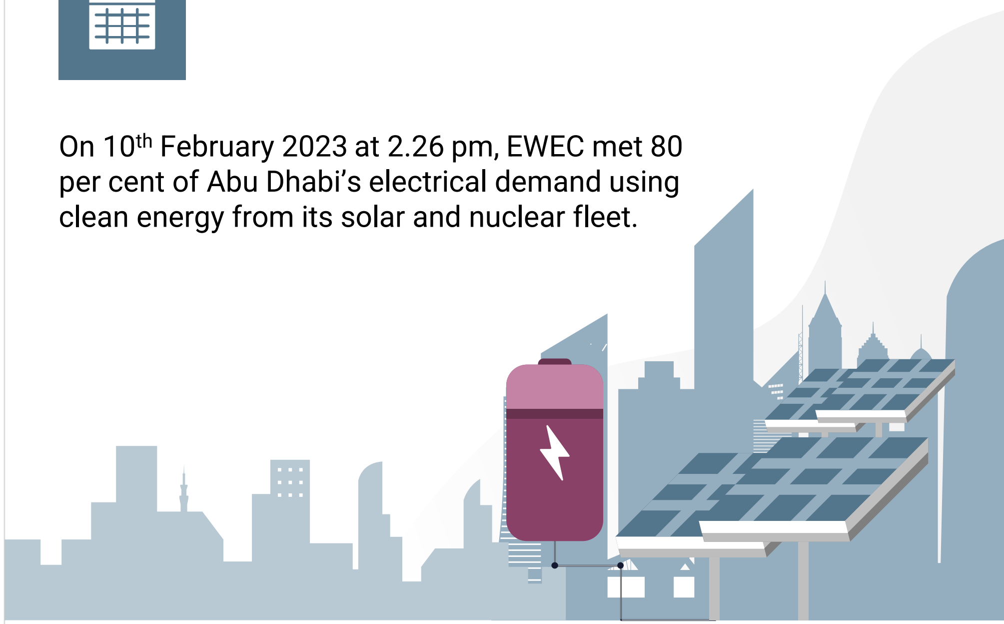
Despite the progress made to date, the most difficult part of the journey has not yet begun. As global emissions continue to rise, the collective responsibility of each country to take corrective action is coming into ever-sharper focus. To this end, the UAE announced its commitment to net-zero by 2050 in late 2021, with a slew of corroborating commitments and implementation strategies following from all aspects of the economy. Most pertinently, our projections suggest that meeting the DoE's CEST will result in an 11 million ton (-33 per cent) decrease in CO_2 emissions between 2023 and 2035, or a halving in emissions intensity relative to 2019 (Figure 4)*. EWEC has already provided technical input into developing MOCCAE's outlook for the UAE's 2050 net-zero pathway, and is now supporting the DoE's effort to develop subsequent CEST milestones beyond 2035.

Whilst the outlook until 2035 is far from certain, EWEC has enough visibility to reshape its business processes, organisational structure, IT and OT systems and asset base to ensure that the CEST can be met at the lowest possible cost to end consumers. EWEC's most recent planning report, discussed more in the following section, recommends immediate procurement of additional solar PV, RO and batteries to initiate the next stage of the transition. It also lays out the current view of how the generation mix will evolve to meet 2035 targets at least-cost, highlighting the need for continued large-scale investment (Figure 5, Figure 6).

Figure 4: EWEC Total Emissions Intensity, Historical and Projected



On 10th February 2023 at 2.26 pm, EWEC met 80 per cent of Abu Dhabi's electrical demand using clean energy from its solar and nuclear fleet.



*We estimate power-only emissions in 2019 at 0.33 tCO_2/MWh, compared to our projection of 0.15 tCO_2/MWh by 2035. Both measures use the same methodology for allocating emissions from cogeneration plants to power and water. Allocating all clean energy to Abu Dhabi customers only would yield a 2035 emissions intensity of 0.10 tCO_2/MWh.

Figure 5: EWEC Historical and Projected Desalination Mix, 2019-2035

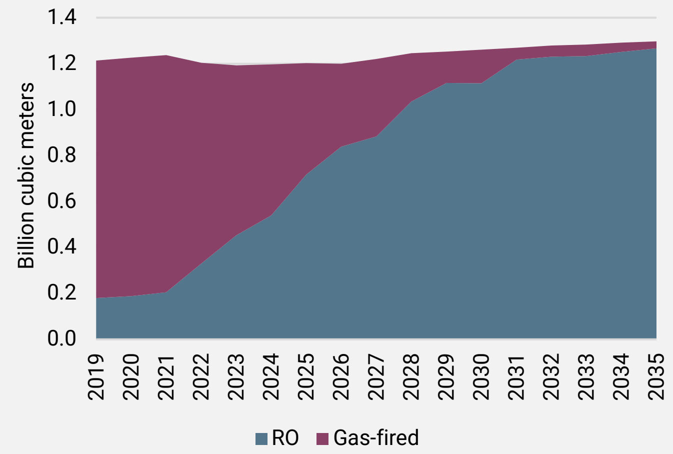
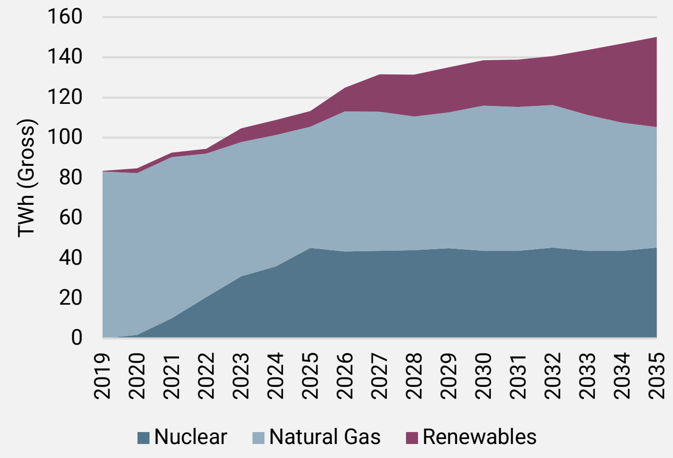


Figure 6: EWEC Historical and Projected Energy Mix, 2019-2035



One of the most evident parts of the transition is the displacement of gas-fired cogeneration with new, lower-carbon sources of power and water. Sixty per cent of EWEC's power today comes from gas-fired plants, predominately cogeneration plants that make both power and desalinated water. These 'cogen' plants were historically a relatively efficient way of producing both products, as exhaust heat from gas-fired power generation could drive a thermal desalination process to remove salt and other impurities from seawater. However, reverse osmosis has emerged as a more efficient and economically viable option, becoming the globally predominant desalination technology by capacity since 2008. It also has the benefit of operating independently of power generation, which in turn allows a wider range of power-only plants to be considered. As costs of RO continue to fall, EWEC is rapidly replacing the older cogen plants with a combination of reverse-osmosis desalination technology and stand-alone power plants.

For stand-alone power generation, the sector is predominantly deploying nuclear, more efficient gas plants and solar PV. By 2025, when all four nuclear reactors (5.6 GW total) are expected to be available, c. 40 per cent (44 TWh) of EWEC's total energy demand will be met by nuclear power. We expect to have similar levels of installed PV capacity by 2027, and for the energy from renewable generation to exceed the output from the four current nuclear plants by 2036. At present, solar PV is the cheapest form of electricity generation available, hence, the first couple of gigawatts are being deployed without any real trade-offs against the energy trilemma. However, as the penetration of nuclear plus solar PV increases into the late 2020s, we expect to see operational challenges due to:

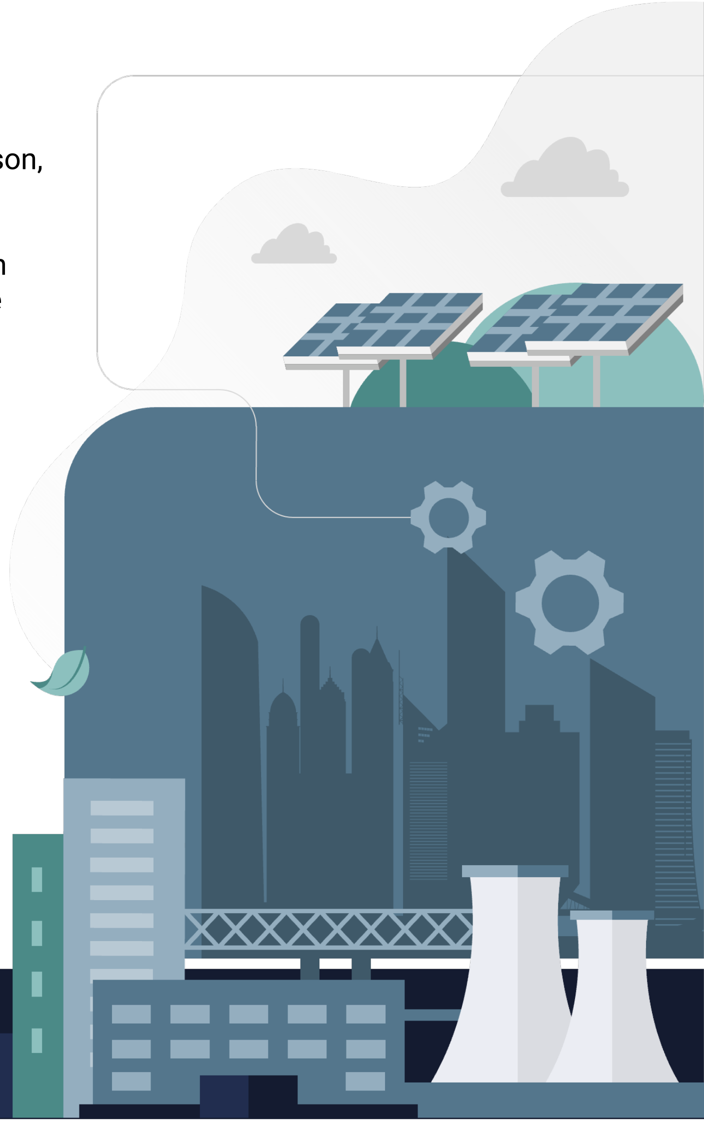
- Continued displacement of gas-fired generation by nuclear, solar PV and eventually wind, which provide energy but little in the way of system support services; and
- Increased variation in supply-side output due to intermittency of solar and wind.
- Challenges in maintaining the levels of gas supply flexibility needed to enable the daily stopping and starting of gas-fired generation as solar PV comes online in the morning and stops generation in the evening.

Operability position paper

EWEC will publish a paper on system operability addressing this issue in more detail.

To mitigate some of the challenges brought about by the shift to clean energy, EWEC is procuring several hundred megawatts of batteries with only one to two hours of storage to respond to sudden changes in the supply-demand balance. By the early 2030s, we also expect to start using deeper batteries with several hours of storage to shift electricity from PV into the night. These will likely form a key part of the overall solution for meeting the 60 per cent clean energy target, along with further PV and other potential clean energy sources such as wind or additional nuclear.

The continued prominence of natural gas plants in our medium-term portfolio outlook reflects the high expected cost of providing secure, round-the-clock generation with any of today's clean energy alternatives. The likely requirement to wean ourselves off gas to meet the 2050 net-zero target presents a major challenge. For this reason, along with many others, the portfolio evolution required to meet 2050 targets remains highly uncertain and dependent on the emergence of viable technology pathways. Will carbon capture become commercially viable in time to allow gas plants to continue forming the backbone of the system, or do we need to start putting a stop on new gas-fired plants by the end of the decade? Will various forms of energy storage, including hydrogen, become cheap enough that all of EWEC's electricity can be generated by intermittent renewables?



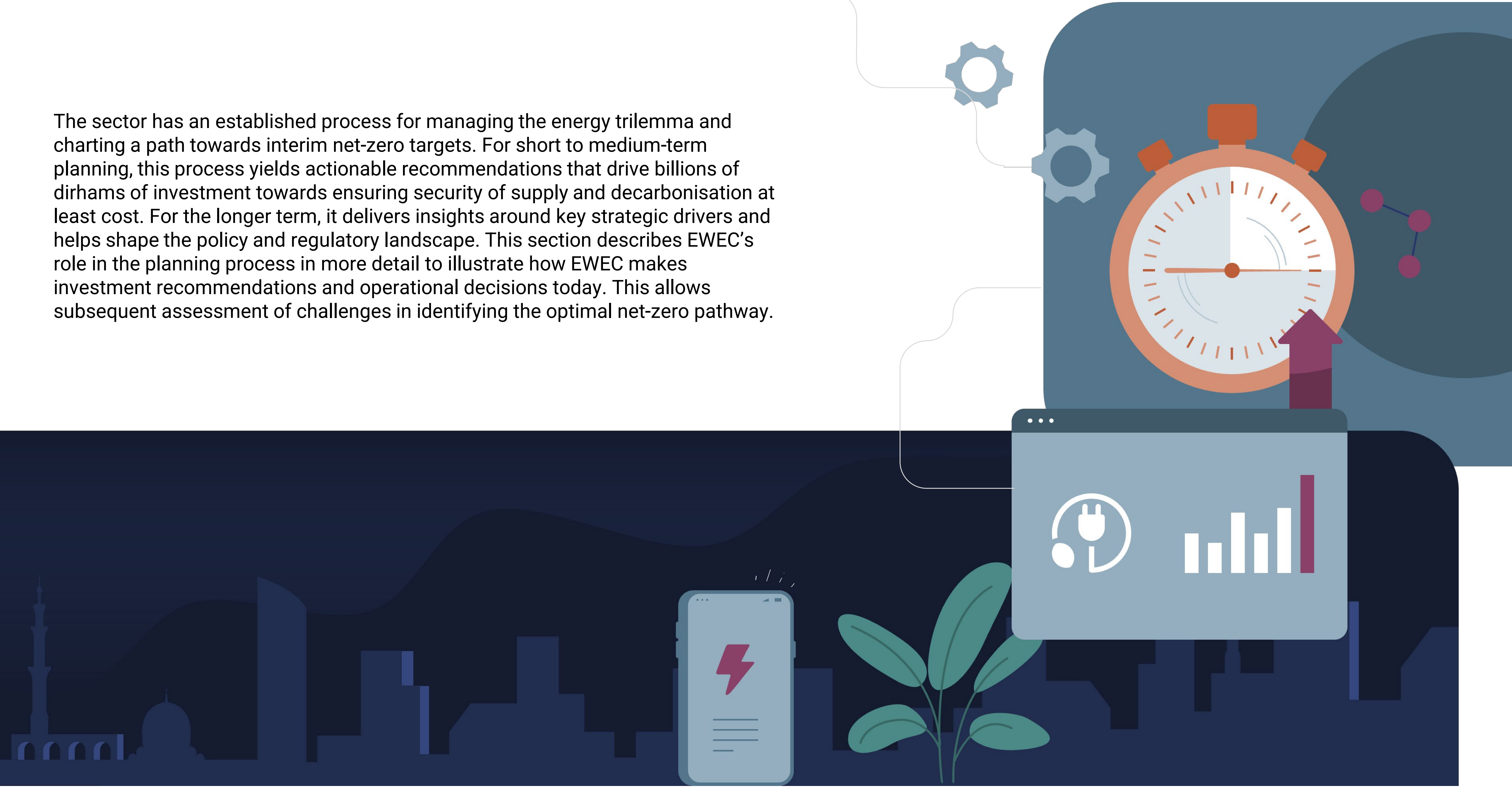
Whilst it is evident that some basic trends of replacing gas-fired generation with renewables will continue well beyond 2035, the rate of technology developments and other elements, such as electrification of other sectors, remain major uncertainties that defy precise long-term projections. The world has yet to demonstrate that clean energy systems without exceptional hydro and geothermal resources can be operated securely for more than isolated snapshots of time and space, leaving a host of procedural design and operational know-how challenges to be overcome in short order. In this context, the subsequent section first describes the planning process EWEC uses to arrive at its 2035 outlook, then critically examines the extent to which this remains fit for purpose for the more daunting prospect of a zero-carbon grid.

2

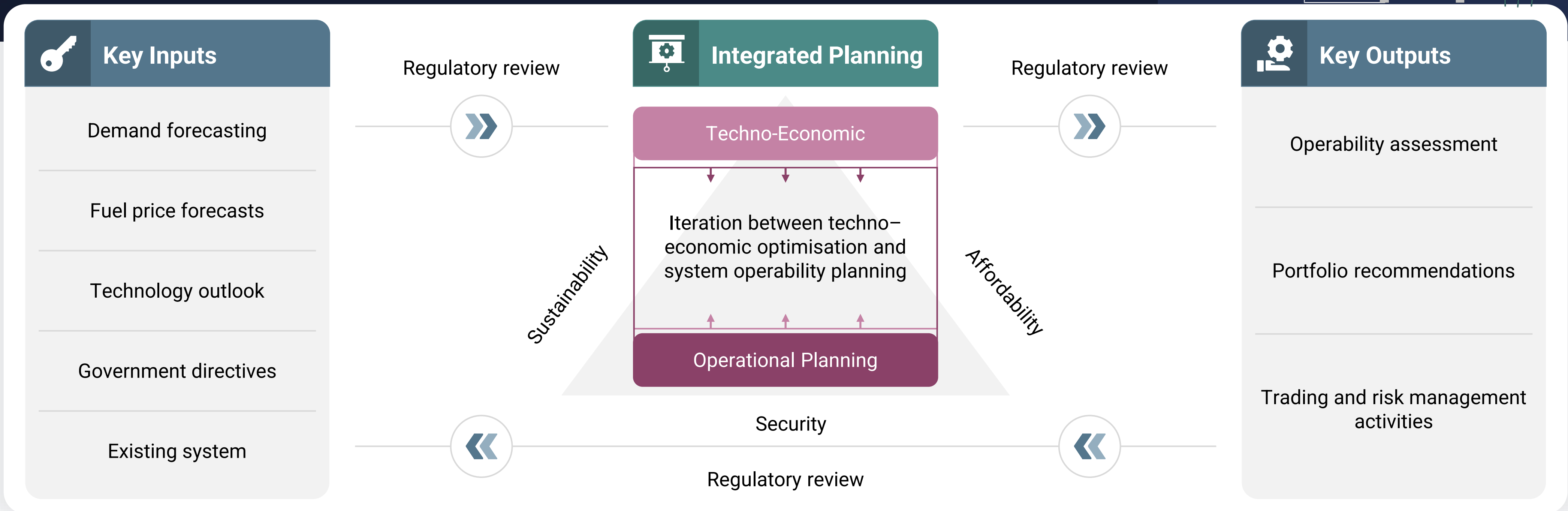
Path to 2035 – Planning and the Statement of Future Capacity Requirements

2 Path to 2035 – Planning and the Statement of Future Capacity Requirements

The sector has an established process for managing the energy trilemma and charting a path towards interim net-zero targets. For short to medium-term planning, this process yields actionable recommendations that drive billions of dirhams of investment towards ensuring security of supply and decarbonisation at least cost. For the longer term, it delivers insights around key strategic drivers and helps shape the policy and regulatory landscape. This section describes EWEC's role in the planning process in more detail to illustrate how EWEC makes investment recommendations and operational decisions today. This allows subsequent assessment of challenges in identifying the optimal net-zero pathway.



Central to EWEC's planning process is the Statement of Future Capacity Requirements (SFCR), an annual report that snapshots key elements of EWEC's continual optimisation process. Through the SFCR, EWEC identifies what new production capacity and system stability services, including gas supply, are required to deliver our parallel objectives of decarbonisation, system reliability and lowest total cost. EWEC also uses this report to disseminate its findings and analysis over a longer 15-year outlook, examining the possible effects of various strategic drivers such as demand growth, natural gas price developments and government policy implementations. After a multi-stage regulatory review process, the SFCR is shared with key stakeholders such as TRANSCO for incorporation into their network planning process. Simultaneously, several downstream processes such as capacity procurement are kickstarted whilst the next SFCR cycle starts again in parallel.



The remainder of this section describes key planning inputs, the modelling process used to arrive at final recommendations, and the downstream processes that develop these recommendations into real-world projects.

2.1 Inputs to the Planning Process

EWEC conducts the core system optimisation planning using a digital twin of the power and water system. The model captures, among other things:

- Detailed representation of how conventional power plants convert fuel to power and water, including limitations on how quickly they can adjust their output in response to changes in demand or renewable generation;
- Existing and potential clean energy plants, including their expected hourly output and measures to account for possible non-availability;
- Water pipeline capacity and power transmission limitations to reflect how power and water can be moved around the system in real life;
- Commercial parameters such as fuel prices and plant costs; and
- Power and water demand.

Creating a harmonised set of projections for each of these inputs for the next 15-25 years is a major task, requiring specialised knowledge across a number of domains and close collaboration with subject matter experts (SMEs).

Demand forecasting is a foundational part of EWEC's mandate. It informs decisions for the entire sector, serving as a primary basis for generation planning, fuel and commercial agreements, and system operations.

On average, EWEC's year-ahead demand forecasts have been within 1.9% and 1.0% of actuals for power and water, respectively, since 2015.

2.2 From Model Outputs to Recommendations

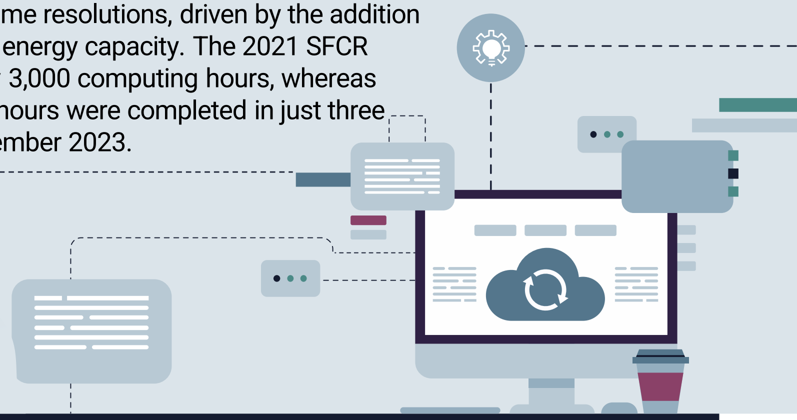
After consultation on inputs with subject matter experts across the sector, EWEC uses its digital-twin optimisation model to identify a range of actions or investments required to minimise the cost of meeting security and decarbonisation objectives for a given set of assumptions.

Recognising that the model outputs are at best as good as the model inputs and model itself, EWEC takes a prudent approach when translating raw model results into a set of recommendations.

Key pillars of EWEC's modelling process include:

Risk minimisation | **Integrated planning** | **Long-term look-ahead**

EWEC uses hundreds of high-spec modelling computers in the cloud to undertake system planning. This requirement has grown rapidly due to the complexity of modelling at finer time resolutions, driven by the addition of more renewable energy capacity. The 2021 SFCR took approximately 3,000 computing hours, whereas 46,000 computing hours were completed in just three months from September 2023.



Risk minimisation

EWEC examines dozens of sensitivities around a central base case to assess the materiality of various assumptions and identify key strategic drivers. Each sensitivity entails optimal capacity investments and despatch forecasts along with cost and emissions projections. By considering many development pathways, EWEC:

- can prepare response plans to quickly pivot to a new set of actions if major inputs change in the real world (e.g. repricing of gas contracts, significant change in the cost of a particular technology or new policy announced); and
- can assess low probability, high impact outcomes and nuance the base case recommendations accordingly. For example, EWEC maintains a portfolio of 'insurance' products to minimise the risk of having insufficient capacity to meet demand. This can take the form of contracting callable energy import options with neighbouring entities, or ensuring the availability of a small amount of low cost but inefficient OCGT to be held in reserve just in case.

Integrated planning

With much of the natural stability mechanisms being removed from the system as renewables replace gas-fired generation, maintaining the balance between supply and demand across the entire network becomes more complicated. No longer can generation planning be considered in isolation from the system in which it operates; it must evolve to become truly integrated system planning and consider the tools and processes required by the real-time operators as well as network requirements. Recognising this, EWEC and its sister companies have restructured in the last two years, with the real-time Load Despatch Center (LDC) moving from TRANSCO to be integrated with the long-term planning function in EWEC. This helps to ensure that operating realities are better factored into long-term planning decisions and vice versa. In addition, EWEC is enhancing its internal system planning capability to ensure generation planning is better synchronised with TRANSCO's network planning activities.

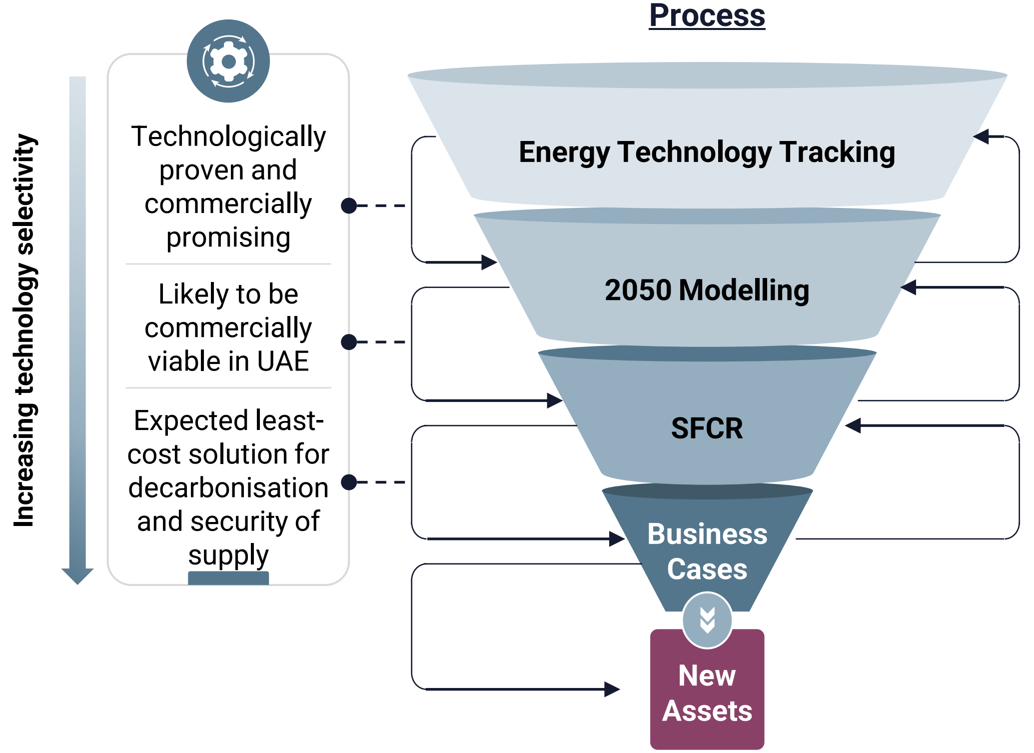
With the transfer of Load Despatch Centre (LDC) to EWEC, EWEC is now responsible for short and long-term operation and planning of water and power production. This includes procuring production capacity and system despatch, as well as other sector services.

Long-term Look-ahead

EWEC considers a fifteen-year outlook when developing its planning recommendations and is transitioning to one that looks to 2050 in light of net-zero commitments.

The scale of the net-zero transition underway is such that forward visibility of possible pathways is critical, even if the details of most likely outcomes remain highly uncertain. Comparing the projected system of 2035 against today's, for example, we can expect that gas will no longer fuel the majority of our generation as it gets displaced by a combination of solar PV, batteries and other clean energy such as wind and nuclear. Beyond 2035, it is possible that currently-emergent technologies such as hydrogen or CCUS begin to play a meaningful role. However, the optimum generation mix is far from certain and numerous intermediate milestones must be navigated before achieving net-zero. Hence, looking far enough afield to explore 'what if' type narratives around potential development pathways is important to avoid major regrets when undertaking investment decisions today.

Figure 7: EWEC's Technology Screening and Recommendation Process



Purpose

- **Monitor** technology landscape for promising technological developments to inform **modelling**
- Model simplified system and promising candidates ~30 years out to construct **development narratives** for informing **policy** and **sector structure**
- Model existing system and most viable candidates to 15 years out to inform **development plans, risk mitigation framework, trade deals, budgeting** etc.
- Conduct detailed due diligence studies to justify immediate procurement of specific assets

2.3 From Recommendations to Implementation

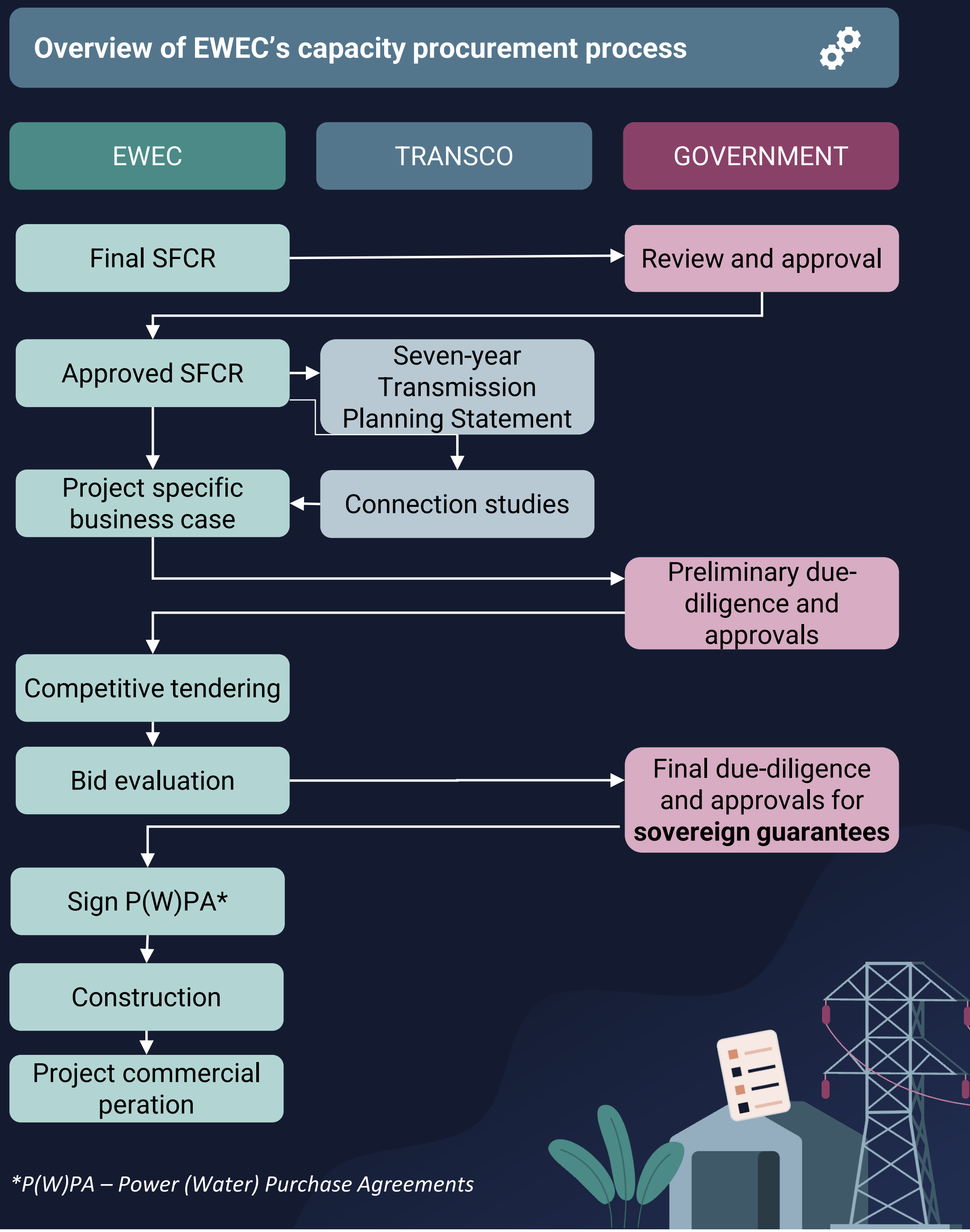
Having assessed the scenarios through technical, economic and regulatory lenses, EWEC moulds the raw modelling outputs into a core set of actions needed to begin the optimal development pathway. These recommendations, which can range from investments in new assets to long-term power supply contracts to redesign of operating procedures, are circulated for stakeholder comment and in many cases regulatory approval before being implemented and fed back into the ongoing planning process.

In parallel with regulatory review of the SFCR, several other downstream processes are also set into motion.

EWEC's SFCR and detailed modelling results are shared with TRANSCO for incorporation into its own seven-year transmission planning process, the findings of which will in turn be fed back into EWEC's subsequent SFCR process.

Following DoE approval of the SFCR, EWEC commences detailed business cases for any new assets or major commercial transactions to support security of supply and decarbonisation at least cost. These project-specific business cases go into more detail with the addition of, among other things, transmission connection studies and plans for financial structuring. Having submitted the business cases through several stages of regulatory approval, EWEC then goes out to market through a competitive tender process that aims to procure the highest quality assets at the lowest possible cost.

Updates from both the transmission planning workstream and asset procurement processes (e.g. expected commissioning dates, latest construction costs for given technology, etc.) are immediately fed back into EWEC's modelling as part of the continual optimisation ethos.



**P(W)PA – Power (Water) Purchase Agreements*

Planning Process Summary

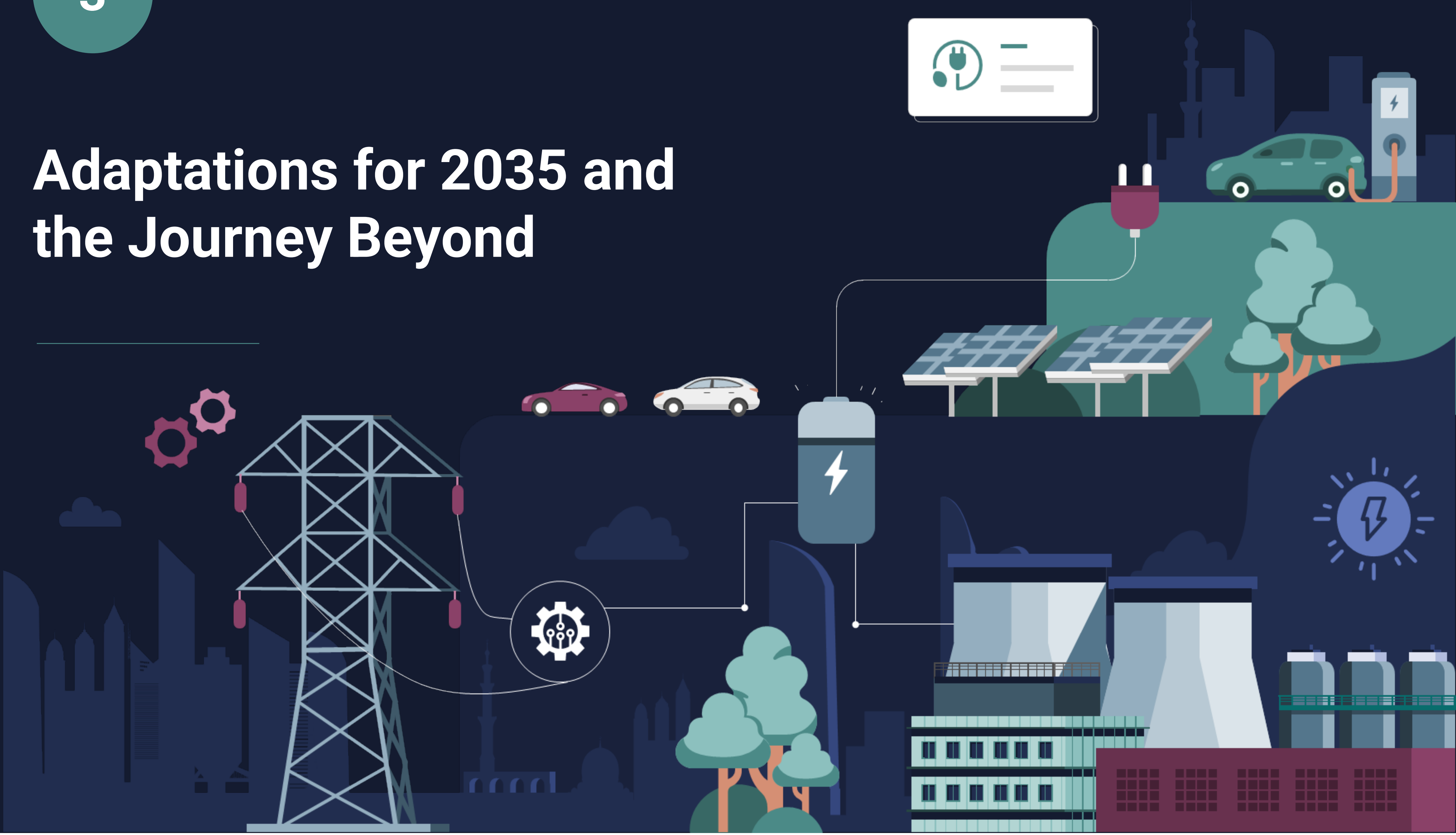
EWEC uses a multi-faceted, technology-agnostic planning process to continually evolve its system portfolio. By continually scanning the technology landscape and exploring long-term development narratives, it can in turn take an integrated approach to assessing credible scenarios and coming up with a final set of risk-weighted recommendations. Whilst the future is highly uncertain, the inherent flexibility in the planning approach and coordination between sector entities should allow EWEC to adapt to future developments.

EWEC is exploring collaborative avenues in knowledge sharing and system modelling with global counterparts. The objective is to bolster energy security in the MENA region and, at a foundational level, to further the UAE's 'Principles of the 50'.[9]

The next section describes some of the adaptations that EWEC has undertaken to arrive where it is today, and the likely adaptations needed to reach milestones along the decarbonisation journey.

3

Adaptations for 2035 and the Journey Beyond

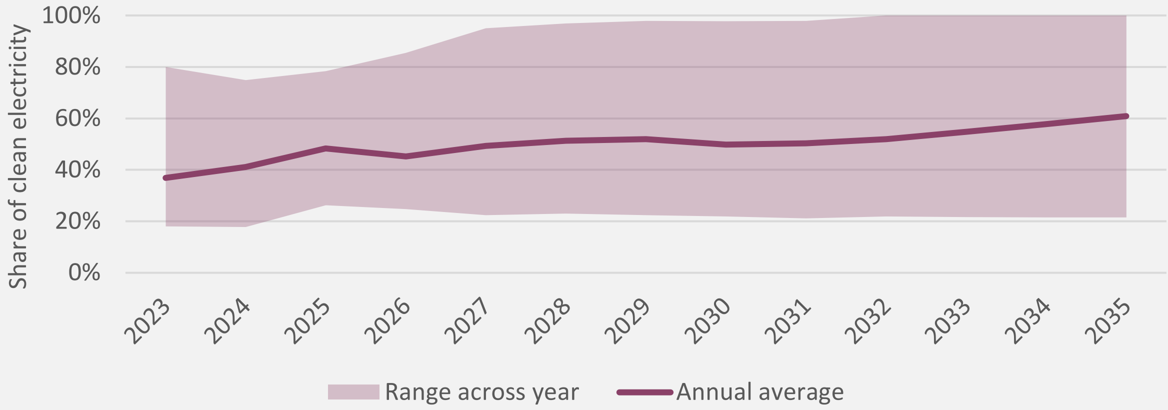


3 Adaptations for 2035 and the Journey Beyond

The path to achieving the 2035 CEST has some obvious first steps that aren't expected to increase total system costs. Switching to fully RO-based desalination and building enough renewables to meet daytime demand appear to be low-regret actions that will reduce system costs and, in conjunction with nuclear, yield ~50 per cent clean energy annually by 2035. Hitting 60 per cent annual clean energy may require higher expenditure if the energy storage costs don't fall as quickly as many anticipate, but fundamentally the high-level generation planning approach entails building more of the same.

However, one of the biggest system design challenges and threats to EWEC's clean energy transition lies in the secure despatch of this clean capacity. Due to the nature of intermittent renewables and imperfect correlation of their output with system demand, meeting a 60 per cent annual clean energy target will necessitate periods of fully clean energy generation intermingled with periods of heavy reliance on natural gas. We expect to start seeing short periods of 100 per cent clean energy penetration by the late 2020s (Figure 8); whether this can actually be despatched safely depends on whether EWEC can build the required human capital capability and develop plus implement the processes, risk frameworks and control systems in time.

Figure 8: EWEC is targeting 60% annual clean energy by 2035, but instantaneous clean energy share has already exceeded 80%



Hence, EWEC sees the first hour of 100 per cent clean generation as the first major milestone on the way to net-zero, and a major point of focus for strategic planning and coordination efforts with EWEC's sister companies. If this hurdle can be overcome without sacrificing security of supply, the subsequent adaptations needed to hit the 2035 CEST might be seen as more relating to large-scale land acquisition and capacity procurement than complete re-assessment of power system design fundamentals.

The next major challenge to these fundamentals will likely arise as we try to decarbonise beyond the 60 per cent target, as deep reliance on renewables without a supporting backbone of gas-fired assets completely changes the dynamics of reliability planning. Managing such a system may entail heavy reliance on currently untested technologies such as CCUS or hydrogen, or relatively unproven participation from the demand side to help match variations in the cost or availability of supply. Conversely, load-following and ancillary-service-providing nuclear plants would help enormously from a technical perspective, but at a much higher cost than power from EWEC's current non-nuclear fleet. Moreover, the multi-decade commitment required for nuclear power stations risks precluding future system planners from taking advantage of improving costs and performance in other clean energy technologies.

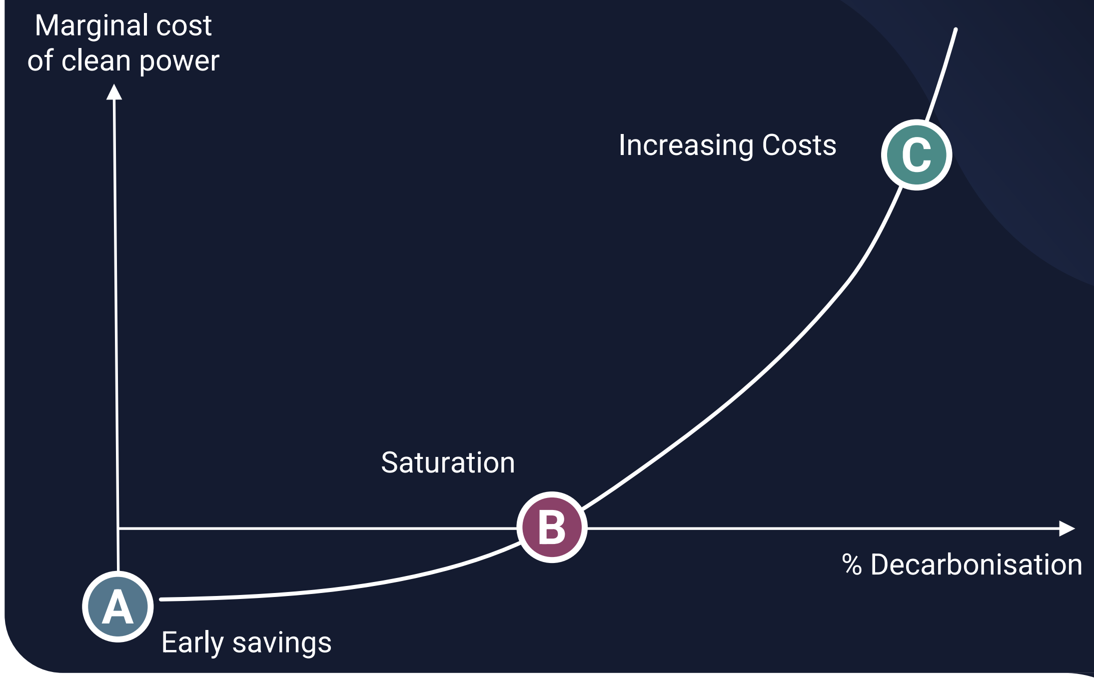
Our EV position paper looks at the potential impact of EVs on the EWEC generation system, highlighting the value of demand-side flexibility

Whilst a myriad of partial solutions exist, finding an optimal investment pathway in the light of such technological uncertainty is no easy feat and the divergence of paths for deeper decarbonisation won't remain academic for long. Meanwhile, understanding the ever-evolving risk profile and coordinating the solutions effectively will bring system planners and operators around the world into uncharted territory.

EWEC's early experience suggests that we are recognising the need for change in time and collaborating effectively with key partners in the sector to keep up with changing demands. Our planning process has so far proven itself to be robust to technological evolution and major developments such as the introduction of net-zero targets. With sufficient foresight and continued coordination across various sector entities in planning for each milestone, there is no reason why EWEC and the UAE can't make a respectable contribution to the international net-zero effort. The first test is just around the corner.

Clean Energy Coda

We will soon saturate our system with cost-saving clean energy, leaving only progressively more expensive options for deeper decarbonisation



A Initial investments in solar PV and RO desalination technologies can offer cost savings by replacing less-efficient gas-fired thermal plants. The marginal abatement cost is negative at this stage, meaning that it actually saves money to reduce carbon emissions.

B Eventually, the most cost-effective clean technologies will saturate the system. At that point, further investments in renewables and RO desalination will no longer offer cost savings. Based on the existing generation portfolio and current technology costs, we estimate the cost-optimal level of decarbonisation to be around 50-55 per cent by 2035.

C As the system approaches full decarbonisation, the marginal abatement cost will continue to increase. Intermittent renewables need disproportionate levels of storage to ensure reliability without gas as a backup; technologies like CCUS or nuclear power become less effective or prohibitively expensive for decarbonising the last stretch.

Milestones on the Path to Net-Zero

Maroon = process and people
Blue = technology and physical assets

Until now

- **Reorganise sector** to have generation despatch and generation planning teams sitting side-by-side
- Implement **Energy Technology Tracking project** to constantly monitor evolution of nascent technologies
- Develop **simple 2050 techno-economic modelling** to support decarbonisation narratives and what-if analysis
- Kick-start transition with first tranches of **nuclear, PV and RO**

100% clean for 1 hour (late 2020s)

- Finish **RO rollout** so water desalination no longer requires natural gas
- **Upgrade existing plants** to increase efficiency and flexibility
- **Overhaul grid codes and operating procedures** to reflect different risk profiles of the clean energy system
- Develop **procurement models** and build enough **batteries** to provide operating reserves and other ancillary services
- **Enhance 2050 techno-economic modelling** capability to support far-reaching investment decisions

Net-Zero (2035-2050)

- Co-develop **platforms**, and **behavioural impetus** for demand-side response to reduce consumption and shift into hours of renewable generation
- Maximise the utilisation of **cross-border transmission networks** and **cooperation frameworks** to maximise variable renewable energy (VRE) utilisation and improve resiliency
- Overhaul **resilience planning framework** to reflect different risk profile of power systems without full redundancy from conventional plants
- Incorporate **emerging technologies** for energy generation and storage, ancillary services and coordination

60% clean energy annually (2035)

- **Expand PV deployment** to meet almost all daytime demand
- **Large-scale deployment of energy storage, wind or other alternatives** to partially decarbonise overnight demand
- **Gear up procurement process** to allow entire programmes of assets to be approved, financed and procured instead of project-by-project
- **Develop operator know-how**, **information systems** and **confidence** for sustained periods of 100 per cent clean generation

References

[1] Electricity share of UAE total final consumption, 2018. Source: International Energy Agency. 2018. *World Energy Statistics and Balances*. Accessed online September 2023, https://energyeducation.ca/encyclopedia/End_use_energy

[2] International Energy Agency. 2022. *World Energy Outlook*. p239. Accessed online September 2023, https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf

[3] IBID

[4] Energy Transitions Commission. April 2021. *Making Clean Electrification Possible: 30 Years to Electrify the Global Economy*. p12. Accessed online September 2023, https://www.energy-transitions.org/wp-content/uploads/2022/07/ETC-Global-Power-Report-Final.pdf

[5] UAE Ministry of Energy and Infrastructure. 2022. *Electricity Statistics 2021*. Accessed online September 2023, https://fcsc.gov.ae/en-us

[6] EWEC analysis and EPA data: Environmental Protection Agency. *Emission and generator resource integrated database.* Accessed online September 2023, https://www.epa.gov/egrid/download-data.

[7] Abu Dhabi National Oil Company. *Our Company*. Accessed online November 2023. https://adnocgas.ae/en/our-company

[8] UAE Government. 2008. *Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy*. Accessed online October 2023. https://www.enec.gov.ae/doc/uae-peaceful-nuclear-energy-policy-5722278a2952f.pdf

[9] UAE Government. 2021. *The Principles of the 50.* Accessed online October 2023. https://u.ae/en/about-the-uae/uae-in-the-future/initiatives-of-the-next-50/the-principles-of-the-50

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