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IN PARTNERSHIP WITH

UNITED ARAB EMIRATES
MINISTRY OF ENERGY & INDUSTRY

الإمارات العربية المتحدة
وزارة الطاقة والصناعة

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A PROJECT BY DIAMOND DEVELOPERS

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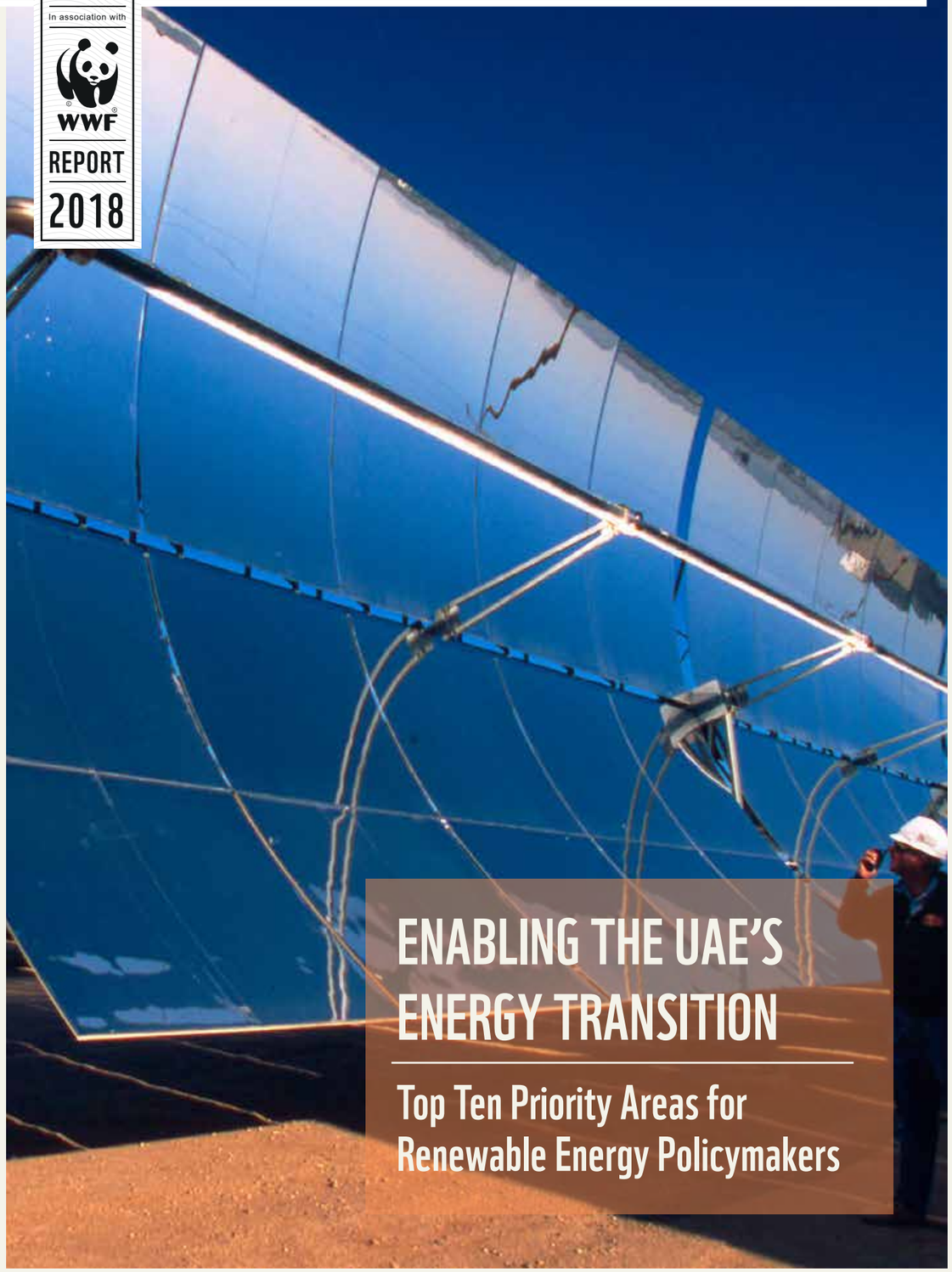

ENABLING THE UAE'S ENERGY TRANSITION

Top Ten Priority Areas for Renewable Energy Policymakers

ENABLING THE UAE'S ENERGY TRANSITION | TOP TEN PRIORITY AREAS FOR RENEWABLE ENERGY POLICYMAKERS

EWS-WWF

EWS WWF

Established in 2001 under the patronage of HH Sheikh Hamdan bin Zayed Al Nahyan, Ruler's Representative in the Western Region, EWS-WWF's mission is to conserve nature and reduce the most pressing threats to the environment by working with people and institutions in the UAE and the region to implement conservation solutions through science, research, policy, education, and awareness.

For more information about EWS-WWF, please visit uae.panda.org

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ABOUT MINISTRY OF ENERGY AND INDUSTRY

The UAE Ministry of Energy and Industry was established in 2004, after the merger of the Ministry of Electricity and Water, and the Ministry of Petroleum and Mineral Wealth. The Ministry strives to contribute to achieving the UAE 2021 vision, represented in the national agenda indicators; and to promoting competitiveness and developing a strategy to ensure the UAE society maintains its resources and enjoys a diverse and sustainable energy mix. It does this by proposing and developing policies, legislations and strategies in coordination with stakeholders. The Ministry aims at achieving security, sustainability and competitiveness of the sectors of energy, water and mineral wealth. It targets reducing greenhouse gas emissions in the country by developing and following up on strategies such as the preparation of the *UAE National Energy Plan 2050*, and the *Water Security Strategy 2036*. It also conducts studies and surveys, develops databases and disseminates information and statistics on energy, water and mineral resources, as well as prepares geological and geophysical studies and maps of the UAE.

The Ministry of Energy and Industry is keen to support and coordinate efforts and innovative initiatives in the field of energy and water, including dams and mineral wealth. The Ministry prepared the National Strategy for Innovation in the water sector, and it coordinated with the distribution companies in UAE regarding the policy on prices of derivatives or petroleum products that were deregulated in August 2015.

For more information please visit: www.moei.gov.ae

ABOUT EMIRATES WILDLIFE SOCIETY IN ASSOCIATION WITH WWF

Emirates Wildlife Society is a national (UAE) environmental non-governmental organisation established in 2001 under the patronage of HH Sheikh Hamdan bin Zayed Al Nahyan, Ruler's representative in the western region and Chairman of Environment Agency – Abu Dhabi.

Emirates Wildlife Society works in association with WWF, one of the world's largest and most respected independent conservation organisations, with offices in 100 countries. The association is commonly known as EWS-WWF.

Our vision is to build a future where humans live in harmony with nature.
Our mission is to conserve nature and reduce the most pressing threats to the environment. We work with people and institutions in the UAE and region, to implement conservation solutions through science, research, policy, education and awareness.

For more information please visit: www.uae.panda.org

ABOUT THE SUSTAINABLE CITY

The Sustainable City is an applied realisation of social, economic and environmental (SEE) sustainability. It embodies a true expression of sustainable living, achieved through innovative design, stakeholder engagement, and performance monitoring to sustain itself, creating a working model of what the future could look like. The project aims to be the first operational Net-Zero Energy city in Dubai, and was proudly named The Happiest Community in the Gulf.

For more information, please visit: www.thesustainablecity.ae

ABOUT KHIDMAH

Khidmah provides world-class property solutions that cover the entire lifecycle of a property. Khidmah's specialised property solutions include Property Management Solutions, Sales and Leasing Solutions, Community and Lifestyle Solutions, Facility Management Solutions and Home Maintenance (Khadamati – My Services). Khidmah leverages state of the art technology and a customised approach for each community it serves from the UAE to Saudi Arabia. Khidmah manages landmark developments across the region, addressing the need for specialised and reliable property solutions. From the early design stage to handover, operation, selling, leasing, managing and maintaining properties and facilities, Khidmah has the breadth, experience, skill set, commitment and resources to deliver on the needs of every property stakeholder.

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ABOUT BARINGA

Baringa Partners is an independent business and technology consultancy, where it helps businesses run more effectively, reach new markets and navigate industry shifts. Baringa uses industry insights, pragmatism and original thought to help each client transform their business. Collaboration runs through all Baringa's operations.

The complex interplay between markets, and national energy policies in the power and water sectors makes the investment environment uncertain. Thus Baringa helps investors and asset owners evaluate their opportunities and risks, and also works with generation companies to develop effective business models, to enable market entry and create new revenue streams.

Baringa deploys leading-edge market and asset models, combined with deep sector expertise, to advise on valuations, contracting and risk management strategies and to undertake economic, commercial and regulatory due diligence. Baringa advises governments on energy policy, analysing the likely impact of different regulations and financial incentives on future investment and plant retirements. Baringa also advises system operators on the implications of different generation mixes, particularly the expansion of variable renewable output, the costs of transporting electricity and balancing the networks.

For more information, please visit www.baringa.com

ACKNOWLEDGEMENTS

This report was made possible thanks to our partnership with the Ministry of Energy and Industry. We would like to thank the Ministry for providing us the opportunity to join their journey towards a low-carbon UAE by 2050, and in acknowledging the role that civil society organisations such as EWS-WWF play in policy development in the UAE. Special thanks are due to H.E. Dr Matar Al Neyadi, Undersecretary of the Ministry, and H.E. Eng. Fatima Al Foora Al Shamsi, Assistant Undersecretary for Electricity and Future Energy, for their continued guidance and leadership during the development of this report and related activities. We would also like to convey our gratitude to the technical team at the Ministry: Ms Reshma Carmel Francy, and Ms Fatma Al Falasi, for their support in the development and review of the report.

We would like to extend thanks to The Sustainable City for their sponsorship of the Climate and Energy Programme, and specifically this report and associated project activities. The Sustainable City's Mr. Faris Saeed and Mr Karim El-Jisr have enriched this report with their on-the-ground experiences. We would also like to thank Khidmah for sponsoring this report.

This report was prepared by Baringa Consulting and Masdar Institute, with technical inputs and support from EWS-WWF. We thank Mr. Nicholas Carter, Mr Stephen Tudhope, Dr Pavlos Trichakis, Dr Sgouris Sgouridis, and Dr Steve Griffiths for their efforts and effective collaboration on this project. We would like to acknowledge Ms Lisa Reinisch for support on communications and production of deliverables.

Finally, we would like to thank all those who have provided valuable insights as part of the stakeholder engagement process.

Emirates Wildlife Society in association with WWF

Enabling the UAE's Energy Transition | Top Ten Priority Areas for Renewable Energy Policymakers

"THE ONE WHO DOES NOT THINK OF ENERGY IS NOT THINKING ABOUT THE FUTURE."

His Highness Sheikh Mohamed bin Rashid Al Maktoum
Vice President and Prime Minister of the UAE and Ruler of Dubai

These images were taken during the Future Lab 2017 event, where the National Energy Plan 2050 was launched.

FOREWORD FROM DR. MATAR AL NEYADI,

UNDERSECRETARY OF THE MINISTRY OF ENERGY AND INDUSTRY

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The Ministry of Energy and Industry is delighted to collaborate with Emirates Wildlife Society in Association with WWF in producing this report. The protection of the natural environment is a priority for the UAE Government, and especially the Ministry of Energy and Industry, particularly in the sustainability of our water resources and our energy sector.

This report builds on the *UAE National Energy Plan 2050*, which was launched by the leadership of the UAE in January 2017. The National Energy Plan sets a firm commitment to deliver a more sustainable future, through the acceleration of clean energy as well as significant measures to improve energy efficiency and preserve natural resources.

Specifically, the Plan targets to cut carbon dioxide emissions by 70 per cent by 2050, while increasing the contribution of clean energy from 25 to 50 per cent and improving energy efficiency by 40 per cent – resulting in savings worth more than AED 700 billion.

The process to design the National Energy Plan is the result of years of collaboration between energy stakeholders across various sectors of the energy industry. Through hard work and dedication, the Ministry worked to achieve a unique consensus for the long-term targets for the energy sector in the UAE that are accepted by all stakeholders.

The result is a fair balance between the three key areas of the National Energy Plan 2050, which are improved national energy security, a more sustainable form of development, and greater happiness of energy users and stakeholders.

The UAE has demonstrated that the ambitious targets of the National Energy Plan are achievable. Together, we have already set global records for the lowest prices of unsubsidised renewable energy technologies through innovative financing mechanisms. The most recently awarded 700 MW Concentrated Solar Power project in Dubai for the fourth phase of Mohammed Bin Rashid Al Maktoum Solar Park is at a levelised tariff of 7.30 US$ cents per kilowatt-hour. A cost level, which is competitive with fossil fuel technologies for dispatchable solar energy through the night.

These breakthroughs in achieving sustainable development through clean energy will ensure prosperity for the nation despite the rising challenges of climate change. The UAE has determined that clean energy is the solution to decarbonising the economy, and energy stakeholders across the nation have successfully established the foundations of a sustainable energy sector and a low-carbon future.

The long-term targets will be reviewed every three years to ensure that the delivery goals of the Plan are on track. In this sense, this report is very timely as it explores the necessary policy frameworks to enable the transition set forth by the *UAE National Energy Plan 2050*.

The policy recommendations in this report are based on the feedback received through a meticulous stakeholder engagement and review process. The outcomes of this work will support the work of the Ministry and promote dialogue on clean energy with other entities in both the public and private domain.

On behalf of the Ministry of Energy and Industry, I would like to thank the efforts of EWS-WWF in supporting the UAE. EWS-WWF was part of the Future Lab in January 2017 where the targets were debated amongst key stakeholders in the sector and unanimously adopted.

Enabling the UAE's Energy Transition | Top Ten Priority Areas for Renewable Energy Policymakers

FOREWORD FROM LAILA ABDULLATIF,

DIRECTOR GENERAL OF EMIRATES WILDLIFE SOCIETY IN ASSOCIATION WITH WWF

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I am delighted to be able to bring this report to you with our partner, the UAE Ministry of Energy and Industry. This report contains policy recommendations that have been designed to expand renewable energy in the UAE and, specifically, to support the development of a robust policy framework for the achievement of the national renewable energy target set by the *UAE National Energy Plan 2050*.

It is exciting to see the remarkable growth in the renewable energy sector globally, especially with record investments in solar and wind. These investments are unleashing a major shift in global energy markets, where renewable technologies are now consistently amongst the cheapest forms of energy and being deployed at increasing speed and scale. Renewable energy is also creating jobs, reducing air pollution and contributing to economic growth. At the same time, its vast potential to reduce global carbon dioxide emissions gives us a fighting chance to hold average temperature rise to below 1.5°C.

The UAE's renewable energy sector has witnessed significant changes over the last few years and I am sure it will continue to see innovation and deployment of competitive technologies, setting up the country to even surpass its current targets. The UAE is now a global hub for renewable energy development, as evidenced by the record low prices for solar photovoltaic in Dubai and Abu Dhabi (at 2.99 and 2.42 US$ cents per kWh, respectively), and the recent world-record low price for the concentrated solar power plant in Dubai (at 7.3 US$ cents per kWh), which will provide 24-hour renewable energy, and will be a game changer for providing predictable base load energy at prices competitive with energy from fossil fuels. We are also seeing more businesses and industries proactively installing solar power on their premises and rooftops.

The fact that these changes are occurring in a major oil-producing country like the UAE is something that I hope will inspire other oil export-dependent countries in the region. We at the Emirates Wildlife Society in association with WWF (EWS-WWF) are committed to actively supporting the UAE's transition to a low-carbon economy, with a focus on continued economic prosperity and human well-being. Left unabated, climate change will have devastating consequences for wildlife, habitats and people on this planet. Therefore, we support a global move to renewable energy as a crucial measure to address climate change and ensure people can live in harmony with nature.

When the *UAE National Energy Plan 2050* was launched in January 2017, EWS-WWF was supportive of the UAE establishing its first ever unified long-term energy plan and we were keen to support the Ministry to help implement the renewable energy target. I am happy to say that EWS-WWF and the Ministry share the goal of putting in place a comprehensive policy framework to achieve and hopefully even surpass the national renewable energy target. This report is in line with our role as a science-based independent civil society organisation.

As a reader, whether you represent a utility, business, university or industry, the findings of this report have been designed to help you make a meaningful contribution to the country's renewable energy vision. I hope you find the report enlightening. EWS-WWF looks forward to working in collaboration with the Ministry of Energy and Industry, utilities, businesses and other key federal and Emirate level stakeholders, to carry forward the recommendations in this report and support the UAE's progress towards a sustainable future.

Enabling the UAE's Energy Transition | Top Ten Priority Areas for Renewable Energy Policymakers

PROJECT SPONSOR: THE SUSTAINABLE CITY

THE SUSTAINABLE CITY
A PROJECT BY DIAMOND DEVELOPERS

From day one, our goal was to design and operate the first net-zero energy development in the region. The Sustainable City embodies best practices in energy efficiency and photovoltaic solar rooftops, with measurable carbon avoidance. This achievement was made possible thanks to technological advances in solar energy and smart regulation – designing low-carbon cities is the only possible future!

Faris Saeed, CEO

REPORT SPONSOR: KHIDMAH

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The *UAE National Energy Plan 2050* has outlined three important pillars to meet the country's growing energy needs and ensure sustainable growth of the economy - reduction in carbon dioxide emissions, utilising clean energy resources and very importantly, improving our energy efficiency. With the development of a policy framework for increased renewable energy in the UAE, individuals, corporations, and government-related entities will be able to make an active contribution to turning the country's energy ambitions into a sustainable reality.

Jahed Rahman, Managing Director

ENABLING THE UAE'S ENERGY TRANSITION

Top Ten Priority Areas for Renewable Energy Policymakers

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Enabling the UAE's Energy Transition

Top Ten Priority Areas for Renewable Energy Policymakers*

Emirates Wildlife Society in association with WWF (EWS-WWF) has partnered with the Ministry of Energy and Industry (MOEI) to identify the most important areas of policy intervention for achieving the federal renewable energy target of 44 per cent by 2050.

The solutions are already there, now it is a matter of putting them into action!

1 Competition
Promote open and fair competition between technologies based on transparent, market-based mechanisms across the energy value chain.

2 CO2 targets
Complement existing renewable energy targets by a pathway for CO2 emissions reductions, taking into consideration costs to society from CO2 emitting technologies.

3 Renewable energy targets
Establish a fully flexible renewable energy policy framework which sets review milestones and interim targets, and promotes uptake across all sectors of UAE society, including installation of rooftop solar panels.

4 Firmness and flexibility
Enable technology-neutral auctions that adapt to changing requirements as the system and energy economics evolve over time.

5 Demand-side management
Accelerate energy efficiency improvements across all sectors with measures that have the greatest energy-saving potential.

6 The water-power nexus
Decouple power generation and water desalination through the introduction of additional stand-alone water production plants (such as reverse osmosis) powered by renewable energy.

7 Emerging technologies
Support the development of, and competition amongst, emerging technologies such as seasonal storage and electric vehicles to further support uptake of renewables.

8 Networks
Prevent congestion and ensure that costs to resolve constraints are kept to a minimum to keep the network as efficient as possible.

9 Interconnection
Build a regulatory framework for efficient dispatch between domestic utilities and consider regional trading with the Kingdom of Saudi Arabia and Oman.

10 Innovation
Encourage research and development by government, private sector and academic institutions for locally relevant solutions.

*This is an abridged version of the top ten priority areas outlined in the report, Enabling the UAE Energy Transition, published by EWS-WWF in partnership with the MOEI. For the unabridged version, which incorporates the latest international policy insights along with local stakeholder inputs from across all emirates and sectors, please visit: www.uae.panda.org/latest_news/publications

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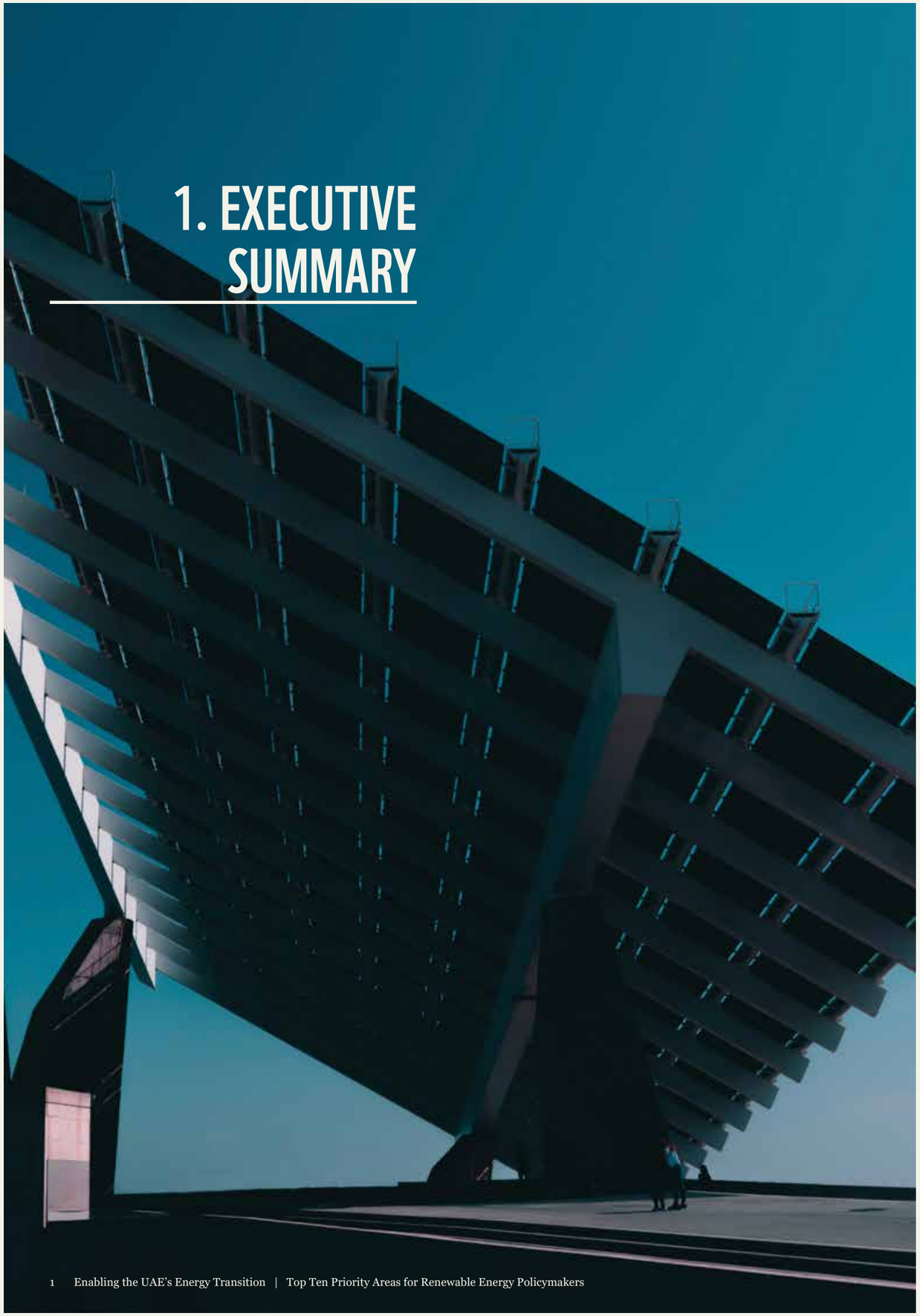


1. EXECUTIVE SUMMARY

IN EARLY 2017, THE UAE INCREASED ITS AMBITION ON RENEWABLE ENERGY WITH THE LAUNCH OF ITS UAE NATIONAL ENERGY PLAN 2050, WHICH INCLUDES A 44 PER CENT RENEWABLE ENERGY TARGET

Motivational Statement

In the past two years, the world has witnessed drastic changes in the economics and dynamics of the renewable energy industry, both in the UAE and worldwide. Costs of technologies continue to decrease, especially for solar photovoltaics (PV) and, more recently, Concentrated Solar Power (CSP), making non-conventional renewable energy technologies now economically competitive with sources such as oil and gas. The UAE is increasingly realising the importance of addressing the impacts of climate change on the wellbeing and livelihoods of its people. In early 2017, the UAE increased its ambition on renewable energy with the launch of its *UAE National Energy Plan 2050*, which includes a 44 per cent renewable energy target. The question that remains is: what policies will the country need to put in place to achieve the 44 per cent target? This is what Emirates Wildlife Society in association with WWF (EWS-WWF) and the Ministry of Energy and Industry (MoEI) aim to answer together through this report, *Enabling the UAE's Energy Transition: Top Ten Priority Areas for Renewable Energy Policy Makers*. This report delves into the potential policy measures that can support the MoEI and the UAE in achieving current targets, and potentially further increasing ambition on renewable energy in the future. Accordingly, this report aims to act as an enabler for stakeholder dialogue amongst key federal and Emirate-level players to identify an effective implementation plan.

What's in the Report?

This report looks at the country's current renewable energy context, including existing strategies, regulations and policies that have been put in place at both the federal and emirate-levels, to support the transition towards renewable energy. It also looks at the changing economics of renewables and successes of renewable energy implementation in the UAE. Most importantly, the report, enriched by comprehensive research and stakeholder dialogue, lays down recommendations that cover an array of areas that the UAE government can refer to for developing a robust policy framework to implement the *UAE National Energy Plan 2050*, and to reassess targets during the plan's scheduled revision cycles. The report is meant to act as an effective tool for policy makers across the UAE, with science-based and stakeholder-driven recommendations.

MoEI and EWS-WWF sought insights and feedback on the challenges and barriers that currently characterise the UAE energy market from key stakeholders in the renewable energy field. Working in partnership, the organisations aimed to understand potential innovative solutions and key priority policy areas to focus on. The MoEI and EWS-WWF co-hosted a stakeholders' roundtable that gathered key entities across public and private sectors, and included utilities, emirate-level energy authorities and regulatory bodies, environmental authorities, academic institutions, international organisations and consulting firms, energy companies and civil society organisations. The list of participating organisations is included in Appendix A. The roundtable provided an opportunity for dialogue on the policies

required to meet the national renewable energy target. Open discussion on key areas for renewables development covered a range of topics including, but not limited to: networks and interconnections; competition; demand-side management; storage and other emerging technologies; and power tariffs transparency.

Closer Look: Policy Recommendations

Table 1 below summarises cross-Emirate policy recommendations included in this report that will enable deep decarbonisation of the power generation sector whilst potentially addressing the two key energy policy challenges of affordability and security of supply. These recommendations are elaborated on further in respective sections within the report.

Table 1: Summary of Policy Recommendations

Topic	Policy recommendations for the UAE
The role of competition	• Remove barriers to open and fair competition between available power generation technologies; • Create a cost-reflective system dispatch to ensure the system is operating as efficiently as possible; • Promote competition using transparent, market-based mechanisms across the energy value chain.
The role of renewable targets	• Establish a fully flexible renewable energy (RE) policy framework which sets review milestones and interim targets; • Investigate the potential for new route to market options for RE (in addition to technology-neutral renewable auctions[1]) such as corporate renewable energy Power Purchase Agreements (PPAs)[2] and Renewable Energy Certificates (RECs); • Harmonise RE policy setting across Emirates; • Introduce and promote rooftop solar PV and streamlined means of getting connected to a local distribution network.
The role of CO_2 targets	• Complement existing RE targets with a pathway for CO_2 emissions reductions in coordination with relevant key stakeholders; • Understand externalities to be able to evaluate the costs to society from CO_2 emitting technologies; • Consider abatement options in different sectors of the UAE economy, not just the power and water sectors, and promote abatement in the sector(s) with the lowest marginal abatement costs.
Firmness and flexibility[3]	• Develop technology-neutral auctions targeting firm and flexible capacity based on specific technical requirements as the system evolves over time; • Develop a remuneration framework for new build thermal generation assets with adequate incentives for high availability and physical delivery (to ensure security of supply), but which also prioritises the provision of firmness and flexibility to allow cost-effective integration of low-carbon generation technologies[4]; • Investigate the future evolution of ancillary services to the system operator, particularly with respect to the increase in reserve levels due to RE penetration and the new nuclear plants; • Consider potential applications of energy storage technologies, beyond the requirement of large volumes of storage to reduce costs of integrating RE generation technologies, in operational timescales (such as resolving local network constraints and providing ancillary services).
The role of demand-side management	• Encourage demand-side management participation at both operational (e.g. to resolve network constraints and provide ancillary services) and investment timelines (e.g. to delay or reduce transmission or generation capacity in the system); • Investigate the introduction of tariffs such as 'time of use' and interruptible tariffs[5]; • Accelerate improvements in energy efficiency with measures that have the greatest energy-saving potential; • Introduce more government-led green initiatives that support or work with RE policies through the implementation of codes, standards and, if necessary, legislation.
The water-power nexus	• Decouple future power generation and water desalination process through the strategic introduction of additional standalone water production plants (e.g. based on Reverse Osmosis (RO) technology); • Create an integrated, long-term UAE water and power strategy that complements the *UAE National Energy Plan 2050* and is informed by local needs; • Explore the optimal trade-offs between increasing flexibility in the power system versus increasing flexibility in the water system.

[1] These technologies include the ones that are either being used or have potential in the UAE, such as solar PV, solar CSP, wind energy, and pumped hydro storage.
[2] A corporate renewable energy PPA is a long-term agreement where a business agrees to purchase renewable energy directly from an energy generator. Generally, this differs from a traditional utility PPA where businesses purchase electricity from utilities.
[3] Firmness refers to the capacity that can be dispatched when required to do so, whereas flexibility refers to the ability to respond quickly and efficiently to fluctuating supply/demand conditions in the power system.
[4] Historically, thermal generators in the UAE have been operating at high load factors to meet an annual generation target as part of their PPA. Going forward, with increased penetration from low-carbon generation technologies, thermal generators may no longer be required to operate baseload, but rather to vary their output depending on hourly demand and supply conditions in the system.
[5] Uninterruptible tariffs cover services, such as most electricity and natural gas supplies, that are intended to be available at all times during a period covered by an agreement. Conversely, an interruptible tariff is a special arrangement under which, in return for lower rates, the customer must either reduce demand on short notice or allow the utility to temporarily cut off the energy supply. This interruption or reduction in demand may, for example, occur during periods of high demand, or when RE output is low.

Topic	Policy recommendations for the UAE
The role of emerging technologies	• Support the development and testing of seasonal storage projects, and exploration of thermal energy storage for air conditioning; • Consider competing emerging storage technologies including solar PV + batteries, solar CSP + integrated thermal storage, pumped storage and other technologies; • Consider incentivising and promoting cost discovery[6] via technology-neutral auctions; • Ensure that any roll-out of electric vehicles aids rather than hinders system flexibility. Align charging infrastructure and incentives to ensure vehicle charging occurs during off-peak hours (e.g. during low demand periods or periods with excess renewable output).
The role of networks	• Prevent, where possible, network congestion from arising without the need for additional network reinforcement; • If some congestion is unavoidable in specific parts of the system, ensure that costs to resolve constraints are kept to a minimum; • Provide efficient transmission investment signals for cases where network reinforcement is the most cost-effective solution in the long-term; • Ensure that transmission costs are included in technology-neutral auctions. • Ensure the stability, reliability and security of the electrical transmission and distribution network (which is essential for the economy as a whole) as the country's electricity grid evolves to accommodate increasing amounts of intermittent renewable energy technologies.
The role of interconnection	• Investigate a framework for efficient dispatch of interconnectors between UAE utilities – including ensuring harmonised calculations of variable cost of generation in each utility; • Investigate a similar framework for trading on existing interconnection between the UAE and other Gulf Cooperation Council (GCC) countries; • Evaluate the benefit of additional interconnectors to neighbouring countries in conjunction with Gulf Cooperation Council Interconnection Authority (GCCIA) trading framework plans. Provide a financing framework to allow Transmission System Operators (TSOs) and/or developers to bring forward projects.
Fostering innovation and supporting policies	• Build on the Shams initiative across the UAE by promoting financial incentives for rooftop solar, initially targeting low-rise buildings; • Encourage clean energy research and development by government, private sector companies as well as academic institutions, for UAE and GCC countries' based solutions; • Promote the establishment of centres of excellence across the UAE, building on the Masdar model[7]; • Promote new green energy policies and funding mechanisms, focusing on customers, in an effort to create upward demand.

[6] Cost discovery is the act of determining the price of a security, commodity, good or service by studying market supply and demand and other factors associated with transactions. For power generation projects in particular, site-specific considerations such as balance of plant costs, average capacity factors, land costs and network connection costs and constraints may only become apparent through a detailed cost discovery process.

[7] This refers to the model upon which Masdar company was established, which included several subsidiaries, one of which is the Masdar Institute of Science and Technology. The institute is responsible for local-level research and development for technologies and solutions in alternative energy and sustainability.

2. UAE'S CURRENT ENERGY AND POLICY CONTEXT

2.1 UAE'S CLIMATE CHANGE EFFORTS

The Paris Agreement, which came into force on 4 November 2016, is a major step forward in the fight against climate change. However, this is only the start of the journey, one that now has a direction and consequently a focus. The UAE has and continues to demonstrate a great desire to promote sustainability in its various forms. Although meeting ambitious climate goals is challenging, there is recognition that such goals help to address the effects of climate change and advance climate-resilient development. The UAE signed and ratified the Paris Agreement in 2016, and created a Ministry of Climate Change and Environment to ensure that climate change efforts are at the forefront of the country's priorities.

In 2017, the government approved the *UAE National Energy Plan 2050*, which sets out targets for carbon emissions reductions, and a 44 per cent target for renewable energy capacity in the energy mix. However, the country is yet to develop a policy framework to achieve this target. The UAE also announced its first *UAE National Climate Change Plan*, which is the UAE's comprehensive framework to address the causes and impacts of climate change, plan the transition into a climate resilient green economy, and achieve a better quality of life.

2.2 THE UAE NATIONAL ENERGY PLAN 2050

THE UAE NATIONAL ENERGY PLAN 2050 AIMS TO REDUCE CO_2 EMISSIONS BY 70%, INCREASE CLEAN ENERGY USE TO 50%, AND IMPROVE ENERGY EFFICIENCY BY 40% BY 2050

At the start of 2017 the UAE Ministry of Energy and Industry announced a far-sighted *UAE National Energy Plan 2050* with cross-Emirate support. This includes plans to cut carbon dioxide emissions by 70 per cent, increase clean energy renewable energy and nuclear capacity by 50 per cent, and improve energy efficiency by 40 per cent across all key energy sectors by the middle of this century. In effect, the Ministry has provided a breakdown of targets for the energy capacity mix to address greenhouse gas (GHG) reductions. The targets recognise the current planned coal developments, and the existence and commissioning of four nuclear power plants. The breakdown is given as 44 per cent from renewable energy sources (RES); 38 per cent from gas; 12 per cent from clean coal and 6 per cent from nuclear power.

The objective of the *UAE National Energy Plan 2050* is to deliver clean, secure, affordable energy and respond to the risks of climate change by reducing greenhouse gas emissions. Through this plan, MoEI is looking to ensure energy security and happiness of the UAE while supporting the country's transition to a green and diverse economy. Several scenarios were tested by MoEI to identify the optimal electricity capacity mix, keeping in mind affordability and security of energy from now until 2050. Figure 1 outlines the different scenarios that were assessed by the Ministry. Figure 2 shows the different indices that were used to evaluate the scenarios, and their respective weight for decision-making.

Figure 1 - Scenarios Assessed by MoEI

Scenario	Basis for Scenario Development	Demand Reduction compared to BAU
Business as Usual (BAU)	• Capacity Additions as per Vision 2021 • Cost competitive selection criteria	
Midway	• Medium efforts towards demand reduction • Medium preference for renewables	***20%***
Environmental	• High efforts towards demand reductions based on best practices • High preference for renewables	***30%***
50 @ 50	• Maximum efforts towards demand-side management based on best available technology • Very high preference for renewables	***40%***
Climate Force	• Maximum efforts towards demand reduction • Very high preference for renewables and Inclusion of carbon value	***46%***

Figure 2 - MoEI's Indices for Scenario Evaluation and Weightage

ENERGY SECURITY AND RELIABILITY

40%

- Per cent of Imported Fuel used in Total Energy Mix
- Number of energy sources

ENERGY AFFORDABILITY

30%

- Average Cost of electricity production
- Total investment for capacity additions

SUSTAINABILITY

15%

Clean Energy and Emissions

- CO_2 emissions per $GDP
- Share of clean energy in generation mix

Energy Efficiency and Productivity

- Electricity use per capita
- GDP Per Unit of Primary Energy Use

HAPPINESS

15%

- Difference in Cost of Electricity Production from 2013
- Total emissions for electricity sector

The final selected scenario adopted as part of the *UAE National Energy Plan 2050* was the "50@50 scenario", which aims to have 50% clean energy capacity by 2050. The Ministry adjudged this as the optimal scenario based on the economic and energy context of the UAE in 2016. The technologies considered in the *UAE National Energy Plan 2050's* 44% renewable energy target are: solar PV; solar CSP; wind; and waste to energy. To account for changes in context, the Ministry has included revision cycles to ensure that the targets reflect market needs, available technologies, and economics of diverse energy sources and technologies.

2.3 UAE ENERGY MARKET CONTEXT AND CHALLENGES

Sustainability is a critical component of federal and emirate-level plans in the UAE. Innovation and sustainability are given significant importance and play a role in tying the country's future to the vision of its leaders. The UAE Vision 2021 has set indicators to measure non-oil GDP and the share of clean energy in the country on an annual basis. In 2015, the UAE Cabinet approved the UAE Green Agenda 2030. In line with the national goals, the country is implementing the *UAE National Energy Plan 2050* as well as the *UAE National Climate Change Plan*. A number of key stakeholders are being engaged in the implementation of these plans, and it is clear that the achievement of set objectives and targets will require buy-in and support from key federal and Emirate-level players in the UAE power and environmental sectors as shown in Figure 3 below.

Figure 3: Key Ministries and Utilities in the Power and Water Sector of the UAE

DoE-AD

Abu Dhabi Emirate

Responsible for the sector in all forms except Nuclear Power

Also functions as Abu Dhabi's regulatory body

RE Policy 7% by 2020

DEWA

Dubai Emirate

Responsible for whole sector, including the procurement of IWPPs and IPPs

Separate regulatory body

Clean Energy 75% by 2050

SEWA

Sharjah Emirate

Responsible for whole sector including the gas distribution

No regulatory body

No announced RE target

FEWA

Emirates of: Ajman
Ras Al Khaimah
Fujairah
Umm Al Quwain

Sets policy and operates in the 4 emirates

No regulatory body

No announced RE target

Ministry of Energy and Industry

Organize the Water and Power (electricity, transport, industry) according to the security supply and economic developments. Diversification of energy resources. Reduction of carbon emissions from relevant sectors. Implementing the *UAE National Energy Plan 2050*, in coordination with relevant entities.

Ministry of Climate Change and Environment

Developing plans, strategies, and policies in the areas of climate change, the environment, waste management, agriculture, livestock, fisheries and biodiversity conservation.
Implementing the *UAE National Climate Change Plan*, in coordination with relevant entities.

The UAE energy market has grown significantly in recent decades. According to The World Bank, electricity demand has increased 43.4 per cent between 2009 and 2014, exceeding population growth which was around 20 per cent during the same period. As it stands now, the generation mix of the UAE is heavily reliant on the use of gas-fired power plants. According to the Federal Statistics and Competitiveness Authority, of the 28.8 GW of installed capacity in 2016, 92.4 per cent was comprised of Combined Cycle Gas Turbines[8] (CCGTs) and Open Cycle Gas Turbines[9] (OCGTs). PV solar represented only 60 MW of installed capacity by 2016 and solar CSP stood at 100 MW. However, this will change over the course of the next few years. Investments are being made in building new capacity to meet future needs. This demand will be met through a varied generation mix and there is an increasing focus in the larger Emirates on the important role that renewable energy technologies will play in the future market.

The requirements for power sector decarbonisation and challenges that present themselves in the UAE are similar to those being seen in other countries with comparable levels of growth and expansion. A summary of these key challenges is provided in Table 2.

Table 2: Key Challenges for the UAE Power Sector

Body	Key Challenges
Government of UAE	• The integration of the *UAE National Energy Plan 2050*, with specific policies that are flexible and fit for purpose in light of global RE developments; • The promotion of alternative, clean power and water production through regulation and intervention policies; • Decarbonising across the whole energy sector (including power and water, transport and industry); • Submission and achievement of progressively ambitious Nationally Determined Contributions to the United Nations Framework Convention on Climate Change (including the country's renewable energy plans), in line with the goals of the Paris Agreement. All signatories to the Paris Agreement will be faced with such challenges with respect to deep decarbonisation if they are to meet the 2050 climate targets as set out in the Agreement.

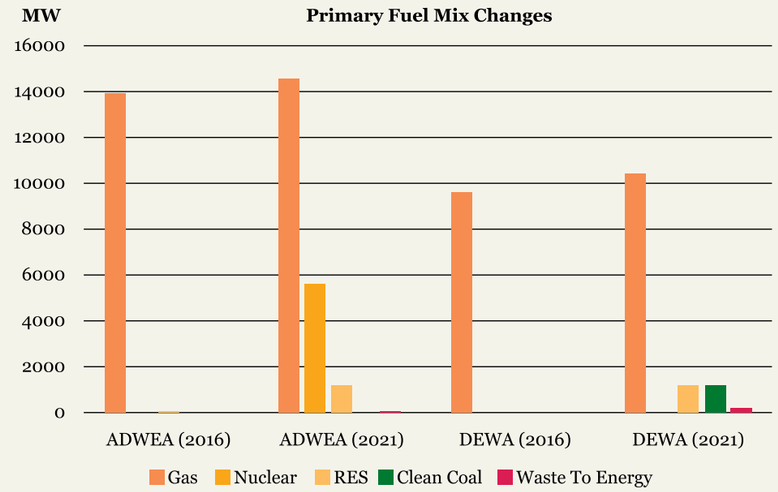
[8] The combination of a gas turbine and steam turbine leading to increased thermal efficiency.
[9] A gas turbine without an additional steam turbine.

Body	Key Challenges
UAE Power and Water Authorities	• The reduction in GHG per capita emissions both as a trend and in absolute terms. Delivery will be dependent upon the introduction of significant load reductions and the migration to renewable energy sources; • The provision of clean primary energy to reduce the domestic burning of fossil fuels (liquids and gas) and the import of gas; • The integration and dispatch of must-run plants, especially nuclear power plants. As the share of intermittent renewable energy technologies increases in the generation mix, power systems will be exposed to greater levels of uncertainty, variability and risk. This will require policy makers and the utilities to incentivise technologies that provide adequate firmness and flexibility to the system in order to avoid excessive curtailment of renewable generation and guarantee security of supply. The growing need for firmness and flexibility, along with the fact that they can be costly to provide, highlights the importance of efficient procurement; • The provision of sufficient water production capacity to meet increasing demand, whilst managing a system with baseload nuclear power and lower power production from gas-fired power plants (with desalinated water as byproduct); • The RE energy mix choices – between utility RES using CSP, PV, wind or distributed RE and the integration/adoption of energy storage systems; • Greater coordination between Emirates regarding planning and system expansion, operation, sharing of primary fuel resources, and dispatch.
Emirates National Grid	• Removing network constraints and enhancing stakeholder coordination for power transfer between Emirates – which would promote more efficiency; • The promotion and implementation of an inter-Emirate power-trading platform to optimise plant utilisation; • GCC inter-country trading and further integration of transmission networks.
Nuclear Power [Emirates Nuclear Energy Council]	• The accommodation of excess electricity from all four must-run nuclear plants in the winter months from 2020 and beyond. There will be a need to transmit excess electricity across Emirates in the winter months when the plants are at full generation.

2.4 LOOKING TO THE FUTURE

Strategies and plans are already in place to significantly change the energy mix, shown in Figure 4, for Department of Energy - Abu Dhabi (DoE-AD) and the Dubai Electricity and Water Authority (DEWA). Note that the contribution of renewable generation is too small to be seen in the 2016 bars. It is notable that waste-to-energy plans are underway in the UAE; amongst these, one is led by DEWA with capacity of 171 MW, another is led by Masdar and Bee'ah which will eventually provide 90MW of capacity to the Sharjah grid, and finally, there is a 100 MW capacity plant in Abu Dhabi Mussafah Sea Port commissioned by Taqa. All these plants are expected to be online by 2021.

Figure 4: DoE-AD and DEWA Expected Generation Mix over the Period 2016 to 2021



Of note are the relatively small increases in gas generation over the period. To some extent this mirrors the increase of alternative primary fuels and also supports the UAE's diversification away from gas. Table 3 illustrates the additional capacity foreseen in the current energy strategies by 2021.

Table 3: Additional planned capacity in the UAE by 2021

Primary fuel	GW Capacity
Nuclear	5.6
Coal [Phase I & II][10]	2.4
Renewable Energy	> 2

[10] According to DEWA, it has instructed that the project meets flue gas emission limits more stringently than emission limits in the Industrial Emissions Directive of the European Union and in the International Finance Corporation Guidelines; environmental studies have been carried out.

Dubai Energy Mix

DEWA has made advances in supporting the uptake of renewable energy in the Emirate of Dubai. The Dubai Integrated Energy Strategy 2030, which includes several sub-strategies related to security of energy supply, demand reduction, and sustainable growth, is one avenue for transitioning Dubai towards a sustainable future.

A sub-set of the integrated strategy, the Dubai Clean Energy Strategy 2050, sets a renewable energy target of 5 per cent by 2030, and a clean energy target of 75 per cent by 2050. To achieve these targets, DEWA is planning to increase the capacity of the Mohammed bin Rashid Al Maktoum Solar Park from 13 MW_{AC}[11] to 213 MW_{AC} by 2017, 1,013 MW_{AC} by 2020 and potentially to 5,000 MW_{AC} by 2030. In addition to utility-scale solar, DEWA is also introducing the target of having solar PV panels on every rooftop by 2030.

The Dubai Demand-side Management Strategy 2030, sets out to reduce water and electricity consumption by 30 per cent by 2030.

DEWA has successfully created renewable energy auction processes that have resulted in all-time low generation costs, as evidenced by the most recent announcement of 7.3 US$ cents per kWh for the CSP plant in the Mohamed Bin Rashid Solar Park.

Abu Dhabi Energy Mix

Similarly, Abu Dhabi is committed to increasing its renewables-based power production capacity to seven per cent by 2020. DoE-AD has recently announced a winning bid for the Sweihan solar PV plant, which was originally planned for 350 MW, and has been expanded to 1,170 MW. This is to be built in addition to the existing 100 MW Masdar solar CSP plant.

In addition, the Emirate is developing the first nuclear power plants in the UAE (and the GCC) with a total capacity of 5,600 MW. The first 1,400 MW unit of the Barakah nuclear plant is expected to be operational in 2018, with all four units to be completed by 2020/21. It is estimated that, when fully operational, the 5,600 MW nuclear plant will provide up to 25 per cent of electricity generation for the Emirate, post 2021.

Furthermore, Abu Dhabi launched the Masdar Initiative in 2006. Aimed as a diversification effort of the Emirate's economy, it focused on developing renewable energy and energy efficiency projects locally and internationally. Working with established international partners, it has participated in the development of a range of global RE projects.

Sharjah and the Northern Emirates

The four Northern Emirates (Ajman, Fujairah, Ras Al Khaimah, Um Al Quwein), which fall under the jurisdiction of the Federal Electricity and Water Authority (FEWA), are currently reliant on gas and diesel for electricity generation locally, and energy imports. However, in 2016, FEWA announced that it will be installing a 200 MW solar power plant and will upgrade the power grid in an effort to meet demand by 2025.

[11] Nominal power output of PV – MW of alternating current

In early 2018, Ras Al Khaimah Municipality announced its new renewable energy and energy efficiency programme, which includes assessing a target of 25-30 per cent clean energy capacity by 2040.

Likewise, Sharjah's utility, the Sharjah Electricity and Water Authority (SEWA), has largely been dependent on gas and diesel, with some import of power from Abu Dhabi. There is no published renewable energy strategy, but there is a desire to explore energy efficiency measures beyond its "One Saving Hour"[12] campaign, to support demand-side response and demand reduction strategies.

Table 4 presents the existing nuclear, renewable and coal targets as declared by DoE-AD and DEWA in comparison to the *UAE National Energy Plan 2050*. These include:

- Commissioning of 4 nuclear power plants at Barakah in the Emirate of Abu Dhabi;
- Building a coal plant in Dubai, commissioned by DEWA;
- The development and building of utility-scale PV installations in Abu Dhabi and Dubai;
- The building of a CSP plant in Dubai;

Table 4: Nuclear, renewable and coal targets as declared by DoE-AD and DEWA

Initiative	Existing (MW)	Declared goals (MW)	Estimated (MW)			
	2016	2018/19	2020	2025	2030	2050
Nuclear Power Plants	-	1,400	5,600	5,600	5,600	5,600
PV (Utility) Abu Dhabi	15	1,170	1,500[13]	1,400	1,400	-
CSP Abu Dhabi	100	-		100	100	-
PV (Utility) Dubai[14]	13	713	1,000	2,513	5,000[14-5]	75%
CSP Dubai[15]	-	-	700	700		
Roof Top Solar Dubai[16]	-	-	-			
Coal Dubai[17]	-	-	600	2,400	2,400	
UAE National Energy Plan 2050						44%
Totals			**9,500**	**12,713**	**15,500**	

[12] Residents of Sharjah are asked by SEWA to switch off all unnecessary devices between 2:30 and 3:30 on 1 July annually, representing the peak hour of highest demand in the year. The aim of the 'One Saving Hour' initiative is to promote the conservation culture and raise awareness in the community about rational use of electricity and water and reduction of toxic emissions.
[13] This represents around 7% of the total installed capacity as planned for Abu Dhabi.
[14] Dubai has declared a target of 7% from renewables by 2020. In addition, they have introduced further targets of 25% by 2030 and 75% clean energy by 2050.
[14-5] Total capacity of the Mohammad Bin Rashid Solar Park.
[15] This initial CSP development is Phase IV of the Mohammed bin Rashid Al Maktoum Solar Park in Dubai.
[16] DEWA has more recently announced mandatory rooftop installations for all buildings by 2030.
[17] The first phase of the project involves the development of four 600 MW units.

It is notable that the UAE's four-reactor Barakah Nuclear Power Plant project, which has been under construction since 2012, is planned to be fully operational by 2020-21. The first unit (1.2 GW) is currently undergoing commissioning and testing prior to regulatory review and receipt of the Operating Licence from the Federal Authority for Nuclear Regulation (FANR), with the remaining three reactors expected to be fully operational by 2020-21. The nuclear power stations were designed for a lifespan of up to 60 years and fulfil the role of 'must-run' base load power generation.

Additionally, the Hassyan coal power plant is based on the independent power project finance model and will generate 2,400 MW under Phase I & II. It is planned to be fully operational by March 2023.

2.5 UAE RENEWABLE ENERGY SUPPORT PROGRAMMES, PROGRESS AND OUTCOMES

When assessing the deployment environment for renewable energy sources, the key factors to consider are market structures, policy frameworks, institutional capacity and access to financing and investment. Within the context of policy frameworks, the key elements are:

1. Government commitment to renewables via clear deployment targets;
2. Supporting policies that include competitive bidding or tendering, direct proposal submissions, feed-in tariffs, net-metering and building codes that mandate the requirement to distribute renewables;
3. Energy-pricing structures that enable fair competition among all forms of energy supply;
4. Pricing signals and/or disincentives that create preferential conditions for renewable energy sources (such as carbon pricing).

Currently there are three types of supporting polices for RE deployment in the UAE:

1. Competitive utility-scale bidding or tendering (Abu Dhabi and Dubai);
2. Net-metering for distributed residential and commercial applications (Abu Dhabi and Dubai);
3. Building code endorsement for RE in the form of energy efficiency ratings.

In all cases, the support systems do not generally constitute a subsidy for renewables and do not rely on public sector funding for their operations.

Independent Power Producer (IPP) Public Competitive Tendering

Building large-scale plants through competitive tendering has been the primary mechanism for building RE capacity in the UAE, using project finance on a build-own-operate (BOO) model, based on long-term off-take agreements.

Recent tender results have generated record-breaking tariffs in quick succession. The 200 MW expansion of Phase II of the Sheikh Mohammed bin Rashid al-Maktoum Solar Park in Dubai was awarded to an ACWA Power and TSK consortium with a winning bid of 5.84 US$ cents/kWh in December 2015. However, sub six-cent bids were to be quickly surpassed when a Masdar-led consortium with Fotowatio Renewable Ventures and Gransolar Group, was selected for the third phase of the Solar Park in Dubai for 800 MW in June 2016 with a bid cost of 2.99 US$ cents/kWh. This was followed by even lower bid offerings for 350MW of PV in Sweihan Abu Dhabi at 2.42 US$ cents/kWh by a Jingo Solar and Marubeni Corporation consortium. This has recently been increased to 1,170 MW, according to DoE-AD, as a result of the reduced cost per kWh.

These recent developments rely on low interest rate financing and rapidly falling PV costs that will eventually plateau. Nevertheless, they are a strong indicator of the potential for large amounts of cost-competitive RE deployment in the region, which does not involve direct subsidies. It should be noted, however, that the competitive bidding framework may incur a degree of indirect government support through provision of land, grid connections, government financing and other elements that could be required costs for bidding companies and consortia in other locations. Consequently, it is extremely difficult to compare costs per kWh globally with a high degree of certainty.

Common elements between these competitive bids centre on the application of a regulatory framework and the introduction of long-term off-take agreements using project financing arrangements. For example, in order to attract developers to build, own and operate power and water plants, governments need to demonstrate that such projects are at a low risk and bankable. Consequently, developers need to minimise their risk, both in terms of building and operating the plant, and in terms of meeting debt and shareholders' equity obligations. Therefore, governments normally create a regulatory body, which is at least semi-independent, establishes a competitive market place and creates a regulatory framework which gives surety to future investors that they can enter the market for a given period. The period is normally around 20 to 25 years where long-term off-take agreements are agreed between the sector and the project company. This is the model, which has been traditionally employed for conventional power plants in the Emirates of Abu Dhabi and Dubai.

'Shams Dubai' Net-Metering Programme

In December 2014, the Emirate of Dubai provided for rooftop PV systems to operate under a net-metering system. This scheme was officially launched by DEWA in 2015 to encourage commercial and residential building owners to fit solar PV panels through the Shams Dubai framework. Companies already signed up to service clients as part of the Shams Dubai scheme include engineering groups expanding into the solar sector, as well as international PV contractors and developers.

Abu Dhabi 'Small-Scale Solar PV Energy Netting' Net-Metering Programme

In 2017, the Abu Dhabi Distribution Company (ADDC) and the Regulation and Supervision Bureau – Abu Dhabi (RSB-Abu Dhabi) launched the 'Small-Scale Solar PV Energy Netting Regulation,' a rooftop solar PV programme for Abu Dhabi customers. Similar to Shams Dubai, this programme provides net-metering benefits to users. ADDC provides the support to install solar panels on rooftops, whereas RSB – Abu Dhabi is responsible for developing the regulations required to support the programme. The programme is currently being rolled out in the Emirate of Abu Dhabi.

Building Rating Systems

100% OF ALL BUILDINGS IN DUBAI WILL INCLUDE ROOFTOP SOLAR BY 2030

Abu Dhabi's Estidama Pearl Rating system for buildings allows for eight out of 44 points in the rating system to be obtained by on-site renewable energy systems. The maximum point value is obtained if on-site generation covers at least 20 per cent of the building's projected demand. Dubai has now mandated that all buildings include rooftop solar systems by 2030. The Safat rating system provides requirements for all new buildings to have at least 5-10 per cent renewable energy electricity generated onsite, depending on the level of certification (basic – platinum).

Table 5 provides a summary of the range of renewable energy and load-reduction initiatives that are being or have been introduced in the UAE. Please note that they are not listed in any order of importance.

Table 5: Select RE initiatives and demand-reduction strategies in place in the UAE

Ref	Case Study	About	Comments/Lessons
1	Small Wind Generator	Sir Bani Yas Island houses a small 850kW wind turbine	There have been proposals to build a much bigger wind farm on this island so the performance of this small unit is important
2	Masdar City PV	This 10MW plant has been in operation for nearly a decade with a few challenges	This pilot illustrates the reliability of solar PV in terms of annual output against 'nameplate' capacity. High component failure rates and maintenance costs were observed, and offers lessons learned for future installations
3	Sheikh Mohammed bin Rashid Solar Park	Potential to develop a total of 5,000 MW of PV and CSP generation (Traceable purchases)	Record-beating bids which have meant that unit rates are at or below grid parity. This includes the record-breaking bid of 7.3 US$ cents/kWh for CSP
4	Renewable Energy Credits	Renewable Energy Certificates can be sold to companies to certify that they are using renewable energy in their operations. DEWA has adopted the international RECs (I-RECs) system, and has sold 25,000 I-REC's generated from DEWA's Mohamed Bin Rashid Solar Park Phase I (13 MW) to Philips Lighting. the I-REC's were issued by the Dubai Carbon Centre of Excellence.	Purchasing RECs from utilities and/or load serving entities that have been issued RECs, is now possible in Dubai
5	Masdar City – Abu Dhabi	Established small-scale development; continuing to expand at a slower rate than initially planned	The City highlights the need to maintain realistic expectations in terms of delivery, and how such a City can become a catalyst for RE cluster development and incubator projects
6	Etihad Energy Service Company (ESCO)	Etihad ESCO is an initiative which promotes an improvement in per capita power and water demand which reduces overall consumption	Etihad ESCO has branched out into tendering for installation of PVs as part of their retrofitting activities
7	'Powerwise,' Peak shifting RSB – Abu Dhabi	Trials on demand-side management – disconnecting AC units at peak times	Trials indicated that such actions were of real benefit to peak demand reduction
8	Shams Dubai Rooftop Solar Programme	Net-metering programme for rooftop solar PV installations in the Emirate of Dubai	Installations are now being seen not only in governmental buildings but also office facilities of businesses
9	Solar PV Rooftop Programme Abu Dhabi	Net-metering programme for rooftop PV panels in residential and commercial buildings in the Emirate of Abu Dhabi	Abu Dhabi Distribution Company and RSB – Abu Dhabi have rolled out a solar PV rooftop programme in the Emirate, after conducting trials previously through the Powerwise programme led by RSB-Abu Dhabi
10	RE-based solar desalination trials in Masdar City (2013-2017)	5 pilot plants were run by Masdar in the pursuit of RE desalination	The potential to reduce environmental and economic impacts of seawater desalination from renewable energy based reverse osmosis technologies in the Emirate of Abu Dhabi is being demonstrated

Ref	Case Study	About	Comments/Lessons
11	Tarsheed Programme DoE-AD	A programme for the promotion of demand-side management measures to meet DoE-AD's target of cutting 20% water and electricity consumption by 2030. Executed through awareness programmes, consultancy services to industry, and maintenance of AC and water facilities in buildings.	Programmes such as Tarsheed show the importance of showcasing and providing DSM measures that reap savings to customers in a short period of time, to encourage them to remain efficient in consumption in the long-term. It also highlights the importance of providing resources to industries and private sector companies that can support in developing measures to reduce consumption through manpower and capacity building.
12	Shams 1 CSP	A hybrid first-in-region 100 MW plant with good operating output	Although no storage is present, with gas supplementary firing it is highly reliable
13	Noor 1 PV - ADWEA	A major potential development of 1,170MW. This plant is seen as a peaking plant without storage	This development started life as a much smaller project (350 MW), but with bids at sub 3 US$ cents per kWh, ADWEA has decided to build a considerably larger plant
14	The Sustainable City by Diamond Developers	The aim of this Dubai development is to establish a net-zero energy community and accelerate the transition to sustainable living	This development is a good example of a significant self-supply enterprise utilising mostly PV panels
15	Dubai Green Fund	DEWA has created a fund, in collaboration with national banks, for investing in environment-friendly companies, and offering loans to businesses in the green sector at reduced interest rates. The total available funds are expected to amount to AED 100 Bn	This is an example of a government grant that can be used for initial capital injection and investment in private sector initiatives and measures related to renewable energy. The Dubai Green Fund is still being developed as funds are still being raised from different entities

2.6 COMPARISON OF LEVELISED ELECTRICITY COSTS IN UAE AND ELSEWHERE[18]

There is significant variation in the estimations of the levelised cost of electricity (LCOE) for different generation technologies in different countries. The primary contributing factors to this variation, in order of importance, include:

- Project financing terms and discount rate;
- Local resource quality and ambient environmental conditions;
- Transmission and interconnection requirements;
- Equipment transportation and land preparation requirements;
- Local import tariffs;
- Bureaucracy and approval requirements;
- Experience with prior installations;
- Energy storage capacity and type.

LCOE ranges for the key renewable energy technologies are summarised in Table 6.

Table 6: Ranges of technology based LCOE costs

Technology[19]	Base and Range (US$ per MWh)	Notes
Biomass	70 (50-100)	Global levelised cost of electricity from utility-scale renewable power generation technologies according to IRENA Renewable Cost Database
Solar Thermal with Storage (CSP)	220 (170-250)	
Onshore wind	60 (40-150)	
Offshore wind	140 (100-220)	
Solar Utility Scale (no storage)	100 (50-250)	
UAE Solar Utility Scale (no storage)	25 - 30	World beating results in Abu Dhabi and Dubai in 2016 and 2017
UAE Solar Thermal with Storage (CSP)	73	Lowest bid to DEWA by a consortium to build a 200 MW plant. 15 hrs of storage

[18] The levelised cost of energy considers the cost of producing an additional unit of electricity and includes all costs such as capital costs, fixed operation and maintenance costs, and all variable generation costs.
[19] Gas and coal technologies have not been included due to global variations in primary fuel prices, especially gas. However, DEWA have published an LCOE for their Hassyan Clean Coal plant of 42.4 $/MWh.

Renewable energy LCOEs have continued to reduce over time and at a more accelerated rate than conventional generation due to greater mass production techniques in the case of PV and in some instances the 'dumping' of cheap PV panels on the global market by countries with large manufacturing bases. However, less modular generation such as CSP may not experience these dramatic price changes as these plants are built on site and not likely to be able to take advantage of such mass production processes as is the case with PV.

In addition, the reader should note that due to the uncertainty of weather-dependent generation, LCOEs are only one measure for total costs of renewable energy. To be able to get a holistic view of the true cost of renewable energy generation, one would also need to take into consideration additional factors such as operation and maintenance costs, transmission costs and losses, added benefits to society such as improved health and job generation, air quality improvement, etc.

The Sustainable City

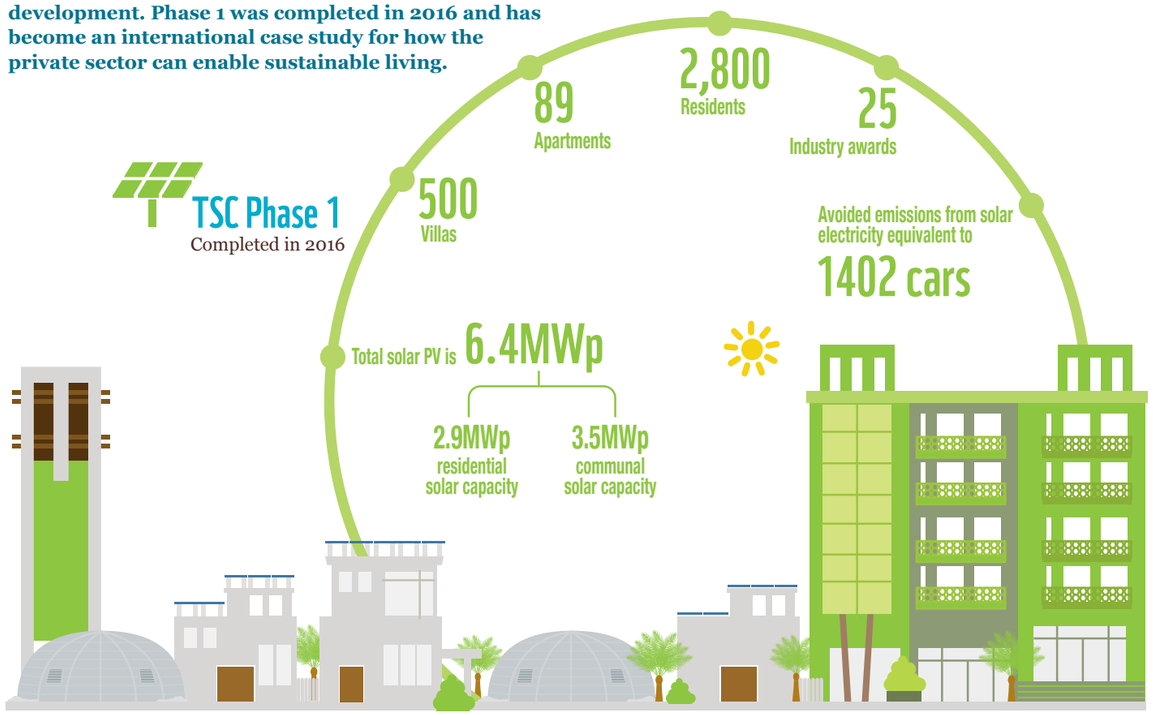
Low-carbon living in Dubai

The Sustainable City (TSC), by Diamond Developers, is a mixed use and residential community aiming to become the region's first operational net-zero energy development. Phase 1 was completed in 2016 and has become an international case study for how the private sector can enable sustainable living.

Going 100% Renewable

The total solar electricity capacity in TSC will be **10MWp**

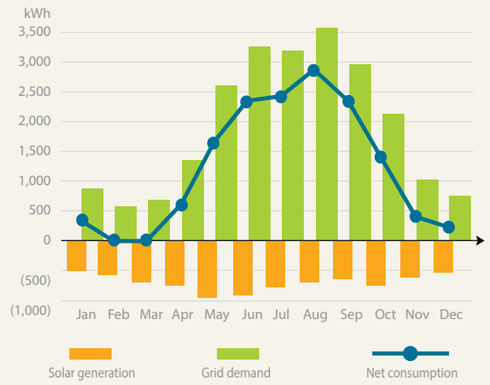
- Phase 1: 6.4MWp
- Phase 2: 3.6MWp



Net-zero energy

Already achievable during winter months

4-bedroom villa energy performance



Levelised cost of electricity

USD 0.073 kWh

Electricity from solar PV at TSC costs lower than the lowest tariff for Dubai expats.

Dubai's lowest utility bills

Thanks to rooftop solar PV and energy efficiency, residents incur zero electricity costs some months per year

4-bedroom courtyard villa energy savings

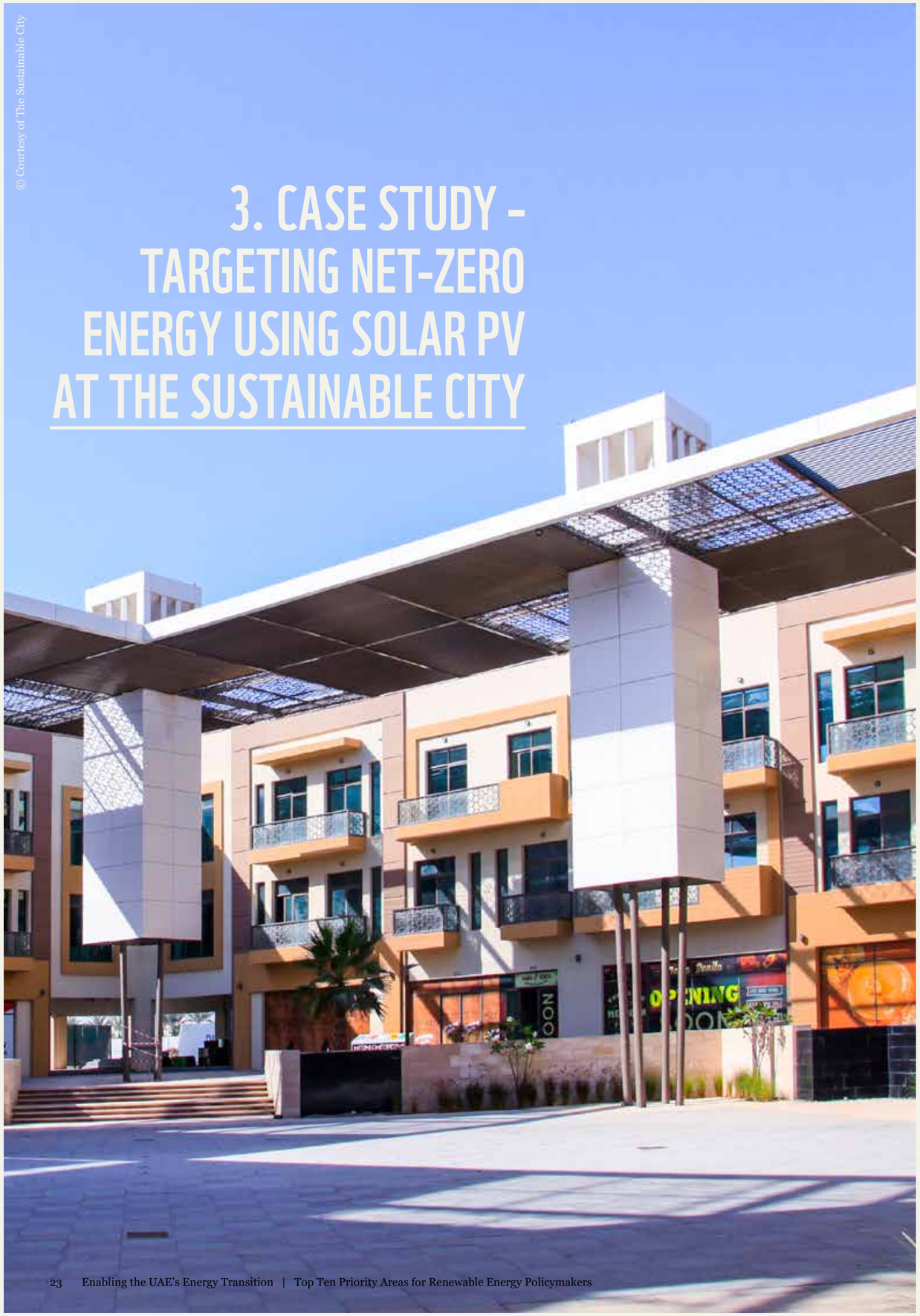
2,700- 4,100 (AED/year)
Expected solar savings

6,700- 10,200 (AED/year)
Expected energy efficiency savings (demand-side management)

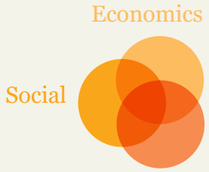
Sources: The Sustainable City.

In October 2016, Emirates Wildlife Society – WWF (EWS-WWF) and The Sustainable City (TSC) formed a strategic partnership with the aim to tackle climate change, promote renewable energy and reduce greenhouse gas emissions.

3. CASE STUDY – TARGETING NET-ZERO ENERGY USING SOLAR PV AT THE SUSTAINABLE CITY



© Courtesy of The Sustainable City



THE SUSTAINABLE CITY APPLIES SUSTAINABILITY PRINCIPLES TO ACHIEVE SOCIAL, ECONOMIC AND ENVIRONMENTAL OUTCOMES

The Sustainable City (TSC) by Diamond Developers is a residential and mixed-use development located in Dubailand. Covering 46 hectares (5 million square feet), the development applies sustainability principles to achieve social, economic and environmental outcomes. Completed in 2016, Phase 1 of the development has become an international case study for sustainable living, work, education, and wellness, and aims to become the first operational Net-Zero Energy development in the region.

3.1 PARTNERSHIP BETWEEN THE SUSTAINABLE CITY AND EWS-WWF

TSC and Emirates Wildlife Society – WWF (EWS-WWF) formed a strategic partnership with the aim to tackle climate change, promote renewable energy and reduce anthropogenic greenhouse gas emissions. As part of this strategic partnership, TSC and EWS-WWF are working together on the climate and energy programme over a three-year period, focusing on the following:

1. Conducting a GHG assessment and report for TSC, utilising the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories;
2. Supporting EWS-WWF's renewable energy project *Enabling the UAE's Energy Transition* by showcasing the benefits of powering a community through solar PV rooftop installations, the challenges faced, and the recommendations/ learnings from the first phase of the development;
3. Organising community events to raise the awareness of residents on sustainable lifestyles and low-carbon practices (e.g. Earth Hour, Earth Day, Electric Vehicles Road Trip).

3.2 SUSTAINABLE DESIGN ELEMENTS

TSC was designed with several low-carbon and sustainability features, including rooftop solar panels that aim to reduce greenhouse gas emissions and set a new benchmark for the development of a sustainable community in a desert environment. The design follows a two-pronged approach.

Approach 1. Demand-Side Management

THE ACTIVE AND PASSIVE DESIGN ELEMENTS IN THE TSC VILLAS RESULT IN **40% LOWER ELECTRICITY CONSUMPTION** COMPARED TO CONVENTIONAL VILLAS IN DUBAI

Living in TSC's villas reduces the per capita carbon footprint of its residents. Several passive and active design features surpass the requirements set forth by all major building rating systems, resulting in lower electricity consumption (and corresponding emissions) by up to 40 per cent compared to conventional villas in Dubai.

Specifically, north-orientated villas avoid the sun and minimise demand for air conditioning. The combination of highly insulated walls and windows (see Table 7) for buildings with glazing-to-wall ratio of less than 40 per cent, variant refrigerant flow (VRF) air conditioning, light-emitting diode (LED) lighting, energy-rated appliances, and solar water heaters further reduce electricity consumption, resulting in a mean Energy Use Intensity of the villas of 97 kWh/m²/year.[20]

Table 7. Comparison of achieved insulation values with local rating system recommendations

Element	U-Values[21]	Current Regulation	TSC
Roof	W/m².K	0.30	0.20
Wall	W/m².K	0.57	0.32
Window	W/m².K	2.10	1.30

Approach 2. Renewable Energy Supply

To meet the estimated annual demand for 16 million kWh to power the development, TSC is installing 10MW peak (MWp) of solar photovoltaic panels. DEWA's net-metering programme allows individual units to generate electricity, consume it directly and/or export the surplus to the grid at the corresponding slab tariff. The accumulated surplus is then deducted from utility bills at the end of the month.

So far, TSC has installed 6.37 MWp of solar PV, including 2.88 MWp on residential rooftops and 3.49 MWp in communal areas, which include parking areas. To verify carbon avoidance, Diamond Developers has registered the solar PV system as a Clean Development Mechanism (CDM) Project with the UN Framework Convention on Climate Change. Dubai Carbon Centre of Excellence (DCCE) is assisting Diamond Developers with component project activities' (CPA) registration, annual monitoring, verification, and issuance of Certified Emission Reduction credits.

[20] Based on actual performance measurement
[21] Thermal Transmittance Values

3.3 ADDRESSING CHALLENGES OF SOLAR ROOFTOP

Solar Design and Integration

Generally, every 1MWp requires about 7,000-8,000 m² of space (the advent of higher efficiency panels will reduce space requirements). The first challenge in solar generation is the integration of solar panels in the urban landscape including rooftops and parking areas (see residential PV in Table 8). To enhance the overall building aesthetics as well as optimise roof shading, the angle of tilt was reduced to five degrees (instead of 22 degrees, which is the yearly optimum tilt angle in the UAE). Frameless panels further improve the final design of the solar rooftops.

Table 8. Breakdown of TSC Villa topography and corresponding solar generation capacity

Villa Type	Number of Units	BUA (sq.ft.)	Solar Capacity (KWp)	Expected Generation (KWh/Yr)	Expected Savings[22] (AED/Yr)
Courtyard 3BED	225	3,400	5.20	8,320	2,454 – 3,702
Courtyard 4BED	225	3,800	5.75	9,200	2,714 – 4,094
Garden Villa	40	5,200	8.19	13,104	3,866 – 5,831
Signature Villa	10	8,000	9.83	15,728	4,640 – 6,999

[22] Including avoided fuel surcharge; range depends on consumption slab and based on 2018 tariffs.

Grid Connection

To generate electricity, villas must be grid-connected and have an active DEWA account. PV systems on vacant villas will remain inactive which represents lost solar generation potential.[23] Once connected, tenants will immediately benefit from solar generation consumed directly by the villa, and surplus electricity will appear on the utility bills when the corresponding Connection Agreement between DEWA and the tenant has been duly processed.

Module Cleaning

Solar rooftop panels are more difficult to clean than for example a solar park. Because the modules are mounted on separate structures, robotic cleaning is not possible. Periodic cleaning, therefore, requires villa access and close coordination with the residents. To save water and avoid sullying the rooftops, the panels are dry cleaned every four to six weeks depending on dust conditions.

Shifting Surplus Electricity

At the community level, solar production can be unevenly generated and distributed. Because the current regulation limits solar electricity production and consumption to within the same plot (called “Generation Unit”), the villas experience a deficit during the summer while the parking areas experience a surplus throughout the year. Achieving Net-Zero Energy requires efficient redistribution of solar electricity between the plots inside the project boundary. At TSC, surplus solar electricity from the parking lots will be shifted to other plots in the community including the farm, the school, and the hotel on condition that all plots are owned by the landlord.

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[23] Additionally, inactive solar PV modules may shorten the expected lifetime of the panels.

3.4 CASE STUDY CONCLUSIONS

The introduction of net-metering in Dubai in 2014 has unlocked great opportunities for renewable energy uptake in the Emirate, with ripple effects in the wider UAE. Despite notable advances in technology and finance, the local market still needs a boost. Several policy incentives can be implemented for increased uptake such as exempting renewable energy from customs and taxes, easing the lending structure, and promoting a cost-sharing infrastructure between parties – following an energy service contract model. Wheeling arrangements for renewable energy trading and transmission, and a mechanism for grid-connecting PV modules from vacant housing units would further accelerate solar PV uptake.

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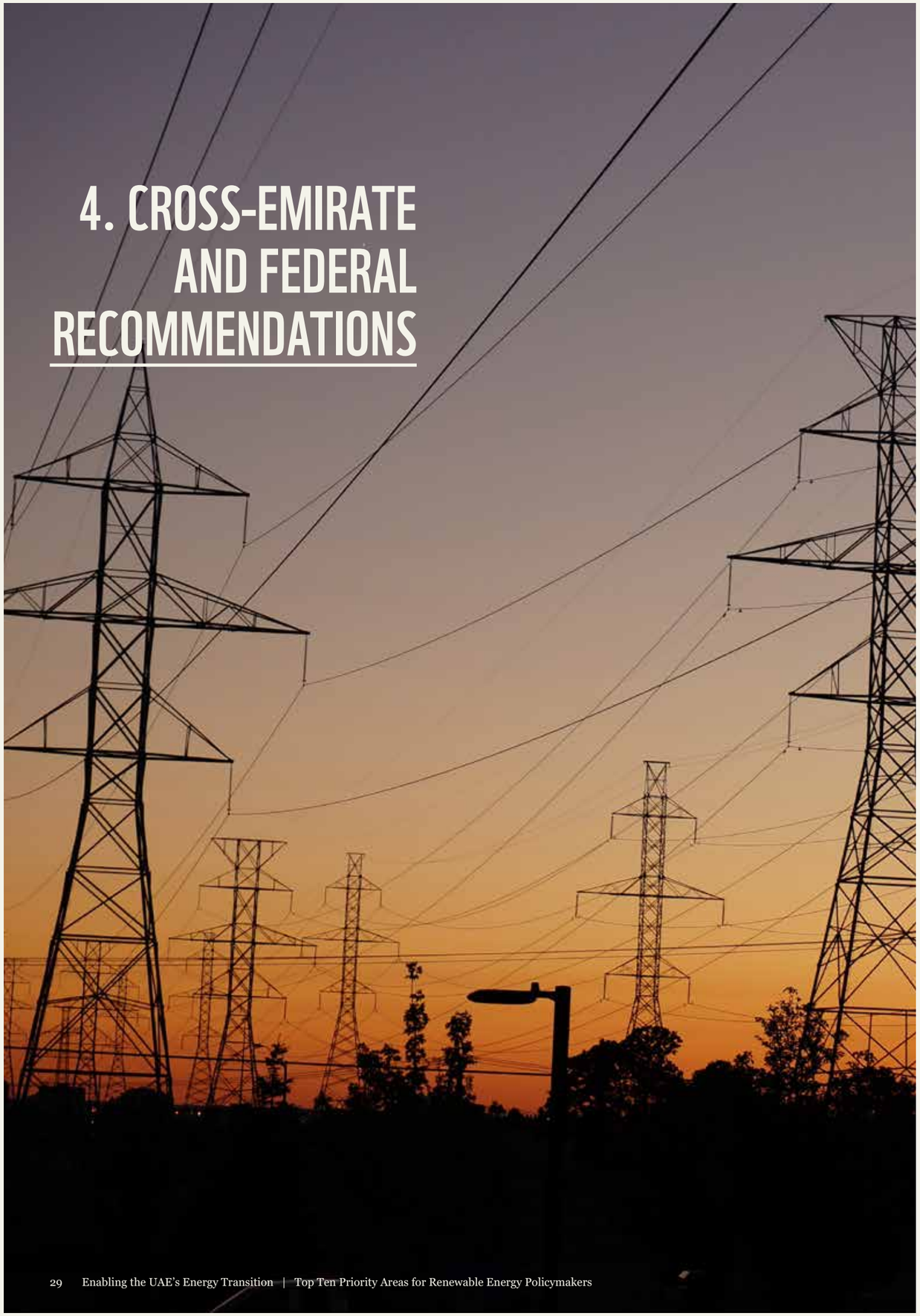


4. CROSS-EMIRATE AND FEDERAL RECOMMENDATIONS

At a time of increasing competition in energy investments globally, the UAE will need to invest heavily over the coming decades to ensure secure, sustainable and affordable power and water supply for homes, businesses and industries. It is therefore imperative that the UAE maintains a regulatory and market environment that is attractive to global energy companies, who have choices in terms of where they can deploy their capital.

To enable these decisions to be taken calls for an ambitious energy policy framework that addresses the energy trilemma of security of supply, affordability and sustainability, whilst also promoting an integrated approach for the long-term planning of the power and water sectors to avoid lock-in of suboptimal resources.

This section presents cross-Emirate policy and regulatory recommendations that will enable deep decarbonisation of the power generation sector whilst at the same time also addressing the other two key energy policy challenges of affordability and security of supply. It also captures areas of recommendation that stakeholders have highlighted as priority for the UAE during stakeholder consultations undertaken for the purposes of this report.

4.1 THE ROLE OF COMPETITION

Ensuring a level playing field for all technologies and promoting competition through transparent, market-based mechanisms

International experience has shown that in order to drive down energy costs, it is important to create a regulatory framework that promotes competition and price discovery. Subsidies and other forms of state support have played an important role in creating markets for new technologies and driving down direct energy costs for consumers. In the GCC countries in particular, fossil fuel energy subsidies have long been considered a form of social contract between governments and their citizens. The UAE stands out as a leader among GCC countries having been carrying out power and water price reforms since 2008, and deregulating petrol prices in 2015. It is important for the country to continue to move towards an operating model in which competitive markets deliver secure, affordable and clean energy that meets UAE needs. Removal of barriers, such as distorted price signals, to create open and fair competition between different technologies[24] improves efficiency of dispatch and operability and is an important prerequisite for true cost discovery.

[24] Technologies available in the UAE to generate electricity.

From a system cost minimisation perspective, the objective for ensuring a level-playing field for all energy technologies is, therefore, two-fold:

- System dispatch: In the short-term, system dispatch timelines ensure that the system is running as efficiently as possible on the basis of actual system costs that are being incurred by all the available technologies online, particularly when considering generator fuel costs and network congestion and system balancing;
- New-build capacity: In the longer term, that investment decisions for new-build capacity are made on a level-playing field for all technologies, as well as on the basis of lowering the LCOE for the UAE power and water system as a whole. This includes considering externalities.

Of particular relevance are:

- Capacity contracts for independent water and power producers (IWPPs) would need to be reconsidered, including potentially reducing firm capacity payments (i.e. paying generators to produce at all times independent of supply/demand conditions in the system – therefore potentially exacerbating the curtailment of RE technologies in the long-term);
- The natural-gas price should be fully visible to the producers and the government.

While the single buyer model has previously been criticised as lacking the discipline to drive efficiency savings, in the context of a deeply decarbonised energy system it has the potential to offer significant advantages compared to other market structures. This is because a single buyer model can improve investor confidence, reduce long-term energy price uncertainty and volatility and thus also lower the cost of project capital, while maintaining a competitive environment for investment (e.g. via competitive auctions)[25]. Low-carbon generation projects, which have high capital costs, would particularly benefit from a low risk investment climate and the overall costs of decarbonising the power sector could be substantially reduced.

KEY RECOMMENDATIONS:

- Remove barriers, such as inadequate visibility of fuel price, to open and fair competition between technologies;
- Create a cost-reflective system dispatch to ensure the system is operating as efficiently as possible;
- Promote competition through transparent, market-based mechanisms across the energy value chain.

[25] On the other hand, it is important to recognise that, while construction and operational risks under the existing single buyer model may lie with generators, fuel price risk and risk of generation assets becoming stranded ultimately lie with consumers.

4.2 THE ROLE OF RENEWABLE TARGET PATHWAYS

Providing a flexible policy framework that allows the UAE to outperform existing renewable targets if there is a favourable shift in renewable market fundamentals

The UAE has recently developed plans to install 44 per cent renewable energy capacity by 2050. It is expected that this would require a total investment of US$163bn in new build renewable projects. Dubai and Abu Dhabi, the Emirates with the largest populations, have been leading green initiatives to promote investment in renewable energy sources and reduce dependence on fossil fuels.

During recent years, the average cost of electricity generated by renewable energy sources (particularly solar and wind technologies) has fallen dramatically. Accelerated clean energy deployment policies are creating economies of scale and bringing technologies rapidly down the learning curve. Due to economies of scale, innovation and technology improvements, it is expected that renewable energy technologies will continue to realise cost reductions over the coming decades.

THE UAE TARGETS PROVIDE A CLEAR SIGNAL THAT RENEWABLE ENERGY TECHNOLOGIES ARE AN IMPORTANT PART OF THE FUTURE

The recently developed UAE renewable targets are excellent in defining current government policy with respect to the expected long-term (2050) evolution of the power generation sector. They provide a clear signal to international investors that renewable energy technologies are an important part of the future UAE energy mix and create incentives to invest in innovation and emerging technologies that would support this transition, such as electricity storage solutions. Increased investor confidence in the UAE renewable energy sector can in turn reduce the cost of capital and accelerate capital allocation, leading to significant economic benefits for the UAE as a whole.

Given the uncertainty about the scale of future cost reductions in key technologies that would support deep decarbonisation of the UAE power sector (e.g. solar CSP, battery storage, and large-scale seasonal storage technologies), the existing renewable targets should be used to define the minimum market size for investors. A flexible policy framework that would allow the UAE to outperform existing renewable targets if there was a more favourable shift in market fundamental conditions could accelerate the transformation of the energy system and lead to lower system costs. In the future, it would be useful to consider further renewable energy technologies to support deep decarbonisation of the power sector, such as solar cooling in buildings, and hydrogen fuel cells as storage options.

Therefore, a flexible RE policy framework which takes account of the recently established Paris Agreement five-year cycle would look to constantly review and re-set progressively higher renewable energy targets in line with new technology developments and environmental pressures.

Such a framework would also look to detail a clear route to market for new build renewable energy technologies and storage. Technology-neutral, fully competitive renewable auctions have been shown to encourage the provision of innovative solutions and drive down costs for consumers. In addition to centrally designed auctions, exploring additional route to market options for new entrants could accelerate the transformation of the energy system and lead to lower system costs.

There is significant interest globally and locally in corporate renewable energy Power Purchase Agreements (PPAs), such as a solar PPA, which allow commercial and industrial enterprises to purchase power on a long-term basis directly from renewable energy generators.

Major players in corporate renewable energy PPAs internationally are some of the largest businesses in the world, including Google, Facebook and Amazon. The delivery of renewable energy is notional and not physical in most cases although for example for the UAE energy intensive industries located in remote areas (e.g. oil refining, petrochemicals, aluminium and steel) it would be expected that they would also require physical delivery. RECs have shown to be a good avenue for corporates globally. As explained in Section 2.5, they are already an available option for companies in Dubai, and can be expanded to other Emirates.

Economics Driving Change

The current economics and market shifts that have been created in the UAE could encourage further investment in renewable generation technologies and lower the overall cost of the power and water generation in the UAE in the future. There is a benefit in setting intermediate targets, as it helps discourage locking in fossil fuel intensive generation capacity even when increased RES penetration can be expected in the future.

Non-harmonised renewable policy across Emirates may create distortions and lead to suboptimal outcomes with respect to investment in new build capacity. A coordinated approach for renewables policy, which includes coordination in planning for additional generation and transmission infrastructure for the future, is desirable because it could improve the economic efficiency of the transition to a low-carbon economy by optimising the development of the most cost-efficient renewable energy resources. Convergence of renewable policy setting across Emirates could also improve simplicity and transparency for investors and lead to operational and administrative efficiency savings.

Finally, the UAE has the potential to look into models such as the wheeling model, where a renewable energy producer (utility or other) can transfer excess electricity from one area to another within its own operations. Having a model like this will limit additional costs from new build capacity, taking advantage of areas in the country with more suitable renewable energy generation conditions.

KEY RECOMMENDATIONS:

- Establish a fully flexible RE policy framework, which sets review milestones and interim targets;
- Investigate the potential for new route to market options for renewables (in addition to technology-neutral renewable auctions) such as corporate renewable energy PPAs and RECs;
- Harmonise renewable policy setting across Emirates;
- Introduce and promote rooftop solar PV and streamlined means of getting connected to a local distribution network.

4.3 THE ROLE OF CO_2 TARGETS

Setting a pathway for CO_2 emissions reductions to complement existing renewable targets

Recent experience in many European markets (most notably, in Germany) has shown that increasing the share of renewable energy sources alone may not be effective at cutting CO_2 emissions from the power generation sector if it is also coupled with an increase in the share of coal-fired generation[26]. Indeed, in some European countries (such as the United Kingdom (UK) for example) the carbon intensity of unabated coal is sufficiently high that current government policy is to phase out coal completely beyond the mid-2020s.

A COMBINATION OF CO_2 EMISSIONS REDUCTION TARGETS AND RE TARGETS WILL INCREASE INVESTOR CONFIDENCE IN LOW-CARBON TECHNOLOGIES

Setting a pathway for CO_2 emissions reduction in the UAE to complement existing renewable targets would reaffirm government commitment to a low-carbon economy and increase investor confidence in low-carbon technologies. Such a pathway needs to be developed in consultation and collaboration with relevant Ministries, and other key federal and Emirate-level stakeholders. The National Energy Plan 2050 included the total emissions avoided from the energy sector as part of the analysis. Additionally, the Ministry of Energy and Industry has initiated collaborative efforts across the key federal and local entities to determine a GHG abatement target for 2050 covering the five key sectors identified by the IPCC.

A greater focus on externalities (for example the use of shadow carbon pricing) will help the UAE gain maximum social and environmental benefits from the portfolio of power and water production technologies it will use in the future. Externalities in this context are environmental and social costs that are not accounted for in the price of electricity or water. With respect to the power generation sector in particular, this would ensure that the true short-run marginal costs to society (particularly regarding CO_2 emissions) from gas- and coal-fired power stations are taken into account during system dispatch timelines. Introduction of shadow carbon pricing or other methodologies of allowing externalities to be evaluated could be researched through further work, including via collaboration with local and international research centres of expertise. According to initial analysis, including a carbon price of US$ 60-75/MWh from 2020 onwards tends to produce a shift towards increased CSP and/or PV with seasonal storage in favour of other sources of energy.[27] This is a factor that needs to be taken into account when investing in diverse generation assets in a world with potential carbon prices.

[26] Note for example that an efficient coal-fired power station emits roughly two times more CO2 emissions compared to an efficient gas-fired power station.

[27] This includes the assumption that water production will be decoupled from electricity generation (e.g. due to additional investments in plant that use RO technology) and can be powered by renewable energy sources.

EU countries have set sector-specific[28] CO_2 pathway trajectories and this can provide additional clarity on the expected evolution of the system, as well with respect to understanding cross-sectoral opportunities for optimising the CO_2 abatement cost curve. The EU, for example, attempts this cross-sectoral abatement via increasing the range of sectors included within the Emissions Trading Scheme (ETS). This is intended to provide cost-discovery and promote abatement in the sector(s) with the lowest marginal abatement cost, which may vary over time.

KEY RECOMMENDATIONS:

- Complement existing renewable targets by setting a pathway for CO_2 reductions in coordination with relevant key stakeholders;
- Understand externalities to be able to evaluate the costs to society from CO_2 emitting technologies;
- Consider abatement options in different sectors of the UAE economy, not just the power and water sectors, and promote abatement in the sector(s) with the lowest marginal abatement costs.

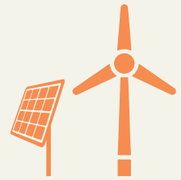
4.4 FIRMNESS AND FLEXIBILITY

Incentivising technologies that provide adequate firmness and flexibility to the system

In any power system, firmness and flexibility are critical components of ensuring security of supply. In simple terms, firmness refers to the capacity that can be dispatched when required to do so, whereas flexibility refers to the ability to respond quickly and efficiently to fluctuating supply/demand conditions in the power system. The provision of ancillary services to the system operator to maintain reliable operation of the system is also typically included within the general concept of flexibility. Note that different timescales are involved in the variations of supply and demand and as a result the discussion on firmness and flexibility has to reflect all involved timescales.

Fully dispatchable generation assets (including coal, gas, and nuclear) provide firm capacity as they can generate electricity on demand and for a period that is only limited by fuel supply and plant availability. Dispatchable storage and flexible demand assets provide the next firmest layer of capacity; these assets can be dispatched on demand although typically only for a limited period[29]. Intermittent generation such as wind or solar provides the least-firm capacity as it is not fully dispatchable and runs at relatively low capacity factors (typically under 50 per cent) which may not coincide with system stress conditions when their output would be needed[30]. As a result, intermittent power generation technologies have lower de-rating factors in any firm capacity calculations. Time of day or seasonal bias of renewable technologies (e.g. solar during the day) will also impact on their de-rating factors.

[28] In addition to the power generation sector, CO_2 abatement opportunities in the UAE also exist in the following sectors: (i) oil and gas; (ii) cement; (iii) iron and steel; (iv) chemicals; (v) transport; (vi) buildings; (vii) waste; and (viii) agriculture.
[29] For storage, the firmness (or de-rating factor) is a function of the maximum number of hours of storage.
[30] Intermittent renewables such as wind and solar can contribute to security of supply at a significantly lower "de-rating" or "capacity credit" than dispatchable thermal generation such as coal or CCGTs.



TECHNOLOGY-NEUTRAL, FULLY COMPETITIVE AUCTIONS ENCOURAGE INNOVATIVE SOLUTIONS

Flexibility in a power system is required to compensate the variability in supply and demand and maintain frequency balance. This capability is measured through the possible rates of increase or decrease of generation or demand as a response to market or operational signals. Additionally, the flexibility of capacity will depend on the timeframe over which the flexibility can be provided, as well as the location or point of connection. The addition of intermittent supply will require conventional sources (rotating machines with a large contribution to system inertia) to be more flexible. Traditionally, thermal generation plants are divided into baseload (e.g. nuclear and coal), mid-merit or cycling generation (e.g. CCGT) and peaking plants (e.g. OCGT). These vary significantly in their flexibility parameters such as ramp rates, start-up costs, minimum stable load and part load efficiency. These factors need to be considered in long-term as well as operational planning exercises to ensure cost-effective investments maintain system reliability[31]. More recently batteries have also been used to provide frequency response services. The provision of flexibility in systems with high RES penetration levels is an area of active research and development and it is recommended that the progress in this area is followed closely in other markets globally to inform future policy decisions.

Technology-neutral, fully competitive auctions (including within the context of a single buyer model) encourage the provision of innovative solutions and drive down costs for consumers. In the past, such auctions have mainly focused on the development of renewable energy technologies as mentioned in Section 4.2. Going forward, similar auctions may be deployed to incentivise the most optimal type of firm and flexible capacity to come to the market, depending on the evolution of the future generation mix. This will ensure for example that the right mix of high efficiency/high capital costs, and lower efficiency/lower capital costs technologies (power generation and storage) are deployed depending on their expected running hours, while at the same time encouraging innovative solutions including storage and demand response mechanisms that minimise total system costs such as batteries, thermal storage, and industrial demand response (discussed in more detail in Section 4.5).

With respect to new build thermal generation assets more specifically, the objective should be to design a remuneration framework that reduces the likelihood of these assets becoming stranded in the future but also ensures that they do not act as a barrier to deep decarbonisation. Although, over time, remuneration should mainly focus on the firm capacity and flexibility that they offer to the system, rather than their generation output. This is because output-based obligations can lead to market distortions such as curtailing renewable energy sources (which have very low short-run marginal costs) in favour of thermal generation assets with higher short-run marginal costs in order to avoid penalties associated with non-delivery.

[31] Base-load generation plants run most of the time at stable levels of output. This operational mode favors a cost structure that can allow for high capital costs, as long as operational costs are low. Mid-merit generation plants are designed to adjust their output upwards and downwards to accommodate changes in demand throughout the day, and are also designed to start and stop frequently, sometimes twice a day. Peak-load generation plants cover periods of very high demand. Peaking plants have superior ramping flexibility, and are well placed to provide short- to medium-term flexibility services.

The growth in intermittent renewable capacity will require the system operator to procure additional reserves[32], such as primary, secondary and tertiary reserve. Currently, operating reserve levels in UAE are relatively predictable and vary mainly with demand level and time of day. However as intermittent solar and wind capacity builds, reserve levels will need to increase in order to mitigate short-term fluctuations of the power output of these generators. Moreover, the introduction of the 5.6 GW Barakah nuclear power station will also increase the largest loss of load (or "in-feed loss") and hence may increase reserve for response requirements in the event of the generator tripping. These operational issues should be investigated fully before issues arise such that the system can be planned for the future. If issues arise then there is a risk that renewables output will have to be curtailed to maintain system operability.[33] Therefore, increasing RES penetration and the new nuclear plants will increase the need for reserve services; batteries could provide these services, especially if battery technology costs continue to fall.

Large-scale seasonal storage is expected to become a key enabler of deep decarbonisation in the UAE. This is primarily due to the differing seasonality on electricity demand and solar PV generation in the UAE. Encouraging developments in seasonal storage technologies should therefore be considered as will later be described in Section 4.7.

KEY RECOMMENDATIONS:

- Develop technology-neutral auctions targeting firm and flexible capacity based on specific technical requirements as the system evolves over time;
- Develop a remuneration framework for new build thermal generation assets with adequate incentives for high availability and physical delivery (to ensure security of supply), but which also prioritises the provision of firmness and flexibility to allow cost-effective integration of low-carbon generation technologies
- Investigate the future evolution of ancillary services to the system operator, particularly with respect to the increase in reserve levels due to RE penetration and the new nuclear plant;
- Consider potential applications of energy storage technologies, beyond the requirement of large volumes of storage to reduce costs of integrating RE generation technologies, in operational timescales (such as resolving local network constraints and providing ancillary services).

[32] The turbines at some production units can automatically detect frequency fluctuations and, where necessary, adjust production within 0 to 30 seconds to provide primary reserve. Secondary reserve is typically between 30 seconds and 15 minutes and is automatically and continually activated both upstream and downward (upward/downward regulation). Tertiary reserve enables system operators to cope with a significant or systematic imbalance in the control area and/or resolve major congestion problems.

[33] An example is the System Non-Synchronous Penetration operational limit on wind in the Single Electricity Market in Ireland, which is currently being raised to accommodate planned wind developments. By contrast, north to south transmission constraints in Germany are causing the curtailment of wind in the north as well as operational issues in neighbouring interconnected countries.

4.5 THE ROLE OF DEMAND-SIDE MANAGEMENT

Encouraging demand-side participation and building an energy efficient UAE

DEMAND-SIDE RESPONSE COULD PLAY AN IMPORTANT ROLE IN REDUCING OVERALL COSTS FOR CONSUMERS

Firmness and flexibility (Section 4.4) have traditionally been provided by a flexible generation portfolio able to respond to a variable, relatively price-insensitive, but a predictable demand base. Due to the expected evolution of the future generation mix, however, this model is likely to change significantly with the demand-side needing to become much more flexible in order to accommodate a variable supply. This is particularly relevant for countries such as the UAE whose demand shape displays significant seasonal variations and would therefore benefit from a flatter demand profile (both seasonal as well as intra-day) to avoid oversizing the system.

Demand-side response as a form of capacity, competing with generation and storage capacity in competitive auctions, could play an important role in reducing the need for additional infrastructure (both generation/storage capacity as well as transmission and distribution infrastructure) and therefore lowering overall costs for consumers. Furthermore, in operational timescales, demand-side response has the potential to reduce the requirement for reserve to be held on part-loaded generation, while reducing the impact of intermittency (e.g. by shifting load away from periods of low renewable output and into periods with high renewable output) and improving security of supply either through load shifting or through voluntary load curtailment.

In addition to demand-side response from large industrial customers (such as aluminium smelters), the application of smart metering and control appliances that can respond to price or other signals could make domestic and small commercial customers more aware of their consumption and allow them to become more active providers of demand-side flexibility. This could be achieved, for example, through energy suppliers offering tariffs such as:

- Dynamic 'Time-of-Use' tariffs, with pricing being set to reflect short-term supply/demand conditions (e.g. tight capacity margins or surplus of renewable energy) and consumers responding to price signals either manually or by relying on smart appliances;
- Alternatively, interruptible tariffs may also be used, with domestic appliances changing consumption patterns automatically and allowing suppliers to offer aggregated demand response in both investment and operational timescales. This interruption or reduction in demand may for example occur during periods of high demand, or when RE output is low.

Energy efficiency measures can also help the UAE's demand shape to become flatter, thereby leading to significant operational savings. Of particular importance to the UAE are energy efficiency measures that would reduce cooling requirements given that is a major contributor to electricity demand in the UAE. Through improvement of thermal efficiency of buildings, and use of district cooling storage, shifting air conditioning load offers particular promise given the potential to shift some demand from night-time to day-time, and therefore allow this load to be met

by solar PV generation rather than thermal generation and/or more expensive storage. Shifting air conditioning loads to the day-time, while having the required solar capacity to meet it, has the potential to significantly reduce system costs through lowering the need for additional generation capacity and reducing RES curtailment levels.

Energy efficiency measures could be accelerated by investment incentives, wider use of certified energy service companies, and financial support at national and local levels. In this context, government authorities should lead by example. Energy criteria (for example regarding energy efficiency, renewables and smart infrastructure) could be introduced in all public procurement of works, services or products.

Alignment between federal and emirate-level energy reduction strategies would reinforce a unified commitment message. In addition, government entities should look to promote a wide range of enabling documents such as policy documents, codes and facilitation of funding mechanisms for green initiatives. An example of such an initiative is the development of the UAE Indoor Lighting Standard, which promotes the import and use of energy efficient lighting appliances in the country, and also bans the import of incandescent bulbs and other inefficient lighting products.

With regards to industry, it is important to support the competitiveness of UAE's industry through energy efficiency measures by widening the environmental requirements for energy and resource-intensive products. The potential effect of voluntary agreements with energy and resource-intensive industry branches should also be explored whilst energy management schemes could be implemented in industry and in the services sector. Efforts are needed in particular to substantially increase the uptake of high-efficiency cooling infrastructure, as cooling forms the largest share of energy consumption in the country. To catalyse change, larger number of qualified and licensed ESCOs need to be established across the country, to provide industries with support on energy audits and implementation of energy efficiency initiatives. An example of such an initiative is Canada's 'Save On Energy' Energy Manager Programme, whereby incentives are provided to companies to bring on board an energy manager to conduct audits and implement efficiency measures in their facilities.

KEY RECOMMENDATIONS:

- Encourage demand-side participation at both operational (e.g. to reduce variable generation costs, provide ancillary services or to resolve network constraints) and investment timelines (e.g. to delay or reduce the need for generation and/or transmission capacity);
- Investigate the introduction of tariffs such as 'time of use' and interruptible tariffs;
- Accelerate improvements in energy efficiency through programmes with the greatest energy saving potential;
- Introduce more government-led green initiatives focused on demand that support or work with an RE policy framework through the implementation of codes, standards and if necessary legislation.

4.6 THE WATER-POWER NEXUS

Encouraging the decoupling of power generation and water desalination processes to increase system flexibility whilst ensuring that future infrastructure is designed and operated optimally

During recent years the UAE policy regarding water-power linkages focused on power and water co-generation facilities taking largely geographical considerations into account. Thus, the main UAE co-generation plants are located near the coast for the raising of steam and treatment of water.

However, while power demand profiles in the UAE display strong seasonality (largely attributed to air conditioning demand during summer), water demand is more constant throughout the year. This difference in power demand profiles from associated water demand profiles results in an underutilisation of overall capacity during the winter season (when power demand is low) and therefore an increase in overall costs. This is due to the existing coupling between power and water production as well as the technical characteristics of co-generation plant which means that in order to produce water, a plant's power output must typically be at least 30-40 per cent of maximum capacity. As a result, since at least some power production is required to ensure water production, almost all co-generation plants in the system must produce at least at their minimum power output during winter, and since power demand is low during this season, most of co-generation plants tend to operate close to this minimum level. Part-loaded operation and underutilisation, however, lead to system inefficiencies and therefore an increase in overall costs.

WATER AND ELECTRICITY GENERATION SHOULD BE CONSIDERED AS AN INTEGRATED SYSTEM THAT IS ADAPTABLE TO THE FUTURE UAE ENERGY MIX

Along with seasonal power-water demand differentials, the anticipated large increase in power-only-plant, such as nuclear and renewable technologies, increases the need to decouple power generation and water desalination processes in order to create more flexibility in the system. This can be achieved through the strategic introduction of additional stand-alone water production plants in the system, such as RO desalination units. It is worth noting that the decoupling of power generation and water desalination processes does not suggest that the future development of power and water systems should be considered separately. Rather, they should continue to be considered as an integrated system but one that is more adaptable to the future UAE energy mix. The exact water membrane desalination technology to be selected for future standalone water plant (e.g. RO), as well as plant size and location, should be determined with a view to optimising power and water requirements, while at the same time ensuring that no mismatch in system capacities occurs at any particular location, including transmission bottlenecks.

This requires the detailing of an integrated, long-term UAE water and power strategy. Such a strategy should recognise that these decisions have an important impact on local economy, energy requirements, environment, water quality and system flexibility and it is therefore imperative that a range of different pathways is explored to cover uncertain factors such as future technological progress, commodity prices, energy demand etc.

In this context, priority should be given to understanding the techno-economic costs and benefits of the various options for increasing flexibility in the power system (e.g. in the form of electricity storage technologies) compared with the options for increasing flexibility in the water system (e.g. in the form of water storage facilities or additional RO capacity). Depending on the future evolution of the energy system, exploring the optimal trade-offs between the two would be beneficial for system planning purposes. This is particularly true for deep decarbonisation scenarios whereby the introduction of water infrastructure that increases system flexibility and redundancy could be a more cost-efficient option compared with other more expensive options of increasing flexibility in the power system. For example, this could take the form of increased electricity demand for water production during sunny periods (thereby leading to lower curtailment of solar PV plant) and then storing this water to be supplied during periods when renewable output is low (e.g. overnight periods) compared to developing more expensive electricity storage options.

KEY RECOMMENDATIONS:

- Decouple future power generation and water desalination infrastructure through the strategic introduction of additional stand-alone water production plant (e.g. based on RO technology);
- Create an integrated, long-term UAE water and power strategy that complements the *UAE National Energy Plan 2050* and is informed by local needs;
- Explore the optimal trade-offs between increasing flexibility in the power system versus increasing flexibility in the water system.

4.7 THE ROLE OF EMERGING TECHNOLOGIES

Demonstrating and creating a market for the emerging energy technologies with the greatest potential to reduce system costs in the UAE in the long-term

In the context of a deeply decarbonised UAE energy sector, some key emerging technologies in terms of their potential to reduce system costs in the UAE in the long-term include, but are not limited to:

- Large-scale seasonal storage;
- Solar CSP;
- Electric vehicles;
- Thermal cold storage (ice storage) for air conditioning.

EMERGING TECHNOLOGIES SUCH AS SEASONAL STORAGE PROVIDE INCREASED OPPORTUNITIES FOR RENEWABLE ENERGY UPTAKE IN THE UAE

Seasonal storage is defined as storage infrastructure with a long timeframe (typically over 1,000 hours), which will allow storage of excess energy up to several months. The most cost-effective seasonal storage technologies are likely to be those that convert power to a different medium, which is cheap to store. The most promising class of technologies currently are known as "power-to-gas" or "power-to-liquid" (referred to as "Power-to-X")[34]. Power to gas transforms electricity into hydrogen or methane (through electrolysis), which can be converted back to electricity at a later date. Similarly, power to liquid transforms electricity into liquified form of gas, which can then be converted into electricity when needed later. For these technologies, the costs of the conversion equipment are high, but those of the storage medium (e.g. storage tanks) are relatively cheap, and hence the overall solution cost scales slowly with the number of hours of storage. Large-scale seasonal storage lowers the total system costs compared to only using battery storage. This is due to the different technical parameters of large-scale seasonal storage (1,000+ hours of storage) versus battery storage (less than 24 hours of storage) as well as differences in capital costs between the two technologies. It is recommended that the UAE supports the development and testing of the most promising seasonal storage technologies, given their long-term potential to reduce overall costs in the UAE whilst also enabling RES deployment.

Based on technology cost assumptions, CSP is unlikely to be able to compete with large scale solar PV on a pure energy-delivered basis. This does not, however, take into account the key advantage of CSP in that it is also able to provide storage capability to the system. Validated by recent auction results in Dubai, a CSP system with 16 hours of storage could be cost-competitive compared with solar PV and batteries for storage lengths of between four to eight hours. It is recommended that the UAE continues to follow global developments in CSP technology with a particular focus on the technical differentiators that would be offered by a CSP system relative to solar PV + batteries. In the long-term, technology-neutral auctions for combined generation and storage facilities could also be considered in the UAE in order to promote price discovery and evaluate the relative competitiveness of CSP, solar PV + batteries, or other technologies including pumped storage.

[34] Power to X is used in this context to illustrate a number of electricity conversions to some form of energy storage thereby utilising surplus electric power which can then be reconverted back to power at a later date.

EV'S CAN INCREASE SYSTEM FLEXIBILITY, ESPECIALLY IF THEY CHARGE DURING HIGH RENEWABLE GENERATION HOURS

The deployment of electric vehicles, whilst increasing electricity demand, would be expected to significantly increase system flexibility as long as electric vehicles are incentivised to charge during off-peak hours or during hours with high renewable generation. The occurrence of off-peak hours during the daytime (solar PV hours) should be considered when locating charging infrastructure (e.g. at workplaces) and corresponding pricing mechanisms. The US State of California is likely to be a good market to study in this area due to relatively high penetration of both solar generation and electric vehicles. Moreover, provided that the power generation sector is also largely decarbonised, electric vehicles would add significant carbon savings. This again demonstrates the importance of considering carbon abatement across sectors.

Finally, the potential to install additional load shifting equipment such as thermal cold storage (ice storage) for air conditioning should also be explored. Such distributed systems can be integrated with a building's cooling system and provide demand-side response for commercial, industrial, and residential customers. An ice storage system works by making ice ("charging") during off-peak hours, and then discharging during peak hours by using the stored ice to cool buildings. These systems are also equipped with two-way communications allowing real time control and monitoring of cooling requirements. Utilities can dispatch individual units, custom groupings or fleets, and schedule them for permanent load shifting or for real-time dynamic load optimisation.

KEY RECOMMENDATIONS:

- Support the development and testing of seasonal storage projects, and thermal cold storage for air conditioning;
- Consider competing emerging storage technologies including Solar PV + Batteries, Solar CSP + integrated thermal storage, pumped storage, and other technologies;
- Consider incentivising and promoting cost discovery via technology-neutral auctions;
- Ensure that any roll-out of electric vehicles aids rather than hinders system flexibility. Align charging infrastructure and incentives to ensure vehicle charging occurs during off-peak hours (e.g. during low demand periods or periods with excess renewable output).

4.8 THE ROLE OF NETWORKS

Reducing network constraint costs by providing efficient long-term transmission investment signals and the application of smart technologies

The location of renewable power generators is driven in large part by the location of the available renewable energy resource. As a result, the addition of these generators to the UAE system may impose costs for the electricity transmission and distribution infrastructure required to connect the plant to the grid. Reinforcement of other parts of the grid infrastructure may also be required if these are not located close to the grid connection point for the new generation.

The existing transmission and distribution network in UAE has been developed against a backdrop of approximately 35 GW of peak generation capacity and 25-30 GW of peak demand. Commissioning large amounts of renewable generation together with the associated need to retain back-up generation and storage infrastructure may result in significantly more capacity being connected to the electricity grid than peak demand.

To reduce the network investment burden associated with a deeply decarbonised power system, three key objectives should be met:

- Firstly, to prevent (where possible) network congestion from arising without the need for additional network reinforcement;
- Secondly, if some congestion is unavoidable at specific parts of the system, to ensure that the short-term costs to resolve these constraints are kept to a minimum;
- Thirdly, to provide efficient transmission investment signals for cases where network reinforcement is the most cost-effective solution in the long-term.

SOLAR PV AND THERMAL INSTALLATIONS COULD SHARE EXISTING GRIDCONNECTIONS, THUS MINIMISING NEW BUILD COSTS

Network constraint costs can be minimised by ensuring that generation capacity is incentivised to be located appropriately. Solar PV generation can displace thermal generation during the daytime; this implies that thermal and solar PV installations could share existing grid connections, minimising the need for new build transmission infrastructure. When there are higher levels of renewable energy penetration, solar PV can be used in conjunction with battery and/or seasonal storage facilities; and again, these facilities could be co-located to minimise the need for transmission investment. Similarly, future interconnection routes could be planned for integration with RES generation. Rooftop versus ground-mounted solar PV is another case of a trade-off between economies of scale (ground-mounted) versus minimising transmission and distribution costs (rooftop).

Developers will only explore these innovative transmission cost minimisation solutions if the right charging incentives exist, for example:

- Ensuring the generation and storage assets are charged for access to the transmission network in a cost-reflective manner;
- Ensuring that generation and storage assets are not penalised for sharing grid connections if appropriate;
- Ensuring that transmission costs are included in technology-neutral auctions.

The traditional reinforcement planning by means of increasing the capacity of network assets can be costly and result in an overinvested network with low utilisation rates of the assets. In recent years, smart monitoring and control technologies have been used to increase the utilisation of network assets and provide a cost-effective and quick solution for managing network congestion. The potential for such smart solutions (such as Dynamic Line Rating[35], Static Volt-Ampere Reactive (VAR) Compensator[36], and Active Network Management[37]) should be exploited and be part of the future energy vision for UAE. An example technology is the use of phase-shifting transformers that can adaptively route power flows in order to minimize congestion and maximize the total transfer capacity of existing transmission corridors. Such devices can be an alternative to costly operational re-dispatch resulting from the need for PV curtailment, and can also delay the need for transmission expansion. It is, therefore, important that network regulation does not always favour investment and asset-heavy solutions to network problems, rather than operational or innovative alternatives that may be more cost-effective.

Network reinforcement can be justified up to the point where the marginal cost of reinforcement equals the marginal reduction in congestion costs brought about by that reinforcement. To that extent, it is important to develop an integrated framework for evaluating the most appropriate size of the required transmission and distribution capacity in UAE against a backdrop of the expected evolution of generation and demand. A key consideration here should be the concept of 'economically-efficient constraints', meaning a network should be reinforced to the point where it is economically efficient to do so. This is because some power system models may size the additional network capacity such that it is able to accommodate the maximum output from the new renewable generation (which may rarely be achieved), whereas it may be more cost-effective overall to size the additional transmission capacity at a lower level and curtail some output for some hours when renewable output is very high.

[35] One of the possible options to exploit the capacity of the transmission and distribution system as much as possible is based on dynamic line ratings by using several available measurement and forecast techniques. The related data acquisition is often combined with meteorological measurements. By having all the information available, line conductor models can be calibrated and used in a subsequent process to gain variable transmission line limits by using environmental cooling or heating conditions as one major input factor. It should be noted that dynamic thermal rating is not a substitute of grid development, but a complementary method to better exploit existing infrastructures.

[36] A static VAR compensator is a set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks. Static VAR compensators may be particularly useful as a part of long-term transmission development plan to facilitate addition of new renewable generation.

[37] Active Network Management connects separate components of a smart grid such as smaller energy generators, renewable generation, storage devices, etc., by implementing software to monitor and control the operation of these devices. Connection of these technologies to the main network ensures they are fully integrated into the energy system and thus can be used in an efficient way, thereby reducing the need to invest in expensive energy network reinforcement

In hours with network constraints it is important that these are resolved at the lowest possible cost. Mechanisms exist in European power markets for transmission system operators (TSOs) to resolve network constraints, although one of the more contentious issues is how and to what level generators are compensated for curtailment. This is because for investors in renewable energy technologies, knowing prior to making their final investment decision whether or not they will be compensated for curtailment for network constraints is a key consideration. It is recommended to carry out network studies in order to investigate this in more detail with higher levels of renewable energy penetration in the future.

Network reinforcement is likely to play an important role in the optimal siting of new generation and storage capacity and more work is needed in this area to ensure both efficient use of existing transmission infrastructure as well as minimising the costs and maximising the value of new transmission infrastructure investments.

KEY RECOMMENDATIONS:

- Prevent, where possible, network congestion from arising without the need for additional network reinforcement
  - Ensuring the generation and storage assets are charged for access to the transmission network in a cost-reflective manner;
  - Ensuring that generation and storage assets are able to share grid connections where appropriate;
- If some congestion is unavoidable at specific parts of the system, to ensure that costs to resolve constraints are kept to a minimum
  - A mechanism is required to resolve network constraints at lowest cost, and a framework is needed so that generators are fairly compensated for curtailment;
- To provide efficient transmission investment signals for cases where network reinforcement is the most cost-effective solution in the long term
  - Ensuring that transmission costs are included in technology-neutral auctions
- To ensure the stability, reliability and security of the electrical transmission and distribution network (which is essential for the economy as a whole) as the country's electricity grid evolves to accommodate increasing amounts of intermittent renewable energy technologies.
  - Note that any new solutions that are introduced to the grid must ensure full compatibility with the existing system.

4.9 THE ROLE OF INTERCONNECTION

Promoting cooperation between the four utilities in the UAE and at the regional level

Electricity interconnection between markets allows the efficient dispatch of resources and reserves across wider geographical areas and takes advantage of differences in instantaneous demand, renewables output, and plant availability. In Europe, for example, trading across interconnectors is very efficient at the day-ahead stage due to market coupling via a common algorithm. European electricity markets are currently working to extend this market coupling to cover intra-day, reserve, and balancing markets.

Existing electricity interconnectors across the four utilities in the UAE should be used as efficiently as possible, both in terms of minimising total UAE generation costs and providing reserves. The key is finding a way to trade optimally. This will also alleviate the land constraints that some Emirates face when considering RE versus competing land use priorities. The European market coupling process has promoted efficient use of generation capacity across countries, although some distortions may exist e.g. due to differing levels of network and balancing charges, and differing levels of fuel or carbon taxes in different countries[38] that are not considered when dispatching interconnectors.

In addition to interconnection capacity within UAE, there are also electricity interconnectors between the UAE and other GCC countries. A common framework for efficient trading of interconnection capacity does not currently exist but that there is ongoing work in this area. The framework for cross-border trade should consider the optimal dispatch of power generation capacity across countries, removing distortions where possible.

New interconnectors to neighbouring countries[39] are likely to provide benefits both to the UAE and the connected market owing to differences in seasonal demand shape, RES generation and existing power generation infrastructure. It is advised to first evaluate the costs and benefits of further interconnection with neighbouring countries and then design the appropriate regulatory and financing framework to develop the socially optimal levels of interconnection. In Europe, for example, development of new interconnection capacity has primarily been led by TSOs, although UK has seen a number of developer-led projects coming forward under Ofgem's "Cap-and-Floor" regime[40].

[38] In the UK, for example, Balancing System Use of System charges, which recover the cost of day-to-day operation of the transmission system, and the Great Britain (GB)-only Carbon Price Support tax are paid only by UK generators but not by generators in interconnected countries, therefore leading to higher wholesale electricity costs in the UK (all other things being equal) and therefore resulting in an import bias via the interconnectors.

[39] Western Europe is an excellent example of closer interconnection promoted by the European Union (EU) Target Model.

[40] In the "Cap-and-Floor" regime, the floor is the minimum amount of revenue that an electricity interconnector can earn. This means that, if an interconnector does not receive enough revenue from its operations, its revenue will be 'topped up' to the floor level. The funds will be transferred from the GB system operator (National Grid), which will in turn recover the sum from transmission charges applied to all users of the national electricity transmission system. Conversely, the cap is the maximum amount of revenue for an electricity interconnector. This means that, should an interconnector's revenue exceed the cap, the interconnector will transfer the excess revenue to the GB system operator, which will in turn reduce transmission charges. For consumers, the cap on revenues provides benefits in return for their exposure in underwriting the floor. For electricity interconnectors, it provides an investment route that complies with use of revenues requirements under EU legislation. There is a wide band of 'merchant' exposure between the cap and the floor.

The UAE, alongside other GCC countries, could support the GCCIA in establishing a blueprint for how GCC infrastructure is likely to evolve in the years to 2050. This blueprint should consider the demand and generation characteristics of each country, as well as potential for interconnection. The aim would be to identify priority infrastructure to be deployed, to ensure the integration of planned large-scale renewable generation facilities, and to ensure security of supply both on a country level and regional level. GCC TSOs could share network development plans and take these forward together with other stakeholders. For example, the Agency for the Cooperation of Energy Regulators is currently developing a common framework for evaluating security of supply across Europe.

KEY RECOMMENDATIONS:

- Framework for efficient dispatch of interconnectors between the UAE Utilities – including ensuring harmonised calculations of variable cost of generation in each Utility;
- Similar framework for trading on existing interconnection between the UAE and other GCC countries;
- Evaluate the benefit of additional interconnectors to neighbouring countries in conjuction with the GCCIA trading framework plans. Provide a financing framework to allow TSOs and/or developers to bring forward projects.

4.10 FOSTERING INNOVATION AND SUPPORTING POLICIES

Examples of fostering innovation tend to follow government incentives or the role of government ownership through the introduction of regulatory frameworks and the sale of government-owned assets. Consequently, RE inspired innovation 'flight-paths' can run in many directions from the establishment of RES 'Centres of Excellence' to the creation of an innovation value chain through government, private or crowd funding support. Given the sheer diversity of what is happening globally this report has sought to illustrate some workable examples in the UAE mostly, as given below.

Table 9: Existing Centres and Developments that focus on renewable energy in the UAE

Masdar Institute of Science and Technology	Now Under the Khalifa University umbrella, it is a graduate level, research-oriented university which is focused on alternative energy, sustainability and the environment located in Masdar City.
Masdar City Free Zone	Global free-zone cluster that offers business opportunities and investments in UAE focused on clean energy solutions.
Masdar City	The city, started in 2008, combines ancient Arabic architectural techniques with modern technology and captures prevailing winds so is naturally cooler and more comfortable during the high summer temperatures. Its PV installation is around 10 MW and seeks to promote "greenprint" for how cities can accommodate rapid urbanisation and dramatically reduce energy, water and waste.

DEWA R&D Center	The building will be a platform to show the latest solar and renewable energy technologies. It will enable DEWA to demonstrate its own achievements in renewable energy and sustainability, and highlight the green strategies incorporated in the Dubai Clean Energy Strategy 2050.
The Sustainable City, Dubai	Dubai's first residential solar project; it produces green energy for more than 500 villas from about 5,000 PV solar panels throughout the complex. The city also recycles all of its water.

Creating Employment

THE RENEWABLE ENERGY SECTOR EMPLOYED 10.3 MILLION PEOPLE IN 2017

According to the latest employment report by IRENA, "Renewable Energy and Jobs – Annual Review 2018", the "renewable energy sector employed 10.3 million people in 2017. The solar PV industry hosts the most jobs, with 3.4 million employees worldwide, reflecting the year's record 94 GW of PV installation." In addition, large hydropower accounted for another 1.5 million direct jobs in 2016. Renewable energy markets and employment continue to be shaped by favourable policy frameworks in several countries, regional shifts in deployment and increased labour productivity. Enabling policy frameworks remain, indeed, a key driver of employment.

Table 10: Key renewable energy driven employment initiatives

Brazil	Wind energy auctions coupled with financing rules to encourage local content; created job opportunities throughout the value chain
China	Has the highest number of RE jobs mainly through large-scale manufacturing
India	National and state level-auctions put ambitious solar targets into action
United States	Federal investment tax credits; working in tandem with state-level net-metering and renewable portfolio standards; helped sustain the growth of jobs in the solar industry

Solar PV employment is growing in Japan, China and the United States. This illustrates the importance of the Shams Dubai solar PV rooftop programme launched in early 2015, as a means for job creation throughout the value chain of the programme.

ASSESSING THE IMPACTS OF CLIMATE CHANGE AND ITS INFLUENCE ON ENERGY AND WATER SYSTEMS IS CRUCIAL FOR THE FUTURE

Clean Energy Research & Development

Building on the model of Masdar Institute, it is important that the UAE continues investing in research and development (R&D) for renewable energy technology innovations. Government entities can partner with academic institutions or private companies, to implement cutting edge projects, where the results can be shared regionally and globally. Each of these sectors play an important role in advancing research and devising locally-relevant solutions.

It would also be useful to assess climate change impacts in the UAE and how these will influence the efficiency of the energy and water system, for instance,

- The impacts of temperature changes on the energy and water demand profiles;
- The impact of temperature changes and water salinity on the efficiency of energy and water production and lifetime of technologies (such as PVs and RO membranes).

KEY RECOMMENDATIONS:

- Build on the Shams initiative across the UAE by promoting financial incentives for rooftop solar, initially targeting low-rise buildings;
- Encourage clean energy R&D by government, private sector companies as well as academic institutions, for UAE and GCC-based solutions;
- Promote the establishment of further centres of excellence across the UAE on the Masdar model;
- Promote new green energy policies and funding mechanisms focusing on customers which creates upward demand.

4.11 SUMMARY OF RECOMMENDATIONS

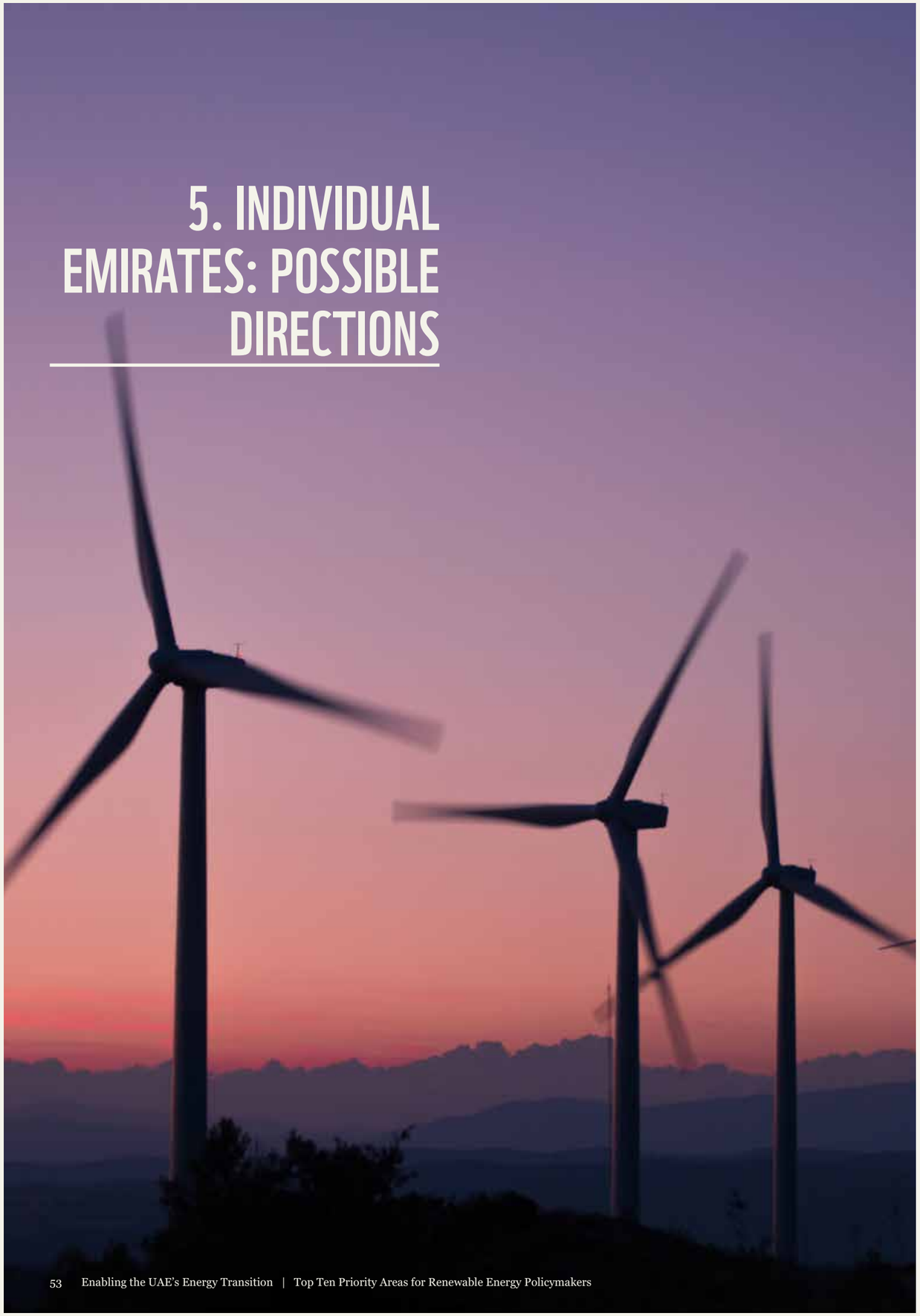
Table 11: Key Recommendations

Topic	Policy recommendations for the UAE
The role of competition	• Remove barriers to open and fair competition between available power generation technologies; • Create a cost-reflective system dispatch to ensure the system is operating as efficiently as possible; • Promote competition using transparent, market-based mechanisms across the energy value chain.
The role of renewable targets	• Establish a fully flexible RE policy framework which sets review milestones and interim targets; • Investigate the potential for new route to market options for RE (in addition to technology-neutral renewable auctions) such as corporate renewable energy Power Purchase Agreements PPAs and RECs; • Harmonise RE policy setting across Emirates; • Introduce and promote rooftop solar PV and streamlined means of getting connected to a local distribution network.

Topic	Policy recommendations for the UAE
The role of CO_2 targets	• Complement existing RE targets by a pathway for CO_2 emissions in coordination with relevant key stakeholders; • Understand externalities to be able to evaluate the costs to society from CO_2 emitting technologies; • Consider abatement options in different sectors of the UAE economy, not just the power and water sectors, and promote abatement in the sector(s) with the lowest marginal abatement costs.
Firmness and flexibility	• Develop technology-neutral auctions targeting firm and flexible capacity based on specific technical requirements as the system evolves over time; • Develop a remuneration framework for new build thermal generation assets with adequate incentives for high availability and physical delivery (to ensure security of supply), but which also prioritises the provision of firmness and flexibility to allow cost-effective integration of low-carbon generation technologies; • Investigate the future evolution of ancillary services to the system operator, particularly with respect to the increase in reserve levels due to RE penetration and the new nuclear plants; • Consider potential applications of energy storage technologies, beyond the requirement of large volumes of storage to reduce costs of integrating RE generation technologies, in operational timescales (such as resolving local network constraints and providing ancillary services).
The role of demand-side management	• Encourage demand-side management participation at both operational (e.g. to resolve network constraints and provide ancillary services) and investment timelines (e.g. to delay or reduce transmission or generation capacity in the system); • Investigate the introduction of tariffs such as 'time of use' and interruptible tariffs; • Accelerate improvements in energy efficiency with measures that have the greatest energy-saving potential; • Introduce more government-led green initiatives focused on demand, that support or work with RE policies through the implementation of codes, standards and, if necessary, legislation.
The water-power nexus	• Decouple future power generation and water desalination process through the strategic introduction of additional standalone water production plants (e.g. based on Reverse Osmosis (RO) technology); • Create an integrated, long-term UAE water and power strategy that complements the *UAE National Energy Plan 2050* and is informed by local needs; • Explore the optimal trade-offs between increasing flexibility in the power system versus increasing flexibility in the water system.

Topic	Policy recommendations for the UAE
The role of emerging technologies	• Support the development and testing of seasonal storage projects, and exploration of thermal energy storage for air conditioning; • Consider competing emerging storage technologies including solar PV + batteries, solar CSP + integrated thermal storage, pumped storage and other technologies. • Consider incentivising and promoting cost discovery via technology-neutral auctions; • Ensure that any roll-out of electric vehicles aids rather than hinders system flexibility. Align charging infrastructure and incentives to ensure vehicle charging occurs during off-peak hours (e.g. during low demand periods or periods with excess renewable output).
The role of networks	• Prevent, where possible, network congestion from arising without the need for additional network reinforcement; • If some congestion is unavoidable in specific parts of the system, ensure that costs to resolve constraints are kept to a minimum; • Provide efficient transmission investment signals for cases where network reinforcement is the most cost-effective solution in the long-term; • Ensure that transmission costs are included in technology-neutral auctions. • Ensure the stability, reliability and security of the electrical transmission and distribution network (which is essential for the economy as a whole) as the country's electricity grid evolves to accommodate increasing amounts of intermittent renewable energy technologies.
The role of interconnection	• Investigate a framework for efficient dispatch of interconnectors between UAE utilities – including ensuring harmonised calculations of variable cost of generation in each utility; • Investigate a similar framework for trading on existing interconnection between the UAE and other GCC countries; • Evaluate the benefit of additional interconnectors to neighbouring countries in conjunction with GCCIA trading framework plans. Provide a financing framework to allow TSOs and/or developers to bring forward projects.
Fostering innovation and supporting policies	• Build on the Shams initiative across the UAE by promoting financial incentives for rooftop solar, initially targeting low-rise buildings; • Encourage clean energy research and development by government, private sector companies as well as academic institutions, for UAE and GCC-based solutions; • Promote the establishment of centres of excellence across the UAE, building on the Masdar model; • Promote new green energy policies and funding mechanisms, focusing on customers, in an effort to create upward demand.

5. INDIVIDUAL EMIRATES: POSSIBLE DIRECTIONS



5.1 EMIRATE-LEVEL OPPORTUNITIES

This report does not recommend specific actions to individual Emirates or power authorities, and focuses largely on potential national level policies. This section looks to identify directions of suitability that if implemented in various geographic areas would support in achieving the *UAE National Energy Plan 2050*. Table 12 below does not exclude other renewable energy technologies, but seeks to identify the more appropriate ones for the emirate/region in question.

Table 12: RE Technology Options for the Four Authorities of the UAE

Authority [Emirate]	Geography	Primary leading RE technologies/actions
DoE-AD [Abu Dhabi]	Significant land mass which overall is flat. Al Ain has generally clearer air as it is inland and far less humid. Wind in the coastal north-west.	• Utility PV + Storage • PV rooftop • CSP • Wind • Seasonal storage • Large-scale DSM including utilisation of smelter generation capacity
DEWA [Dubai]	A city-state where land is at a premium. Generally flat. Many high-rise blocks.	• Utility PV + Storage • PV rooftop • CSP (likely however to be limited due to land constraints) • Large-scale DSM • Pumped Hydro Storage
FEWA [4 Northern Emirates]	Less populated than Abu Dhabi and Dubai. Mountainous – many water catchment areas. Relatively more wind than other Emirates	• Wind in the East • Pumped hydro system • Utility PV + Storage • PV rooftop
SEWA [Sharjah]	Spans east and west of the UAE. Densely populated in main city. Low rise buildings. Land constraints.	• Utility PV + Storage • PV rooftop • Possible pumped hydro in the east

5.2 UTILITY-BASED CONSIDERATIONS

Abu Dhabi (DoE-AD)

Abu Dhabi due to its land-mass has the potential to maximally develop utility-scale RE resources. To do so, effectively, the ability to integrate and incentivise for early built-out is important. Abu Dhabi needs to move from the take-or-pay approach in the current contract structure for independent water and power producers towards a more delivery-oriented structure. This would better align the incentives of the IWPPs to provide flexibility and cost-optimisation operations.

Demand-side management for both residential/commercial and industrial operators should be further prioritised and explored. In both cases a time-of-use tariff is recommended, exploiting the existing smart-meter infrastructure to provide the appropriate incentives for users to adjust their operations and shift demand intelligently to meet system capabilities. The attractiveness of this approach is that it embeds flexibility that can be used both for distributing the load evenly, in support of the current fossil-based system, but also concentrating during the high RE production as the system moves to higher RE penetration. A time-of-use tariff will allow, for example, the thermostat adjustments in smart buildings, the introduction of home-level battery systems, and local thermal storage systems like phase-change storage (e.g. ice or other fluids more suitable for the current chiller systems in place).

For heavy industry, the lowering of RE PV costs to less than 3 US$/kWh provides an opportunity to decouple from the mandatory reliance on cheap natural gas and also explore opportunities for production scheduling to optimise energy consumption. The example of aluminium smelters being able to pause production for up to three hours every day, offers a tool that should be investigated given the significant capacity of the industry in the country.

Dubai (DEWA)

Dubai has a rather clear DSM strategy to 2030 with many aspects that can be adopted as best practice. Generally, demand management drives how supply and storage will ultimately need to evolve. Dubai's willingness to promote new RES technologies in the region will establish their leadership in innovative solutions going forward. However, space and a lack of heavy industry demand will probably see incremental improvements in CO_2 reductions.

DEWA started developing, alongside Electricite Du France, a 250 MW pumped hydro systems (PHS) scheme for the use of demand-side management applications.

Sharjah (SEWA)

The Emirate of Sharjah is low-rise, but densely populated so is ideal for a range of initiatives such as the introduction of ESCOs to reduce per capita demand and the promotion of roof-top PV panels especially with battery storage. This would help with their peak demand by phase shifting, especially as they have limited land coastal resources to develop large power plants. SEWA can also make use of wind on the east coast.

Northern Emirates (FEWA)

The four northern Emirates effectively straddle the Straits of Hormuz. PHS's unique operational flexibility and storage capacity is likely to make it a cost-effective way of integrating intermittent renewable energy technologies by acting as a load during surplus conditions, and acting as a generator during tight system conditions. The bulk of the dams and water pools are in either Fujairah or Sharjah; while they do not lend themselves to long-term storage they would be ideal for demand management purposes. However, they would likely require a continued replenishment programme and given the evaporation losses and limestone beds in places, environmental issues may negate their usefulness.

5.3 TECHNOLOGICAL CONSIDERATIONS

Seasonal Storage

As explained above under the FEWA section, PHS are not likely to be of benefit for long-term storage solutions. Therefore, seasonal storage options could be either compressed air or compressed fuel gas. While the former has the advantage of using a single stage for the transformation, it has very low energy density and therefore would require very substantial underground cavern sizes. A compressed fuel on the other hand would require more stages and losses but would likely be less demanding in the size of the storage space. Importantly, a Power-to-X option provides additional flexibility in terms of the use of the fuel for non-electricity purposes, e.g. for transport, export, industrial synthesis etc.

Wind

In the east of the UAE, both SEWA and FEWA are well positioned to take advantage of wind energy. Of particular note is the development of building floating wind turbines[41] which would allow a fixed mooring just off the coast of Fujairah (FEWA area) or Sharjah with good connections into the Emirates National Grid in Fujairah. An assessment informed by existing infrastructure (such as port facilities) would be useful in identifying suitable locations for onshore and offshore wind infrastructure.

Other Considerations – Supply Side

Utility-scale PV auctions in Abu Dhabi and Dubai have already demonstrated the ability to drive PPAs as low as possible and so the model should be continued. Auctions where the off-taker, land, solar resources and grid connections are certain will always bring the lowest cost financing and lowest PPAs. The necessary evolution would be renewables auctions designed to require storage/firm capacity as the share of renewables in the power system grows. Rather than suggesting all Emirates build out significant renewables, grid interconnection particularly from Abu Dhabi seems to be the most appropriate solution assuming transmission and distribution can be effectively structured.

Demand-side Management

The three largest Emirates of Abu Dhabi, Dubai and Sharjah are well placed to lead DSM since they are the locations of major demand and have the urbanisation that makes significant progress achievable.

[41] Statoil is currently building the world's first floating wind farm called Hywind off the East Coast of Scotland – capacity of 30MW. It is expected to be fully operational by 2018 or late 2017.

6. CONCLUSIONS

Since the UAE's ratification of the Paris agreement, the country has been taking steps to advance the transition towards a low-carbon economy, as we have seen through the development of the *UAE National Energy Plan 2050*, the *National Climate Change Plan*, the UAE Green Agenda 2030, as well as well as Emirate-level strategies and policies. There is potential for additional action on the ground both federally and locally, especially in the creation of a market that allows for increased level of renewable energy capacity and generation to support the successful implementation of the *UAE National Energy Plan 2050*. To push for more renewable energy use and increased ambition, relevant policies and incentives need to be put in place, within a federal policy framework, to provide appropriate signals to the market. Accordingly, this policy report lays down ten key areas of intervention.

The outcomes of this report are a first step in creating cross-sectoral dialogue on policy development. The areas of policy action highlighted in the report include: fair competition in the energy market; targets for renewable energy deployment and reduction in carbon emissions; harmonisation of the network across the Emirates, and ensuring it is firm yet flexible enough to include different types of technologies; demand-side management measures; the water-power linkage for future capacity planning; and exploration of emerging technologies and innovation in clean energy solutions in the UAE.

The proposed next steps would be to use the recommendations of this report to advance multi-stakeholder action for a federal level policy framework, which includes economic and market incentives that create a pull for increased renewable energy uptake and innovation, and a competitive and flexible energy market such that any new advancements and disruptive technologies can be captured and utilised. The revision cycles built into the *UAE National Energy Plan 2050* will allow the country to benefit from advancements in renewable energy technology, rapidly changing economics of renewables, and emerging best practices.

THE DEVELOPMENT OF A DYNAMIC RENEWABLE ENERGY MARKET WILL REQUIRE ACTIVE PARTICIPATION FROM ALL SECTORS OF THE UAE

The development of a dynamic renewable energy market will require active participation from the public, private and civil society sectors alike. UAE stakeholder will continue to be engaged in the ongoing policy dialogue. Readers of this report are encouraged to support the Ministry of Energy and Industry in successfully implementing the goals of the *UAE National Energy Plan 2050*, in their capacity as federal or Emirate-level regulatory agencies, utilities, private renewable energy developers, energy service providers, or energy consumers. Collaboration is key to UAE's journey towards becoming a low-carbon economy.

LIST OF ACRONYMS

Term	Description
ADDC	Abu Dhabi Distribution Company
ADWEA	Abu Dhabi Water and Electricity Authority
BAU	Business As Usual
BOO	Build, Own, Operate
BSUoS	Balancing System Use of System
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
COP	Convention of Parties
CPA	Component project activities
CSP	Concentrated Solar Power
DEWA	Dubai Electricity and Water Authority
DCCE	Dubai Carbon Centre of Excellence
DSM / DSR	Demand-Side Management (or Demand-Side Response)
ESCO	Energy Services Company
EWS-WWF	Emirates Wildlife Society in association with WWF
FEWA	Federal Electricity and Water Authority
GB	Great Britain
GCC	Gulf Cooperation Council
GW	Giga Watts -109
IPP	Independent Power Producer
I-REC	International Renewable Energy Certifications
IWPP	Independent Water and Power Producer

Term	Description
KWh	Kilo Watt hour
LCOE	Levelised cost of electricity
LED	Light-emitting diode
MW / MWh	Mega Watt – 106 MWh – 1 MW for one hour
MW_{AC}	Nominal Power Output of PV in alternating current
MWp	Mega Watt peak
MoCCAE	Ministry of Climate Change and Environment
MoEI	Ministry of Energy and Industry
OCGT	Open Cycle Gas Turbine.
PHS	Pumped Hydro System
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable Energy
REC	Renewable Energy Certifications
RES	Renewable Energy Sources
RO	Reverse Osmosis
RSB-AD	Regulation and Supervision Bureau – Abu Dhabi
SEWA	Sharjah Electricity and Water Authority
TSO	Transmission System Operator
VRF	Variable refrigerant flow
UK	United Kingdom

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APPENDIX A
LIST OF PARTICIPATING STAKEHOLDERS

Abu Dhabi Sustainability Group
City Solar
Clean Energy Business Council
Department of Energy - Abu Dhabi
Department of Transport - Abu Dhabi (DoT)
Diamond Developers (The Sustainable City)
Dubai Carbon Centre of Excellence
Dubai Electricity and Water Authority (DEWA)
Dubai Supreme Council of Energy (DSCE)
EU-GCC Clean Energy Network
Emirates Green Building Council
Energetics Incorporated
Engie
Environment Agency - Abu Dhabi (EAD)
Ernst and Young
Etihad Energy Service Company (Etihad ESCO)
Federal Electricity and Water Authority
First Abu Dhabi Bank
First Solar
Global Green Growth Institute
Masdar Institute
Ministry of Climate Change and Environment
Pricewaterhouse Coopers
Ras Al Khaimah Municipality
Regulatory & Supervision Bureau - Dubai (RSB)
Shams Power Company
Sharjah Electricity and Water Authority (SEWA)
Yellow Door