International Renewable Energy Agency

Power sector planning in Arab countries

Incorporating variable renewables

Summary report for the technical workshop,
"Exchanging best practices to incorporate variable renewable energy into long-term energy/power sector planning in Arab countries,"

Amman, Jordan
21-24 April 2019

ISBN: 978-92-9260-184-3

Citation: IRENA (2020), *Power sector planning in Arab countries: Incorporating variable renewables*, International Renewable Energy Agency, Abu Dhabi.

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy – including bioenergy, geothermal, hydropower, ocean, solar and wind energy – in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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Acknowledgements

This report was prepared by IRENA in partnership with the League of Arab States (LAS), the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) and the Islamic Development Bank (IsDB). The input was based on the findings and outcomes of a technical workshop, held in Amman, Jordan, under the title “Exchanging best practices to incorporate variable renewable energy into long-term energy power sector planning in Arab countries”.

The report benefited from the input of Tractebel (Benoit Janssens) and from the over 50 participants present at the workshop from the different ministries and utilities.

IRENA is grateful for the generous support of the Islamic Development Bank, which made the publication of this report a reality.

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HIGHLIGHTS

- The **Pan-Arab Clean Energy (PACE)** initiative aims to promote the integration of higher shares of renewables into regional power systems and improve the energy planning practices of Arab countries.

- Variable renewable energy (VRE) deployment must be supported by **robust long-term energy and power sector planning** – the focus of the "AVRIL" (Addressing Variable Renewable Energy in Long-Term Energy Planning) project initiated by the International Renewable Energy Agency (IRENA) in 2013.

- A report from IRENA (2017), ***Planning for the renewable future: Long-term modelling and tools to expand variable energy power in emerging economies***, provides an overview of methodologies to better reflect the variability of solar and wind energy in long-term planning tools.

- IRENA and regional partners, including the **League of Arab States** and the **Regional Center for Renewable Energy and Energy Efficiency (RCREEE)**, are working together with the **Islamic Development Bank (IsDB)** to address the challenges of variability in long-term planning for Arab power systems.

- A joint workshop in April 2019 brought together **more than 50 participants from 10 Arab countries** to discuss best practices and identify priorities for improvement.

- Many Arab countries currently show **low to negligible renewable energy use** yet have set ambitious targets to increase their shares of renewables.

- Power-system planning in some countries is constrained by **cost-related challenges**, along with the lack of first-hand experience with renewables.

- Government ministries play a crucial role in **adapting power sector planning practices** to create robust, long-term energy strategies.

- While countries are at various stages of VRE planning and deployment, the opportunities for **regional dialogue and collaboration** are significant.

- Follow-up analysis and further workshop discussions could focus on specific planning elements, such as **cost projections, capacity credits, flexibility, zoning** and **system stability**.

CONTENTS

TABLES

ABBREVIATIONS

AVRIL	Addressing Variable Renewable Energy in Long-Term Energy Planning
CCGT	Combined cycle gas turbine
CSP	Concentrated solar power
EDL	Electricité du Liban (Lebanon)
EEHC	Egyptian Electricity Holding Company
EGEAS	Electric Generation Expansion Analysis System
EPRI	Electric Power Research Institute
EWA	Electricity & Water Authority (Bahrain)
GCC	Gulf Cooperation Council
GDP	Gross domestic product
GECOL	General Electricity Company of Libya
GIS	Geographic information system
GW	Gigawatt
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IsDB	Islamic Development Bank
Kw	Kilowatt
LAS	League of Arab States
LCEC	Lebanese Center for Energy Conservation
LCOE	Levelised cost of energy
LOLE/P	Loss of load expectation/probability
MOG	Ministry of Oil and Gas (Oman)
MW	Megawatt
NREAP	National Renewable Energy Action Plan
NREL	National Renewable Energy Laboratory
OCGT	Open cycle gas turbine
OETC	Oman Electricity Transmission Company
ONEE	Office National de l'Electricité et de l'Eau Potable (Morocco)
OPWP	Oman Power & Water Procurement Company
PACE	Pan-Arab Clean Energy Initiative
PENRA	Palestinian Energy and Natural Resources Authority
PHS	Pumped hydro storage
PSS/E	Power system simulator for engineering
PV	Photovoltaic
RCREEE	Regional Centre for Renewable Energy and Energy Efficiency
RES	Renewable energy source
TSO	Transmission system operator
VRE	Variable renewable energy

ABOUT THE TECHNICAL WORKSHOP

BACKGROUND

The renewable energy market is booming in Arab countries. Scaling up the contribution of renewables to the future energy mix has become a major policy priority across the region.[1] This comes as countries also seek to diversify their economies against the backdrop of fast-growing domestic energy demand and – for today's oil and gas exporters – the desire to safeguard hydrocarbon export revenues for the future.

The fourth Arab Economic and Social Development Summit, held in Beirut in January 2019, has kept renewables high on the regional agenda.[2] The Pan-Arab renewable energy strategy sets a solid basis for regional co-operation to drive deployment, committing countries to increase the region's installed renewable power generation capacity from 12 GW in 2013 to 80 GW in 2030.

In support of this strategy, the International Renewable Energy Agency (IRENA) partnered with the League of Arab States (LAS) and the Regional Centre for Renewable Energy and Energy Efficiency (RCREEE) to implement the Pan-Arab Clean Energy (PACE) Initiative, one of the initiatives included in the Roadmap of Actions to implement the strategy.

The PACE initiative is thus a regional strategy that aims to promote the integration of greater shares of renewables in Arab regional power systems. Among other objectives, it aims to improve the energy planning practices of Arab countries so that they better account for the variability of wind and solar power. The variable and only partially predictable nature of variable renewable energy (VRE) sources, such as solar or wind, translates into higher levels of uncertainty and is often regarded with caution when considering higher penetration rates. To allay those concerns, ambitious VRE deployment must be supported by robust long-term energy and power sector planning, and particularly by sets of quantitative techno-economic analyses to define feasible transition scenarios.

IRENA member states, including several countries in the Arab region, have been proactive in this regard, and expressed a keen interest in improving their energy planning practices to better account for the variability of wind and solar power. In the modelling methodologies used by national planning offices for long-term capacity expansion planning, such variability and its economic consequences can be difficult to represent.

To address this challenge, IRENA initiated the Addressing Variable Renewable Energy in Long-Term Energy Planning (AVRIL) project in 2013. Building on the expertise gained through various discussions and sessions held under the AVRIL project, IRENA released its *Planning for the renewable future: Long-term modelling and tools to expand variable renewable power in emerging economies* report in January 2017. The report provides an overview of a range of methodologies that are practiced around the world to improve the representation of VRE in long-term planning tools.

1 As documented in IRENA's Renewable energy in the Arab region – Overview of developments (2016) and Renewable energy market analysis: GCC 2019 reports.

2 The summit included the endorsement of the Pan Arab Strategy for Sustainable Energy 2014-2030, updated from the Pan Arab Strategy for the Development of Renewable Energy 2010-2030, first adopted at the third Arab Economic and Social Development Summit by the League of Arab States in 2013.

In this regard, between 21-24 April 2019, a regional workshop was held in Amman in co-operation with the LAS, the RCREEE and the Islamic Development Bank (IsDB) to discuss the *Planning for the renewable future* report and its relation to long-term energy/power sector planning with VRE in the context of the Arab region. By carrying out this workshop, IRENA, with its partners, addressed the variability of renewable energy sources in long-term planning in the Arab region, one of the key components of the PACE Action Plan.

The workshop, entitled **"Exchanging best practices to incorporate variable renewable energy into long-term energy/power sector planning in Arab countries"**, brought together over 50 participants, including energy planners nominated by the respective governments of ten Arab countries – Algeria, Bahrain, Egypt, Iraq, Jordan, Libya, State of Palestine, Qatar, Saudi Arabia and Somalia – as well as experts from international/regional organisations.

The workshop had two main objectives:

The **primary objective** was to exchange and discuss regional – as well as global – best practices to enhance capacity expansion planning to achieve significant renewable energy deployment.

More specifically, the discussion focused on five main topics related to the representation of VRE in long-term planning tools:

- VRE investment costs
- generation adequacy (i.e., capacity credit of VRE)
- system flexibility
- VRE siting and zoning evaluations (and their link to transmission investment)
- Stability-related operational constraints in a system.

The **secondary objective** of the workshop was to identify priorities for improvement in planning methodologies based on the topics discussed, which could potentially be addressed through follow-up regional or bilateral technical co-operation.

On the first days of the session, national representatives presented an overview of their respective institutional planning and long-term modelling frameworks, and how VRE is represented in those areas (see country presentations, notes and session recording[3]). The remainder of the workshop was dedicated to the technical input presentations by attending experts, and discussion/exchange of country experience.

The presentations and discussions held during the workshop delivered a wealth of information about current country practices and challenges and future priorities for the integration of VRE in long-term energy planning/modelling. This report is meant to synthesise that information and act as a platform for bilateral networking between countries around specific issues, or follow-up co-operation with IRENA.

For the sake of completeness, in addition to the contributions of the representatives of the attending countries (Algeria, Bahrain, Egypt, Iraq, Jordan, Libya, State of Palestine, Qatar, Saudi Arabia and Somalia), other Arab countries (Lebanon, Morocco, Oman, Sudan and Yemen) transmitted key information regarding national power sectors, the way VRE is taken into account during planning processes, and the main challenges and priorities in the sector. This information is also presented in this report.

3 Available through this link:
www.irena.org/ArabVRE

CONCLUSIONS

The high-level takeaways from the workshop are as follows:

Renewable energy and VRE characteristics in participant countries (Chapter 1)

- Renewable energy shares are currently relatively low to non-existent among many of the participant countries, with Jordan being a notable exception considering its relatively high share of installed capacity.
- Renewable energy shares are set to grow, however, given the ambitious targets set for the coming decades in many countries.
- The vast majority of this renewable energy capacity expansion will be VRE. A notable exception is Egypt's plan to add 2.4 gigawatts (GW) of pumped hydro to its system by 2027.
- In many cases, national plans to expand VRE capacity represent rapid increases relative to current shares over a short period of time.
- The inclusion of renewable energy in the national energy strategies is mainly supported by the desire to save fuel and to accommodate increasing energy demand at the lowest cost while reducing greenhouse gas emissions. Another important aspect is increasing energy security and independence through diversification.

National modelling tools, planning frameworks and approaches (Chapters 1, 2 and 3)

- Established power sector planning practices are not present in all of the participant countries. Some countries with less developed energy systems due to political and historical contexts currently lack the necessary framework, tools and approaches for robust, long-term energy planning.
- Ministries play an important role in all participant countries. In some countries, utilities, regulators and transmission system operators (TSOs) are also key. Mandates vary, and not all country planning processes are integrated across these players. In a few countries, the private sector plays an important role due to the lack of well-established government institutions.
- Many countries reflect projections of renewable energy costs in their long-term modelling, though translating international projections into local contexts is a challenge.
- Fewer countries thoroughly represent the contribution of VRE to generation adequacy (i.e., capacity credit). For those countries that don't, capacity credits are not expected to have an important impact on the system; e.g., the capacity credit of solar photovoltaics (PVs) is expected to be negligible if peak load occurs at night.
- System flexibility is considered in fewer of the modelling approaches. Must-run units are seen as a possible flexibility issue that will cause VRE curtailment as higher shares are integrated. Interconnections are seen as an important source of flexibility if they are possible. When talking about storage solutions, the main issue is forecasting the cost of these solutions.
- While most countries have developed solar and wind resource maps, the general co-optimisation of generation and transmission expansion planning processes has historically not been applied. Most countries are aware of the challenge, however, and practices are being adapted.
- Grid codes should be adapted to ensure they adequately reflect the qualities of new VRE technology and to avoid future issues with higher levels of integration.

Country conclusions and follow-up opportunities (chapters 2 and 4)

- This was the first regional workshop focusing on planning and modelling for VRE.
- As most countries are expecting significant growth in VRE integration in their systems, but have little experience to rely on, there is a need for such dialogue. Having a forum to exchange national experience and learn from other country approaches is extremely helpful for planners and currently lacking in the Arab region. Participating countries will bring back new ideas and methods to their national planning context.
- As reflected in chapters 2 and 4 of this report, there is now an extensive list of working-level topics that countries in the region are eager and able to follow up on – though countries are at different stages of VRE planning and deployment, the opportunity for collaboration is significant. All areas discussed during the workshop are seen as potential priorities for follow-up work, to varying degrees:

1. Renewable energy cost projections

Depending on the exact aspect of the topic, six to eight participating countries are interested in improving their VRE cost projections, learning how to adapt them to the local context and exploring the influence of the related uncertainties. **This was generally seen as a medium/high priority**.

2. Capacity credits of VRE

Depending on the exact aspect of the topic, six to eight participating countries are interested in strengthening their methodologies to evaluate the capacity credits of VRE on their system. **This was generally seen as a medium/high priority**.

3. Flexibility

Eight participating countries are interested in improving their approach towards assessing the flexibility of the system at higher levels of VRE penetration and the benefits and costs of flexibility solutions. **This was generally seen as a high/very high priority**.

4. VRE zoning and siting

Seven participating countries are interested in improving the co-optimisation of generation and transmission of VRE resources. **This was generally seen as a medium/high priority**.

5. System stability

Eight participating countries are interested in building capacities in validating long-term results through grid integration studies, as well as adapting the grid code to ensure stability with VRE integration. **This was generally seen as a high/very high priority**.

- Topics beyond the modelling: Chapters 2 and 4 of this report also highlight how several countries consider improvements in data acquisition, management and transfer between institutions, along with adequately training their staff in new methods, to be crucial going forward.

1. REGIONAL CONTEXT

RENEWABLE SHARES

Table 1 summarises current and future renewable shares in the countries attending the workshop, compiled from country presentations and group discussions. IRENA statistics were used to fill any gaps in the data provided about current renewable shares.

Table 1: **National renewable energy shares**

Country		Current	Expected	Notes on expected amounts
Algeria	RE share		30 GW by 2030	National programme for 22 GW of renewable energy source (RES) in 2030
	VRE	Wind: 10 megawatts (MW); solar: 410 MW	13.6 GW solar PV by 2030 (62%); 5 GW wind (23%)	
Bahrain	RE share	<1% of installed capacity (2014)	255 MW installed capacity (5%) by 2025 and 710 MW (10%) by 2035	National Renewable Energy Action plan targets
	VRE	1 MW building integrated wind; 5 MW solar PV (2018)	50 MW wind; 200 MW solar by 2025 300 MW wind; 400 MW solar by 2035	100 MW solar farm on a landfill site in the pipeline
Egypt	RE share	Hydro ~4.7% and ~2.3% wind of installed capacity	20% of electricity generated by 2022; 42% by 2035	Egyptian Renewable Energy National Strategy targets
	VRE	Wind: ~1 125 MW installed capacity; solar: ~750 MW	Generation mix – wind: 12%; solar: 2% by 2022	2 465 MW of solar PV, 2 620 MW of wind and 100 MW of concentrated solar power (CSP) under development
Iraq	RE share		2 000 MW over the next four years	
	VRE	Solar: 37 MW	Renewable energy targets: 5% of generation capacity from renewable energy by 2030	Iraq screening 755 MW solar PV power projects
Jordan	RE share	15.7% of installed capacity and 6.5% of generation	20% of generated electricity by 2025	National Energy Strategy 2025 target
	VRE	283 MW of wind and 851 MW of solar PV (out of which 360 MW of small-scale solar PV)	2 400 MW of wind and solar by 2021; 334 MW of wind and 596 MW of solar under construction	Feasibility study for contribution of CSP by 2030 and pumped hydro storage (PHS)
Lebanon*	RE share	120 MW hydro (1 660 MW total installed capacity)	12% in 2020 and 30% in 2030	
	VRE	No VRE connected to the grid	2030: 500 MW wind, 360 MW PV and 300 MW PV + storage	Provided by EDL
Libya	RE share	No renewable energy connected to the grid	22% by 2030	
	VRE	No VRE connected to the grid	850 MW wind; 3 350 MW solar; 400 MW CSP	Proposed Strategy for Renewable Energy Development in Libya

Table 1 (continued)

Country		Current	Expected	Notes on expected amounts
Morocco*	RE share		42% by 2020 and 52% by 2030 in terms of total capacity (wind, solar and hydro)	National energy strategy launched in 2009
	VRE			
Oman*	RE share	No renewable energy connected to the grid	Oman's Grid Master Plan has presented that 15% of renewable energy can be injected into the grid	
	VRE	No VRE connected to the grid		
State of Palestine	RE share	~21.6 % of installed capacity; ~12.1% of generation; 1.3% of electricity consumption	130 MW of installed capacity by 2020 (10% of generation); 300-500 MW (25% of generation) by 2030;	Renewable Energy Strategy 2012. Currently only 40 MW installed
	VRE		65 MW solar, 44 MW wind by 2020; 400 MW solar, 50 MW wind by 2030	65 MW solar target on track, wind power development is not
Qatar	RE share	No renewable energy connected to the grid		
	VRE		500 MW of solar PV tender launched	
Saudi Arabia	RE share	No renewable energy connected to the grid (2017)	32.4 % of installed capacity	Cost optimal 2030 Energy Mix
	VRE	No VRE connected to the grid (wind: ~3 MW; solar: ~139 MW)	16.2 GW wind (~9%), 2.7 GW CSP (~1.5 %), 39.3 GW solar PV (~22%)	
Somalia	RE share			Power Master Plan under development (publish October 2019)
	VRE	1.5 MW solar; 750 kilowatts (kW) wind (Garowe mini-grid)		
Sudan*	RE share	Renewable energy: 23 MW; hydro: 1 877 MW (according to Master Plan 2012-2031)	195 MW in 2031 (Master Plan 2012-2031))	Generation and Transmission Master Plan 2012-2031
	VRE			
Yemen*	RE share			N/A
	VRE			

* Countries not attending the regional workshop held between 21-24 April 2019 in Amman. Answers to the questionnaire were provided after the workshop.
RE = renewable energy
VRE = variable renewable energy (solar and wind)

PLANNING TOOLS

Table 2 summarises power sector planning tools currently used in the countries attending the workshop, compiled from country presentations, pre-workshop surveys and group discussions.

Table 2: **Power sector planning tools**

Country	Tool	Planning steps - Tool coverage				Notes
		Technical network studies	Dispatch simulation	Power demand forecast	Generation expansion	
Algeria	MAED			X		
	DAP			X		
	NOMITOR			X		
	WASP				X	
	MESSAGE		X		X	Modelling of renewable energy capacity expansion including capacity credits and flexibility of the system
	SPIRA package	X				
	SIMONE	X				
Bahrain	PSS/E (Power System Simulator for Engineering)	X	X			Power demand forecast and generation expansion including renewable energy sources is done by consultant's Master Plan
Egypt	Eviews			X		
	EGEAS (Electric Generation Expansion Analysis System)		X		X	Developed by EPRI; capacity credits of VRE as a percentage of the installed capacity; limited representation of operational constraints; does not consider access to transmission grid
	PSR models	X	X		X	Includes the following tools: OptGen, SDDP, NCP, NetPlan Models VRE characteristics such as variability, firm capacity, stochastic nature, etc.; connection to transmission grid reflected in optimisation process
	PSS/E	X				-
Iraq	N/A					
Jordan	PLEXOS			X	X	VRE siting and transmission investments represented
	Excel model			X		
	WASP		X			
	PSS/E	X				VRE capacity credits and power system stability represented
	DIgSILENT Power Factory	X				VRE capacity credits and power system stability represented

Table 2 (continued)

Country	Tool	Planning steps - Tool coverage				Notes
		Technical network studies	Dispatch simulation	Power demand forecast	Generation expansion	
Lebanon*	Estimation		X	X		EDL
	CYME	X				EDL
	Remap				X	Ministry of Energy and Water
Libya	N/A					
Morocco*	MAED			X		
	OPTGEN				X	
	SDDP		X		X	
	NCP					
	PSS/E	X				
Oman	N/A					
State of Palestine	Excel model			X	X	
	ETAP	X				No VRE specific issues represented in modelling tool
Qatar	Excel Model + @RISK			X		Residential demand: Regression and probabilistic risk assessment
	In-house model		X	X		Industrial demand: End use method with relevant coincident (surveys)
	PLEXOS				X	Year ahead dispatch
	PSS/E; PSS SINCAL	X				Power system stability issues to be identified during operation of first solar project (Al-Kharsaa)
Saudi Arabia	Mothra				X	In-house model
	SUPER				X	In-house model
	Strategist (+ stratRob)	X	X			In-house model
	PLEXOS				X	Combination with geographic information system (GIS) analysis
	KEM		X		X	
	ProMod		X			
	PSS/E	X				Static and dynamic stability analysis
	In-house tool			X		In-house model; a combination of bottom-up modelling of the energy sector and top-down econometrics
Somalia	Excel model			X		
Sudan*						Medium-term and long-term system planning study carried out in 2011 by an international consultant
Yemen*	N/A					

* Countries not attending the regional workshop held between 21-24 April 2019 in Amman. Answers to the questionnaire were provided after the workshop.

PLANNING MANDATES

Table 3 summarises the institutions responsible for different stages of power sector planning in the countries attending the workshop, compiled from pre-workshop surveys.

Table 3: **Institutions responsible for power sector planning**

Country	Planning steps – Institutional responsibility‡		
	Energy system planning	**Generation capacity expansion planning**	**Transmission planning**
Algeria	Ministère de l'Énergie	Commission de Régulation de l'Électricité et du Gaz (CREG) ; Ministère de l'Énergie	Sociéte Nationale de l'Électricité et du Gaz (Sonelgaz)
Bahrain	Electricity & Water Authority (EWA)	Electricity & Water Authority (EWA)	Electricity & Water Authority (EWA)
Egypt	Ministry of Electricity and Renewable Energies (MoERE); Ministry of Petroleum	Egyptian Electricity Holding Company (EEHC)	Egyptian Electricity Transmission Company (EETC)
Iraq	Planning and Study Office, Ministry of Electricity	Planning and Study Office, Ministry of Electricity	Planning and Study Office, Ministry of Electricity
Jordan	Ministry of Energy and Mineral Resources (MEMR)	Grid expansion section, National Electric Power Company (NEPCO)	Transmission planning section, National Electric Power Company (NEPCO)
Lebanon*	Lebanese Center for Energy Conservation	Ministry of Energy and Water and Electricité du Liban (EDL)	Ministry of Energy and Water and Electricité du Liban (EDL)
Libya	General Electricity Company of Libya (GECOL)	General Electricity Company of Libya (GECOL)	General Electricity Company of Libya (GECOL)
Morocco*	Ministry of Energy	Office National de l'Électricté et de l'Eau Potable (ONEE)	ONEE
Oman*	Ministry of Oil and Gas	Oman Power & Water Procurement Company (OPWP)	Oman Electricity Transmission Company (OETC)
State of Palestine	Palestinian Energy and Natural Resources Authority (PENRA); Palestinian Electricity Transmission Company (PETL); Palestine Electric Company (PEC); Palestinian Electricity Regulatory Council (PERC)	Palestinian Energy and Natural Resources Authority (PENRA)	Palestinian Electricity Transmission Company (PETL)
Qatar	Qatar General Electricity and Water Corporation (KAHRAMAA)	Qatar General Electricity and Water Corporation (KAHRAMAA)	Qatar General Electricity and Water Corporation (KAHRAMAA)
Saudi Arabia	Ministry of Energy, Industry and Mineral Resources (MEIM)	Ministry of Energy, Industry and Mineral Resources (MEIM)	Ministry of Energy, Industry and Mineral Resources (MEIM); Saudi Electric Company
Somalia	Ministry of Energy & Water Resources	Private & public sector	Ministry of Energy & Water Resources
Sudan*	Ministry of Water Resources, Irrigation and Electricity	Ministry of Water Resources, Irrigation and Electricity	Ministry of Water Resources, Irrigation and Electricity
Yemen*	Not available	Not available	Not available

* Countries not attending the regional workshop held between 21-24 April 2019 in Amman. Answers to the questionnaire were provided after the workshop.
‡ Source: Country surveys in Annex 3.

2. COUNTRY PROFILES

The country profiles that follow are based on national presentations, group discussions and conclusions from the workshop. For more details on countries' energy planning frameworks and modelling approaches, please see links provided to country workshop presentations and in-depth country surveys in Annex 3.

A compilation of all countries' current practices and improvement priorities related to VRE representation in long-term planning/modelling can be found in Chapter 4, "Matching matrix: Country practices and improvement priorities".

> Many Arab countries, despite low to negligible renewable energy use at present, have set ambitious targets to increase their shares of renewables

ALGERIA

WORKSHOP PRESENTATION

Energy planning framework/methodology

- Create security of supply (gas and electricity) by diversifying the energy mix and promoting energy efficiency.
- Partnered with Res4MED to conduct a renewable energy integration study.
- Perform deterministic and probabilistic studies for system stability, with detailed data on renewable energy-based generation profiles and conventional generation parameters.
- Determine the size of required reserve to cope with intermittency due to VRE; identification of maximum penetration rate to be safely integrated; identification of required grid reinforcements; evaluation of operational benefits due to renewable energy (operational costs, energy not served, etc.).

Current approach to VRE representation

- National programme aims to reach 22 GW of RES in 2030.
- Programme will be mainly solar (PV: 62% and CSP: 9%) and wind (23%) but also biomass (4%), cogeneration (2%) and geothermal (0.09%).
- Implement a favourable policy and regulatory framework.
- The office that is responsible for assessing capacity credits uses a probabilistic tool to evaluate the number of hours with and without VRE production.
- Benefits for the local economy thanks to "domiciliation" of equipment manufacturing and partnerships for industry and engineering.
- Carry out pilot projects and strategic partnerships (Ghardaia and Kabertane plants, Hassi Rmel, etc.).
- The first phase of capacity expansion was therefore to have smaller plants closer to the load centres. A second phase will consist of larger projects in the south combined with interconnections.

Known challenges related to renewables

- There exists a strong variation in load from north to south, but this does not correlate with the resource potential as most solar resources are south, where the demand is low.
- Project of interconnection of isolated grids in the south with the National Interconnected Grid through integration of renewable energy projects.

Final workshop remarks and reflection on future priorities

- While there are existing data to work on, there is a need for more reliable data as well as statistical data from solar and wind.
- There is also a general lack in training related to different tools.

Table 4: **VRE planning/modelling practices and improvement priorities: Algeria**

Country:**ALGERIA**	Is this current practice?	Is this an improvement priority?	How high a priority is it?
	Yes/No	Yes/No	Low/Medium/ High/Very High
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Yes	Yes	High
2. Translating international cost forecasts into local estimates	Yes	No	N/A
3. Using scenarios to explore the influence of VRE cost uncertainty	Yes	Yes	High
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	Yes	Yes	High
2. Using hourly VRE data to represent VRE generation profile	Yes	Yes	High
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	Yes	Yes	High
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Yes	Yes	High
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	Yes	Yes	High
3. Assessing the contribution of storage and demand response to flexibility	No	Yes	Medium
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	Yes	Yes	High
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Yes	Yes	High
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Yes	Yes	High
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	Yes	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	High

Government ministries play a crucial role in adapting power sector planning practices to create robust, long-term energy strategies

BAHRAIN

WORKSHOP PRESENTATION

Energy planning framework/methodology

- The Sustainable Energy Unit is a United Nations Development Programme-supported unit set up to formulate a coherent sustainable energy strategy.
- The National Renewable Energy Action plan is considered to be an important long-term planning benchmark.
- The goals of renewable energy deployment are related to optimisation of gas resources, reducing greenhouse gas emissions, improving economic competitiveness, decreasing peak demand and improving energy security.

Current approach to VRE representation

- The current EWA Master Plan does not represent VRE-specific issues such as capacity credits, flexibility, VRE siting and transmission needs, or system stability.
- The generation characteristics of a 5 MW solar power plant are being transmitted in real time to the distribution control centre.
- The first utility-scale solar PV power plant is currently being constructed.
- A wind resource map has been developed.

Known challenges related to renewables

- Information not provided.

Final workshop remarks and reflection on future priorities

- Information not provided.

VRE planning/modelling practices and improvement priorities

- Information not provided.

EGYPT

WORKSHOP PRESENTATION

Energy planning framework/methodology

- The New and Renewable Energy Authority, under the Ministry of Electricity and Energy, is responsible for planning and exploration of renewable energy resources.
- The Egyptian Electricity Holding Company (EEHC) is responsible for planning and hosts the expansion planning models. It is responsible for sharing data and policies with other companies and reflecting them in their long-term planning.
- The main objectives of the planning are to meet future demand at least cost and with high quality, as well as fuel diversification. Renewable energy and interconnection are part of this strategy.
- Generation expansion planning is data intensive and uses demand forecasts, available resources, constraint, policies and targets, etc.
- A special authority for renewable energy conducts site measurements and provides data to complement the wind/solar atlases and historical meteorological data. The expected generation data from the sites are then used as inputs for the planning process.
- The long-term strategy feeds into the search for investors for the desired projects based on the timeline of the resulting plan.
- Considering the expected new renewable capacity on the system, a consultant has been hired to perform stability studies using PSS/E and to prepare a Network Master Plan.

Current approach to VRE representation

- Egypt has a wind and solar resource atlas.
- New planning concepts have appeared, from time-slice representation to hourly and even sub-hourly resolution of the model to capture correlation between VRE generation and demand, as well as account for the need for flexibility.
- More concepts around flexibility are being introduced, not only in the operations phase but also in the planning phase.
- Capacity credit, site data and transmission grid effects are being accounted for.
- Capacity credits are modelled as a percentage of renewable energy capacity. They are calculated based on the historical record of VRE generation during peak load, with the average taken to estimate the capacity credit. The EGEAS tool has been developed by the Electric Power Research Institute (EPRI). It models hourly generation data (from a resource or a specific site) and is capable of modelling VRE firm capacity as a percentage of installed capacity. It also permits co-operation with MARKAL/TIMES and MESSAGE modelling communities.
- PSR tools have also been acquired, with the most important capability being the stochastic optimisation that permits capture of the uncertainty in VRE generation. The suite of models (OptGen, NetPlan, SDDP, etc.) can capture various scales of investment decision making.

Known challenges related to renewables

- Operational constraints related to system flexibility or access to transmission grid cannot be defined by the EGEAS model.
- Further studies are necessary concerning firm capacity of different VRE sources across the available sites.
- The modelling process for VRE needs to be enhanced.
- Wind resources during bird migration need to be closely analysed. Active turbine management allows the turbines to be stopped only when birds are detected, not during the whole season.
- Operational aspects of VRE integration will continue to be a challenge, and local capacity building is needed.

Final workshop remarks and reflection on future priorities

- The main issue is the need for training of the national planning teams around the topics discussed during the workshop but tailored to the specificities of the Egyptian network.

Table 5: **VRE planning/modelling practices and improvement priorities: Egypt**

Country: **Egypt**	Is this current practice?	Is this an improvement priority?	How high a priority is it?
	Yes/No	Yes/No	Low/Medium/ High/Very High
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Yes	No	N/A
2. Translating international cost forecasts into local estimates	Yes	No	N/A
3. Using scenarios to explore the influence of VRE cost uncertainty	No	Yes	High
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	Yes	Yes	High
2. Using hourly VRE data to represent VRE generation profile	Yes	Yes	High
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	Yes	Yes	Low
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Yes	Yes	High
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	Yes	Yes	High
3. Assessing the contribution of storage and demand response to flexibility	No	Yes	High
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	No	Yes	High
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Yes	Yes	Medium
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	No	Yes	Medium
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	No	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	Medium

IRAQ

WORKSHOP PRESENTATION

Energy planning framework/methodology

- The status of Iraq's electricity system (destruction, governance) does not allow for the kind of long-term planning discussed during the workshop.

Current approach to VRE representation

- IRENA helped to produce a solar atlas, and a wind atlas has also been developed.

Known challenges related to renewables

- Regulation needs to be adapted for utility-scale projects.

Final workshop remarks and reflection on future priorities

- The acquisition and development of tools and accompanying training are the first priorities.
- Another important point is to implement international standards related to renewable energy concerning inputs, parameters and data formats.

The joint workshop in April 2019 brought together more than 50 participants from 10 Arab countries to discuss best practices and identify priorities for improvement

Table 6: **VRE planning/modelling practices and improvement priorities: Iraq**

Country: IRAQ	Is this current practice? Yes/No	Is this an improvement priority? Yes/No	How high a priority is it? Low/Medium/ High/Very High
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Yes	Yes	High
2. Translating international cost forecasts into local estimates	Yes	Yes	Medium
3. Using scenarios to explore the influence of VRE cost uncertainty	No	Yes	Medium
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	No	Yes	High
2. Using hourly VRE data to represent VRE generation profile	Yes	Yes	Medium
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	No	Yes	High
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	No	Yes	Very high
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	No	Yes	Very high
3. Assessing the contribution of storage and demand response to flexibility	No	Yes	High
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	No	Yes	Medium
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	No	Yes	High
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Yes	Yes	High
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	Yes	Yes	Very high
2. Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	High

JORDAN

WORKSHOP PRESENTATION 1 AND 2

Energy planning framework/methodology

- The National Energy Strategy 2025 has a target to reach 20% of generated electricity from renewable energy sources by 2025.
- This strategy was initially launched without much long-term planning with the focus being on reducing fuel use.
- The National Renewable Energy Action Plan (NREAP) has been developed with support from the European Union to expand the strategy to 2030 and potentially to 2050. The final draft of the NREAP is currently under revision.

Current approach to VRE representation

- VRE siting and transmission investment needs determined through the modelling tool PLEXOS.
- Capacity credit and power system stability issues in DIgSILENT PowerFactory and PSS/E.
- Flexibility requirements have already been established in regulations and the grid code. Better data from the grid would support flexibility and the development of a smart grid.
- Most of the solar and wind resources are concentrated in the same area, which introduced stress on the grid.
- VRE capacity expansion is now done side-by-side with the transmission grid expansion. The ministry cannot proceed with the project without co-ordinating with the off-taker, who evaluates transmission congestion constraints. Investments are now being made to absorb further projects.

Known challenges related to renewables

- Important integration of renewables into the national grid creates many grid-related challenges and will require RES curtailment.
- There is a need to introduce flexibility measures for current and future conventional generation facilities to accommodate a higher share of VRE. Plans have been drafted for the development of pumped storage and battery energy storage.
- The search for new energy markets to export the excess power generation via interconnection with neighbouring countries such as Saudi Arabia, Iraq and the State of Palestine.

Final workshop remarks and reflection on future priorities

- There are uncertainties surrounding developments in technology and how they will impact the future system.
- Another important point is institutional co ordination in long-term planning.

Table 7: **VRE planning/modelling practices and improvement priorities: Jordan**

Country: **JORDAN**		Is this current practice?	Is this an improvement priority?	How high a priority is it?
		Yes/No	Yes/No	Low/Medium/ High/Very High
Costs:				
1.	Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Yes	Yes	Medium
2.	Translating international cost forecasts into local estimates	Yes	Yes	Medium
3.	Using scenarios to explore the influence of VRE cost uncertainty	No	Yes	High
Generation adequacy/Capacity credit:				
1.	Considering the contribution of VRE to firm capacity	No	Yes	High
2.	Using hourly VRE data to represent VRE generation profile	Yes	Yes	Medium
3.	Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	No	Yes	High
Flexibility:				
1.	Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	No	Yes	Very high
2.	For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	No	Yes	Very high
3.	Assessing the contribution of storage and demand response to flexibility	Yes	Yes	High
Geo-spatial resolution/VRE zoning and siting:				
1.	Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	Yes	Yes	Medium
2.	Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Yes	Yes	Medium
3.	Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Yes	Yes	High
Stability:				
1.	Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	Yes	Yes	High
2.	Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	High

LEBANON

WORKSHOP PRESENTATION 1 AND 2

Energy planning framework/methodology

- Long-term planning is carried out by the Ministry of Energy and Water in collaboration with Electricité du Liban (EDL). The objectives are set by the government through a policy paper. The Lebanese Center for Energy Conservation (LCEC) focuses on long-term energy planning for renewable energy.
- The goals of renewable energy deployment are related to optimising gas resources, reducing greenhouse gas emissions, improving economic competitiveness, decreasing peak demand and improving energy security.

Current approach to VRE representation

- For the medium-term, the evolution of VRE is defined by the NREAP (2016-2020), which considers current generation and demand, yearly increase in energy demand, capacity factors of RES, potential of RES, and the levelised cost of energy (LCOE) as per international trends.
- The master plan cost distribution is based on a cost/benefit analysis scenario. Only the 200 MW wind farm is mentioned in the transmission plan proposed by EDL.

Known challenges related to renewables

- An important increase of VRE share is expected to bring stability issues in the relatively small Lebanese system. As part of the solution, EDL recommends increasing the conventional thermal capacity and the level of interconnection with other systems.
- The introduction of VRE will likely change the operation of existing and future combined cycle plants, which are currently used on base load.
- Another challenge is to acquire sufficient knowledge of both demand (real demand profiles instead of raw data and assumptions, and long-term demand projection

Final workshop remarks and reflection on future priorities

- Not in attendance.

Table 8: **VRE planning/modelling practices and improvement priorities: Lebanon**

Country: LEBANON	**Is this current practice?**	**Is this an improvement priority?**	**How high a priority is it?**
	Yes/No	**Yes/No**	**Low/Medium/ High/Very High**
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Yes	Yes	High
2. Translating international cost forecasts into local estimates	Yes	Yes	High
3. Using scenarios to explore the influence of VRE cost uncertainty	No	Yes	Medium
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	Yes	Yes	High
2. Using hourly VRE data to represent VRE generation profile	No	Yes	Medium
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	No	No	NA
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Yes	Yes	High
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	No	Yes	Medium
3. Assessing the contribution of storage and demand response to flexibility	Yes	Yes	High
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	No	Yes	High
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	No	Yes	Medium
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Yes	Yes	High
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	Yes	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	High

LIBYA

WORKSHOP PRESENTATION

Energy planning framework/methodology

- General Electricity Company of Libya (GECOL) and its national utility are the key players in electricity system investments.
- The strategic plan for renewable energy sets a goal of 22% renewable energy penetration by 2030 (up from nearly non-existent in 2018). This would be done mainly through solar PV, with an addition of about 1 GW every two years.
- The plan, developed in collaboration with the University of Hamburg and supported by the World Bank, resulted in a full map with suggested locations for wind, CSP and solar PV stations based on a linear optimisation programme, with hourly resolution and multiple scenario analysis.

Current approach to VRE representation

- There exists a wind and solar atlas for the country. Moreover, there are some 26 wind and 30 solar meteorological stations over the country, whose hourly timeseries are introduced into the planning software.

Known challenges related to renewables

- Challenges related to transmission grid coverage and performance, although the current grid coverage could allow for more renewable energy connections.
- Reflecting costs in the tariffs.

Final workshop remarks and reflection on future priorities

- Experiencing issues with data availability and their quality. Therefore, obtaining reliable resource and generation data is a priority, as well as the transfer of data between different institutes.

Table 9: **VRE planning/modelling practices and improvement priorities: Libya**

Country: LIBYA	Is this current practice? Yes/No	Is this an improvement priority? Yes/No	How high a priority is it? Low/Medium/ High/Very High
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Yes	Yes	Low
2. Translating international cost forecasts into local estimates	No	Yes	Medium
3. Using scenarios to explore the influence of VRE cost uncertainty	No	Yes	Medium
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	Yes	Yes	High
2. Using hourly VRE data to represent VRE generation profile	Yes	Yes	High
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	No	Yes	High
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Yes	Yes	High
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	Yes	Yes	High
3. Assessing the contribution of storage and demand response to flexibility	Yes	Yes	High
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	No	Yes	Low
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Yes	Yes	High
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Yes	Yes	High
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	Yes	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	High

MOROCCO

Energy planning framework/methodology

- Long-term energy planning (30 years) is carried out by the Ministry of Energy and defines the evolution of the energy mix and investment needs. Generation (30 years) and transmission (10–20 years) are carried out by the Office National de l'Electricité et de l'Eau Potable (ONEE).
- Morocco has long experience with utility-scale VRE projects, with several solar and wind power plants operational for some years. To manage the increasing penetration rate and to be able to reach its objective of supplying 52% of its energy needs from renewable energy, recent improvements in planning generation have been carried out, focused on modelling through the purchase of new tools (OPTGEN for expansion, SDDP & NCP for operation) and a regional distribution of renewable energy profiles.

Current approach to VRE representation

- The new simulation tools allow more adequate representation of the impact of VRE, notably taking into account the flexibility of the system through hourly commitments (start-ups, ramping, continuous minimum up/down, etc.) and storage.
- The costs of renewables technologies are based on the publications of the International Energy Agency (IEA) and benchmarks among manufacturers.

Known challenges related to renewables

- Datasets of generation profiles for each technology (wind, solar) for each site.
- Evolution of the cost for each renewable technology in the long-term.
- Enhancing flexibility systems based on new storage technologies (mainly batteries). The issue is related to their economic competitiveness regarding conventional flexible power plants such as CCGT/OCGT (combined cycle gas turbine/open cycle gas turbine) and hydro-pumped storage.

Final workshop remarks and reflection on future priorities

- Not in attendance.

Table 10: **VRE planning/modelling practices and improvement priorities: Morocco**

Country: MOROCCO	Is this current practice?	Is this an improvement priority?	How high a priority is it?
	Yes/No	Yes/No	Low/Medium/ High/Very High
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Partially Yes	Yes	Medium
2. Translating international cost forecasts into local estimates	Yes	No	NA
3. Using scenarios to explore the influence of VRE cost uncertainty	Yes, as sensitivity analysis	Yes	Medium to High
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	Yes	No	NA
2. Using hourly VRE data to represent VRE generation profile	Yes	No	NA
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	Yes	No	NA
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Yes	No	NA
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	Yes	No	NA
3. Assessing the contribution of storage and demand response to flexibility	Yes	No	NA
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	Yes	No	NA
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Yes	No	NA
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Yes, in iterative process	Yes	Medium to High
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	Yes	No	NA
2. Ensuring stability needs for VRE are reflected in grid codes	Partially Yes	Yes	High

OMAN

Energy planning framework/methodology

- The long-term energy mix is determined by the Ministry of Oil and Gas (MOG). Its optimisation is driven by the security of supply and based on the defined target and policy.
- Oman Power & Water Procurement Company (OPWP) carries out the demand forecast study and the generation capacity expansion planning. This analysis is updated every year and has a planning horizon of seven years.
- Oman Electricity Transmission Company (OETC) annually updates the transmission planning study with a five year horizon.

Current approach to VRE representation

- The energy model used for setting renewable energy targets is based on the sector's expected growth and demand requirement. The model is updated and reviewed regularly.
- Oman's Grid Master Plan states that 15% of renewable power generated can be injected into the grid. Another key objective is the integration of the isolated systems of Oman thanks to transmission networks extension and reinforcement. The increase in system size is expected to allow the integration of more VRE installed capacity
- Studies have shown that large-scale projects (solar) are competitive compared to conventional generation in Oman.

Known challenges related to renewables

- One of the main challenges is the co-ordination of future VRE and conventional projects allowing the maintenance of a sufficient security of supply.
- Another key subject for future projects is the cost of energy and the duration of the contracting period.

Final workshop remarks and reflection on future priorities

- Not in attendance.

Table 11: **VRE planning/modelling practices and improvement priorities: Oman**

Country: OMAN	Is this current practice?	Is this an improvement priority?	How high a priority is it?
	Yes/No	Yes/No	Low/Medium/ High/Very High
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	No	Yes	High
2. Translating international cost forecasts into local estimates	Yes	Yes	Medium
3. Using scenarios to explore the influence of VRE cost uncertainty	No	Yes	High
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	No	Yes	High
2. Using hourly VRE data to represent VRE generation profile	Yes	Yes	High
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	No	No	NA
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Yes	No	NA
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	No	No	NA
3. Assessing the contribution of storage and demand response to flexibility	No	Yes	High
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	No	Yes	Medium
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Yes	Yes	Medium
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Yes	Yes	High
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	Yes	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	Medium

STATE OF PALESTINE

WORKSHOP PRESENTATION

Energy planning framework/methodology

- A strategy was developed with a consulting company in 2012 for the 2022 horizon. This is currently being updated because the implementation showed that the reality was different than expected.
- The implementation of Nationally Determined Contributions is assessed alongside long-term planning.
- Energy security and independence are key objectives of long-term planning.
- The private sector is important as it is the implementing party in the State of Palestine.
- Improving energy efficiency is also a major focus.
- A national team has been formed to restructure the energy sector in the State of Palestine with a five-year strategy.
- The main decision maker is the Palestinian Energy and Natural Resources Authority (PENRA), which is the policy maker and head of planning.

Current approach to VRE representation

- A solar and wind atlas was drafted in 2014.

Known challenges related to renewables

- The planning of renewable projects is not centralised and includes various institutions.
- Demand growth is the key driver as well as grid needs.
- Forecasting demand and increasing interconnections are challenges.
- The relationship with Israel has an impact on land availability and authorisations.
- Flexibility of the generation system should be increased by diversifying the mix and interconnection with other systems.

Final workshop remarks and reflection on future priorities

- The main issue that remains is the political barrier. Beyond this, however, capacity building and data availability are important areas for improvement. Obtaining the necessary financial resources is another problematic point. Table 12 shows the VRE planning/modelling practices and improvement priorities.

Table 12: **VRE planning/modelling practices and improvement priorities: State of Palestine**

Country: STATE OF PALESTINE	**Is this current practice?**	**Is this an improvement priority?**	**How high a priority is it?**
	Yes/No	**Yes/No**	**Low/Medium/ High/Very High**
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Yes	Yes	High
2. Translating international cost forecasts into local estimates	Yes	Yes	Low
3. Using scenarios to explore the influence of VRE cost uncertainty	No	Yes	High
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	No	Yes	Medium
2. Using hourly VRE data to represent VRE generation profile	No	Yes	Medium
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	No	No	NA
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Yes	Yes	High
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	No	Yes	Low
3. Assessing the contribution of storage and demand response to flexibility	No	No	NA
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	No	Yes	Medium
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Yes	Yes	High
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Yes	Yes	High
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	No	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	High

QATAR

WORKSHOP PRESENTATION

Energy planning framework/methodology

- Energy planning is governed by the Ministry of Energy Affairs, which is responsible for long-term planning together with the utility. The utility performs demand forecasts, the capacity expansion plan, transmission and distribution, and a five-year business plan.
- The ten-year demand forecast is updated annually and used as an input for the five-year business plan, which is also updated annually. The demand forecast is also used as an input for the 25-year long term optimisation plan, which is updated every five years.
- The main objectives of the long-term planning are reliability, sustainability and cost reduction.
- Private companies are responsible for operation. The relationship with the utility is governed by the ministry.
- Electricity and water are based on a single buyer model.
- The Ministry of the Environment is responsible for site allocation and corridor approval.

Current approach to VRE representation

- As all generating units are CCGT, flexibility is not an important issue. There are some must-run cogeneration units that might cause an issue in the wintertime, however, when the load is low. Since the existing plants are independent power producers, there is little transparency about their operation. In addition, there are time-of-use tariffs for some industrial and bulk consumers, which increases flexibility.
- VREs considered are mainly solar PV, as CSP and wind are not yet present.
- The capacity credit is assumed depending on penetration levels. The difference between the maximum of both load duration curve and residual load duration curve is used as a capacity credit.
- The main goal is fuel saving.
- Weather stations have been installed, and there is collaboration with academia to improve solar data (both on resources and generation).
- The first PV project is expected to provide a lot of knowledge and experience.
- VRE siting is not fully integrated in the long-term planning process, but whenever a capacity expansion is planned the TSO is consulted to rank the potential sites based on several relevant criteria.

Known challenges related to renewables

- There is little experience with intermittent operation. This raises questions about must-run units and curtailments. These challenges will decrease as desalination technologies emerge, however.
- Uncertainties concerning policy exist. There is today no feed-in-tariff at the distribution level.
- There is a lack of historical solar data.
- The grid code does not include integration guidelines for renewable energy.

Final workshop remarks and reflection on future priorities

- Information not provided.

Table 13: **VRE planning/modelling practices and improvement priorities: Qatar**

Country: QATAR	**Is this current practice?**	**Is this an improvement priority?**	**How high a priority is it?**
	Yes/No	**Yes/No**	**Low/Medium/ High/Very High**
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Yes	Yes	Medium
2. Translating international cost forecasts into local estimates	Yes	Yes	Medium
3. Using scenarios to explore the influence of VRE cost uncertainty	Yes	Yes	Medium
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	Yes	Yes	High
2. Using hourly VRE data to represent VRE generation profile	Yes	Yes	High
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	Yes	Yes	High
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	No	Yes	High
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	Yes	Yes	High
3. Assessing the contribution of storage and demand response to flexibility	No	Yes	Medium
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	Partially	Yes	Medium
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Yes	Yes	High
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Partially	Yes	Medium
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	Yes	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	High

SAUDI ARABIA

WORKSHOP PRESENTATION

Energy planning framework/methodology

- The Power Sector Integration Committee is where all stakeholders co ordinate all planning efforts.
- The planning is interested not only in cost optimisation but also in socio-economic spillovers.
- Whereas previously the approach was in silos, there has been a move towards a more integrated approach with an inclusion of spatial elements.
- Over the course of time, the ministry has built a portfolio of tools to address different optimisation problems. For demand, a combination of methods and techniques are used to perform forecasts, many of which have been developed in-house by statisticians.
- Planning is an iterative exercise due to new information always emerging.
- The concept of capacity credit is applied by initially performing an optimisation without capacity credits. The model is then re-run with the use of capacity credits for the VRE sources to evaluate the reduction in the investment need for thermal generation. For the representation of demand, full-hourly resolution was found to be redundant. The statistical technique of K-means clustering provides representative samples of data (for the summer, the winter and the transition period), which reduces the computational needs. Flexibility is important when dealing either with forecasting errors or in case of failure.
- Desalination units are must-run units during winter and summer, which poses flexibility issues. However, aluminium smelters could provide flexibility by curtailing their demand to support the operation of the grid.
- Interconnection is an option worth exploring for flexibility, as there have already been instances in which neighbouring countries from the Gulf Cooperation Council (GCC) have covered for failures.

Current approach to VRE representation

- The Saudi system is characterised by a strong link between water and power production (desalination) and must-run constraints on numerous thermal power plants.
- A variety of computational tools are used to better represent capacity credits. Both static and dynamic methods are used. Generation adequacy assessment is performed to meet a 13% margin.
- Over 50 solar and wind resource monitoring stations are distributed in the country, and the System Advisory Model from the National Renewable Energy Laboratory (NREL) is used to better understand the generation profile of solar power and how VRE matches demand.
- The results are then handed to the utilities, which perform more detailed analysis of the network and test locations for future plants. The latest long-term planning study foresees a 30% renewable energy penetration rate in 2030. The development of renewable energy is only based on least cost optimisation.
- Assumptions are made on the evolution of prices (investment cost, fuels, etc.), and sensitivity analysis is carried out on different key factors (fuel price, gas availability, technologies cost, etc.).
- The long-term capacity expansion plan includes a simplified representation of the transmission system that is used to explore where there is a need for more infrastructure and where the best VRE sites are.
- Once the targets and energy mix emerge from the planning exercises, they are used in technical network modelling to test for contingencies. New projects are analysed in GIS to evaluate the cost of the interconnection and transport losses.

Known challenges related to renewables

- Difficulties with forecasting future costs of renewable energy. Other uncertainties include performance, peak demand and developments in storage technologies.
- Some challenges have appeared concerning resolution, particularly in terms of commercially available models and their alignment with other tools. Earlier models did not account for hourly resolution planning.
- Capacity credits estimation can be challenging.

- Highlighted in the country survey, other important challenges for system planning with a high share of VRE are assessing the role and impact of the different types of storage (power to X, pumped hydro, batteries, etc.) and developing robust methodologies for multi-criteria assessment (i.e., balancing jobs, gross domestic product [GDP], oil saved and system cost).
- Due to the stochastic nature of VRE, forecasting of renewable power generation is an important topic for improvement.

Final workshop remarks and reflection on future priorities

- While the planning is centralised at the ministry level, the Power System Integration Committee shares data very well. The process of building a data warehouse to streamline the process is currently under way.
- The central issue is human resource development. There is a need for qualified personnel in the areas of economy, computation and data science.

Table 14: **VRE planning/modelling practices and improvement priorities: Saudi Arabia**

Country: SAUDI ARABIA	Is this current practice?	Is this an improvement priority?	How high a priority is it?
	Yes/No	Yes/No	Low/Medium/ High/Very High
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	Yes	Yes	Medium
2. Translating international cost forecasts into local estimates	Yes	Yes	Medium
3. Using scenarios to explore the influence of VRE cost uncertainty	Yes	Yes	Medium
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	Yes	Yes	Medium
2. Using hourly VRE data to represent VRE generation profile	Yes	No	NA
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	Yes	No	NA
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Yes	Yes	High
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	Yes	Yes	High
3. Assessing the contribution of storage and demand response to flexibility	Yes	Yes	Medium
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	Yes	No	NA
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Yes	No	NA
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Yes	No	NA
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	Yes	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	Yes	Yes	High

SOMALIA

WORKSHOP PRESENTATION

Energy planning framework/methodology

- After the collapse of government in 1991, private companies stepped in to provide power. Currently, the country has only urban grids without a transmission network.
- The energy strategy, which has been supported by the World Bank and executed by a British consulting company, involved performing city-by-city planning of demand and supply due to the lack of a transmission grid.
- Given the political and social situation, the planning methodology is not expected to be improved.

Current approach to VRE representation

- There is a solar and wind atlas for the country.

Known challenges related to renewables

- Main barriers are related to the building of a national transmission grid and obtaining data from the private companies.

Final workshop remarks and reflection on future priorities

- Primary issues are institutional, political and managerial. Secondary issues relate to a lack of financial resources and investments.
- There is a need for training and capacity building, acquiring the right tools, and getting necessary information.

Table 15: **VRE planning/modelling practices and improvement priorities: Somalia**

Country: SOMALIA	**Is this current practice?**	**Is this an improvement priority?**	**How high a priority is it?**
	Yes/No	**Yes/No**	**Low/Medium/ High/Very High**
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	No	Yes	High
2. Translating international cost forecasts into local estimates	No	Yes	High
3. Using scenarios to explore the influence of VRE cost uncertainty	No	Yes	High
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	No	Yes	High
2. Using hourly VRE data to represent VRE generation profile	No	Yes	High
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	No	Yes	High
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	No	Yes	High
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	No	Yes	High
3. Assessing the contribution of storage and demand response to flexibility	No	Yes	Medium
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	No	Yes	High
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	No	Yes	High
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	No	Yes	High
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	No	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	No	Yes	High

The opportunities for regional dialogue and collaboration are significant

SUDAN

WORKSHOP PRESENTATION

Energy planning framework/methodology

- The main objectives of long-term planning are to interconnect the different isolated systems to the main grid and to provide the majority of the population with access to electricity.
- An international consulting company carried out a national study defining the development objectives and required investment in the medium term (2012-2016) and the long term (2012-2031).
- These master plans include a renewable energy objective considering economic and technical limitations. The goals are diversification of energy sources to increase security of supply and reduce dependency, and the valorisation of hydro potential.

Current approach to VRE representation

- Information not provided.

Known challenges related to renewables

- Information not provided.

Final workshop remarks and reflection on future priorities

- Not in attendance.

VRE planning/modelling practices and improvement priorities

- Information not provided.

YEMEN

Energy planning framework/methodology

- Information not provided.

Current approach to VRE representation

- Information not provided.

Known challenges related to renewables

- The present war crisis in Yemen and local currency instability make the development of a national policy related to renewable energy impossible.
- There is an absence of an official entity to perform the standardisation process, which is an important gap facing renewable energy's generation capacity expansion planning.
- The unstable security situation in the country prevents the establishment of expansion in renewable energy projects.
- The country is facing a lack of international support.

Final workshop remarks and reflection on future priorities

- Not in attendance.

Improved methodologies can better reflect the variability of solar and wind energy

Table 16: **VRE planning/modelling practices and improvement priorities: Yemen**

Country: YEMEN	**Is this current practice?**	**Is this an improvement priority?**	**How high a priority is it?**
	Yes/No	**Yes/No**	**Low/Medium/ High/Very High**
Costs:			
1. Having a clear view of which cost components (e.g. finance, labour, etc.) will drive future wind and solar cost reductions	No	Yes	High
2. Translating international cost forecasts into local estimates	No	Yes	High
3. Using scenarios to explore the influence of VRE cost uncertainty	No	Yes	High
Generation adequacy/Capacity credit:			
1. Considering the contribution of VRE to firm capacity	No	Yes	High
2. Using hourly VRE data to represent VRE generation profile	No	Yes	High
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	No	Yes	High
Flexibility:			
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	No	Yes	High
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	No	Yes	High
3. Assessing the contribution of storage and demand response to flexibility	No	Yes	High
Geo-spatial resolution/VRE zoning and siting:			
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	No	Yes	High
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	No	Yes	High
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	No	Yes	High
Stability:			
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feedback the costs of stability solutions	No	Yes	High
2. Ensuring stability needs for VRE are reflected in grid codes	No	Yes	High

3. CURRENT APPROACHES TO VRE REPRESENTATION IN LONG-TERM CAPACITY EXPANSION PLANNING

The sections that follow are based on national surveys and group discussions from the workshop. The topics presented here are structured in line with the workshop agenda, which can be found in Annex 1.

Expert input presentations to the group discussions can be found at this link:
www.irena.org/ArabVRE

REPRESENTING VRE INVESTMENT COSTS

Table 17 summarises country survey responses to the question, "How are future trends or forecasts of renewable generation technology costs represented in your country's long-term capacity expansion planning?"

Table 17: **Country survey responses — future cost trends**

Country	Represented in long-term capacity expansion?		Description of approach
	Yes	No	
Algeria	X		Based on international market technology costs. In Algeria, there has been only one experience of building renewable energy power plants (354 MW out of which 344 MW in PV and 10 MW in wind).
Bahrain		X	Work in progress.
Egypt	X		Usually forecasted considering the studies performed by the international organisations (IEA, EIA, IRENA...etc.) as well as considering the costs of the under-construction or future projects that have received financing offers.
Iraq	X		
Jordan	X		Future trends of the renewable generation technology costs forecasted via the available international practices.
Lebanon*	X		Based on international trends.
Libya		X	N/A
Morocco*	X		The costs of renewables technologies are based on the publications of the IEA and benchmarking among manufacturers.
Oman*	X		Decreasing by 5% yearly (on average) over five years.
State of Palestine	X		Considered competitive for large-scale projects (solar).
Qatar		X	N/A
Saudi Arabia	X		Adopted from renewable technology road map studies published by international agencies in combination with in-house forecasting models.
Somalia		X	
Sudan*		X	
Yemen*		X	Because of the present war crisis in Yemen and local currency instability, future trends of renewable generation technology costs cannot be forecasted.

Key points from workshop discussion

- Many member countries use forecasts from international institutions such as the IEA, IRENA, etc. International cost levels can vary quite a lot from local ones, however. Therefore, already constructed projects can help in estimating costs.
- Uncertainty about the evolution of costs is sometimes taken into account with sensitivity analysis.
- Business models have been adapted from feed-in-tariffs to bidding programmes – this can affect cost projections.
- Questions remain surrounding the future costs of energy storage.

PRESENTING GENERATION ADEQUACY (I.E., CAPACITY CREDIT OF VRE)

Table 18 summarises country survey responses to the question, "How is the capacity credit of VRE represented in your country's long-term capacity expansion planning?"

Table 18: **Country survey responses — capacity credit**

Country	Represented in long-term capacity expansion?		Description of approach
	Yes	No	
Algeria	X		Based on renewable energy penetration.
Bahrain		X	N/A
Egypt	X		As a percentage of the renewable installed capacity. This percentage will be considered during the evaluation of the system firm capacity and the calculation of the reliability indices.
Iraq		X	N/A
Jordan	X		In DIgSILENT PowerFactory.
Lebanon*		X	N/A
Libya	X		Data from meteorological stations is used to provide hourly time series to SAM and PV Syst software. The generation data is then used in the planning models to obtain a capacity credit.
Morocco*	X		Dedicated reliability assessment is carried out.
Oman*		X	N/A
State of Palestine		X	N/A
Qatar	X		Estimated based on the penetration level. The difference between the maximum of both load duration curve and residual load duration curve is used as a capacity credit.
Saudi Arabia	X		A variety of computational tools are used to better represent capacity credits. Both static and dynamic methods are used.
Somalia		X	N/A
Sudan*		X	N/A
Yemen*		X	N/A

Key points from workshop discussion

- The concept of capacity credit associated to VRE is used in many of the countries, explicitly or implicitly, by using hourly profiles for the demand and the availability of the VRE resources. Probabilistic approaches are also increasingly used for long-term planning in some of the surveyed countries.
- According to the countries' experience, the shape of the daily demand has a major impact on the capacity credit of VRE, i.e., their contribution to the adequacy of the system. For Saudi Arabia and Qatar, the capacity credit from solar decreases – from 50% with low penetration, to between 10% and 15% with high penetration. For Egypt and Libya, presenting a peak demand in the evening, the considered capacity credit for PV is 0.
- For wind, capacity is considered to be between 10% and 20% of the installed capacity in Egypt and 20% in Libya.
- Storage can significantly improve the capacity credits of VRE and should be further considered. Solutions such as battery, electric vehicle and pumped hydro are currently being studied by different countries.

REPRESENTING SYSTEM FLEXIBILITY

Table 19 summarises country survey responses to the question, "How is energy system flexibility represented in your country's long-term capacity expansion planning?"

Table 19: **Country survey responses — flexibility**

Country	Represented in long-term capacity expansion?		Description of approach
	Yes	No	
Algeria	X		Based on flexibility potential and network availability.
Bahrain		X	N/A
Egypt	X		By providing the detailed operational limits for generation units (ramp rates, minimum generation levels, minimum up/down times, maximum number of start-ups/shutdowns and shutdown costs).
Iraq		X	N/A
Jordan		X	N/A
Lebanon*		X	N/A
Libya			N/A
Morocco*	X		Hourly unit commitment taking into consideration dynamic operational constraints (start-ups, ramping, continuous minimum up/down, etc.).
Oman*	X		The target can be updated and the model can be revised.
State of Palestine		X	N/A
Qatar	X		N/A
Saudi Arabia	X		A combination of minimum reserve and LOLE/P.*
Somalia		X	N/A
Sudan*		X	N/A
Yemen*		X	N/A

Key points from workshop discussion

- Some of the countries consider the constraints on the dispatch of units to follow the net demand (evolution of load + VRE) on the basis of an hourly analysis.
- At low VRE penetration rates, system flexibility is ensured by having adequate conventional units always connected to the grid. With increasing penetration rates, the operational constraints of desalination and cogeneration plants, as well as independent power producers with non-flexible contracts, can limit the possible response of the system to the variability of the system and become challenging for the operation of the grid.
- Flexibility requirements for new units (and possibly large consumers) should be considered in grid code considering the special nature of VRE.
- One important source of flexibility considered by most member countries is interconnection with other systems.

REPRESENTING VRE SITING AND ZONING EVALUATIONS

Table 20 summarises country survey responses to the question, "How is VRE siting and related transmission investment represented in your country's long-term capacity expansion planning?"

Table 20: **Country survey responses — VRE siting and related transmission investment**

Country	Represented in long-term capacity expansion?		Description of approach
	Yes	No	
Algeria		X	N/A
Bahrain		X	N/A
Egypt	X		Renewable siting is reflected through providing hourly generation data to reflect the diurnal and seasonal characteristics of the available renewable resources at the site as well as the correlation with the system demand. The connection of the variable renewable energy site to the transmission grid and the related technical factors are also reflected in the optimisation process.
Iraq		X	N/A
Jordan	X		Represented through PLEXOS.
Lebanon*		X	N/A
Libya			N/A
Morocco*	X		Determination of optimal hosting capacity from economic point of view as well as from grid integration.
Oman*	X		Oman's Grid Master Plan has presented that 15% of renewable energy can be injected in the grid. Other efforts are ongoing for the integration of transmission networks in Oman (a strategic project).
State of Palestine		X	N/A
Qatar	X		N/A
Saudi Arabia	X		Through a combination of GIS analysis and power system simulation of the full network.
Somalia		X	N/A
Sudan*		X	N/A
Yemen*		X	N/A

Key points from workshop discussion

- Application of simplified models of the grid at generation planning level is used among the countries, especially for countries that have clearly separated operating areas, such as Saudi Arabia.
- Using the development of a large-scale VRE plant in a remote area to interconnect two previously separated systems is being studied, notably by Saudi Arabia and Algeria.
- For many of the countries, the development of a VRE project is preceded by a detailed grid integration study, which can lead to a revision of the siting of the plant based on the hosting capacity of the different possible substations.

REPRESENTING STABILITY-RELATED OPERATIONAL CONSTRAINTS

Table 21 summarises country survey responses to the question, "How are stability-related operational constraints represented in your country's long-term capacity expansion planning?"

Table 21: **Country survey responses — stability related operational constraints**

Country	Represented in long-term capacity expansion?		Description of approach
	Yes	No	
Algeria		X	N/A
Bahrain		X	N/A
Egypt	X		Not directly represented in the model but can be represented through the combination of the NetPlan model and the more detailed PSS/E model.
Iraq		X	N/A
Jordan	X		Represented in DIgSILENT PowerFactory.
Lebanon*		X	N/A
Libya			N/A
Morocco*	X		Carrying dynamic/transient simulations of the power system.
Oman*		X	N/A
State of Palestine		X	N/A
Qatar		X	Will be identified during the operation of first project (AL-KHARSAA) and will be considered in the new updated Grid Code.
Saudi Arabia	X		Static and dynamic stability are analysed with commercial (e.g., PSSE) and in-house power system simulation models.
Somalia		X	N/A
Sudan*		X	N/A
Yemen*		X	N/A

Key points from workshop discussion

- These issues must be integrated into the grid code at an early stage to avoid issues with higher levels of integration.
- In Jordan, developers need to submit a grid impact study including dynamic issues that is reviewed by the authorities. This has resulted in the developers making the necessary investments to reduce variation at very short time scales (milliseconds).
- One way to address the stability issue is by developing an ancillary services market, such as in the European grids. Jordan and Morocco apply constraints to VRE producers on ramp rates.

4. MATCHING MATRIX: COUNTRY PRACTICES AND IMPROVEMENT PRIORITIES

Table 22 summarises current practices and improvement priorities identified by countries attending the workshop, related to VRE representation in long-term planning/modelling. The table was compiled from country presentations, pre-workshop surveys and group discussions.

Improvement priorities for system operators across the region relate to costs, generation adequacy, flexibility, stability, and VRE zoning and siting

Table 22: **Current practices and improvement priorities**

	Algeria		Bahrain		Egypt		Iraq		Jordan		Lebanon*		Libya		Morocco*	
Costs:	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?
1. Having a clear view of which cost components (e.g. finance, labor, etc.) will drive future wind and solar cost reductions	Y	1			Y	N	Y	1	Y	0.5	Y	1	Y	0	Y	0.5
2. Translating international cost forecasts into local estimates	Y	N			Y	N	Y	0.5	Y	0.5	Y	1		0.5	Y	N
3. Using scenarios to explore the influence of VRE cost uncertainty	Y	1				1		0.5		1		0.5		0.5	Y	1
Generation adequacy/ capacity credit:																
1. Considering the contribution of VRE to firm capacity	Y	1			Y	1		1		1	Y	1	Y	1	Y	N
2. Using hourly VRE data to represent VRE generation profile	Y	1			Y	1	Y	0.5	Y	0.5		0.5	Y	1	Y	N
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE	Y	1			Y	0		1		1		N		1	Y	N
Flexibility:																
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Y	1			Y	1		1.5		1.5		1	Y	1	Y	N
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation	Y	1			Y	1		1.5		1.5		0.5	Y	1	Y	N
3. Assessing the contribution of storage and demand response to flexibility		0.5				1		1	Y	1	Y	1	Y	1	Y	N
Geo-spatial resolution/ VRE zoning and siting:																
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions	Y	1				1		0.5	Y	0.5		1		0.5	Y	N
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Y	1			Y	0.5		1	Y	0.5		0.5	Y	1	Y	N
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Y	1				0.5	Y	1	Y	1	Y	1	Y	1	Y	1
Stability:																
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feed back the costs of stability solutions	Y	1				1	Y	1.5	Y	1	Y	1	Y	1	Y	N
2. Ensuring stability needs for VRE are reflected in grid codes	Y	1			Y	0.5	Y	1	Y	1	Y	1	Y	1	Y	1

Current: Current practice?
Priority: Improvement proirity

Low | Medium | High | V. High

Table 22 (continued)

	Oman*		Palestine		Qatar		Saudi Arabia		Somalia		Sudan*		Yemen+		# of countries	
Costs:	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?	Current?	Priority?
1. Having a clear view of which cost components (e.g. finance, labor, etc.) will drive future wind and solar cost reductions		1	Y	1	Y	0.5	Y	0.5		1				1	10	9
2. Translating international cost forecasts into local estimates	Y	0.5	Y	0	Y	0.5	Y	0.5		1				1	10	6
3. Using scenarios to explore the influence of VRE cost uncertainty		1		1	Y	0.5	Y	0.5		1				1	4	10.5
Generation adequacy/ capacity credit:																
1. Considering the contribution of VRE to firm capacity		1		0.5	Y	1	Y	0.5		1				1	7	11
2. Using hourly VRE data to represent VRE generation profile	Y	1		0.5	Y	1	Y	N		1				1	9	9
3. Performing probabilistic analysis (e.g. Monte Carlo simulation) of available system generation with and without VRE		N		N	Y	1	Y	N		1				1	5	7
Flexibility:																
1. Validating that your long-term capacity mix meets short-term flexibility requirements (e.g. ramping), and assessing flexibility costs (e.g. cycling costs, efficiency losses, etc.)	Y	N	Y	1		1	Y	1		1				1	7	12
2. For more advanced flexibility analysis at higher VRE penetration levels, hourly representation		N		0.5	Y	1	Y	1		1				1	6	11
3. Assessing the contribution of storage and demand response to flexibility		1		N		0.5	Y	0.5		0.5				1	5	9
Geo-spatial resolution/ VRE zoning and siting:																
1. Including multiple nodes in your models to capture VRE resource quality and generation profiles in different regions		0.5		0.5	Y	0.5	Y	N		1				1	5	8
2. Adding site-specific transmission investment costs for VRE projects or zones before they are chosen for investment	Y	0.5	Y	1	Y	1	Y	N		1				1	9	9
3. Co-optimising generation and transmission planning (i.e. fully integrating both planning processes)	Y	1	Y	1	Y	0.5	Y	N		1				1	10	11
Stability:																
1. Performing grid integration studies on long-term VRE capacity scenarios, to assess and feed back the costs of stability solutions	Y	1		1	Y	1	Y	1		1				1	9	12.5
2. Ensuring stability needs for VRE are reflected in grid codes	Y	0.5	Y	1	Y	1	Y	1		1				1	11	12

Current: Current practice?
Priority: Improvement proirity

Low | Medium | High | V. High

5. SYNTHESIS OF CURRENT SITUATION AND NEXT STEPS

Table 23 summarises the current situation regarding VRE integration into long-term planning. Countries presenting a similar level of practices for long-term renewable energy planning are grouped in tiers. For each of these tiers, recommendations are made for next steps to improve the current practices.

Building on the outcomes of the workshop and the recommendations put forth in the report, IRENA, in collaboration with its partners, has envisioned follow-up workshops as part of its upcoming work programme for the years 2020-2021. The workshops will be tailored to the similarities and issues identified in planning practices across the region, defined in the following sub-regional groupings: North Africa and the Middle East, respectively.

Table 23: **Countries with similar level of practices in long-term renewable energy planning**

Tier	Practices for integration of VRE into long-term planning	Countries	Proposal for next steps	Examples to keep moving forward
1	Advanced practices already in place. Availability of adapted simulation tools and methodologies, trained staff to carry out the required tasks on a regular basis.	Algeria, Morocco, Qatar, Saudi Arabia	Large-scale renewable energy integration has begun or will begin. Implementation of feedback loops from local operational experience to planning procedures (capacity building, improvement of tools, etc.). Incentives/market for ancillary services required to integrate large shares of renewable energy.	**Germany** for renewable energy-dedicated long-term planning studies and legal and technical framework. **Denmark** and **Ireland** for relatively small systems with very high shares of VRE. Operation with important AC and DC connections for Denmark. Almost isolated operation for Ireland and dedicated market for ancillary services linked to reserves and stability. **China** for the rapid development of renewable energy, increase of renewable energy share and adaptation of previously non-flexible thermal generation systems.
2	Initiation phase. Some practices exist. Knowledge-gathering process is ongoing (renewable energy resources mapping, measurement stations, capacity building, etc.). Renewable energy integration objectives taken into account in long-term planning.	Egypt, Iraq, Jordan, Lebanon, Libya, Oman, State of Palestine	Practices to be extended to all aspects of long-term renewable energy integration. Grid code dedicated to renewable energy. Participation of renewable energy plants to the regulation of the system. Interconnection with neighbouring systems and agreement to share resources and reserves.	**South Africa** with regular publication of road maps and integrated resource plans. **WAPP/ ERERA**: Initiative for a West African electricity market allowing more flexibility for the exchanges between countries and sustaining large-scale renewable energy. **ENTSOE**: Update of reserve sizing to take into account high renewable energy penetration and increased variability.
3	Renewable energy integration process into planning not yet started. (No practices in place. Sometimes, long-term renewable energy integration objectives are defined.)	Bahrain, Somalia, Sudan, Yemen	Public authorities to be made aware of renewable energy economic interest and a framework to be put in place for renewable energy integration. Survey of the national renewable energy potential. Survey of costs of renewable energy technologies (for the local context) and comparison to current generation options. Creation of department dedicated to planning within utility or ministry.	**Senegal** and **Ghana** with a high potential for renewable energy and where a legal and technical framework was put in place to structure the applications of promoters and the development of projects. Also, extension of the grid and interconnection with neighbouring systems to increase stability and possible exchanges.

FURTHER READING

IRENA (2019), *Global energy transformation: A roadmap to 2050* (2019 edition), International Renewable Energy Agency, Abu Dhabi, *www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Apr/IRENA_Global_Energy_Transformation_2019.pdf*.

IRENA (2019), *Renewable energy market analysis: GCC 2019*, International Renewable Energy Agency, Abu Dhabi, *www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jan/IRENA_Market_Analysis_GCC_2019.pdf*.

IRENA (2017), *Planning for the renewable future: Long-term modelling and tools to expand variable renewable power in emerging economies*, International Renewable Energy Agency, Abu Dhabi, *www.irena.org/publications/2017/Jan/Planning-for-the-renewable-future-Long-term-modelling-and-tools-to-expand-variable-renewable-power*.

IRENA (2016), *Renewable energy in the Arab region: Overview of developments*, International Renewable Energy Agency, Abu Dhabi, *www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Arab_Region_Overview_2016.pdf*.

Large-scale solar and wind deployment must be supported by robust long-term energy planning

ANNEX 1:
MEETING PROGRAMME AND AGENDA

Exchanging best practices to incorporate variable renewable energy into long-term planning in Arab countries

Dates: 21-24 April 2019

Organisers: IRENA, IsDB, LAS, RCREEE

Language: English/Arabic and French with simultaneous translation

Venue: Amman, Jordan

Background

The Arab region enjoys an abundance of renewable energy resources with high deployment potential. However, the majority of these sources remains untapped despite recent efforts of countries in the region to include greater shares of renewables in the energy mix. The rising power demand, due to the rapid economic and demographic growth, is driving the need to accelerate deployment of renewable energy in the region. In addition, Arab countries need to diversify their economies and strengthen their engagement on climate change, within the framework of the Paris Agreement and the Sustainable Development Goals.

The Pan-Arab Strategy for the Development of Renewable Energy 2010-2030, adopted at the third Arab Economic and Social Development Summit by the League of Arab States in 2013 and updated to the Pan-Arab Strategy for Sustainable Energy 2014-2030, sets a solid basis for regional co-operation to drive renewable energy deployment in the Arab world, committing countries to increase the region's installed renewable power generation capacity from 12 GW in 2013 to 80 GW in 2030.

In support of this strategy, the International Renewable Energy Agency (IRENA) partnered with the League of Arab States (LAS) and the Regional Centre for Renewable Energy and Energy Efficiency (RCREEE) to implement the Pan-Arab Clean Energy Initiative (PACE), one of the initiatives included in the Roadmap of Actions to implement the strategy.

As such, the PACE is a regional initiative that aims to promote the integration of greater shares of renewables into power systems of the Arab region by improving, among other objectives, the energy planning practices of Arab countries to better account for the variability of wind and solar power. By carrying out this workshop, IRENA with its partners will be addressing the variability of renewable energy sources into long-term planning in the Arab region, one of the key components of the PACE Action Plan.

The region has a dynamic renewable energy market, and scaling up the contribution of renewable energy to the future energy mix is a major policy priority in many countries throughout the region, to fuel economic growth while meeting climate change targets. IRENA's *Global energy transformation: A roadmap to 2050* finds that a shift to renewable energy and energy efficiency can lead to global gains of up to USD 6 trillion annually by 2050 accompanied by a 90% reduction in energy-related CO_2 emissions to meet the "well below 2 degrees objective" of the Paris Agreement. Solar power in particular could become a pillar of the region's power sector development, but other renewable technologies are also rapidly coming to the forefront.

The type of political ambition described above, however, is often met with concerns around ensuring reliable power supply with large shares of variable renewable energy (VRE). Such ambition therefore needs to be supported by sets of quantitative techno-economic analyses to define long-term transition scenarios, as well as near-term actions.

IRENA member states, including several countries in the Arab region, have expressed a keen interest in improving their energy planning practices to better account for the variability of wind and solar power. Given the modelling methodologies used by national planning offices for long-term capacity expansion planning such variability and its economic consequences can be difficult to represent.

In order to address this specific challenge, IRENA, with the support of its partners, initiated the Addressing Variable Renewable Energy in Long-Term Energy Planning (AVRIL) project in 2013. Building on the expertise gained through various discussions and sessions held under the AVRIL project, IRENA released its *Planning for the renewable future: Long-term modelling and tools to expand variable renewable power in emerging economies* report in January 2017. The report gives an overview of a range of planning methodologies that are practiced around the world to specifically address the improved representation of VRE in long-term planning tools.

Meeting objectives

The objectives of this workshop are two-fold.

The *primary* objective is to exchange and discuss the regional – as well as global – best practices to enhance capacity expansion planning to achieve significant renewable energy deployment. Participants are expected to encounter novel, cutting-edge approaches, and emerge with new ideas that could be applied in their national and/or regional planning contexts.

More specifically, the discussion around best practices to enhance capacity expansion planning would focus on five main topics:

- generation adequacy (e.g. capacity credit of VRE)
- system flexibility
- VRE siting and zoning evaluations (and their link to transmission investment)
- stability-related operational constraints in a system
- VRE investment costs.

For each topic, input presentations from international experts are to be followed by a discussion of practices and experiences which could be particularly relevant and applicable in the Arab region for capacity expansion planning.

The *secondary* objective is to identify major planning gaps from the workshop discussions, which could potentially be addressed through follow-up bilateral technical co-operation projects.

Meeting outputs

In addition to a completed workshop, the output of this meeting will include a full knowledge report developed by a participating international expert consultant. The report is to be based on material gathered in pre-workshop questionnaires and on workshop content. It could cover:

- **Regional context:** Renewable shares, planning tools, and planning mandates
- **Country-specific profiles in VRE representation:** Planning framework/methodology, current approaches to VRE representation, known challenges, and future priorities
- **Issue-specific profiles in VRE representation:** Approaches to representing VRE investment costs, generation adequacy, system flexibility, VRE siting and zoning evaluation, and system stability
- **Matching of current country practices and improvement priorities:** For identification of potential technical co-operation opportunities.

Participation and participant qualifications

The primary audience for this workshop is professional staff from planning offices, or specialised organisations/institutions involving in energy and power sector planning. It is designed to be a technical meeting for energy planning and modelling practitioners responsible for long-term energy sector master plans or generation expansion planning for respective governments. Participants with a working knowledge of energy planning models and how those are used in the respective countries are preferred.

Each country is expected to nominate two participants: one with the above qualifications from the relevant government ministry, and one from a major national utility.

DAY 1 – (21 APRIL 2019)

Time	Session title	Speaker / facilitator
09:00 - 09:30	Registration	
Session 1	**Opening session**	
9:30 – 10:15	Opening and welcome remarks • H.E. Hala Zawati, Minister of Energy and Mineral Resources, Jordan • Ms Jamila Matar, Head of Energy Department, LAS General Secretariat, Energy Department • Dr Ahmed Badr, Executive Director, Regional Center for Renewable Energy and Energy Efficiency (RCREEE) • Dr Zoheir Hamedi, Regional Programme Officer, IRENA	
10:15 – 10:45	Self-introduction and expectations of participants	
10:45 – 11:30	Long-term energy planning under high renewable energy scenarios – introduction and workshop overview • Define the focus of the workshop: long-term generation expansion planning • Based on IRENA's *Planning for the renewable future* report, discuss role of long-term energy planning; tools used in energy planning; features of VRE; and how VRE features have been incorporated in long-term energy planning • Introduce the objective and structure of the workshop in relation to the planning concepts	Asami Miketa (IRENA)
11:30 – 12:00	*Group photo and coffee break*	
12:00 – 13:00	Presentation: RCREEE Engagement in the Arab region	Dr Ahmed Badr
13:00 – 14:00	*Lunch*	
Session 2	**Country experience**	**Chaired by LAS**
14:00 – 15:10	Introduction of the format • Discuss each country's long-term planning process for generation capacity expansion, including how utility and government work together • Describe energy or power system models used for generation capacity expansion planning • Describe how solar and wind are currently modelled in these modelling tools • Discuss challenges in developing scenarios with high shares of solar and wind using these tools Country presentations – Group 1 [15 minutes presentation plus 5 minutes discussion]	Daniel Russo (IRENA) Participating country representative(s)
15:10 – 15:40	*Coffee break*	
15:40 – 16:40	Country presentations – Group 2	Participating country representative(s)
16:40 – 19:00	*Intermission/ Break*	
19:00 – 21:00	Round table discussion: Establishing the monitoring mechanism for the implementation of the Arab Strategy for Sustainable Energy Reception	
21:00 – 22:00	*Dinner*	

DAY 2 – (22 APRIL 2019)

Time	Session title	Speaker / facilitator
9:00 – 9:30	Recap from Day 1 Plan for Day 2 / Q&A	Reem Korban (IRENA)
Session 2	**Country experience (continued)**	**Chaired by Dr Maged Mahmoud, Technical Director (RCREEE)**
9:30 – 10:30	Country presentations – Group 3	Participating country representative(s)
10:30 – 11:30	Country presentations – Group 4	Participating country representative(s)
11:30 – 12:00	*Coffee break*	
12:00 – 13:00	Key planning considerations with a higher share of VRE • Briefly introduce four planning concepts – capacity credit, flexibility, transmission investment needs, and stability constraints, in relation to long-term energy planning • Discuss the need for high-quality, location- and time-specific renewable energy resource data, and the value of iteration between capacity, dispatch, and power flow models	Asami Miketa (IRENA)
13:00 – 14:00	*Lunch*	
Session 3	**Planning with accurate VRE cost data**	**Chaired by LAS**
14:00 – 15:00	Input presentation 1: Cost reduction of VRE and its relevance to long-term energy planning • Discuss how cost influences the future mix of technologies • Discuss the cost reduction trends of VRE in the past and projected future trends – global perspective and regional perspective	Daniel Russo (IRENA)
15:00 – 15:30	*Coffee break*	
15:30 – 16:45	Exchange of country experiences and discussions • Questions and clarifications to the input presentations • Discuss the best sources for VRE costs and how to integrate them regularly into models and forecasts • Discuss the gaps in the planning process	Moderated by Zoheir Hamedi (IRENA)

DAY 3 – (23 APRIL 2019)

Time	Session title	Speaker / facilitator
9:00 – 9:30	Recap from Day 2 Plan for Day 3 / Q&A	Reem Korban (IRENA)
Session 4	**Planning for generation adequacy**	**Chaired by LAS**
9:30 – 10:25	Input presentation 1: The generation adequacy and capacity credit concept and its relevance to long-term energy planning under high share of VRE • How generation adequacy is impacted by a high share of VRE in a system • What is capacity credit? • What would happen when the capacity credit is not reflected in the capacity expansion planning? • Examples of how the capacity credit concept is used in the capacity expansion planning	Benoit Janssens (IRENA/Tractebel)
10:25 – 11:15	Input presentation 2: How the generation adequacy and capacity credit concept may be reflected in energy planning models • Discuss ways to mimic the capacity credit concept and its implications in capacity expansion models, including defining time slices better, using capacity margin constraints	Asami Miketa (IRENA)
11:15 – 11:45	*Coffee break*	
11:45 – 13:00	Exchange of country experiences and discussions • Questions and clarifications to the input presentations • Discuss the relevance of the capacity credit concept in each country's planning process • Discuss how the capacity credit concept is implemented in each country's model • Discuss the gaps in planning process	Moderated by Zoheir Hamedi (IRENA)
13:00 – 14:00	*Lunch*	
Session 5	**Planning for a flexible power system**	**Chaired by Dr Maged Mahmoud, Technical Director (RCREEE)**
14:00 – 15:00	Input presentation 1: The flexibility concept and its relevance to long-term energy planning under high share of VRE • What is flexibility? • What are the measures to improve flexibility and which of these are particularly relevant to capacity expansion planning? • Discuss what would happen when flexibility is not reflected in capacity expansion planning • Discuss the flexibility of power plants (fossil, hydro, and renewable plants) • Discuss roles of inter-connectors, storage (including pumped hydro), demand side management and self-consumption • Examples of how the flexibility concept is used in the capacity expansion planning	Benoit Janssens (IRENA/Tractebel)
15:00 – 15:30	*Coffee break*	
15:30 – 16:15	Input presentation 2: How the flexibility concept may be reflected in energy planning models • Discuss ways to mimic the flexibility concept and its implications in capacity expansion models, including defining time slices better, using flexibility balances, linking with dispatch models	Asami Miketa (IRENA)
16:15 – 17:30	Exchange of country experiences and discussions • Questions and clarifications to the input presentations • Discuss the relevance of the flexibility concept in each country's planning process • Discuss how the flexibility concept is implemented in each country's model • Discuss the gaps in planning process	Moderated by Zoheir Hamedi (IRENA)

DAY 4 – (24 APRIL 2019)

Time	Session title	Speaker / facilitator
9:00 – 9:30	Recap from Day 3 Plan for Day 4 / Q&A	Reem Korban (IRENA)
Session 6	**Planning for adequate transmission**	**Chaired by IRENA**
9:30 – 10:25	Input presentation 1: VRE resource and zoning evaluations, the trade-off between transmission investment and renewable energy resource quality, and its relevance to long-term energy planning under high shares of VRE • Discuss the importance of geospatial information for planning with VRE • Discuss the methodologies to assess transmission investment needs • Zone planning: renewable energy zones • Discuss how to feature transmission constraints in planning process • Discuss the ways to represent the transmission investment, including detailed geospatial representation of a model, and cost mark-up methodology	Benoit Janssens (IRENA/Tractebel)
10:15 – 11:15	Exchange of country experiences and discussions • Questions and clarifications to the input presentations • Discuss the best sources for VRE geospatial data and how to integrate it into models • Discuss the relevance of the VRE's transmission investment needs in country's planning process • Discuss how the VRE linked transmission investment needs is implemented in each country's model • Discuss the gaps in the planning process	Moderated by Zoheir Hamedi (IRENA)
11:15 – 11:45	*Coffee break*	
Session 7	**Planning for stability related operational constraints**	**Chaired by Dr Maged Mahmoud, Technical Director (RCREEE)**
11:45 – 12:45	Input presentation 1: Stability-related operational constraints and their relevance/irrelevance to long-term energy planning • Discuss the sources of limits to instantaneous penetration of VRE • Discuss the relevance of power system operation with limited synchronous generators in long-term energy planning • Discuss the importance of reflecting VRE adequately in grid codes • Establish different types of stability problems and discuss their relevance/irrelevance to long-term energy planning	Benoit Janssens (IRENA/Tractebel)
12:45 – 13:30	Exchange of country experiences and discussions • Questions and clarifications to the input presentations • Discuss the relevance of the stability concerns in country's planning process • Discuss available VRE grid integration studies and how they relate to long-term capacity expansion planning • Discuss the gaps in planning process	Moderated by Zoheir Hamedi (IRENA)
13:30 – 14:30	*Lunch*	
Session 8	**Planning gaps**	**Chaired by IRENA**
14:30 – 16:30	Identification of planning gaps • Identify the gaps in each country's planning process with aiming at a higher share of VRE, including planning concepts, data, methodologies, human resources	Dr Maged Mahmoud, Technical Director (RCREEE)
16:30 – 17:00	*Coffee break*	
17:00 – 17:45	Identification of areas for follow up action • Identify the areas of follow up actions that can be supposed by IRENA and partners	
17:45 – 18:15	Closing of the workshop • Jordan's Ministry of Energy and Mineral Resources • Regional Center for Renewable Energy and Energy Efficiency (RCREEE) • Dr Zoheir Hamedi, Regional Programme Officer, IRENA	

ANNEX 2:
OFFICIAL PARTICIPANT LIST

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ANNEX 3: COUNTRY ENERGY PLANNING SURVEYS

Tables on the pages that follow, as completed by workshop participants, outline the general energy planning framework for each country, along with the prevailing planning practices for the power sector and generation capacity expansion, how renewable energy sources are represented in planning tools, and the achievements to date and the remaining challenges to be overcome in the expansion of solar and wind power.

The Pan-Arab Clean Energy (PACE) initiative aims to promote the integration of higher shares of renewables and improve planning practices

ALGERIA

Name: Bassi Khaled & Boudjema Yacine

Institution: Ministry of Energy / SONELGAZ (Algerian Company of Electricity and Gas

Country: Algeria

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	Long-term prospective study	Ministry of Energy	Strategic vision 2035	• Hydrocarbon and gas production • Electricity and gas demand • Electricity and gas infrastructures • Energy mix • Investments needs	If needed
Generation capacity expansion planning	Indicative plan of power generation capacity	CREG (regulation authority)/ Ministry of Energy	10 years	Additional power generation capacities	2 years
Transmission planning	Master plan	Sonelgaz	10 years	The main axes of the transport network taking into account several localisation of the additional power generations utilities.	5 years
	Repartition network development studies		10 years	Additional power substations (UHV/HV and HV/MV with the associate OHL and UGC.	2 years
	Studies of evacuation of power stations		According to the localisation of the new Power Plant and the decision to build it.	The connection scheme with the necessary equipment. The associate reinforcements of the network due to these new power plants.	
	Studies of connection to the network of industrial customers		According to the demand	The connection scheme with the necessary equipment.	

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	MAED DAP NOMITOR (gas)	• CREG (Regulation authority) for ten-year forecast • Sonelgaz for long-term horizon
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	WASP MESSAGE	• CREG (Regulation authority) for ten-year plan; • Sonelgaz for long-term horizon.
Future generation dispatch scenarios	SPIRA Package	• Sonelgaz
Network studies	SPIRA Package (elec); SIMONE (gas)	• CREG (Regulation authority); • Sonelgaz /OS.

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	• Feeding the forecasted demand • Security of supply • Optimised energy mix • Diversification of resources • Energy efficiency
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☐ Distributed generation ☒ Demand response ☐ Storage ☒ Transmission investment ☒ Link to non-power sector (e.g., transport, industry, buildings) ☒ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	International market technology costs (in the case of Algeria, only one experience of building RES power plants (354 MW: 344 in PV and 10 MW in wind).

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	MESSAGE
Capacity credit of variable renewable energy	☒ Yes, it is represented **Based on the history of the capacity installed on the network and the rate of integration of renewables (long term, marginal reserve).** How? Please describe **R: load curve and installed capacity** ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☒ Yes, it is represented • How? Please describe **- Depending on the potential.** **- Depending on the availability of the network.** ☐ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	Modelling renewable energy (use of tools that integrate renewables (MESSAGE)) • Preparing a dataset of RES generation potential (Atlas Solar and Atlas Wind). • Building an experimental PV power plants for testing several technologies of PV. • Since 2015 the building of a total capacity of 354 MW of RES power plants.
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	• An appropriate regulatory framework to promote RES integration • An adapted financial mechanisms of RES program to the Algerian context (taking into account the subsidy of electricity). • The preparation of network grid to integrate these new kinds of sources in term of planning and operating issues (performing studies, tools, approach, grid code, RES control centre, etc).

BAHRAIN

Name: Qahtan Alfaris

Institution: Electricity & Water Authority

Country: Kingdom of Bahrain

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	EWA Master Plan	EWA	2030		5 years
Generation capacity expansion planning	EWA Master Plan	EWA	2030		5 years
Transmission planning	EWA Master Plan	EWA	2030		5 years

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	By Consultant	EWA
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	By Consultant	EWA
Future generation dispatch scenarios	PSSE	EWA
Network studies	PSSE	EWA

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☒ Distributed generation ☐ Demand response ☐ Storage ☐ Transmission investment ☐ Link to non-power sector (e.g., transport, industry, buildings) ☐ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	In progress.

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	Done by Master Plan Consultant
Capacity credit of variable renewable energy	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	For 5 MW solar project, generation characteristics are being transmitted in real time to the distribution control centre.
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	

EGYPT

Name: Mohamed Moustafa Abdel Zaher

Institution: Egyptian Electricity Holding Company

Country: Egypt

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	Egypt Integrated & Sustainable Energy Strategy to 2035	Ministry of Electricity and Renewable Energies + Ministry of Petroleum	Up to year 2035	Scenarios for the evolution of the country future energy mix along with the investments needs and assessment of the energy resources consumption.	Every 5 years. But can be updated in case of any change in the underlying assumptions.
Generation capacity expansion planning	EEHC Generation Expansion Plan	Egyptian Electricity Holding Company	Up to year 2027	Determine what amount of generation capacities are required in the future, when to enter the service and what type of capacities are required.	Every 5 years. But can be updated in case of any change in the underlying assumptions.
Transmission planning	EETC Master Plan	Egyptian Electricity Transmission Company	Up to year 2027	Determine what amount of transmission projects are required in the future and, when to enter the service.	Every 5 years. But can be updated in case of any change in the underlying assumptions.

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	Eviews	Egyptian Electricity Holding Company
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	EGEAS, PSR Models	Egyptian Electricity Holding Company
Future generation dispatch scenarios	EGEAS, PSR Models	Egyptian Electricity Holding Company
Network studies	PSSE, PSR Models	Egyptian Electricity Transmission Company

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	Find the diversified mix of generation capacities to meet the forecasted electricity demand with least cost and maximum reliability. The methodology also considers the national targets such as reducing the GHG [greenhouse gas] emissions from the power sector, increasing the share of renewables in the future energy mix, etc.
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☐ Distributed generation ☒ Demand response ☒ Storage ☒ Transmission investment ☒ Link to non-power sector (e.g., transport, industry, buildings) ☒ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	The trends for the future renewable generation costs are usually forecasted considering the studies performed by the international organisations (IEA, EIA, IRENA...etc.) as well as considering the costs of the under-construction or future projects that have received financing offers.

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	**Model Name:** Electric Generation Expansion Analysis System (EGEAS) Purpose: Preparation of the long-term generation expansion plan considering the different technical and economic factors. **Input Data:** Demand forecast, hourly load pattern, hourly generation pattern for renewables, technical and economic data about the existing, committed and candidate power plants, reliability criteria…etc. **Outputs:** Generation Expansion Plan, system costs, new investments required, reliability indices, dispatch of generation units, fuel consumption, GHG emissions…etc.
Capacity credit of variable renewable energy	☒ Yes, it is represented • How? Please describe **As a percentage of the renewable installed capacity. This percentage will be considered during the evaluation of the system firm capacity and the calculation of the reliability indices.** ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☒ Yes, it is represented • How? Please describe **Renewable siting is only reflected through providing hourly generation data to reflect the diurnal and seasonal characteristics of the available renewable resources in this site.** ☐ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept

[Tool 2]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	**Model Name:** PSR Planning tools **Purpose:** Preparation of the long-term integrated generation and transmission expansion plan considering the different technical and economic factors. This suite of planning tools is adapted to the representation of integrated energy systems under uncertainty – involving multiple generation technologies and taking into account the availability of renewable resources, fuels and transport restrictions in transmission lines and pipelines. The various models use stochastic optimisation techniques to solve operational and planning problems. The planning suite includes the following tools: • OptGen: Optimal long-term Generation Expansion Planning tool • SDDP: a probabilistic multi-area hydro-thermal production costing tool • NCP: detailed short-term generation scheduling tool • NetPlan: transmission network planning and analysis tool **Input Data:** Demand forecast, hourly load pattern, hourly generation pattern for renewables, detailed data about water resources and hydro generation, technical and economic data about the existing, committed and candidate generation and transmission capacities, reliability criteria...etc. **Outputs:** Integrated Generation and Transmission Expansion Plan, system costs, new investments required, reliability indices, dispatch of generation units, fuel consumption, GHG emissions...etc.
Capacity credit of variable renewable energy	☒ Yes, it is represented • How? Please describe **As a percentage of the renewable installed capacity. This percentage will be considered during the evaluation of the system firm capacity and calculation of the reliability indices.** ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☒ Yes, it is represented • How? Please describe **Through providing the detailed operation limits for generation units (ramp rates, minimum generation levels, minimum up/down times, maximum number of start-ups/shutdowns and shutdown costs).** ☐ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☒ Yes, it is represented • How? Please describe **Renewable siting is reflected through providing hourly generation data to reflect the diurnal and seasonal characteristics of the available renewable resources in this site as well as the correlation with the system demand. Also, the connection of the variable renewable energy site to the transmission grid and the related technical factors are reflected in the optimisation process.** ☐ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☒ Yes, it is represented • How? Please describe **Not directly represented in the model but can be represented through the combination of the Netplan model and the more detailed PSSE model.** ☐ No, it is not represented ☐ We are not familiar with this concept

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	• Gathering a huge amount of historical data about the possible renewable generation patterns (on hourly and sub-hourly levels) for different sites in the country. • Wind atlas and solar atlas have been released showing the suitable geographical sites for renewable generation in the country along with the required technical data. • Acquiring modern generation expansion planning software capable of: 1. Modelling the detailed hourly characteristics of variable renewable energy for each individual site and the access to the transmission grid. 2. Modelling the stochastic nature of variable renewable energy into the generation expansion planning process 3. Modelling the detailed operation limits and flexibility characteristics of generation units into the generation expansion planning process
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	1. Continue updating and analysing data about the available sites for renewable generation in the country. 2. Continue the studies about capacity credit and integration of renewable energy into the national grid. 3. Continue enhancing the modelling of variable renewable energy in the generation expansion planning process.

IRAQ

Name: Dr Mohammed Ahmed Salih

Institution: Ministry of Electricity

Country: Iraq

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning		Planning and Study Office Ministry of Electricity	2030	Power generation plans Investment in power generation	Yearly
Generation capacity expansion planning		Planning and Study Office Ministry of Electricity	2030	Power generation plans Investment in power generation	Yearly
Transmission planning		Planning and Study Office Ministry of Electricity	2030	Power generation plans Investment in power generation	Yearly

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	Many softwares	Planning and Study office
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	Many softwares	Planning and Study office
Future generation dispatch scenarios	Many softwares	Planning and Study office
Network studies	Many softwares	Planning and Study office

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	Policy design. Investment in power generation (traditional + renewable energy). Forecast of load demand.
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☒ Distributed generation ☒ Demand response ☐ Storage ☐ Transmission investment ☒ Link to non-power sector (e.g., transport, industry, buildings) ☒ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	Reducing the cost.

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	In processing.
Capacity credit of variable renewable energy	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	

JORDAN

Name: Ahmad Tahseen Abudyak

Institution: National electric power company

Country: Jordan

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	National Energy Strategy	MEMR	2025	20% renewable contribution to generated electricity.	Every 5 years
Generation capacity expansion planning	MASTER PLAN	Grid expansion section NEPCO	2034	The future need for generation due to demand growth and economic figures.	Every 5 years
Transmission planning	MASTER PLAN	Transmission planning section NEPCO	2034	The allocation of any future generation capacity and the needed investment for transmission system.	Every 5 years

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	PLEXOS, in house excel model	Power production planning dept
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	PLEXOS	Grid expansion section NEPCO/ Power System Planning Dept
Future generation dispatch scenarios	WASP / In house excel model	Grid expansion section NEPCO/ Power System Planning Dept
Network studies	PSSE, DIgSILENT PowerFactory	Transmission planning section NEPCO / Power System Planning Dept

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	The future need for generation due to updated demand growth and economic figures for Jordanian electrical system. Setting of future generation mix target that insures both security of supply and the lower cost of electricity sales.
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☐ Centralised generation ☐ Distributed generation ☒ Demand response ☒ Storage ☒ Transmission investment ☐ Link to non-power sector (e.g., transport, industry, buildings) ☐ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	Future trends of the renewable generation technology costs forecasted via the available international practices.

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[PLEXOS]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	PLEXOS – has a range of features that seamlessly integrates electric generation systems and is the preferred choice for co-optimisation modelling. It is recently used for Jordanian model due to the need for problem-solve these sophisticated levels of constraints and uncertainties due to large integration of renewables into power system in near and future system scenarios.
Capacity credit of variable renewable energy	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☒ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept

[DIgSILENT PowerFactory]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	DIgSILENT power simulation is power simulation software developed by Siemens and is widely used for load flow, short circuit steady state analysis in addition to dynamic stability analysis on the available dynamic model of power grid.
Capacity credit of variable renewable energy	☒ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☒ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept

[PSSE]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	Power system simulation tool is power simulation software developed by Siemens and is widely used for load flow, short circuit steady state analysis in addition to dynamic stability analysis on the available dynamic model of power grid. This programme is used also for interconnection studies with neighbouring countries.
Capacity credit of variable renewable energy	☒ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☒ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	The recent integration of new programming tools such as PLEXOS and the enhancement of current used tools such as WASP and other used programmes and excel models.
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	The huge integration of renewables into the national grid which creates many grid challenges and requires the RES curtailment. The need to introduce the flexibility measures for the current and future conventional generation to accommodate the high share of variable renewable energy. The search for new energy markets and to export the excess power generation via interconnection with neighbouring countries such as KSA, Iraq and the State of Palestine.

LEBANON

Name: Ramzi El Dobeissy

Institution: EDL

Country: Lebanon

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning		Ministry of Energy and Water and Electricite du Liban	2030	Existing mix: CCGT ~950 MW, Thermal ~440 MW, OCGT ~150 MW, Hydro 120 MW	3 to 5 years
Generation capacity expansion planning		Ministry of Energy and Water and Electricite du Liban	2030	2030: CCGT ~5475 MW, OCGT ~160 MW, Hydro ~370 MW, Wind ~500 MW, PV ~360 MW, PV+storage ~300 MW	3 to 5 years
Transmission planning		Ministry of Energy and Water and Electricite du Liban	2030	OHTL, substations, UGC	3 to 5 years

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	Estimation	EDL
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	NA	Ministry of Energy and Water
Future generation dispatch scenarios	Estimation	EDL
Network studies	CYME	EDL

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	Policy paper set by the government and investment planning to reach targets estimated based on forecasted demand.
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☒ Distributed generation ☐ Demand response ☒ Storage ☒ Transmission investment ☐ Link to non-power sector (e.g., transport, industry, buildings) ☐ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	NA

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	Software (CYME) calculates the future power plants evacuation required investments.
Capacity credit of variable renewable energy	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☒ We are not familiar with this concept
Flexibility of energy system	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☒ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☒ We are not familiar with this concept
VRE's related power system stability issues	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	The integration of renewable energy on a high scale brings stability problems to small semi isolated networks like the Lebanese electric system, especially with the shortage in generation capacities in the present time. Several steps should be taken to overcome this problem like an increase in installed capacities on conventional power plants level and interconnection with other systems.

MOROCCO

Name:

Institution: Office National de l'Electricité et de l'Eau Potable (ONEE)

Country: Morocco

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	Internal use	Ministry of Energy	Next 30 years	Energy mix, investment needs	Updated as necessary.
Generation capacity expansion planning	Internal use	ONEE	Next 30 years	Capacity mix, investment needs, O&M [operation and maintenance] costs, expected energy not to be supplied, expected curtailment, etc.	Updated as necessary (usually 1 every year).
Transmission planning	Internal use	ONEE	Next 10 to 20 years	Reinforcements, investment needs, losses, etc.	Updated as necessary (usually 1 every year).

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	MAED from IAEA	ONEE
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	OPTGEN/SDDP	ONEE
Future generation dispatch scenarios	SDDP/NCP	ONEE
Network studies	PSS/E	ONEE

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	Since 2009, Morocco has launched a national energy strategy based on the development of electricity-mix by increasing the share of the renewables technologies (wind, solar, hydro) for 42% by 2020 and 52% by 2030 in terms of total capacity.
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☒ Distributed generation ☒ Demand response ☒ Storage ☒ Transmission investment ☐ Link to non-power sector (e.g., transport, industry, buildings) ☒ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	The costs of renewables technologies are based on the publications of the IEA and benchmark among manufacturers.

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	✓ Model for expansion (OPTGEN) ✓ Model for operation (SDDP & NCP)
Capacity credit of variable renewable energy	☒ Yes, it is represented • How? Please describe **Reliability assessment** ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☒ Yes, it is represented • How? Please describe **Hourly unit commitment taking into consideration dynamic operational constraints (start-ups, ramping, continuous minimum Up/Down, etc.** ☐ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☒ Yes, it is represented • How? Please describe **Determination of optimal hosting capacity from economic point of view as well as from grid integration.** ☐ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☒ Yes, it is represented • How? Please describe **Carrying dynamic/transient simulations of the power system.** ☐ No, it is not represented ☐ We are not familiar with this concept

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	Considering Morocco's objectives in renewable energy development, and in order to represent the characteristics of variable renewable energy, recent improvements in planning generation have been done and focused in particular on modelling through the purchase of new tools (OPTGEN for expansion, SDDP & NCP for operation) and a regional distribution of renewable energy profiles.
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	✓ Datasets of generation profiles for each technology (wind, solar) for each site; ✓ Learning curves for each renewable technology (future costs in the next 30 years); ✓ Enhancing flexibility system based on new storage technologies (mainly batteries). The issue is related to their economic competitiveness with regard to conventional flexible power plants such as CGGT/OCGT and hydro-pumped storage.

OMAN

Name: Ali Salim Al-Rashidi

Institution: Ministry of Oil & Gas (MOG)

Country: Oman

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	Non	MOG	Non	Non	Non
Generation capacity expansion planning	Oman Power & Water Procurement Company (OPWP)	Oman Power & Water Procurement Company (OPWP)	7 years	Demand, supply	Every year
Transmission planning	Oman Electricity Transmission Company (OETC)	Oman Electricity Transmission Company (OETC)	5 years	Transmitted power, total transmission lines, power stations.	Every year

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	Macroeconomic analysis, historical growth, quantitative analysi.s	Oman Power & Water Procurement Company
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	Demand requirement, other policy.	Oman Power & Water Procurement Company with private sector
Future generation dispatch scenarios	7 years statement (forecast).	Oman Power & Water Procurement Company
Network studies	All sector input (Generation, Transmission, Distribution.)	Authority for Electricity Generation

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	Target setting, policy, security of supply.
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☐ Centralised generation ☒ Distributed generation ☐ Demand response ☐ Storage ☒ Transmission investment ☐ Link to non-power sector (e.g., transport, industry, buildings) ☒ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	Competitive for large scale projects (solar).

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	Oman energy model used for setting renewable energy target based on the sector expected growth and demand requirement, it is updated and reviewed regularly.
Capacity credit of variable renewable energy	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☒ Yes, it is represented • How? Please describe **The target can be updated and the model can be revised.** ☐ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☒ Yes, it is represented • How? Please describe **Oman's Grid Master Plan has presented 15% of renewable energy can be injected in the grid. Other efforts for integrating the transmission networks in Oman (a strategic project).** ☐ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☒ We are not familiar with this concept

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	Renewable energy project not operated yet.
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	Co-ordination, contracting period, cost, security of supply.

STATE OF PALESTINE

Name: Nedal Aburubi

Institution: PEC/PENRA

Country: State of Palestine

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	2017-2022 Energy Sector Strategy 2027 Transmission Planning	PENRA/PETL/ PEC/PERC	2022 Strategy 2027 Transmission	50% of local consumption to be produced locally. 10% of local production is renewable energy.	5 years, strategy Once a year, transmission
Generation capacity expansion planning	480 MW 400 MW 130 MW/ renewable	PENRA (Planning) Private Sector (Implementation)	2022-2027	USD 4 Billion	Every 5 years
Transmission planning		PETL	2027		Every year

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	Excel	PETL
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	Excel	PENRA
Future generation dispatch scenarios		
Network studies	ETAP	PETL

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	• Meet future demand • Independency • Security • Feasibility
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☐ Centralised generation ☒ Distributed generation ☐ Demand response ☐ Storage ☐ Transmission investment ☐ Link to non-power sector (e.g., transport, industry, buildings) ☒ Rural electrification ☒ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	Decreasing by 5% yearly (average) in 5 years.

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	ETAP
Capacity credit of variable renewable energy	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☒ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☒ We are not familiar with this concept
VRE's related power system stability issues	☐ Yes, it is represented • How? Please describe ☒ No, it is not represented ☒ We are not familiar with this concept

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	• Improvement in data collection • SCADA • DATA BASE
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	• Lack of grid studies • Inaccurate load forecast • System stability • Lack of control on network • Shortage in generation • Increase in demand • Lack of data • No demand side management (DSM)

QATAR

Name: Maryam

Institution: KAHRAMAA

Country: Qatar

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	NA	NA	NA	NA	NA
Generation capacity expansion planning	1. Demand Forecast Report 2. Demand Supply Balance Report 3. Long term capacity expansion plan (25 – 5-year rolling) 4. 5 years business plan	KAHRAMAA	1. 10 years 2. 10 years 3. 25 years 4. 5 years	1. 10 years demand forecast with 6% reserve margin (base case, low case and high case) 2. Existing and planned resource adequacy to cover the demand 3. Investment programme, capacity mix, timing and technology 4. Planned expansion projects and reserve margin level	1. Annually 2. Annually 3. Every 5 years 4. Annually
Transmission planning	1. Demand Forecast Annual Report 2. System Studies Report and Development Plan	KAHRAMAA	5 years	Expansion plan and Investment needs	Annually

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	Excel model + @risk	KAHRAMAA
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	PLEXOS	KAHRAMAA
Future generation dispatch scenarios	In-house excel model	KAHRAMAA
Network studies	PSSE, SINCAL	KAHRAMAA

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	• Target Reserve Margins 6% (min) • Economic cost
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☐ Distributed generation ☐ Demand response ☐ Storage ☐ Transmission investment ☒ Link to non-power sector (e.g., transport, industry, buildings) ☐ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	NA

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	PLEXOS, PSSE, excel model
Capacity credit of variable renewable energy	☒ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☒ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☒ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	Will be identified during the operation of first project (AL-KHARSAA) and will be considered in the new updated Grid Code.

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	1. Instalment of weather stations for better data 2. Co-operating with Academia (QEERI) for data measurement and solar panels studies 3. Implementing the first solar PV project in the country (Al-Kharsaa project) to act as basis for future projects (data, operation experience... etc.)
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	1. Distribution level feed in policy is not in place yet 2. Lack of actual historical solar data 3. Current grid code does not include renewables integration guidelines

SAUDI ARABIA

Name: Eng. Ali A. Al-Heji

Institution: Deputyship of Policy & Strategic Planning, Ministry of Energy, Industry and Mineral Resources (MEIM)

Country: Kingdom of Saudi Arabia

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	Public: Saudi Arabia Renewable	Public: Saudi Arabia Renewable	Public: Saudi Arabia Renewable	Public: Saudi Arabia Renewable	Public: Saudi Arabia Renewable
Generation capacity expansion planning	Covered by Energy Planning				
Transmission planning		Saudi Electricity Company (SEC)/Principal Buyer (PB)	2030 and 2040		Once a year

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	A combination of bottom-up modelling of the energy sector and top-down econometrics.	MEIM with SA, SEC and KAPSARC
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	In-house (Mothra & SUPER) and commercial (PLEXOS) plus in-house energy sector optimisation models (KEM).	MEIM with SA, SEC and KAPSARC
Future generation dispatch scenarios	In-house and commercial (e.g., PLEXOS, ProMod) simulation and optimisation models.	MEIM with SEC
Network studies	In-house and commercial (e.g. PSS/E) models.	SEC

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	The planning objective is to reliably meet electricity demand at minimum cost subject to reliability, fuel availability and emission constraints.
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☒ Distributed generation ☒ Demand response ☒ Storage ☒ Transmission investment ☒ Link to non-power sector (e.g., transport, industry, buildings) ☒ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	The numbers are adopted from renewable technology road map studies published by international agencies in combination with in-house forecasting models.

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	A mix of in-house and commercial tools (mentioned above).
Capacity credit of variable renewable energy	☒ Yes, it is represented • How? Please describe **Static (e.g. ELCC) and dynamic approaches depending on the employed model.** ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☒ Yes, it is represented • How? Please describe **A combination of minimum reserve and LOLE/P.** ☐ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☒ Yes, it is represented • How? Please describe **A combination of GIS analysis and power system simulation of the full network.** ☐ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☒ Yes, it is represented • How? Please describe **Static and dynamic stability are analysed with commercial (e.g. PSSE) and in-house power system simulation models** ☐ No, it is not represented ☐ We are not familiar with this concept

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	The use of data-driven approaches for renewable power simulation while attempting to resolve temporal, spatial, technological complexity to the furthest extent.
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	The role of fuel storage (gas). The role of energy storage (e.g. pumped hydro and electrical). Better treatment of stochastic properties of VRE including forecasting.

SOMALIA

Name: Abdullahi Sheikh Mohamed

Institution: Ministry of Energy & Water Resources

Country: Somalia

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	Power Master Plan	Ministry of Energy & Water Resources	To 2037	Generation capacity expansion, generation options, institutional development (policy, regulation, and human resources).	Once every 5 years
Generation capacity expansion planning	Included in the Power Master Plan	Private Sector & Public Sector	To 2037	To reach 3 000 MW, USD 2.8 billion .	Once every 5 years
Transmission planning	Still not developed	Ministry of Energy & Water Resources			

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	Customised excel	Ministry of Energy & Water Resources
Generation Capacity Investment Scenarios (Generation capacity expansion plan)		
Future generation dispatch scenarios		
Network studies		

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	• To produce power master plans for authorities and the sector that will guide the introduction and establishment of modern cost-effective reliable electricity supply systems over a 20-year planning period. • To produce detailed plans for developing the electricity supply in the main cities.
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☐ Centralised generation ☐ Distributed generation ☐ Demand response ☐ Storage ☐ Transmission investment ☐ Link to non-power sector (e.g., transport, industry, buildings) ☐ Rural electrification ☒ Other (please specify below) **Privately owned companies in each of the main cities**
Q: How are future trends of the renewable generation technology costs forecasted?	Renewable energy technology, especially solar PV, is planned to use in rural electrification using mini off-grid systems; and to convert to hybrid systems in the cities in the long term.

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

No specific tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	NA
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	NA

SUDAN

Name:

Institution: Ministry of Water Resources, Irrigation and Electricity

Country: Republic of Sudan

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	Lahmeyer International Company	Ministry of Water Resources, Irrigation and Electricity	2012-2031	Increase the overall national electrification ratio to at least 80% by 2031 Utilise a high share of domestic energy sources – as far as practicable Utilise a high share of renewable energy sources considering economic and technical limitations. Diversify the energy sources – as far as practicable – in order to increase security of supply and reduce dependency. Utilise all hydro potential in the country – as far as practicable.	A medium-term plan for the period 2012 2016. A long-term power system planning study to cover the period 2012-2031.
Generation capacity expansion planning	Lahmeyer International Company	Ministry of Water Resources, Irrigation and Electricity	2012-2031		A medium-term plan for the period 2012 2016. A long-term power system planning study to cover the period 2012-2031.
Transmission planning	Lahmeyer International Company	Ministry of Water Resources, Irrigation and Electricity	2012-2031	Connect all states of Sudan to the national grid by 2031 – as far as practicable.	A medium-term plan for the period 2012 2016. A long-term power system planning study to cover the period 2012-2031.

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	• Power system in Sudan – historic, actual and outlook • Political and administrative frame • Demographic frame • Geographic frame • Economic frame	Electricity sector National Statistics Council Ministry of Finance
Generation Capacity Investment Scenarios (Generation capacity expansion plan)		Electricity sector
Future generation dispatch scenarios		Electricity sector
Network studies		

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	The main planning objectives for planning the expansion of the generating capacity are: • Access to electricity for the majority of the population and service areas, especially the remote areas of the centre • Electricity use in agriculture • The use of electricity in the industrial field
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☒ Distributed generation ☒ Demand response ☒ Storage ☒ Transmission investment ☒ Link to non-power sector (e.g., transport, industry, buildings) ☒ Rural electrification ☒ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

[Tool 1]

The name of the modelling tool used and its brief description (e.g., main purposes, key inputs, key outputs etc)	The possible future use of renewable energy sources (RES) other than large-scale hydro is assessed in the Renewable Energy Master Plan (REMP) 25. This study analyses the physical, technical and economic potential of these sources as well as the implementation opportunities and barriers in Sudan. The results of this analysis are transferred to the Long and Medium-Term Power System Plans (LMTPSP). The following show the development of RES installed capacity and estimated electricity generation for the study period to be considered in the successive expansion modelling. In summary: • Based on the planned RES projects (some of them already in the tendering phase) and further projects identified in the REMP the installed capacity of renewable energy will grow considerably during the next five years (up from no RES capacity in the base year 2012). • Afterwards the capacity and generated electricity is assumed to grow by an annual average of around 8%. • This leads to a forecasted average share (of total generated electricity) from RES growing from currently zero to between 8% (for the high demand scenario) and 11% (for the moderate demand scenario) in 2018 (after the considerable increase of renewable energy capacity).
Capacity credit of variable renewable energy	☐ Yes, it is represented • How? Please describe **The expansion of generation from renewable energy would contribute 3% to 11% of annual electricity from 2014 onwards. The installed capacity would grow from around 100 MW in 2014 to 1.6 GW in 2031. The dependable capacity in the critical month would be around 160 MW through biogas/waste-based steam turbines and engines and the envisaged solar based CSP pilot plant. Hence, in the medium to long term the RES development would ease the need for new capacity.** ☐ No, it is not represented ☐ We are not familiar with this concept
Flexibility of energy system	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
Variable renewable energy siting and transmission investment needs	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept
VRE's related power system stability issues	☐ Yes, it is represented • How? Please describe ☐ No, it is not represented ☐ We are not familiar with this concept

No further tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	

YEMEN

Name: ENG. Ahmed Zaki Murshed

Institution: Ministry of Electricity & Energy

Country: Republic of Yemen

1. General energy planning framework

How long-term planning frameworks are officially implemented in the country.

	Name of official planning publication	Responsible institution(s)	Planning time horizon (e.g. to 2040)	Main quantitative outputs (e.g. capacity mix, investment needs, etc)	Frequency of update (e.g. once a year, every 5 years)
Energy system planning	NA	NA	NA	NA	NA
Generation capacity expansion planning	NA	NA	NA	NA	NA
Transmission planning	NA	NA	NA	NA	NA

2. Power sector planning

Which of the below steps are taken for power system planning in the country?
Who is responsible and which tools are used?

	Tools used	Responsible institution(s)
Power demand forecast	NA	NA
Generation Capacity Investment Scenarios (Generation capacity expansion plan)	NA	NA
Future generation dispatch scenarios	NA	NA
Network studies	NA	NA

3. Generation capacity expansion planning

The questions below refer to the coverage of generation capacity expansion planning.

	Responsible institution(s)
Q: What are the key planning objectives for the generation capacity expansion planning performed in your country (e.g., policy design, investment planning, target setting, etc)? Please describe.	NA
Q: Which of these issues are currently covered in your country's generation capacity expansion planning? Please select.	☒ Centralised generation ☒ Distributed generation ☒ Demand response ☐ Storage ☒ Transmission investment ☒ Link to non-power sector (e.g., transport, industry, buildings) ☒ Rural electrification ☐ Other (please specify below)
Q: How are future trends of the renewable generation technology costs forecasted?	Because of the present war crisis in Yemen and the local currency instability, future trends of renewable generation technology costs cannot be forecasted.

4. Representation of renewable energy in generation capacity expansion planning tools

Participants describe tools used for generation capacity expansion planning in the country and which factors are represented in the tools.

No specific tools are used.

5. Achievements and remaining challenges in planning generation capacity expansion with a high share of variable renewable energy

Q: What are the recent improvements to represent characteristics of variable renewable energy in your country's generation capacity expansion planning (e.g., data collection, modelling etc)?	NA
Q: Please identify three of the most important gaps in your country's current generation capacity expansion planning to represent a high share of variable renewable energy.	1. The absence of an official entity that performs the standardisation process, which is the important gap facing the renewable energy's generation capacity expansion planning. 2. The unstable security situation in the country which prevents the establishment of expansion in renewable energy projects. 3. Lack of international support.

Further discussions and analysis could focus on cost projections, capacity credits, flexibility, zoning and system stability

IRENA

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