International Renewable Energy Agency

Planning and Prospects for Renewable Power in Africa

Insights from IRENA and CMP (Continental Power Sector Masterplan) for Africa

26 March 2024

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Contents

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1. Overview - IRENA's support for African energy transition planning & CMP
2. Energy Transition in Africa - Insights from SPLAT analyses
   - CMP - Key capacity expansion modelling outcomes
   - Case study Namibia – Impacts of regional integration
   - Case study North Africa – Energy transition scenarios including green hydrogen
3. Ongoing work: Regional Energy Transition Outlook for five African regions including hydrogen

Overview - IRENA’s support for African energy transition planning & CMP

Planning and prospects for renewable power report series

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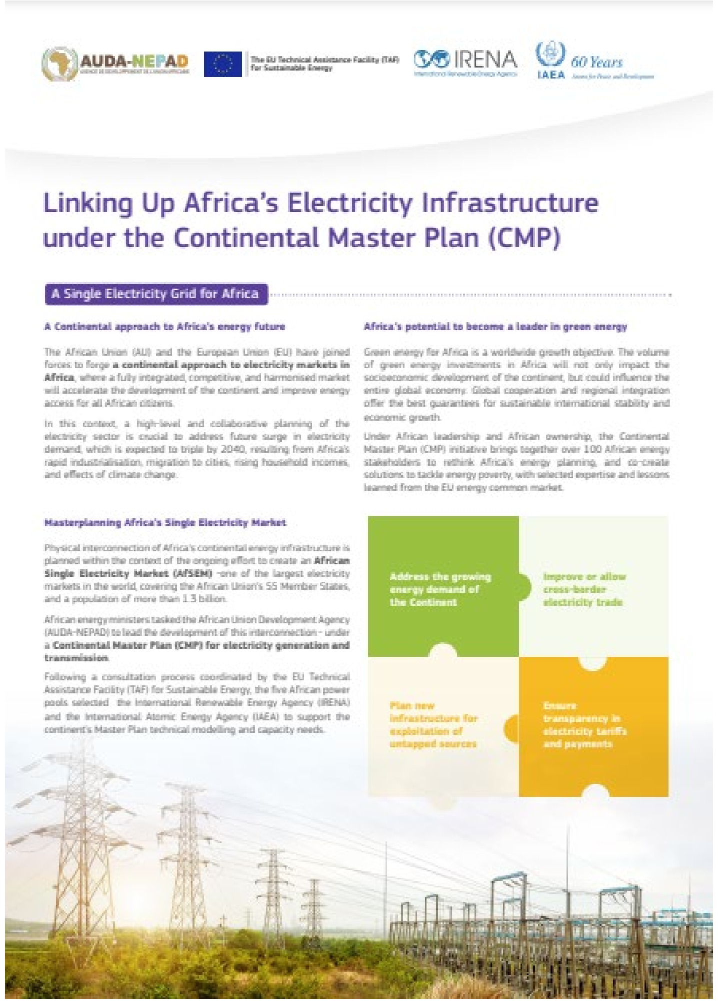

AUDA-NEPAD
The EU Technical Assistance Facility (TAF) for Sustainable Energy
IRENA
IAEA 60 Years

Linking Up Africa's Electricity Infrastructure under the Continental Master Plan (CMP)

A Single Electricity Grid for Africa

A Continental approach to Africa's energy future

The African Union (AU) and the European Union (EU) have joined forces to forge **a continental approach to electricity markets in Africa**, where a fully integrated, competitive, and harmonised market will accelerate the development of the continent and improve energy access for all African citizens.

In this context, a high-level and collaborative planning of the electricity sector is crucial to address future surge in electricity demand, which is expected to triple by 2040, resulting from Africa's rapid industrialisation, migration to cities, rising household incomes, and effects of climate change.

Masterplanning Africa's Single Electricity Market

Physical interconnection of Africa's continental energy infrastructure is planned within the context of the ongoing effort to create an **African Single Electricity Market (AfSEM)** -one of the largest electricity markets in the world, covering the African Union's 55 Member States, and a population of more than 1.3 billion.

African energy ministers tasked the African Union Development Agency (AUDA-NEPAD) to lead the development of this interconnection - under a **Continental Master Plan (CMP) for electricity generation and transmission**.

Following a consultation process coordinated by the EU Technical Assistance Facility (TAF) for Sustainable Energy, the five African power pools selected the International Renewable Energy Agency (IRENA) and the International Atomic Energy Agency (IAEA) to support the continent's Master Plan technical modelling and capacity needs.

Africa's potential to become a leader in green energy

Green energy for Africa is a worldwide growth objective. The volume of green energy investments in Africa will not only impact the socioeconomic development of the continent, but could influence the entire global economy. Global cooperation and regional integration offer the best guarantees for sustainable international stability and economic growth.

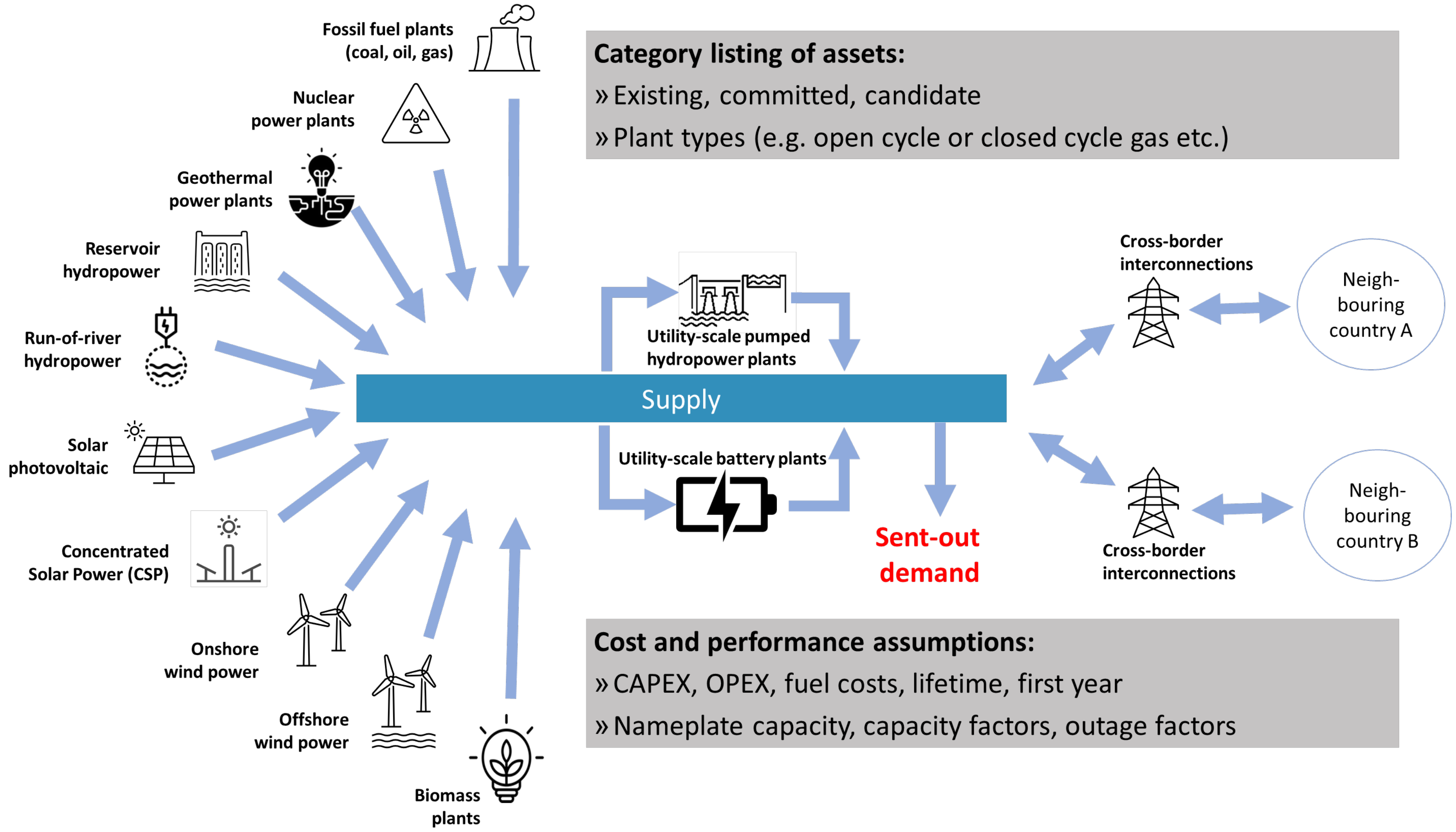
Under African leadership and African ownership, the Continental Master Plan (CMP) initiative brings together over 100 African energy stakeholders to rethink Africa's energy planning, and co-create solutions to tackle energy poverty, with selected expertise and lessons learned from the EU energy common market.

Address the growing energy demand of the Continent
Improve or allow cross-border electricity trade
Plan new infrastructure for exploitation of untapped sources
Ensure transparency in electricity tariffs and payments

https://www.irena.org/Energy-Transition/Planning/SPLAT-Models-for-Africa
https://www.irena.org/Energy-Transition/Planning/SPLAT-Models-for-Africa/Prospects-for-Renewable-Power-in-Africa

Introduction to SPLAT models

- **Coverage:** 48 countries (all continental countries) + two island States (Sao Tome and Principe, Cabo Verde)
- **Time horizon:** 2019-2040
- **Scope:** Investments in utility scale generation and cross-border interconnections
  - ✕ Domestic T&D grid investments
  - ✕ Off-grid investments

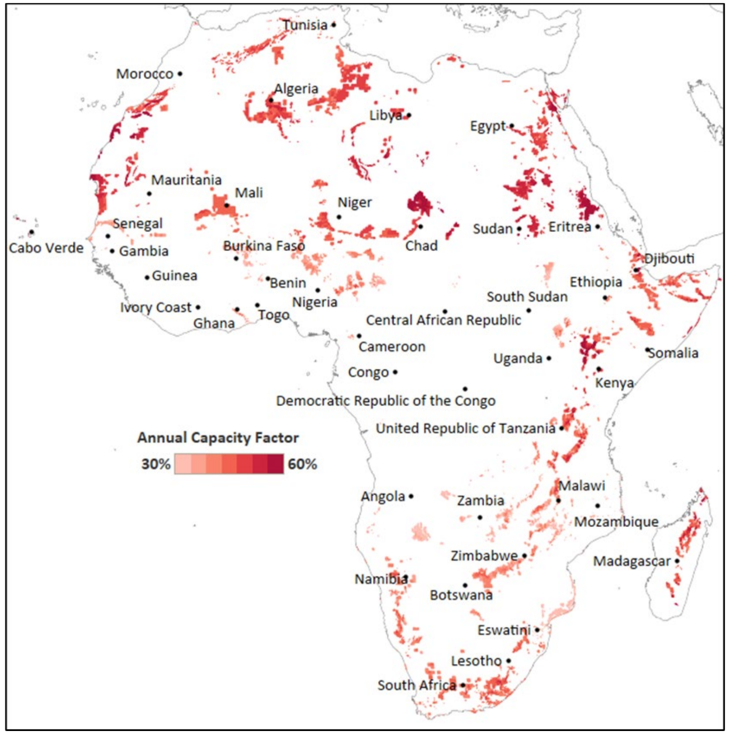


SPLAT Reference Energy System

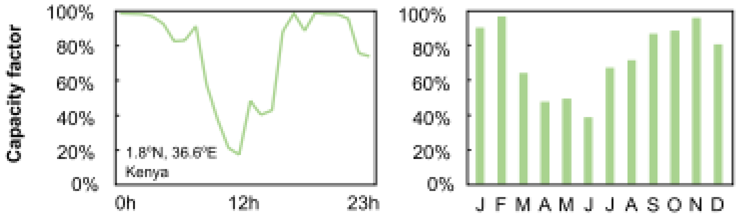
Technology resolution: Wind and solar supply options

- SPLAT models include geo-referenced supply options:
  - Region specific resource potential
  - Region-specific representative generation profiles
  - Cost markups for connection infrastructure (grid tie & connection roads)
- This allows optimal capture of spatio-temporal complementarities
- **Coverage:** Onshore & offshore wind, Solar PV, Solar Thermal

Methodology paper: Link
https://www.nature.com/articles/s41597-022-01786-5



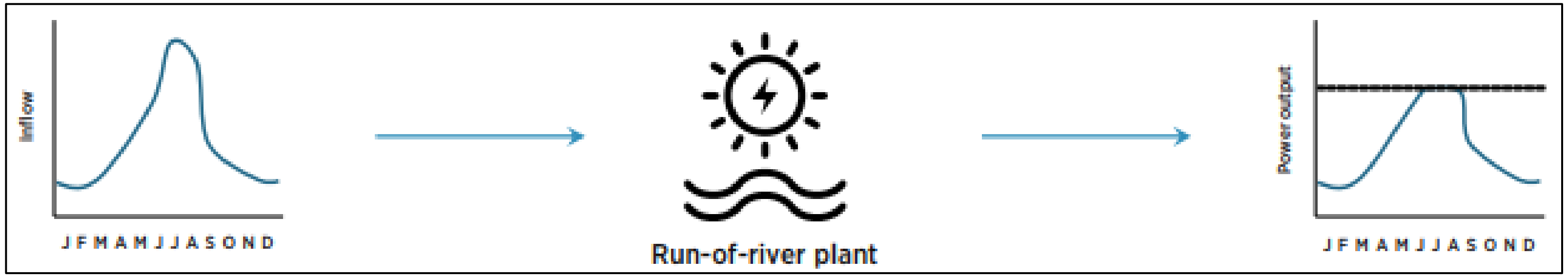
Onshore wind resources



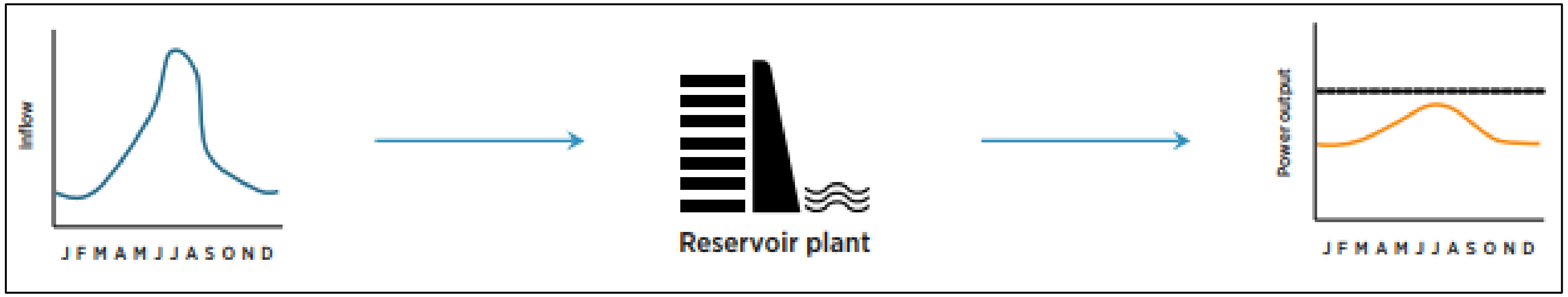
Example onshore wind profile

Technology resolution: Hydropower profiles

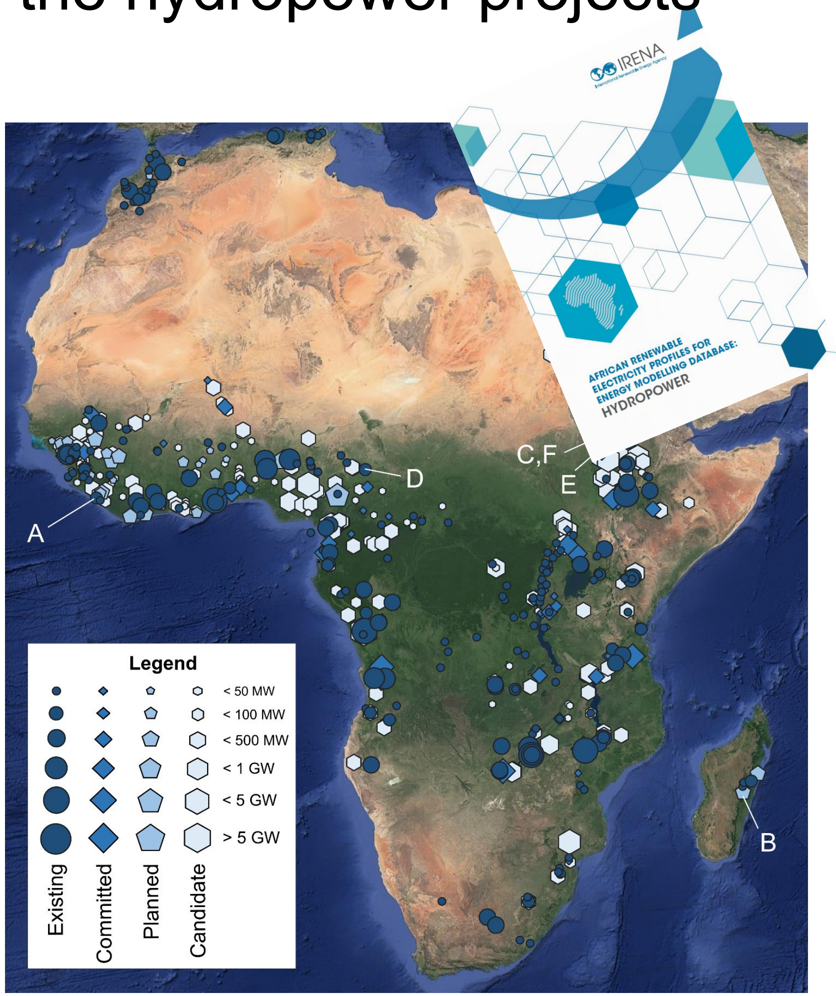
- SPLAT models include site specific generation profiles for the hydropower projects
- Dispatch of dam-based hydropower plants is optimized



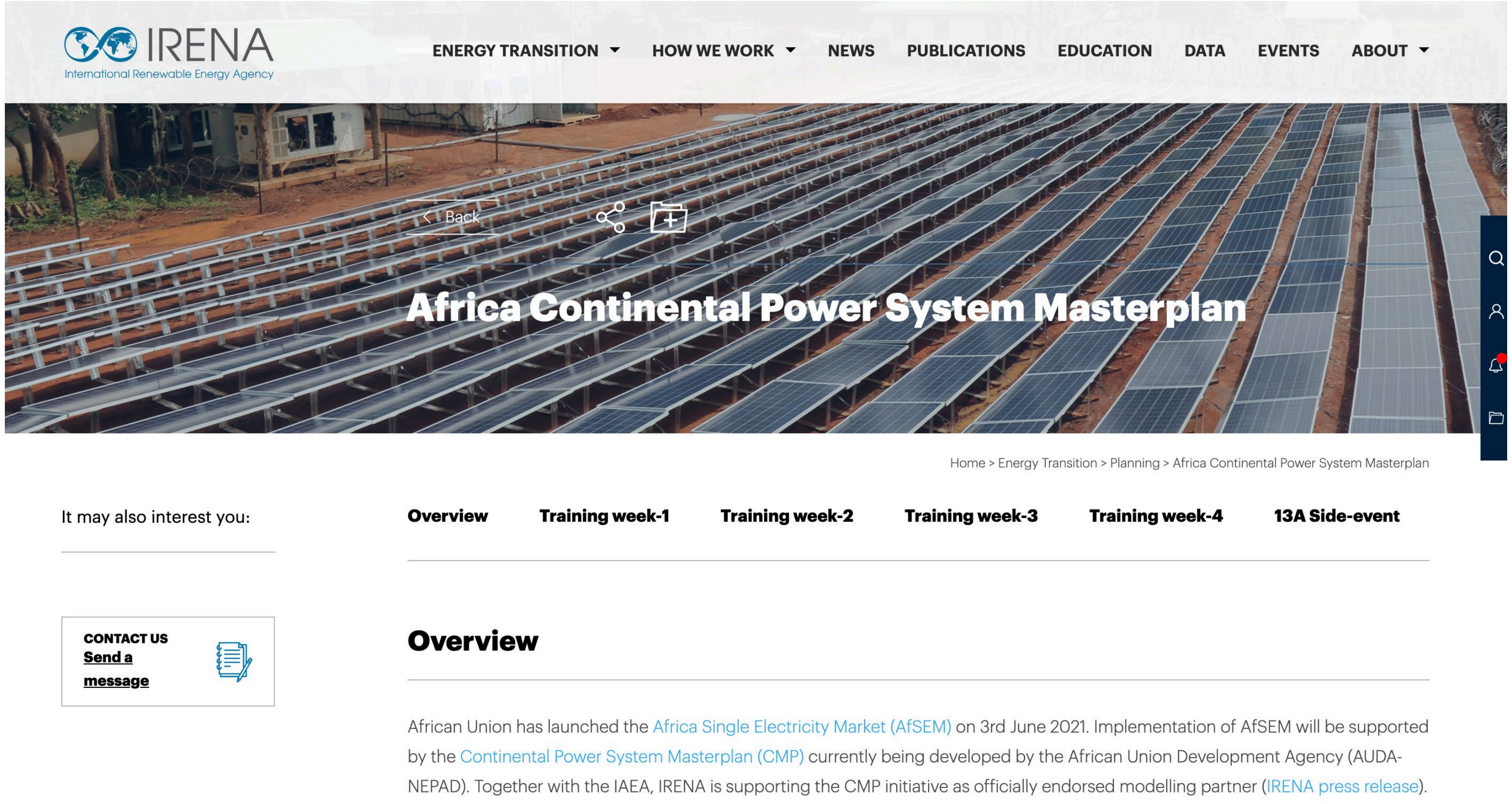
Generation profiles for run of river based hydropower plants



Generation profiles for dam based hydropower plants



IRENA report:
https://www.irena.org/publications/2021/Dec/African-Renewable-Electricity-Profiles-Hydropower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Back

Africa Continental Power System Masterplan

Home > Energy Transition > Planning > Africa Continental Power System Masterplan

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Overview | **Training week-1** | **Training week-2** | **Training week-3** | **Training week-4** | **13A Side-event**

Overview

African Union has launched the Africa Single Electricity Market (AfSEM) on 3rd June 2021. Implementation of AfSEM will be supported by the Continental Power System Masterplan (CMP) currently being developed by the African Union Development Agency (AUDA-NEPAD). Together with the IAEA, IRENA is supporting the CMP initiative as officially endorsed modelling partner (IRENA press release).

https://www.irena.org/Energy-Transition/Planning/Africa-Continental-Power-System-Masterplan

Relevant Continental Initiatives for power sector development

- **Programme for Infrastructure Development in Africa (PIDA) – AUC/AUDA/AfDB**
- **Africa Single Electricity Market (AfSEM) - AUC**
- **Continental Masterplan – AUDA under AU**
  - Blueprint for the AfSEM, identifying key priorities for generation and transmission projects
  - Selection of IRENA and IAEA as modelling partners
  - Phase I: Baseline studies (2020), Phase II: the development of the CMP (2021-2023), Phase III: mobilization of finance, energy planning capacity building support, updating the CMP (2024-2029)

CMP Flagship Project

- IRENA inputs developed to support decision-making on energy component in Africa.
- In 37th AU assembly on 17-18 Feb 2024, the African heads of States officially endorsed the first CMP plan as an AU Agenda 2063 Flagship Project

CMP TOR – Modelling CMP (Phase 2)

Baseline studies by EU-TAF team (CMP phase 1)

- Review of regional masterplans
- Development of TOR for the CMP phase 2 (Jan 2021)

Key elements in the TOR

- Inform PIDA process by identifying the priority projects of regional significance
- Create harmonized planning process across 5 power pools
- Detailed modelling and planning studies
  - Transfer of know-how to ensure the sustainability
  - Permanent modelling team at AUDA-NEPAD and Power pools
  - Adoption of common modelling tools
  - Participatory, collaborative, consultative process
  - Coherence with PIDA, and AfSEM process


AUDA-NEPAD
Mission in Johannesburg
CAPP - COMELEC - EAPP - SAPP - WAPP
17-19 November 2021
IRENA
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Contents

1. Overview - IRENA's support for African energy transition planning & CMP
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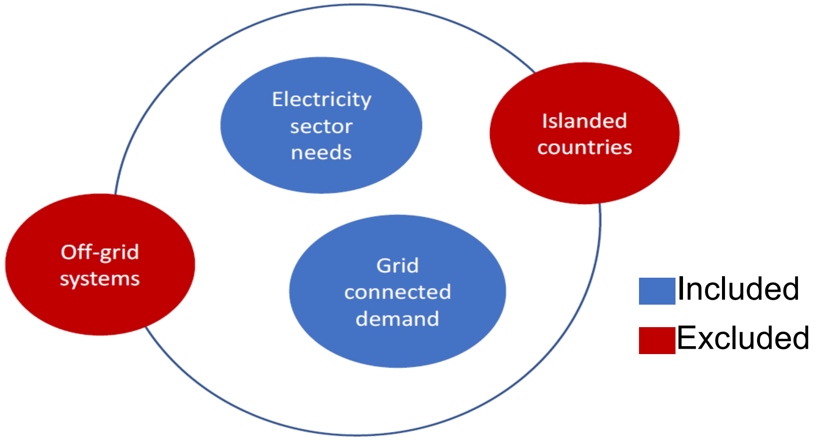
CMP – Key capacity expansion modelling outcomes

CMP modelling team (Kigali, March-2023)

Tools and Scope of first CMP exercise

➢ **Demand projections prepared for:**

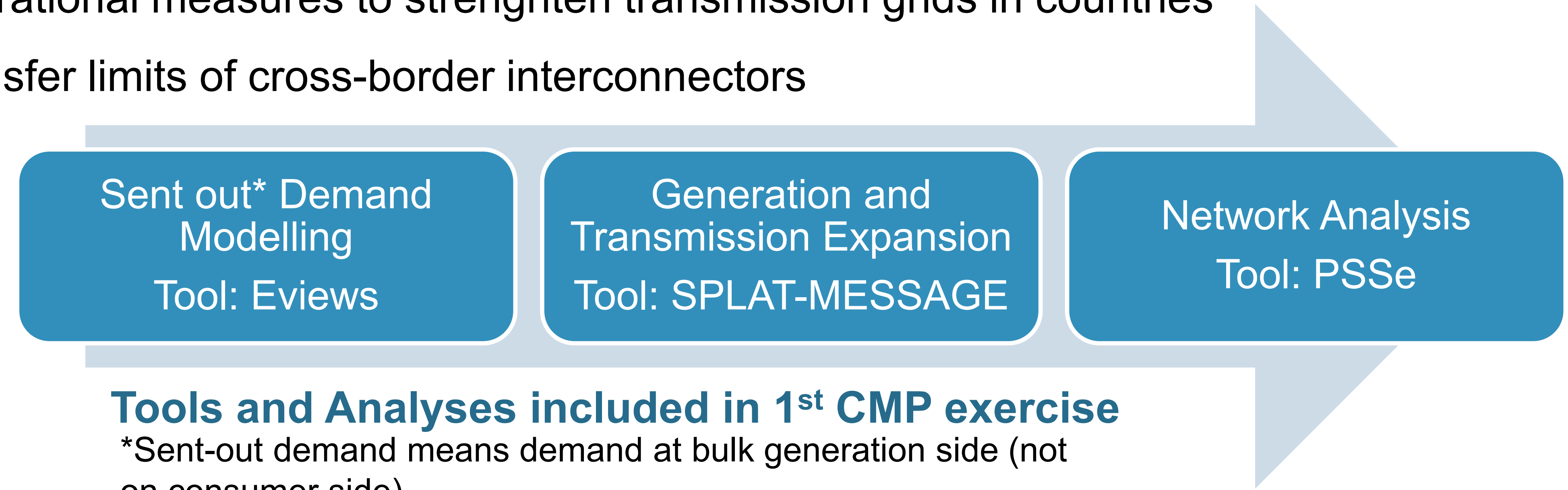
- Business-as-usual case
- Three cases of higher demand growth (Slow, Medium, High) to meet socio-economic goals as per African Union Agenda 2063



Analysis Boundary

➢ **Network analysis included assessment of:**

- Operational measures to strenghten transmission grids in countries
- Transfer limits of cross-border interconnectors



Tools and Analyses included in 1st CMP exercise

*Sent-out demand means demand at bulk generation side (not on consumer side)

Scenario definitions

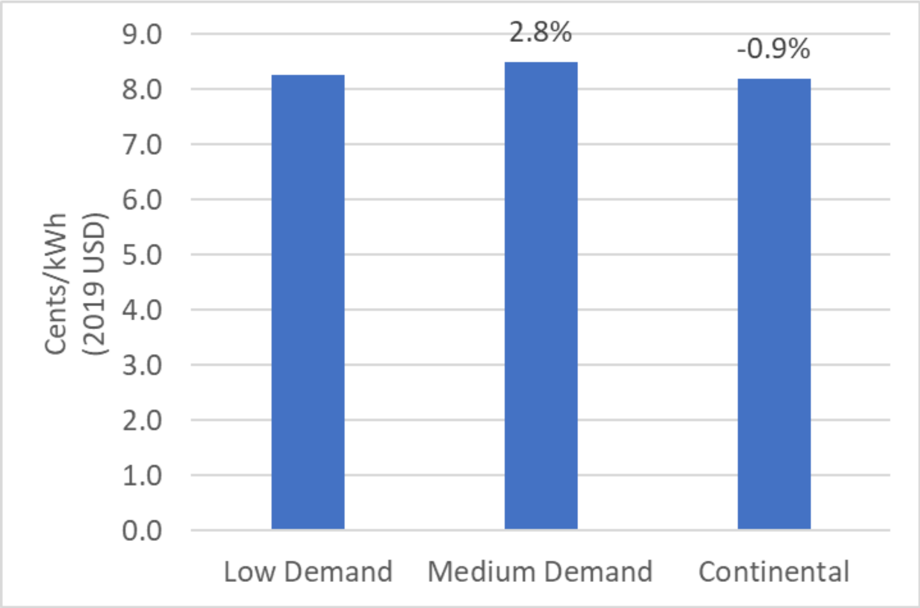
» For CMP scenario defining, stakeholders agreed on two dimensions: **Demand evolution and degree of coordination among African countries**

Demand-side Scenarios	**Cross-border integration levels**		
	Planned integration	Full regional integration	Full continental integration
Reference	**Low Demand, ***		
Transition - Low			
Transition - Medium	**Medium Demand**	*	**Continental, ***
Transition - High			

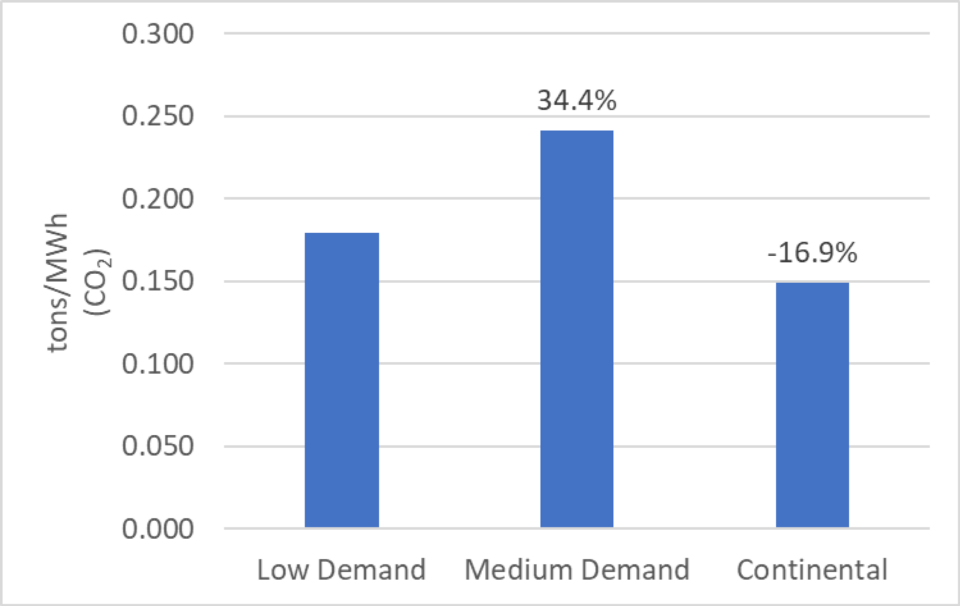
* The CMP scenarios officially designed

Key outcome of CMP expansion scenarios

- The increased energy demand can be met at lower emission and cost rate through more cross-border integration of national electricity systems



Average unit cost of generation through 2019-2040



Average emission intensity through 2019-2040

Key outcome of CMP expansion scenarios

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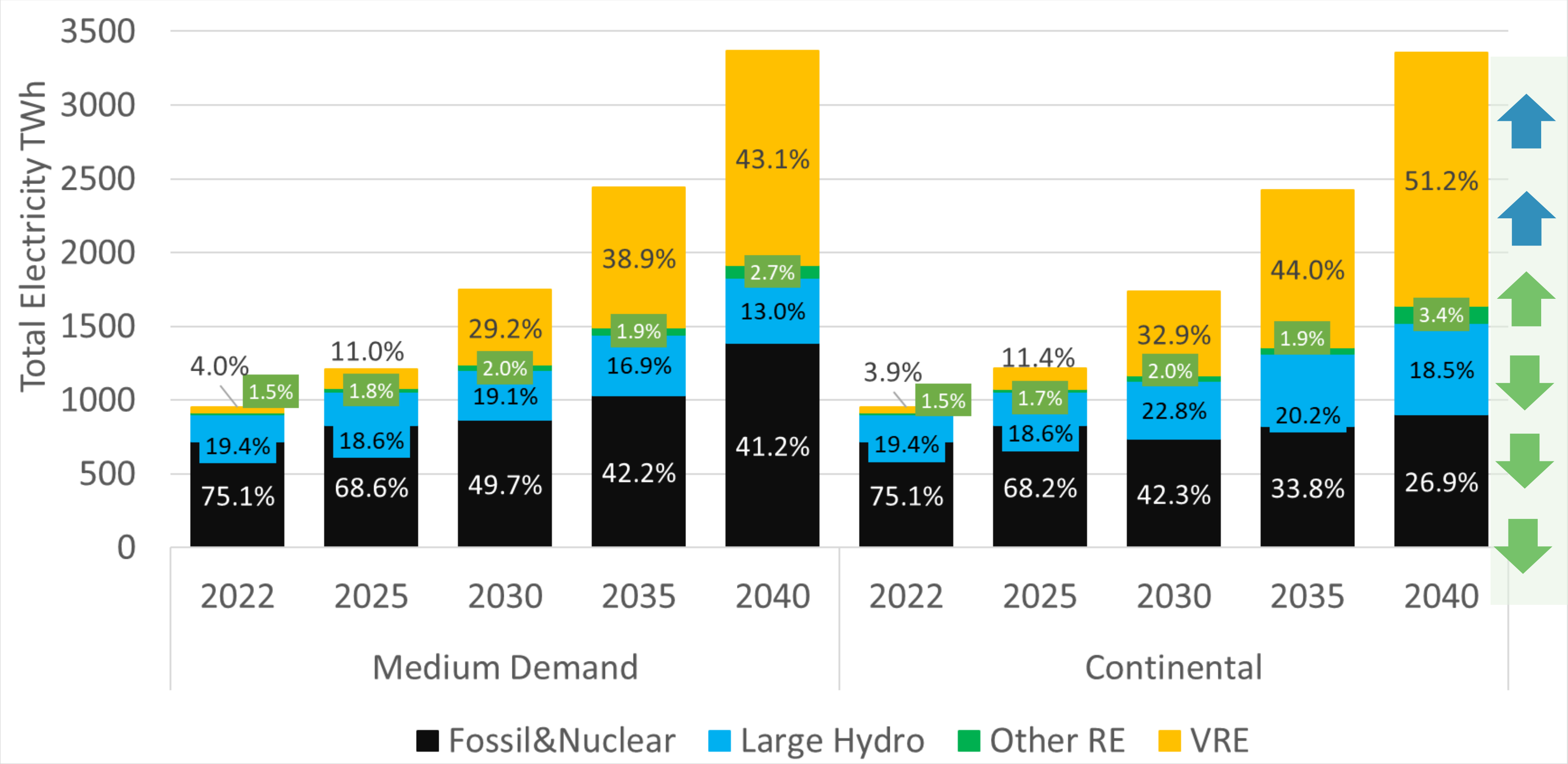
- Regional integration promotes renewable electricity & lowers reliance on fossil fuels



- 151 GW Interconnection capacity in 2040 vs 42 GW in medium demand scenario (+253%)
- 12 % more investment *
- 14.3% higher RE share in 2040
- 13% lower CO_2 emissions *
- 14% lower fuel costs in 2040
- 2.5% lower unit production price through 2019-2040

* Cumulated 2022-2040

Note: Variable Renewable Energy VRE (solar PV, Wind onshore & offshore); Other RE (Geothermal, solar thermal, Biomass); Large Hydro (Dam or Run of River)

Installed Capacity in continental integration scenario

Significant expansion needs:

- **Total installed capacity in 2040 is over 5 times higher than in 2022.**
- **VRE corresponds to 42% of total installed capacity in 2040**

Installed Capacity GW		
	2022	**2040**
VRE		
Solar PV	6	224
Wind	8	335
Storage		
Battery Storage	0	28
Pump Storage	3	7
Large Hydro PP		
Large Hydro ROR	10	77
Large Hydro Dam	27	47
Other RE		
Geothermal	1	5
Solar Thermal	1	13
CrossBorder Interconnectio	19	151

Investment requirements

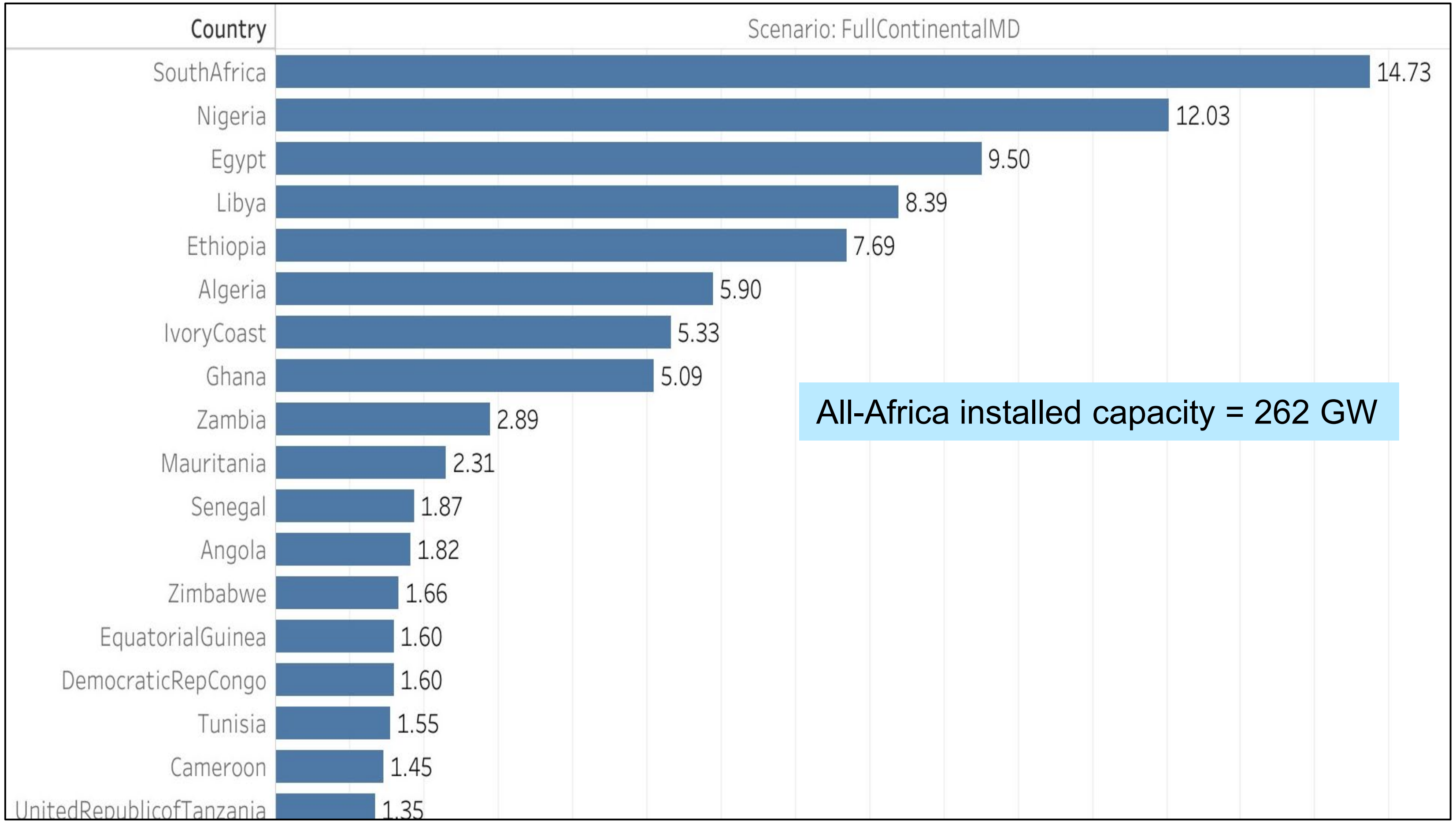
- Total investments per annum would represent roughly 2.1 % of Africa's current GDP (~3.1 Trillion USD as per Statistica.com)
- Roughly 1 trillion USD would be needed for low-carbon technologies

Technologies	Investment Bln. USD	% of total
Wind onshore	498	35.2%
Natural Gas	315	22.3%
Run of River Hydro	160	11.3%
Utility Solar PV	154	10.9%
Coal	60	4.2%
Dam Hydro	56	4.0%
Solar Thermal	47	3.3%
Nuclear	32	2.2%
Interconnections (generic)	31	2.2%
Battery Storage	21	1.5%
Geothermal	17	1.2%
Diesel	7	0.5%
Pump Storage	6	0.4%
Interconnections (Committed & Candidate)	5	0.3%
Biomass	3	0.2%
HFO	2	0.2%
Total	**1,413**	

Investment requirements for the continental integration scenario through 2019-2040 (2019USD)

RE Hubs – Technology specific lead countries (Continental integration Scenario)

Solar PV, Wind onshore and Run of River Hydro make up 91% of RE capacity in 2040

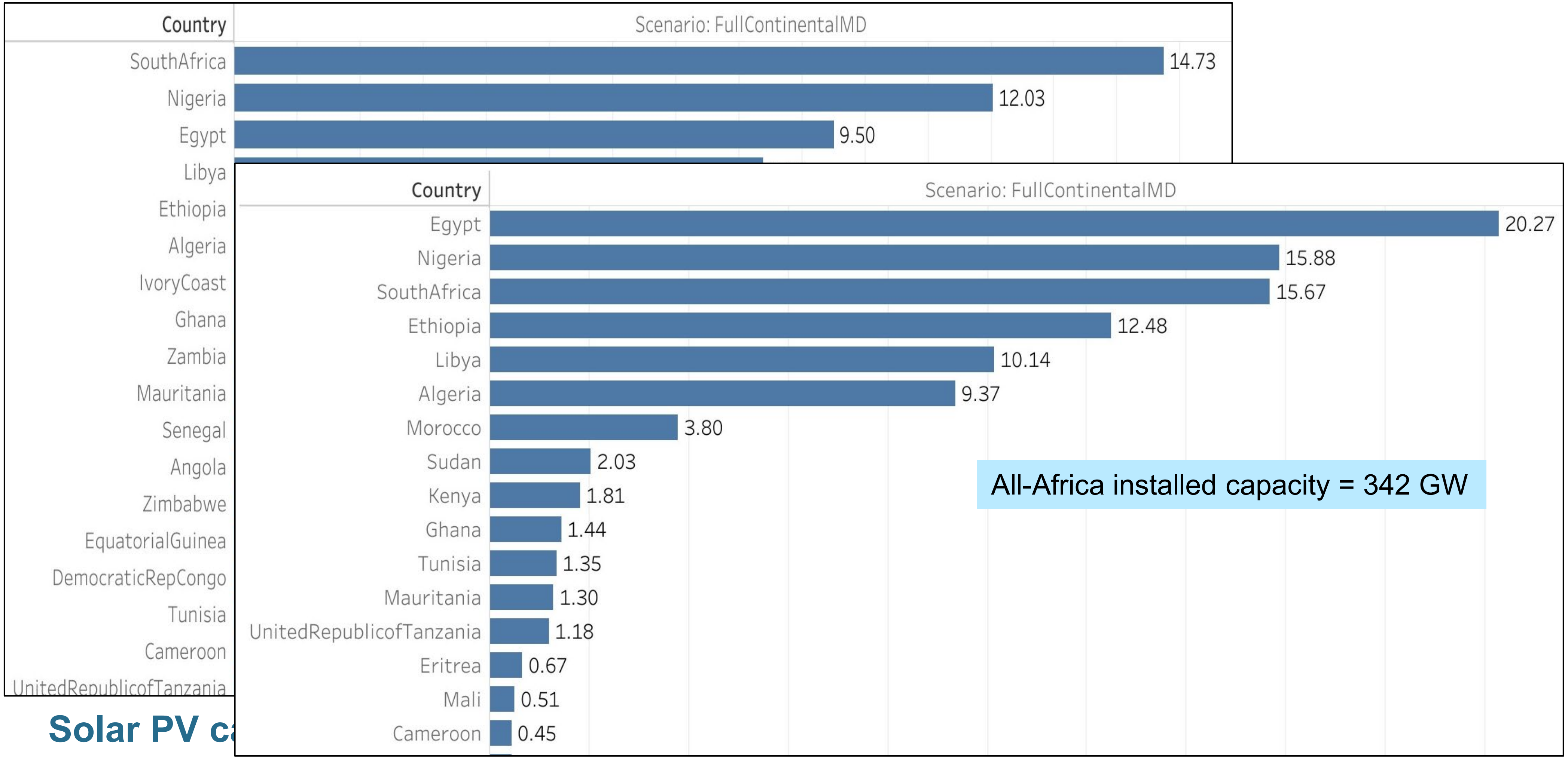


Solar PV capacity (% of continental sum) (2040)

RE Hubs – Technology specific lead countries (Continental integration Scenario)

Solar PV, Wind onshore and Run of River Hydro make up 91% of RE capacity in 2040

» The big six countries will have 58% Solar PV and 84% Wind onshore



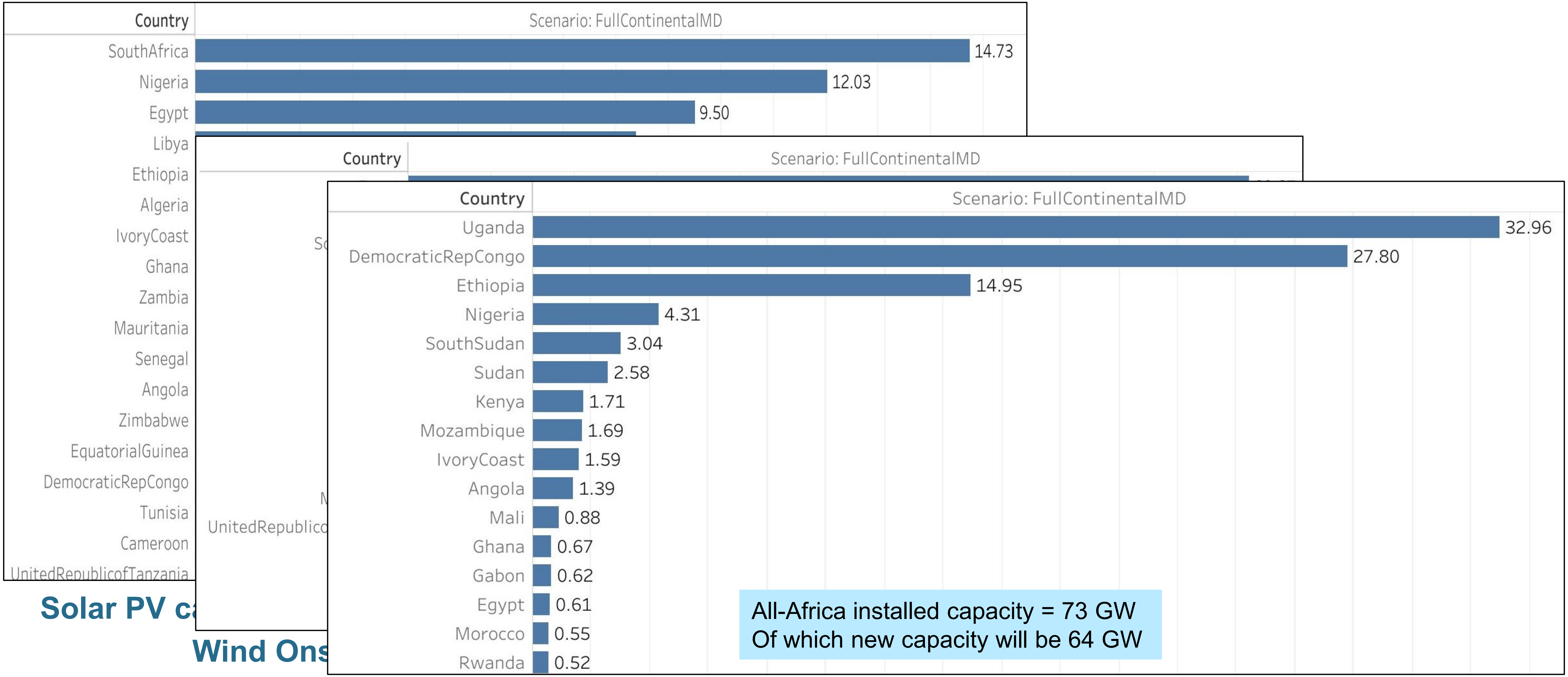
Solar PV ca

Wind Onshore capacity (% of continental sum)(2040)

RE Hubs – Technology specific lead countries (Continental integration Scenario)

Solar PV, Wind onshore and Run of River Hydro make up 91% of RE capacity in 2040

- The big six countries will have 58% Solar PV and 84% Wind onshore
- 90% of run of river hydro will be concentrated in just 10 countries

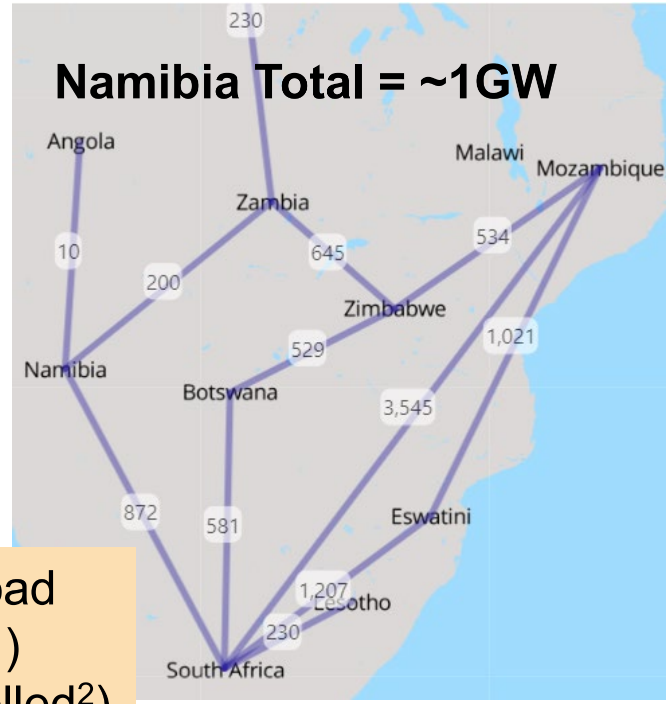


Run of River Hydropower Capacity (% of continental sum) (2040)

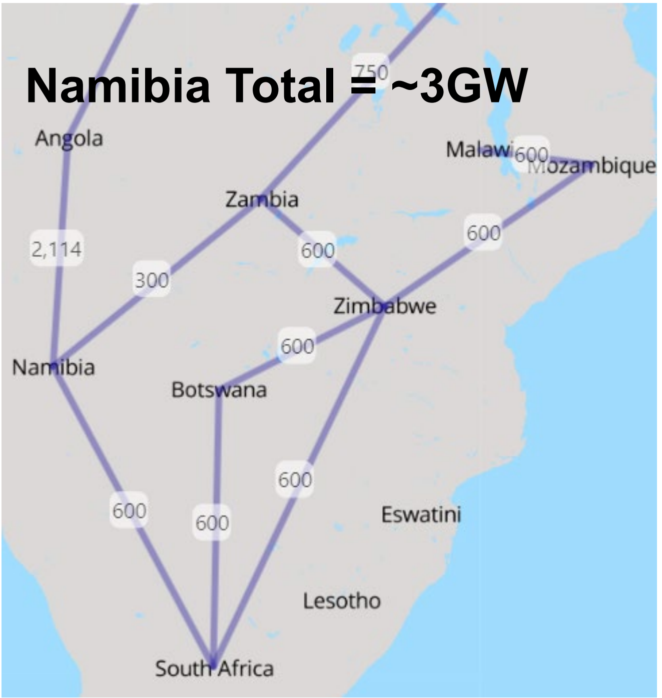
Case study Namibia – Impacts of regional integration

Scenarios

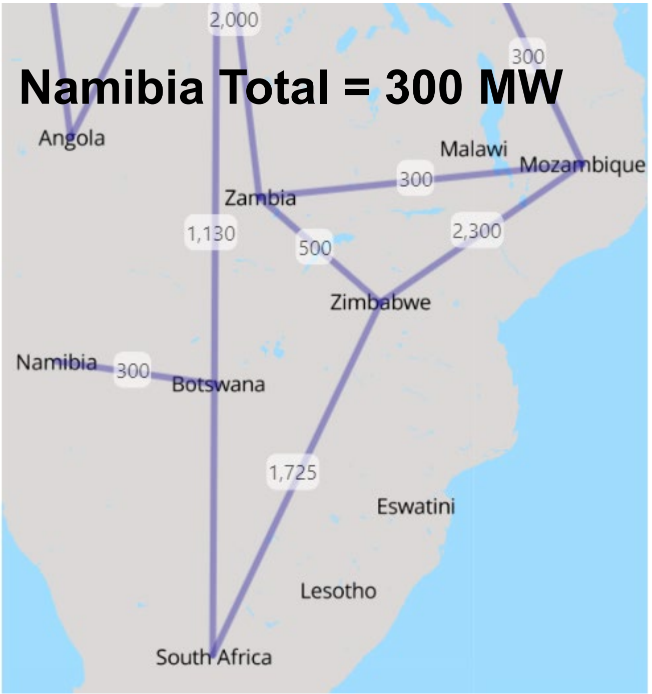
- **No Integration:** only Namibia supply is optimized, no trade & reserve capacity shared from crossborder
- **Constrained Integration:** CMP medium demand scenario in which Namibia must achieve 100% self sufficiency by 2040 (i.e. zero net annual imports), reserve capacity shared from crossborder
- **Full Integration (Optimal Case):** CMP medium demand scenario involving optimal energy trade, reserve capacity shared from crossborder



Existing



Committed



Planned

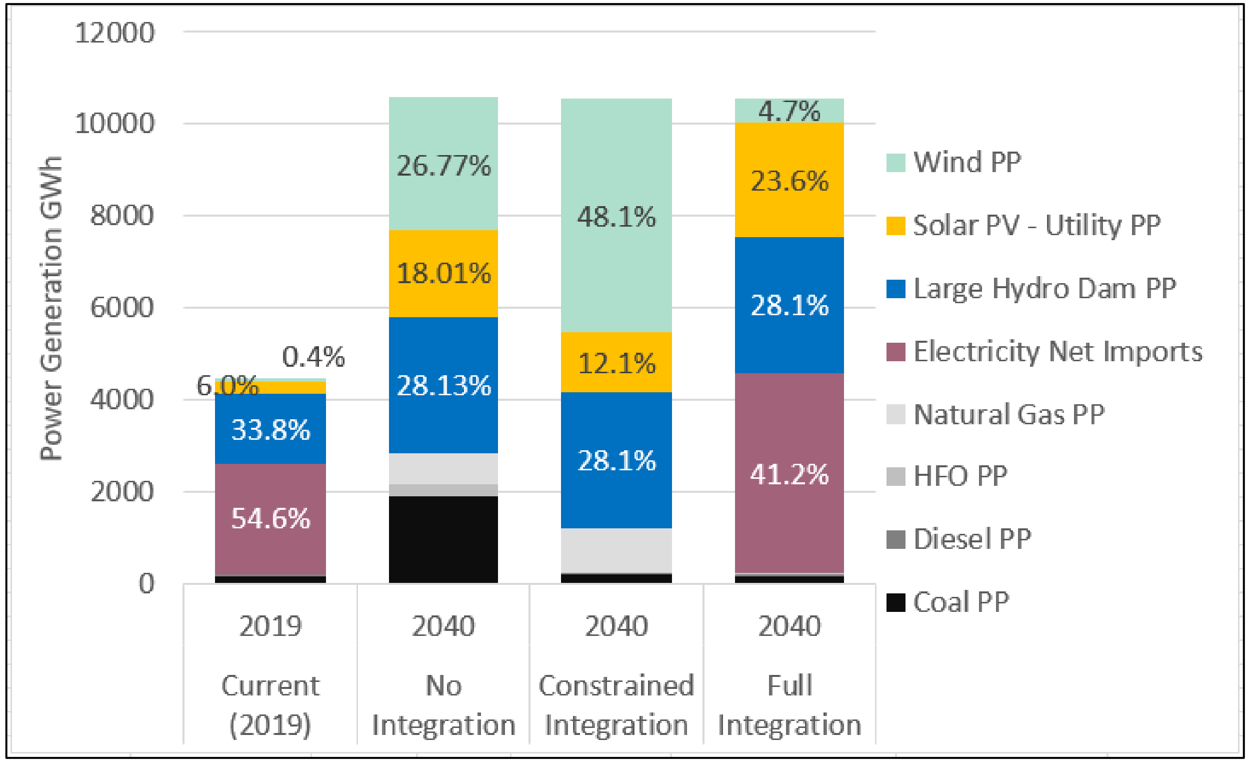
Namibia's peak load
0.63 GW (2019[1])
1.2 GW (2040 modelled[2])

Cross-border interconnection capacity (MW) represented in continent's reference energy system (region relevant to Namibia)

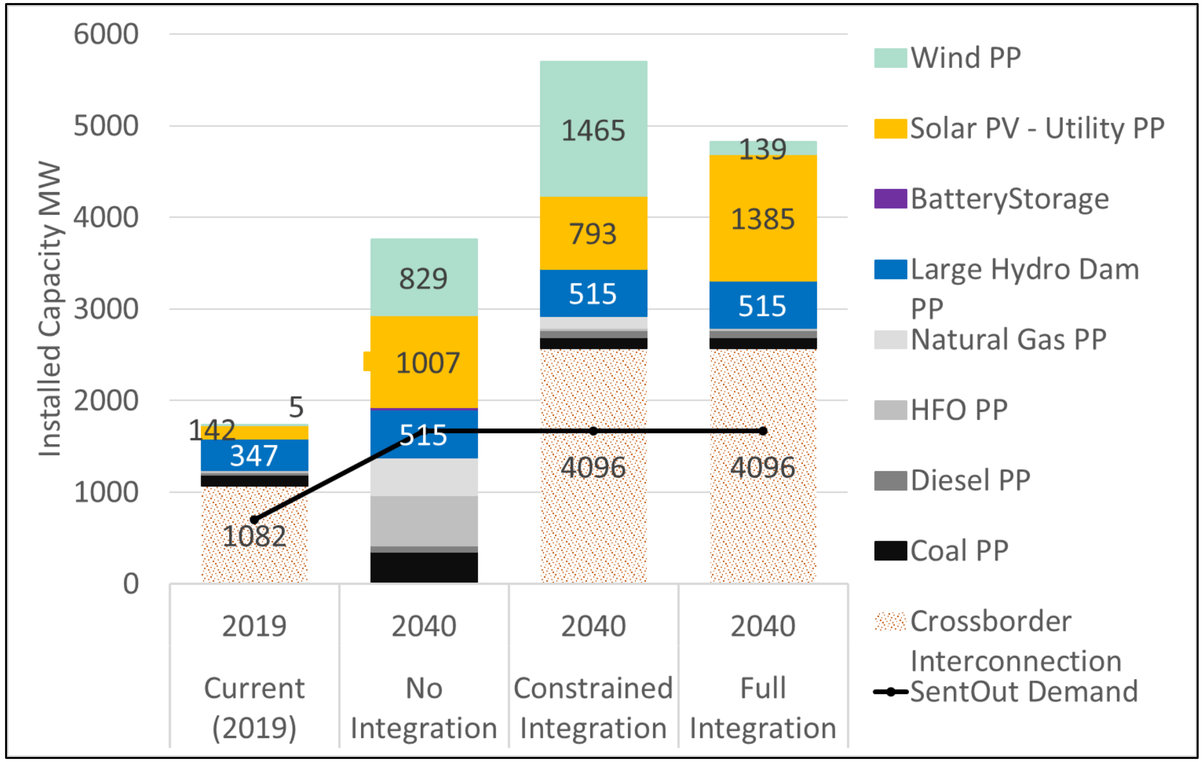
[1](Gov. Namibia, 2022)
[2](AUDA-NEPAD, 2023)

Key takeaway: Regional integration promotes RE

- Dam-based hydro is fully utilized in all scenarios
- **No Integration scenario** favors fossil capacity to meet reserve margin needs
- **Constrained integration scenario** sees dominant role of wind combined with bi-directional energy trade



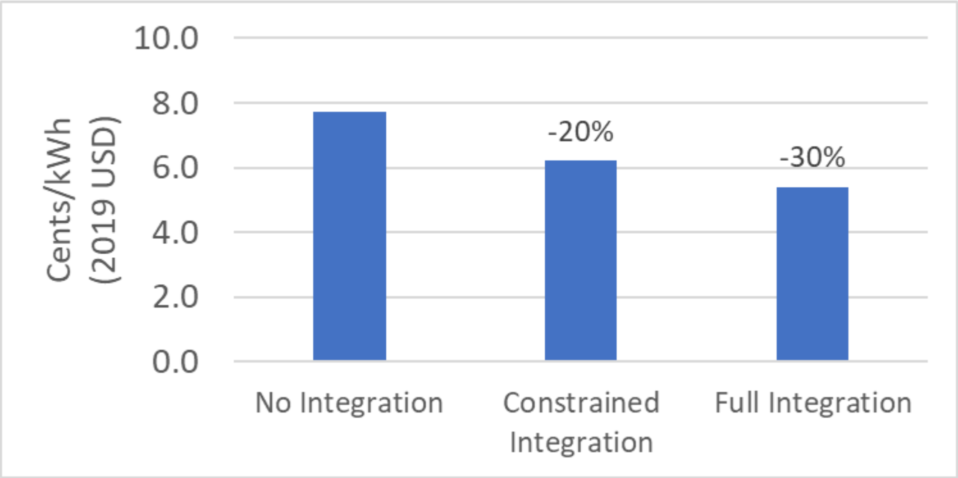
Electricity production mix



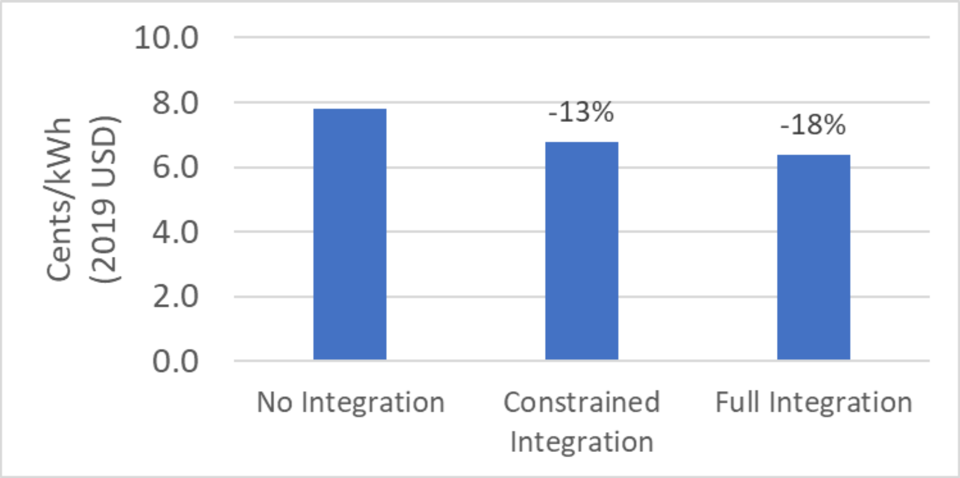
Generation capacity mix

Key takeaway: Regional integration lowers unit energy costs

- Unconstrained trade allows lower unit costs of electricity and less dependence on fossil fuels



Average unit cost of domestic production through 2019-2040



Average unit cost of domestic production in 2040

- Continental framework of SPLAT-MESSAGE is key to capture benefits of trade!

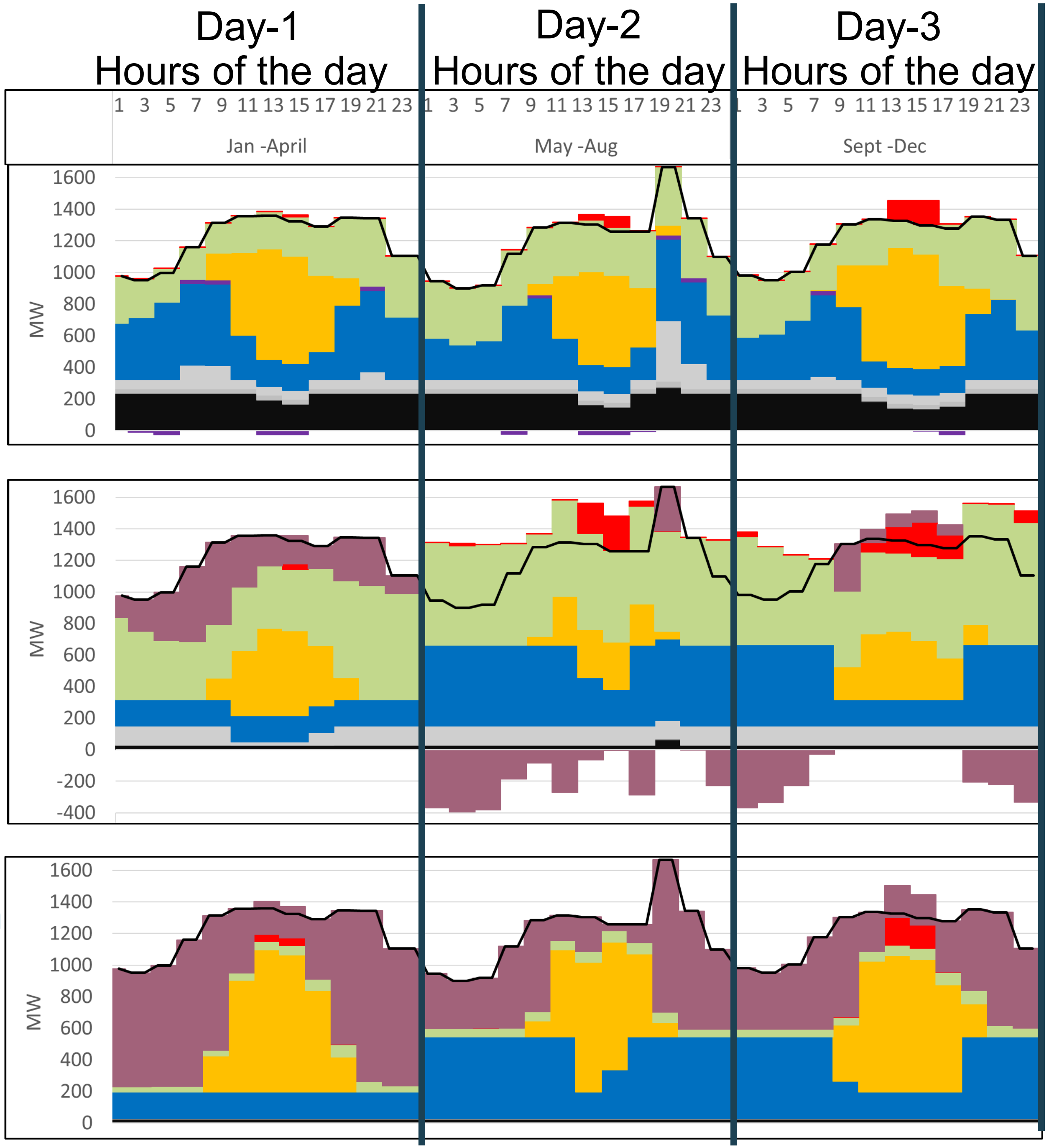
Role of different Resources

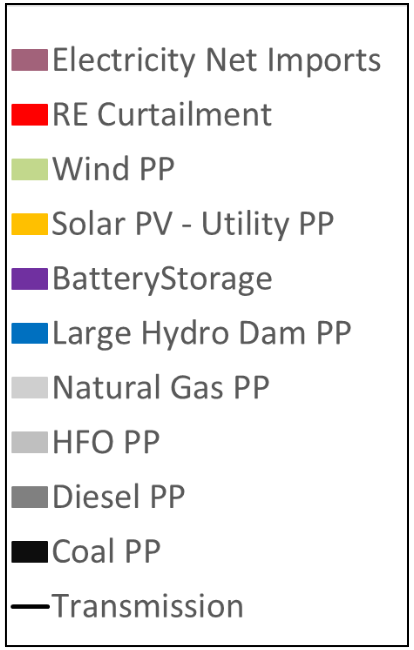
- Hydro flexibility is critical in all scenarios
- Battery plays a minor role only in **no integration scenario**
- In **constrained integration scenario**, wind is favored as it complements regional needs & periods of no sun

No Integration

Constrained Integration

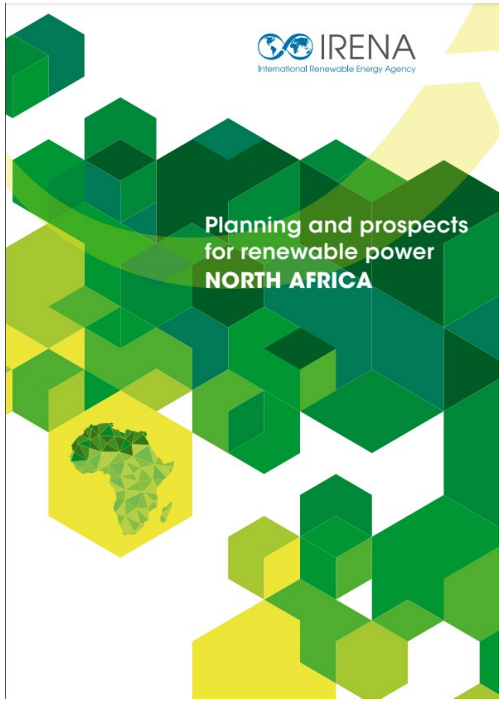
Full Integration





Case study North Africa – Scenarios of energy transition including green hydrogen

https://www.irena.org/Publications/2023/Jan/Planning-and-prospects-for-renewable-power-North-Africa



Planning and prospects for renewable power: North Africa

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International Renewable Energy Agency

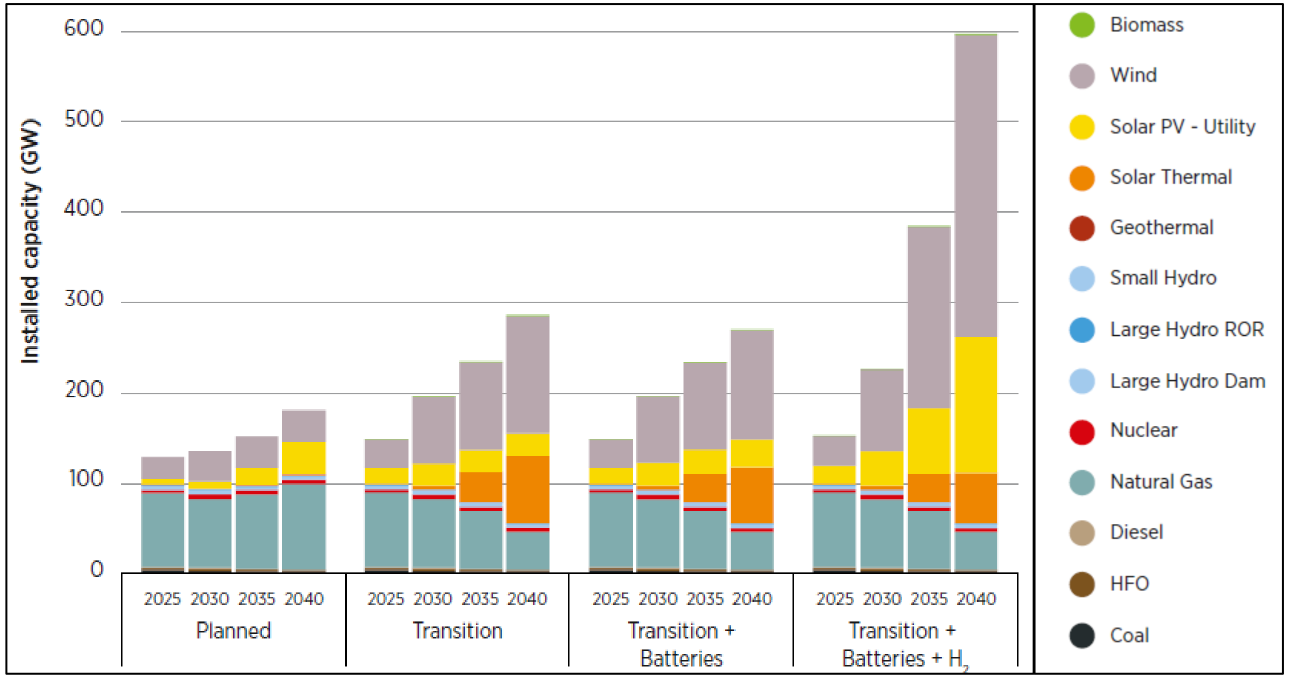
- The report outlines different power supply expansion scenarios for North Africa using SPLAT-MESSAGE

PLANNED	TRANSITION	TRANSITION + BATTERIES	TRANSITION + BATTERIES + H_2
Historic demand growth and electrification levels Current interconnection capacity Countries' renewable energy targets are met but not surpassed	Higher demand growth with higher electrification of end uses Possibility to increase interconnection capacity No fossil-fuel-based generation investment after 2025 Renewable energy targets can be surpassed	Higher demand growth with higher electrification of end uses Possibility of increasing interconnection capacity No fossil-fuel-based generation investment after 2025 Renewable energy targets can be surpassed	Higher demand growth with higher electrification of end uses Possibility of increasing interconnection capacity No fossil-fuel-based generation investment after 2025 Renewable energy targets can be surpassed
		Battery storage	Battery storage
			Hydrogen production

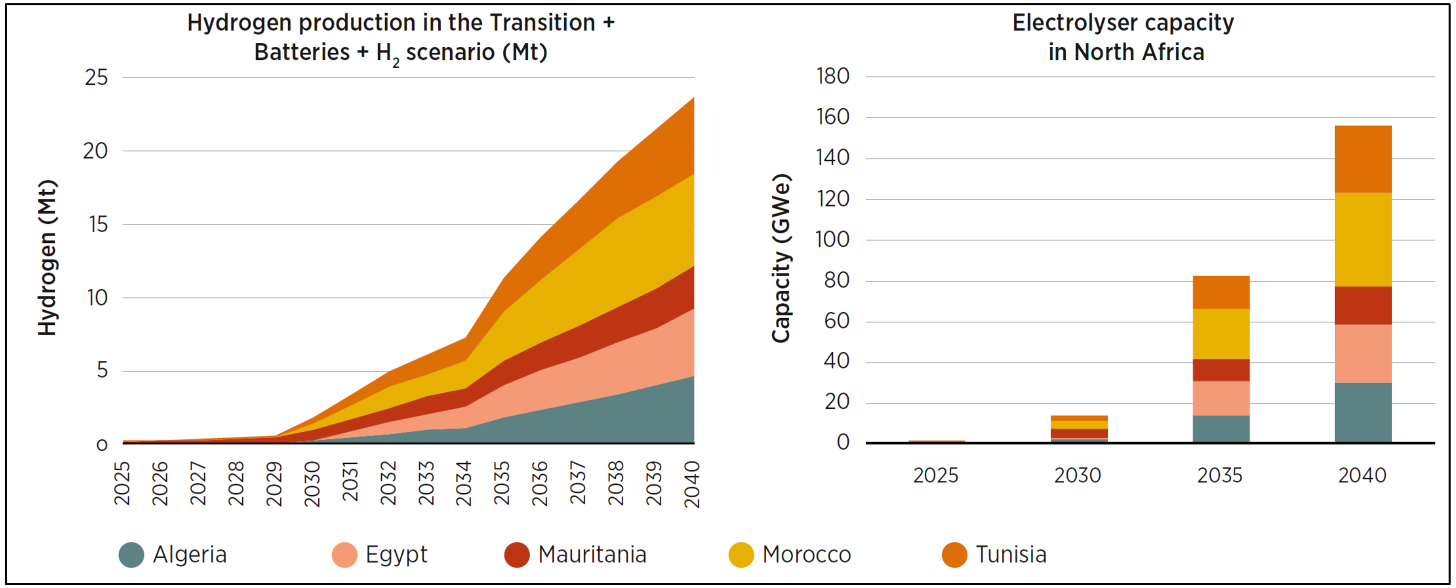
Supply scenarios for North Africa

Assessment of North Africa's potential for hydrogen supply

- **Question addressed by the hydrogen scenario:** Against an assumed acceptable export price of green hydrogen starting from 3.5 USD/kgH_2 in 2025 and ending at 2 USD/kgH_2 in 2040, how much green hydrogen can be produced in North-Africa from electricity sourced through bulk grid



Installed capacity projections in four scenarios



Country wise potential to produce hydrogen for exports

Impact on the bulk supply system

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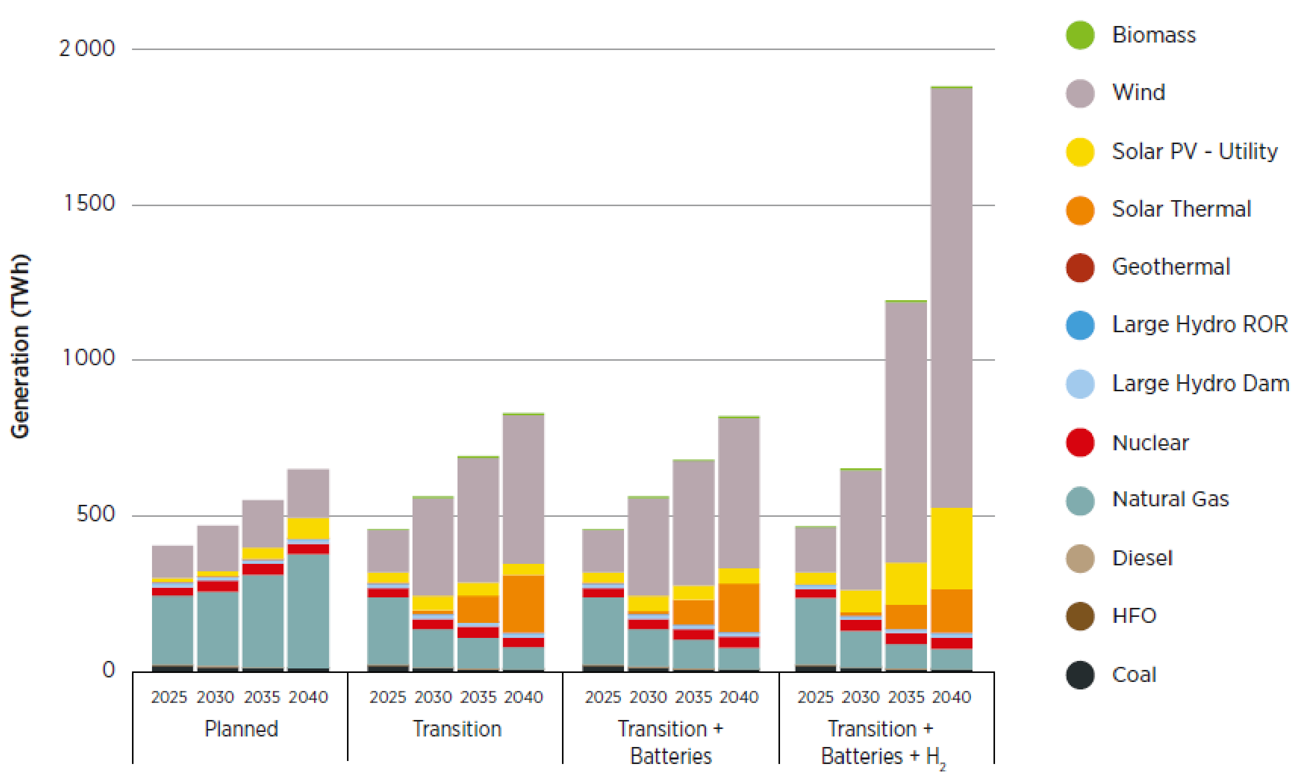
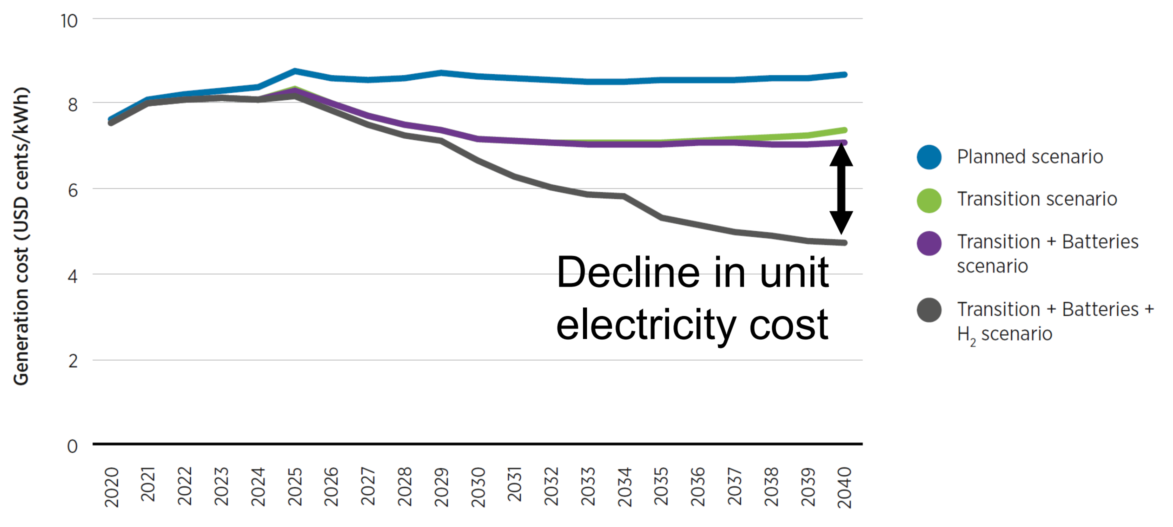
- Investing in RE generation infrastructure to tap hydrogen export market will make the bulk supply more cost-efficient



Note: H_2 = hydrogen; PV = photovoltaic; ROR = run-of-river; TWh = terawatt hour.

Evolution of energy mix in four scenarios



Evolution of unit energy costs in four scenarios

Electrolyzer flexibility potential

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- Electrolyzers unlocked additional flexibility in the system

YEAR	SCENARIO	TOTAL SENT-OUT ELECTRICITY (TWH)	POWER EXCHANGES (TWH)	SHARE OF POWER EXCHANGES IN TOTAL POWER DEMAND
2018	Historical	363	6	1.5%
2040	Planned scenario	662	24	3.6%
	Transition scenario	795	69	8.7%
	Transition + Batteries scenario	795	56	7.0%
	Transition + Batteries + H_2 scenario	795	43	5.4%

Total electricity trade flow projections in four scenarios

Hydrogen supply seasonality

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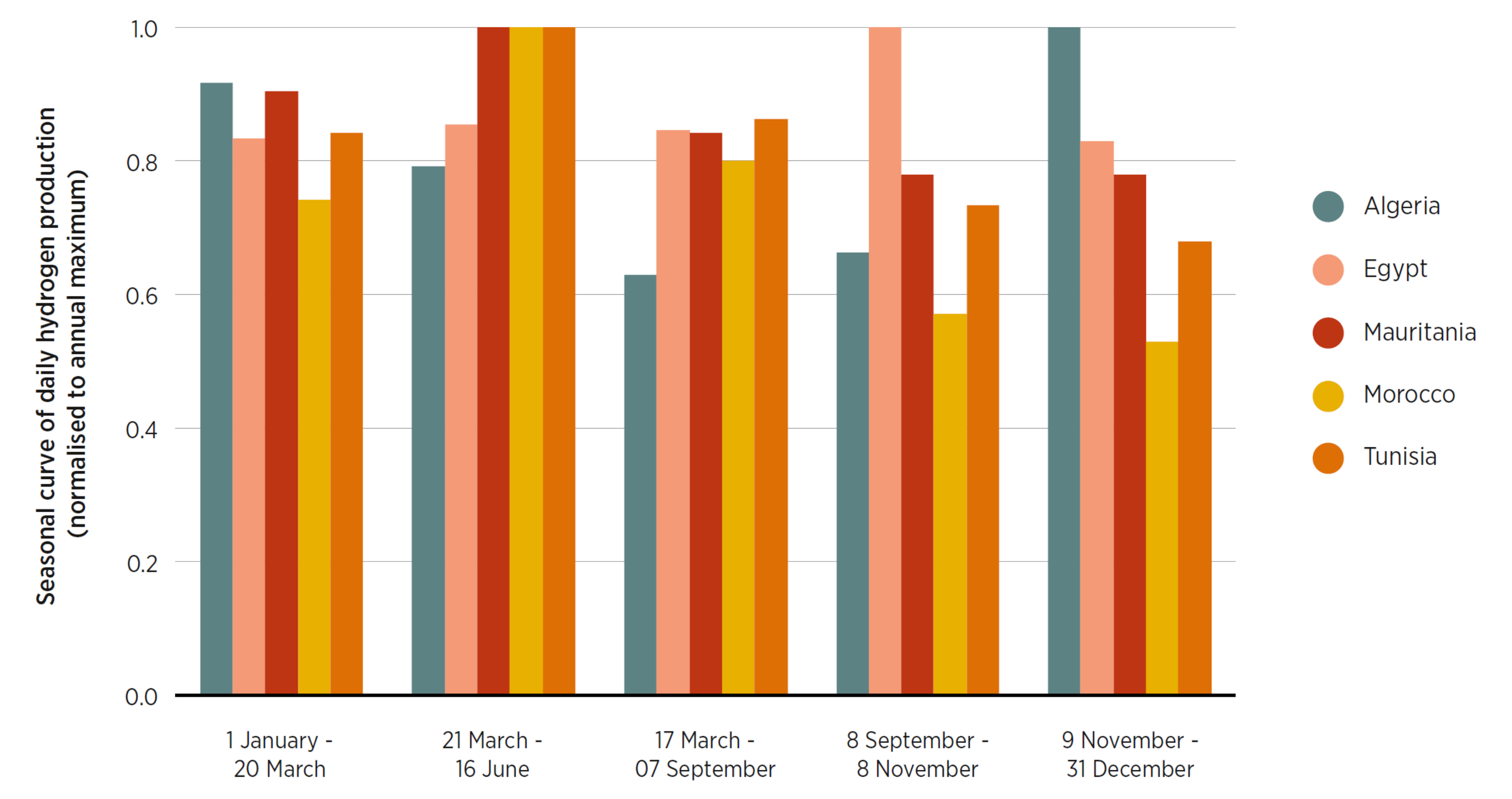
International Renewable Energy Agency

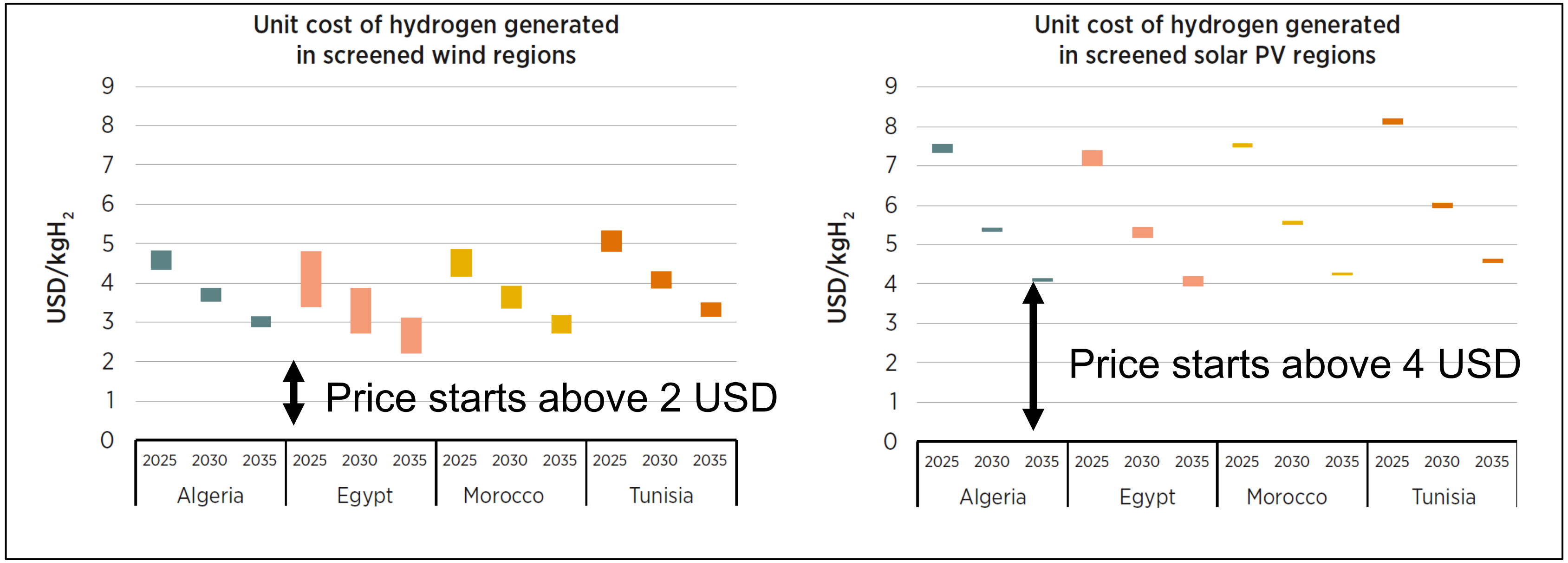
- Complementarity between countries can ensure stable hydrogen supply across the region



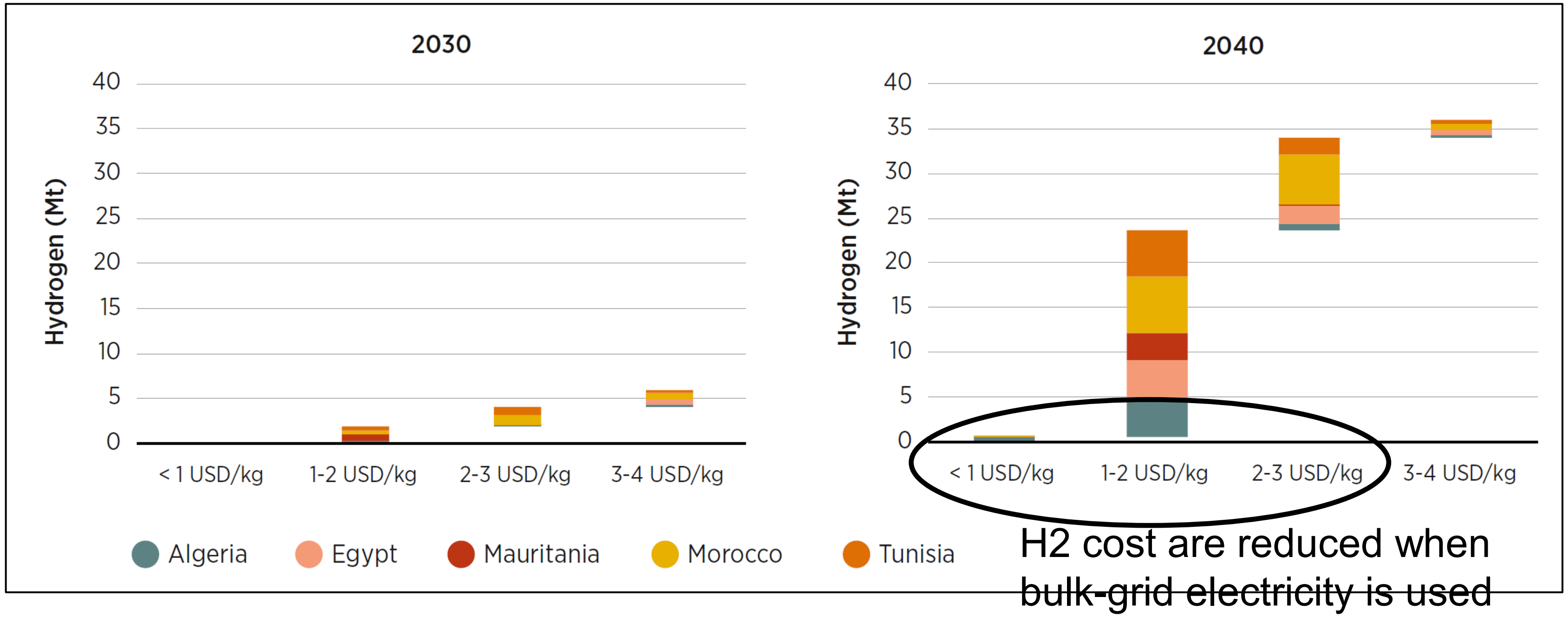
2040 Seasonal hydrogen production in transition + battery + H2 scenario

Cost of H2
Dedicated vs bulk grid supply

Hydrogen supply curve using **dedicated power supply**



Hydrogen supply curve using **electricity from bulk grid**



Ongoing work on SPLAT and other energy planning tools developed at IRENA

Regional Energy Transition Outlooks for Africa

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International Renewable Energy Agency

→ RETOs provide a scenario-based analysis for Africa's energy transition (2050) consistent with economic and sustainable development goals.

→ Scope: five regions with a key country.

→ RETO includes: 1) renewable energy transition in end-use sectors; 2) power systems analysis; 3) socio-economic analysis; 4) Policy and finance

Region	Deep dives
Central Africa	D.R Congo
Eastern Africa	Kenya
North Africa	Egypt
Southern Africa	South Africa
West Africa	Nigeria

Power sector and H2 analysis Framework

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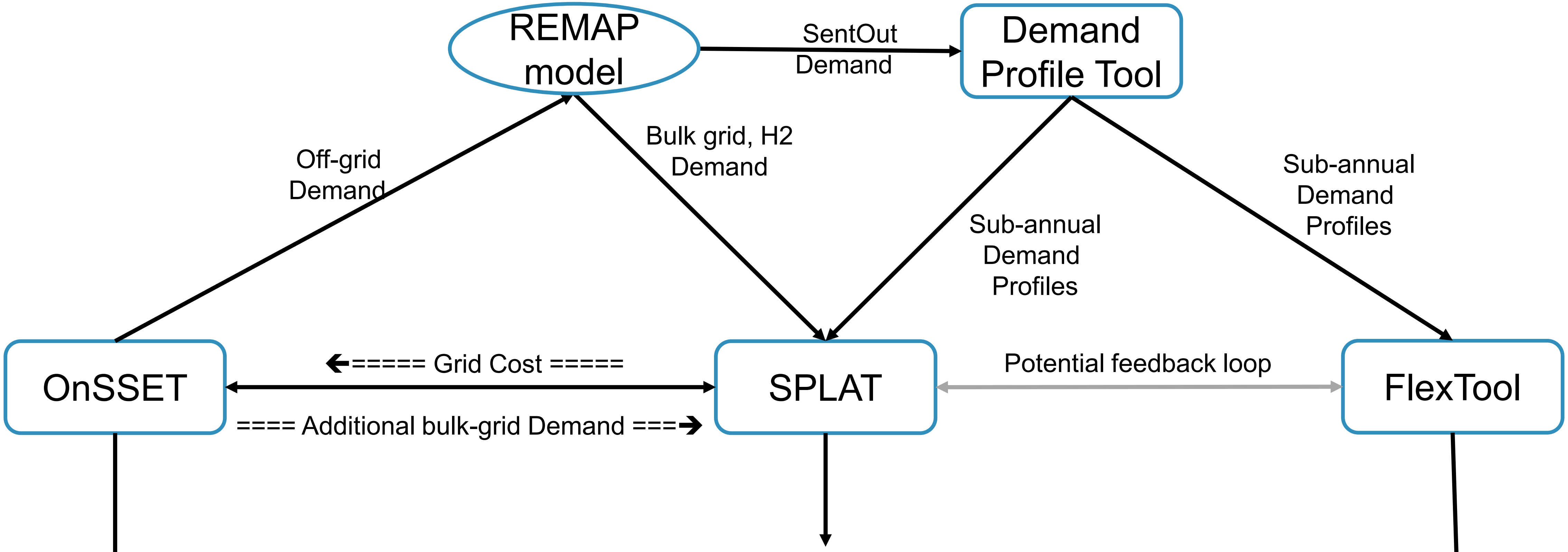


<u>Rural electrification planning</u>
(off-grid vs grid demand,
off-grid technologies and costs)

<u>Power Capacity Expansion</u>
(Generation and cross-border Tx expansion to meet future demand)
+
Hydrogen production for domestic use and exports

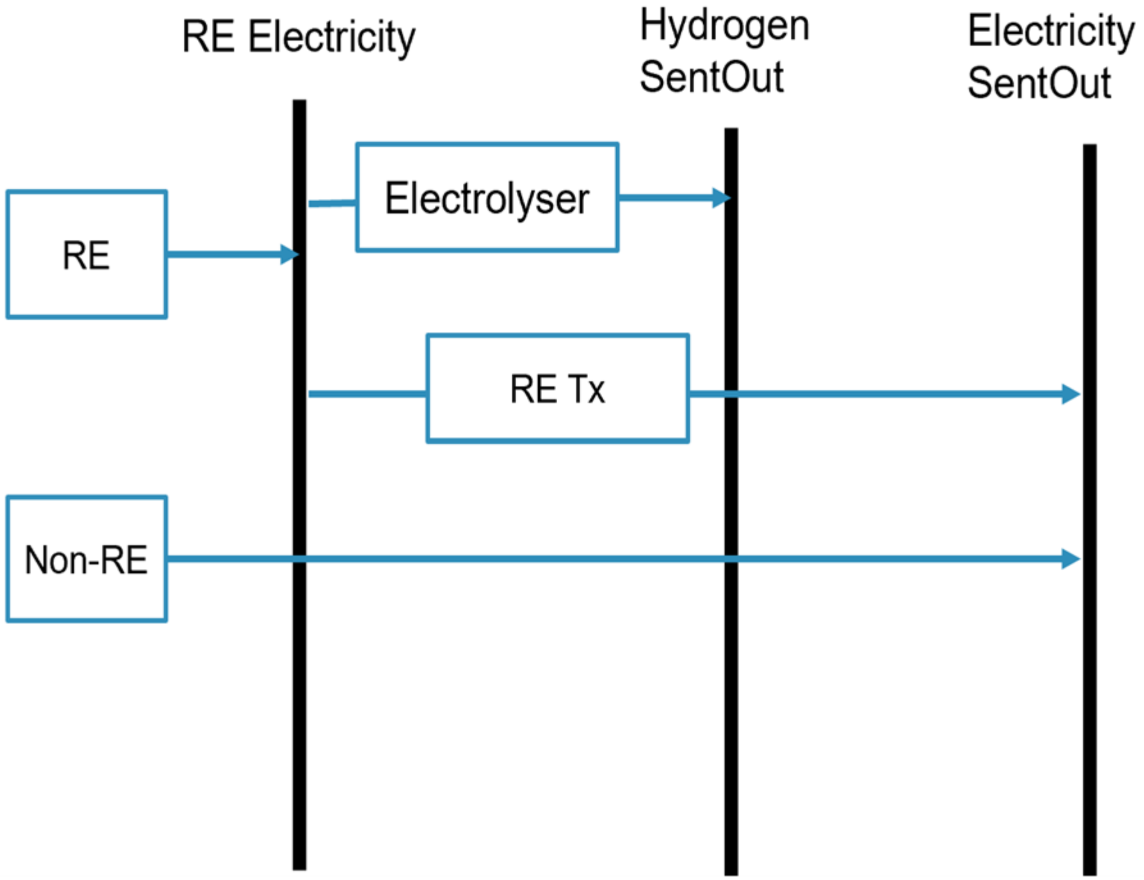
<u>Flexibility Assessment</u>
(hourly dispatch, loss of load, Curtailment, etc)

Power sector and H2 analysis Framework

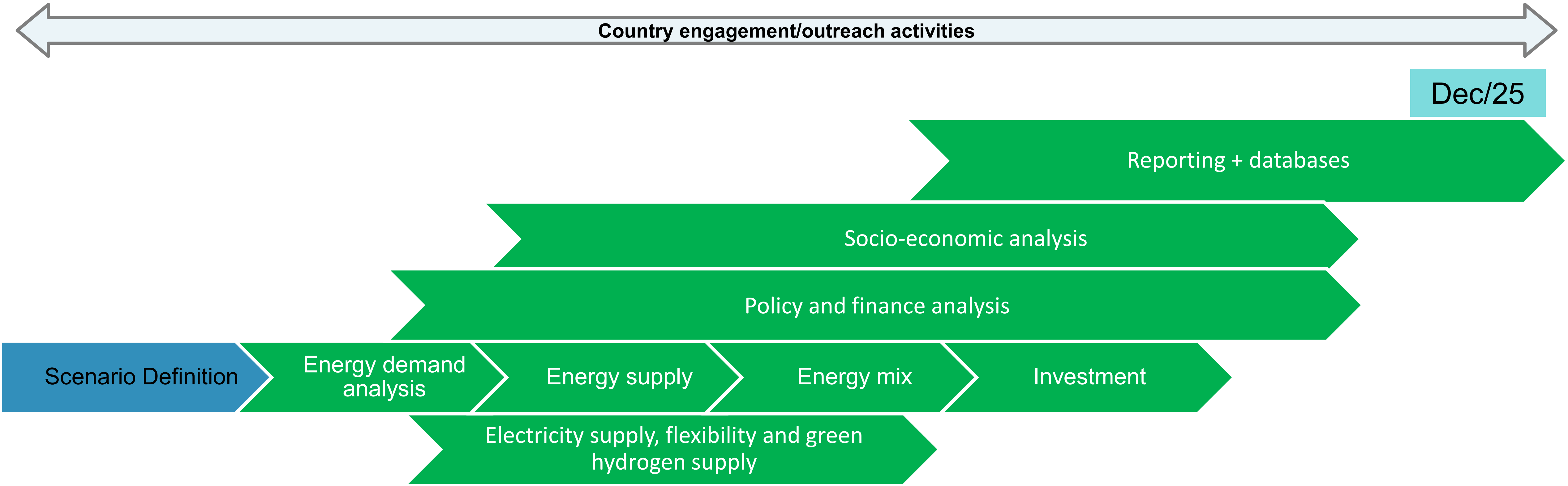
- Green hydrogen demand for domestic use and trade will be shared by REMAP

- Electrolyzers to be fed by utility scale renewable electricity generators that are also feeding the grid

- What we seek:
  - Countries with high green H2 potential
  - Lowering of unit electricity production costs
  - Investment requirements attached to H2 demand



Timeline


Country engagement/outreach activities
Dec/25
Reporting + databases
Socio-economic analysis
Policy and finance analysis
Scenario Definition
Energy demand analysis
Energy supply
Energy mix
Investment
Electricity supply, flexibility and green hydrogen supply

Thank You!

References

- AUDA-NEPAD (2023), "Integrated Continental Demand Forecasts-Scenario Analysis", https://cmpmwanga.nepad.org/publications
- Gov. Namibia (2022), Namibia Integrated Resource Plan (NIRP) Review and Update, https://www.mme.gov.na/files/publications/f74_29a_ELECTRICITY%20SECTOR%20NATIONAL%20INTEGRATED%20RESOURCE%20PLAN%20(NIRP)%202016%20FINAL%20REPORT.pdf