THE FUTURE OF HYDROPOWER
FROM A TECHNOLOGY PROVIDER’S VIEW
DIEGO VILANOVA
JULY, 9TH, 2023
"IT ALWAYS SEEMS IMPOSSIBLE UNTIL IT'S DONE."

—NELSON MANDELA
HUMAN WELL-BEING IS A DIRECT FUNCTION OF POWER CONSUMED

Electricity – blood stream for human development

Source: Dr. Bruce Dale, Michigan State University
Hydropower generation
~150,000 GWh/year

Technically feasible potential
~1,600,000 GWh/year

Hydropower demand by 2030 *
~ +150,000 GWh/year

* Sustainable Africa Scenario (SAS) states that doubling of the current hydro capacity is required by 2030 capacity.

Source: Hydropower & Dams World Atlas 2022
AFRICA - TODAY

Hydropower capacity by region in 2022

- **North and Central America**: 206 GW Hydropower capacity
  - New hydropower installed capacity: 1,142 MW
- **Europe**: 258 GW Hydropower capacity
  - New hydropower installed capacity: 2,712 MW
- **South and Central Asia**: 164 GW Hydropower capacity
  - New hydropower installed capacity: 1,940 MW
- **South America**: 177 GW Hydropower capacity
  - New hydropower installed capacity: 1,525 MW
- **Africa**: 40 GW Hydropower capacity
  - New hydropower installed capacity: 1,860 MW
- **East Asia and Pacific**: 548 GW Hydropower capacity
  - New hydropower installed capacity: 24,944 MW

Hydropower generation by region in 2022 (TWh)

- **East Asia and Pacific**: 1,714 TWh
- **North America**: 723 TWh
- **South America**: 569 TWh
- **Europe**: 712 TWh
- **South and Central Asia**: 539 TWh
- **Africa**: 150 TWh

Source: IHA, 2023 World Hydropower Outlook
Hydropower remains the continent's primary renewable resource at over 40 GW of installed capacity.

### Ranking by total installed hydropower capacity

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country/Territory</th>
<th>Installed capacity (MW)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ethiopia</td>
<td>4,624</td>
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<tr>
<td>2</td>
<td>Angola</td>
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<tr>
<td>3</td>
<td>South Africa</td>
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<td>4</td>
<td>Zambia</td>
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<td>5</td>
<td>Egypt</td>
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<td>6</td>
<td>Democratic Republic of the Congo</td>
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<td>30</td>
<td>Senegal</td>
<td>84</td>
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</tbody>
</table>

*Including pumped storage

**Top 5 countries by capacity added in 2022**

- **1st** Ethiopia: 750 MW
- **2nd** Guinea: 450 MW
- **2nd** Zambia: 450 MW
- **3rd** Mali: 140 MW
- **4th** Madagascar: 28 MW

“Considering Africa’s high potential for hydropower development and a need to rapidly increase electricity to meet demand, accelerating access to financing and sustainable construction is crucial for the region.”

Source: IHA, 2023 World Hydropower Outlook
**Large range of low-carbon capacity available**
- From kW to GW in a single project
- Option to export electricity in regional grids

**Operational flexibility and efficiency**
- Fast start-up and shut-down
- Highly efficient and adjustable output

**Storage and back-up**
- Rapid availability, and ancillary services
- Option to absorb surplus (pumped storage)

**Multiple freshwater services**
- Water supply, irrigation, navigation, tourism
- Climate-change adaptation (flood and drought mitigation)

Source: IHA, International Hydropower Association, R. Taylor
RENEWABLES DEVELOPMENT

All figures show the IEA main case

Source: IEA, Renewables 2022 - Analysis and forecast to 2027
RENEWABLES DEVELOPMENT

All figures show the IEA accelerated case

Source: IEA, Renewables 2022 - Analysis and forecast to 2027
IEA categorizes the integration of VRE into a “phase assessment framework” of six different phases.

**IEA VRE integration phases**

- **Phase 1: No noticeable impact from VRE**
  - 2020: 84 countries at phase 1, whereas it is expected that by 2025, only 50 will remain.

- **Phase 2: 5-10% VRE share**
  - Integration challenges begin to emerge.
  - Differences between load and net load become noticeable.
  - But VRE still have a minor impact on the system as a whole.

- **Phase 3: ~15-30% VRE share (annually) and beyond**
  - VRE determine the operating pattern of the whole power system.
  - And additional flexibility options are needed.

- **Phase 4: periods where VRE make up almost all or all generation**
  - Currently only 6 countries.

- **Phase 5: growing amounts of VRE surplus or deficit compared to total electricity demand**
  - For days to weeks.

- **Phase 6: growing amounts of VRE surplus or deficit compared to total electricity demand**
  - For days to weeks.
  - And seasonal or inter-annual imbalances.

**Evolution of countries’ VRE integration phases**

Note: Bubble size reflects the share of VRE in total electricity generation.
THE KEY DRIVERS

Hydropower is facing opportunities and challenges

• **Growing electricity demand**
  - Emerging Countries (both residential and industry)
  - Decarbonization > Electrification of industries
  - Decarbonization / sector coupling > Powering green hydrogen production

• **Flexibility and storage for integrating wind & solar PV**
  - Flexible and firm capacity as a backup
  - Growing demand for reservoir and pumped storage > the “water battery”
  - Hybrids and integrated systems

• **Ageing hydropower fleet / optimization of O&M**
  - Rehabilitation, Upgrade, Digitalization

• **Climate Change Resilience and Adaptation**
  - Change of flow regimes, extreme weather events, ..
  - Resilience of Equipment and Infrastructures
  - Prevention from floods and droughts, freshwater management

• **Impact on nature and local communities**
  - Water quality, river connectivity and other environmental impacts
  - net-positive benefits on society
New energy concepts based on hybrid solutions balancing the energy before stressing the grid

- combination of a solar and wind power station with a pumped storage plant

Kidston / Australia

2 x 125 MW reversible pump turbines
Main focus: supply balanced energy into the grid!
Hydropower – Battery Hybrids
• Improve fast and dynamic frequency response by coupling hydropower and batteries
• Significantly reduce turbine wear and tear

PSP – Wind – PV Hybrids
• Balancing the energy before stressing the grid

Hydropower – floating Solar PV Hybrids
• Co-locating with existing hydro sites can double power output while reducing variability and utilizing existing transmission infrastructure
• Huge potential (“Floating solar panels on 1% of reservoirs ‘could double’ Africa’s hydropower capacity”)
• Europe’s largest floating PV plant; EDP / Alqueva reservoir / 5MWp / online in mid 2022
• Recently announced: Endesa / Alto do Rabagao dam / 42MWp / online 2026
New Generator Technologies

- **Variable Speed DFIM (Double Fed Induction Machine)**: approx. +/- 7 % speed range
- **Variable Speed (full size converters)**: ≈ 50% speed range, other base frequency
- **Synchronous Condenser**: Providing reactive power and inertia to the grid, new customers

### Why Variable Speed?
- Regulation of pump input power
- Speed adjustment for optimum operation (efficiency, stability)
- Needed for large head variation and special grid services

**Variable Speed DFIM:**

**Kühtai II**: 2 x 95 MVA, full size converter fed synchronous generator

**Synchronous Condensers**: Brazil, Australia, USA
FAST REACTION TO GRID INSTABILITIES
+/- 500 MW WITHIN 20-30 SECONDS

KOPS II / Austria
- 3 x 180 MW (Tu) - 150 MW (Pu)
- Full load: 20-30 s (Tu and Pu mode)
- Head: 826 m
- Unique Ternary concept
- Pressurized downstream chamber

- In operation since 2009
  8,000 operating hours/year!
ENVIRONMENTAL PERFORMANCE

Oil-free design / Fish friendliness / Dissolved Oxygen

TARGET
• Continue R&D efforts in environmental questions

MARKET POTENTIAL FOR PRODUCTS AND RELATED SERVICES
• Oil-free design
• Fish friendliness
• Dissolved Oxygen via Runner – downstream oxygen content will be raised to the ecologically favorable range via turbine operation
MAKING MOST OF THE EXISTING REFURBISHMENT, UPGRADE, DIGITALIZATION, CYBER SECURITY

Diagnosis

Analysis

Therapy
Additional renewable energy

- For each 30 GW upgraded per year and for each 5% of increase of performance, rehabilitation programs will create 1.500 MW of renewable and predictable energy.
DIGITAL O&M AND ASSET MANAGEMENT

CUSTOMER CENTRIC O&M SUPPORTED BY DIGITAL SOLUTIONS

Operation & Maintenance
Predictive Maintenance
Metris DiOMera digital platform

ISO 55001:2014
Green hydrogen production to grow from 0.7 Mt/a in 2020 to 300 Mt/a in 2050

Main drivers for green hydrogen scale up:
1. Decarbonization of industries (refineries, chemicals, steel), transportation and energy storage, e.g. EU Green Deal
2. Reducing price of renewable energy (down to < 20 €/MWh)
3. Money in the market (funding and investors) for sustainable investments

Info:
1 Mt/a Hydrogen = 12 GW installed
Today’s costs for Green H2 is between 3 to 6 €/kg. The aim would be to reach 2€/kg
And you need 9 liter water per kg H₂

Source: Hydrogen Council, Hydrogen Insights 2022
1) Annual storage reservoir
2) Short-term storage reservoir
3) Conventional river power plant
4) Small hydropower plant
5) Ecological Flow
6) Urban river power plant
7) Low head hydropower plant
8) Tidal power plant
9) Pumped storage power plant (fresh water); energy storage for solar power plant
10) Pumped storage power plant (salt water); energy storage for wind park
11) Energy island; off-shore pumped storage power plant for wind/solar/tidal
12) Tidal stream power array
13) Irrigation system
14) Desalination plant
15) Flood control pump station
The future depends on what we do in the present

Mahatma Gandhi