Potential for increased capacity and balancing from Sweden's hydropower

A report by AFRY Management Consulting for the Swedish Association of Engineers

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Sveriges Ingenjörer

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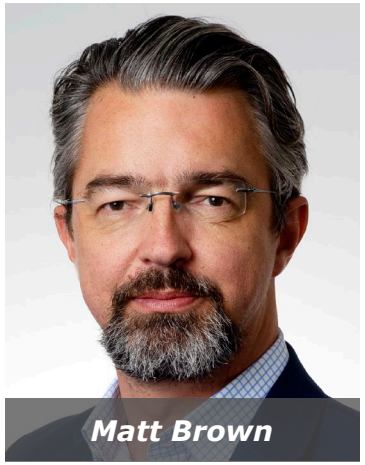

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ABOUT THE PROJECT

AFRY has investigated the potential of existing hydropower in terms of increased capacity and balancing

The project has been conducted on behalf of the Swedish Association of Engineers during the summer of 2024, with delivery in October

AFRY has investigated the potential in existing hydropower in terms of increased capacity and balancing contribution

The project was carried out through a literature review, interviews with experts and a quantitative analysis

Despite its important role for the future energy system, limited focus has been placed on potential for increased hydropower capacity and balancing

Situation

- Sweden’s electricity demand expected to double by 2045
- The share of intermittent power, mainly wind, expected to increase
- Hydropower has a key role for baseload generation and balancing, now and in the future

Complication

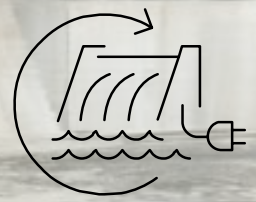
- Hydropower is largely considered to be built-out – limited potential for new plants
- Swedish hydropower undergoing re-assessment of permits, creating uncertainty for owners
- Limited focus placed on the potential in existing hydropower plants

Key question

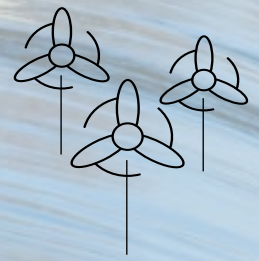
What is the potential for increased capacity and balancing from Sweden’s hydropower?

SUMMARISED CONCLUSIONS

Increased hydropower capacity is an important contribution to the electricity system, but challenges exist to realise this potential



There is potential to increase the capacity of **existing hydropower** by **~4 000 MW** (~24%)



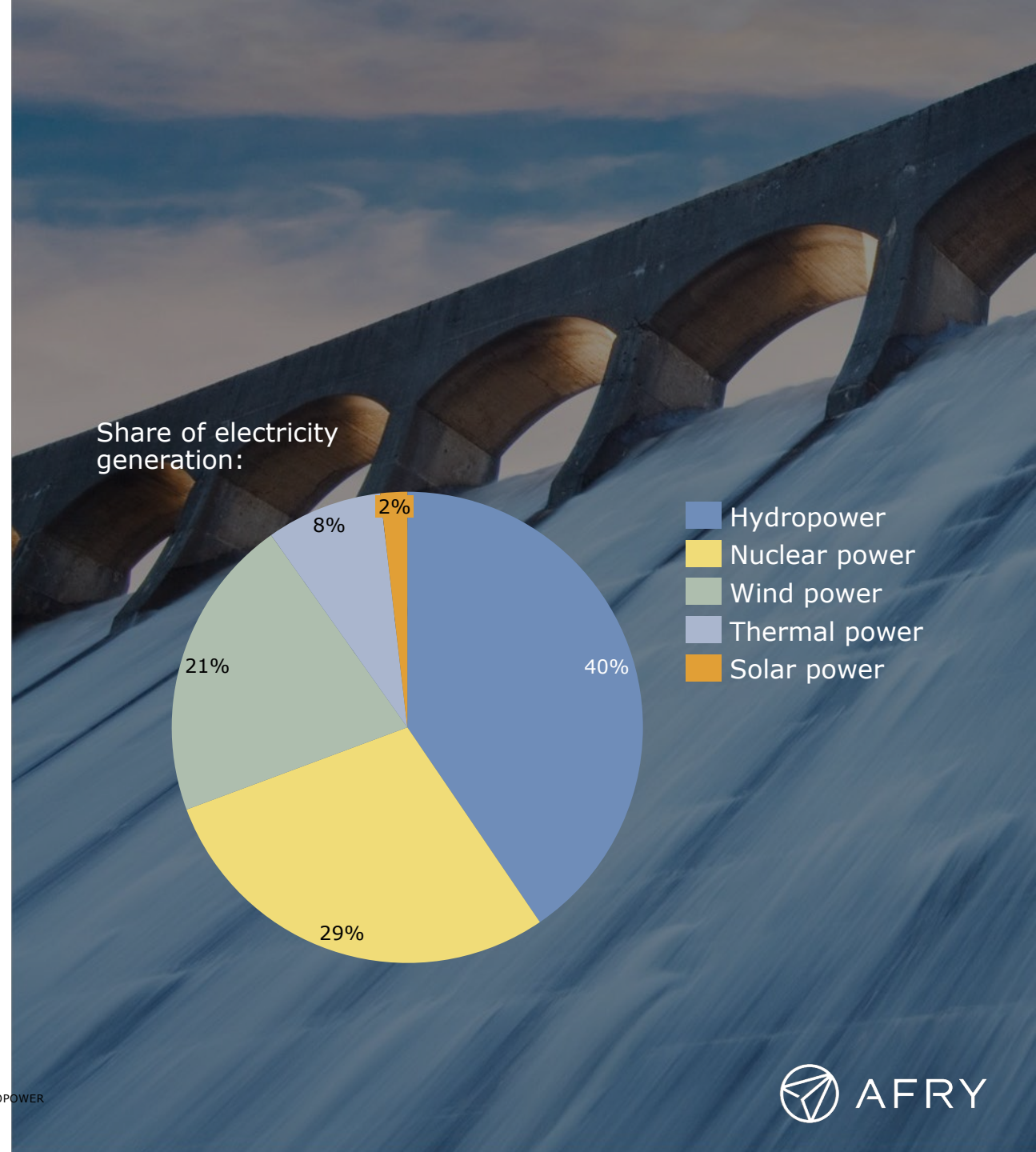
An increase in hydropower capacity can enable an increase of **~800-1 200 MW** in **wind power** (0.2-0.3 MW per MW additional hydro capacity)

Main challenges for the expansion are **hydropower permit re-assessment**, **permits for changed water flows** and **profitability** for hydropower owners

CURRENT SITUATION

Hydropower accounts for ~40% of electricity generation in Sweden

- **Generation (2023):** 66 TWh
- **Installed capacity (2023):** 16.4 GW
- **Number of plants:** ~2 000
- Large-scale hydropower plants with capacity equal to or above 10 MW account for 94% of hydropower installed capacity



Source: Swedish Energy Agency, Energiföretagen

CURRENT SITUATION

Hydropower capacity has remained constant - renewables have grown substantially

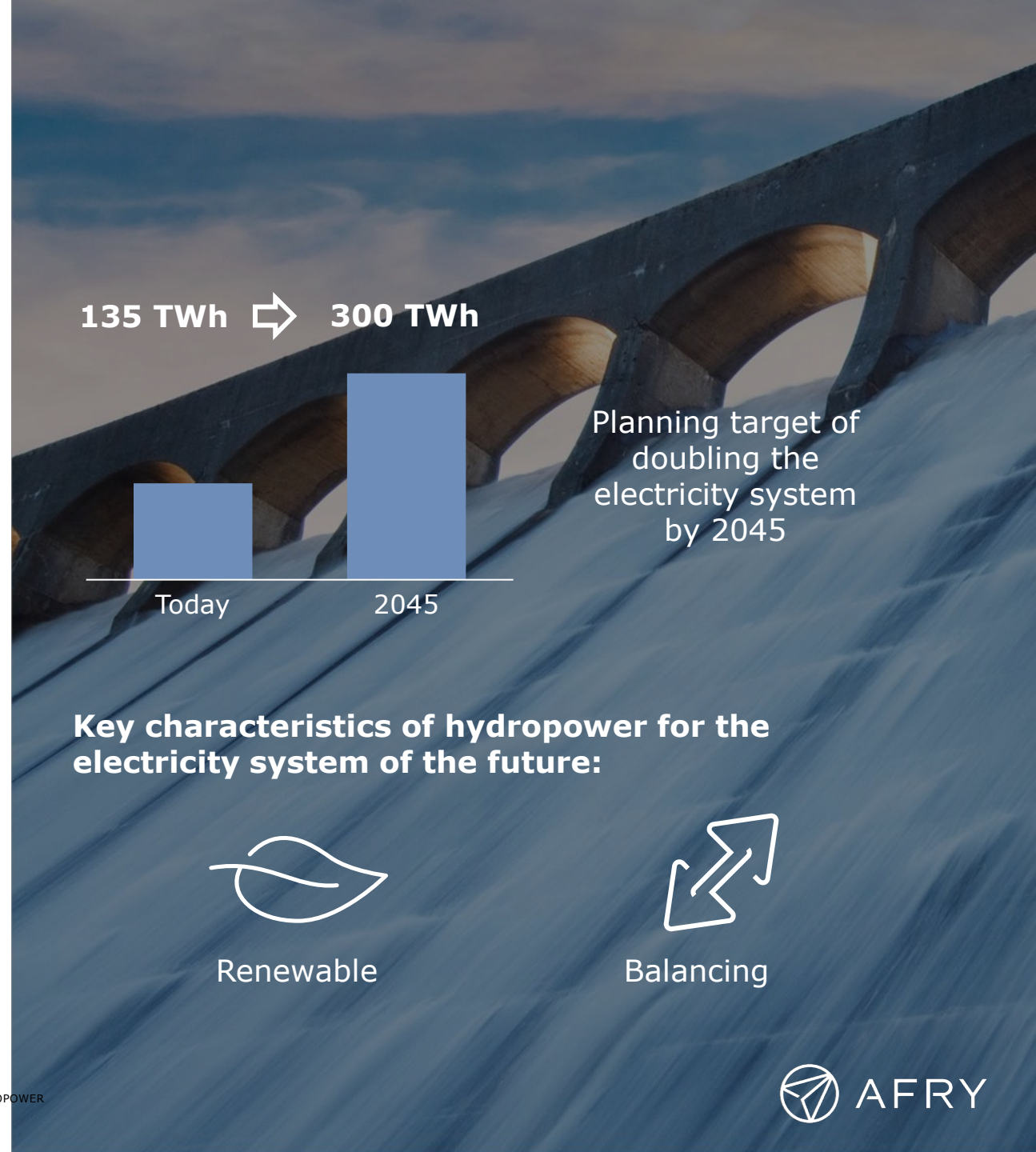
- Total installed capacity in Sweden has increased by 14.5 GW between 2010 and 2023
- Wind- and solar power have increased, while hydropower has remained largely unchanged
- An electricity system with an increasing share of intermittent generation has a growing need for balancing
- It is therefore relevant to investigate opportunities for increased capacity in hydropower as it can contribute to balancing

Source: Swedish Energy Agency, Energiföretagen

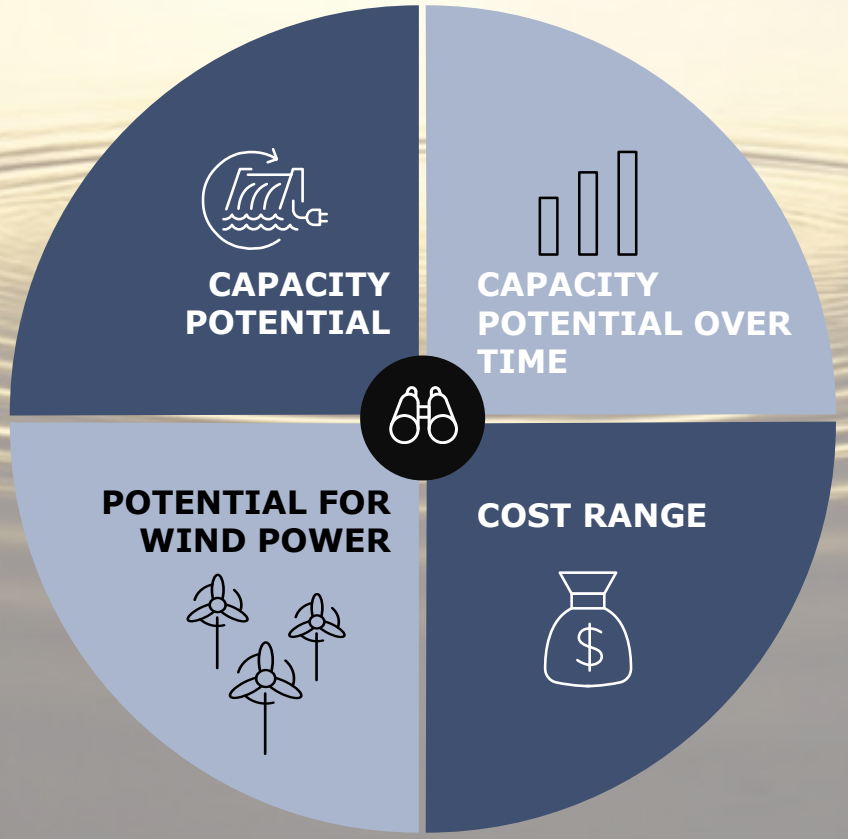
HYDROPOWER IN FORECASTS

Hydropower has an important role to play in the future energy system

- Electricity generation in Sweden in several projections is required to double to meet electricity demand by 2045 in several projections and the governments planning target
- Hydropower remains a key component of the future energy system through its balancing capability as intermittent electricity generation is expected to increase
- In e.g., Svenska kraftnät's (TSO) scenarios in the Long-term Market Analysis 2024, the importance of hydropower for balancing is highlighted

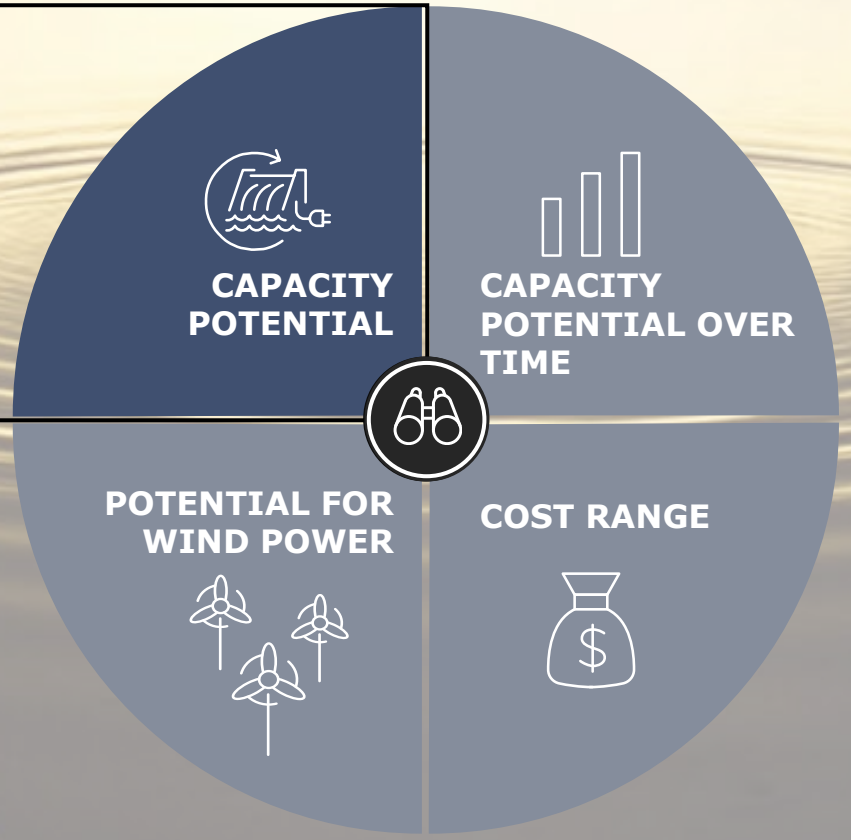


The four main parts of the study



The four main parts of the study

– Quantitative result in terms of potential capacity increase in MW from hydropower



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The analysis showed three main measures that can be taken to increase the capacity of existing hydropower plants

Full or partial upgrade of turbine

- Replacement of all or part of the turbine to increase the flow rate and/or efficiency and thus increase in capacity

Upgrade of power unit

- Replacement of an entire power unit, including turbine, generator and ancillary equipment, to increase the flow rate and/or efficiency and thus increased capacity

Installation of additional power units

- Installation of additional power units, where the power station is prepared for additional units, for increased absorption capacity and thereby a capacity increase

CAPACITY POTENTIAL

Studied measures could add ~4 000 MW more capacity from hydropower

- Measures studied include:
  - upgrade of turbine
  - upgrade of power units
  - Installation of additional power units
- The identified potential of ~4 000 MW represents ~24% of current installed capacity
- The capacity increase has been estimated through the potential to remove bottlenecks in Sweden's largest rivers and renovate large and small-scale plants with investment needs related to age and investment cycles

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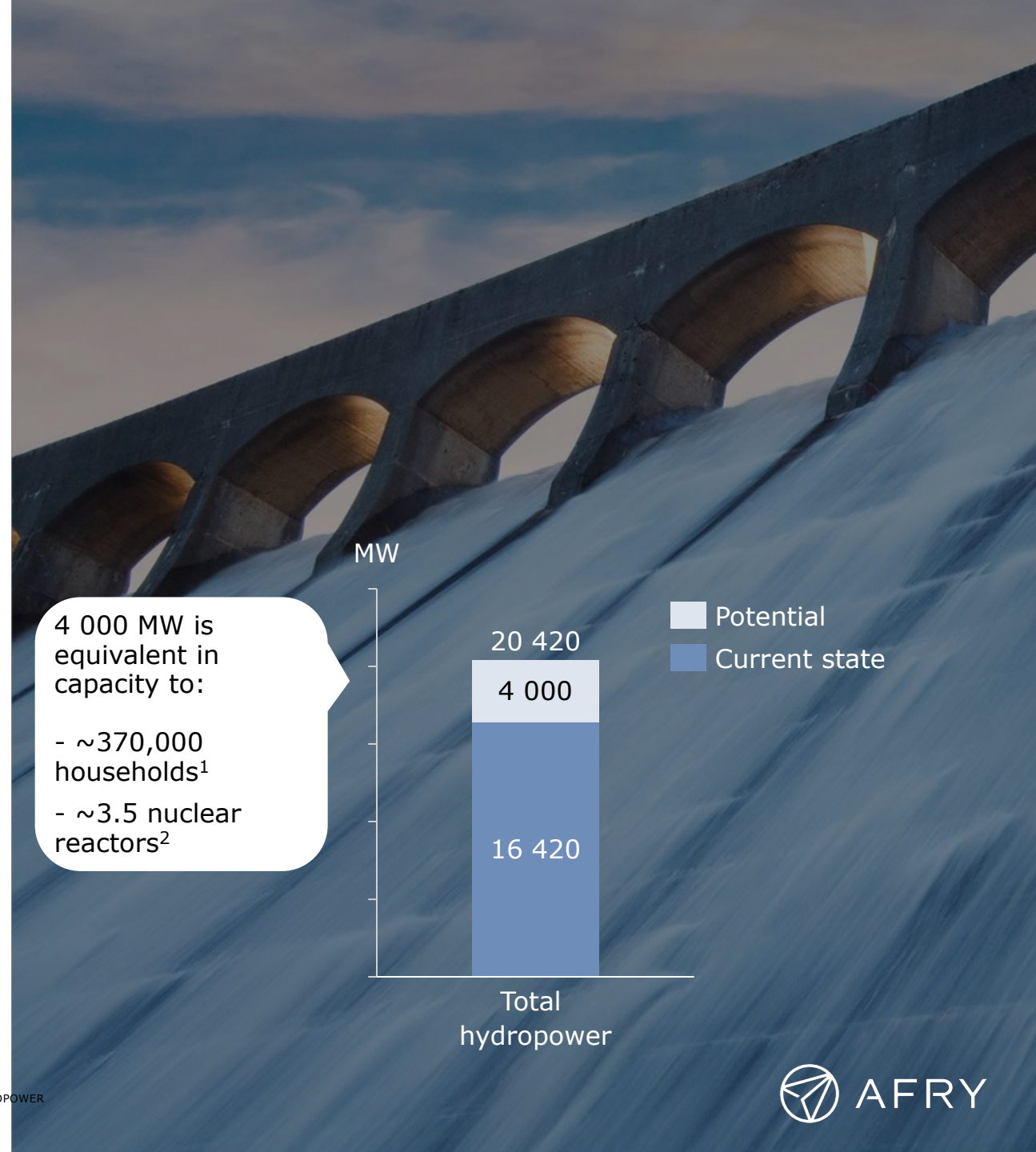


1) Average house in Sweden with 20 000 kWh annual consumption and 11 kW maximum capacity, 2) Average nuclear reactor in Sweden of 1 165 MW

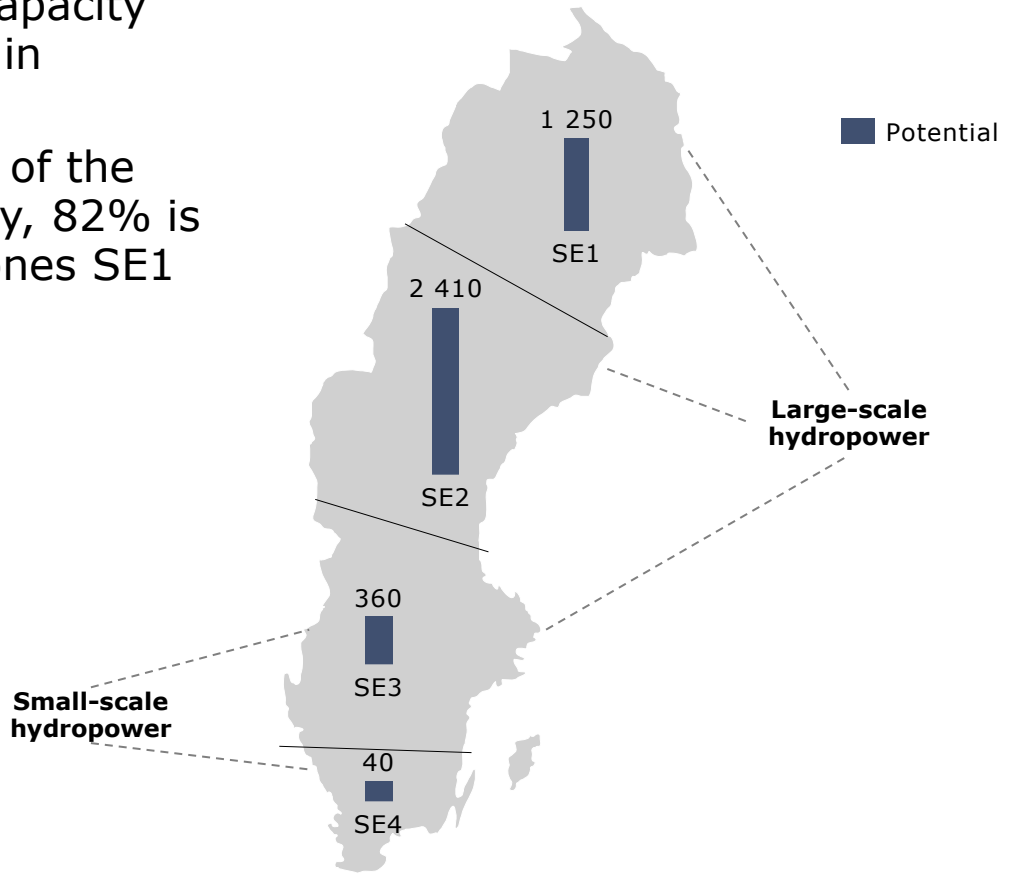
CAPACITY POTENTIAL

The largest share of the potential is linked to removing bottlenecks in the large-scale hydropower plants

- Of the total potential for capacity increase, ~98% is in the large-scale hydropower
- There are two main reasons for this:
  - The potential to remove bottlenecks includes large-scale hydropower
  - Larger existing capacity means that percentage improvements result in greater impact

The greatest potential for capacity increase has been identified in northern Sweden

- The greatest potential for capacity increase is estimated to be in northern Sweden
- This relates to the fact that of the current hydropower capacity, 82% is in the northern-most bid zones SE1 and SE2



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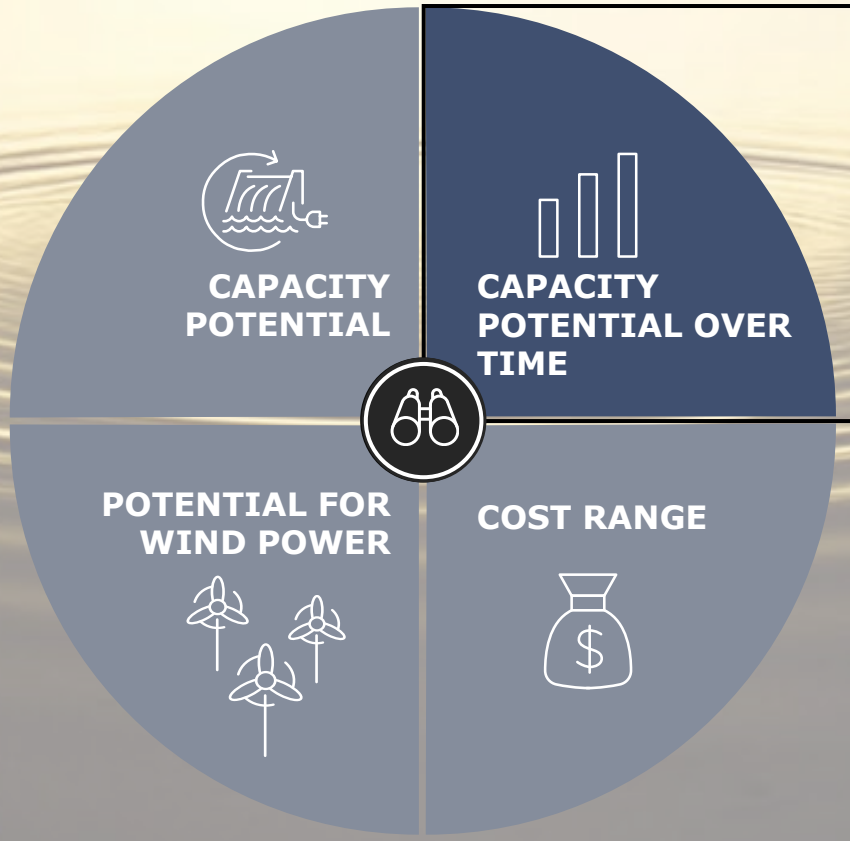

– The potential over time to realise capacity increases has been analysed based on factors affecting the timelines for implementation

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CAPACITY POTENTIAL OVER TIME

~1 300 MW can be realised by 2035, and ~3 200 MW by 2045

- The potential for capacity increases for different time periods is estimated to:
  - 2035: 1 360 MW
  - 2045: 3 215 MW
- Based on:
  - Estimation of timelines for completing different types of measures
  - Realisation of measures in conjunction with the re-assessment of environmental permits for hydropower related to the EU Water Framework Directive
  - Annual investment requirements

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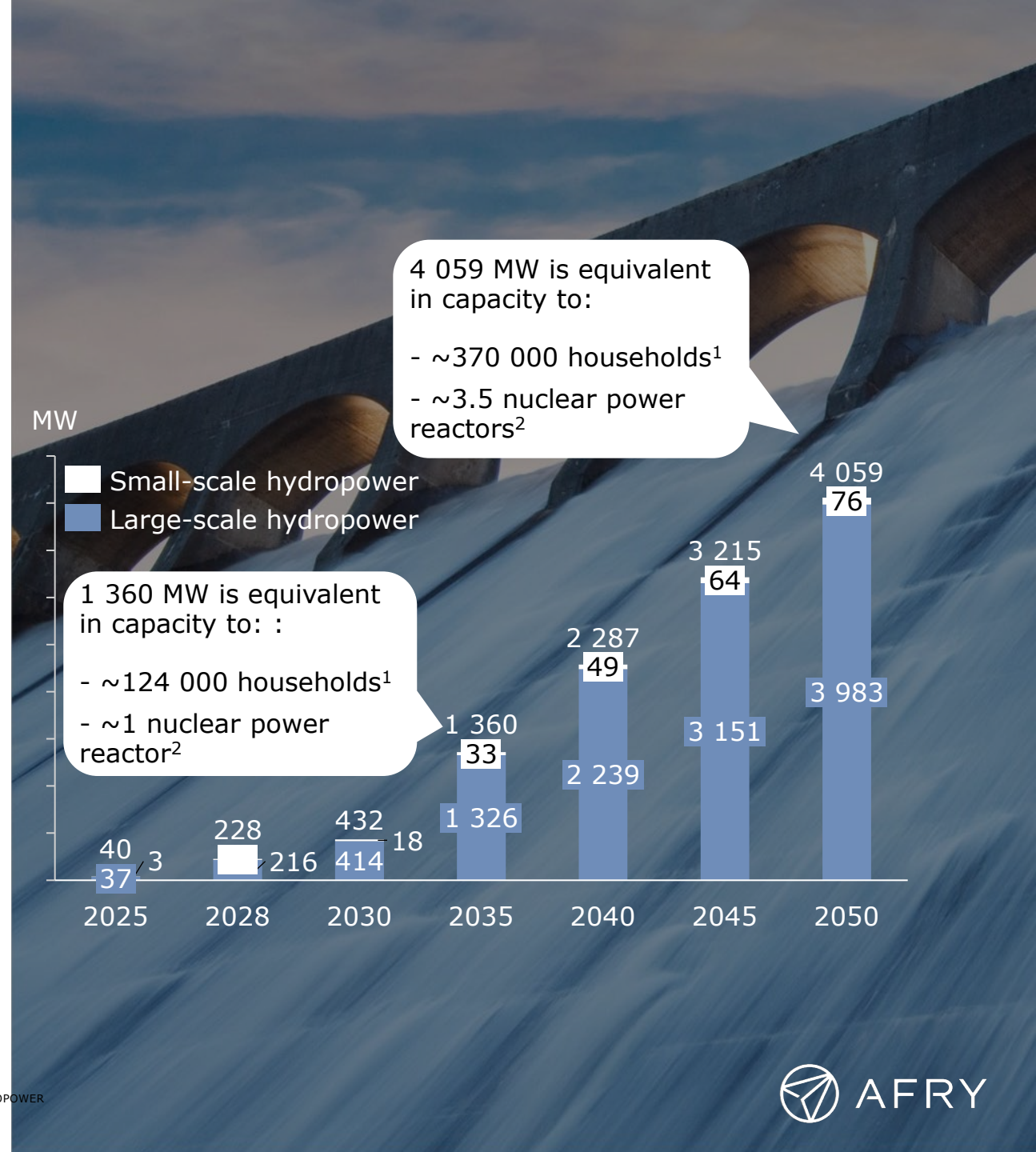

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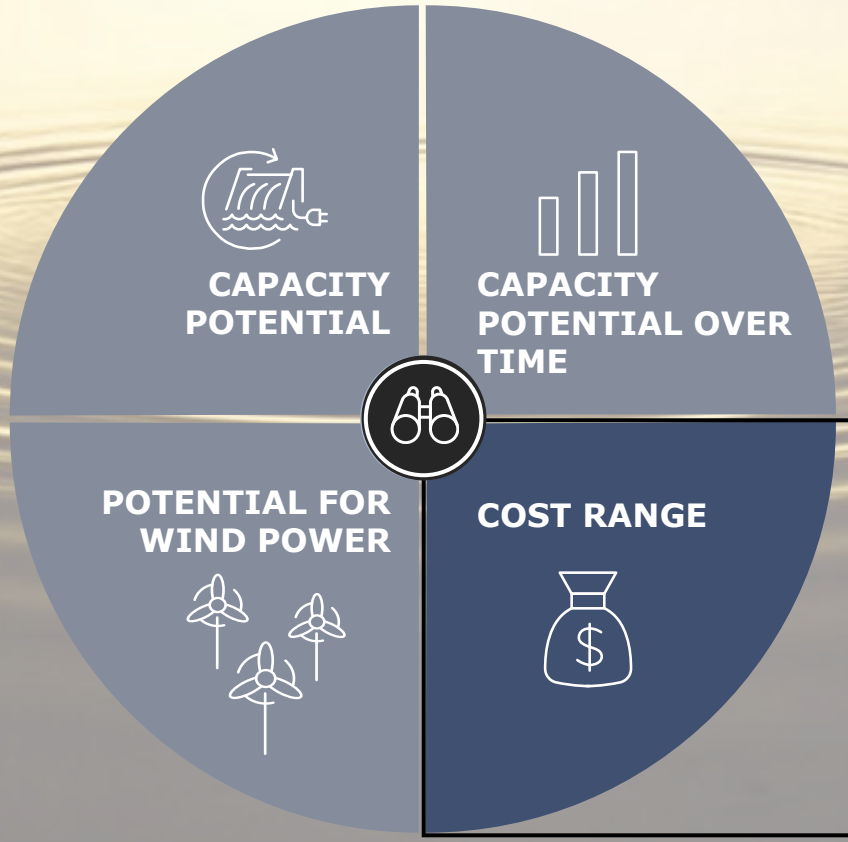
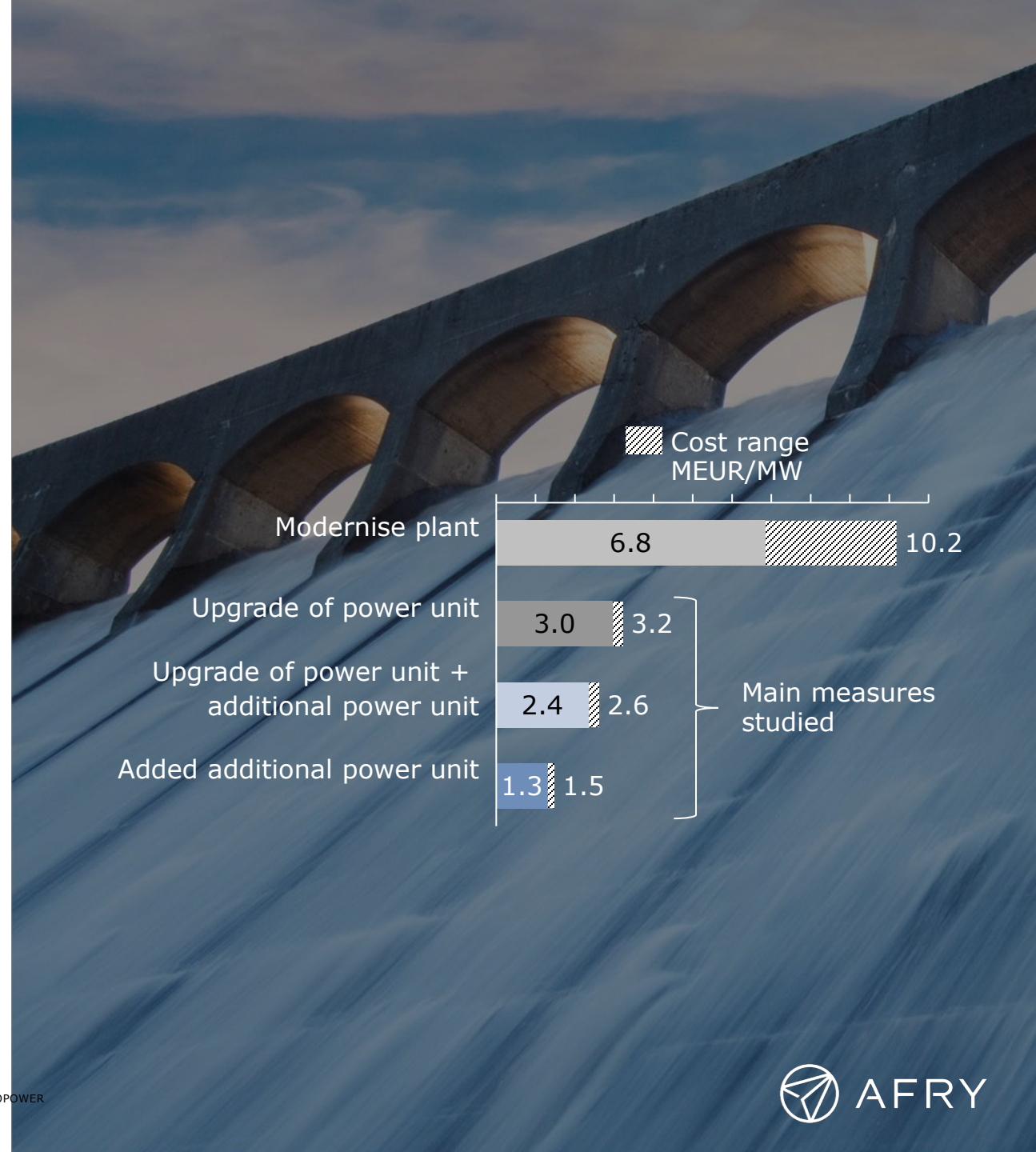


– The cost of increasing capacity has been analysed based on project data and studies

COST RANGE

Estimated cost of increasing capacity is ~1.3-3.2 million EUR/MW

- Development costs for hydropower projects are highly site-specific, hence a wide cost range
- The project data studied shows that the cost range for increasing capacity by upgrading or adding additional power units is ~1.3-3.2 million EUR/MW
- This has been used as an indicative range for the three main measures of the analysis



COST RANGE

Total cost range is ~5.3-13.1 billion EUR

- With this assumed cost range, the total cost of realising the capacity potential is
  - 2035: ~1.8-4.4 bn EUR (1 360 MW)
  - 2050: ~5.3-13.1 bn EUR (4 060 MW)

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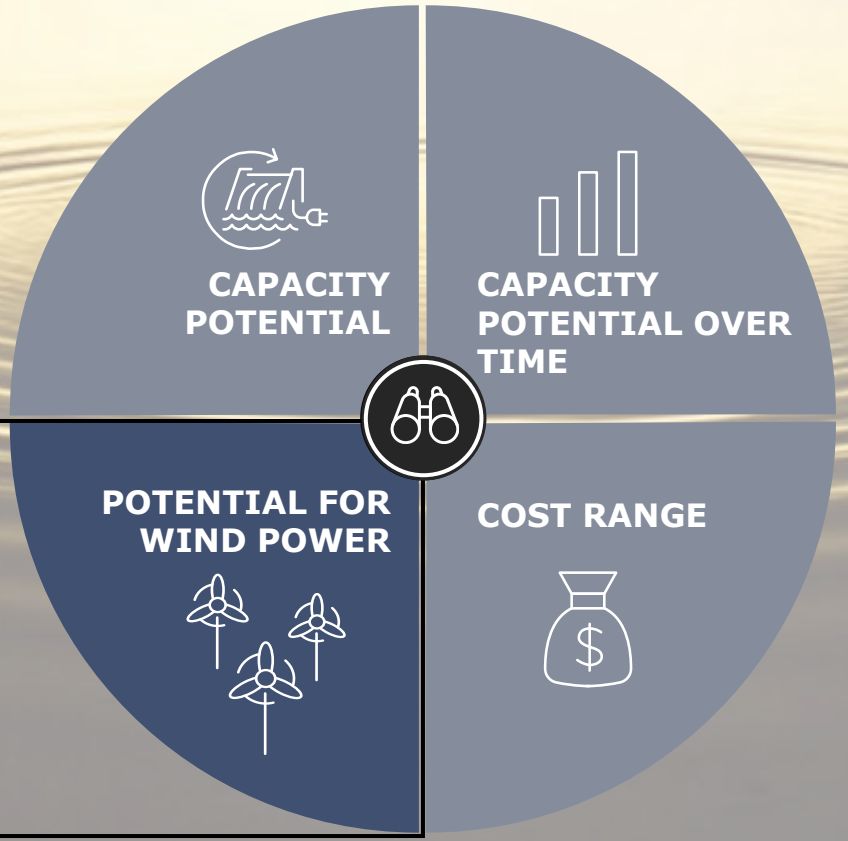


– Using power market modelling, AFRY has analysed what the capacity increase in hydropower can mean for increasing capacity in wind power

POTENTIAL FOR WIND POWER

Increased hydropower capacity can contribute to increased wind power capacity

- Modelling in the BID3 electricity market model shows that onshore wind power capacity can increase by ~20-30% of the increased hydropower capacity while maintaining economic efficiency
- Thus, each increased MW of hydropower can provide ~0.2-0.3 MW onshore wind
- With AFRY's identified potential for increased capacity in hydropower, the total added potential for onshore wind power is ~800-1 200 MW by 2050

IDENTIFIED CHALLENGES

Three main challenges have been identified for the realisation of hydropower potential during the work process

National plan for the re-assessment of hydropower permits

- The ambiguity concerning the implementation of the initial benchmarks for acceptable production loss has created great uncertainty
- Currently paused until July 1, 2025, public consultation of legislation proposal recently completed

Permit for water flows

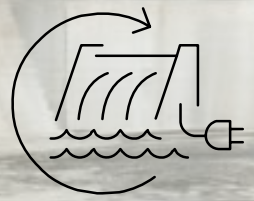
- Impacts on water flows, water levels and regulation of these usually require changes to permits

Profitability

- Profitability of investments is a prerequisite for owners – an identified challenge given high costs and uncertain external factors

SUMMARISED CONCLUSIONS

Increased hydropower capacity is an important contribution to the electricity system, but challenges exist to realise this potential



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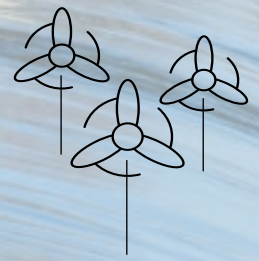

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Contact us

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