ARENA

ARENA INSIGHTS SPOTLIGHT: IEA HYDRO ON FLEXIBILITY

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IEA HYDRO

Australian Government
Australian Renewable Energy Agency

INTRODUCTION

Hydropower is the largest source of renewable electricity generation and storage in the world, so it's important to be at the forefront of the latest knowledge and insights. In this spotlight piece, we capture highlights, challenges and opportunities for hydropower from Australian representatives to the International Energy Agency (IEA) Hydropower Technology Collaboration Programme who are supported through the ARENA-funded International Engagement Program. Hydro Tasmania representatives Alex Beckitt and Luke Middleton as well as the IEA Hydropower Secretariat, Niels Nielsen, reflect on key hydropower and pumped hydro milestones in Australia and discuss rich lessons learnt from the international experiences.

1.0

WHAT HAVE BEEN THE KEY MILESTONES OR ADVANCEMENTS THAT HAVE ALLOWED AUSTRALIA TO BETTER UNDERSTAND THE POTENTIAL ROLE OF HYDRO/PHES IN THE FUTURE ENERGY MIX?

A key feature of Australia's energy market transition (like most around the world), is ensuring the seamless integration of higher penetrations of competitive low-cost renewable energy sources, particularly wind and solar. The increasing and important role of lower-emissions sources in the energy mix has created new challenges in maintaining the security and reliability of the grid. An enhanced understanding of the challenges associated with the effective integration of variable renewable energy (VRE) technologies has brought the importance of flexible and dispatchable low-emissions generation and storage assets into sharp focus, and the importance and value of hydropower.

A variety of research programs and initiatives have been pursued to inform policy-makers, developers and others on the potential for conventional storage hydro and pumped hydro energy storage (PHES) in a lower-carbon future. For instance, ARENA has supported a number of initiatives, including: the production of the Australian National University's 'Atlas of PHES' to identify, at a very high level, the national potential for resources; numerous studies including those for the *Battery of the Nation* program; and Hydro Tasmania's participation in the International Energy Agency's Hydropower Technology Collaboration Program (IEA Hydro) as part of the International Engagement Program.

These important research initiatives have identified significant opportunity for hydro and PHES development in Australia: the *Battery of the Nation* program has identified up to 3,400MW of PHES in Tasmania; Snowy Hydro are pursuing plans to develop Snowy 2.0; and various other potential PHES developments are also under assessment throughout the National Electricity Market (NEM). Understanding the challenges facing the energy sector, and the potential for PHES developments to assist in alleviating these challenges, has generated renewed interest from market bodies to consider the future of hydropower in Australia. For instance, the Australian Energy Market Operator (AEMO) released an Integrated System Plan (ISP) Insights Paper in July 2019 on how PHES can enhance power system resilience.

International expertise and knowledge sharing are an important input to inform policy-makers and energy market stakeholders about the challenges, opportunities and optimal roles for hydropower going forward. A diversity of international experiences demonstrate that with well-considered strategies, hydropower can play a central role in contributing to the transitioning energy system and in managing a number of current and anticipated challenges facing the Australian energy sector.

Through the IEA Hydro research task on Valuing Hydropower Services ('Annex IX'), IEA Hydro member countries with an interest in hydropower are working together to better conceptualise and understand the importance of the many flexibility services hydropower can provide to support the low-cost and effective integration of VRE – particularly over multiple time-scales (from sub-seconds to inter-annual). The Annex IX participants recently released a whitepaper titled 'Flexible Hydropower providing value to renewable energy generation'.

The next phase of IEA Hydro's flexibility research will provide insight into how markets can appropriately define multiple flexibility services and their relative importance in the operation of energy systems, the manner in which these services are priced and procured in different places, the capability of hydropower (and other technologies) to deliver these services, and international case studies to provide specific insights into how markets are valuing these services.

2.0

YOUR TEAM IS CURRENTLY INVOLVED IN THE INTERNATIONAL ENERGY AGENCY'S HYDROPOWER TECHNOLOGY COLLABORATION PROGRAMME (HYDROPOWER TCP) THROUGH THE ARENA-FUNDED INTERNATIONAL ENGAGEMENT PROGRAM. WHAT HAS BEEN THE MOST INTERESTING ASPECT OR LEARNING EXPERIENCE FROM BEING PART OF THESE PROGRAMS?

While hydropower is a mature energy technology, there is a significant amount of innovation and R&D underway to determine and understand how hydropower technologies can be best applied in the future to achieve the energy 'trilemma' objectives of affordability, reliability and sustainability. Hydropower R&D initiatives have traditionally focussed on aspects and approaches to maintenance, refurbishment and modernisation. However, there is now increased attention on aspects related to supporting increased penetration of VRE as energy systems transition globally – including operating modes, data management, communications, materials, science and hybridisation with other technologies.

Hydropower can be versatile in its operation, dependent on system needs. However, as global energy systems transform, hydropower operations too, must change. Participation in IEA Hydro has revealed that energy systems globally are experiencing similar issues and challenges when integrating increasing shares of VRE. These challenges are typically determined by the extent to which VRE has connected to the grid. The IEA's System Integration of Renewables (SIR) unit have conducted significant analysis to conceptualise these various challenges dependent on the degree of VRE penetration. IEA's 6 phases of VRE integration are captured in Table 1 below.

Against these phases, the IEA SIR unit have also developed a guide to understand the 'flexibility' services required for the power system to operate safely and securely under different levels of VRE penetration.

Using this analysis as a "backdrop", IEA Hydro have identified that energy markets/regulatory frameworks are not necessarily providing sufficient incentives to underpin investment or re-investment in hydro assets that can deliver these integral system services. Further, many R&D initiatives are heavily focussed on flexibility in the shorter-term (system stability, frequency management etc.), but very few initiatives seem to focus on medium to longer-term flexibility to address issues such as significant surplus or deficit of VRE output. As Australia continues to connect large quantities of VRE to the grid, market settings must also adapt to ensure that the necessary services are available to support the operation of the system in different regions from different technologies with different capabilities. Defining and valuing flexibility is explored in the recent Annex IX white paper, and remains a central focus of the Annex IX work stream going forward.

TABLE 1: DIFFERENT PHASES OF VRE INTEGRATION

PHASE	DESCRIPTION
1	At initial stage of VRE deployment with no relevant effects in system operation
2	Additional flexibility needs can be met by minor adjustments in existing operations
3	VRE generation determines system operations to maintain stability
4	Additional investments in flexibility resources are needed to balance the system
5	Structural surpluses of VRE generation from weeks to months may lead to curtailment
6	Structural over- or under-supply over seasons to years validates the need for sector coupling

TABLE 2: DIFFERENT TIMESCALES OF POWER SYSTEM FLEXIBILITY

FLEXIBILITY TYPE	SHORT TERM			MEDIUM TERM	LONG TERM	
Time-scale	Sub-seconds to seconds	Seconds to minutes	Minutes to hours	Hours to days	Days to months	Months to years
Issue	Ensure system stability	Short term frequency control	More fluctuations in the supply/ demand balance	Determining operation schedule in hour- and day-ahead	Longer periods of VRE surplus or deficit	Seasonal and inter-annual availability of VRE
Relevance for system planning and operation	Dynamic stability; inertia; voltage and frequency	Primary and secondary frequency response	Balancing and real-time market (power)	Day-ahead and intra-day balancing of supply and demand (energy)	Scheduling adequacy (energy over longer durations)	Hydro-thermal coordination, adequacy, power system planning

3.0

WHAT ARE SOME KEY LEARNINGS AUSTRALIA CAN TAKE AWAY FROM THE INTERNATIONAL EXPERIENCE WITH STORAGE HYDRO – PARTICULARLY PHES?

Discussion and experience in the international hydropower community reveals many valuable learnings which can be applied in the Australian context. However, two key/universal lessons have been that, as the penetration of wind and solar progresses:

i. Energy market and regulatory frameworks must evolve; and

ii. Transmission networks must be expanded to enhance complementary least cost renewable resource sharing between regions and countries.

I. EVOLVING ENERGY MARKET AND REGULATORY FRAMEWORKS

As the penetration of VRE increases, the suite of system services required to safely and securely operate the energy system also change. Operationally, energy markets can consist of a variety of combinations including energy only, real-time/balancing markets, ahead or day-ahead markets, and/or capacity mechanisms. Further, methods to manage system security (frequency, voltage etc.) may also differ. The optimal approach to energy market evolution is contingent on a variety of factors, but are all typically driven by very similar challenges. The largest universal issue for investment and reinvestment in hydropower assets is clear long term investment signals. Given the long project lead times for hydro and PHES often targeted or bespoke hydropower infrastructure support programs are required.

The necessity for market evolution is particularly relevant in the Australian context, where the Energy Security Board are driving a broad and ambitious agenda as part of their Post-2025 Market Design program. As part of this reform process, key issues for hydropower assets, and particularly Pumped Hydro Energy Storage, relate to how we can: (1) provide investment signals for new, flexible and dispatchable capacity; (2) ensure long-term revenue certainty to underpin these investments; and (3) ensure issues 1 and 2 can be delivered far enough in advance to allow the construction of assets with long lead times (such as PHES) and for these to be delivered on time and concurrent with other energy assets retiring.

II. NETWORK EXPANSION AND RESOURCE SHARING

The pairing of complementary energy resources between regions and countries can support the provision of affordable, reliable and sustainable energy for consumers. To achieve this pairing, expansion strategies for transmission networks are being enacted globally. For instance, the European Commission enacted policy in 2015 for all EU member countries to achieve interconnection of at least 10 per cent of their installed capacity. This policy was developed in recognition of the role of transmission in increasing energy competition across regions in the EU, ultimately placing a downward pressure on energy prices, enhancing system resilience, and supporting VRE integration.

Norway currently has strong interconnection with neighbouring Nordic countries, and is pursuing new interconnection opportunities with other European countries. This is largely driven by the complementary nature of Norway's flexible hydropower assets with regions of high VRE penetration. Strategies are in place for Norway to develop sub-sea interconnection with Germany, the UK and Scotland. These transmission assets will allow Norway to ramp hydropower assets to export to countries experiencing low VRE outputs, and conversely, import VRE output during times of high production.

4.0

ARE SOME COUNTRIES PROVIDING LEADING EXAMPLES ON HYDRO FLEXIBILITY SERVICES/PHES, AND WHAT IS UNIQUE ABOUT THEIR WORK/SITUATION?

There are many countries investing in research initiatives to understand the future role and value of Hydropower in energy systems. The Norwegian research institute, the Centre for Environmental Design of Renewable Energy (CEDREN), and the US Department of Energy's research on pumped hydro valuation research provide good examples.

NORWAY'S CEDREN HYDROBALANCE PROJECT

The goal of the CEDREN HydroBalance project was to investigate the feasibility of using Norwegian hydropower for supporting integration of VRE in Europe. The work combines technological, environmental and social science. HydroBalance has demonstrated the value of energy storage from hydropower compared to other sources of flexibility and storage such as natural gas and batteries. A model for operating hydropower in a multimarket setting with more variable prices was tested on a fictive case in a real watercourse, showing a large potential for investing in pumped hydro.

A very accurate wind and solar power output model was developed for Europe and this was used to understand system impacts under a future energy scenario with higher VRE penetration. Clear political strategies are needed to enable this. HydroBalance has developed new knowledge about how hydropower operations effects physical conditions and ecology in reservoirs. A roadmap for large-scale balancing and energy storage from Norwegian hydropower summarizes findings and points out the main steps to be taken to enable Norwegian hydropower to become the "green battery of Europe".

US DEPARTMENT OF ENERGY'S PUMPED HYDRO VALUATION RESEARCH

The US Department of Energy through the Argonne National Laboratory has undertaken an extensive study on pumped hydro valuation. This included an analysis of market structures in the USA covering energy and ancillary services and how PHES can offer 'value' in these markets.

The electricity market in the USA is complex with three large interconnections and eight market system operators providing a variety of key ancillary services. The report identifies energy services and contributions of PHES in these various utility systems and shows how they can support grid integration of wind and solar, and reduce cycling and ramping of thermal units, thereby reducing overall system operating costs.

5.0

LASTLY, WHAT MAKES YOU AND YOUR TEAM MOST EXCITED AND/OR PASSIONATE ABOUT HYDROPOWER/PHES AS PART OF THE RENEWABLE ENERGY TRANSITION?

There are a numwber of factors that drive our passion for the future of hydropower and PHES in Australia's energy transition.

The IEA have recognised that hydropower is the world's largest renewable energy generation and grid-connected storage resource in the world. Despite this, as observed by the IEA's Executive Director Fatih Birol, Hydropower is "...an often forgotten workhorse of electricity generation, [and] remains an essential source of flexibility." In acknowledging this oversight, the IEA have committed to placing a spotlight on the role of hydropower in evolving energy systems. The IEA's upcoming flagship 'Renewables Market Report 2020' will explore challenges and opportunities relating to: hydropower investment and developments; modernisation and refurbishment; and system flexibility.

Hydropower can work harmoniously with VRE technologies globally and in Australia. In the longer-term, the transition of our energy sector can also support decarbonisation in other sectors across our economy. For instance, a low-emissions energy sector, underpinned by flexible generation and storage assets such as hydropower and PHES, can support the broader electrification of the economy, including the transport sector. The dual benefits of reducing national emissions while concurrently enhancing our energy security by reducing reliance on energy imports must be compelling.

Hydropower is a long-lived energy asset (80+ years). The role that hydropower already plays and can play into the future to support the further decarbonisation of the economy can have a profoundly positive influence on generations to come. It is on this basis that we are driven to deliver these investments to support an affordable, reliable and sustainable energy supply for decades to come.

For more information on the work of IEA Hydro, including the recently released Annex IX white paper, please contact Niels Nielsen (IEA Hydro Secretariat) at nielsen_kator@iprimus.com.au, Alex Beckitt at alex.beckitt@hydro.com.au or Luke Middleton at luke.middleton@hydro.com.au

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