HydroCen

NORWEGIAN RESEARCH CENTRE FOR HYDROPOWER TECHNOLOGY

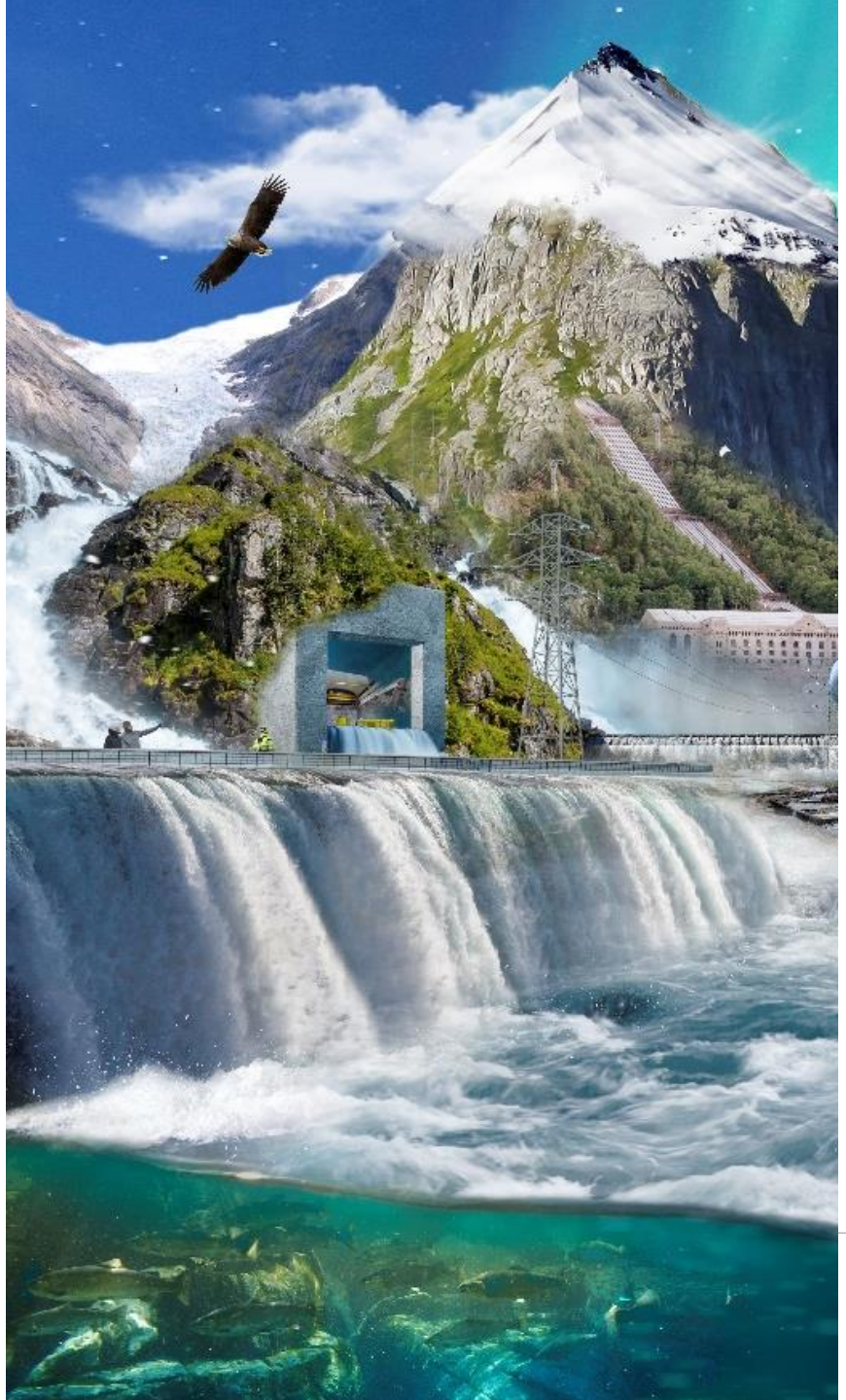
Norges forskningssenter på vannkraftteknologi

Ole Gunnar Dahlhaug 7. oktober 2020

HydroCen has received funding from the Research Council of Norway

Forskningsrådet
The Research Council of Norway

NTNU SINTEF NINA Norsk institutt for naturforskning NVKS NORSK VANNKRAFTSENTER



HydroCen
NORWEGIAN RESEARCH CENTRE FOR HYDROPOWER TECHNOLOGY

Content

- Background
- Organization and partners
- Ongoing projects
- Students and publications
- Innovations
- International cooperation
- Some project results


100
80
50
25
10
5
Value creation/revenue/budget
2014
2015
2016
2017
2018
2019
2024 →
2020:
HydroCen Labs:
55 MNOK
HydroCen
NORWEGIAN RESEARCH CENTRE
FOR HYDROPOWER TECHNOLOGY
2019: EERA,
New JP Hydropower
✓ 29 members
✓ 13 countries
NVKS
NORSK VANNKRAFTSENTER
2017-2024:
→ HydroCen 400 MNOK
→ 35 New projects: >300 MNOK
2014-2017
→ 15 projects, 200 MNOK
→ Associated projects, 120 MNOK
R&D funding from the
hydropower industry

HydroCen

NORWEGIAN RESEARCH CENTRE FOR HYDROPOWER TECHNOLOGY

HydroCen is a research centre for environmentally friendly energy. Our main objective is to enable hydropower to meet complex challenges and exploit new opportunities through innovative technological solutions.

EERA
European Energy Research Alliance

IEA Hydropower

KEY FACTS

- 400 mill. NOK
- 8 years (2017-2024)
- 43 Partners
- 21 active projects
- >35 associated projects
- >100 Scientists & personell
- 27 PhD & Post doc.
- >400 MSc. students
- >3000 m² laboratories

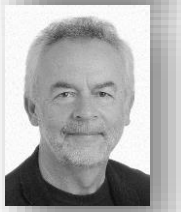
THE HYDROCEN ORGANISATION
per June 2020

INNOVATION MANAGER
Jonas Bergmann-Paulsen

INNOVATION FORUM

SCIENTIFIC COMMITTEE

Prof. Markus Aufleger
Hydraulic engineering
University of Innsbruck



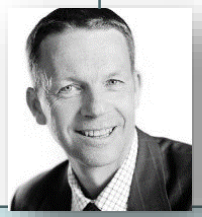
Prof. Thomas Staubli
Mechanical engineering
Hochschule Luzern

Prof. Juan Ignacio Pérez-Díaz
Power systems and -scheduling
Technical University of Madrid

Sr. Researcher Dr. Niels Jepsen
Aquatic ecology
Technical University of Denmark

EXECUTIVE DIRECTOR
Liv Randi Hultgreen

INDUSTRY REP.
Sigve Næss



NTNU
Ole Gunnar Dahlhaug

SINTEF Energy
Michael Belsnes

NINA
Line E. Sundt-Hansen

WP 1
HYDROPOWER STRUCTURES
Prof. Leif Lia

WP 2
TURBINE AND GENERATOR
Prof. Arne Nysveen

WP 3
MARKET AND SERVICES
Dr. Birger Mo

WP 4
ENVIRONMENTAL DESIGN
Dr. Torbjørn Forseth

CENTRE COORDINATOR
Ida Antonsen

COMMUNICATIONS OFFICER
Juliet Landrø

FINANCE OFFICER
Birk Fiveltun

MORE THAN 100 SCIENTISTS, PHD, POST DOC AND TECHNICAL PERSONNEL

MORE THAN 100 INDUSTRIAL MEMBERS
PARTICIPATING IN TECHNICAL COMMITTEES & PROJECTS

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Research partners

NTNU

SINTEF

NINA
Norwegian Institute for Nature Research

University of South-Eastern Norway

NGI

NTNU Technology Transfer as

The Research Council of Norway

User-partners from industry and government

agder energi

BKK

ECO

Eidsiva

NVKS
NORSK VANNKRAFTSENTER

EnergiNorge

GLITRE ENERGI

HELGELAND KRAFT

Hydro

Lyse

NTE

SFE

Sira-Kvina KRAFTSELSKAP

Skagerak Energi

NVE

SKL

SKS

Sognekraft

Statkraft

SUNNFJORD ENERGI

TAFJORD

TrønderEnergi

TUSSA

VATTENFALL

ØSTFOLD ENERGI

MILJØ-DIREKTORATET

EDR MEDESO

FOB

SediCon
Removing sediments

ABB

ANDRITZ Hydro

GE Renewable Energy

RAINPOWER

VOITH HYDRO POWER GENERATION

DR. TECHN. OLAV OLSEN

Multiconsult

Norconsult

SWECO

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Ongoing projects

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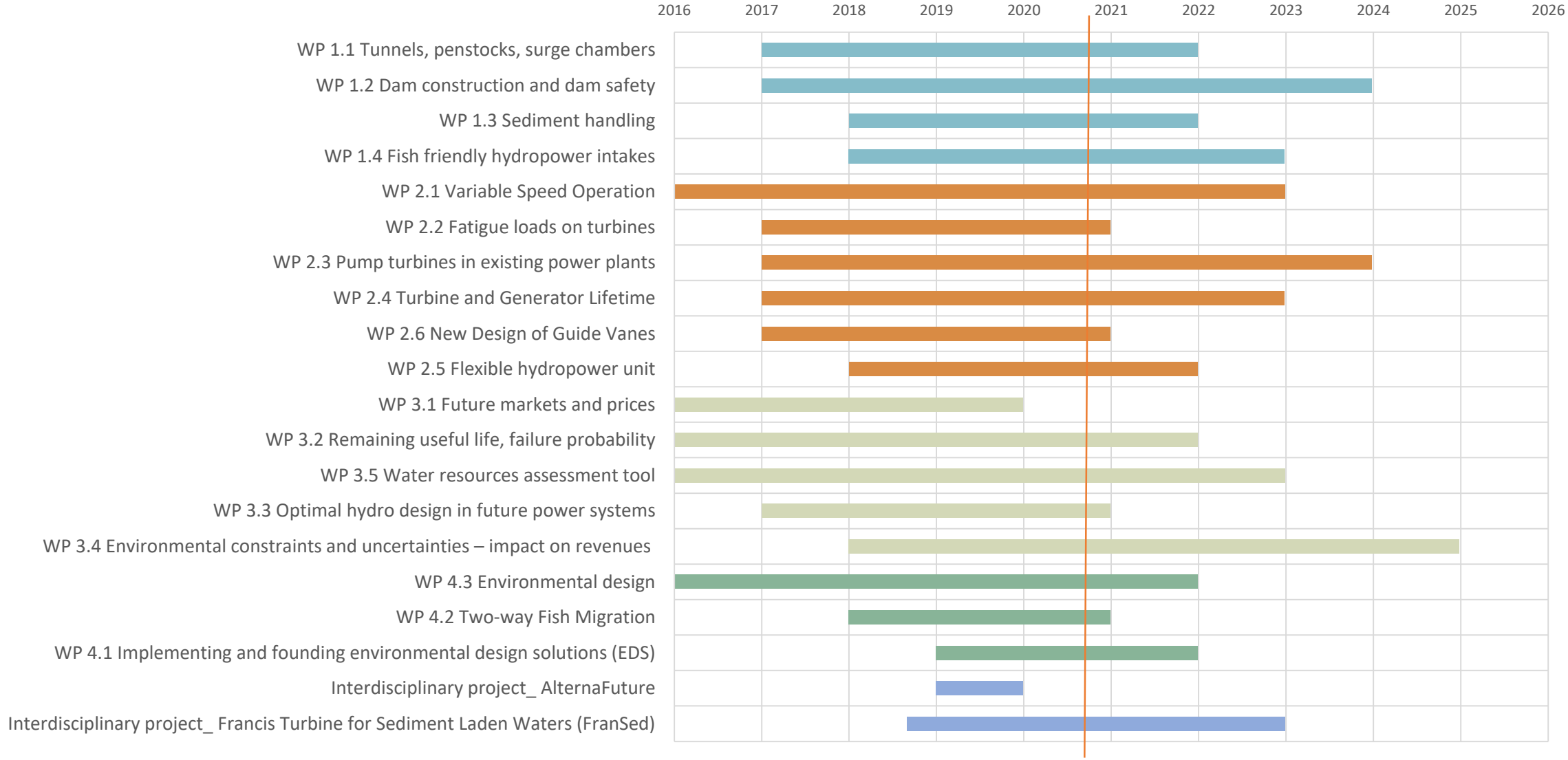
Projects in HydroCen

WP1 Hydropower Structures Leif Lia	1.1 Hydropower tunnels, penstocks and surge chambers	Bjørn Nilsen
	1.2 Dam Construction and dam safety	Fjola Sigtryggsdottir
	1.3 Sediment handling	Nils Ruther
	1.4 Fish-friendly hydropower intakes	Leif Lia
WP2 Turbine and Generator Arne Nysveen	2.1 Variable speed operation	Arne Nysveen
	2.2 Fatigue loads on turbines	Torbjørn Nielsen
	2.3 Pump turbines in existing Power plants	Pål-Tore Storli
	2.4 Turbine and generator lifetime	Maren Istad
	2.5 Flexible Hydropower Unit	Kjetil Uhlen
	2.6 New design of guide vanes	Pål-Tore Storli
WP3 Market and Services	3.1 Future market structures and prices	Birger Mo
	3.2 Remaining useful life, failure probability	Arnt Ove Eggen
	3.3 Optimal hydro design in the future power system	Birger Mo
	3.4 Environmental constraints and uncertainties – impact on revenues	Arild Helseth
	3.5 Water resources assessment	Lennart Schönfelder
WP4 Environmental Design Torbjørn Forseth	4.1 Market opportunities for profitable environmental design operation	Audun Ruud
	4.2 Ecological connectivity for fish in regulated rivers	Torbjørn Forseth
	4.3 Environmental design for multiple interest under future flexible hydro power	Atle Harby
Nye prosjekter	AlternaFuture	Kaspar Vereide
	ValuFlex	Michael Belsnes
	Digitalization	Hans Ivar Skjelbred

Timeline for 20 HydroCen Projects



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Timeline for 39 Associated Projects

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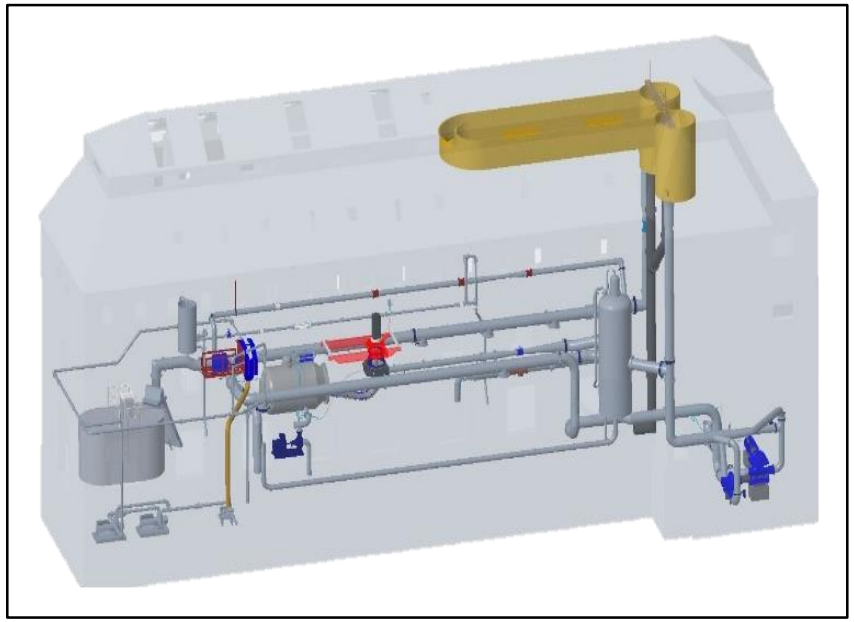
HydroCen Labs

National research infrastructure

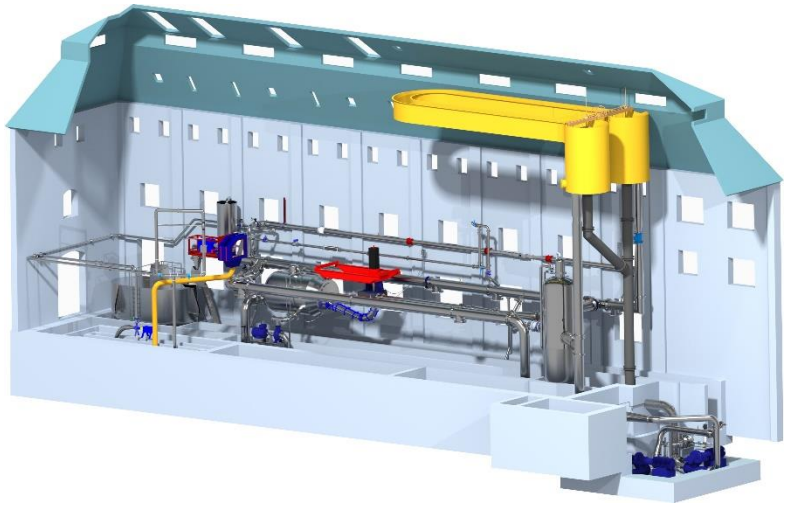
- The project is divided in 3 phases (budget; NOK 197 millions)

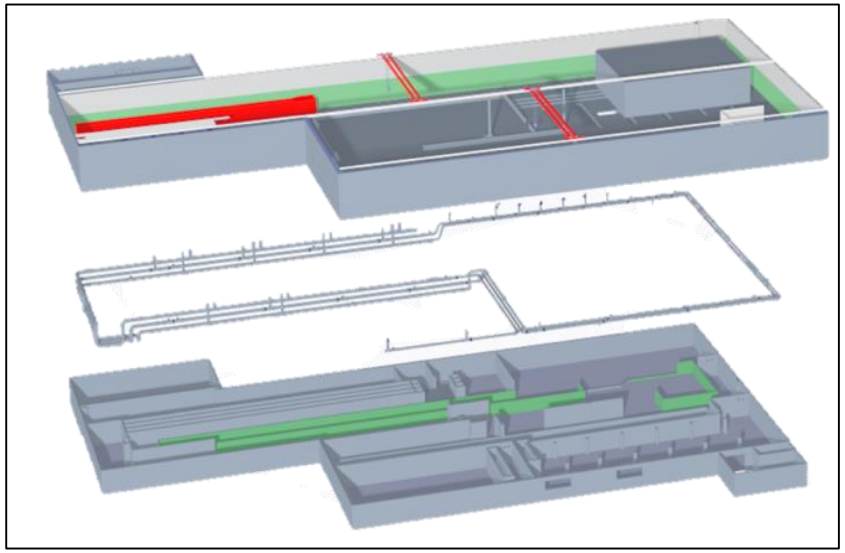
- Phase 1 (budget; NOK 55 millions)
  - Waterpower Laboratory
  - Hydraulic Laboratory
  - Geology Laboratory
  - SmartGrid Laboratory
  - Generator Laboratory
  - Material test Laboratory



HydroCen Labs

- Waterpower Laboratory
  - Upgrading and maintenance of existing pipe system and turbine test rigs
  - Virtual connection between the Waterpower Laboratory and the SmartGrid Lab
- Material test Laboratory
  - New test rig for fatigue in materials
- Generator Laboratory
  - Generator multi-stress test rig
- Geology Laboratory
  - Test rig for investigating tunnel containment and stability
- Hydraulic Laboratory
  - Miniflume
  - Multipurpose flume
  - Infrastructure for model construction and new instrumentation
  - Field laboratory (Sagelva)





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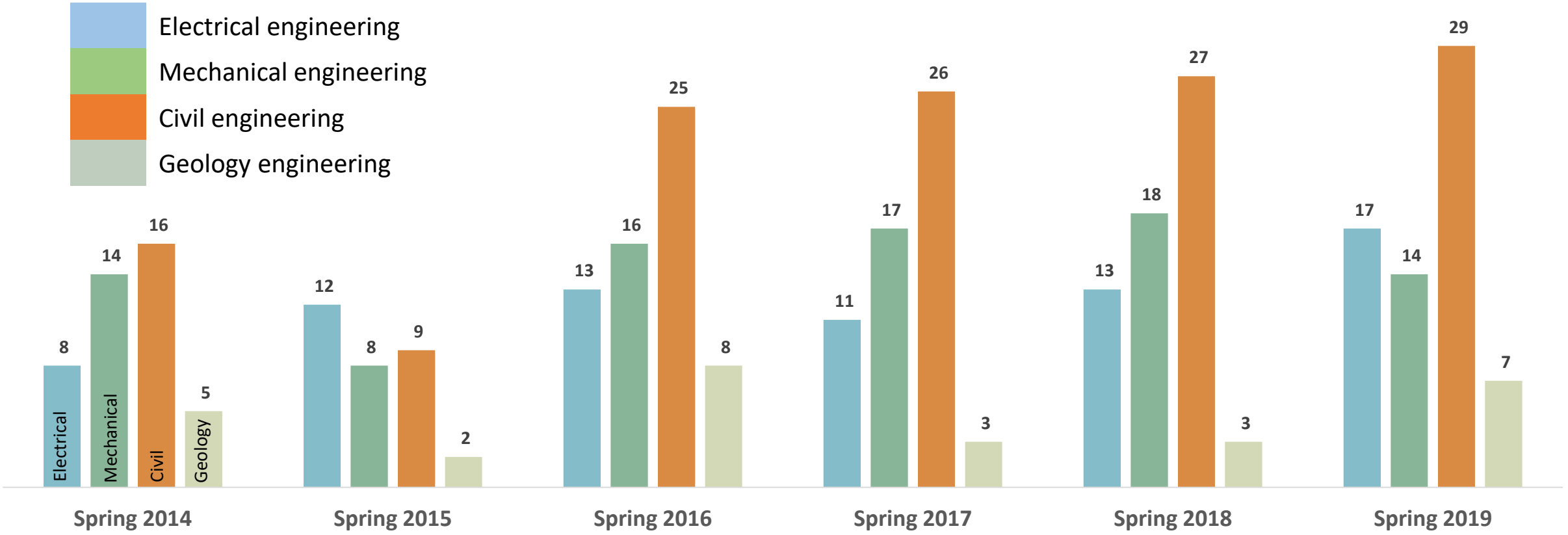
Master students 2014-2019



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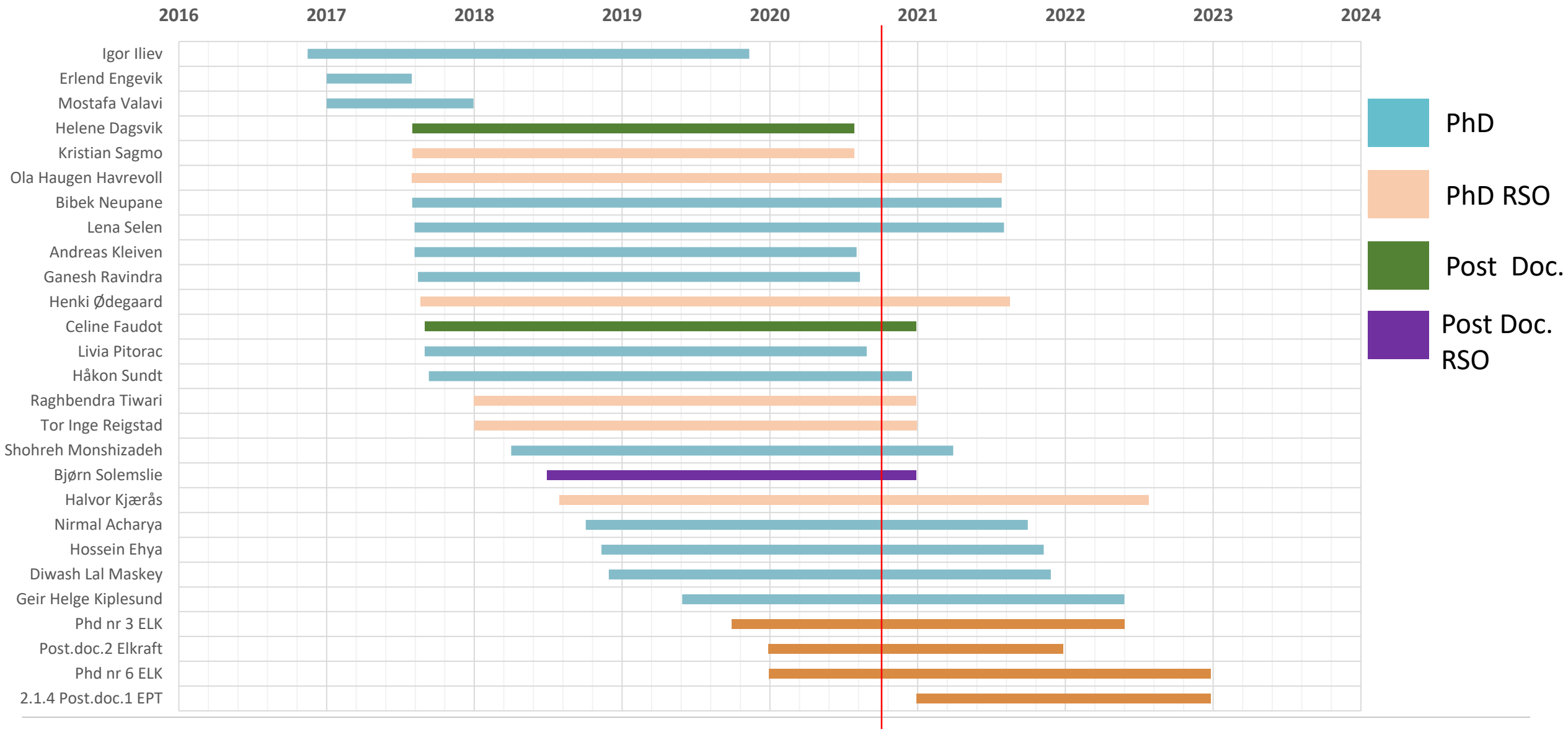
PhD & Post docs in HydroCen



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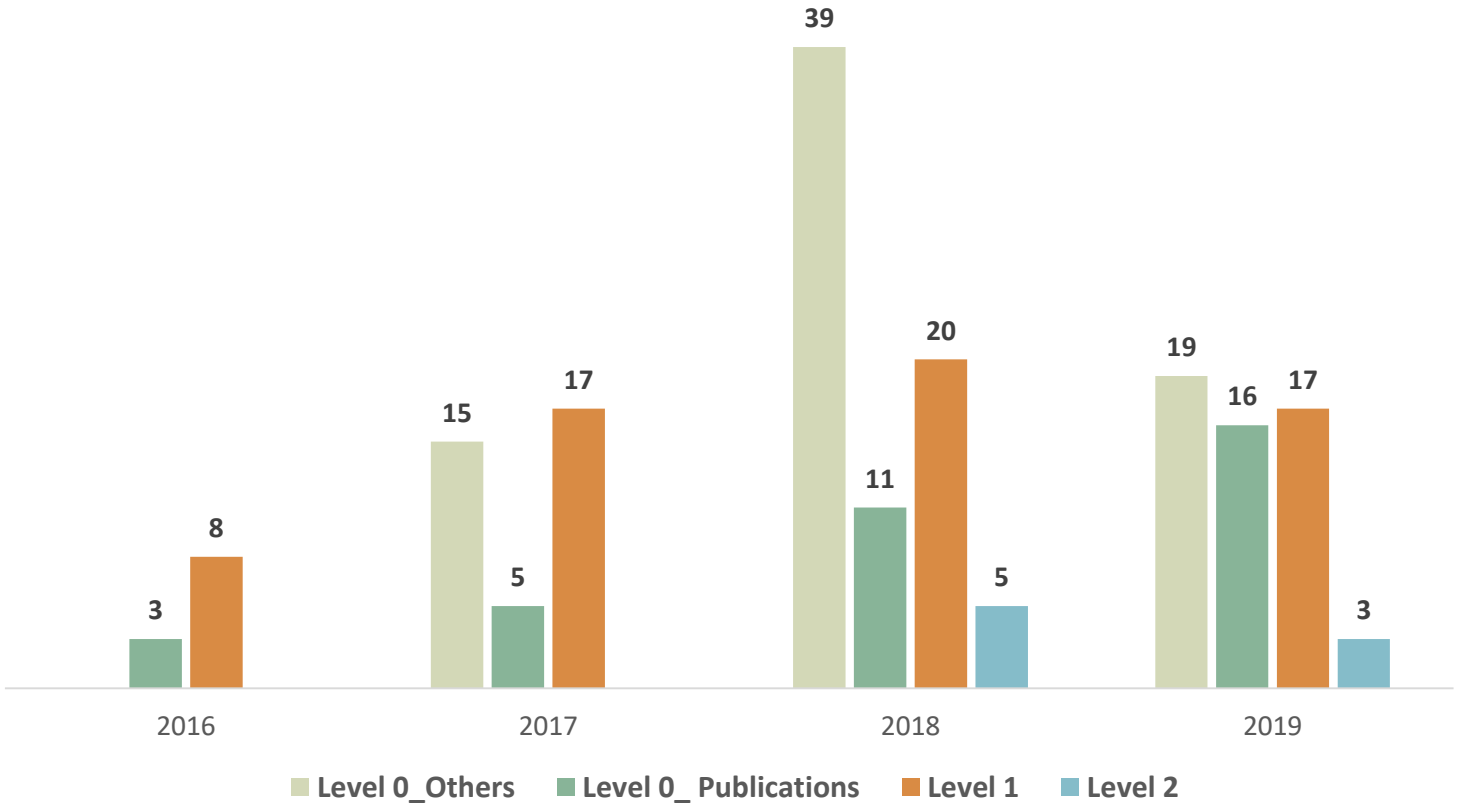
Scientific publications

178 publications 2017-2019

Level	Type	#	Points
0	Publications, reports	35	0
0	Presentations, lectures, etc.	73	0
1	Scientific Publication	62	62
2	Scientific Publication	8	23



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Norges smarteste oppussingsprosjekt

Det er gjennomført en hypotesestudie som underbygger at vi gjennom bedre utnyttelse av det eksisterende norske vannkraftsystemet kan sannsynliggjøre økt fornybar energiproduksjon tilsvarende vindkraftpotensialet i Norge. Gjennom et debattinnlegg i Aftenposten presenterte Leif saken. Dette ble raskt et faktabasert innspill til den pågående debatten om utbygging av vindkraft, og førte til en rekke oppfølgende medierunder for Lia. HydroCen er stolte av at våre forskere fremmer klare budskap basert på den kunnskapen vi sitter med.

Les innlegget her: **https://bit.ly/2Ynqz6a**

NRK TV innslag:
https://tv.nrk.no/serie/kveldsnytt/201906/NNFA23062519/avspiller

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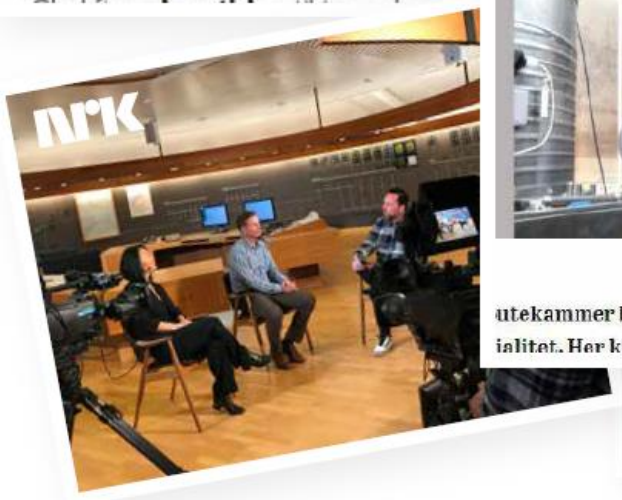
HYDROCEN IN THE MEDIA

This year HydroCen had been featured in several media outlets, ranging from national tv, newspapers to local websites, and technical magazines. In total HydroCen research has been mentioned in 67 articles or broadcasts in the media.



OUR OULETS

Newsletter:
Public newsletter, 4 publications, 204 subscribers and an opening ratio of 30-50%

Blog:
50 blog pieces with information and news from Hydrocen in 2018, more than 5000 visitors and 11 000 views.

Vannposten:
Weekly newsletter for researchers. 30 publications and 150 recipients.

Website:
Information and contact details for all projects and researchers in HydroCen. Publications and innovations are also accessible from www.hydrocen.com

SOCIAL MEDIA

Twitter:
147 tweets, 10 000 views per month and 387 followers.

10000

Facebook:
348 followers and an average post reach of about 3000

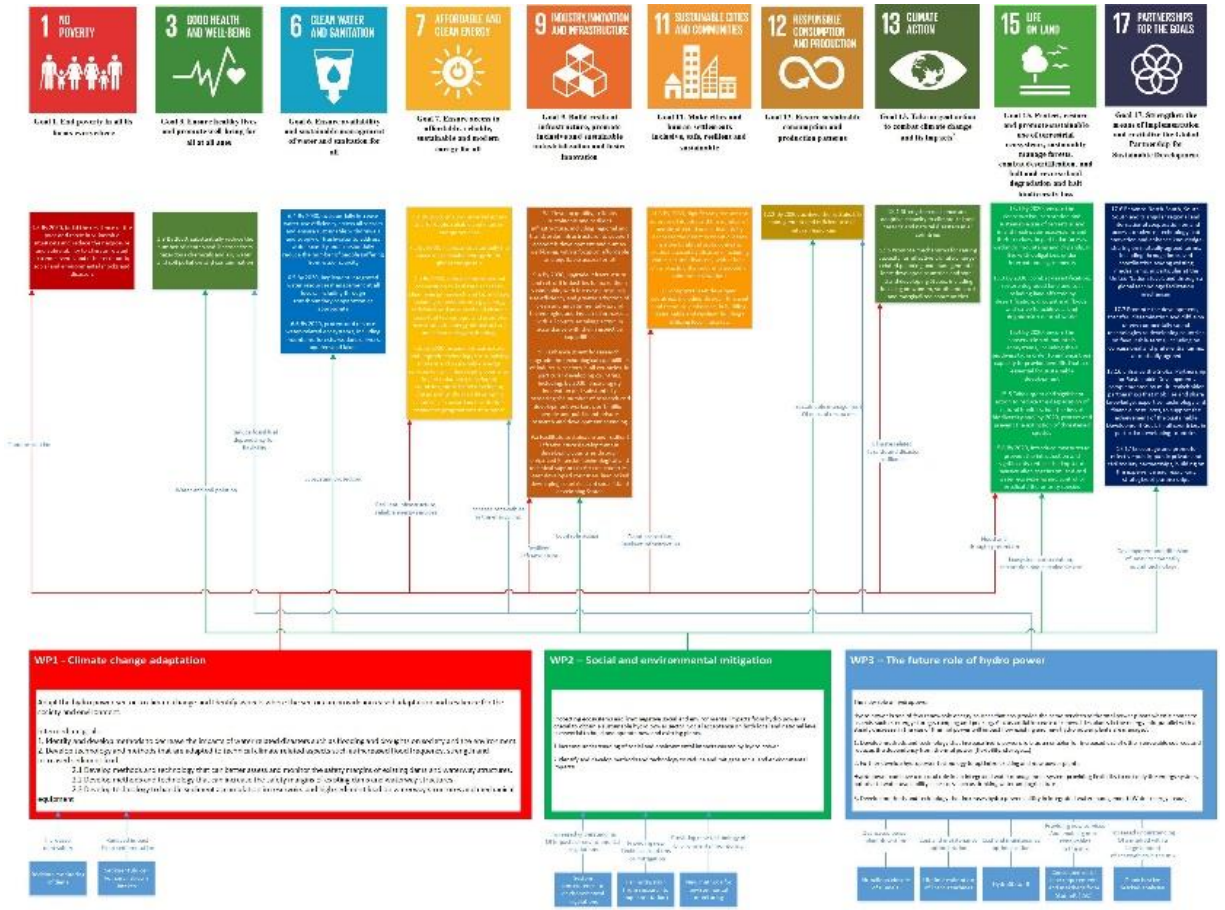
348

LinkedIn:
171 and increased activity

171 +

Innovation in HydroCen

- New
  - Taken care of by the role of research
  - Focus on identifying results with innovation potential
- Usefull
  - Prioritize results that can contribute to value creation and / or societal benefit
  - The projects has to be anchored in UN's sustainability goals
- Utilized
  - Ensure early anchoring in the HydroCen's partners
  - Ensure access to funds throughout the innovation process



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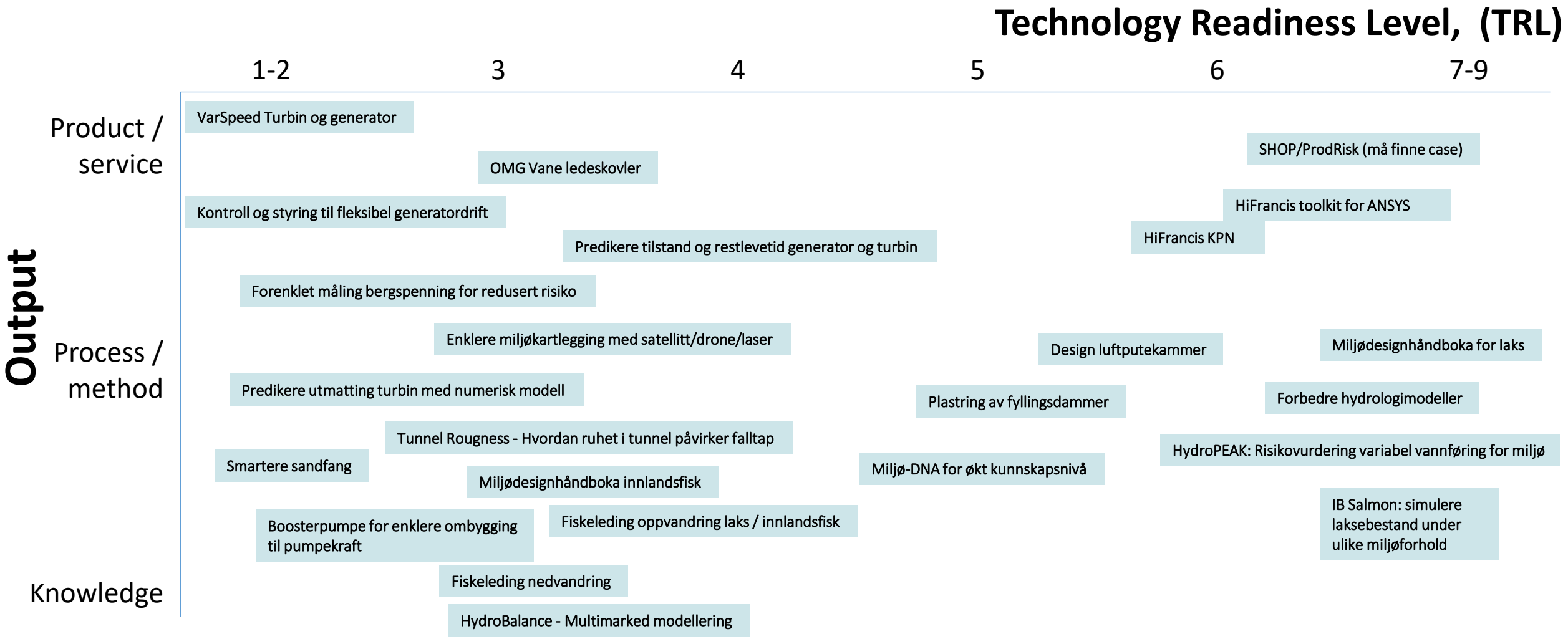
HydroCen's innovations



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Innovation	Description
OMG Vane	Serated edge on foils to remove/reduce problems induced by vortex shedding
Rotor Fault Detection in Hydro generators	The idea is to detect turn-to-turn rotor faults in hydro generators in early stages and provide warnings. The fault is detected using harmonic analysis of terminal signals (i.e. stator voltage and/or stator current).
LeakReg	An innovation that reduces leakage water from Francis turbines and provides the opportunity to control the axial forces on the rotor in the unit with Francisturbin.
Floating fish guidance bar-rack	Design based on hydrodynamic behavioral barrier to avoid fish and migrating smolt to enter hydropower intakes.
Booster pump	A booster pump for retrofitting of pump capacity in existing power plants
Downhole rock stress estimation	Use of straddle packers equipped with AE (Acoustic Emission) sensors as a fast and inexpensive method for carrying out rock stress measurements in connection with placement of cone
Image based monitoring for erosion in hydro power turbines	Use of camera in combination with position sensor and image recognition algorithm for error detection
Fish Friendly Tunnels	Hydropower plant reduce the quality of natural fish habitatsa s they remove most of the water from the natural river. To compensate,it is possible to adapt the tunnels in the hydropower plant to become new habitats instead.
Hydraulic design of Francis turbines for variable speed operation	An optimization algorithm for design of Francis turbine runners specifically constructed to improve the variable speed operation (VSO) performance.

A Global Hydropower R&D - innovation Community

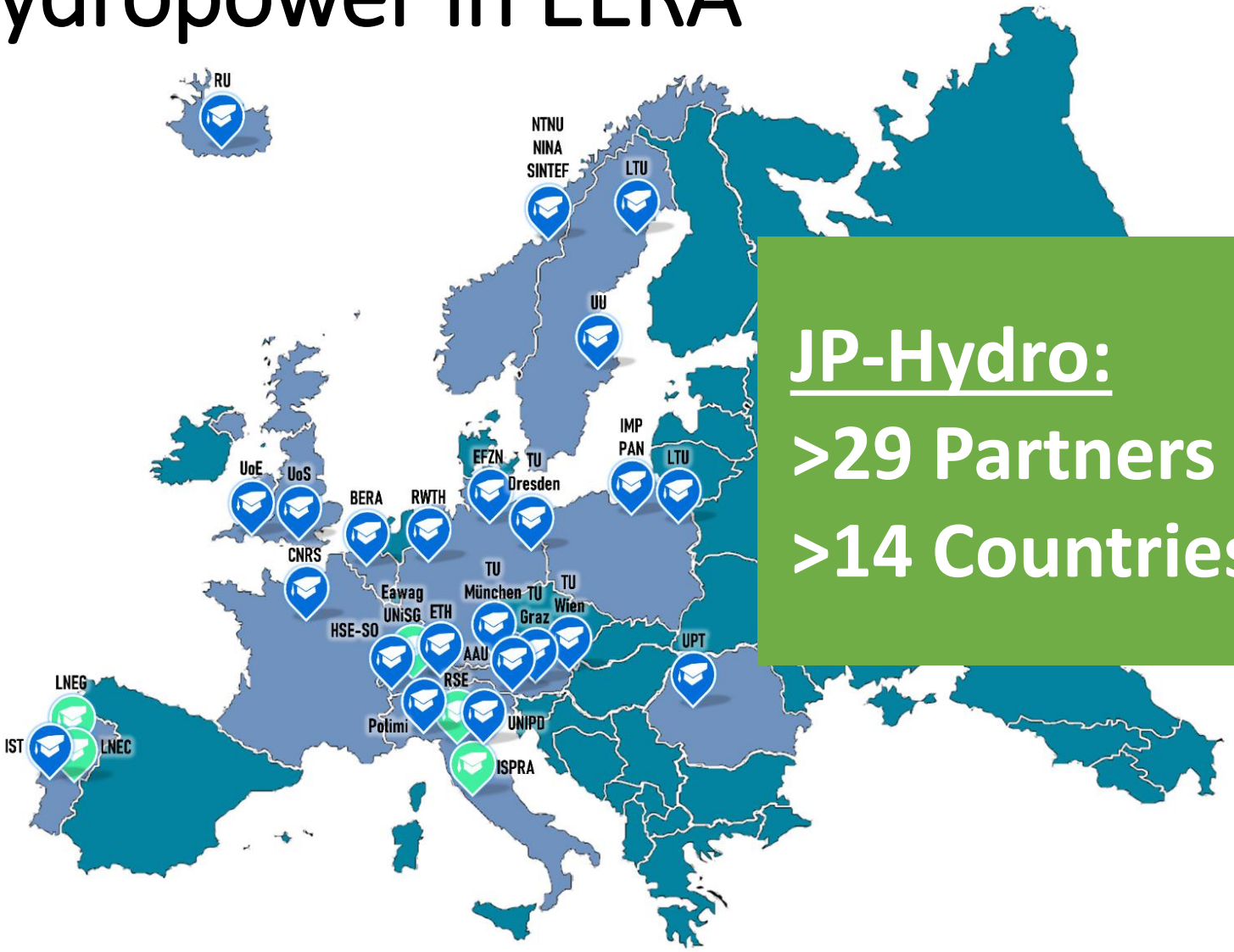
EERA
European Energy Research Alliance
Hydropower

The EERA Joint Programme on Hydropower

Advancing research on and implementation of innovative hydropower solutions for a climate-neutral Europe

Joint Programme Hydropower in EERA

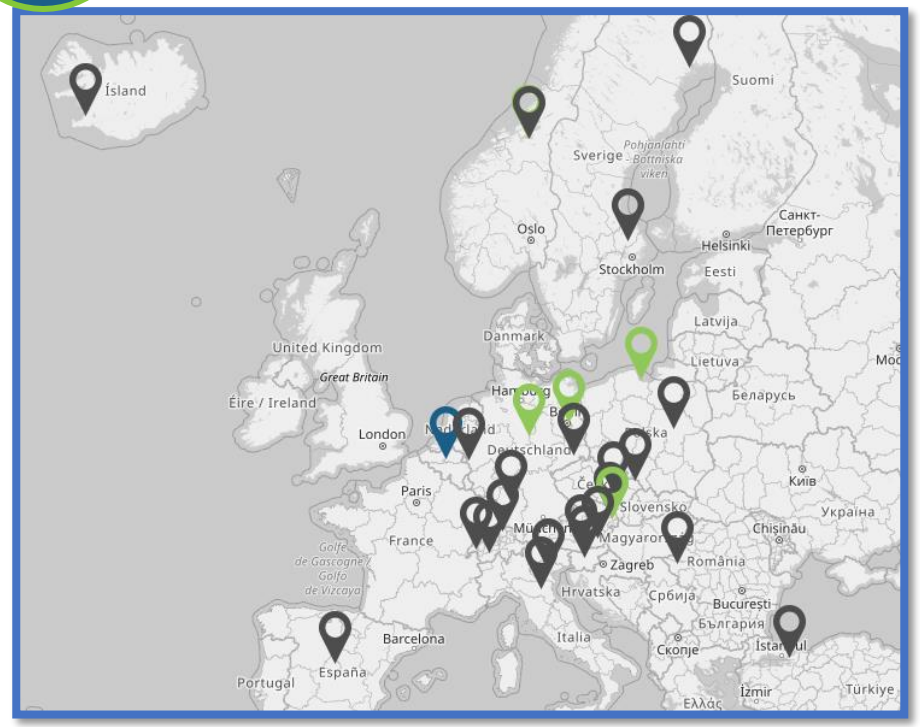
AMPEA	BIOENERGY	CARBON CAPTURE AND STORAGE	CONCENTRATED SOLAR POWER (CSP)
ECONOMIC ENVIRONMENTAL AND SOCIAL IMPACTS (JPE3S)	ENERGY EFFICIENCY IN INDUSTRIAL PROCESSES	ENERGY STORAGE	ENERGY SYSTEMS INTEGRATION
FUEL CELLS AND HYDROGEN	GEOTHERMAL	**HYDRO**	NUCLEAR MATERIALS
OCEAN ENERGY	PHOTOVOLTAIC SOLAR ENERGY	SMART CITIES	SMART GRIDS
WIND ENERGY	SHALE GAS (DISCONTINUED)		

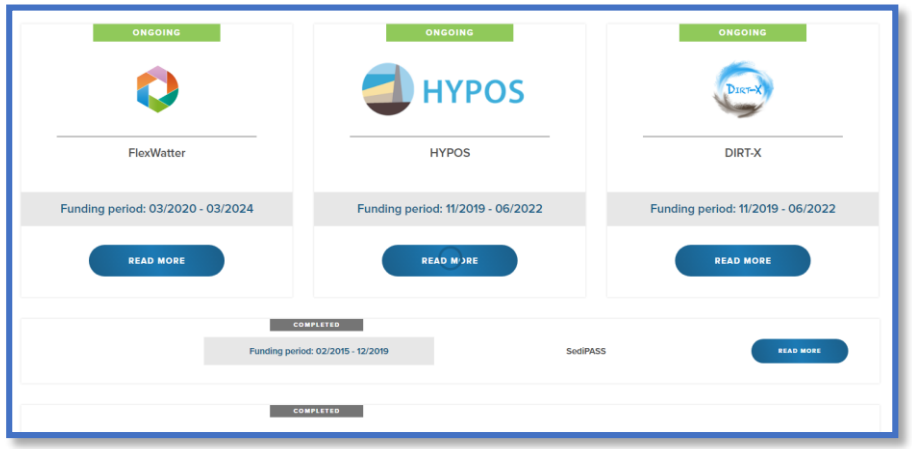


JP-Hydro:
>29 Partners
>14 Countries

EERA's mission is to catalyse European energy research for a climate-neutral society by 2050

About JP Hydropower





29 Partners

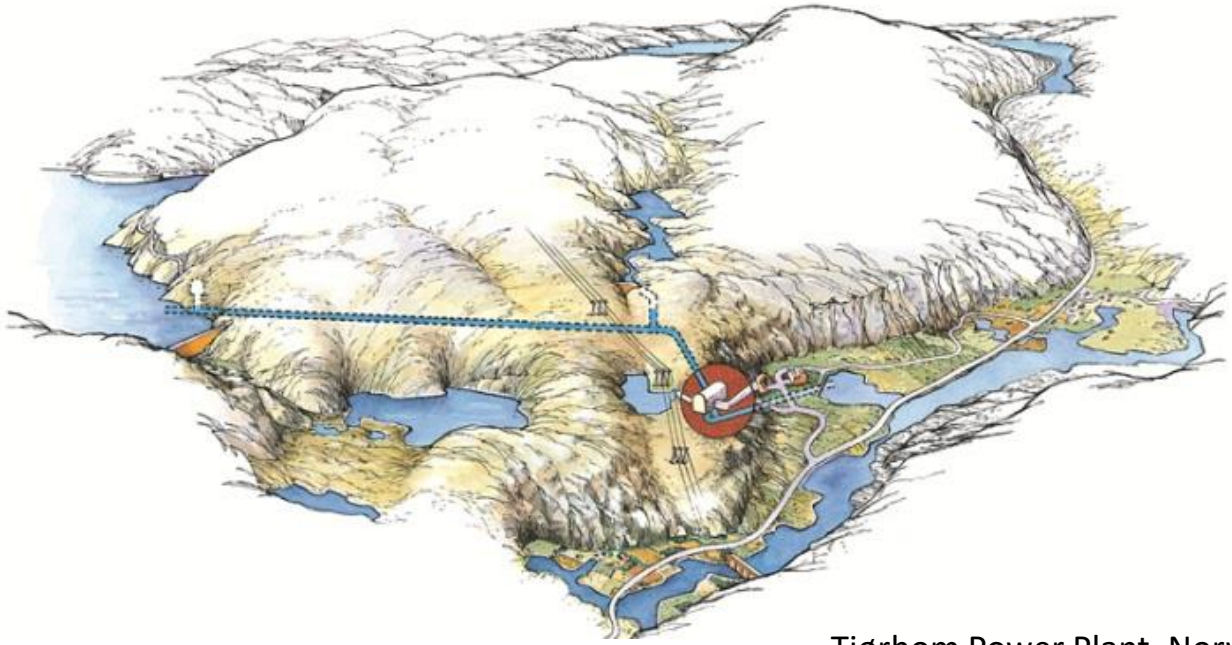
14 Countries

15 Ongoing EU Projects

NTNU
Universität Klagenfurt
AIT Austrian Institute of Technology
TOMORROW TODAY
TU Graz
TU WIEN Technische Universität Wien Vienna University of Technology
BERA Belgian Energy Research Alliance
Brno University of Technology
eco logic
efzn Energie-Forschungszentrum Niedersachsen
RWTH Rheinisch-Westfälische Technische Hochschule Aachen
Technische Universität Dresden
University of Stuttgart
Università degli Studi di Padova
SINTEF
NINA Norwegian Institute for Nature Research
IMP PAN Gdańsk
Universitatea Politehnica Timișoara
Politécnica
Luleå University of Technology
Uppsala Universitet
EPFL École Polytechnique Fédérale de Lausanne
ETH zürich
Hes-so
Univerza v Ljubljani
VSB Technical University of Ostrava
TÜBİTAK MAM

Hydropower's role in the energy system

- Sustainable, reliable and secure energy supply
- Enabler for other renewables
- Safety of supply
- System resilience
- Energy Storage
- High flexibility
- Stability
- Water management
- Climate adaptation



Tjørhom Power Plant, Norway
Source: Sira-Kvina Kraftselskap

IEA Hydropower

Vision: *"Through the facilitation of worldwide recognition of hydropower as a well-established and socially desirable energy technology, advance the development of new hydropower and the modernization of existing hydropower"*

Mission: *"To encourage through awareness, knowledge, and support the sustainable use of water resources for the development and management of hydropower."*

HydroCen is asked to host the secretariat for IEA Hydro from March 2021

- Australia
- Brazil
- China
- European Union
- Finland
- Japan
- Norway
- Switzerland
- United States

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Hydropower Summit

4th – 6th February 2020, Trondheim

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Cooperation between US DoE, US National Labs and HydroCen

Hydropower Optimization

- IEA Annex IX
  - Valuing Hydropower Flexibility in Evolving Electricity Markets
  - Flood control and drought management
- Price formation in future energy market
- Comparison and co-development of power system models

Technological Challenges

- Digitalization roadmap
- Hydrofleet dispatch variability
- Realtime monitoring control on generators
- System Fatigue/Wear Modeling

Environmental Conditions

- eDNA
- Fish Passage and fish monitoring technology
- Fish tags
- FIThydro wiki and Decision Support Tools
- Hydropower flexibility impacts on ecosystems (Hydropeaking impacts)

Suksesshistorie WP1

Doktorgradsarbeid i WP1 har avdekket at den nederste delen av fyllingsdammer (bilde) kan få seg en knekk når tyngden fra steinfyllinga blir for stor, for eksempel hvis den flommer over.

Nå bygger vi en modell i laboratoriet, og dataene fra doktorgradsarbeidet skal brukes til å utvikle bedre design på damkroner (toppen av demningen). Forskning som rocker!

Både kraftverk og tunneler i Norge er dimensjonert og bygget for andre tider, med stabil produksjon og stabilt forbruk. Nå setter nye kjøremønster og en ny energimiks helt andre krav til tunneler og kraftverk.

I HydroCen undersøker vi nå både hvor mye eksisterende tunneler og kraftverk tåler, samtidig som vi utvikler nye løsninger for utforming. Spesielt ser vi på ombygging av eksisterende kraftverk til pumpekraftverk.

Suksesshistorie WP2

Vi har designet og utviklet en ny type turbin som kan «skifte gir».

- Tradisjonelle turbiner er laget for å produsere strøm jevnt og trutt, men denne kan kjøre i ulike hastigheter og starte og stoppe mye raskere enn i dag.
- En sånn type strømproduksjon fra vannkraft betyr at vi kan legge til rette for mer strøm fra vind og sol i kraftsystemet.
- Samtidig er det utviklet verktøy for design av generatoren som kobles til en slik turbin.

Vi har utviklet metoder som finner feil inni generatorer.

- Siden 90-tallet har vannkrafta drevet med såkalt effektkjøring (at man starter og stopper strømproduksjon avhengig av etterspørselen i markedet). Det fører til mer slitasje på komponenter inni generatoren som er vanskelig å oppdage og fører til store kostnader hvis man må ta ut generatoren for reparasjon.
- Nå har vi utviklet en testmetode som kan finne flere typer feil på et tidlig stadium ved bruk av billige og smarte sensorer.

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Suksesshistorie WP3

Vi utvikler datamodeller som kan forutsi markedet og prisene i framtidas energisystem.

- EU har et mål om mer grønn energi og vi har blant annet utviklet to scenarioer for det Europeiske kraftsystemet i 2030 og sett på variasjon i strømpriser i Nord-Europa 2030.
- Vi ser at det blir mer variasjon i strømprisene i et lav-utslippssystem enn i dag der mye strøm er produsert med kullkraft. Når det blir økt variasjon i strømprisene, vil også verdien av fleksibel vannkraft stige, særlig hos produsenter i Sør-Norge.

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Suksesshistorie WP4

- Bærekraft og miljø må være bærebjelken i grønn energiproduksjon, og vannkraft påvirker både elver, fisk, næring, friluftsliv og arter på land. Vi har utviklet **miljødesign**; en metode som både bedrer vannmiljø og samtidig tar hensyn til kraftproduksjon.
- **Miljø-DNA** er en ny høyteknologisk genetisk metode, der forskerne kan ta vannprøver og finne DNA fra alle artene som lever der! Det er et unikt nytt verktøy som utvikles videre i HydroCen.
- I HydroCen har vi brukt avanserte målinger og datamodeller for å utvikle **ledegjerder** som skal føre laksesmolt forbi kraftverksinntaket og unngå at de går gjennom turbinen og blir sushi! Disse testes nå i stor skala i Mandalselva, og hvis det er en suksess vil de kunne brukes i kraftverk i hele verden for å unngå store tap av fisk i elver med kraftverk!

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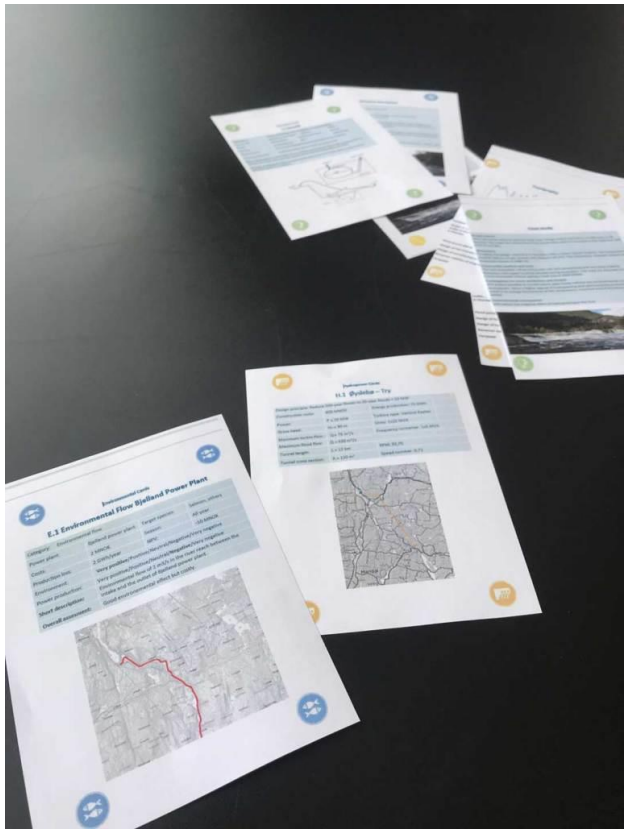
AlternaFuture - ekstrem ombygging av vannkraft



Prosjektet utvikler ny tverrfaglig metodikk, «Kortstokkmetoden», og benytter Mandalsvassdraget som case. Forestill deg at vi skulle bygd opp hele vannkraftsystemet på nytt, eller at vi ikke hadde noen begrensninger på hva vi kunne gjort. Vil vi da kunne lagd et system som både var bedre for naturen og som produserte mer kraft? Det er også et mål i seg selv å styrke det tverrfaglige samarbeidet innen vannkraftforskningen, og øke den helhetlige tilnærmingen rundt vannkraft i dette prosjektet.

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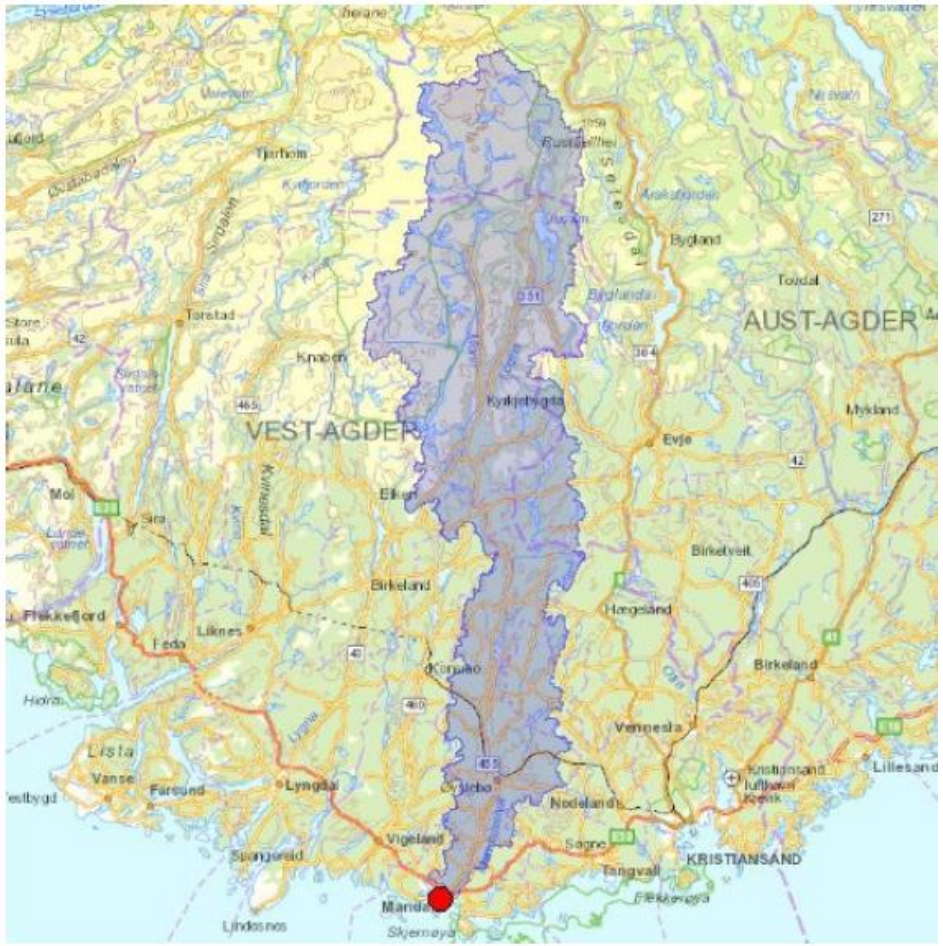
AlternaFuture – project in the Mandal river

- Characteristics
  - 140 km long river
  - Maximum elevation 1160 m, outlet to the sea
  - 6 existing hydropower plants
  - Total installed capacity = 384 MW
  - Annual production = 1,7 TWh
- Design criteria
  - Minimum triple the installed capacity, including pumped storage
  - A positive impact on the environmental condition of the river basin
  - Existing environment protection shall be respected
  - Water use and the interests of the local municipalities shall be considered



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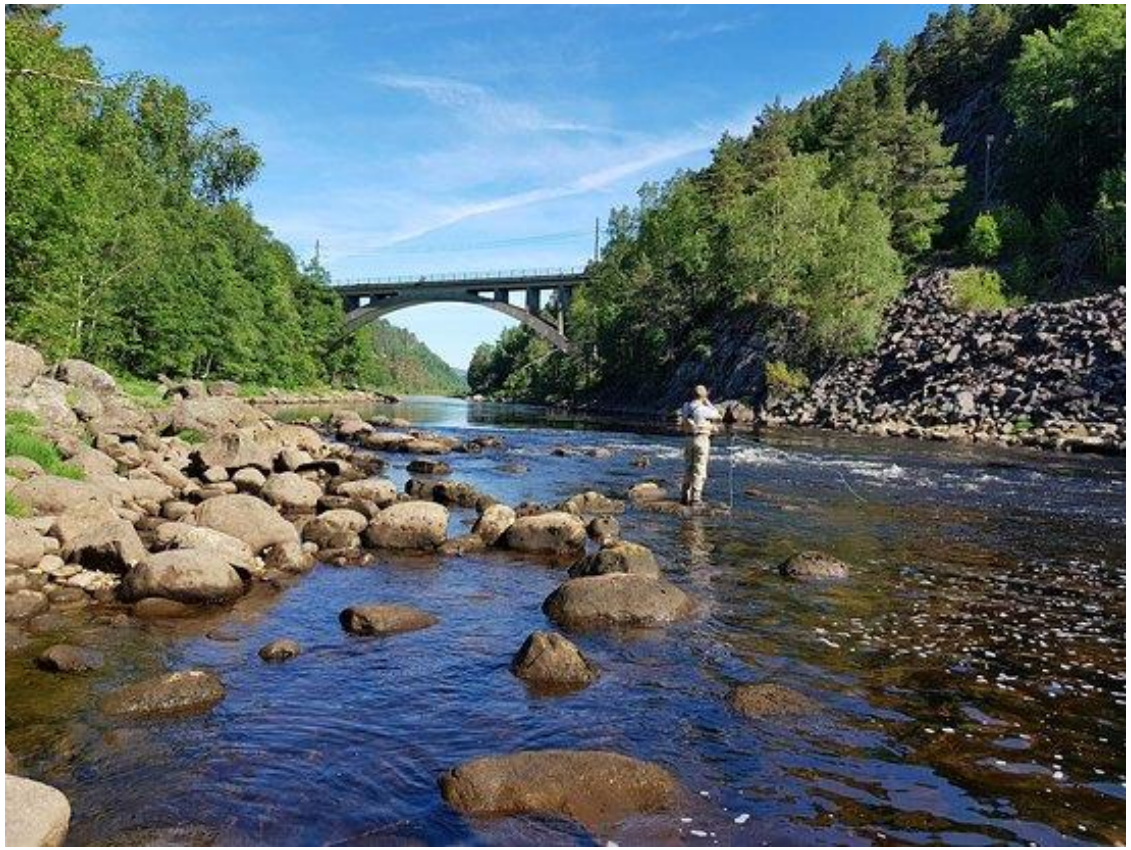
AlternaFuture – Some Findings

- Extreme upgrading
  - Environmentally friendly extreme upgrading is found to be possible for all three scenarios
  - Not profitable in the current market
  - New and interesting hydropower projects can still be found in existing schemes
  - The concept of flood power plants is found especially interesting in Mandal
- Flood Power Plants
  - Combined flood bypass tunnel and hydropower plant
- Fish friendly pumping intakes
  - Identifies as a challenge without a current solution
  - But solutions were discussed at user meeting seminar



How can we introduce more cooperation between Sweden and Norway ?

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