

H-HOPE

Powering the Digital Water Future through Energy Harvesting

Prof. Giovanna Cavazzini
University of Padova
H-HOPE coordinator



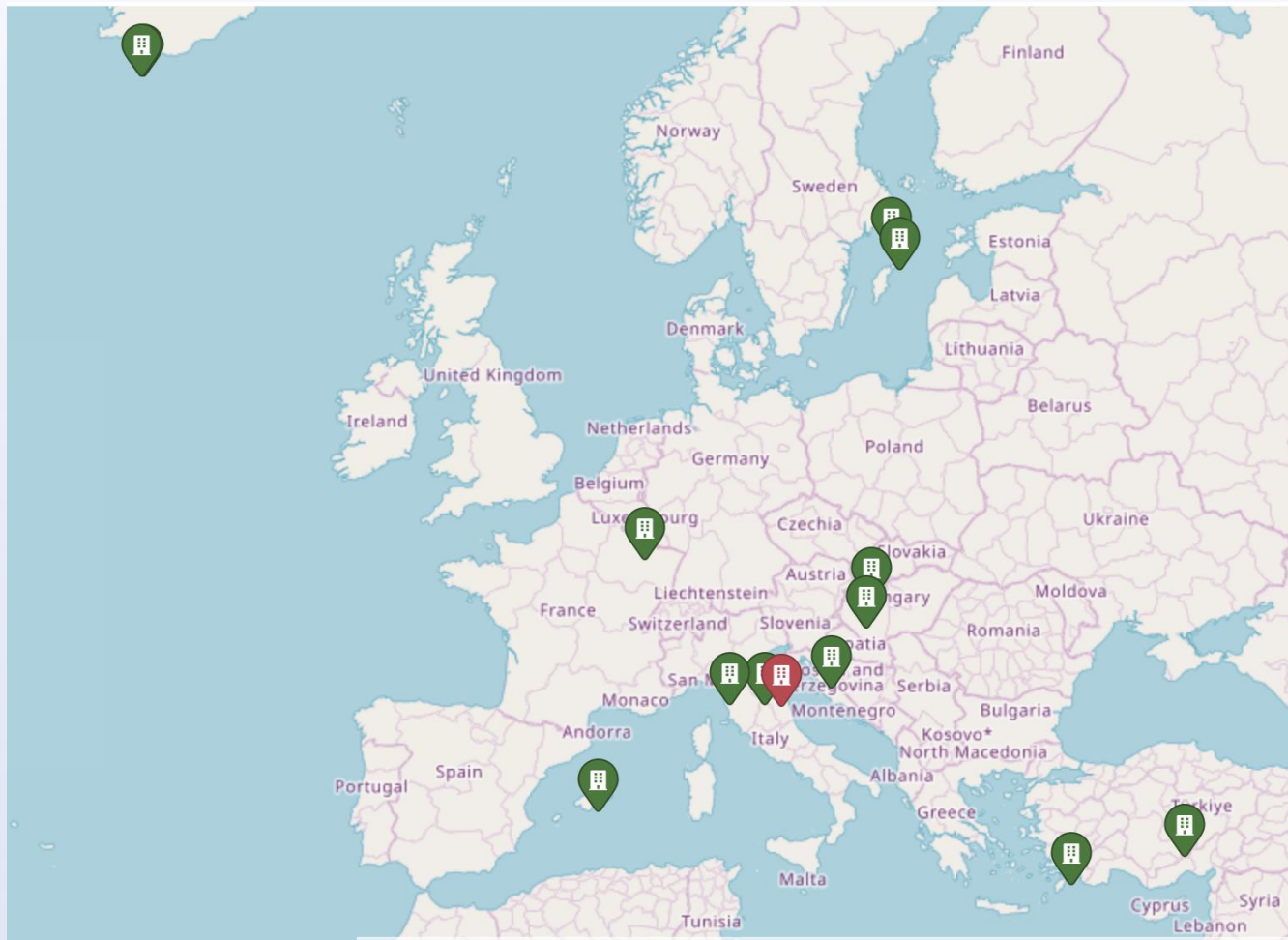


The H-HOPE project

Hidden Hydro Oscillating Power for Europe

Duration: 11/2022-10/2026

Budget: 4.8M€



14 partners



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Coordinator



University of Ljubljana



UPPSALA
UNIVERSITET



TÜBİTAK



CJH Multisourcing

H-HOPE



Hidden Hydro Oscillating Power for Europe project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement n. 101084362



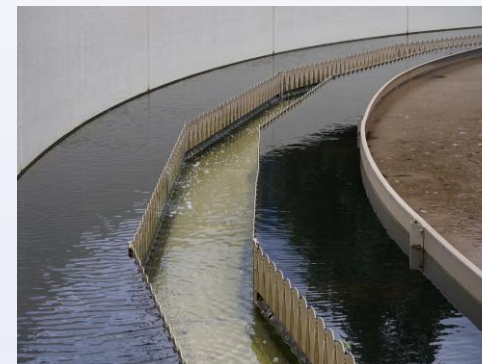
Untapped hydropower potential in natural and artificial water flows



Water distribution networks



Irrigation channels



Waste water treatment channels



Lagoon natural flows

Untapped because of:

- Limited water energy
- Too high cost of traditional technologies



The state of the art....not suitable for micro-power solutions

Examples of hidden hydropower innovative technologies

[IEA report, 2023. «IEA Hydropower Task 16 - Hidden and Untapped Hydropower Opportunities at Existing Infrastructure»]



01 La Zour
Municipal water

Head = 217 m
Flow rate= 300 l/s
Power= **465 kW**



02 The Momura (Japan)
Irrigation channels

Power= **120 kW**



03 The Duo-Two axial
turbine

Head = **80 m**
Flow rate= 10 l/s
Power= 5 kW



The H-HOPE concept





The H-HOPE project: the concept

The idea of H-HOPE is to exploit a phenomenon known as «resonance condition».....



*Collapse of the
Tacoma bridge*

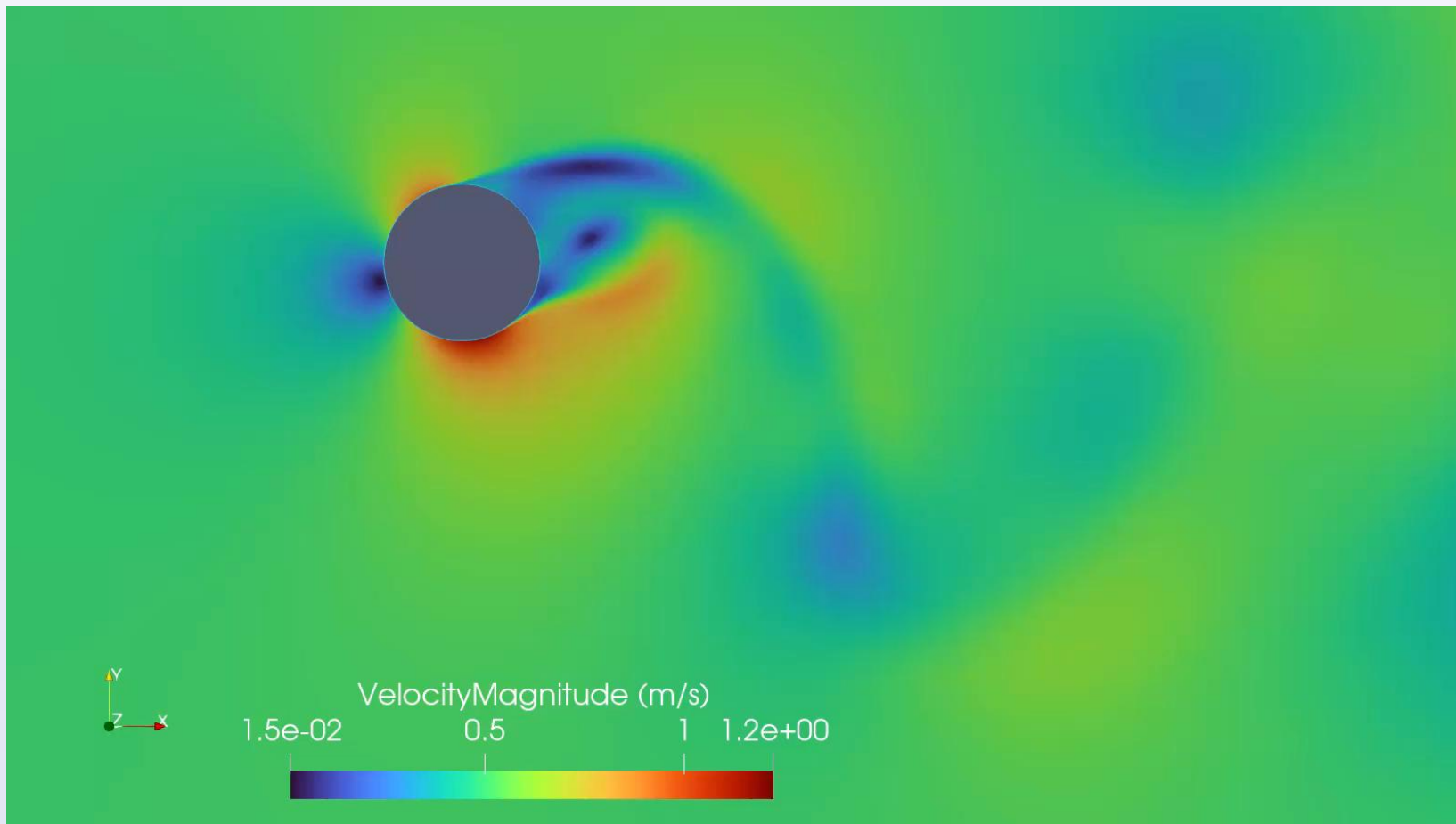
**....to produce
energy!!**





The H-HOPE project: the concept

The idea of H-HOPE was to develop an **innovative technology** capable of extracting energy from the **vibrations** induced by fluid vortexes on a body immersed in the fluid

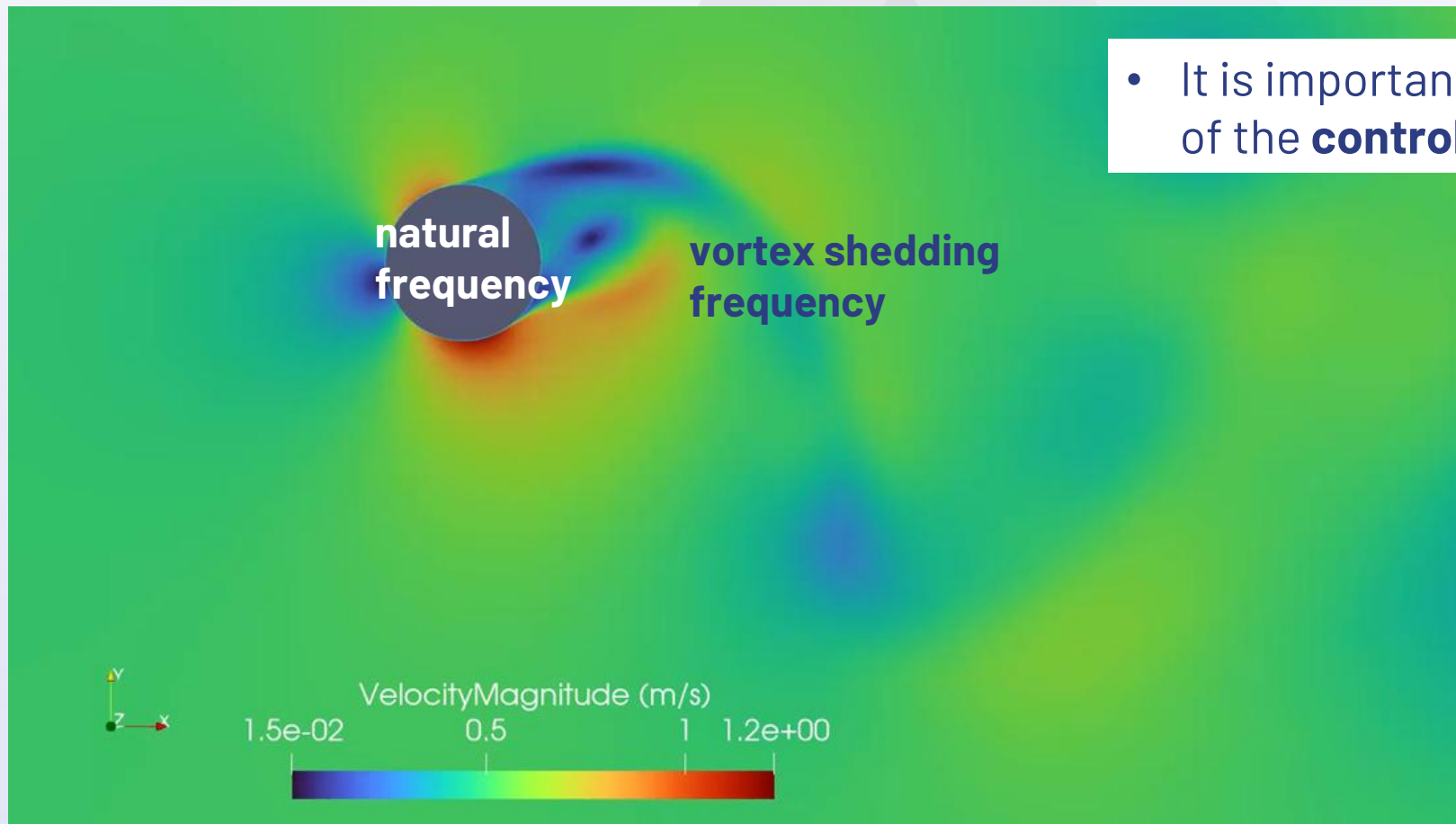


Vibrations are stronger in resonance conditions



The H-HOPE project: the concept

- The resonance condition requires the **synchronization** between the water **vortex shedding frequency** and the **natural frequency** of the immersed body....



- It is important also to consider the influence of the **control system** (e.g. damping factor)

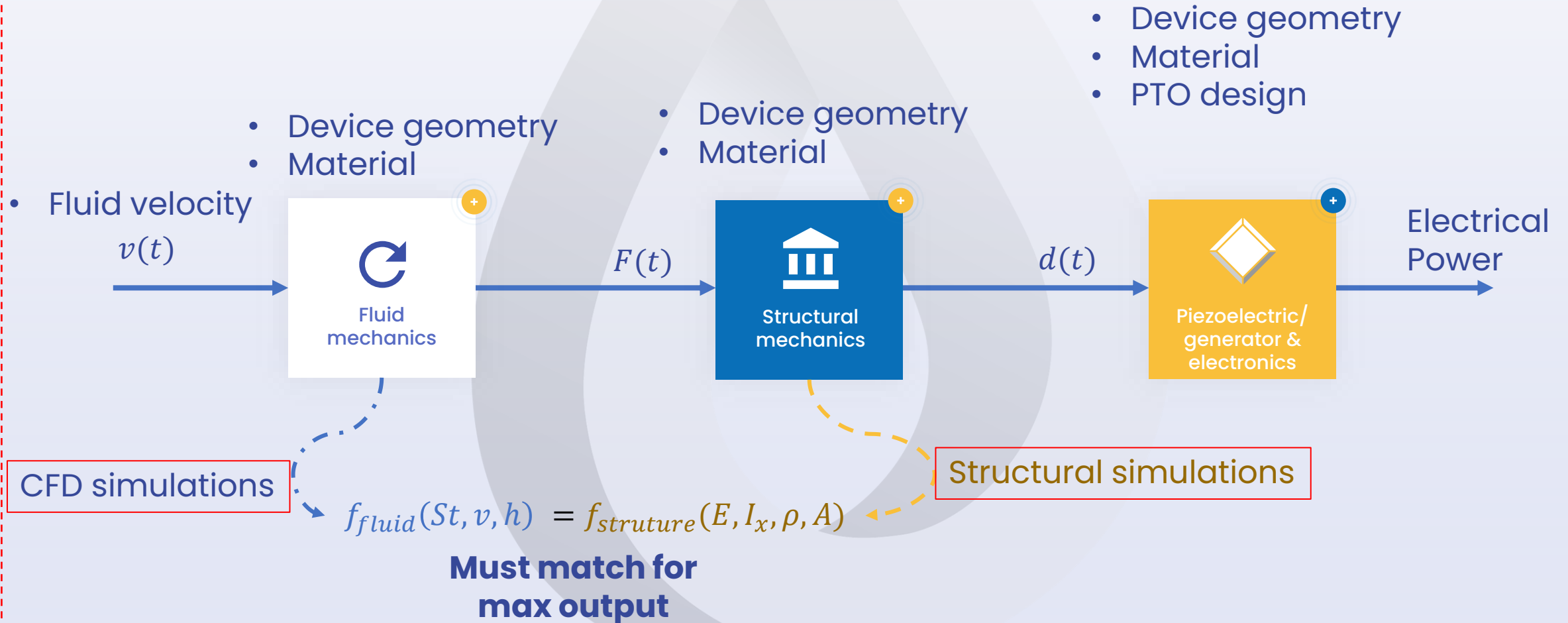


MULTI-PHYSICS PROBLEM

.....with different constraints and issues depending on the application



General process to 1D modelling

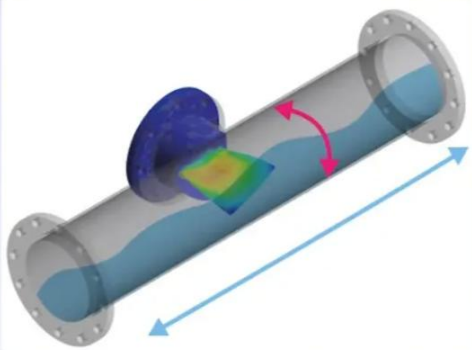




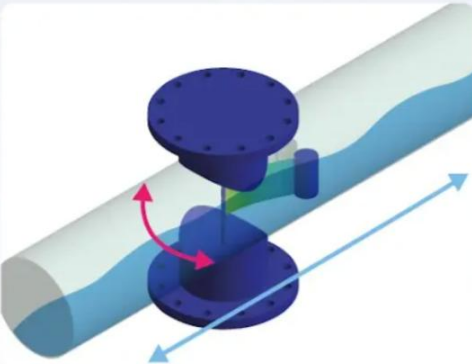
The prototypes

PIPING

1. OPTION

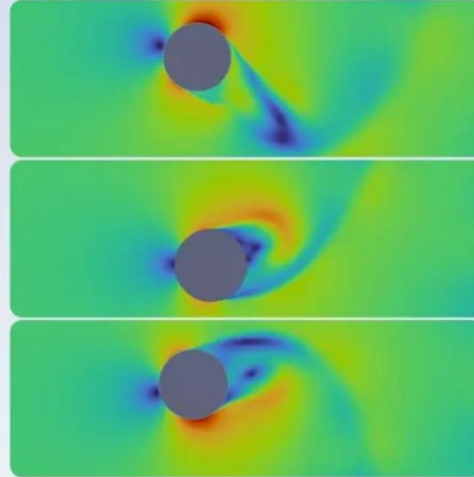


2. OPTION

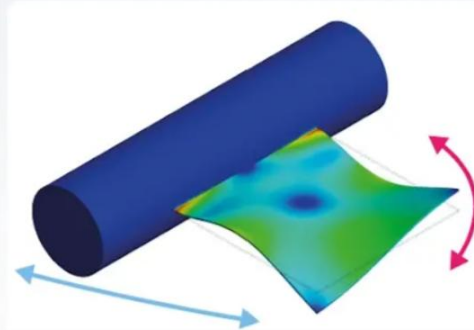


OPEN STREAMS

1. OPTION

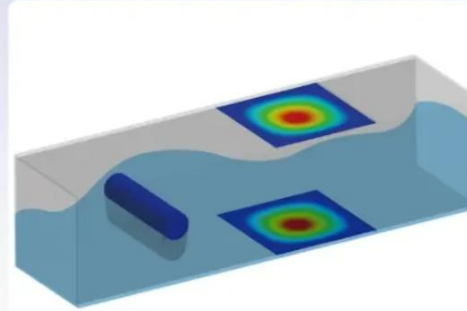


2. OPTION



OPEN CHANNEL

COMBI OF
OSCILLATION + BENDING



- Depending on the characteristics of the application, **different configurations** have been proposed
- Prototypes have been tested in **real operating conditions**





The case studies

- 4 water distribution networks;
- 1 hot water distribution network;
- 1 waste-water treatment network;
- 2 open channels
- 1 lagoon



Determine the water flow characteristics



Piping

Reykjavík
Energy



Piping



Piping
Open stream



Open channel

Piping



Piping



Open channel



Open channel



Piping
Open channel



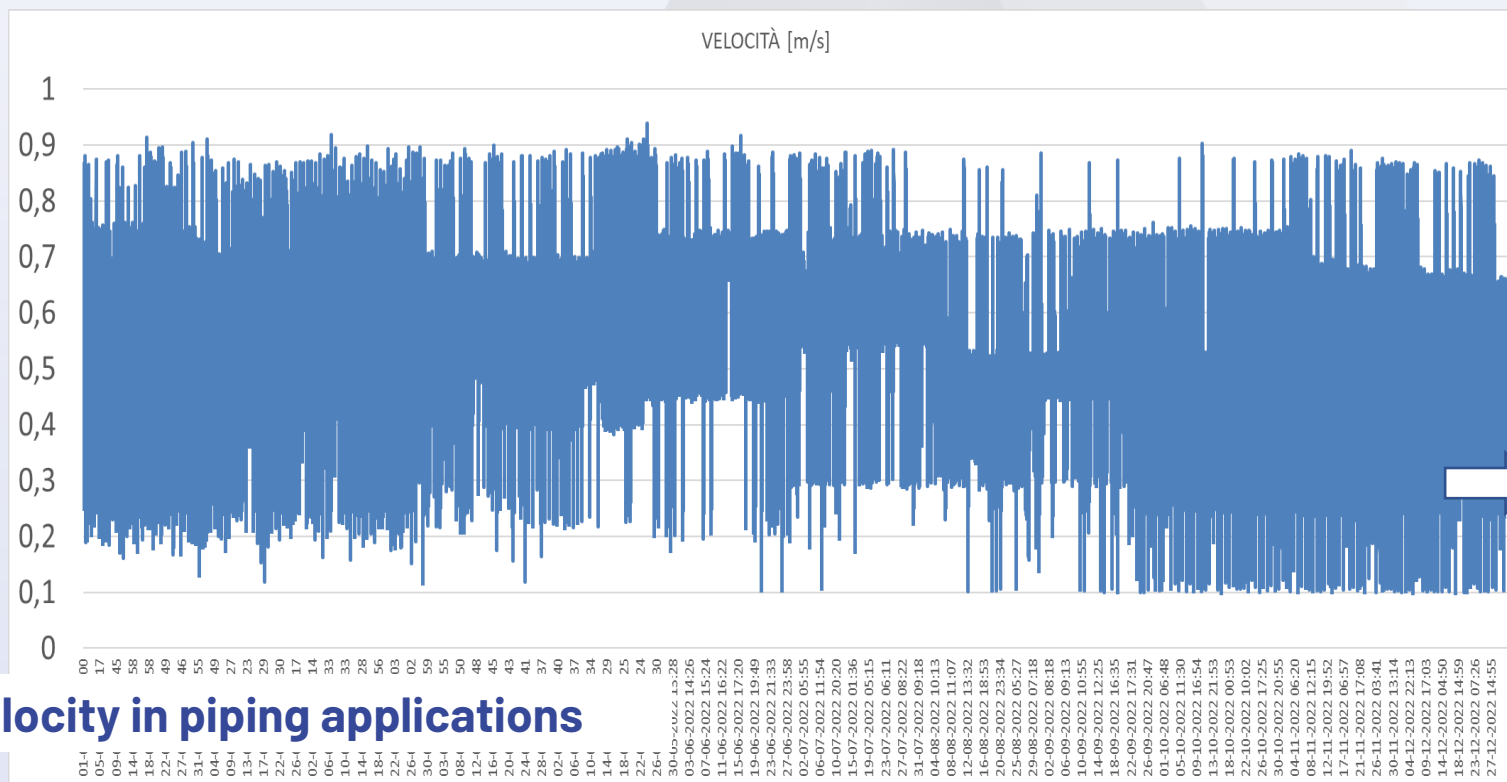
Hidden Hydro Oscillating Power for Europe project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement n. 101084362



Data collection and energy production

Data and **information** were collected and analysed during the project to define and verify:

- The water velocity **characteristics** of the different applications
- The energy production **potential** (turbulent kinetic energy of the flow)
- The possible **use** of the harvested energy to digitalize the hydraulic networks



Water velocity in piping applications

Influence of:

- Application
- Flow velocity and stability
- Harvester size

P_{harv} from mW
to dozens of W

Is this
enough?



YES!....networking with other EU projects

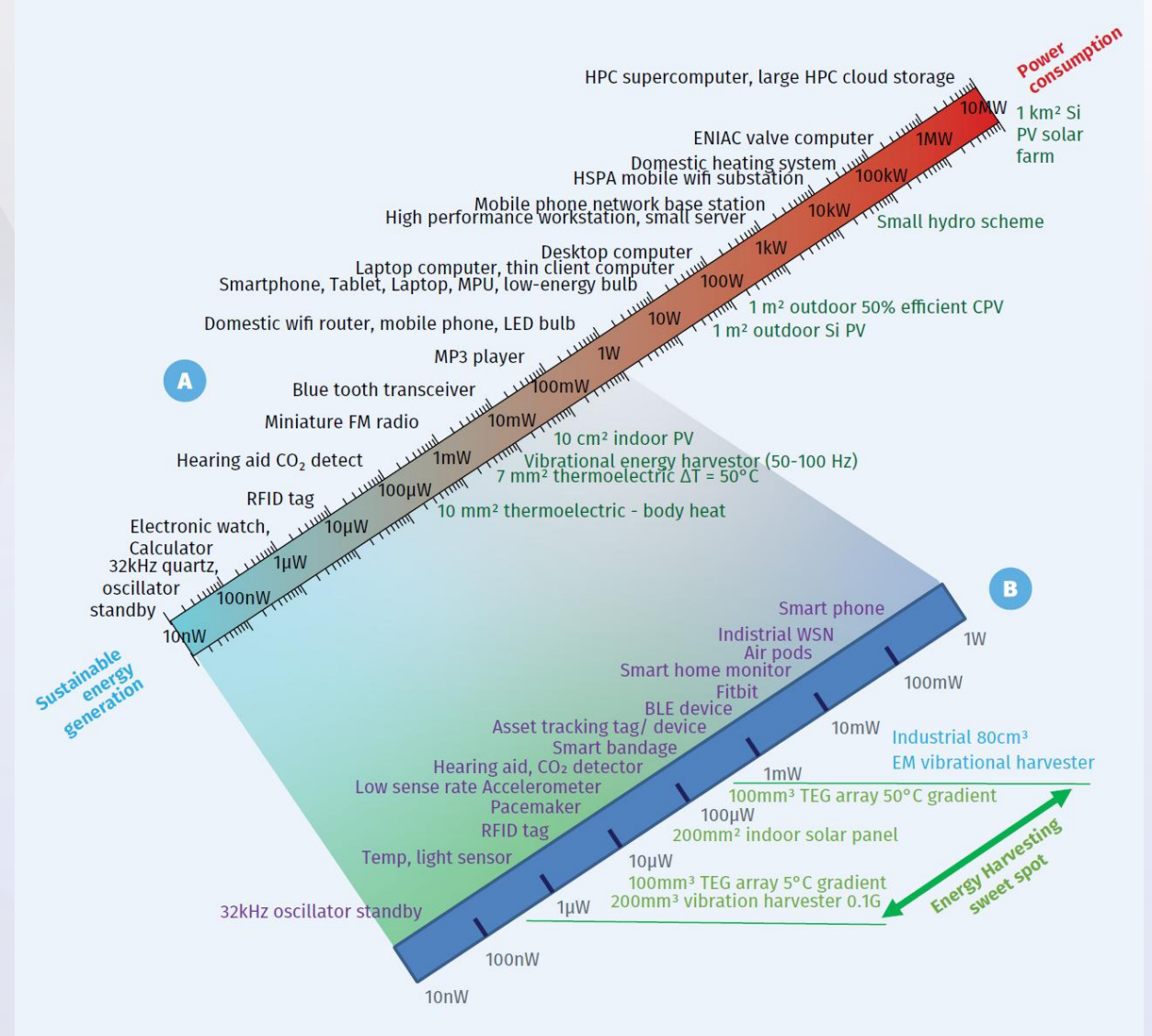
EnABLES

European Infrastructure
Powering the Internet of Things



INFRACHIP

European Research Infrastructure
on Semiconductor Chips





Continuous interaction with stakeholders

- Sensoring distribution networks
- Monitoring remote locations
- Replace battery sensors
- CAPEX and OPEX
- Endurance and reliability
- Effects of hydraulic fluctuations
- Effects of pollutants

11

Individual meetings

12

Identified potential pilots for piping and open channel/stream

7

Data sets from piping and open channel/stream

5

Stakeholder events



H-HOPE for prosumers: Do-It-Yourself platform

- The **Do-It-Yourself approach** targeted small prosumers and science enthusiasts, promoting the development of self-made prototypes to be used in domestic context.
- Simple and **low-cost manufacturing** strategies
- **Guidelines** for designing and manufacturing their own device



H-HOPE DIY Energy Harvester

This guide is **Part I** of a **three-part H-HOPE DIY build series**. Part I shows how to build the mechanical H-HOPE DIY energy harvester (the 'harvester') (the frame, oscillating cylinder, springs, transmission, flywheel and mechanical coupling) as either a **standalone demonstrator** or as a **complete mechanical module ready to connect to the H-HOPE DIY generator**. It contains everything a builder, student, or maker needs to go from parts to a working mechanical harvester:

[Part II - H-HOPE DIY Generator](#) - Instructions for building the H-HOPE DIY generator that converts the harvester's rotary/mechanical output into electrical power

[Part III - H-HOPE DIY Electronics](#) - Power control electronics that convert the H-HOPE DIY generator's AC output into a USB-compatible DC supply for charging phones and small devices.

Table of Contents

- [Introduction and principle of operation](#)
- [Materials & Tools](#)
 - [Bill of Materials & Price Estimate](#)



H-HOPE



H-HOPE



H-HOPE



H-HOPE

H-HOPE

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15

Thank you

For updates, follow us on social media
or on the project website:

www.h-hope.eu

giovanna.cavazzini@unipd.it





H-H²OPE

Hidden Hydro Oscillating Power for Europe



Dr. Eduard DOUJAK
TU Wien



19/10/2026



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UNIVERSITET

TÜBİTAK

**VATTENFALL**

CJH Multisourcing





The case study classification



14.100 km

Piping at district
networks



4.000 km

Piping at
wastewater
networks

H-HOPE

Piping application



DN2500

Highest pipe
diameter



0,4 – 2 m/s

Average
velocities



361 L/s

Highest flow
rate reported



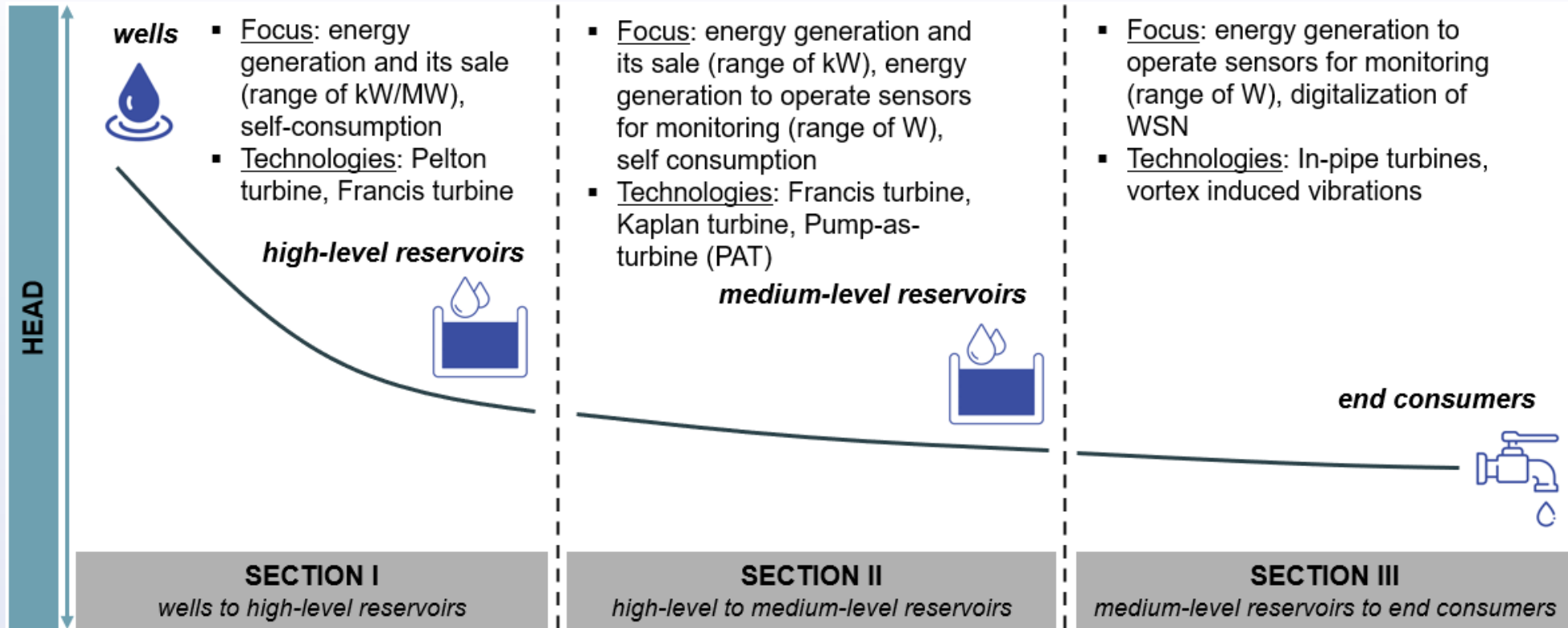
130°C

Highest
operating
temperature





Energy Potential in Water Supply Systems



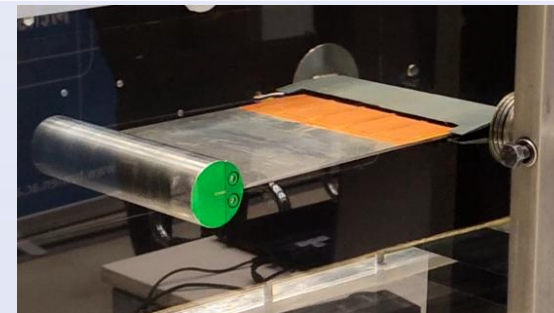
Source: DIWIEN Project, Puschnigg et. al. (2025). Digitalization and hydropower integration in water supply systems: Unlocking energy potential, efficiency, and resilience



Source: aguayagricultura.iica.int/en/copy-of-tecnologias-1-1/turbina-pelton



Source: Morabito, A. & Hendrick, P. (2019). Pump as turbine applied to micro energy storage and smart water grids: A case study. *Applied Energy*, 241, 567–579



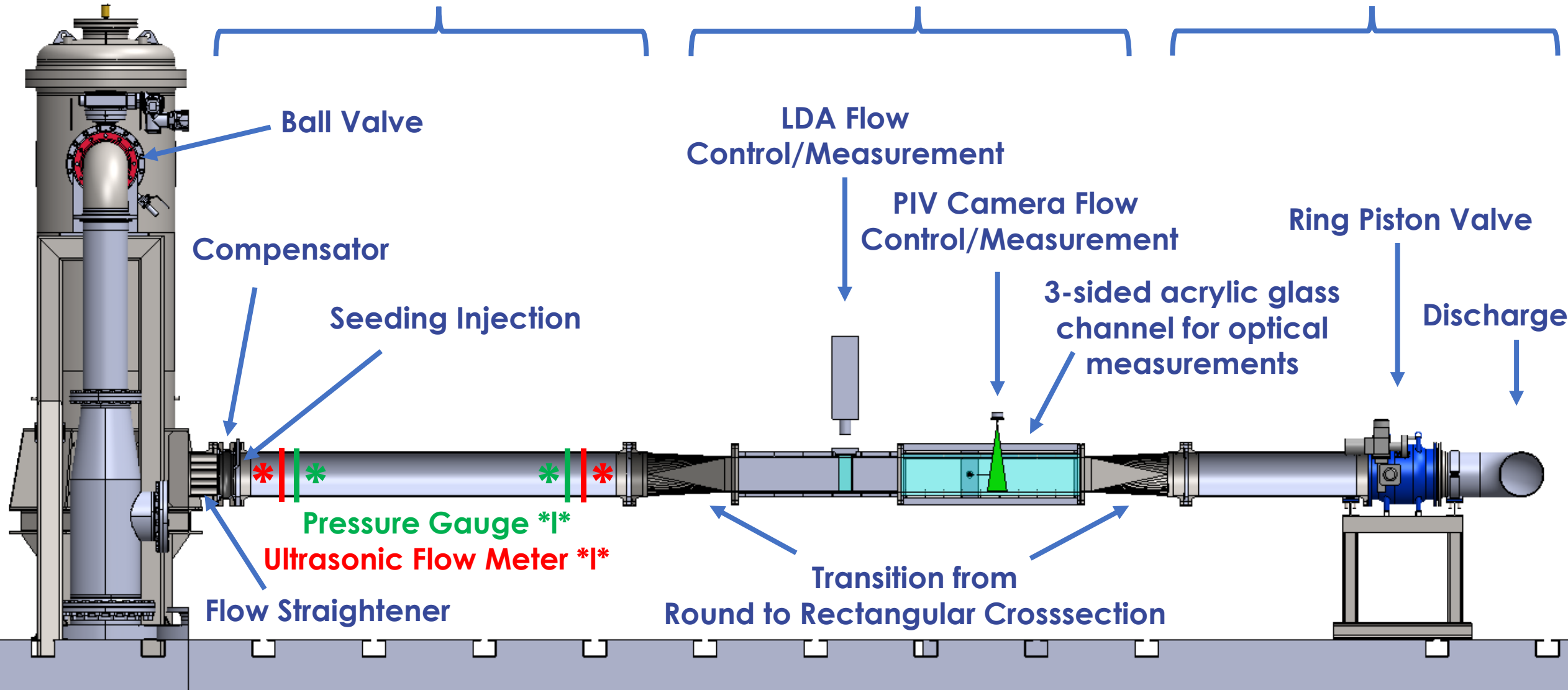
H-HOPE TEST RIG

Calming
Vessel

Pre-Run-Section

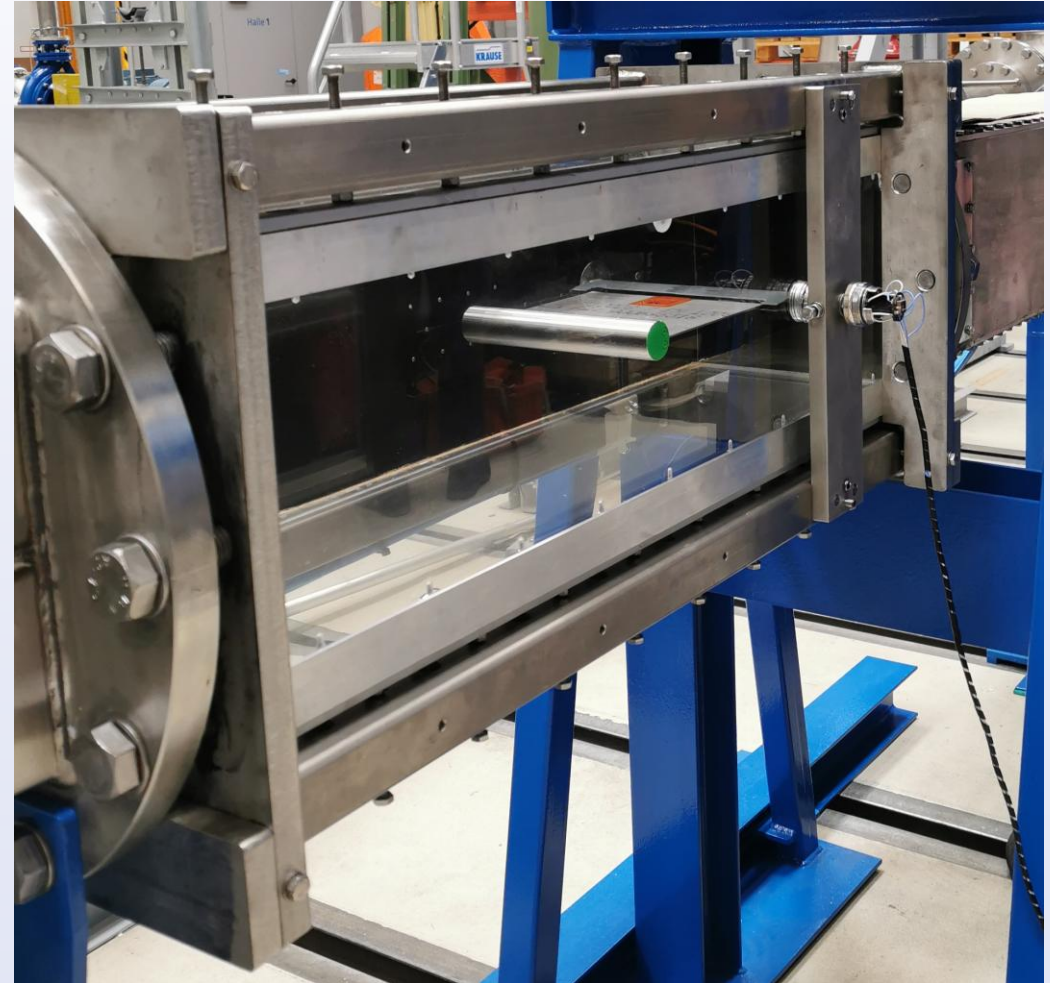
Test Section

Discharge Section





The TU Wien test rig



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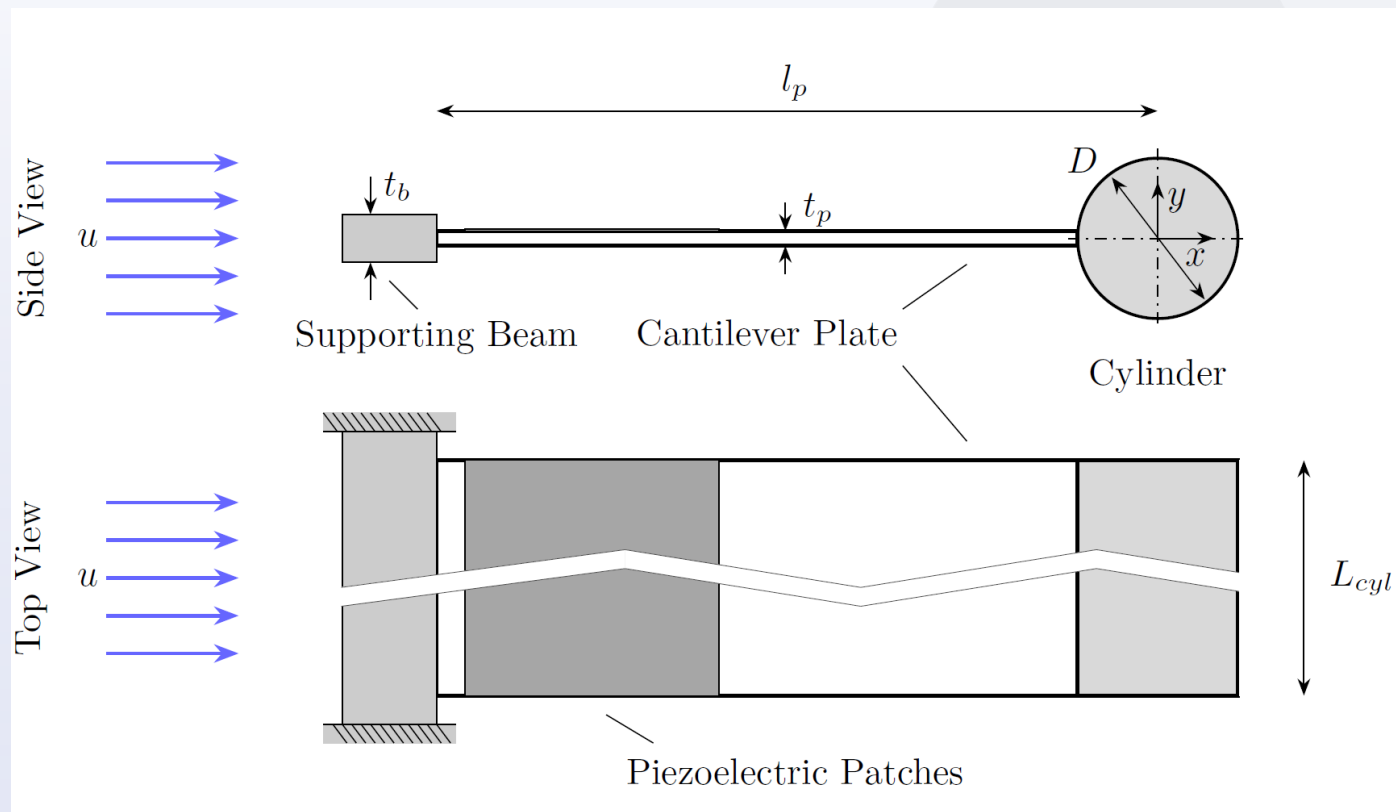
The TU Wien test rig



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Energy Harvester

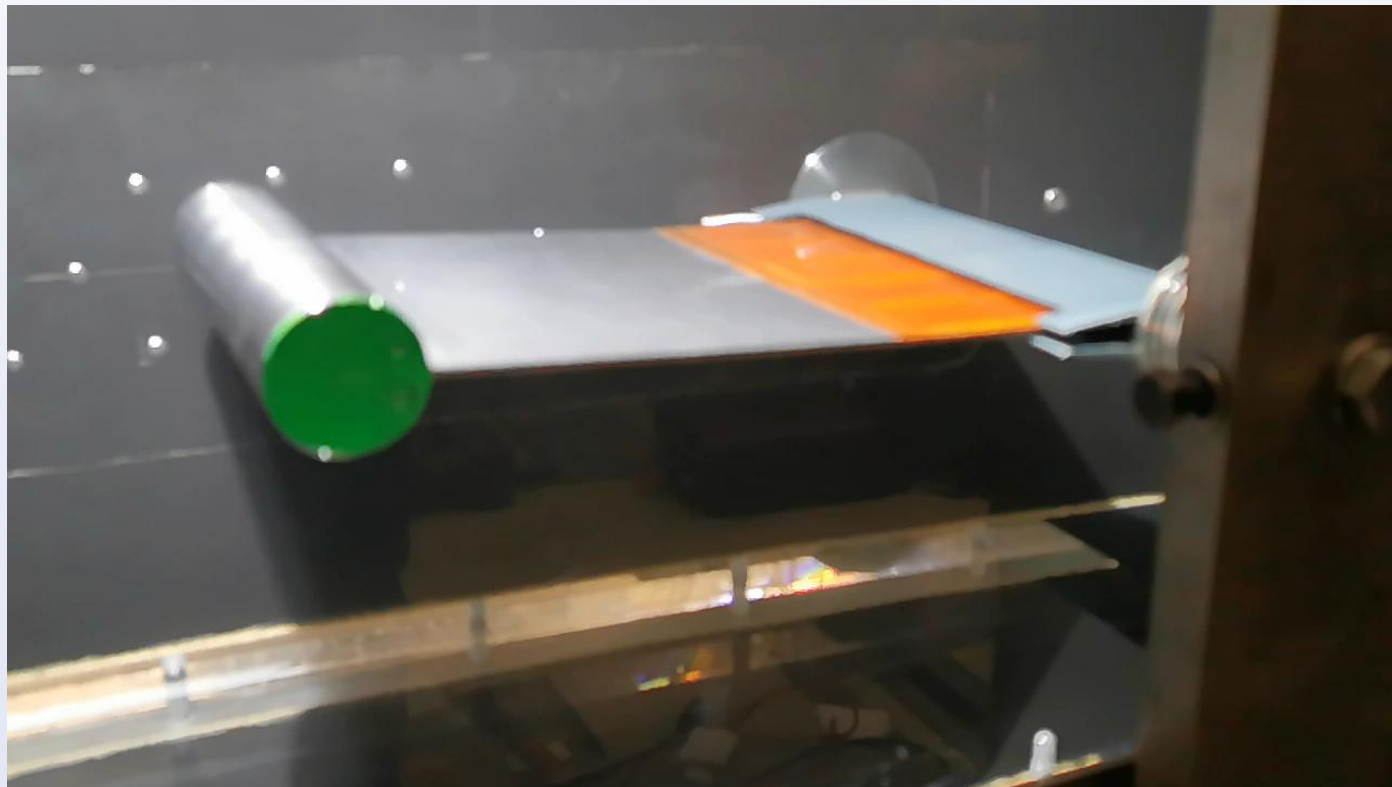


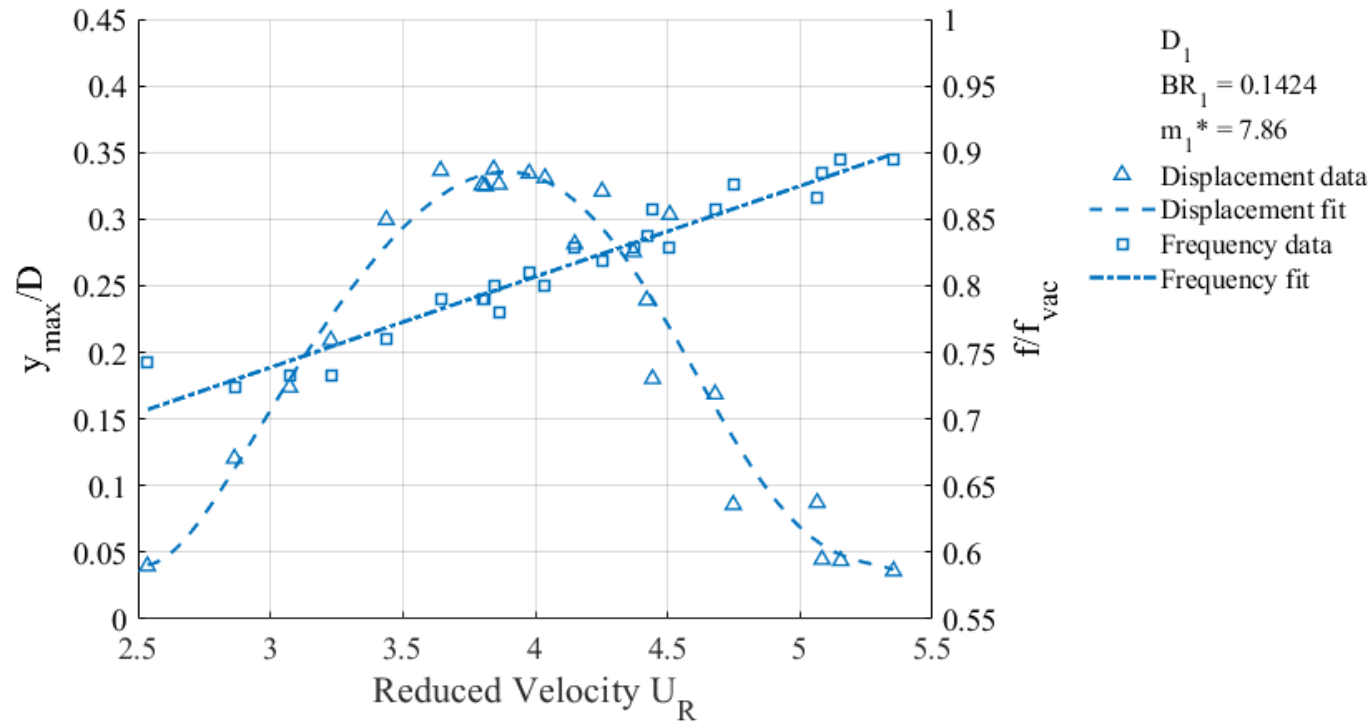
- Energy Harvesting with **piezoelectric patches** → convert **mechanical strain** into **electrical energy**





Energy Harvester





Original configuration:
Lock-in from $U_R = 3.5 \sim 4.5$

Dimensionless displacement:

$$\frac{y_{max}}{D}$$

Frequency ratio:

$$\frac{f}{f_{vac}}$$

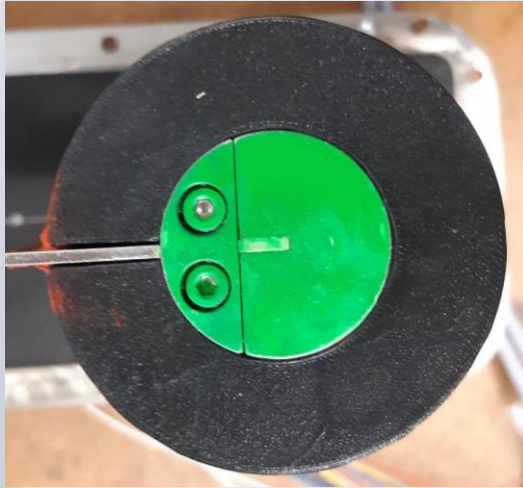
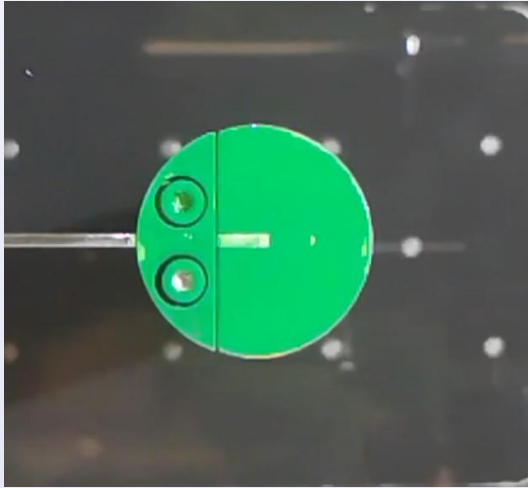
Reduced Velocity:

$$U_R = \frac{u}{f_{vac} D}$$





Energy Harvester Configurations



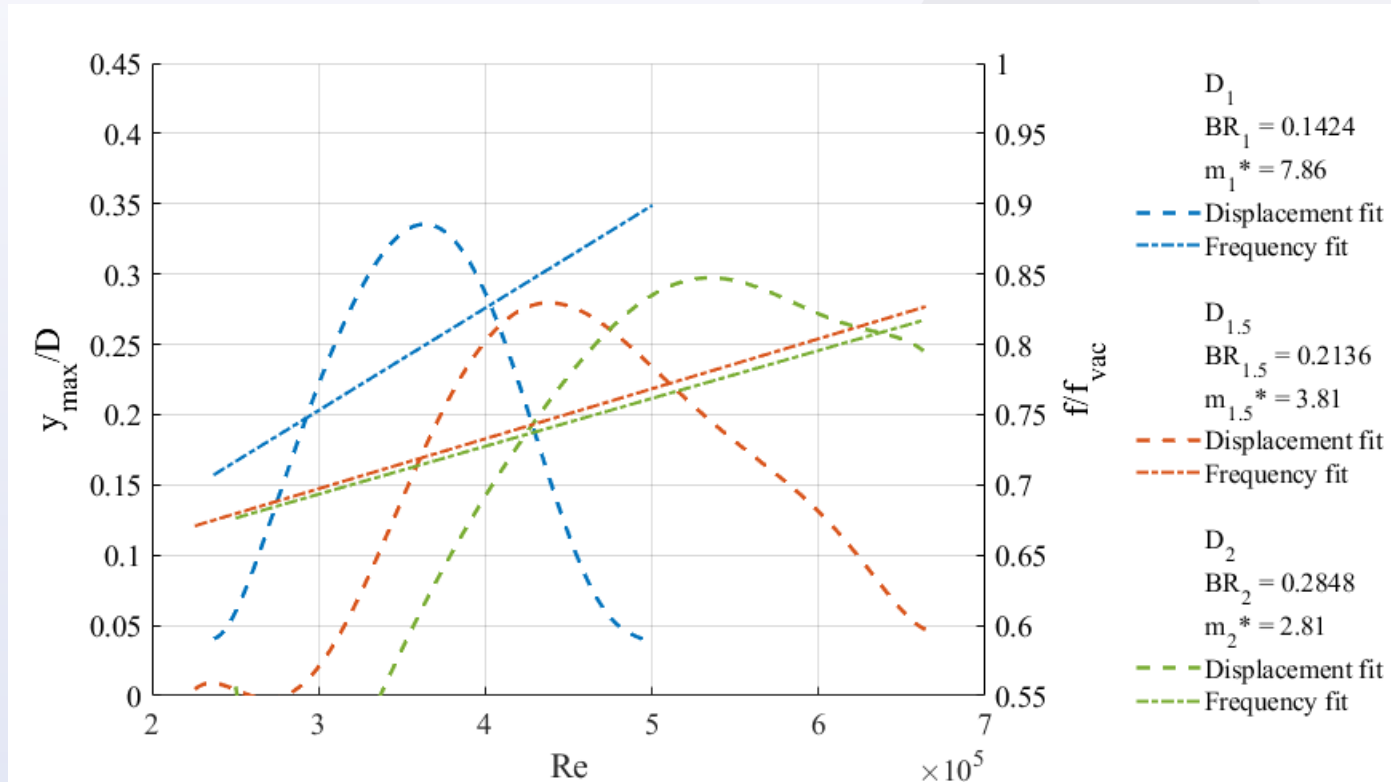
More configurations:

- Diameter change
- Mass ratio variation
- Plate length/thickness adaptation





Energy Harvester Configurations



Result:

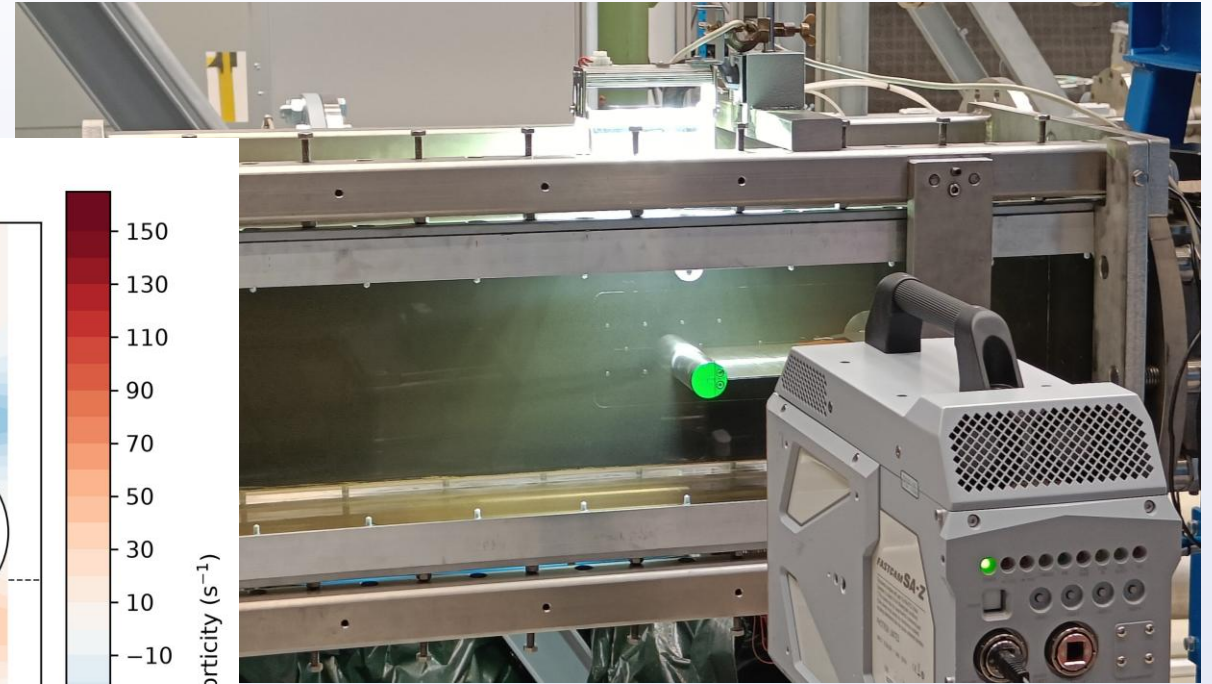
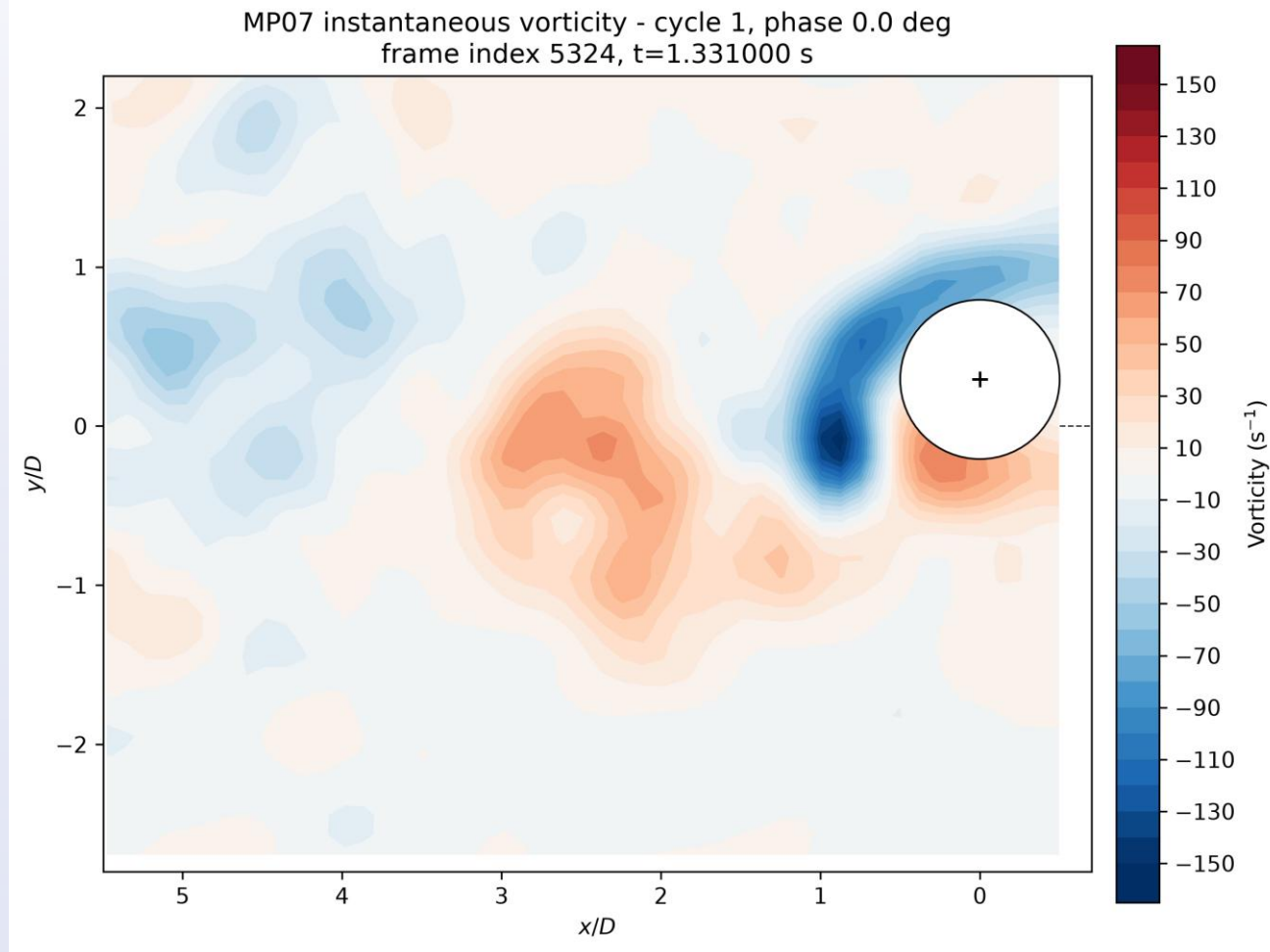
- **Increasing Diameter**
→ lock-in region at higher velocities
- **Decreasing Mass ratio**
→ Wider lock-in regions
→ Reduced relative displacement

Reynolds number of Piping: $Re = \frac{u \cdot D_{\text{piping}}}{\nu}$



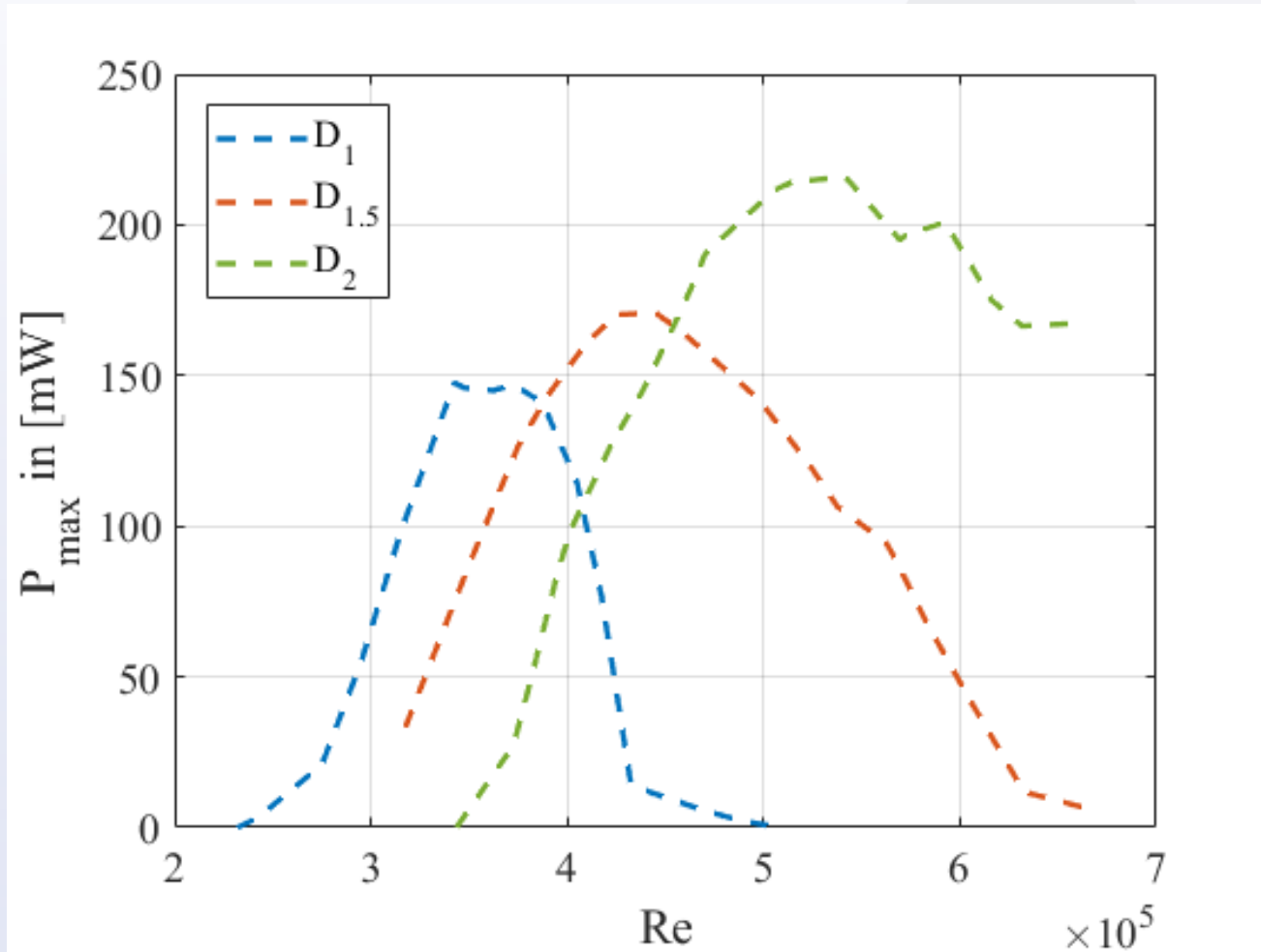


Particle Image Velocitmetry (PIV) measurements





Energy Harvester Power output

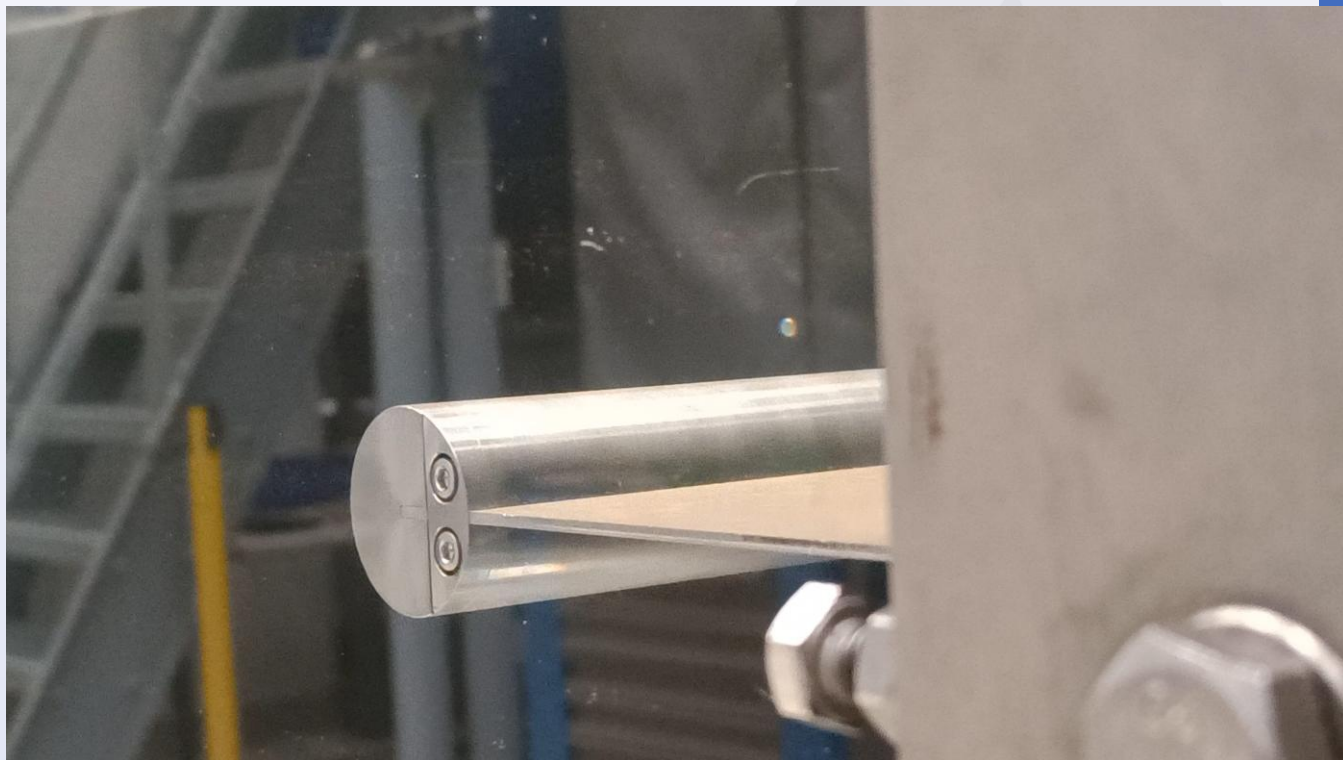


- Increasing diameter
→ Increased power output
(at higher velocities)
- Power output does not
scale linearly with
Diameter
- Largest configuration
produces ~220mW AC
Power
- Potential to power
multiple low-power
sensors and a LoRaWAN
node





Conclusions



- **Knowledge of flow velocity required**
- **Adaptation of geometric and material properties to shift lock-in range**
- **Potential to power multiple sensors and IoT devices**
- **Digitalization of water supply systems**
- **Reduction of water leakage**
- **Water quality improvement**



Thank you

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Staying in resonance across scales: from laboratory open-stream tests to full-scale open-channel demonstration



Pavel RUDOLF



UPPSALA
UNIVERSITET

Urban LUNDIN





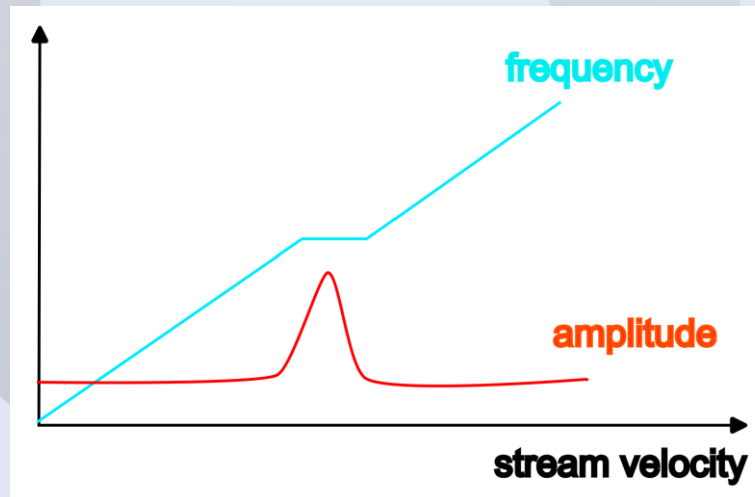
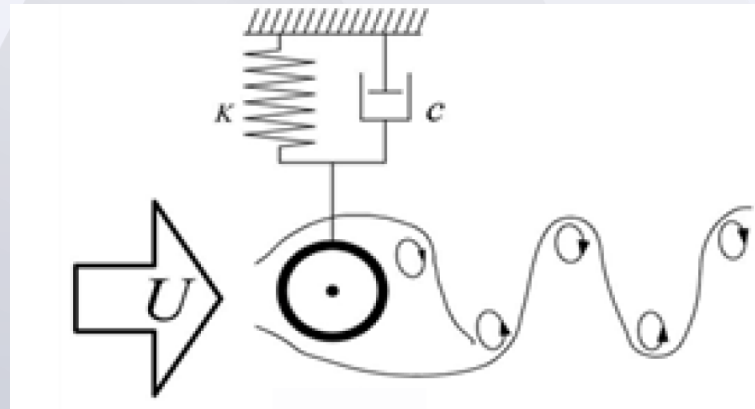
Application areas for vortex induced vibration harvesters

Power: $P \propto v^3$

Resonance:

$$f_{\text{vortex}} \cong f_{\text{harvester}}$$

$$f_{\text{harvester}} \approx \frac{\text{stiffness}}{\text{mass}}$$

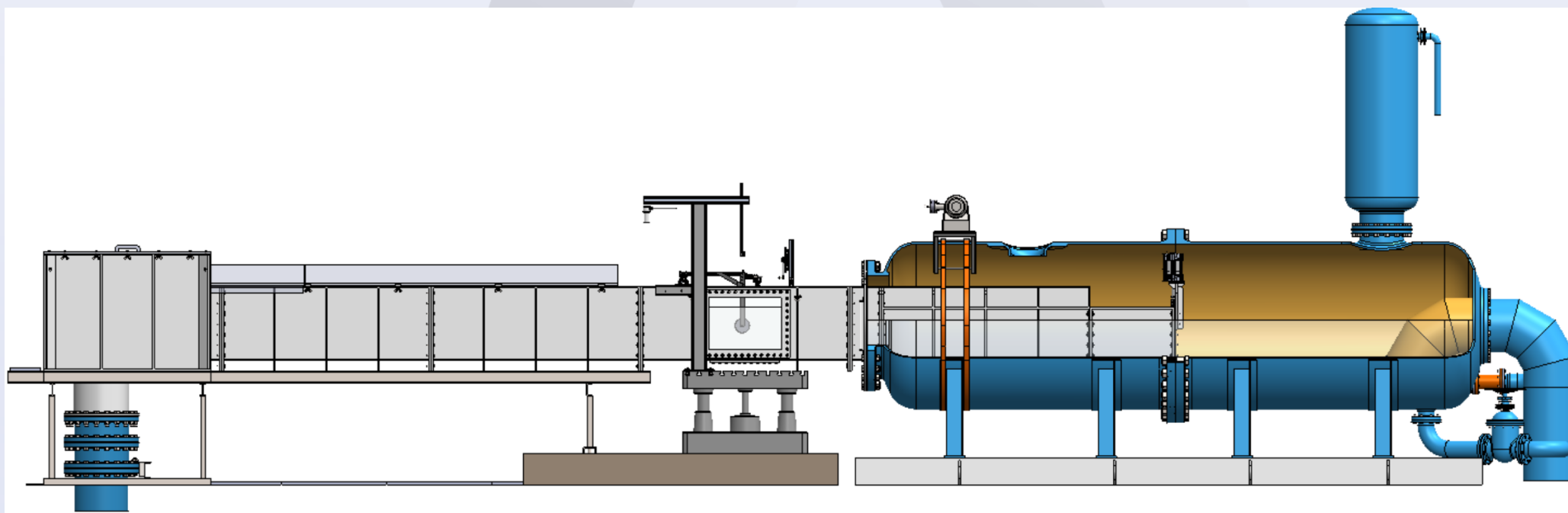
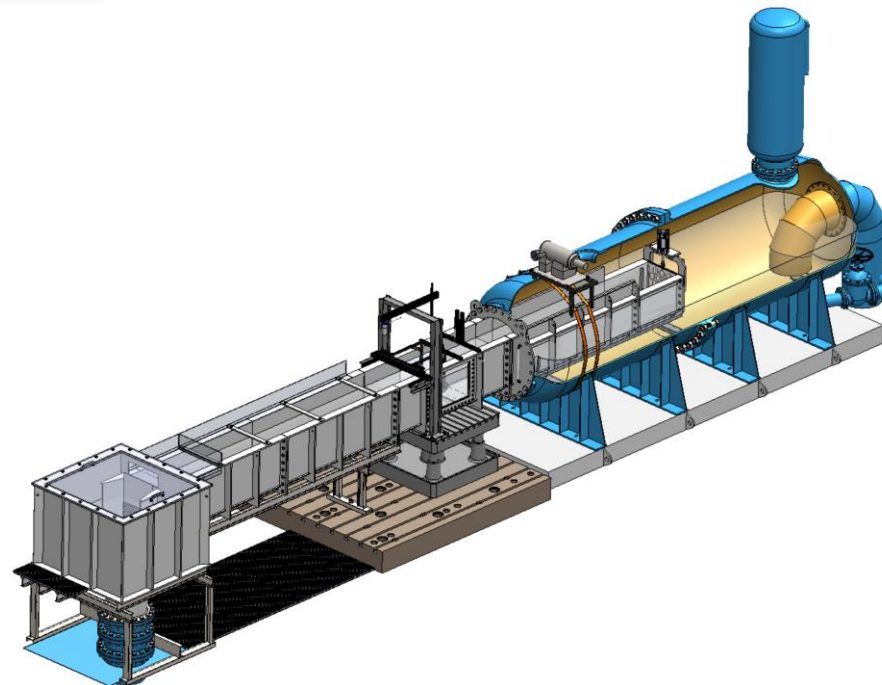




Open channel test circuit

$$v_{max} = 1 \text{ m.s}^{-1}$$

$$Q_{max} = 0.250 \text{ m}^3.\text{s}^{-1}$$



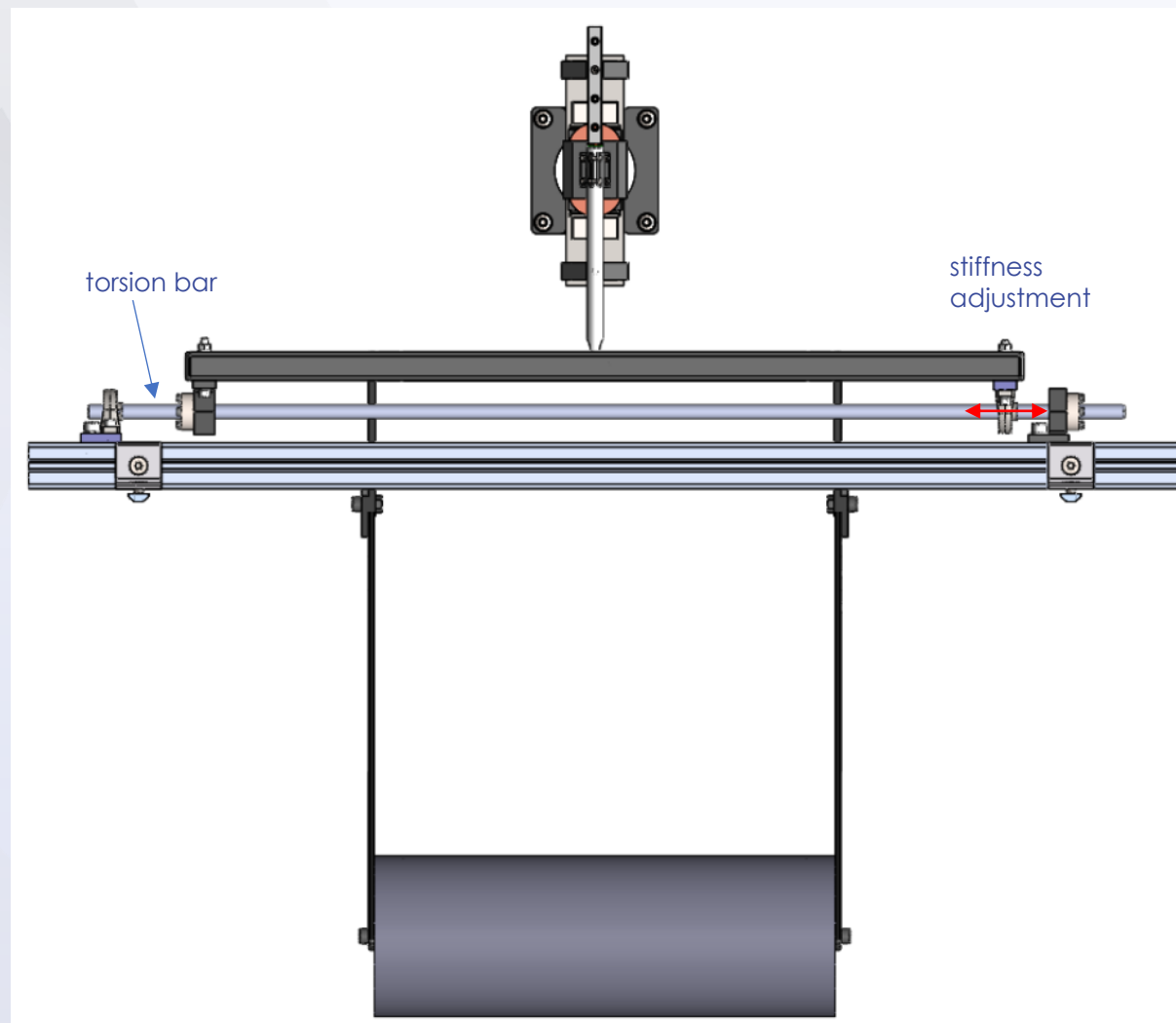
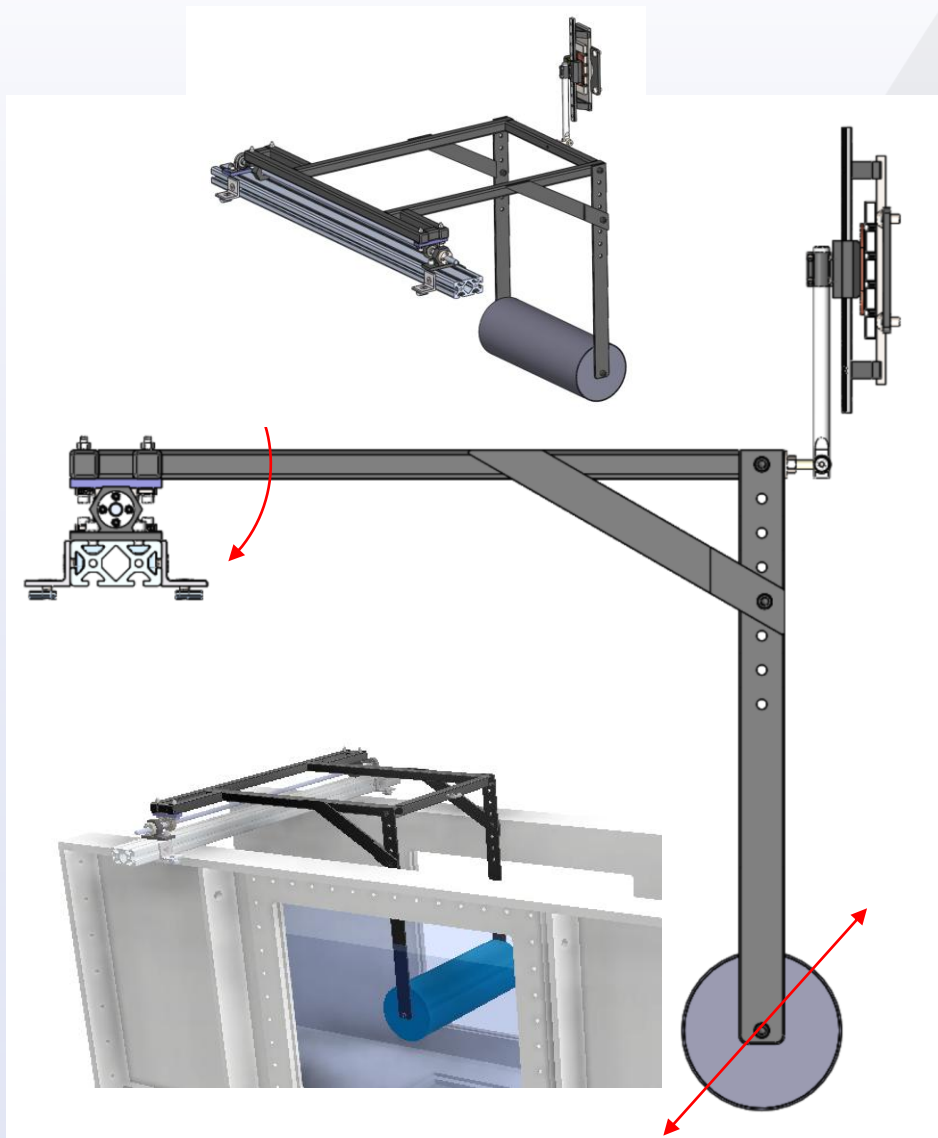


Open channel test circuit



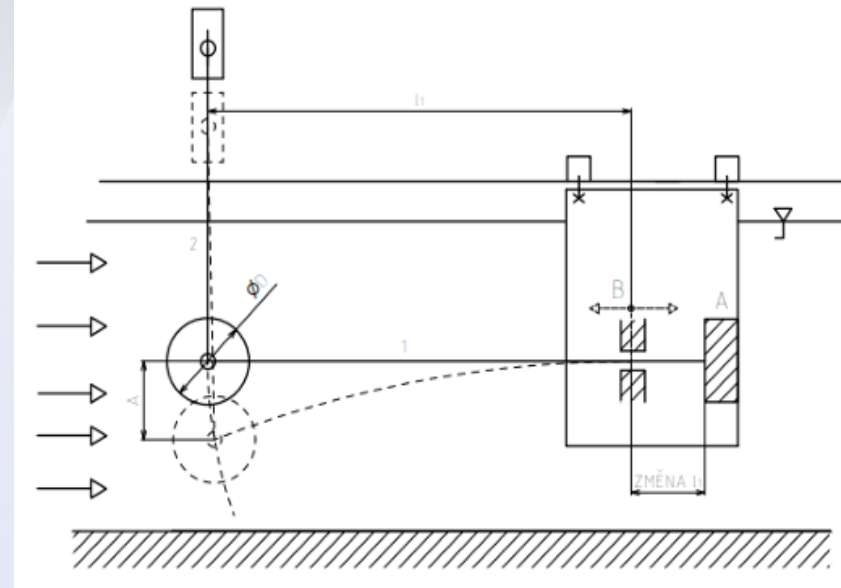
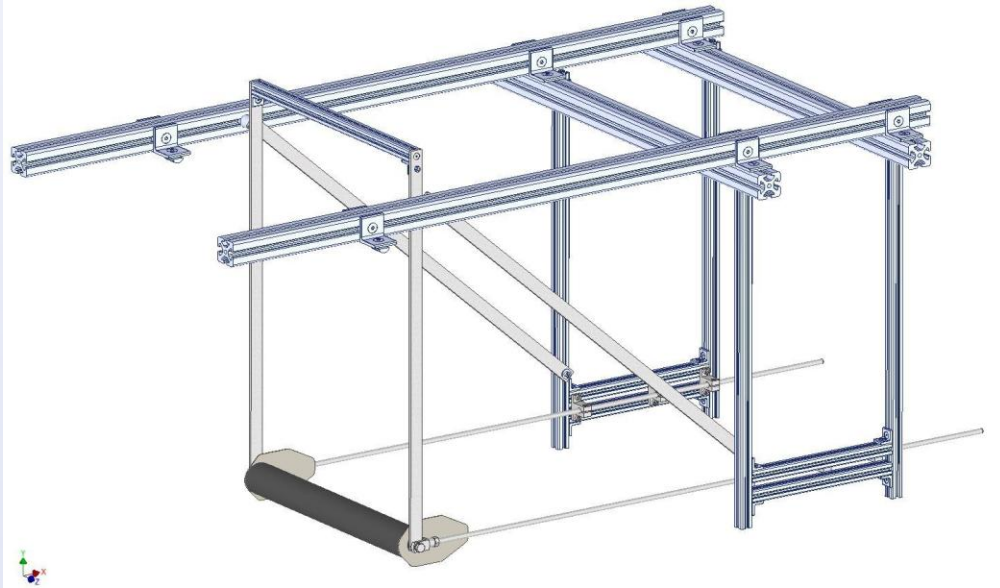


„Torsion bar“ harvester – torsion stiffness





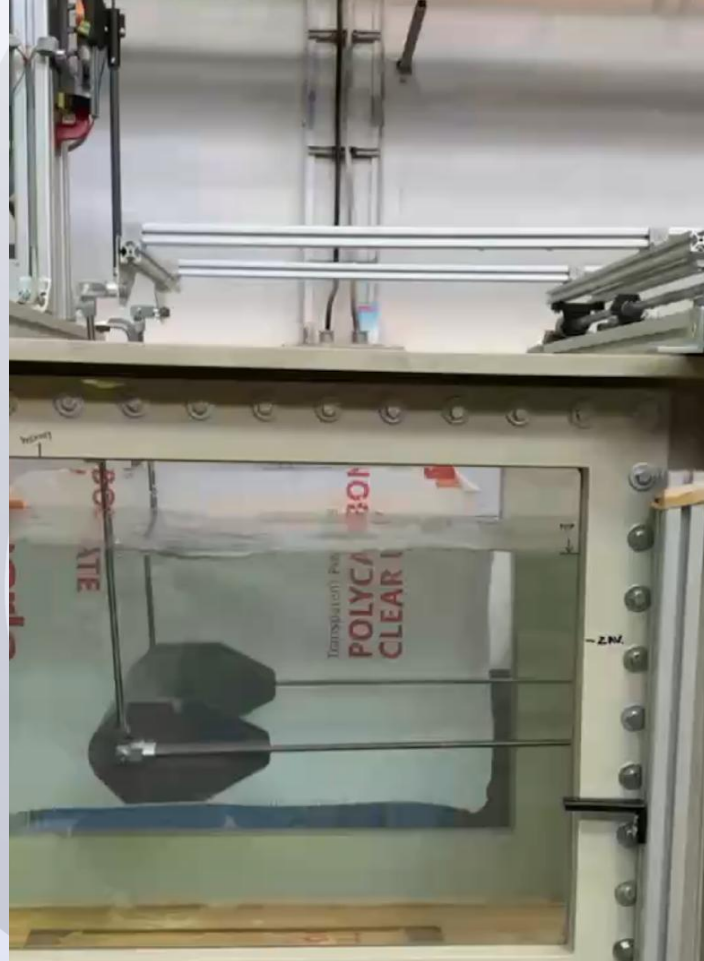
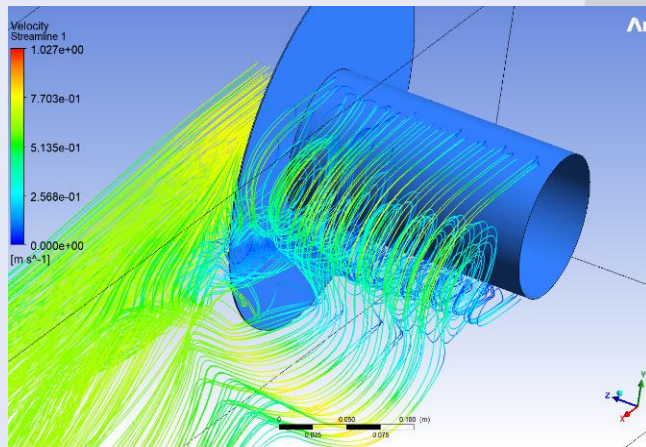
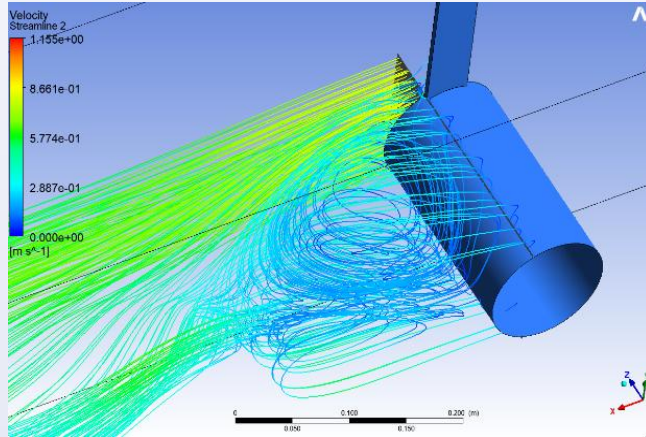
„Elastic beams“ harvester – bending stiffness





Optimization

Winglets – elimination of parasitic vortices

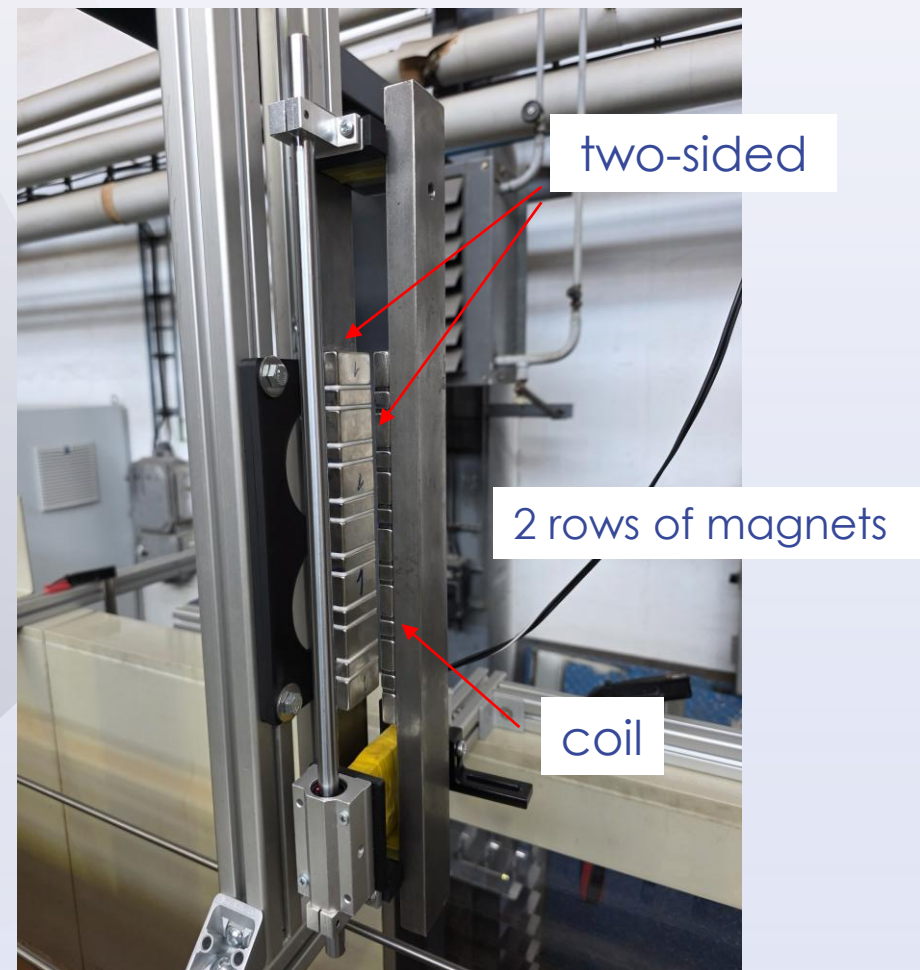
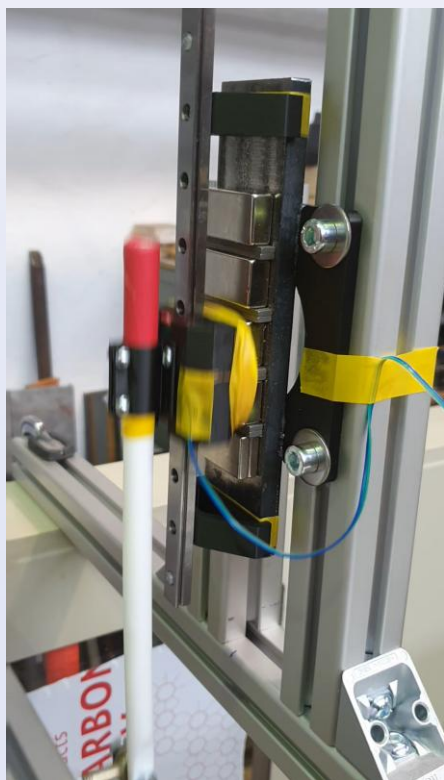
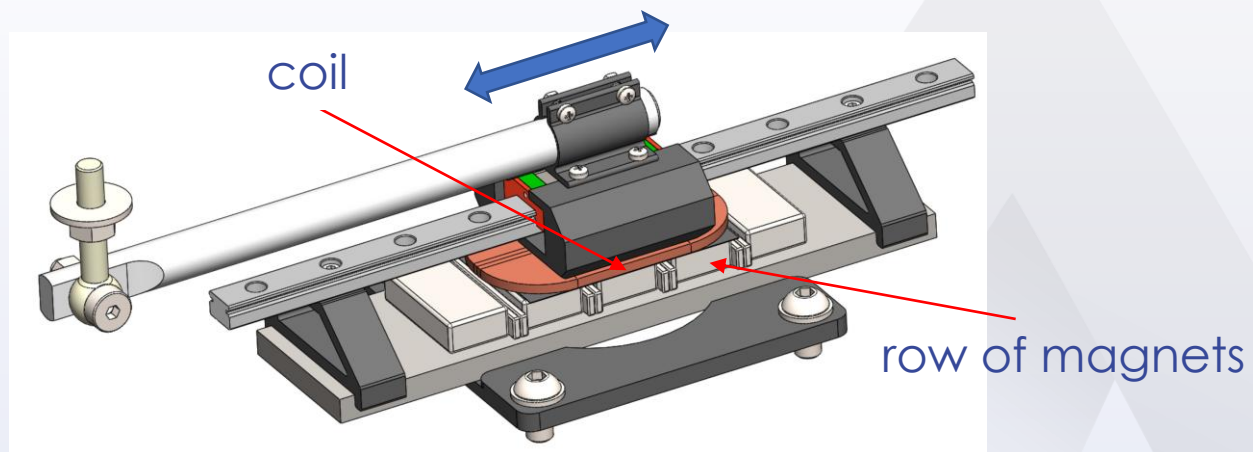


Passive turbulence control





Linear electrical generator

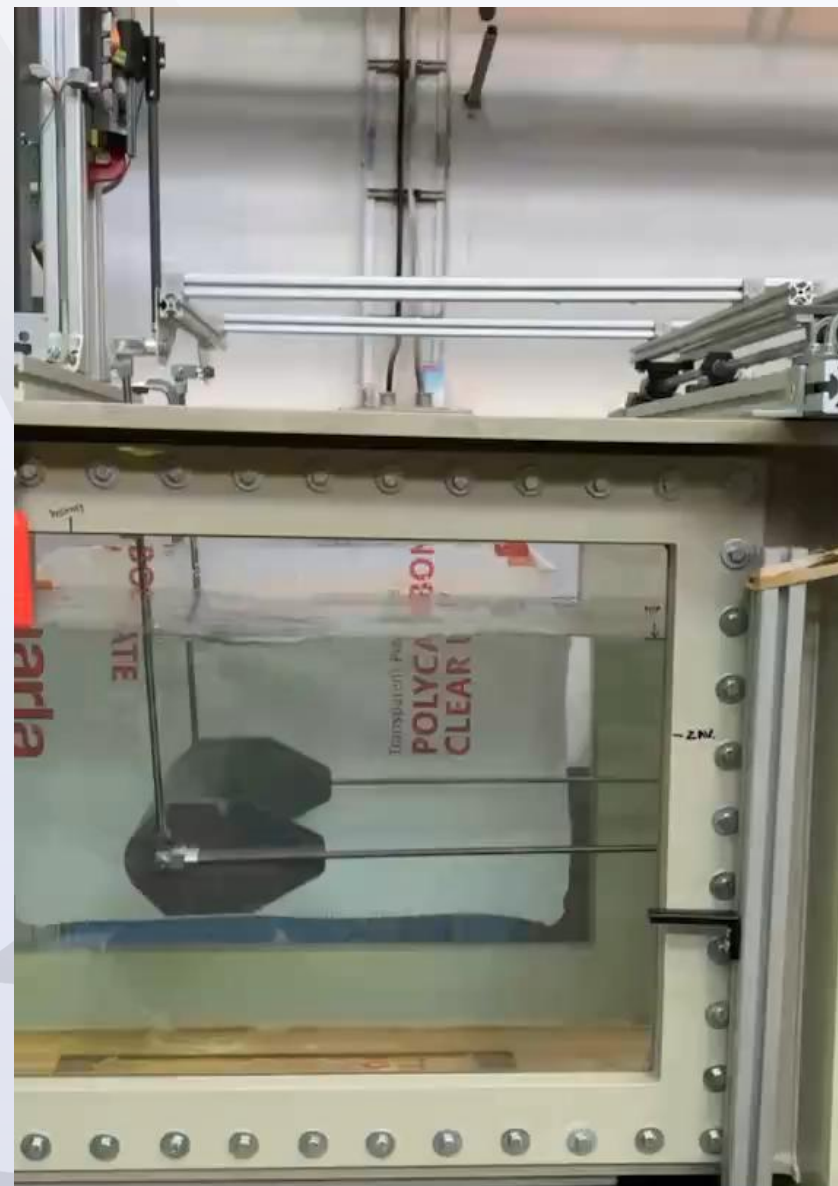




Harvester with torsion bar and parallelogram - torsion stiffness

Max power output ≈ 1 W

D = 75 mm
L = 400 mm

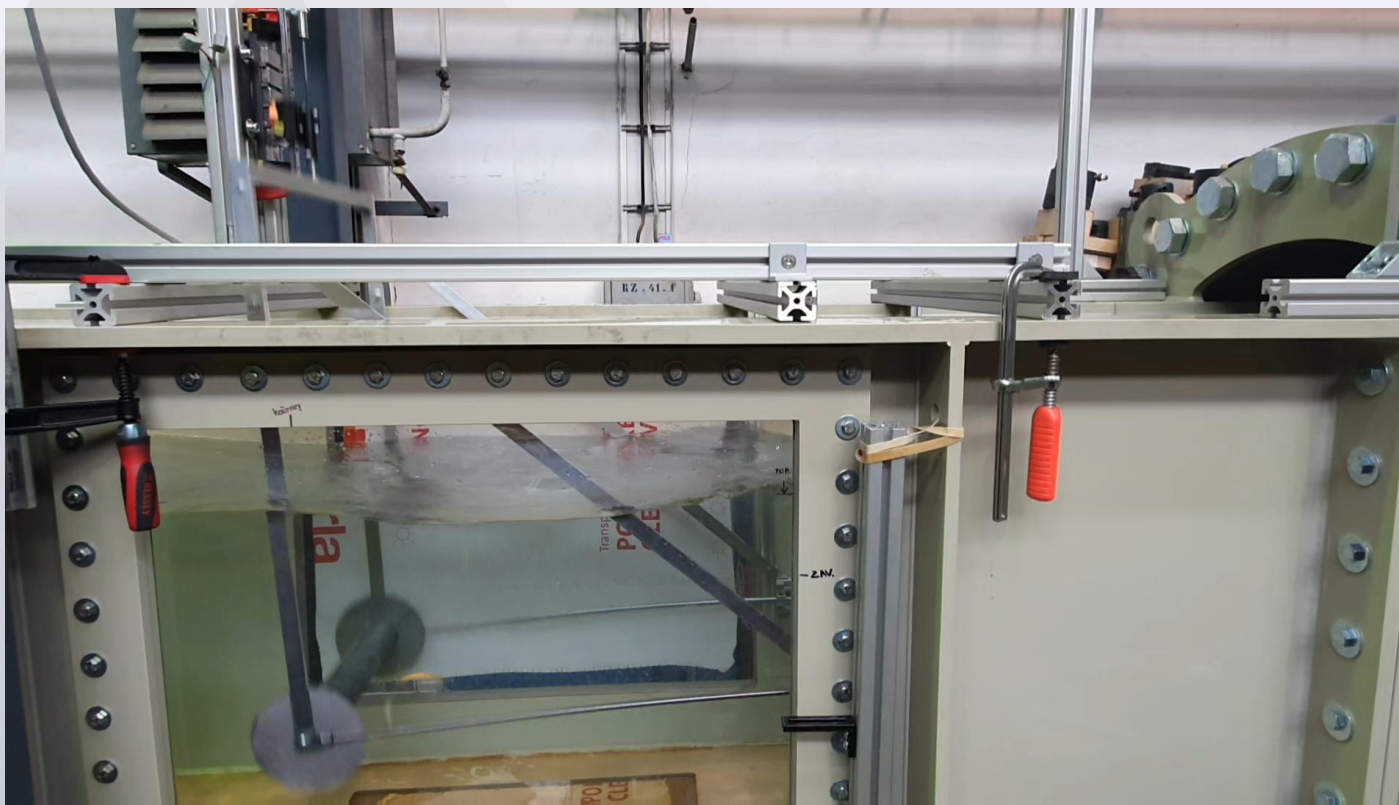


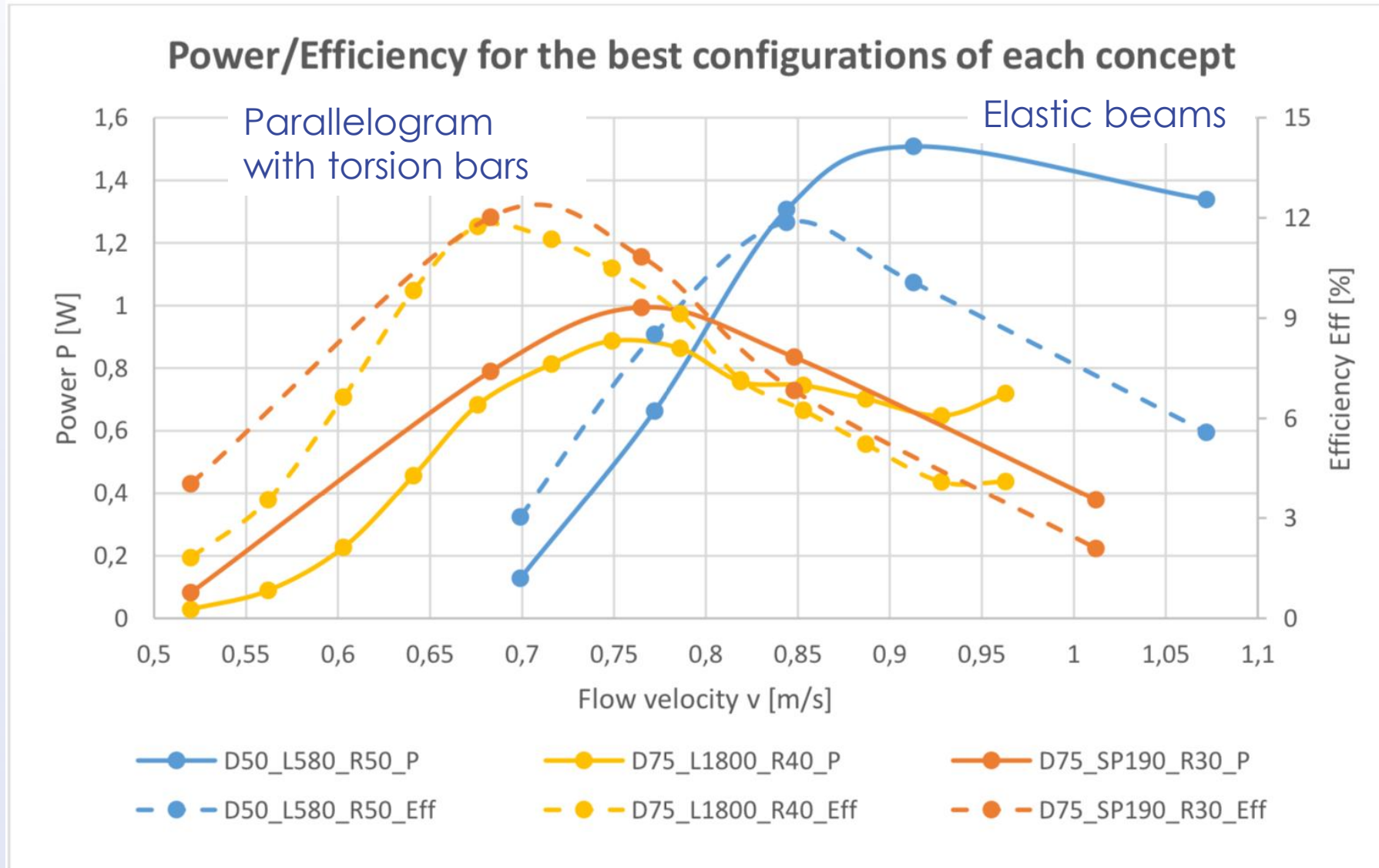


Harvester with elastic beams - bending elasticity

Max power output $\approx 1,5$ W

D = 75 mm
L = 400 mm





Staying in resonance across scales: from laboratory open- stream tests to full- scale open-channel demonstration

Urban Lundin, Uppsala University
4th Brussels Hydropower Day
8 Sept 2026





Aim and ambition

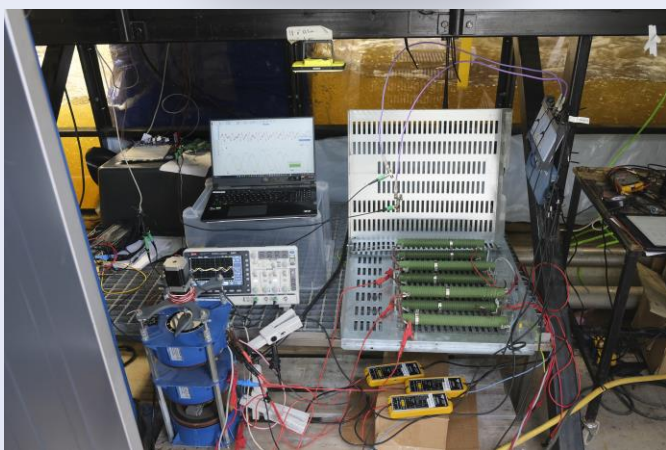
- Upscaling with lessons learnt from the Brno device to open-channel sizes
- Making a hybrid device, Piezoelectric patches and a bespoke linear generator for Power Take Off
- Control system to maximize power uptake and keep in resonance



Actual device, *in situ*



Patches



Electrical system
Control & Measurements



Linear
generator

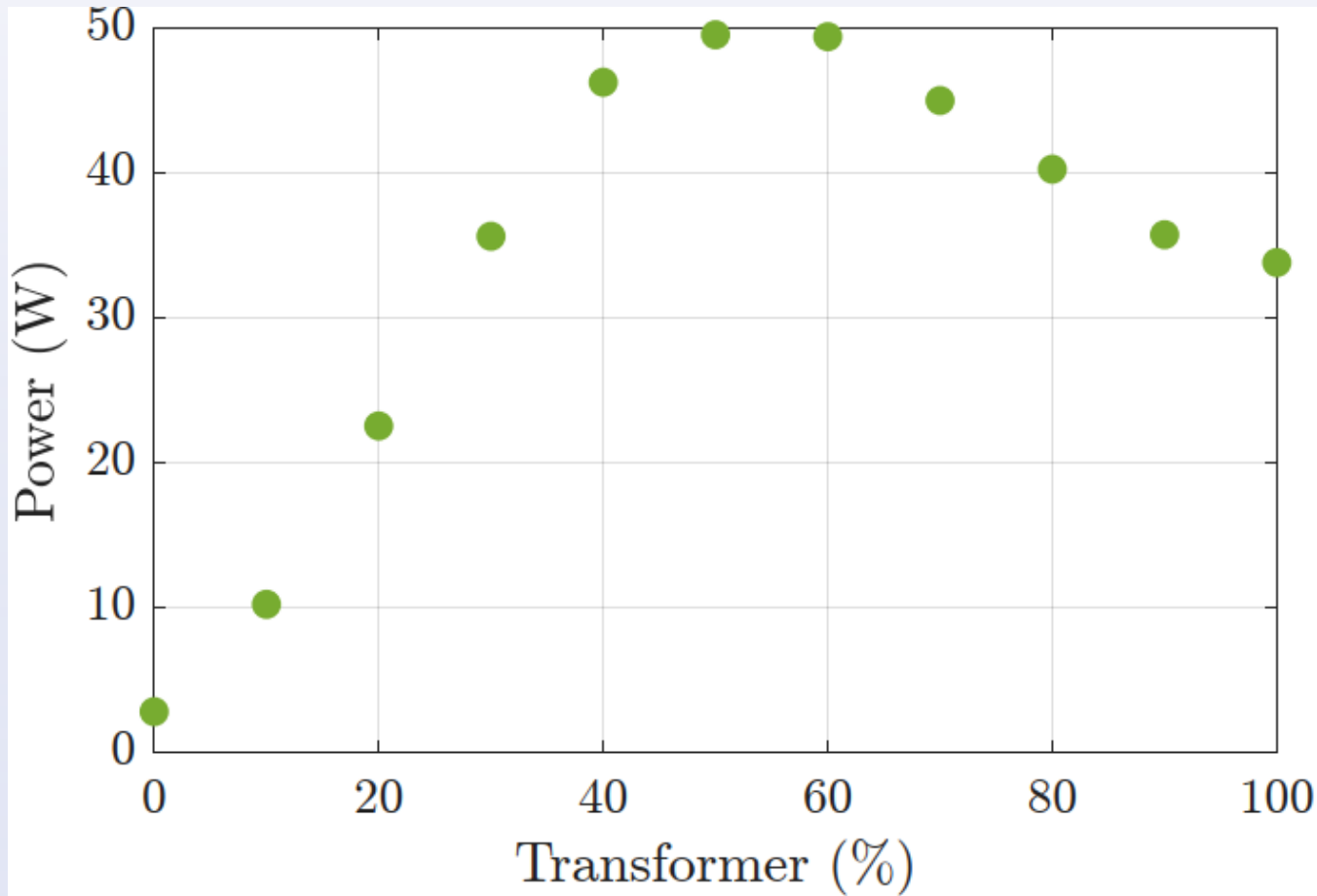
Pipe;
Absorbator



- When operation gets close to the resonance, the motion is stable, enabling automatic tuning of the load towards maximum power and lock-in to resonance.
- Patches can be used both to boot the control system and acts as sensors - input about the actual motion of the device (amplitude and frequency). Great sensors!



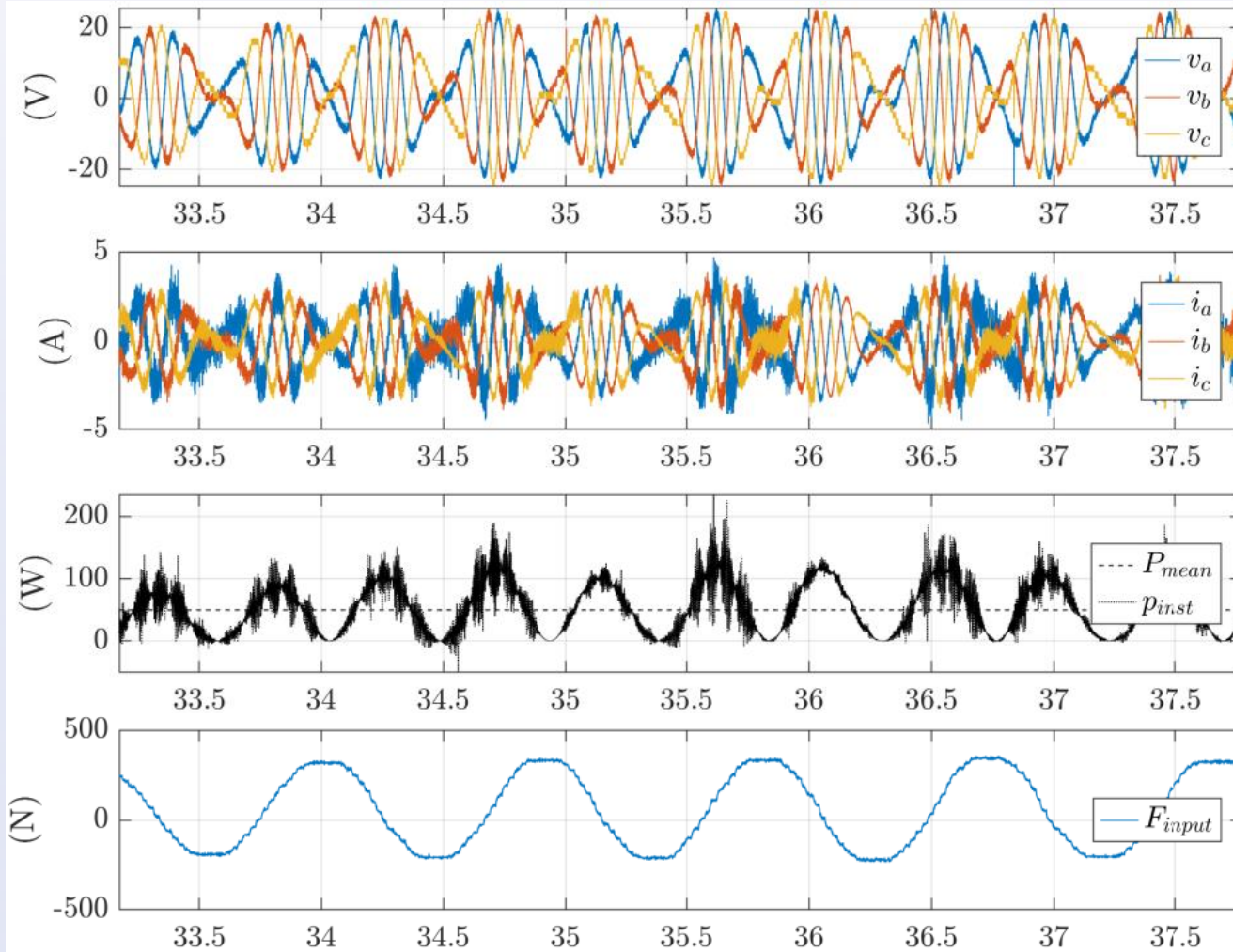
Experimental Outcome



- Power versus load (effective resistance via transformer change) shows a peak and thus can be reached with the MPPT



Experimental Outcome



- Induced voltage
- Current
- Electric Power
- Force sent to the translator



Conclusions

- The device setup works as intended. Further upscaling possible but needs more anchoring material.
 - Influence from mooring & support structure negligible (open channel), but being sufficiently submerged remote from surface is important for symmetrical behaviour
- Tuning of the cylinder diameter to flow velocity is important for maximum power absorption
 - Challenge in places where the water speed changes a lot, the control system (Maximum Power Point Tracking) helps but will not reach lock-in
 - Possibility to tune stiffness gives a larger operating range in terms of water speeds



Conclusions

- Possible to achieve continuous energy harvesting of energy for remote electrification
- Completely submerged structures are possible
- Design requires understanding of mechanical and electrical engineering
- One version of the MPPT implemented in DIY hardware ESP32 cost < €10
- To maximize power, special effort needed in the power electronics (Power Factor Correcting, PFC, rectifier)



Beyond the Flow: Social, Economic and Environmental Value of Self-Powered Digital Water Networks

4th Brussels Hydropower Day
David Christian Finger
Energy security and digitalization
in Europe's power system
8th of September 2026 in Bruxelles



19/10/2026





Reykjavík

Svartsengi/
Blue Lagoon

Grindavík

Geothermal Energy in Iceland

$h = 803$

Earthquakes

Eruptions

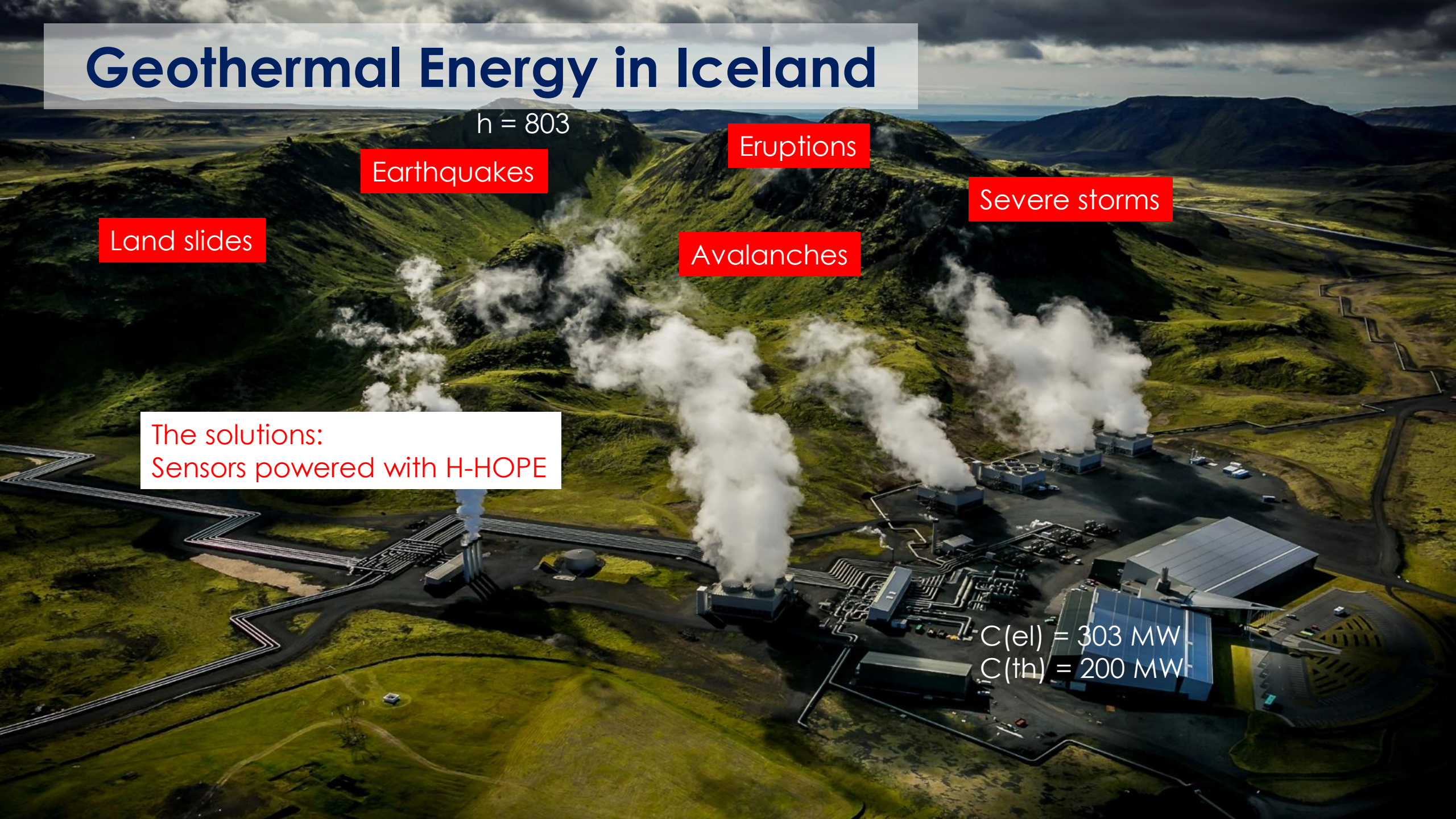
Severe storms

Land slides

Avalanches

The solutions:
Sensors powered with H-HOPE

$C(e) = 303 \text{ MW}$
 $C(th) = 200 \text{ MW}$



Water Monitoring in the Venetian Lagoon, Italy

Acqua Alta

Sediment

Eutrophication

Chemical Pollution

Salinity

marine heatwaves

The solutions:
Sensors powered with H-HOPE

$V=2 \text{ m/s}$

Width: 400 meters
Depth: 12 meters





Water supply in Verona

Drought

Nitrate Pollution

PFAS "Forever Chemical"

Severe storms

Infrastructure

Huge water distribution network
Verona: ~ 1,145 km
Province of Verona: over 6,100 km

The solutions:
Sensors powered with H-HOPE

Type: Piping
Application: drinking water supply
Population served: 644,000
Climate: Mediteranen



Water supply in Izmir, Türkiye

Mount Bozdağ: 2,159 m asl

Drought

Huge water distribution network
Verona: ~ 9,900 km
Serving 4.5 Million inhabitants

Nitrate Pollution

Severe storms

PFAS "Forever
Chemical"

Infrastructure





Water supply in Ferlach, Austria

Severe storms

Landslides

Ferlacher Horn: 1,840 m asl

Water distribution network Total
(Main + House): 166 km

Leaks

Infrastructure

Drought

Nitrate Pollution





Water supply in Ferlach, Austria



Severe storms

Tibidabo: 512 m asl

Huge water distribution network
Barcelona: ~ 4,300 km
Serving 1.6 Million residents

Water Energy
Nexus

Leaks

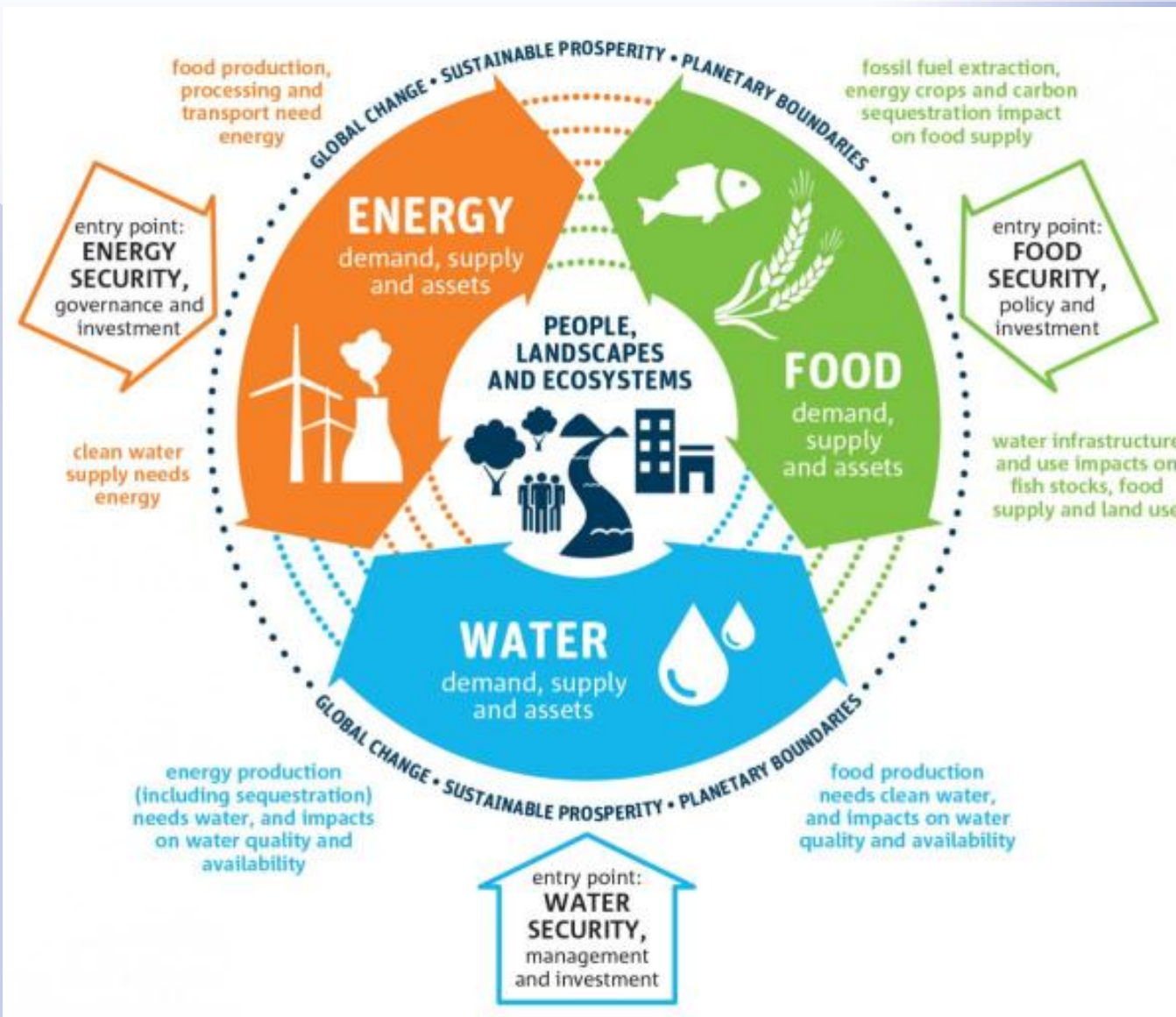
Infrastructure

Pollution

Drought



Water Energy Food Nexus



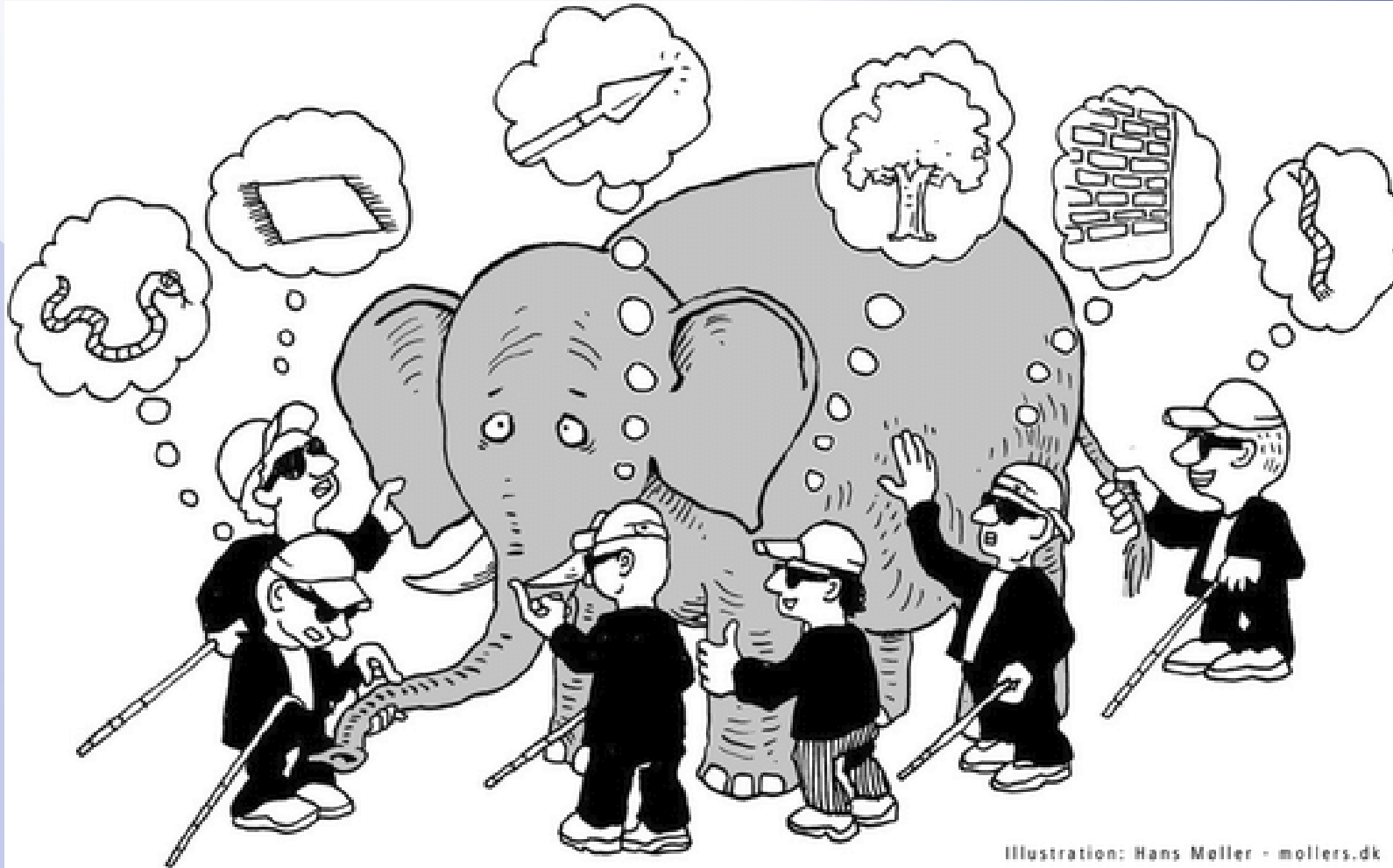
By accounting for the Water Energy Food Nexus we can address Social, Economic and Environmental Value

Bronkema et al. (2025)





The perception of Stakeholders





Stakeholder Interviews, Workshops and Surveys

Type	Location	H-HOPE case study	Nr of participants	Link
Interview	Reykjavik, Iceland	District heating in Reykjavik	4	In person
Interview	Verona, Italy	<u>Acque Veronesi</u>	1	In person
Interview	Barcelona, Spain	<u>Cetaqua Barcelona</u>	3	In person / Hybrid
Interview	Klagenfurt, Austria	Aste Energy	1	In person
Workshop	Brussels, Belgium	General, All case studies	2	Hybrid
Workshop	EGU conference in Vienna, Austria	General, All case studies	15	https://meetingorganizer.copernicus.org/EGU25/session/54620
Workshop	H-HOPE meeting in Padova, Italy	General, All case studies	30	In person / Hybrid
Workshop	DEMI conference in Banja Luka, Bosnia and Herzegovina	General, All case studies	40	https://enpower-bih.eu/panel-discussion-energy-harvesters-for-energy-poverty-solutions/
Online survey	online	General, All case studies	>20	https://forms.office.com/Pages/ResponsePage.aspx?id=YCvZlPrmwEOABec-AoEsNJmjrLx9X9Hmw5hOi5vEPFUMjhOTE5NV09JUzKxN1FHVjlUVjhGTlgxUC4u



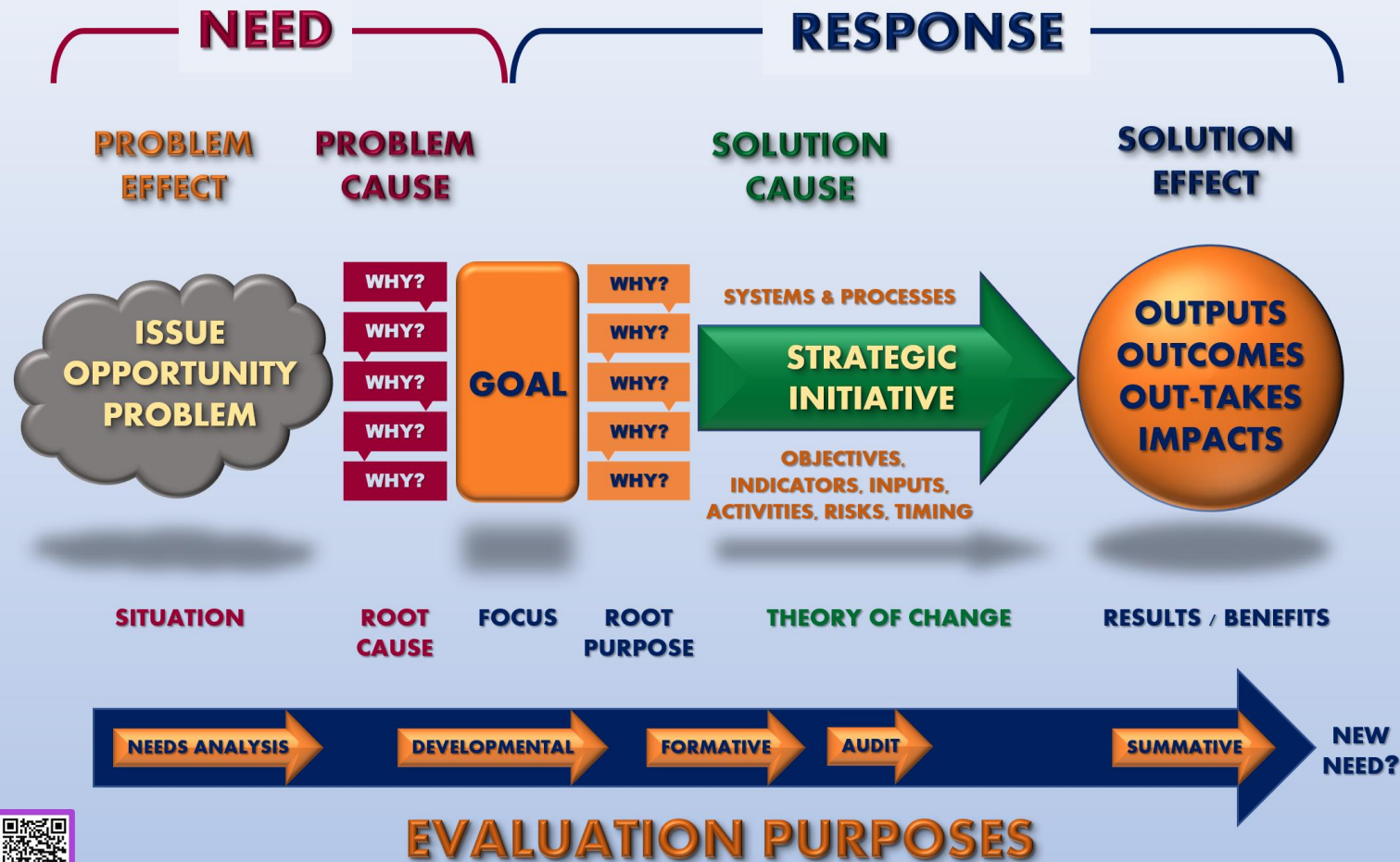
Over 150 Experts from key H-HOPE demonstration sites participated in workshops and interviews (Stepanovic et al. 2025)





Causality for Stakeholders

STRATEGIC CAUSALITY

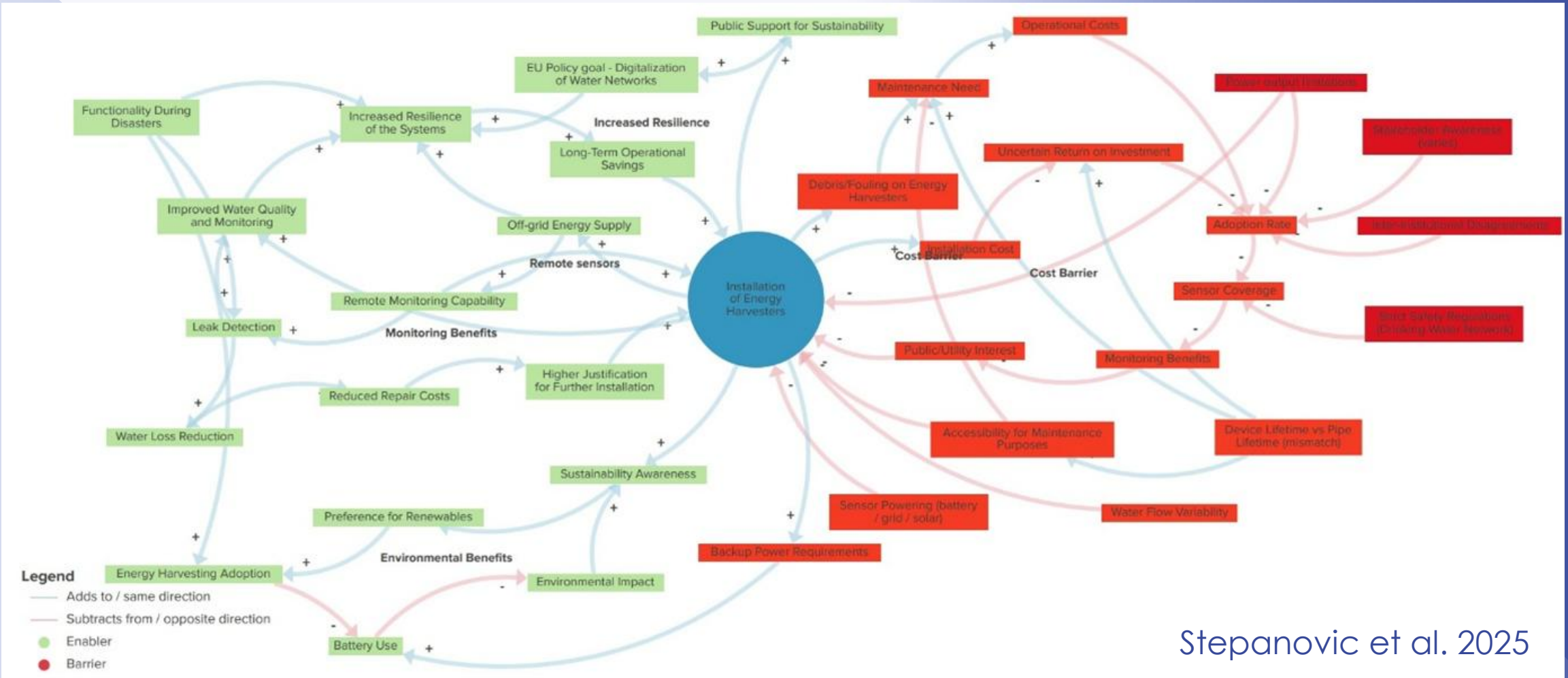


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Causality of the implementation of H-HOPE technology



Stepanovic et al. 2025



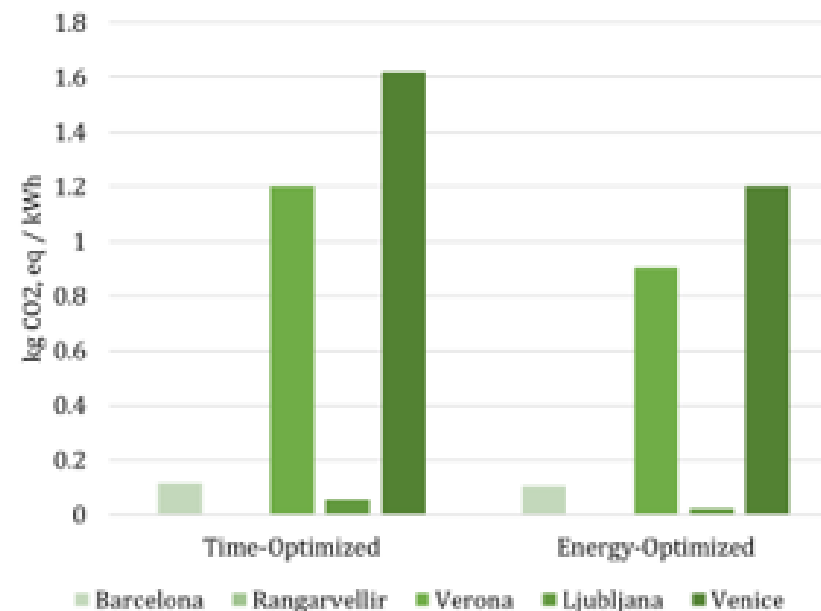


Environmental Impacts

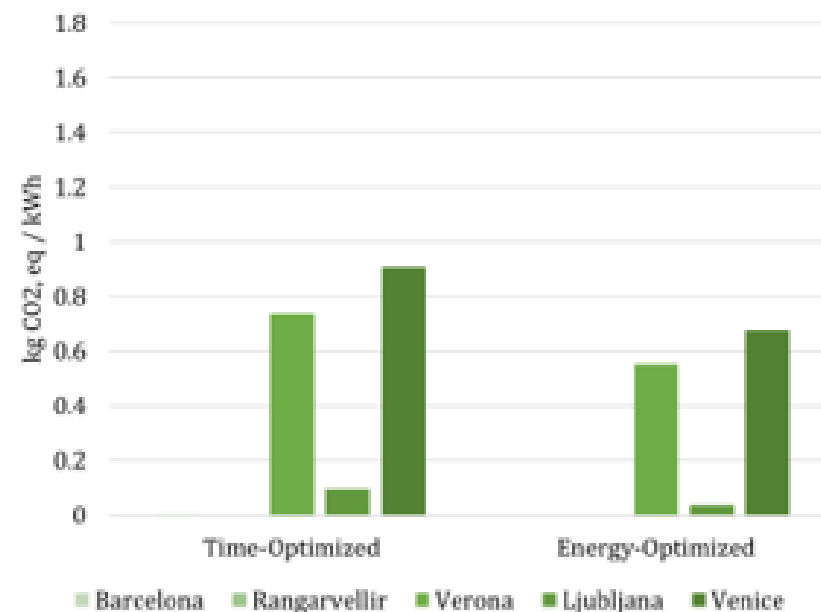
Case	CF _t	CF _p	Energy _t [kWh]	Energy _p [kWh]	Sample Rate	I _i
Barcelona	52%	49%	41.3	46.2	10 min	0.99
Rangárvellir	52%	43%	253.8	257.6	60 min	0.026
Verona	70%	25%	64.7	86.1	1 min	0.858
Ljubljana	88%	8%	211.3	536.4	24 hrs	N/A
Venice	59%	5%	3553.6	4783.9	30 min	1.742

8 Impact factors were assessed: i) Ionizing radiation, ii) Marine Ecotoxicity, iii) freshwater ecotoxicity, iv) carcinogenic toxicity, v) human toxicity, vi) land use, vii) fossil depletion, viii) energy demand (Bronkema et al. 2026)

a) Stainless Steel, 20 Years

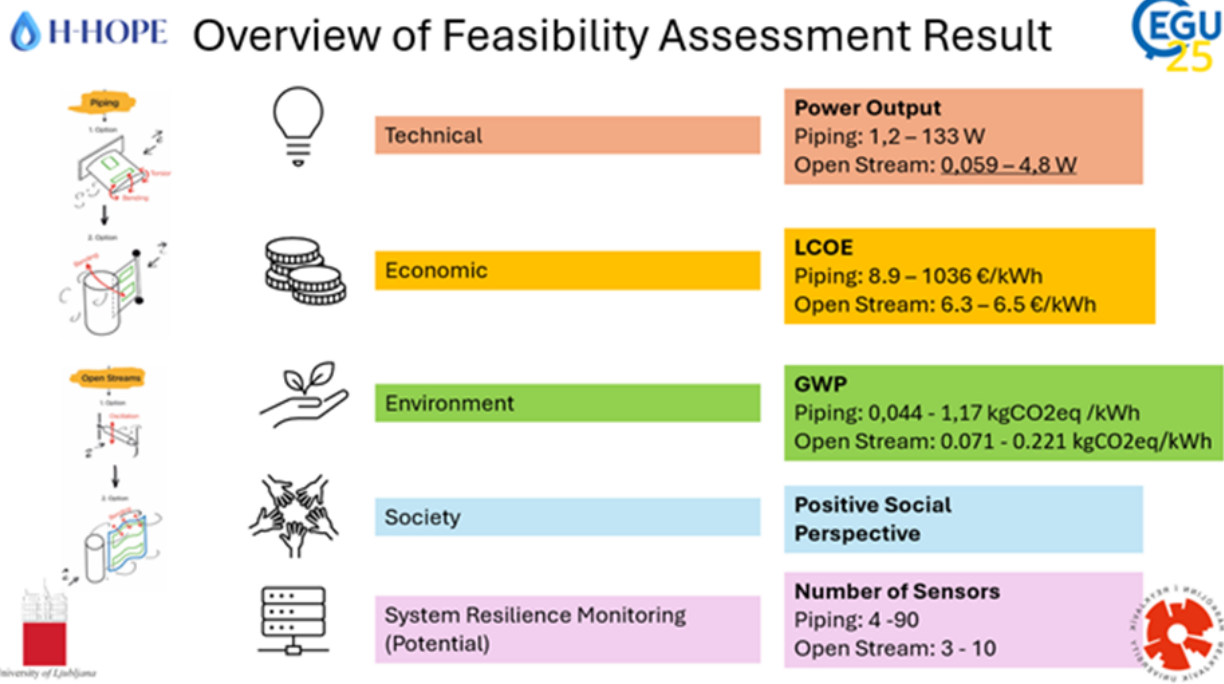


b) Polyethylene, 12 Years





Assessment Framework





Input to the Framework

Return to Cover

Return to Introduction

USER INPUT
to Linked Data Cells in Calculation Overview

Rest Input Cells

Case Study Information

Select Case Type
Select Location
Select Case Study

Case Type:
Location:
Case ID:

Open_Stream
Slovenia
S01-1

Material Flow

Parameter	Value	Unit
Cylinder_Filling - boll	0.95	%
Material_Density	Brass	kg/m³

% of Cyl_Centre

Economic Analysis - Cost Factors

Parameter	Value	Unit
CAPEX		
Operational Licences Costs	750	[Euro]
CAPEX - Work Requirement		
Design and Manufacturing (Phase 1)	4	Weeks
Construction/Installation (Phase 1)	5	Weeks
OPEX		
Fuel Costs	0	[Euro]
Administration Costs	150	[Euro]
Variable Cost	0	[Euro]
OPEX - Work Requirement		
O&M (Phase 2)	2	Weeks
Operational Costs Savings		
Battery Replacement Cost Reduction	80	[Euro]

Operational Characteristic - Customized Scenerio Analysis

Parameter	Value	Unit
Device_Lifetime	15	[Years]
Installed_Device	7	[Number of Devices]

Risk Assessment

Parameter	Possibility	Impact
Device's Structural Design	Medium	Very High
Device's Installation	Low	High
Material Corrosion	Very High	Very High
Device's Manufacturing Quality	Medium	Medium
Fouling (dissolved in the water)	Low	Low
Sediments	Medium	Low
Velocity - High	Medium	Low
Velocity - Low	Low	Low

Social Prespective Assessment

Parameter	Co-benefit
Support for remote communities	Yes
Improved infrastructure monitoring and maintenance	No
Enhanced resilience	Yes
Cost-effective services for communities	No
Contribution to environmental sustainability -	No
Promotes technological innovation	No
Prevention of water loss and environmental impact	No
Environmental monitoring for public safety	Yes
Diverse applications	No
Long-term resilience and security	Yes
Economic impact on families	No
Better collaboration with municipalities and stakeholders	Yes
Educational opportunities	No
Improving water network resilience	No

Parameter	Enabler	Challenges
Energy Savings	Very High	Medium
Reduce Operational Costs	Medium	Very Low
System Resilience	Medium	Medium
Reduce System Failures	Very High	Very Low
Enhanced System Monitoring Capabilities	High	Very High

Procced to Visualization of Result

Procced to Overview of Calculation

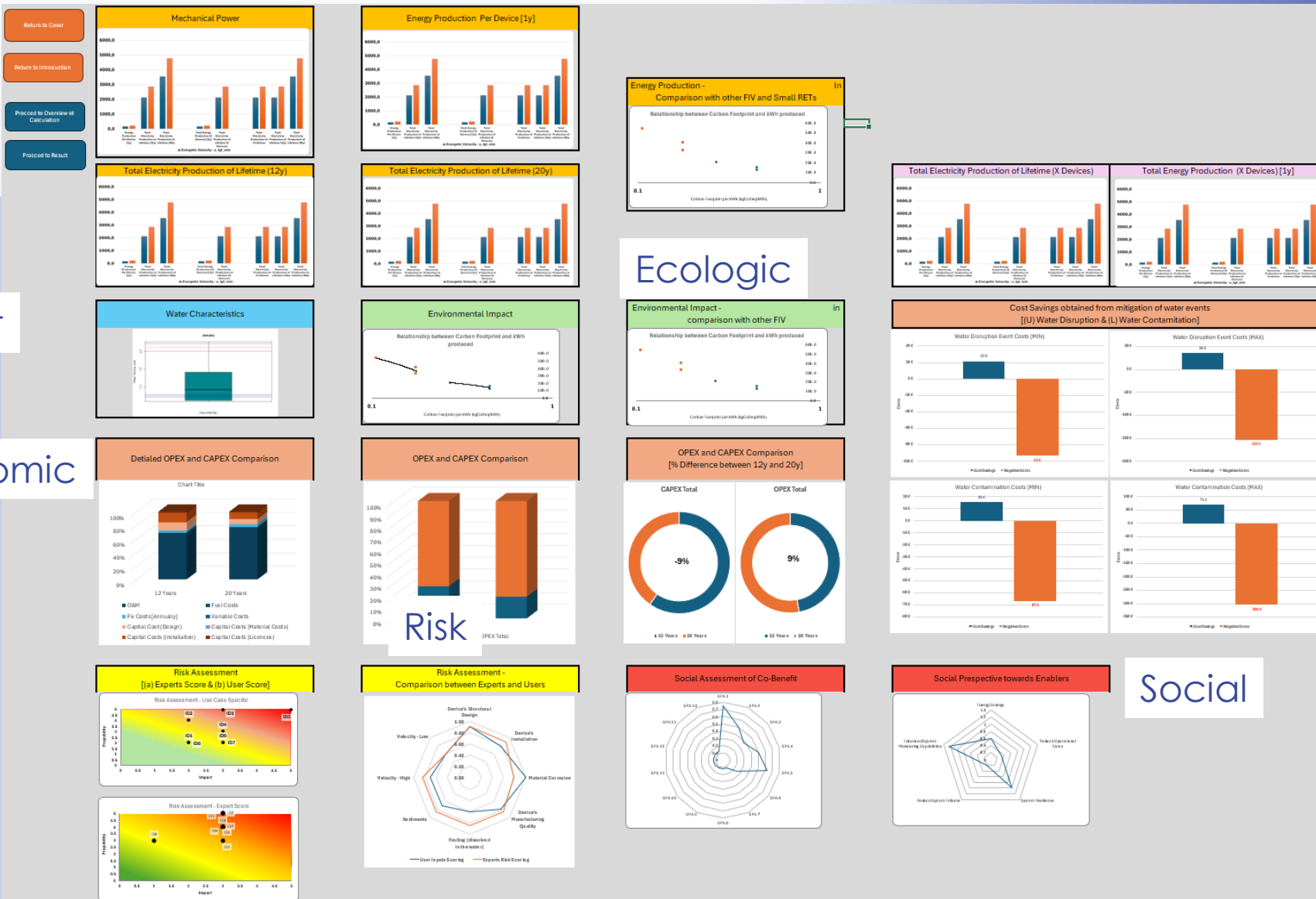
Procced to Result





Results of the Framework

Technical



Water

Economic

Risk

Social

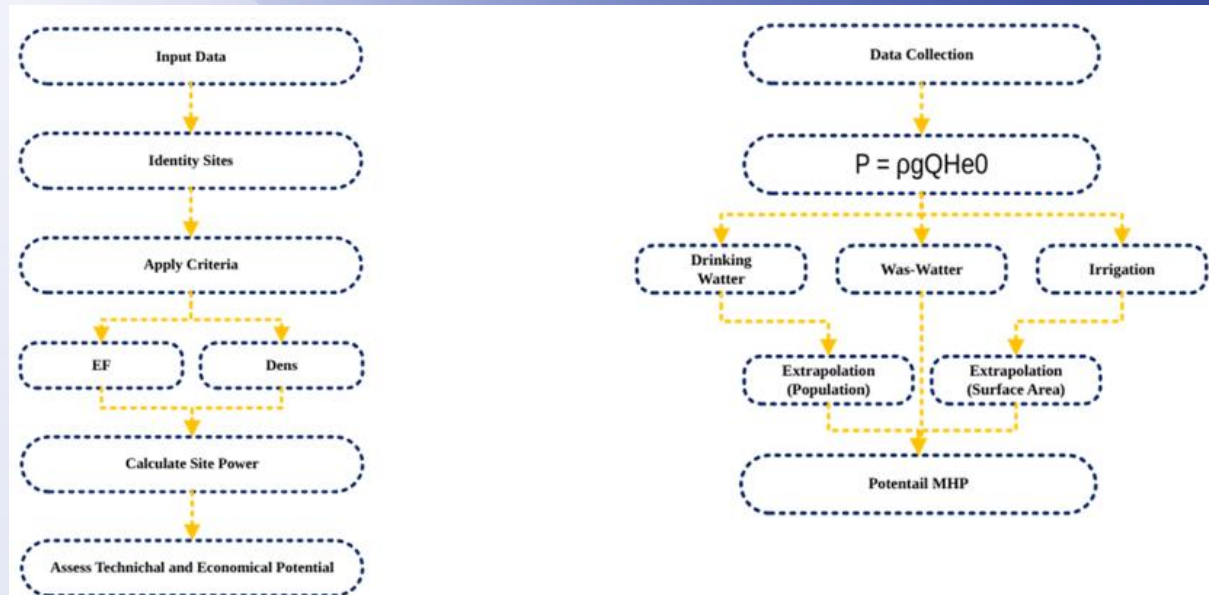


Pan-European potential

Methodologies in Selected Publications

Feature	Quaranta et al.	Mitrovic et al.	Miskat et al.	Bousquet et al.	Hamlehdar et al.
Type	Theoretical/ GIS-based	Empirical/ Statistical	Review/ Empirical	Empirical/ GIS-based	Empirical/ Model-based (EPANET)
Coverage	Entire EU (screening-level)	6 EU countries	Bangladesh	Switzerland (national)	Tehran, Iran (local WDN)
Technologies	DROR, HTs, water wheels, PATs	PATs in WDNs/WWTPs	SSHP, LSHP, pumped hydro	Pelton, Kaplan, PATs, Archimedes screws	Cross-flow, PATs, Pelton
Resolution	100m scale	Site-level (8828 sites)	Site-specific (232 rivers & 19 sites)	WWTP- level (900+ sites)	PRV-level (15 stations)

Comparison of methodology:
Quaranta et al. vs. (b) Mitrovic et al.





Thank you!



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