# Hidden hydropower potential in EU: micro-hydro technologies and hydro fleet modernization

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*28/02/2022*

# Hydropower debate: benefits vs impacts

Renewable energy, storage, flexibility

Water management

Tourism

Market development

Job opportunities

Fish injury

Sedimentation

Fragmentation

Hydropeaking

Flooding upstream

Hydro alterations

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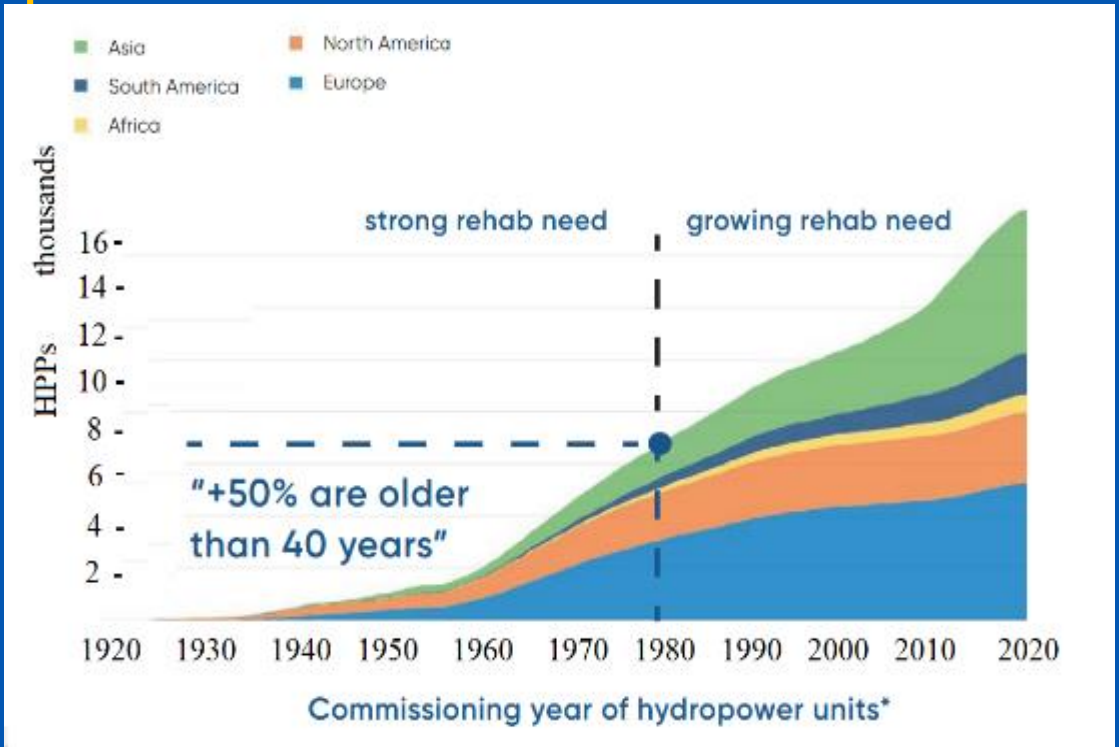
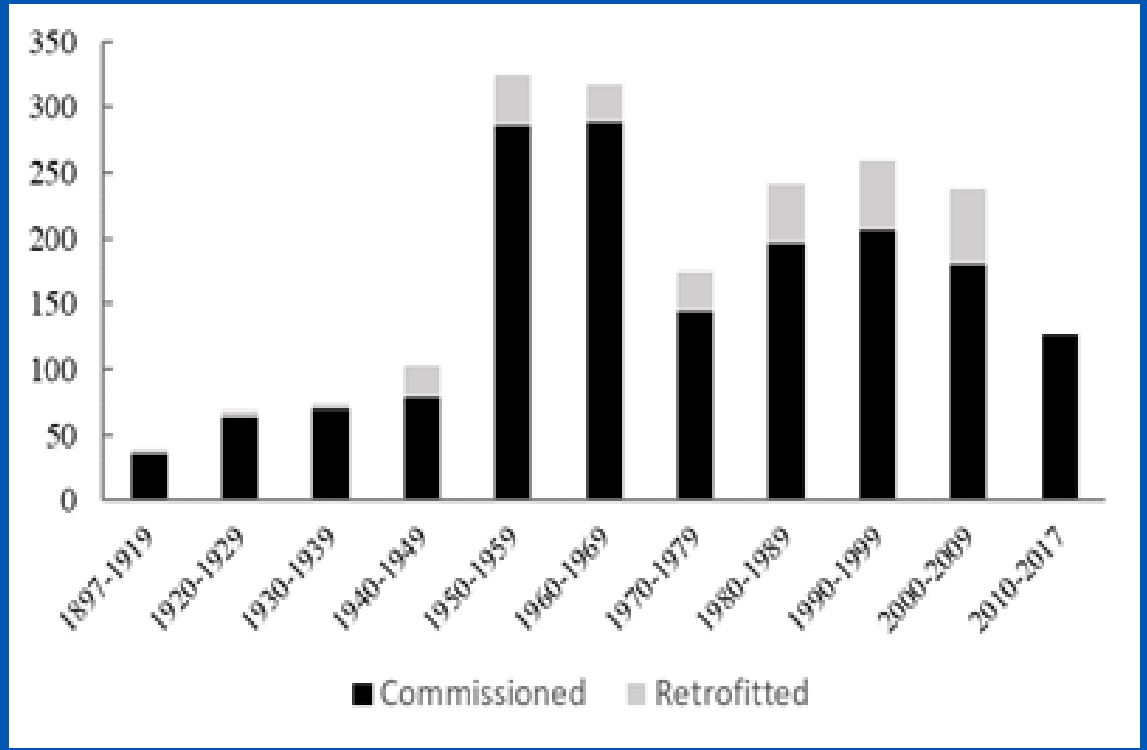
# SustHydro (exploratory activity)

- Retrofitting of the existing hydropower fleet (considering different retrofitting strategies): *improvement of generation and flexibility without additional impacts.*
- Run-of-River hydro potential under different ecological scenarios (e-flow and distances): *which is the best compromise between environmental safeguard and renewable energy target?*
- Hydropower potential (retrofitting and new plants) from historic low head sites (e.g. water mills): *hydropower and safeguard of cultural heritage.*
- Hydrokinetic turbines in European rivers: *no-dam hydropower and remote electricity*
- Hydropower from WDNs and WWTPs: *retrofitting of existing hydraulic infrastructures.*
- *Which are the novel materials?*

# Age of the hydropower fleet

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Quaranta et al., 2021a

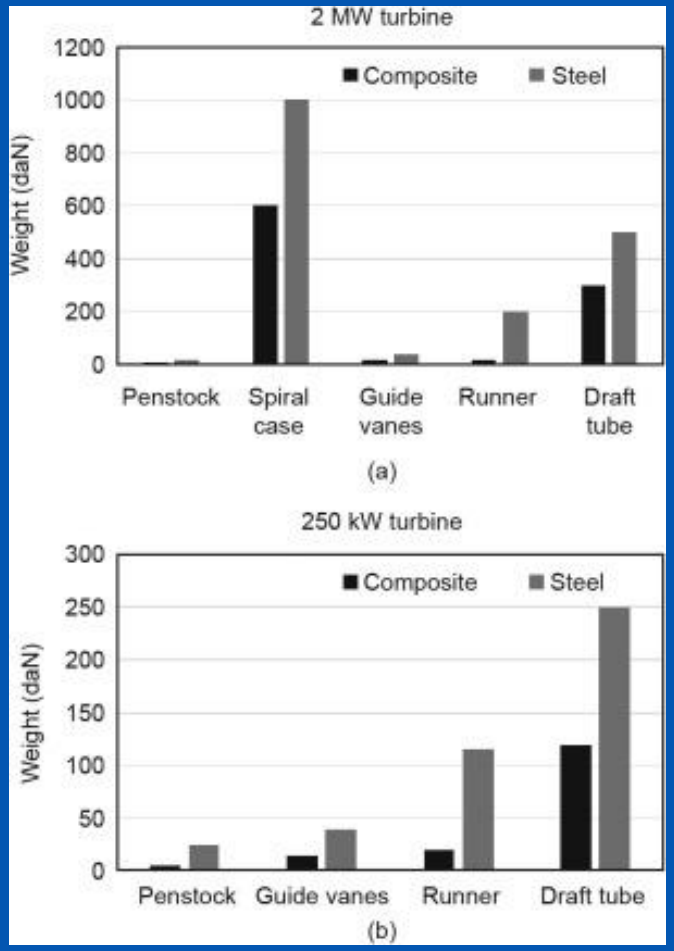
| Modernization practice | $\Delta E_{id}$ EU | $\Delta E_{id}$ Europe | Interpretation | Comment |
|---|---|---|---|---|
| Dam heightening – *H- strategy* | 0.05% | 0.22% | Increase of peak installed power | High investments, not always feasible; main benefit in increasing off-season generation by larger storage capacity. |
| Waterways and penstock, *H-Q strategy* | 2.3% | 3.2% | Increase of peak power of 3.6 GW and 8.2 GW, and annual generation of 8.4 TWh and 20 TWh | – |
| New equipment: weighted efficiency increase over wide range, *η- strategy* | 5.0% | 4.9% | Increase of peak power of 7.7 GW and 12 GW, and annual generation of 17.9 TWh and 30 TWh. | Fish friendly turbines may result in a lower efficiency (2% less) with respect to new standard turbines, thus halving the benefit in the worst case, but they are limited to low heads (<40 m) and their costs is lower [48]. |
| Digitalization *Q-t-strategy* | 1.0%/ 11% | 1.0%/ 11% | Increase of efficiency of 1%, while annual generation can increase by 11% | Reduced costs and outage time not estimated. |
| Floating PV *Q*-strategy (evaporation reduction) | 0.02% | 0.05% | Increase of annual generation equivalent to 500 mini HPP with 100 kW of average power. | Stability of the floating structure, reservoirs covered by snow and ice and difficult for PV. PV on dam surface is a modern practice. The PV generation dominates additional hydro output due to evaporation reduction. |
| Floating PV: solar energy from PV | | 729 GW | Installed power of floating PV covering 14% of the reservoir surface [105] | This should not be considered an increase in hydro generation. |
| Reservoir interconnection, *Q-strategy* | 4 TWh | 28.6 TWh | Increase of energy storage. | Connecting reservoirs within 20 km, from Gimeno-Gutiérrez and Lacal-Arántegui [67]. |
| Virtual reservoir interconnection, *Q-t strategy* | | 140 TWh | Virtual Energy Storage Gain on 14 year period. | Coordinated operation of HPP within 3000 km, from [187]. |
| Increase of peak discharge RoR, *Q-strategy* | 4.4% | 3.0% | Increase of annual generation of 15.8 TWh and 18.6 TWh. | Not quantified, but reasonably estimated |
| Increase of peak discharge SPP by new waterways, *Q- strategy* | 0–100% | 0–100% | Increase of peak power | Not quantified, site-specific |
| Increase of annual inflow, *Q-strategy* | – | – | Increase of annual generation | Not quantified, site-specific, may be negative in some regions due to climate change |
| Start and stop improvement | – | – | Increase of annual operating hours and lifespan extension | Not quantified |
| Overall indicator | 8.4% | 9.4% | | (excluding the last four strategies, reservoir interconnection and coordinated operation, and energy from floating PV) |

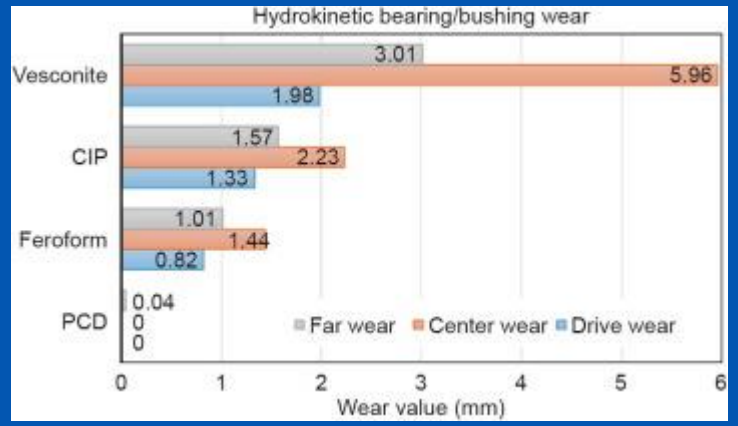
# Environmentally Enhanced Turbines for Hydropower Plants: Current Technology and Future Perspective

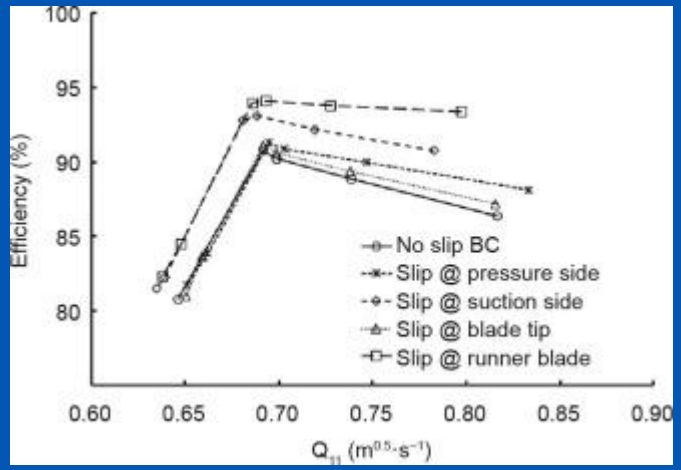
| | Alden | Francis | MGR |
|---|---|---|---|
| Hub diameter (m) | 3.9 | 2.5 | 2.7 |
| Rot. speed (rpm) | 120 | 190 | 277 |
| Runner blades | 3 | 13 | 5 |
| Guide vanes | 14 | 20 | 24 |
| Survival rate for a fish of 200 mm | 98% | <50% | 86% |
| Max. efficiency | 93.6% | 95% | 95% |

Quaranta et al., 2021b

# Emerging and Innovative Materials for Hydropower Engineering Applications




Quaranta and Davies., 2021

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# Hidden potential of micro hydropower

(*in press, confidential*) Quaranta et al., 2022.

| Technology | Overall potential (TWh/y) | Description | Investment costs |
|---|---|---|---|
| **Hydrokinetic turbines in rivers** | 0.2-1.2 | Lower and upper limit of the economic potential, assuming $C_p$=0.3 and 25% of the river cross section exploited, 8,760 annual operating hours and FDC. | Average 5,000 €/kW, 0.04-0.1 €/kWh (single installation) and 0.3-0.8 €/kWh for a HT array |
| **Water wheels in existing mills** | 1-2 | Economic potential. At old mill sites. It may be higher because the database does not include all the EU mills. Plant efficiency assumed around 70%, depending on the wheel type, 8,760 annual operating hours. EU+UK | Average 4,800 €/kW including civil costs 7,000-20,000 € that may not be necessary at old mill sites, thus costs may be overestimated of 1.3-1.5 times in certain cases. |
| **Hydro in pressurized water networks and WWTPs** | <3.1 | Technical potential. Plant efficiency 50%, 8,760 annual operating hours. EU+UK | Use of existing infrastructure replacing pressure reduction valves. Average 5,000 €/kW, 0.1-0.3 €/kWh for WWTPs |
| **Hidden micro hydro not here quantified (from literature data)** | 7-8 | Pressurized conduits for irrigation and industrial flows. Hydropower tailrace, existing barriers (EU+UK) | As above |

# Retrofitting the hydropower industrial heritage: vertical axis water mills

Quaranta et al., 2021c

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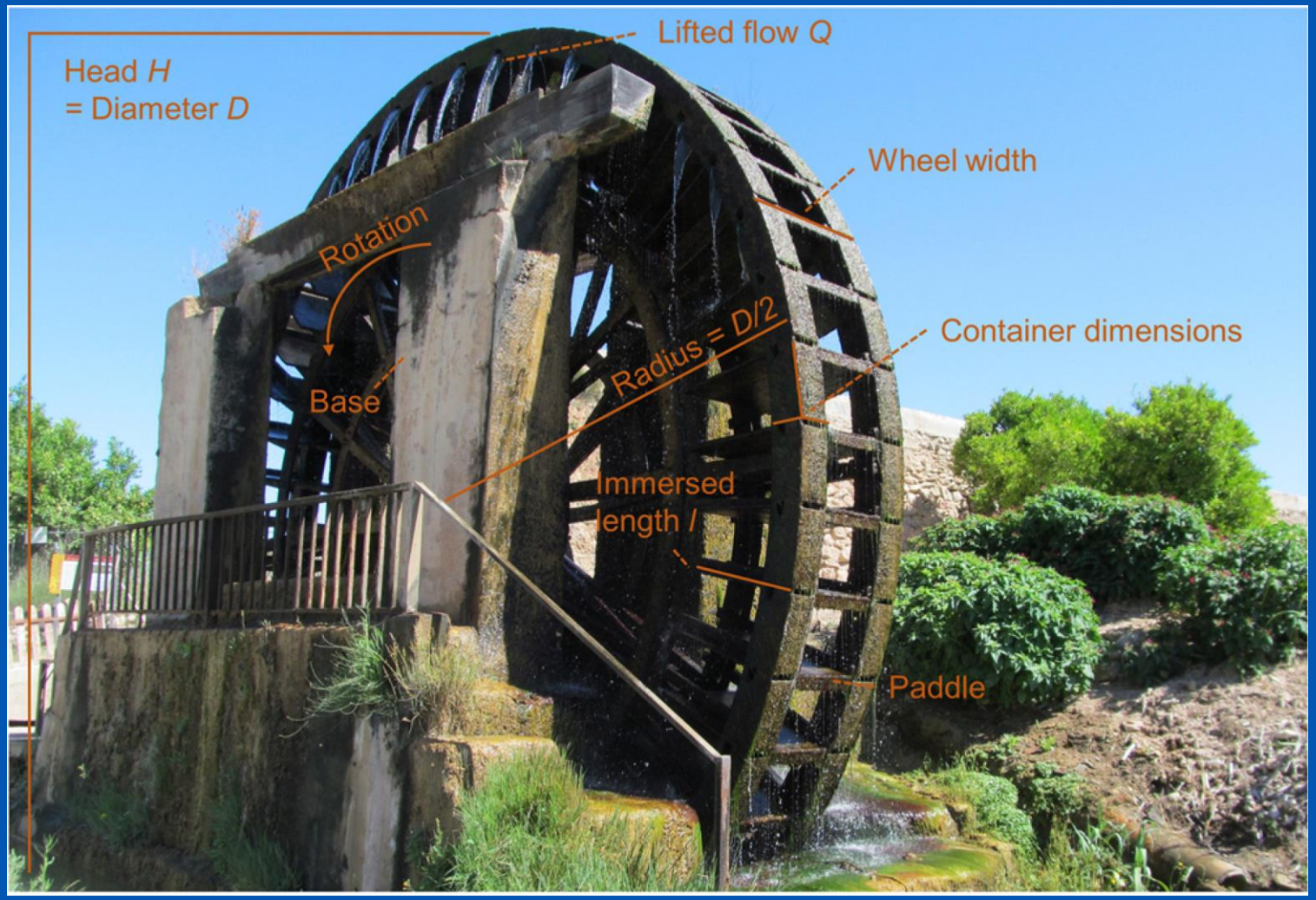
# Retrofitting of hydropower industrial heritage: water lifting devices (norias)




Heider, Quaranta, et al., 2022

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# Thank you



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