Next generation wave energy technologies: a structured assessment of solid-state conversion technologies

Paul. Kerr, Henry. Jeffrey , D. Noble, J. Hodges and A. Rae

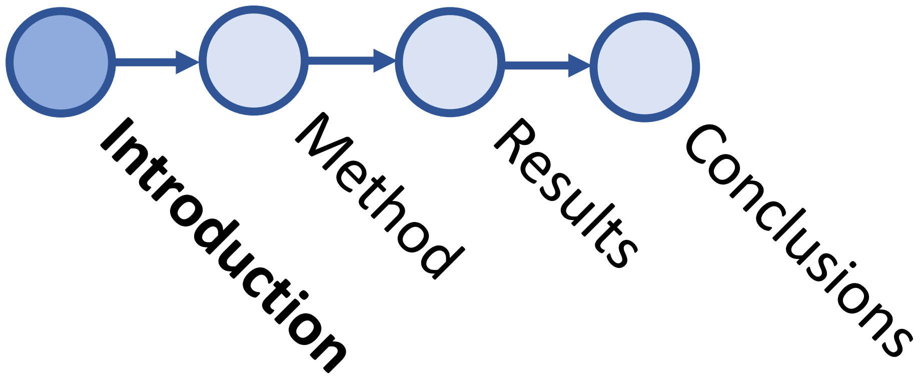
[1] *University of Edinburgh*
[2] *University of Edinburgh*
[3] *University of Edinburgh*
[4] *Wave Energy Scotland*
[5] *University of Highlands and Islands*

Donostia / San Sebastián 2022

paul.kerr@ed.ac.uk

Presentation overview

- **Introduction** – why I am carrying out the research, overall aims
- **Method** – screening process and parameters
- **Results** – screening results for 6 conversion technologies
- **Discussion** – findings from the process



Why are we doing this research?

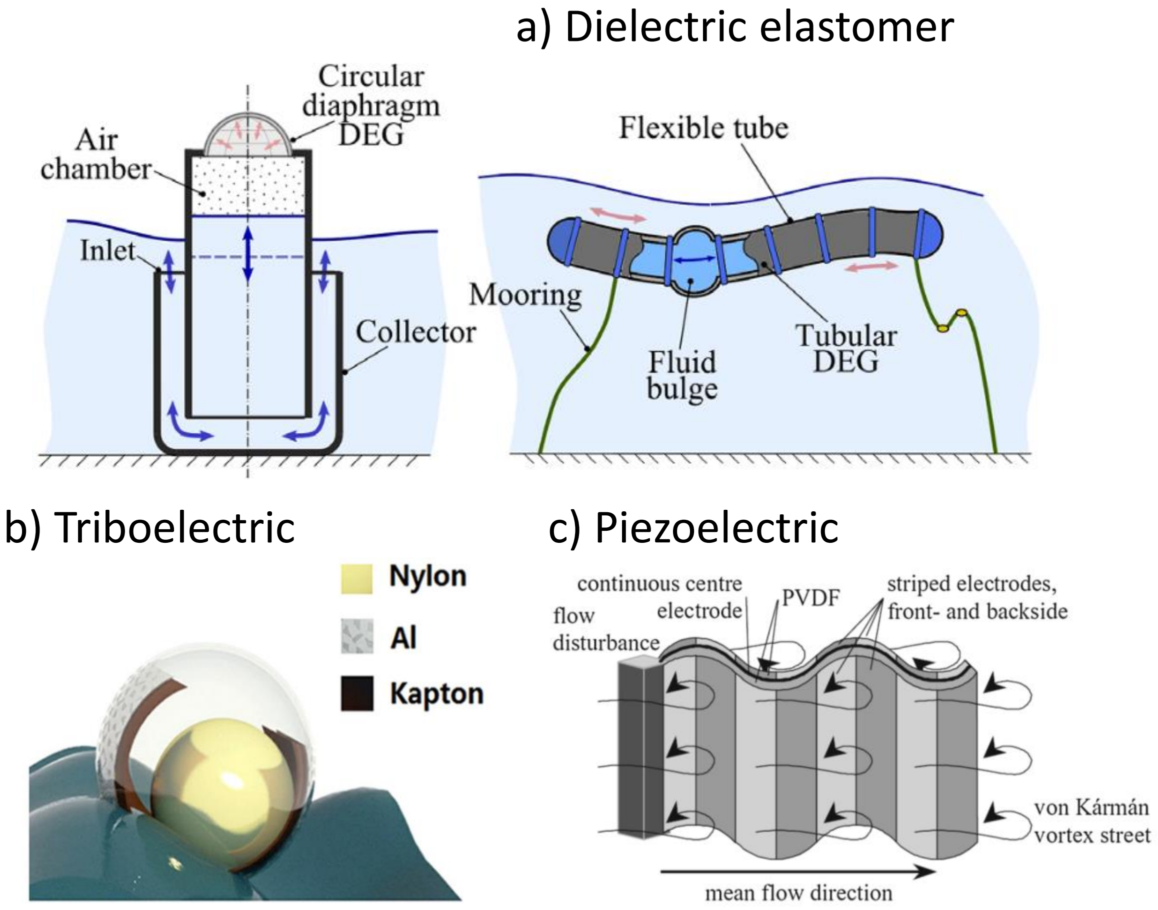
- Wave energy not yet commercially viable
  - In general: high cost, high complexity, low reliability
- Solid state conversion - multiple potential benefits including:
  - Low cost, low corrosion materials
  - Direct generation (no transmission)
  - Reduced maintenance requirements
  - Novel WEC design (e.g. distributed PTO)
- Several proposed technologies
  - Want to understand which have potential
  - Need a set of metrics to compare/evaluate

Oceanlinx 2.5 MW WEC [1]

Conversion technologies

Six technologies, based on 4 conversion principals:

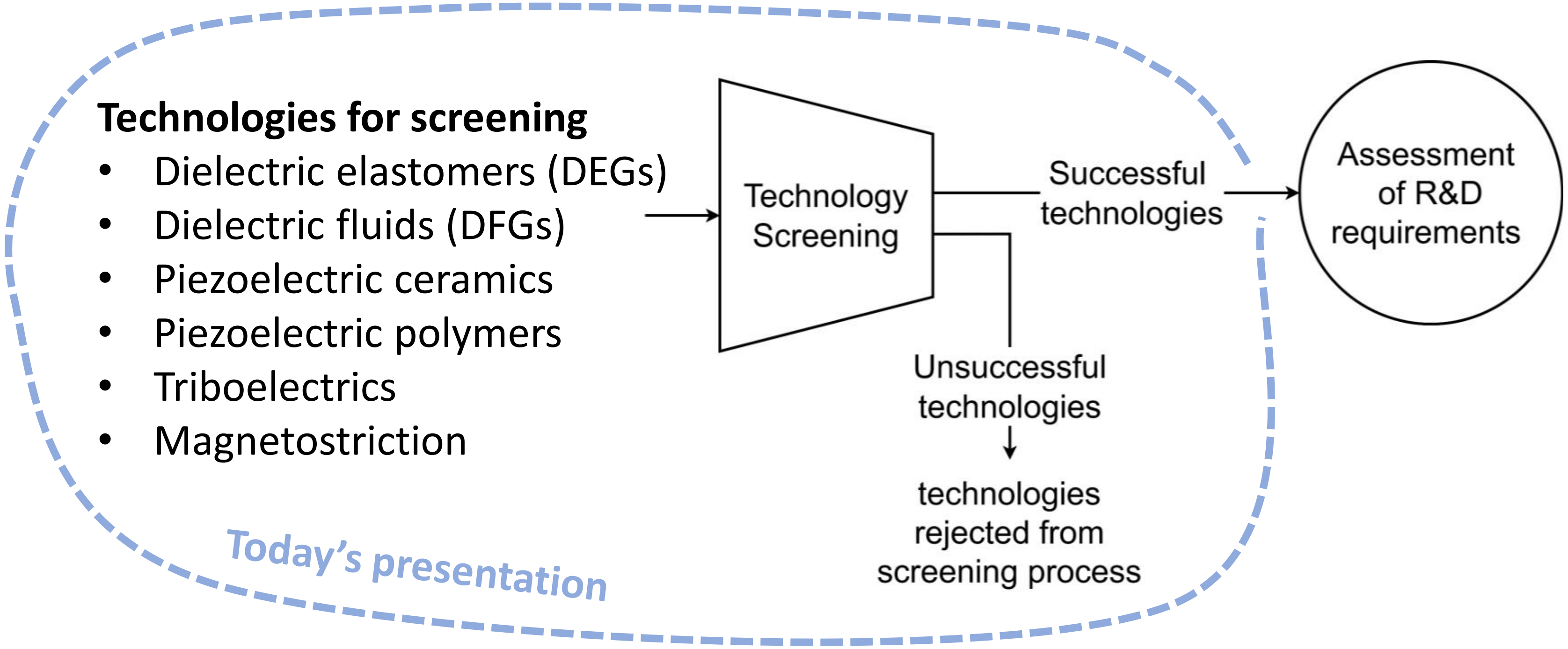
- Dielectric elastomers (DEGs)
- Dielectric fluids (DFGs)
- Piezoelectric ceramics
- Piezoelectric polymers
- Triboelectrics
- Magnetostriction



Selection of solid state conversion technology wave energy concepts [2-4]

Overall aims

- Develop process to screen out technologies
- Apply process to a selection of conversion technologies
- Assess R&D requirements for successful technologies (not covered in presentation)



Method – essential technology requirements

a. IEA-OES ocean energy evaluation metrics

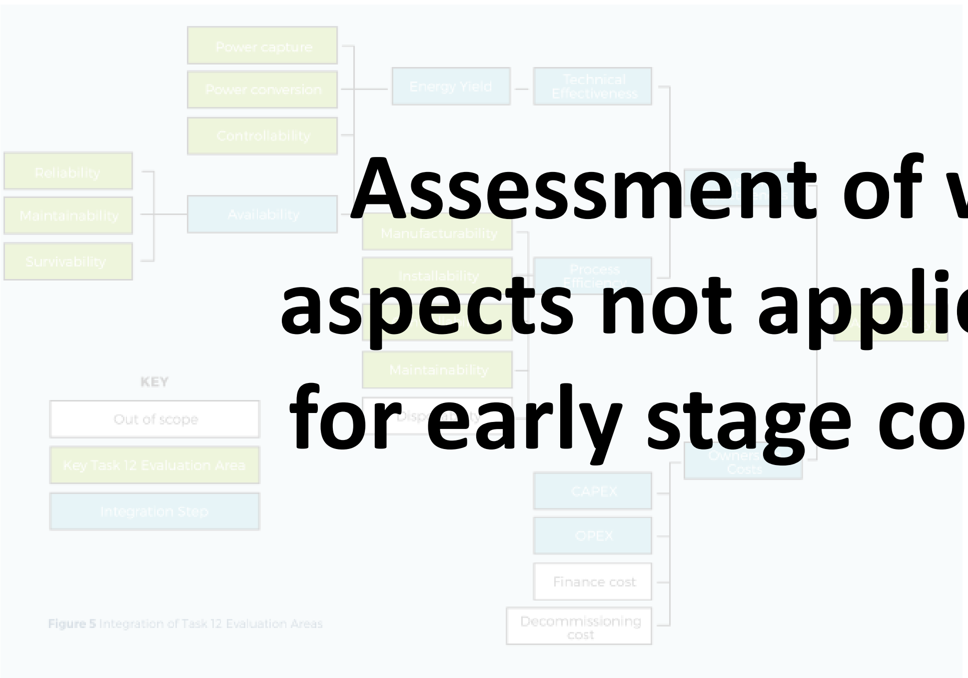
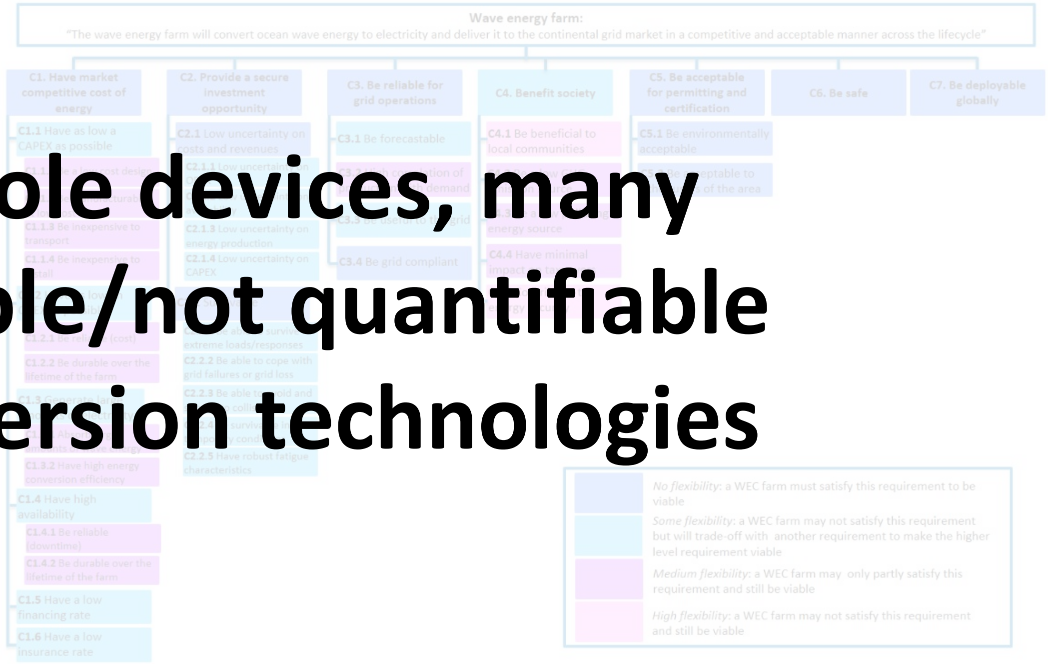


Figure 5 Integration of Task 12 Evaluation Areas

b. Technology Performance Level



Assessment of whole devices, many aspects not applicable/not quantifiable for early stage conversion technologies

Method – parameters for early stage technology screening

- **Filter 1 – Peak performance** assessment parameters:
  - 1.1) Conversion efficiency
  - 1.2) Maximum energy density
  - 1.3) Raw material cost per unit energy
- **Filter 2 – Through-life performance** assessment parameters:
  - 2.1) Through-life energy density
  - 2.2) Through-life cost
  - 2.3) Through-life embodied carbon
  - 2.4) Ultimate limit state

Cut-offs indicating the minimum requirement: Pass, Fail, Uncertain

Filter 1 – Peak performance

1.1) Conversion efficiency (%)

- Cut off value ≥ 25%

Minimum requirements, not necessarily indicative of 'high performance'

1.2) Maximum energy density (J/kg)

- Cut-off driven by material cost

1.3) Raw material cost per unit energy (€/J)

- Cut-off value ≤ 0.1 €/J

Filter 2 – Through-life performance

2.1) Through-life energy density (J/kg)

- Cut off value dictated by through life cost and embodied carbon

2.2) Through-life cost (€/J)

- Cut-off ≤ $2.6*10^{-9}$ €/J (9.4 €/MWh)

2.3) Through-life embodied carbon ($kgCO_{2e}$/J)

- Cut-off value ≤ $4.2*10^{-9}$ $kgCO_{2e}$/J (15 $kgCO_{2e}$/MWh)

2.4) Ultimate limit state

- No cut-off value

Overall results (Numerical results can be provided)

Filter 1 – Peak performance

	1.1) Conversion efficiency	1.2) Energy density	1.3) Raw material cost per unit energy	Filter assessment
DEGs	Pass	No cut-off	Pass	Pass
DFGs	Pass		Uncertain	Uncertain
Piezo ceramics	Pass		Fail	Fail
Piezo polymers	Fail		Fail	Fail
Triboelectrics	Pass		Fail	Fail
Magnetostrictive	Uncertain		Fail	Fail

DEGs + DFGs progress

Filter 2 – Through life performance

	2.1) Through-life energy density	2.2) Through-life energy costs	2.3) Through-life embodied carbon	2.4) Ultimate failure state	Filter assessment
DEGs	No cut-off	Fail	Uncertain	Pass	Fail
DFGs		Uncertain	Uncertain	Pass	Uncertain

Key findings

- Dielectric elastomers (DEGs) ?
  - Most promising technology based on available data
  - Low demonstrated through-life energy density (limited experimental data)
  - R&D needed on fatigue life

- Dielectric fluids (DFGs) ?
  - Promising technology, very limited experimental data
  - Insufficient data to make evaluation in second filter
  - R&D needed on fatigue life
  - R&D needed on energy density limits and compatible materials

- Piezoelectric (ceramics & polymers), Triboelectric, Magnetostrictive ✗
  - Poor experimental/theoretical maximum energy densities
  - Limited viability in grid scale wave energy applications