European Commission

ENTEC

Energy Transition Expertise Centre

Terms of Reference

The potential of osmotic energy in the EU

Terms of Reference - The potential of osmotic energy in the EU

Consortium Leader

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Content

1 Request of the EC

In the framework of EnTEC DG Ener requests a study on the potential of osmotic energy in the EU. Better knowing the potential of osmotic energy would inform the decision to prioritise support for medium to large scale deployment with EU funding instruments. Results would ideally be expected within 3 months, but later delivery would be acceptable.

1.1 Background

- Osmotic energy is about converting salinity gradient between two water flows into electricity, using reverse electrodialysis (RED). It is renewable energy that is produced 365/24/7 and has low environmental impact (no noise nor emissions, no moving parts except water pumps)
- The Osmotic energy potentials (roughly) estimated by REDstack are: 1.7 GW in the NL, 60 GW in EU, 1 TW worldwide. For the EU, it would correspond to an annual production of 60GW * 8000h = 480 TWh, or 16% of the EU27 gross electricity production (2911 TWh in 2021), to be compared 26% for nuclear (also a baseload source)
- Several technologies are competing, the most advanced are presently at TRL7, meaning tested in real environment, but not yet at full scale (e.g. REDstack, NL, thanks to FP7 and H2020 projects).
- The REDstack pilot plant in Afsluitdijk has a power of 0.5 kW (500 m² membrane area in very thin stacked layers), tested in real environment (TRL7), it has benefitted from several FP7 and H2020 projects. It will be scaled up to a full scale stack of 16 kW (3.5m long, 0.8m diameter) by 2024 to reach TRL8; investment of 13M€, including 1-2M€ for environmental impact analysis.
- The future full scale plants will use thousands of these stacks, to produce hundreds of MW. The LCOE of electricity produced by an osmotic energy plant of 100 MW is expected to be 0.011 €/kWh, and would further reduce to 0.005 €/kWh by 2050; the plant size would be approximately 110m x 290m
- Typically a power of 1MW can be exploited from 1 m^3/s of salty water and 1 m^3/s of fresh water flow. So, a 100MW plant would use 100 m^3/s. To be compared with average river flows of: Rhine 2000, Rhone 1600, Po 1500 m^3/s. Only a fraction of the river flow would be used

1.2 Objective of the study

1) Evaluate the technical and economic potential of Osmotic energy in the EU
2) Given the fresh water usage of the process, and a reasonable fraction of river water captured, what could be the technical potential of osmotic energy of the major rivers and sewage water flowing into the seas, taking also environmental constraints into account. What would be the seasonal fluctuation of energy production (e.g. due to droughts).
3) (optional – if data are available) evaluate/verify the statements of the industrial actors about the LCOE at short term (2025-2030) and long term (2050) for an osmotic energy plant of 100MW, including some sensitivity analysis in function of the salinity gradient and average water temperature (both parameters depend on the geographic location).
4) Taking as assumptions the targeted LCOE for 100MW plant in the short term (0.011 €/kWh) and in the long term (0.005 €/kWh), evaluate the economic viability, taking into account the baseload capability, as well as the capacity to switch off power (flexibility offer in case of negative spot price). The two options: either sell on the spot market or on the futures market (PPA) should be considered. The aim is to know whether financial support through green certificates or contract for differences would be needed to support the deployment.

1.3 Attached annexes

	BACKGROUND
Reverse Electro-Dialysis, technology, Used by REDstack	• RED (Reverse Electro-Dialysis) takes advantage of the fact that salts are made up of ions: positively and negatively charged particles. In seawater these are mainly Na+ (the sodium ion) and Cl- (the chloride ion). And when a salt is dissolved in water, these ions appear as loose particles in the water. Two types of membranes are now used at RED: membranes that only allow positive ions to pass through (CEM, Cation Exchange Membranes) and membranes that only allow negative ions to pass through (AEM, Anion Exchange Membranes). • When salt water flows between two such membranes (with fresh water on the other side of the membranes), the ions from the salt water will want to migrate to the fresh water. However, because of the membranes used, a CEM on one side and an AEM on the other, the two types of ions will therefore migrate in opposite directions. This creates a transport of positively charged parts in one direction and negatively charged parts in the other direction. So this creates a + and a - side, a kind of battery, an electrochemical cell.
OE4EU – Osmotic Energy for EU - association	• OE4EU’s members represent technology producers, energy suppliers and researchers. • with the ambition to promote Osmotic Energy as a source of renewable energy and provide the grassroot push for the creation of an adapted regulatory framework at EU level

	BACKGROUND
The projects	**About REDstack** • REDstack BV develops and implements the RED Blue Energy technology using ion-selective membranes in stacks. The pilot plant (TRL7) is operating successfully at the Afsluitdijk in the Netherlands and is ready to be up scaled to TRL 8 on the same site. Industrial pilot plants are under construction in Spain, focusing on using brines and treated wastewater as feedwater to generate power. Demonstration projects of 3 MW are being prepared in the Netherlands and India. • REDstack benefitted from one FP7 and three H2020 projects, for a total EC contribution of approximately EUR 2.5 million **About Saltpower** • SaltPower founded in 2015 has developed the technology of Pressure Retarded Osmosis (PRO) to industrial level and the first industrial installation is commissioned in the first quarter of 2023 for the company Nobian near Hobro in Denmark. The PRO technology utilizes saturated brine in industrial production of salt for energy production. Projects of up to 1MW are being planned throughout the EU. • The H2020 SaltPower project (May 2020 – Apr 2023, EC funding 2.4M€) aims to upscale its current mobile 20 kW Osmotic Power Unit (OPU) to a 100 kW unit. The electricity generated from our OPU unit will cost 0.021 €/kWh, or approx. only 20% of current average EU market price of 0.10 €/kWh. As production scales and membranes are developed even further, the price of electricity from SaltPower's OPU can be as low as 0.01 €/kWh - Coordinator: SALTKRAFT APS (DK) (2.4M€) **About Sweetch Energy** • Founded in 2015 and based in Rennes (France), Sweetch Energy is a renewable energy player specializing in osmotic energy. Its INOD® technology enables the production of clean and competitive electricity from salt water. Sweetch Energy benefits from the support of many renowned European and French public, financial and research institutions. • As part of the Transition 2022 programme, driven by the European Innovation Council (EIC), we have received a €2.5 million grant to carry out a research programme that will expand the range of applications for our disruptive nanofluidic platform to waste heat. This research programme will allow our INOD® technology to produce clean electricity by channelling low-temperature waste heat (<100°C) in a closed loop circuit.

	EU Funded Projects	**EC contrib.**	**Start – end**
H2020	**IntelWatt** - intelligent Water Treatment (separation) Technologies for water preservation combined with simultaneous energy production and material recovery in energy intensive industries. Three TRL7 case studies will be implemented in crucial EU and global industrial applications such as electricity production, mining, and metal plating. Partners include **REDstack BV (0.9M€)**	10.3 M€	Oct 2020 – Mar 2024
H2020	**SaltPower** project has developed osmotic power units (OPUs) that are delivered in containerised modules and generate non-fluctuating baseload power for own consumption or the power grid. The aim of the project is to **upscale its current mobile 20 kW OPU to a 100 kW** unit. The electricity generated will cost 0.021 €/kWh. As production scales and membranes are developed even further, the price can be as low as 0.01 €/kWh - Coordinator**: SALTKRAFT APS (DK) (2.4M€)**	2.4 M€	May 2020 – Apr 2023
H2020	**BAoBaB** - The “Blue Acid/Base Battery” (BAoBaB), stores electrical energy using pH and salinity differences in water. Our goal is to develop this totally new, environment-friendly, cost-competitive, scalable, water-based electrical energy storage system from TRL3 to TRL5; validate under accepted utility use conditions an automatically operated BAoBaB system at a scale of 1 kW power and 7 kWh energy storage. Partners incl: **University di Palermo (0.4 M€)**	4.0 M€	May 2017 – Jul 2021
H2020	**ZERO BRINE** - Re-designing the value and supply chain of water and minerals: a circular economy approach for the **recovery of resources from saline impaired effluent (brine) generated by process industries.** Partners include: **University di Palermo (0.4 M€),**	10.0 M€	Jun 2017 – Nov 2021
H2020	**REvivED** - Low energy solution for drinking water production by a REvival of ElectroDialysis (ED) systems. A multistage ED system for industrial-scale seawater desalination; Combinations of the multistage ED system with the latest salinity gradient power systems (**Reverse ElectroDialysis** - RED), which can further reduce energy consumption for seawater desalination. Partners include: **REDstack BV (1.0M€), University di Palermo (0.8 M€)**	9.8 M€	May 2016 – Jul 2020

	EU Funded Projects	EC con-trib.	Start – end
H2020	**RED-Heat-to-Power** - generation of electricity from salinity gradient using Reverse Electrodialysis – objective: develop the necessary materials, components and know-how for bringing it to the level of a lab prototype generating electricity from low-grade heat - partners include : **University di Palermo (0.9M€), REDstack BV (0.4 M€)**	4.0 M€	May 2015 – Apr 2019
H2020	**ReWaCEM** - **Resource recovery from industrial waste water** by cutting edge **membrane technologies** - Diffusion Dialysis (DD) and Membrane Distillation (MD) as an integrated hybrid process. This combination of existing technologies will be adapted to fit the requirements of 4 pilot demonstration sites in the metallurgical industry. Partners include: **University di Palermo (0.4 M€),**	5.0 M€	Oct 2016 – Nov 2019
FP7	**STAGE-STE** - Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy - encompasses Solar Thermal Electricity (STE), Solar Fuels, Solar Process Heat and Solar Desalination	10.0 M€	Feb 2014 – Jan 2018
FP7	**REApower** - Reverse Electrodialysis Alternative Power Production – Create components (membranes …); Optimise the design of the salinity gradient power – reverse electrodialysis (SGP-RE) cell pairs and stack; test in lab. Partners include **REDstack BV (0.25M€)**	2.7 M€	Oct 2010 – Sep 2014
FP7	**MEDIRAS -** The project objective is the development and demonstration of cost effective and very reliable solar driven desalination systems for water scarcity affected regions with high insolation. The modular system set up is based on the highly innovative **Membrane Distillation** technology.	2.1 M€	Sep 2008 – Aug 2011
TOTAL		**60.3 M€**	

2 Work packages

2.1 Work package 1

Research question/request

Technical and economic efficiency evaluation of osmosis systems

Approach/Methodology

- Basic consideration of the design and operation of osmotic power plants and identification of essential components
- Derivation of relevant process parameters for the process control of osmotic power plants (temperature, salt concentrations, optimal working pressures etc.)
- Determination and evaluation of the energy and material efficiency of osmotic power plants on the basis of VDI 4663 Part 1 - Evaluation of Energy and Material Efficiency - Methodical Application of the Physical Optimum
- Derivation of economic key figures for the cost structure of osmotic power plants (investment and operating costs, derivation of process parameters which influence power plant performance and economic efficiency). If available, data of the European Industry Association for Osmotic Energy will be included.
- Profitability of osmotic power plants: relevant inputs are i) electricity prices (scenario with future base load prices e.g. shadow prices from Enertile (electricity market model), sensitivities with upper and lower price limits based on the electricity prices spreads in the EU, and accounting for flexibility revenues) and ii) electricity generation profile

Output/results

- Technical system efficiency evaluation of osmotic power plants, and listing of potentials for technical efficiency improvement
- Economic key figures for the evaluation of osmotic power plants including costs and potential revenue streams (based on electricity prices and generated electricity)

Excel sheet (e.g. cash flow model) with electricity price assumptions, generated electricity, and cash-flow and net present value calculationsDeliverable/Milestone

- D1.1: Technical system assessment
- D1.2: Economic system assessment (Excel based tool of economic profitability)
- M1: Interim presentation and interim report on work package 1

2.2 Work package 2

Research question/request

Potential of osmotic energy in the EU accounting for environmental restrictions (e.g. natural protection zones)

Approach/Methodology

- Representation and derivation of water surpluses on land for osmotic power generation according to precipitation-evaporation-runoff models and accounting for environmental issues (e.g. see REDstacl NL)
- Presentation of potential parameters and derivation of partial potentials of seas and rivers within the EU
- Listing of seas and the most water-rich rivers in Europe with characteristic values for mean discharge, salinity, energy density, maximum power, etc. (water rich rivers covering at least 80% of total river potential, and of which a percentage of water flow, compatible with navigability and environment constraints, is used for energy generation)
- Derivation of the partial potentials for the previously described water sources via a sensitivity analysis
- Evaluation of the influences of daily and seasonal fluctuations
- Presentation of the potential of salt lakes for osmotic energy production
- Derivation of optimal site parameters for osmotic power plants.
- Derivation of optimal sites, as well as power plant technology (underground / above ground osmotic power plants etc.)

Include information on additional potential of osmotic energy use derived from interviews with industrial partners that is beyond the scope of this study (e.g., harvesting osmotic energy in the salt extraction industry)

Output/results

- Listing of the aggregated potential at national level (in each of the 27 MS) and at EU level, and detailed listing of river potentials (Excel spreadsheet)
- Influence of fluctuations on energy potentials
- Location parameters for osmotic power plants

Deliverable/Milestone

- D2.1: List of partial potentials of individual water sources
- D2.2: Location parameters for osmotic power plants
- M2: Presentation of results and report on results of the project

3 Time line and work organisation

Start date: 26.06.2023

End date: 26.11.2023

Involved experts: Fraunhofer IFF

Table 1 Deliverables and reporting

Deliverable/ Activity/ milestone	Content/type	Start date	End date	Output
Activity	Project coordination	26.06.2023	26.11.2023	-
Milestone	Kick-off Meeting	26.06.2023		protocol
M1	Interim presentation and interim report on work package 1		29.09.2023	presentation
M2	Presentation of results and Final report		29.09.2023	presentation
D 1.1	Technical system assessment	26.06.2023	29.09.2023	subreport
D 1.2	Economic system assessment	14.08.2023	29.09.2023	subreport
D 2.1	List of partial potentials of individual water sources	29.09.2023	26.11.2023	subreport
D 2.2	Location parameters for osmotic power plants	02.10.2023	26.11.2023	subreport
Deliverable	Final Meeting/Work shop		08.12.2023	presentation
Deliverable	Final Report		08.12.2023	

4 Budget

In total we calculate with 40 person days.

Table 2 Resources

Work packages	Resources in days
Project coordination	3
Work package 1	
D 1.1	7
D 1.2	10
Work package 2	
D 2.1	15
D 2.2	5
Total	**40**

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