Interreg
Baltic Sea Region

Co-funded by
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ENERGY TRANSITION
Energy Equilibrium

PESTLE analysis results on storage solutions

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https://interreg-baltic.eu/project/energy-equilibrium/

General comments on energy storage

The drivers behind interest in energy storing:

- International, EU, national and possible municipal level climate targets
- The goals of energy self-sufficiency
- Increased share of renewable electricity
    - Fluctuating production of energy – energy market price variation
- Societies dependency on energy

PESTLE Analysis

PESTLE is a broad fact-finding activity around the external factors that could affect an organisation’s decisions, helping it to maximise opportunities and minimise threats.

PESTLE audits six external influences on an organisation: P for Political, E for Economic, S for Social, T for Technological, L for Legal, and E for Environmental.

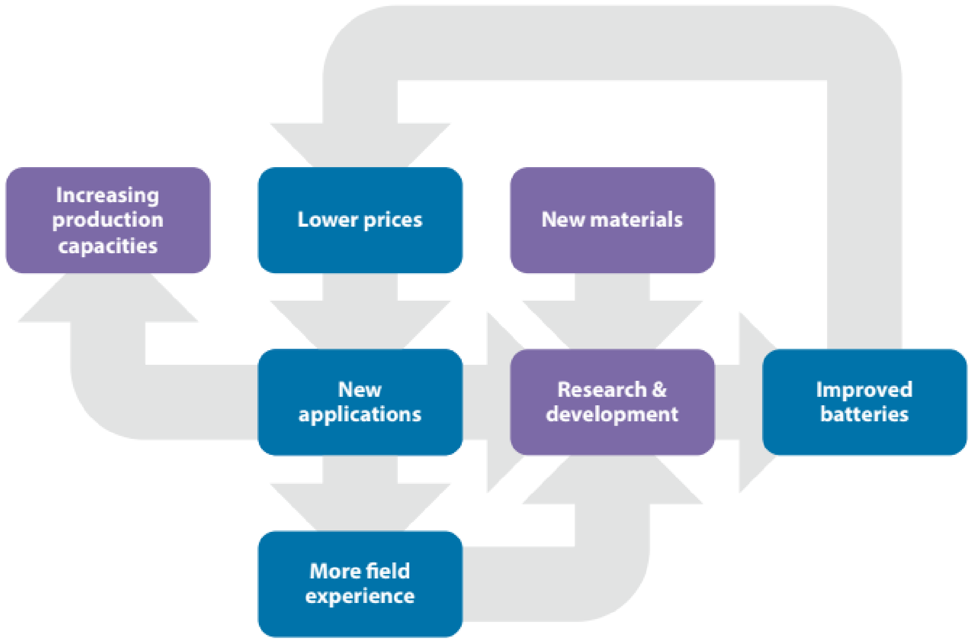
It can give an overall view of the environment under study, from many different angles, when considering a particular idea or plan.

https://pestleanalysis.com/what-is-pestle-analysis/

Technology groups included in the analysis

1. Batteries
2. Accumulation in the form of thermal energy
3. Accumulation in the form of hydrogen
4. Accumulation in the form of biomethane
5. Accumulation in the form of potential energy

1- Batteries



Source: International Renewable Energy Agency.

Batteries
Short overview

- Electricity is store and released via electrochemical reactions
- Often have a finite number of cycles
- Several different chemical combinations used
- Chosen technologies:
    - Lithium-ion battery for grid-scale storage
    - NA-S (Sodium-Sulfur) batteries (molten sodium anode, molten sulfur cathode, β-alumina oxide solid state electrolyte)
    - Vanadium redox flow batteries (VRB)

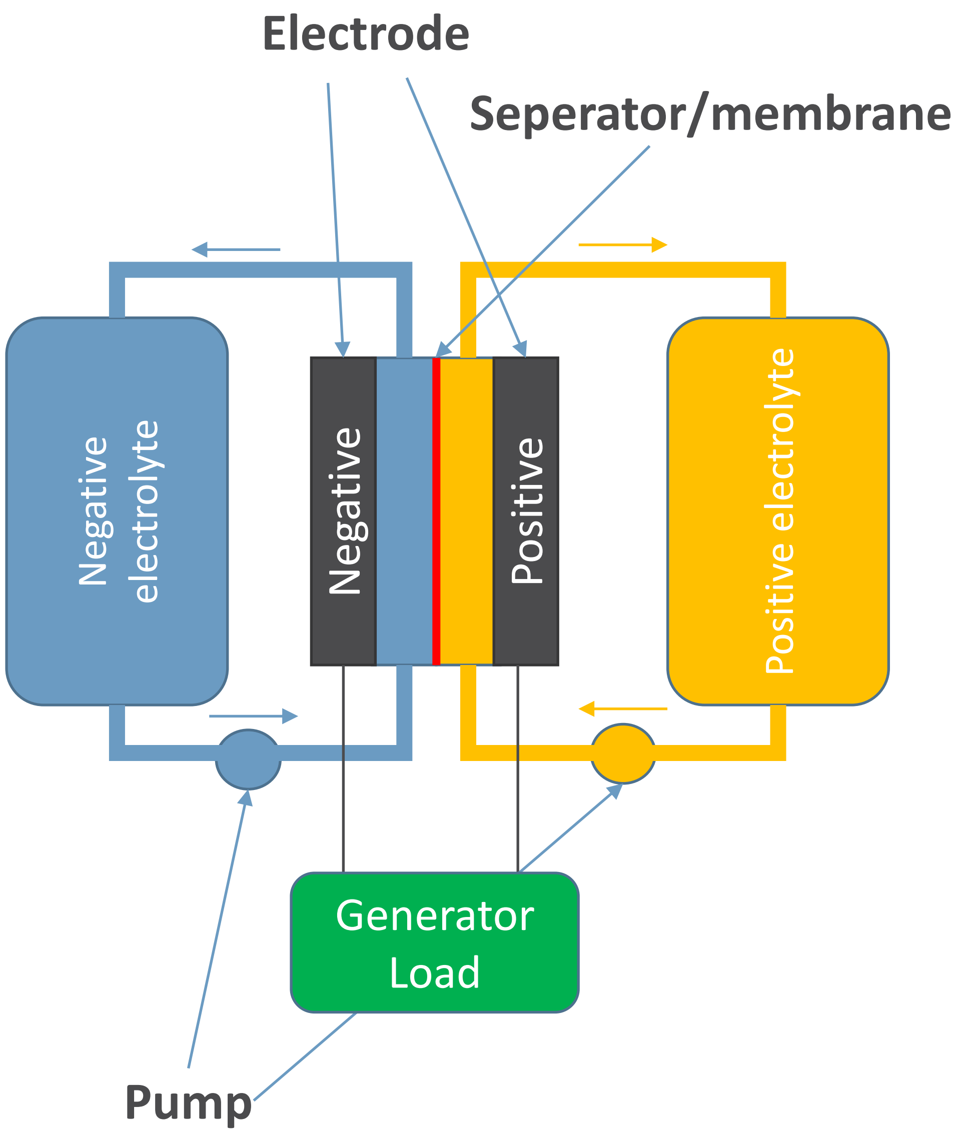


Figure. Schematic of flow battery.

Original M. Manahan, N. Jewell, D. Link, and B. Westlake, "Program on Technology Innovation: Assessment of Flow Battery Technologies for Stationary Applications," EPRI, 2016.

Comparison of chosen battery technologies

TECHNOLOGY	advantages	disadvantages
Li-ion	Relatively high energy density, no requirement for a scheduled cycle to maintain battery life, commercially available in many sizes	Tendency to overheat and even combust, can be damaged by high voltage, aging, Challenges related to availability and mining of lithium, cannot store energy for several months
Na-S	Unexpensive and abundant raw materials, suitable for energy intense applications, commercially available (limited availability)	High temperature (300-350C), limited amount of freeze –thaw cycle (~20), not suitable for idle storage
Vanadium redox flow batteries (VRB)	Flexible installation size, Storage capacity and power capacity can be varied independently, use of full battery capacity without degradation, possibly unlimited cycle lifetime (up to 20 years)	High initial investment (Relatively high and volatile price of vanadium), low grid-to-grid efficiency

PESTEL findings for batteries

Political	Economic	Technical	Social	Environmental	Legal
Circular battery economy, material recovery, e-mobility, some countries offer financial support for energy storage including batteries	Raw material costs often high, expected for prices of applications to come down, operation and maintenance cost vary	RES integration, peak shaving, emergency back-up, time shifting, black starting, good power quality, many types available commercially	Usually well accepted, concerns related to raw material mining etc.	Impact of materials used both in manufacturing and in recycling	EU level: Recycling rates for batteries and their materials, digital battery passport (usage history)

2- Accumulation in the form of thermal energy

Source: Storing heat and power - EPV

Thermal energy storage

Short overview

Thermal energy or electricity stored as thermal energy and used as thermal energy or to produce electricity. Waste heat utilization possible.

The chosen technologies:

- Sensible thermal water-based energy storage
- Sensible heat sand-based energy storage
- Sensible molten-salt storage
- Latent phase-change material (PCM)
- Thermo-chemical heat storage

Comparison of chosen thermal energy storage technologies

TECHNOLOGY	advantages	disadvantages
Water-based	High heat capacity, low cost, easily available, scalable	Temperatures higher than 100 C require pressurization to prevent boiling
Sand based	Low-cost material, easily available, high melting point (1700 C), high temperature range (600-1200 C), seasonal storage possible	only a few commercial applications, low heat capacity,
Molten-salt	Temperature range (e.g. 62-560 C),	To keep salt mixture molten “cold” side must have a high enough temperature, corrosion
Phase-change materials	Temperature range depends on used material,	Some materials have a high cost, cycle limitations possible
Thermo-chemical	Negligible heat loss, high energy density temperature range depends on chemicals used, compact	Few commercial applications, high costs, technically complex

PESTEL findings for thermal energy systems

Political	Economic	Technical	Social	Environmental	Legal
Waste heat, solar energy, and district heating related policies; Some countries offer subsidies for thermal heat storages	The initial investment and operational costs vary significantly between the different types of thermal energy storages, often having a use for energy in thermal form is beneficial	There are many commercially available technologies and some still on their way to be commercialized	Consumers expect any investment should reduce energy costs in the long run.	The impact on the environment depends heavily on the chosen technology and the scale of the implementatio n.	Thermal storage follow national legislation in terms of environmental impact, health and safety issues. New technologies bring new challenges.

3- Accumulation in the form of hydrogen

Picture: Liquid organic hydrogen carrier (LOHC)-installation, Provider: Hydrogenious
Danish Energy storage, Danish Energy Agency, 2018

Accumulation in the form of hydrogen

Short overview

Interest in hydrogen has been growing greatly. The main interest is on producing hydrogen by excess renewable electricity, or even renewable energy produced solely for the production of hydrogen, via electrolysis of water. Hydrogen can be stored as hydrogen or converted to another compound via power-to-x processes. The actual use of hydrogen in the energy system as an energy storage will be only a fraction of its uses.

Here the focus is on the use of hydrogen in the energy system as an energy storage.

The chosen technologies:

- Hydrogen in pressure containers
- Liquid organic hydrogen carrier (LOHC)

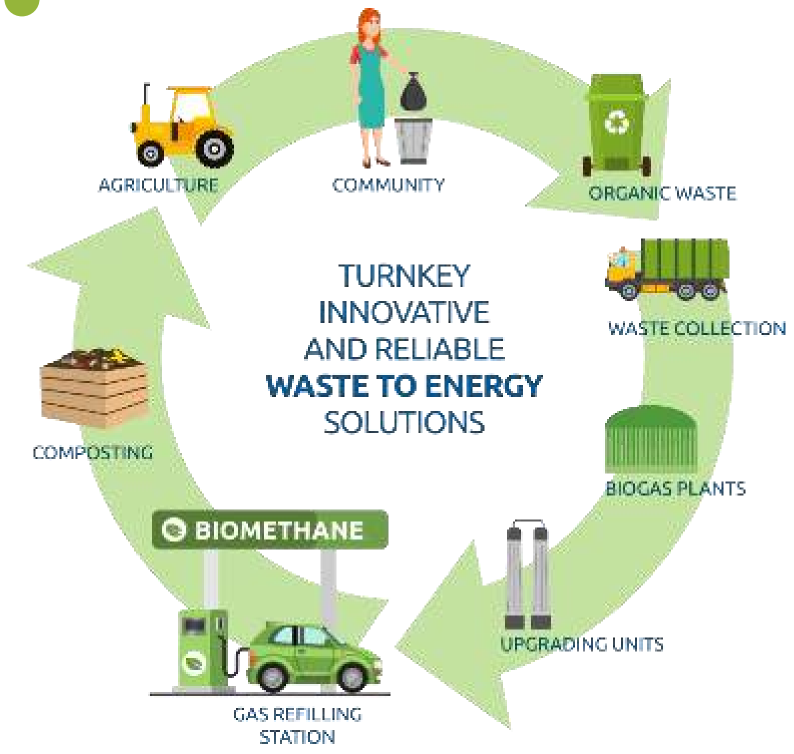
Comparison of chosen hydrogen technologies

TECHNOLOGY	advantages	disadvantages
Hydrogen in pressure containers	Commercially available, combined with a fuel cell makes for quick electricity production,	Small or medium scale storage, short to medium term storage, high pressure requirements to containers, hydrogen embrittlement of the container, hydrogen permeation (trought sealings), whole system efficiency 40-45 %
Liquid organic hydrogen carrier	Stored in liquid form in ambient temperature and atmospheric pressure, easy to transport, no storage losses, ideal for large scale hydrogen storage	Prototypes on market, hydrogen liberation is energy consuming, possibly toxic

PESTEL findings for Accumulation in the form of

Political	Economic	Technical	Social	Environmental	Legal
Hydrogen is expected to play a significant role in the green transition, national hydrogen strategies are under way in some countries. Some countries have subsidies for hydrogen related investments	Electricity price has significant impact, economical aspect under considerati on	Relatively new applications of technology. Electricity production, quick response to seasonal storage, peak shaving, RES integration, black start,	LOHC can use the same infrastructure as petrol and diesel. Wind farm related opposition might affect hydrogen.	Large leakages could speed up the destruction of the ozone layer, LOHC related flammability, toxicity etc. Low toxicity LOHC are researched.	For now, hydrogen follows similar safety and health legislation as natural gas.

4- Accumulation in the form of biomethane



https://www.iesbiogas.it/en/what-is-biomethane/

Accumulation in the form of biomethane

How is biomethane produced? How is the biomethane stored?

For production two possible routes are included:

- Biomethane production via digestion from biomass and upgraded from biogas (main focus)
- Methanation of the hydrogen ($CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$)

The possible storage technologies:

- High- or low-pressure storage tanks
- Cryogenic storage tank (liquified gas)
- Absorbed gas storage (porous material)

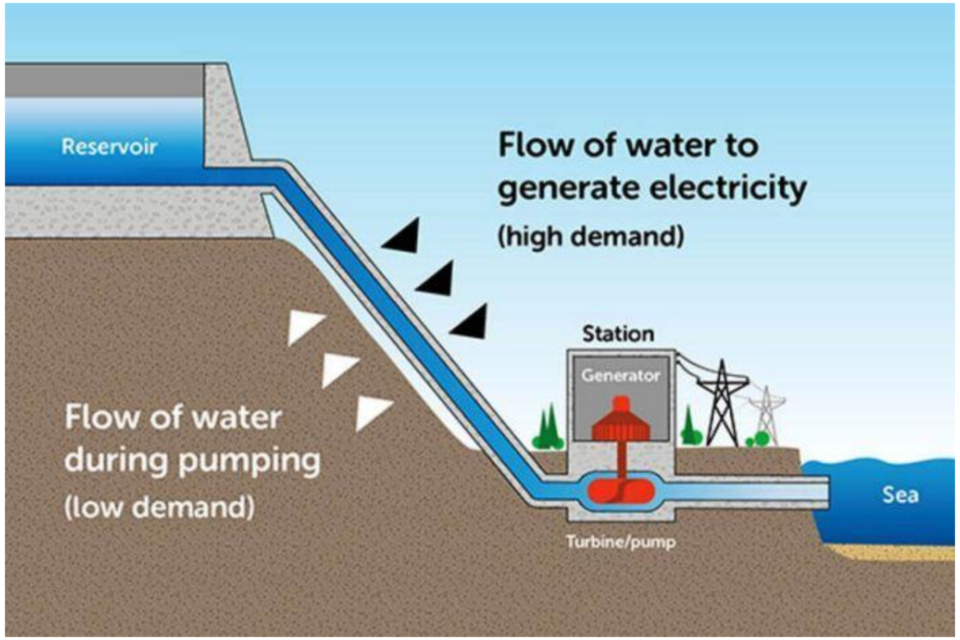
Comparison of possible biomethane related technologies

TECHNOLOGY	Advantages	disadvantages
Upgrading from biogas	Biogas production is well established,	The uptake of biogas has been relatively slow, upgrading biogas requires investments
Methanation of hydrogen	One form of utilizing hydrogen	Hydrogen production is an upcoming technology
Low pressure	Lowest costs, on-site application	Short term storage,
High pressure	Longer storage periods, smaller space requirements, transportation possible	Higher costs and more safety regulations, requirements on gas purity
Cryogenic (Low temperature)	Smaller space requirements, transportation possibility,	Transportation requires large enough volumes,
Absorbed	Smaller space requirement, can be stored at ambient temperature and atmospheric pressure	Materials being researched

PESTEL findings for Accumulation in the form

Political	Economic	Technical	Social	Environmental	Legal
Biogas has a differing position between countries	Local job creation in the biomethane production chain, initial investment is often relatively high	Biogas production well established technology, biomass collection, Power-to-power efficiency with Hydrogen methanation approx. 21 %	Local community engagement possibilities	Possible methane leakages and the effect on climate change, Waste management,	Biogas is often governed by national regulation for natural gas in relation to safety.

5-Accumulation in the form of potential energy



How pumped hydro works [CREDIT: EnergyAustralia]

https://www.greencarreports.com/news/1122395_pumped-hydro-could-deliver-100-percent-renewable-electricity

Accumulation in the form of potential energy

Short overview

Pumped hydro:

- Hydroelectric energy storage for load balancing (used by electric power system).

- The method stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation.

- Low-cost surplus off-peak electric power is typically used to run the pumps. During periods of high electrical demand, the stored water is released through turbines to produce electric power.

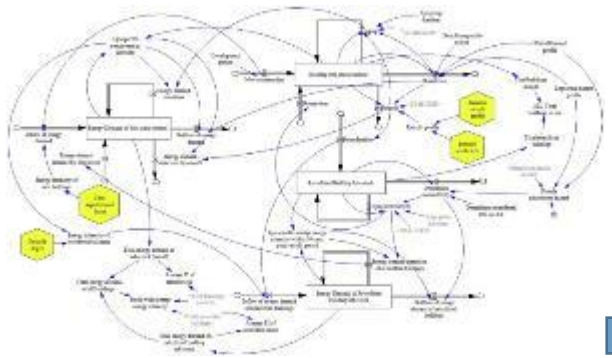
Comparison of chosen potential energy storage technologies

TECHNOLOGY	advantages	disadvantages
Pumped hydro	Pumped hydro energy storage can provide municipalities with opportunities for energy cost management. By storing electricity during off-peak hours when electricity prices are low and releasing it during peak hours when prices are high, municipalities can optimize their energy consumption and reduce their electricity costs.	Pumped hydro is not included in the calculation of RES produced (RES directive), Integration of intermittent renewable energy sources with pumped hydropower storage* (HYDROPOWER AND PUMPED HYDROPOWER STORAGE IN THE EUROPEAN UNION-2022)

What’s next?

Integrating PESTLE analysis results into Energy Equilibrium platform building

Data and findings from PESTLE will be used as input parameters for development of simulation tool – Energy Equilibrium Platform



System Dynamics modeling approach will be used to develop model structure based on PESTLE findings

Creating an interactive online tool that will be tested in municipalities

Image source: https://enterslice.com/learning/pestle-analysis-a-mechanism-for-analysis-of-businesses/

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Thank you !

We encourage participants to learn more about the techniques presented in the Poster session:

At 12:00 Interactive workshop: Walking lunch and poster walk.

Topics of PESTLE analysis on walls with "moderators" –

Welcome!