PATHFNDR project

The impact and challenges of long-term thermal storage in the Swiss context

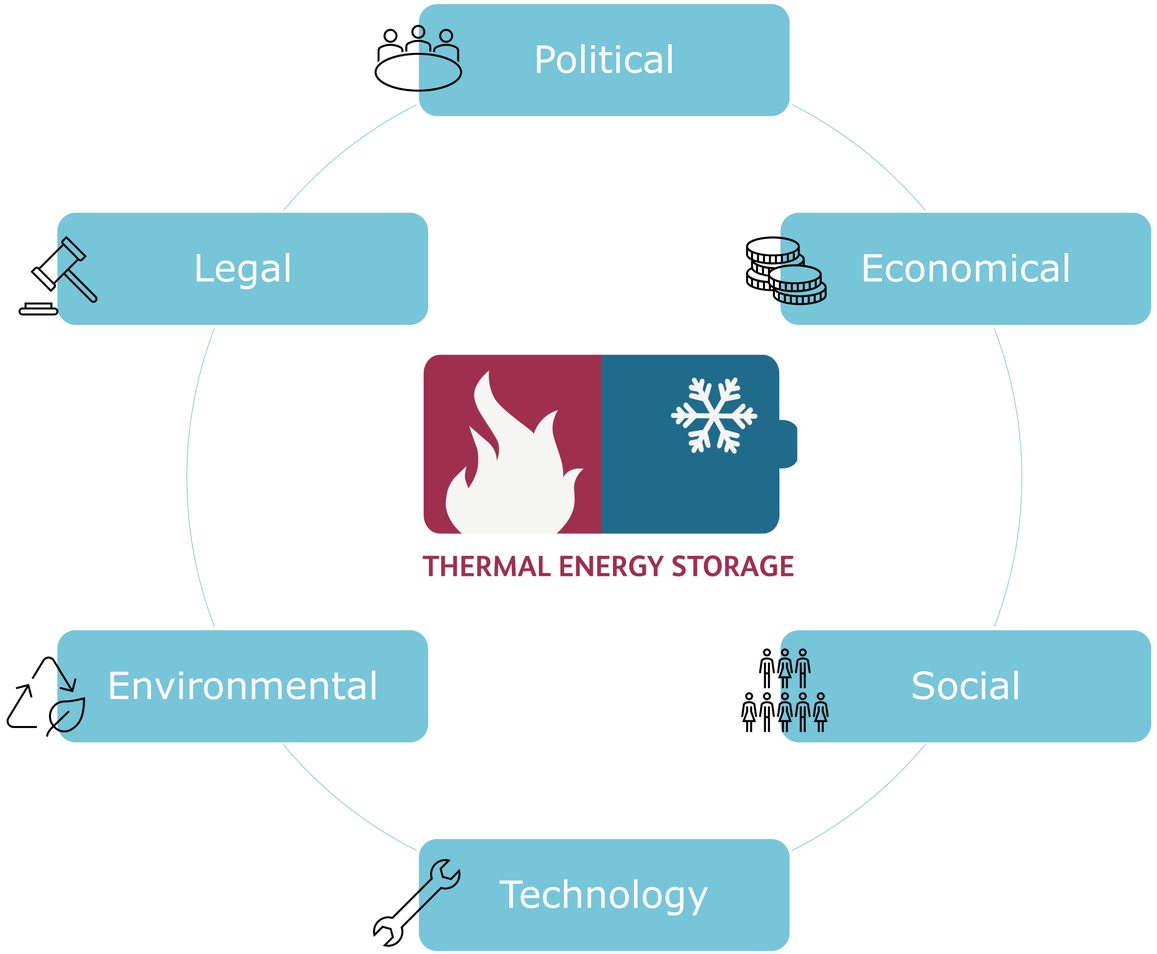
Prof. Dr. Jörg Worlitschek
HSLU Seasonal Thermal Energy Storage (STES) (CC-TES)

sweet swiss energy research for the energy transition

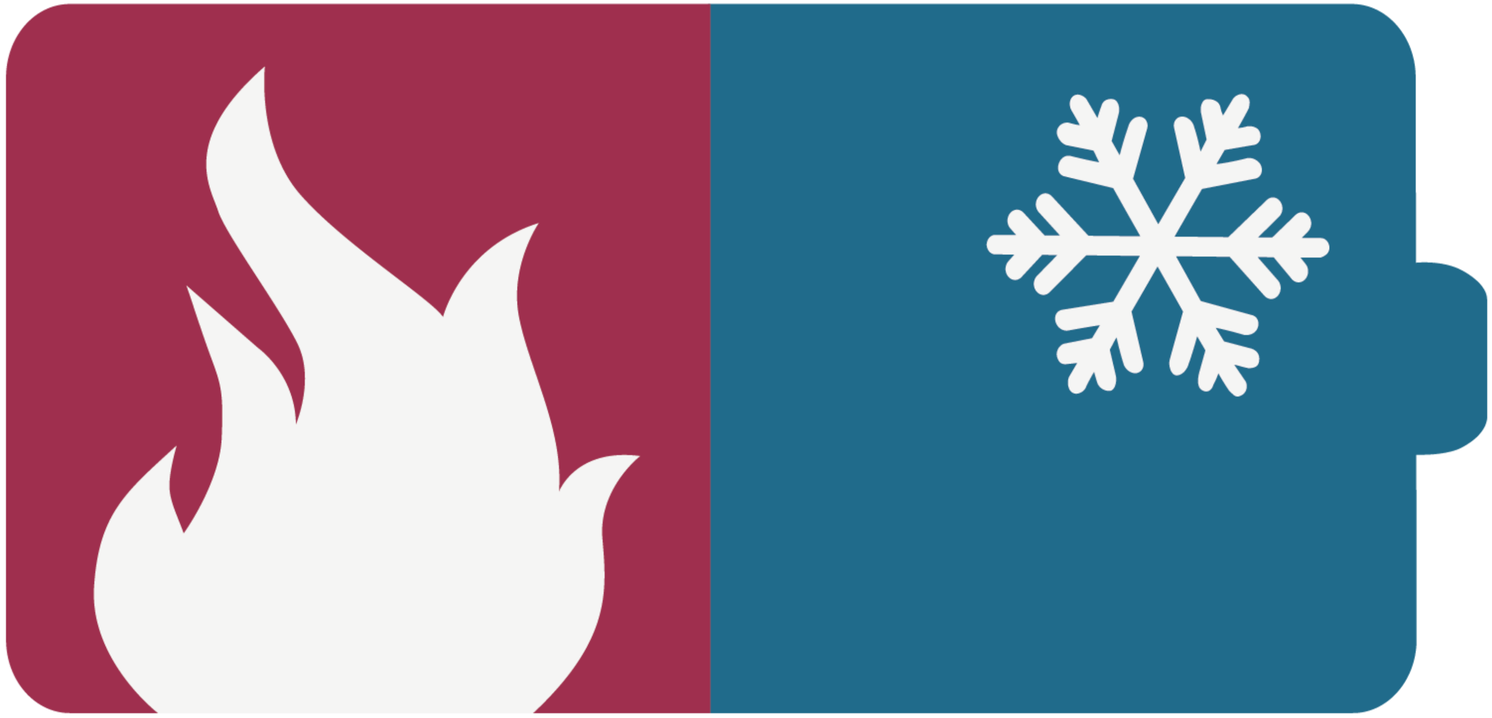
PATHFNDR

HSLU ETH zürich Empa PAUL SCHERRER INSTITUT PSI zhaw HOCHSCHULE LUZERN UNIVERSITÉ DE GENÈVE EPFL TU Delft

Research Questions regarding Seasonal Thermal Energy Storage (STES)

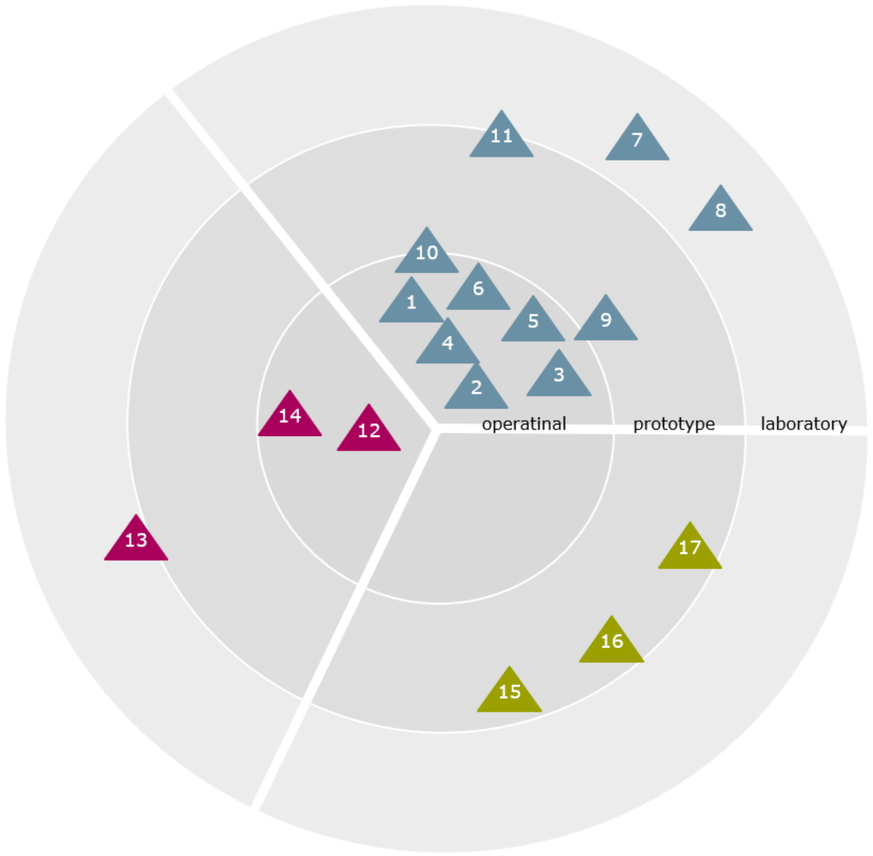


Research Questions regarding Seasonal Thermal Energy Storage (STES)



THERMAL ENERGY STORAGE

Seasonal Thermal Energy Storage (STES) - Technology Radar



Sensible thermal energy storage

1 Tank thermal energy store (TTES)
2 Borehole thermal energy storage (BTES)
3 Near-surface BTES
4 Building foundation storage
5 Pit thermal energy storage (PTES)
6 Aquifer storage
7 Lake as heat storage
8 Closed storage in the lake
9 Deep geothermal storage BTES
10 Vacuum-insulated tank
11 Hot water storage in converted rooms

Latent thermal energy storage

12 Ice thermal energy storage
13 Seasonal latent thermal energy storage
14 Latent thermal energy storage (not seasonal)

Thermochemical energy storage

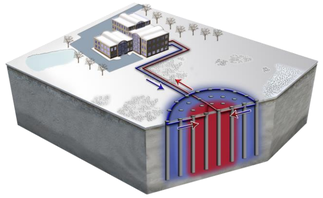
15 Adsorption storage
16 Absorption storage
17 Reaction storage

Seasonal Thermal Energy Storage (STES) - Technology Radar

Germany's first pit storage - Meldorf

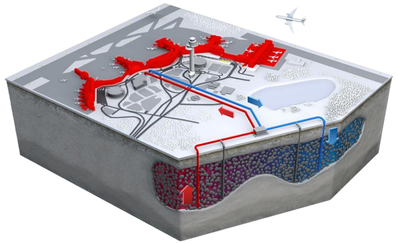
Source: https://www.ramboll.com/de-de/projekte/energie/erdbecken-warmespeicher-in-deutschland

Borehole Thermal Energy Storage



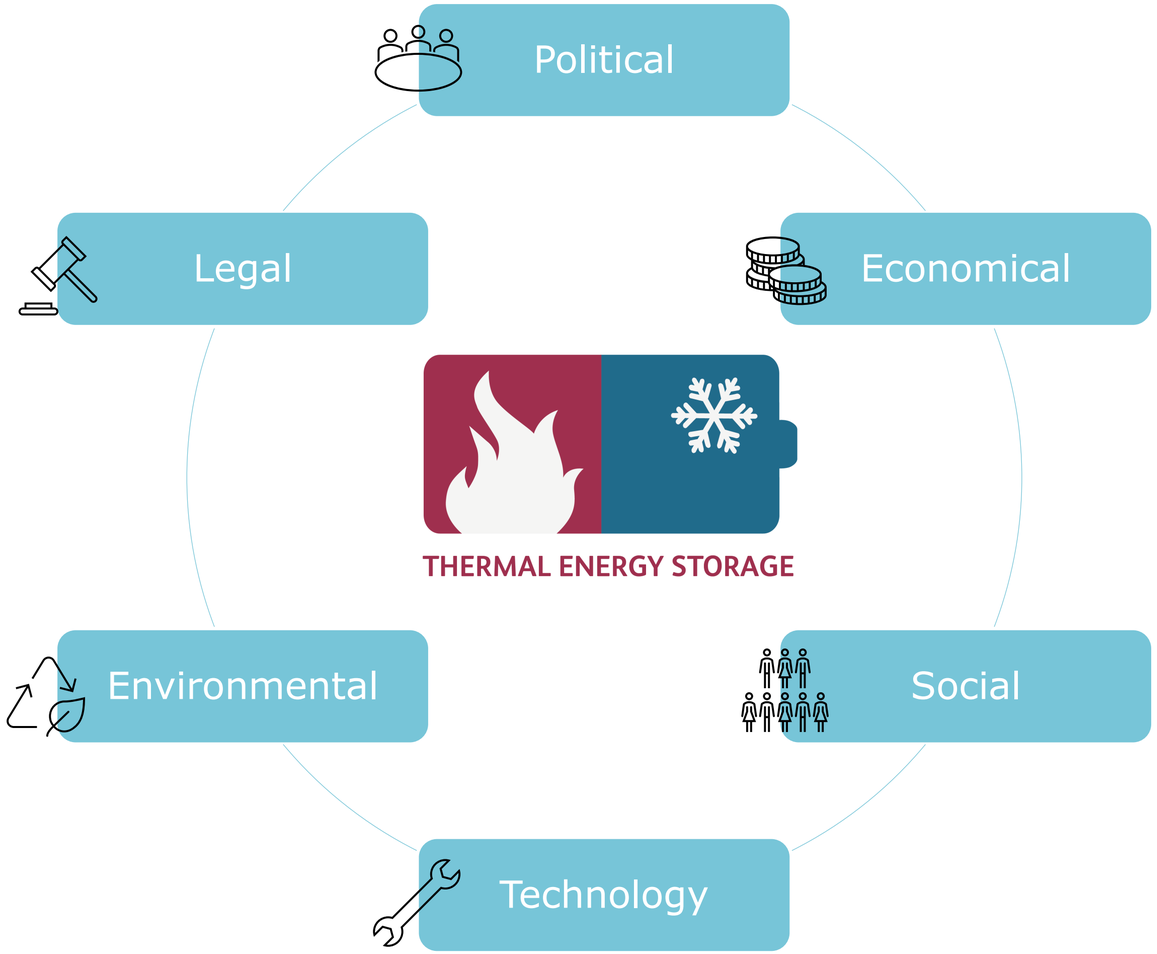
Source: https://www.pv-magazine.com/2020/05/22/borehole-thermal-energy-storage-for-solar/

Aquifer Thermal Energy Storage

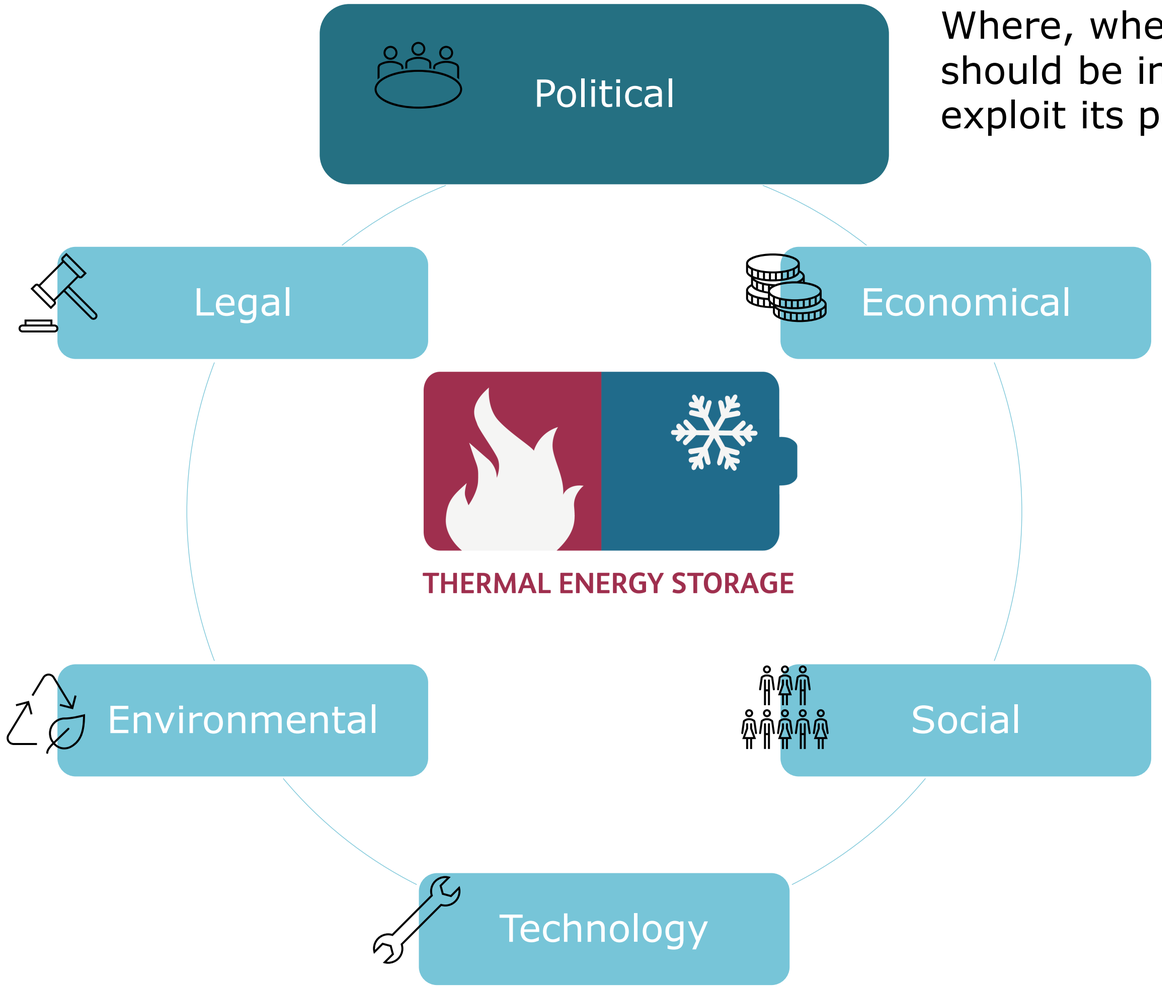


Source: https://underground-energy.com/our-technology/ates/

Research Questions regarding Seasonal Thermal Energy Storage (STES)



Research Questions regarding Seasonal Thermal Energy Storage (STES)



Where, when, and which large STES facilities should be installed in Switzerland to ideally exploit its potential?

Political aspects and impact of Seasonal Thermal Energy Storage (STES)

- “Positionspapier des Forums Energiespeicher Schweiz”
  - Autors:
    - Dr. Gianfranco Guidati, Energy Science Center (ETHZ)
    - Dr. Luca Baldini, Building Energy System and Technologies (ZHAW)
    - Prof. Dr. Jörg Worlitschek, Competence Center Thermal Energy Storage (HSLU)
    - Dr. Michel Haller, Institute for Solar Technik (OST)

FORUM ENERGIESPEICHER SCHWEIZ

aeesuisse
Dachorganisation der Wirtschaft für erneuerbare Energien und Energieeffizienz

Positionspapier des Forums Energiespeicher Schweiz

Bern, im Mai 2022

Winterstrombedarf und saisonale Wärmespeicher – mit Sommerwärme Strom im Winter sparen

Saisonale Wärmespeicher sind ein Schlüsselelement für eine resiliente und kosteneffiziente Energieversorgung der Schweiz im Winter, wenn in Zukunft keine fossilen Energieträger zum Heizen eingesetzt werden. Die Speicherung von im Sommer anfallender Wärme über mehrere Monate hat jedoch noch weitere Vorteile: Saisonale Wärmespeicher reduzieren den Strombedarf im Winter deutlich und damit das Risiko einer drohenden Strommangellage.

Die zwingend notwendige Dekarbonisierung unserer Energieversorgung lässt sich im Gebäudebereich insbesondere durch den Einsatz von Wärmepumpen für die Bereitstellung von Raumwärme und Warmwasser realisieren. Raumwärme wird vor allem im Winter benötigt, was zu einem erhöhten Bedarf an Winterstrom führt. Ein zweiter Pfeiler der Dekarbonisierung ist der Ausbau der erneuerbaren Stromversorgung, welcher vorwiegend über Photovoltaik erreicht

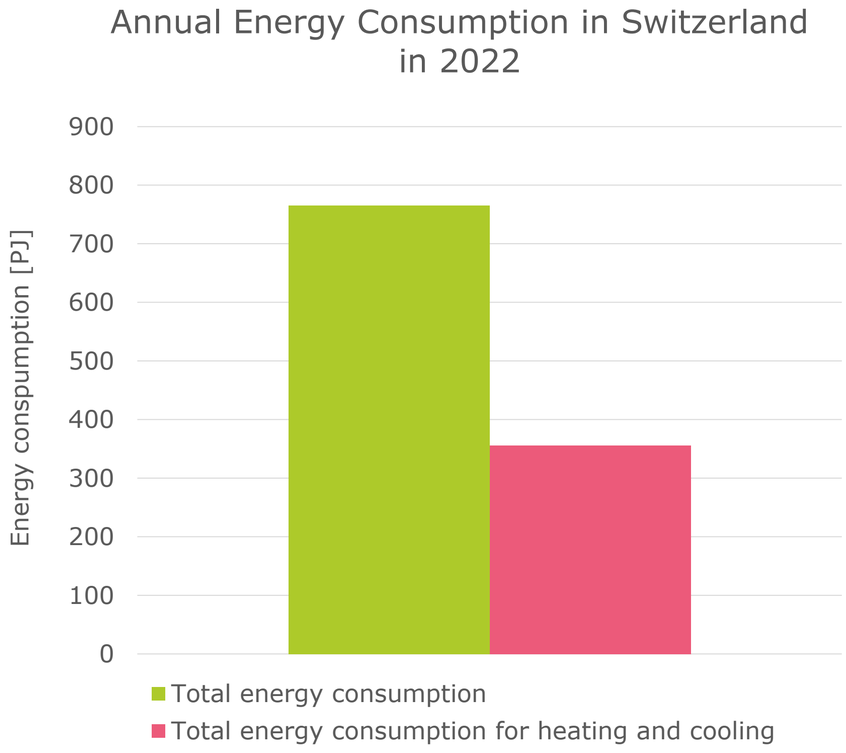
Coordinated **spatial and energy planning** to optimally take into account infrastructure for seasonal heat storage

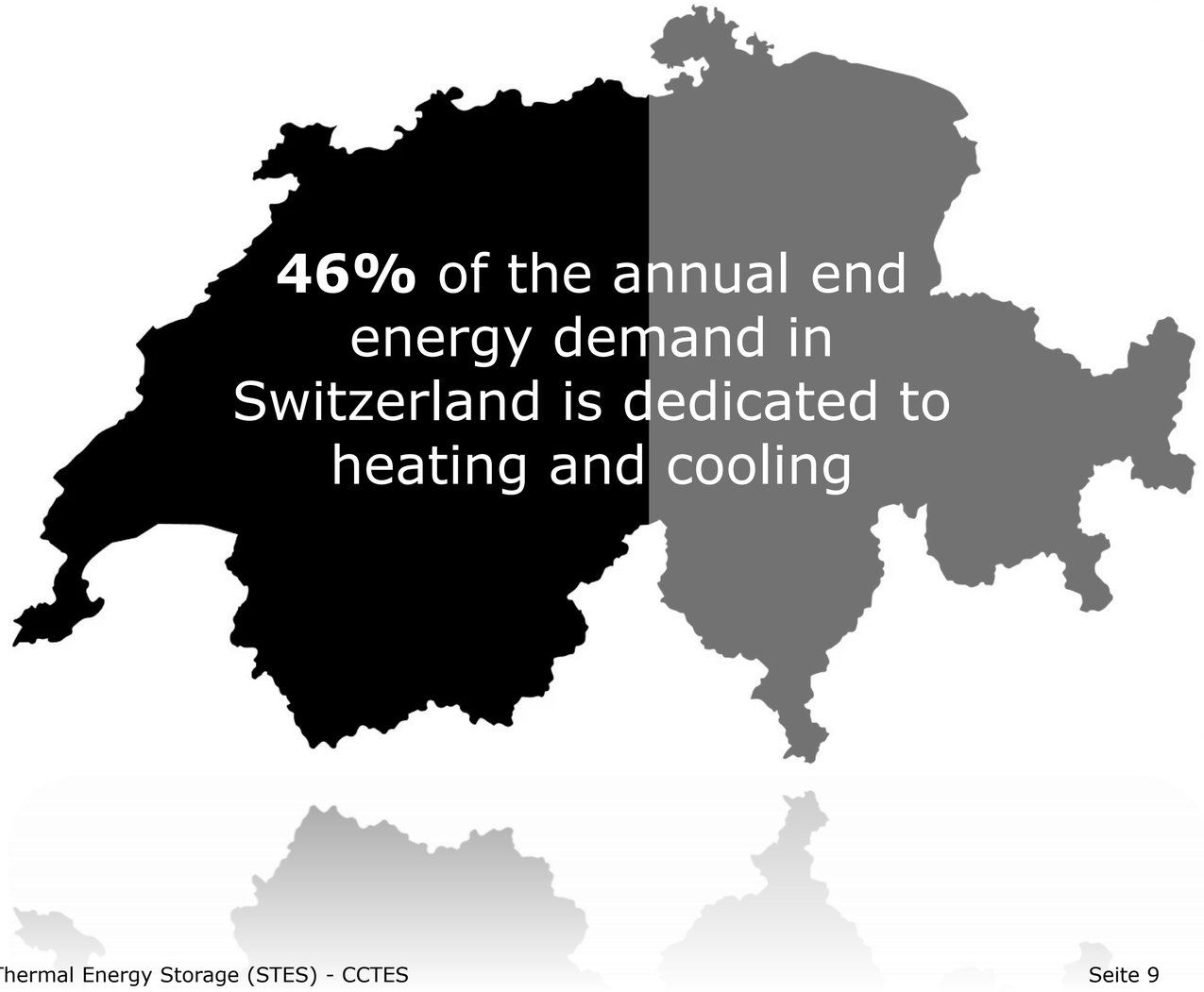
Realization and promotion of **specific seasonal heat storage projects** in Switzerland

Knowledge and understanding of the Swiss subsoil must be improved. Adaptation of the legal regulations on **groundwater warming**

Positionspapier des Forums Energiespeicher Schweiz: https://www.hslu.ch/de-ch/technik-architektur/ueber-uns/organisation/kompetenzzentren-und-forschungsgruppen/technik/thermische-energiespeicher/positionspapier/

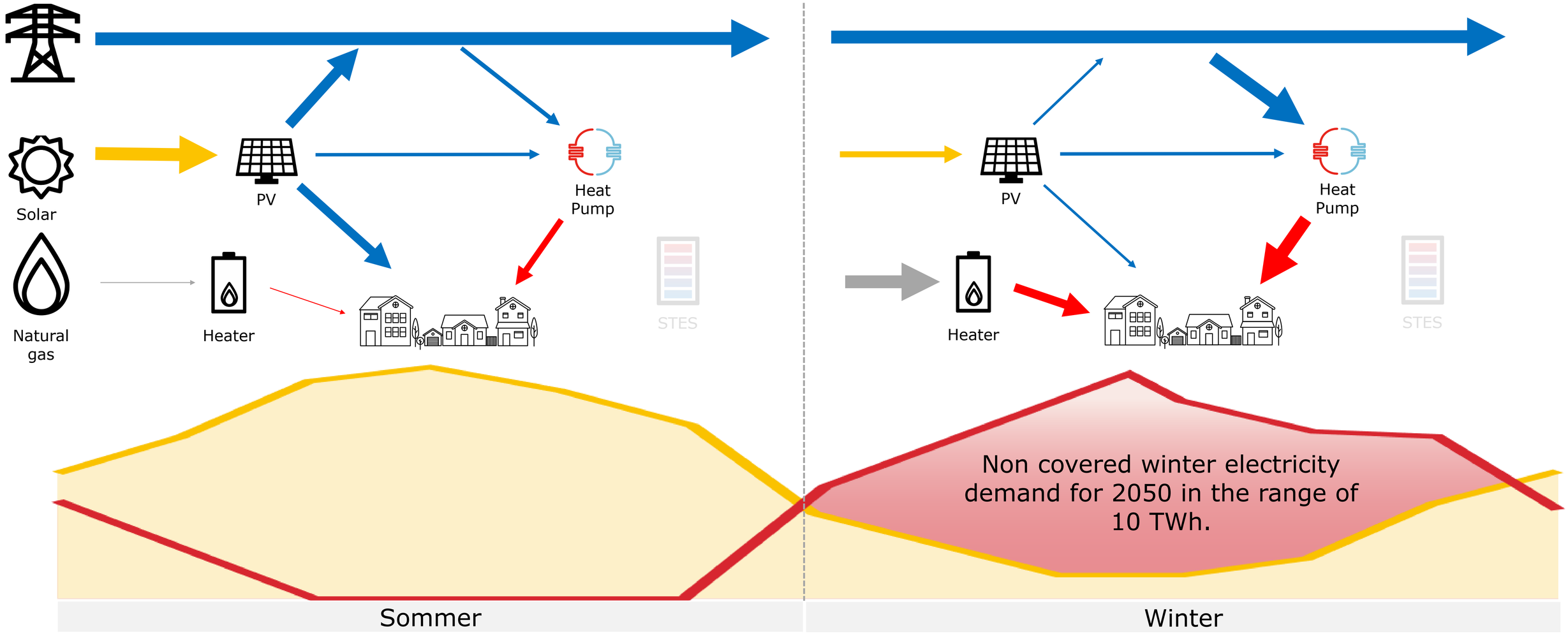
Political aspects and impact of Seasonal Thermal Energy Storage (STES)





Source: BFE - Analyse der schweze4rischen Energieverbrauchs 2000-2022 nach Verwendungszwecken (https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/energieverbrauch-nach-verwendungszweck.html/)

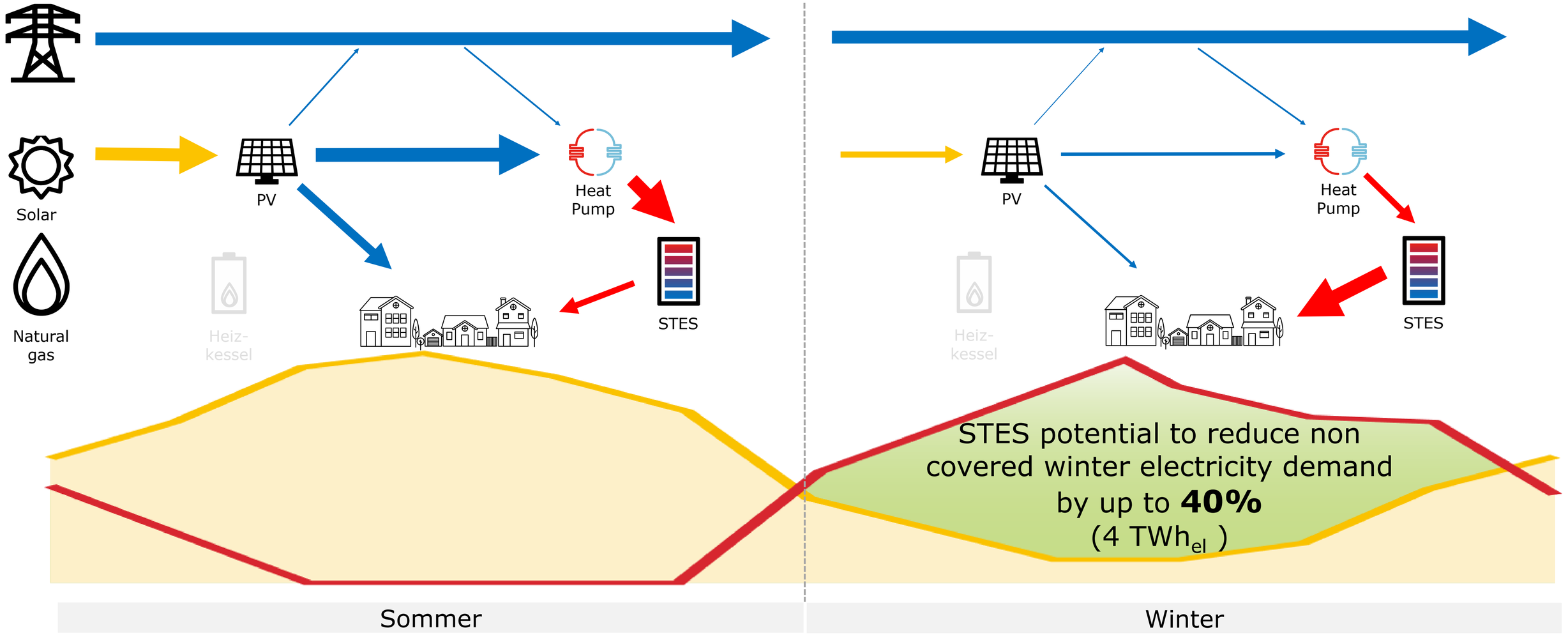
Political aspects and impact of for Seasonal Thermal Energy Storage (STES)



PATHFNDR

Positionspapier des Forums Energiespeicher Schweiz: https://www.hslu.ch/de-ch/technik-architektur/ueber-uns/organisation/kompetenzzentren-und-forschungsgruppen/technik/thermische-energiespeicher/positionspapier/

Political aspects and impact of Seasonal Thermal Energy Storage (STES)



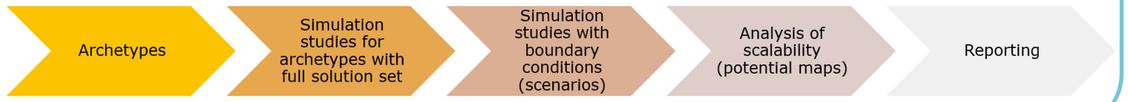
Positionspapier des Forums Energiespeicher Schweiz: https://www.hslu.ch/de-ch/technik-architektur/ueber-uns/organisation/kompetenzzentren-und-forschungsgruppen/technik/thermische-energiespeicher/positionspapier/

Political aspects and impact – next steps

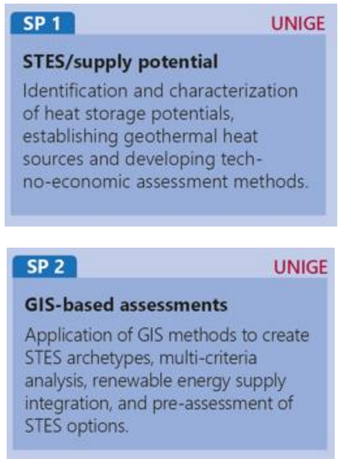
Running Projects for in depth analysis of the research question *"Where, when, and which large STES facilities should be installed in Switzerland to ideally exploit its potential?"*

WinTes "Positionspapier 2.0"

- In-depth analysis of the potential of STES to positively influence the resilience of the Swiss energy system



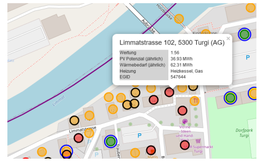
Flagship SwissTES



sweet swiss energy research for the energy transition – DeCarbCH

- Identification of thermal network archetypes, considering demand and supply/infrastructure characteristics
- Definition of reference cases
- Assessment of renewables and storages in thermal networks

sweet swiss energy research for the energy transition – EDGE

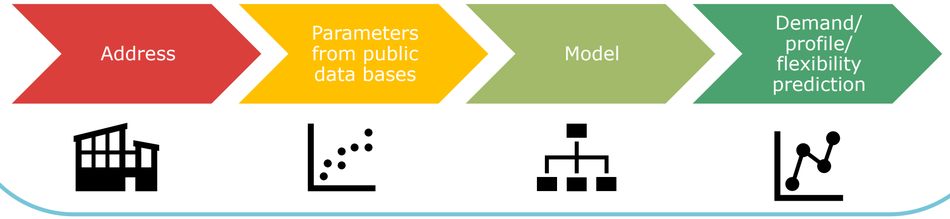


- Create recommender tool for local energy planning of municipalities and communication for energy providers
- Build district energy model for optimization of energy flows, storage, cost and emissions

sweet swiss energy research for the energy transition – PATHFNDR

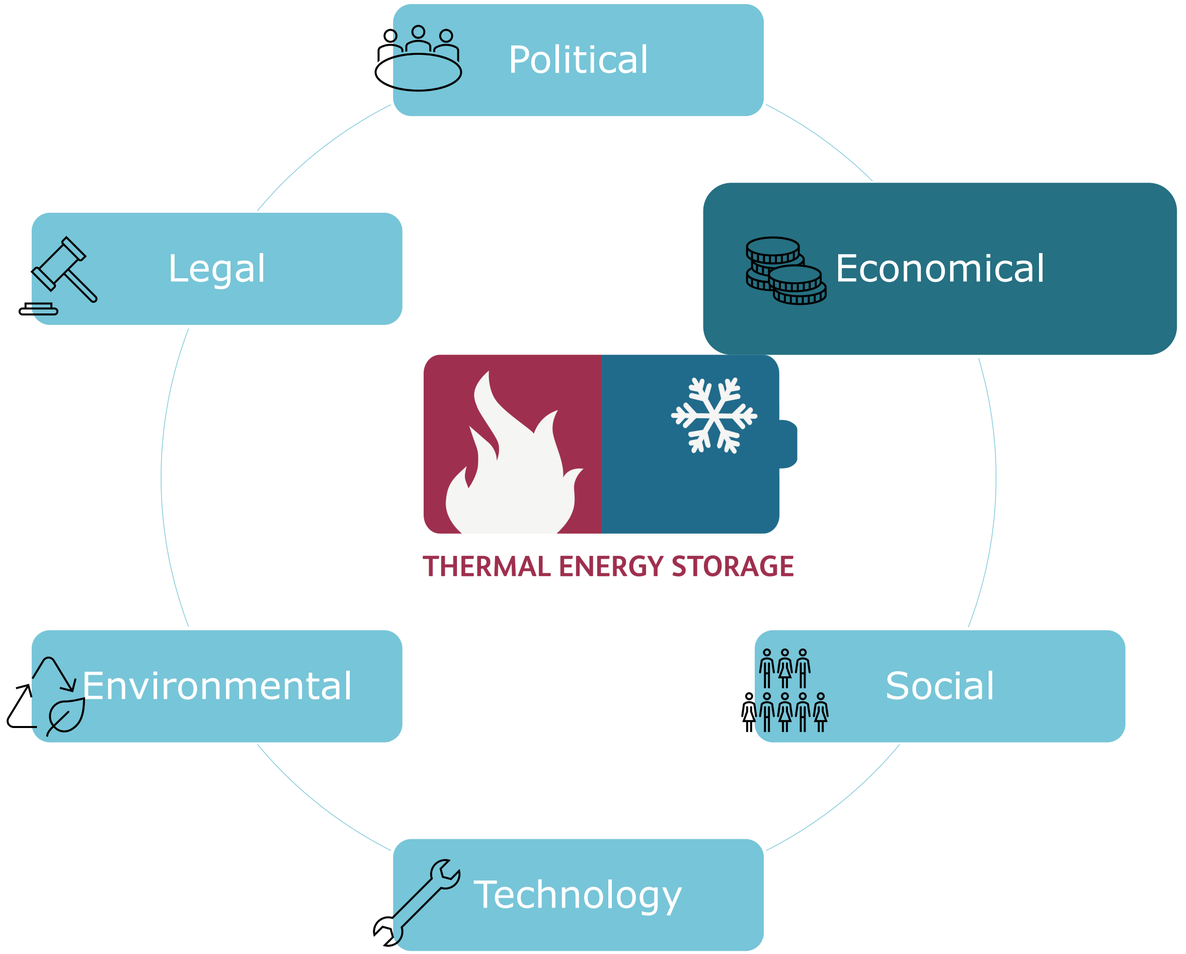
Flexibility potential estimation for the Swiss building park

- Estimating heat/electric load (profiles) of (residential) buildings based on public data
- Assessing flexibility in electrical consumption of (residential) buildings due to thermal inertia



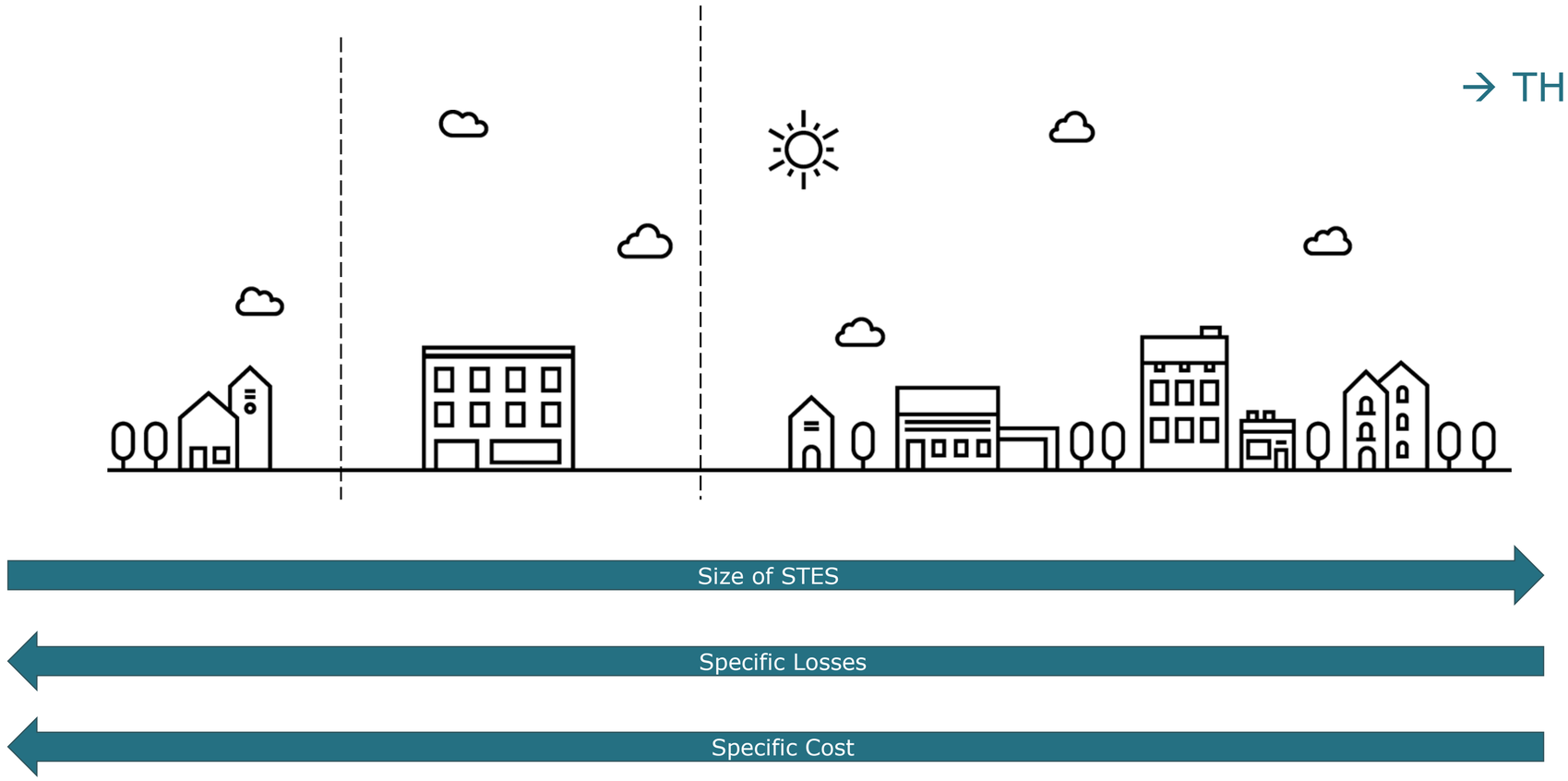
PATHFNDR

Research Questions regarding Seasonal Thermal Energy Storage (STES)



How to reduce cost of STES technologies?

Economical Factors for Seasonal Thermal Energy Storage (STES)

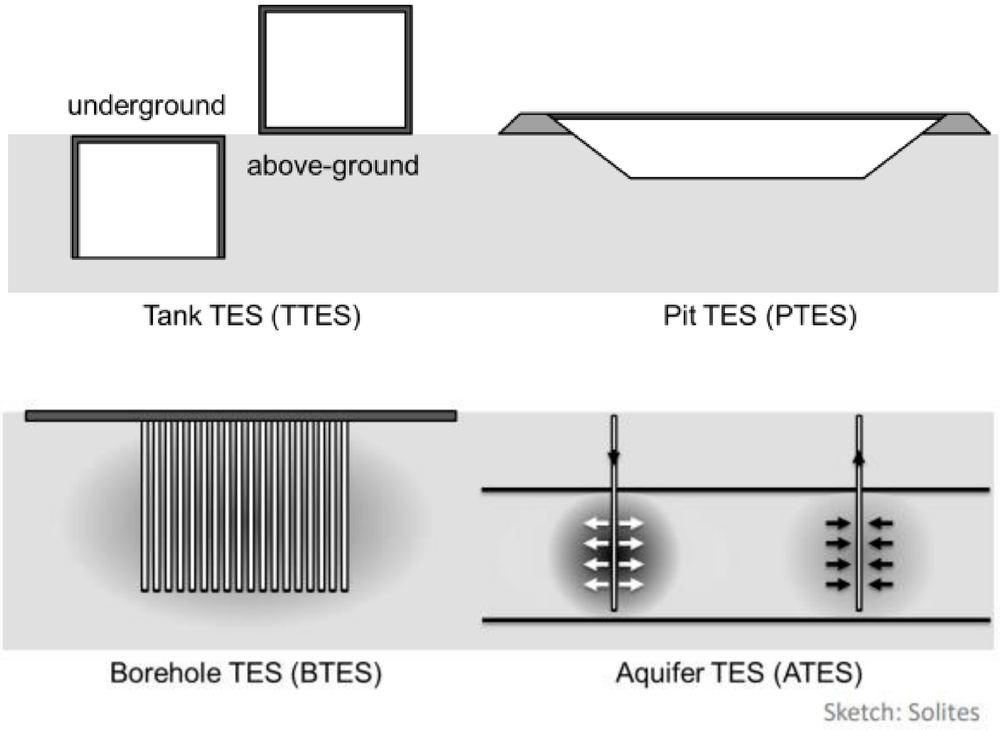


→ THE BIGGER THE BETTER

Economical Factors for Seasonal Thermal Energy Storage (STES)

Available Technologies for **large sensible** STES

TTES are large tanks (usually cylindrical) filled with water and thermally insulated at the top and to the sides. Most examples are implemented above ground, but they can also be underground. The storage medium is water



PTES are pits dug in the ground, filled with water and thermally insulated at the top and sometimes on the sides as well. The storage medium is usually water, but can also be in some cases a mix of sand, gravel and water

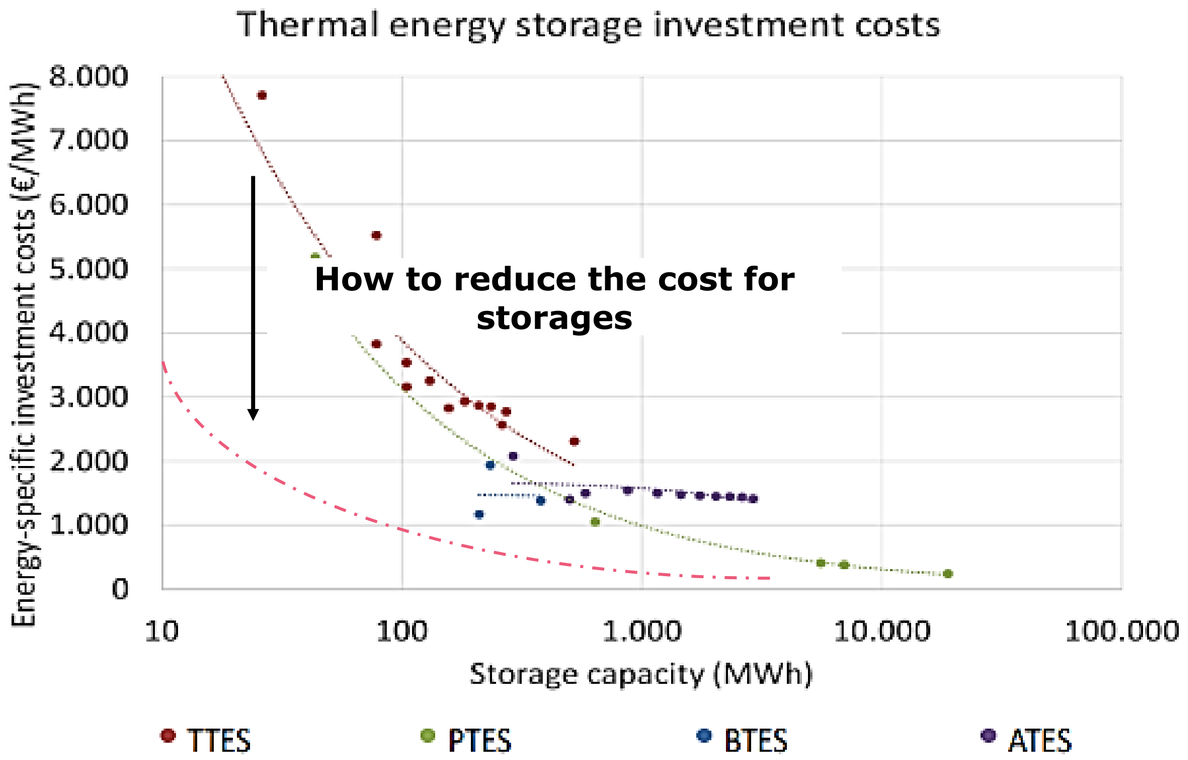
BTES are a series of boreholes dug in the ground, where a series of heat exchangers are inserted to circulate a heat transfer fluid (usually water). The storage medium is the ground itself

ATES are aquifers directly used to store heat: wells are drilled into an aquifer layer, one for the cold side and one for the warm side. The storage medium is water and ground in the aquifer

Quelle: IEA-ES Task 39 brochure Large Seasonal Thermal Energy Storage (STES)s for District Heating – Introduction

Economical Factors for Seasonal Thermal Energy Storage (STES)

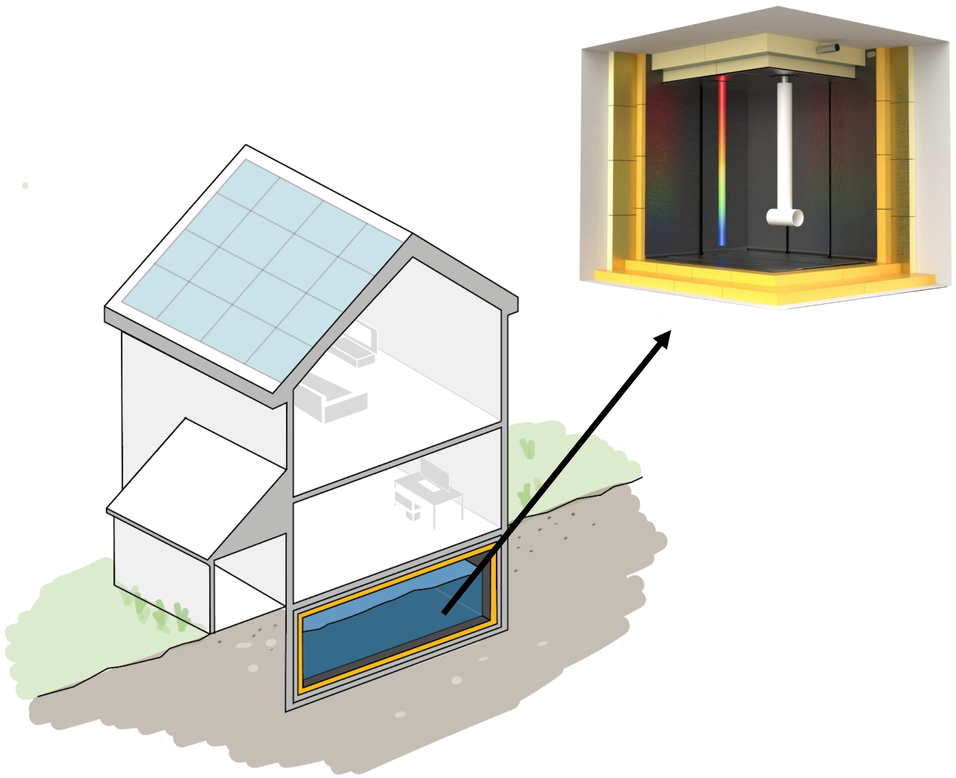
Investment cost for **large sensible** STES

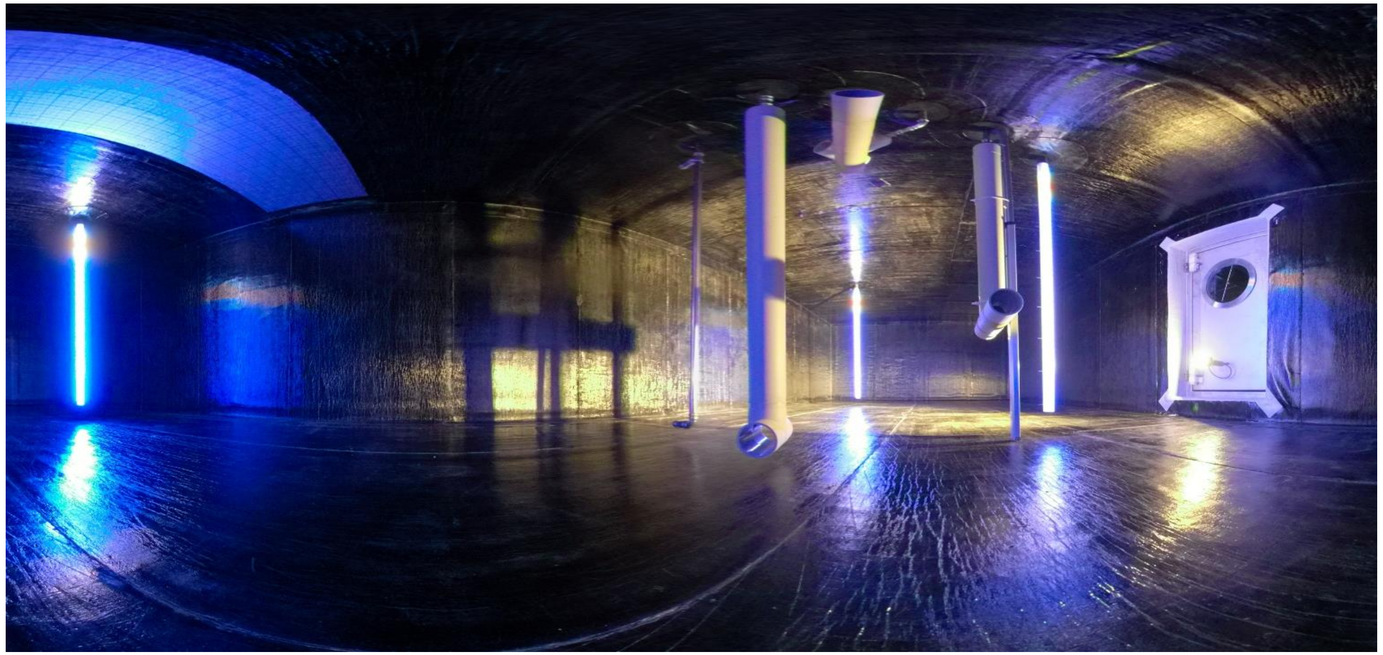


Planenergi https://www.coolheating.eu/images/downloads/5-The-Integration-of-Large-Scale-Solar-Thermal-and-Heat-Pumps-in-District-Heating-Systems.pdf

Economical Factors for Seasonal Thermal Energy Storage (STES)

Reducing the cost for small Seasonal Thermal Energy Storage (STES)s – Geas Project HSLU & Swisspor



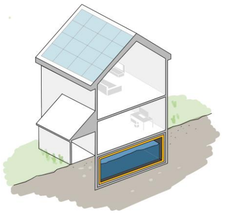


Economical Factors – next steps

Running Projects for in depth analysis of the research question
"How to reduce cost of STES technologies?"

GEAS

- Material sciences
- Water vapour diffusion-tight insulation system



Cost Data Base

- Find accurate cost functions for different technologies to be integrated with the models to run a cost optimization

sweet swiss energy research for the energy transition

Flagship SwissTES

- Bringing the GEAS project further
- Reducing Cost by reusing existing Cavities

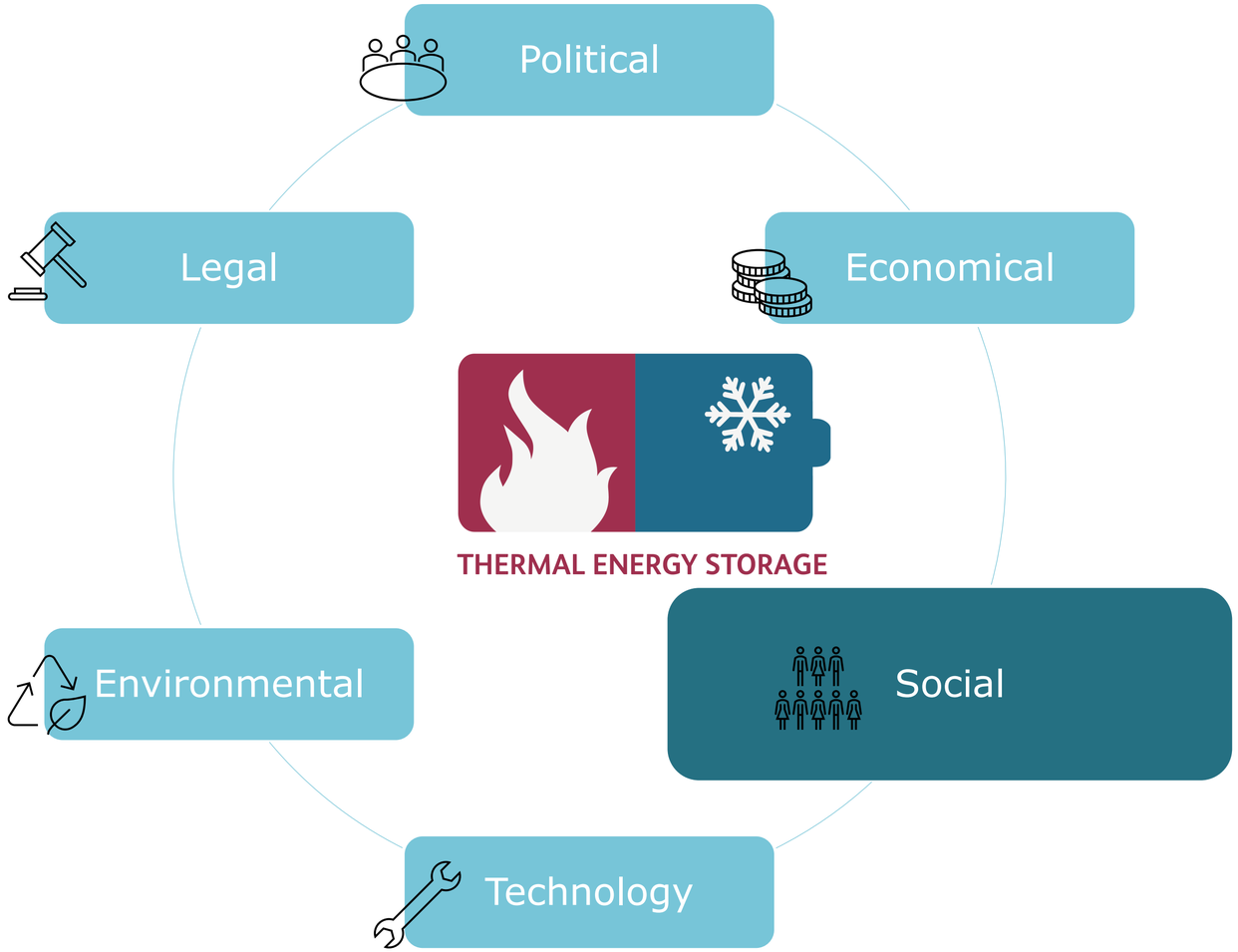
- Multipurpose use to reduce cost
- Reduce cost by increasing surface to volume ratio

BigStoreSwarm

OST Ostschweizer Fachhochschule

- Development and assessment of the potential of swarm intelligence systems
- Investigate the impact of peak load reduction on the CO2 balance of buildings, with a focus on the dynamic aspect of the CO2 electricity balance.

Research Questions regarding Seasonal Thermal Energy Storage (STES)

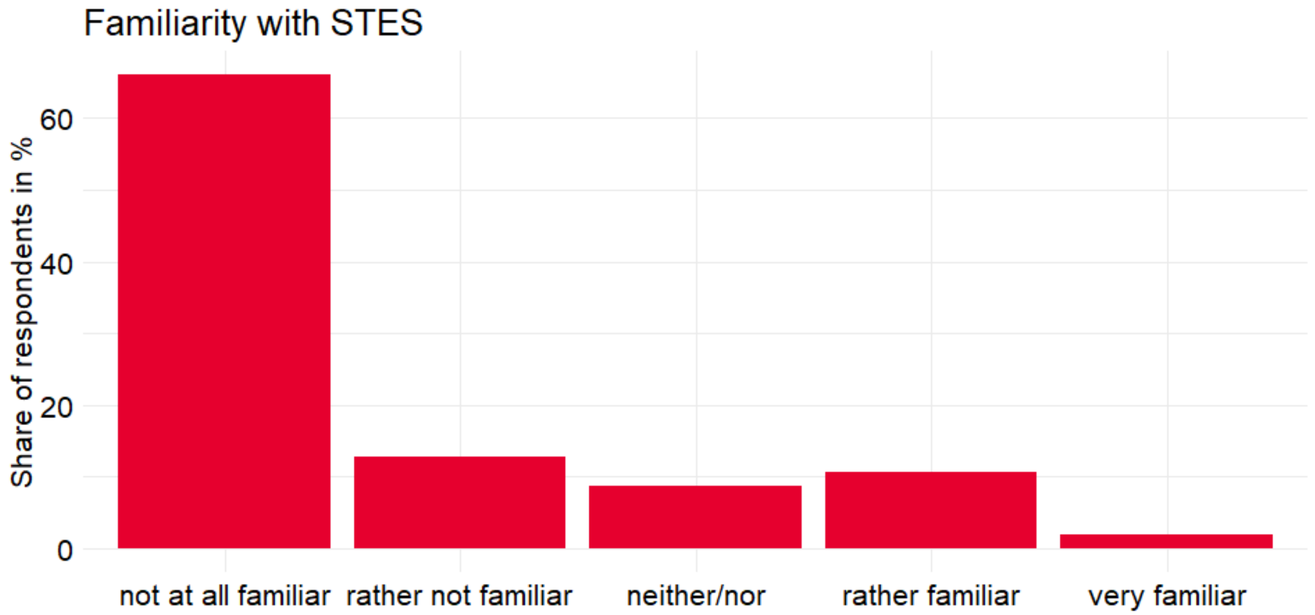


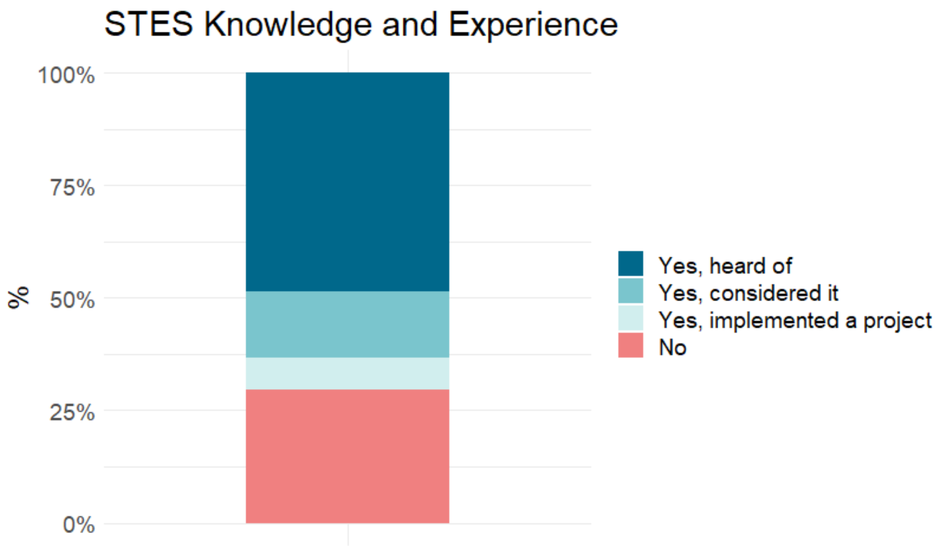
How to increase the social acceptance of Seasonal Thermal Energy Storage (STES) technologies?

Social acceptance of Seasonal Thermal Energy Storage (STES)

SOTES

Only few people and a minority of stakeholders know STES





Social acceptance of Seasonal Thermal Energy Storage (STES)

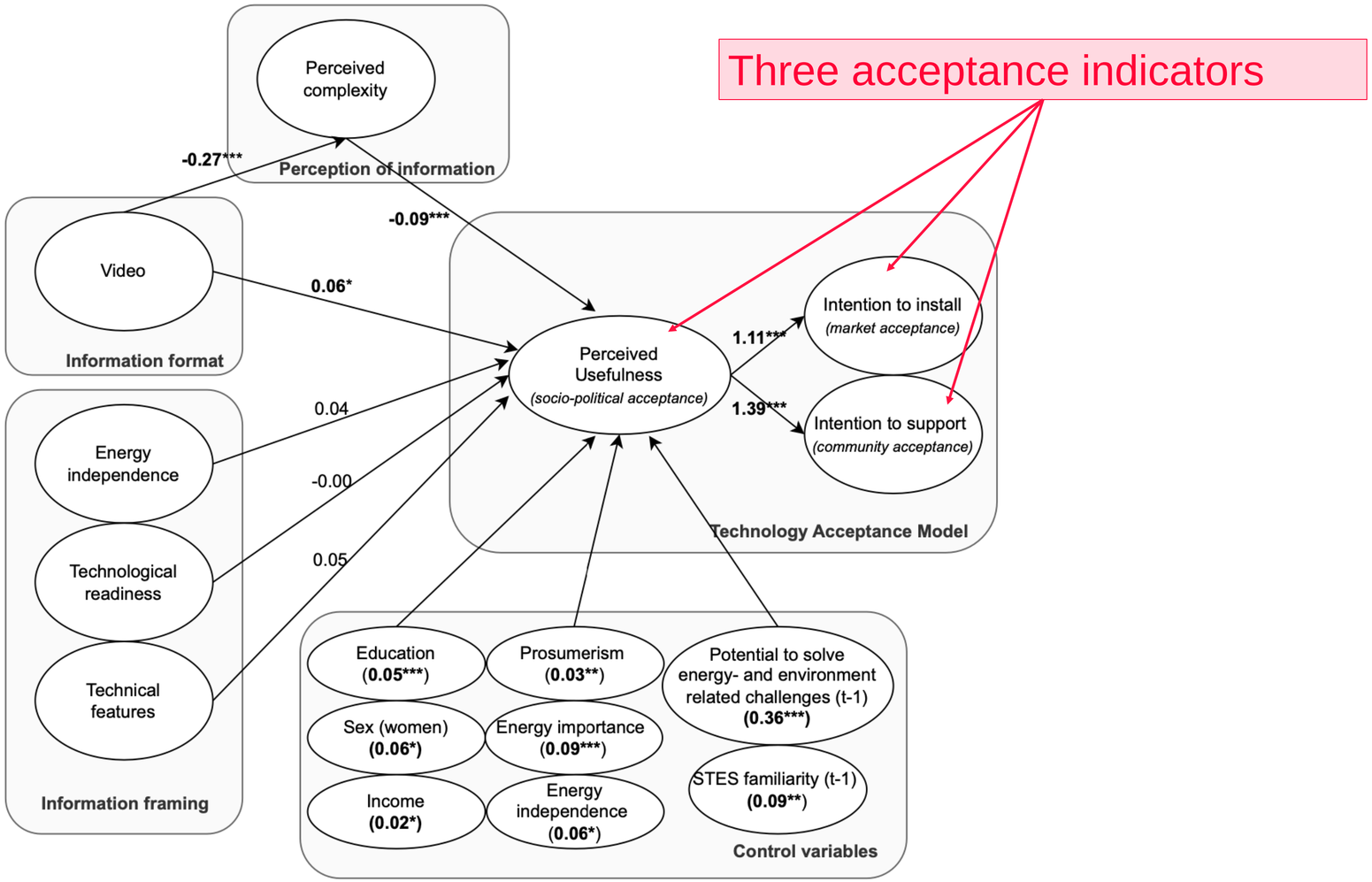
SOTES

Finding 1: Perceived usefulness affects intention to install and to support

Finding 2: Video-Information increases perceived usefulness directly and indirectly

Finding 3: The framing of the information does not matter

Finding 4: Public ownership increases acceptance compared to private ownership

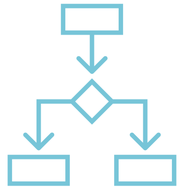


Social acceptance – next steps

Running Projects for in depth analysis of the research question *"How to increase the social acceptance of Seasonal Thermal Energy Storage (STES) technologies?"*

SOTES

- Further combination of technoeconomic and sociopolitical assessment
- Results for Decision Tree Selection Process

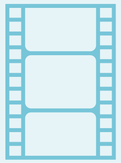


D4TES

Develop Dissemination Strategy

Test the Dissemination Strategy

Identify relevant stakeholders



Movie Project with Swiss museum of Transport and Design & Arts

SwissSTES

- Non-Technical Challenges

UNIVERSITÉ DE GENÈVE · zhaw · HSLU · OST Ostschweizer Fachhochschule · u UNIVERSITÄT BERN · HSG

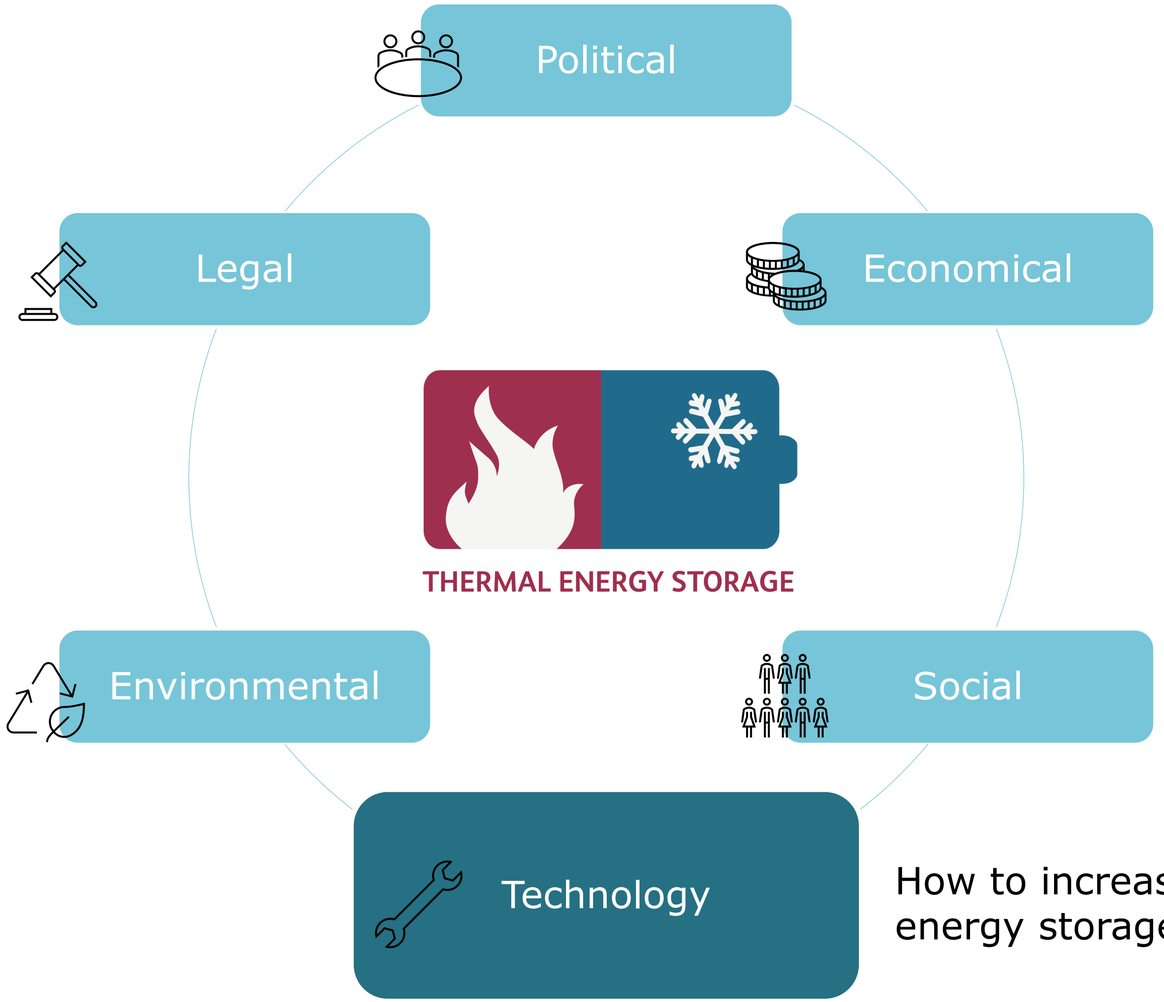
SP 3.1 Legal perspective

SP 3.2 Spatial planning perspective

SP 3.3 Social acceptance perspective

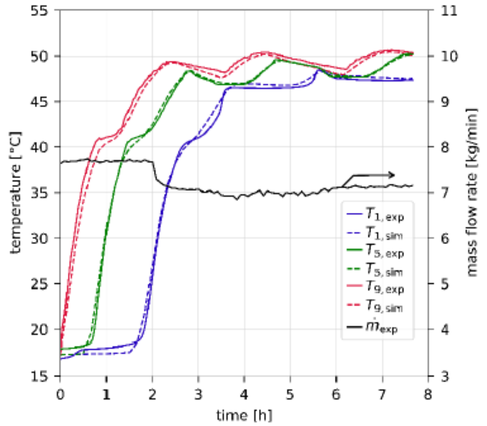
SP 3.4 Business model perspective

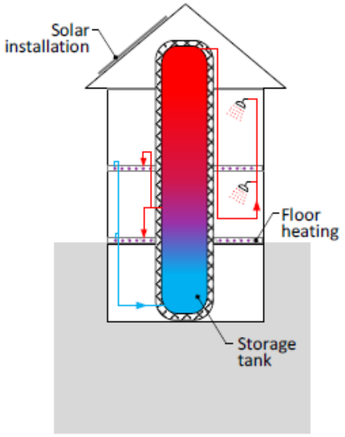
Research Questions regarding Seasonal Thermal Energy Storage (STES)



How to increase the compactness of thermal energy storage?

Technological aspects of Seasonal Thermal Energy Storage (STES)

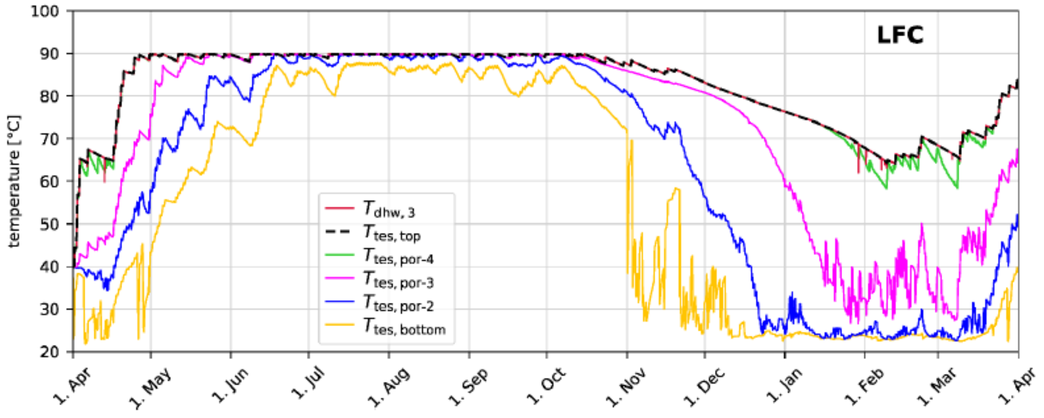




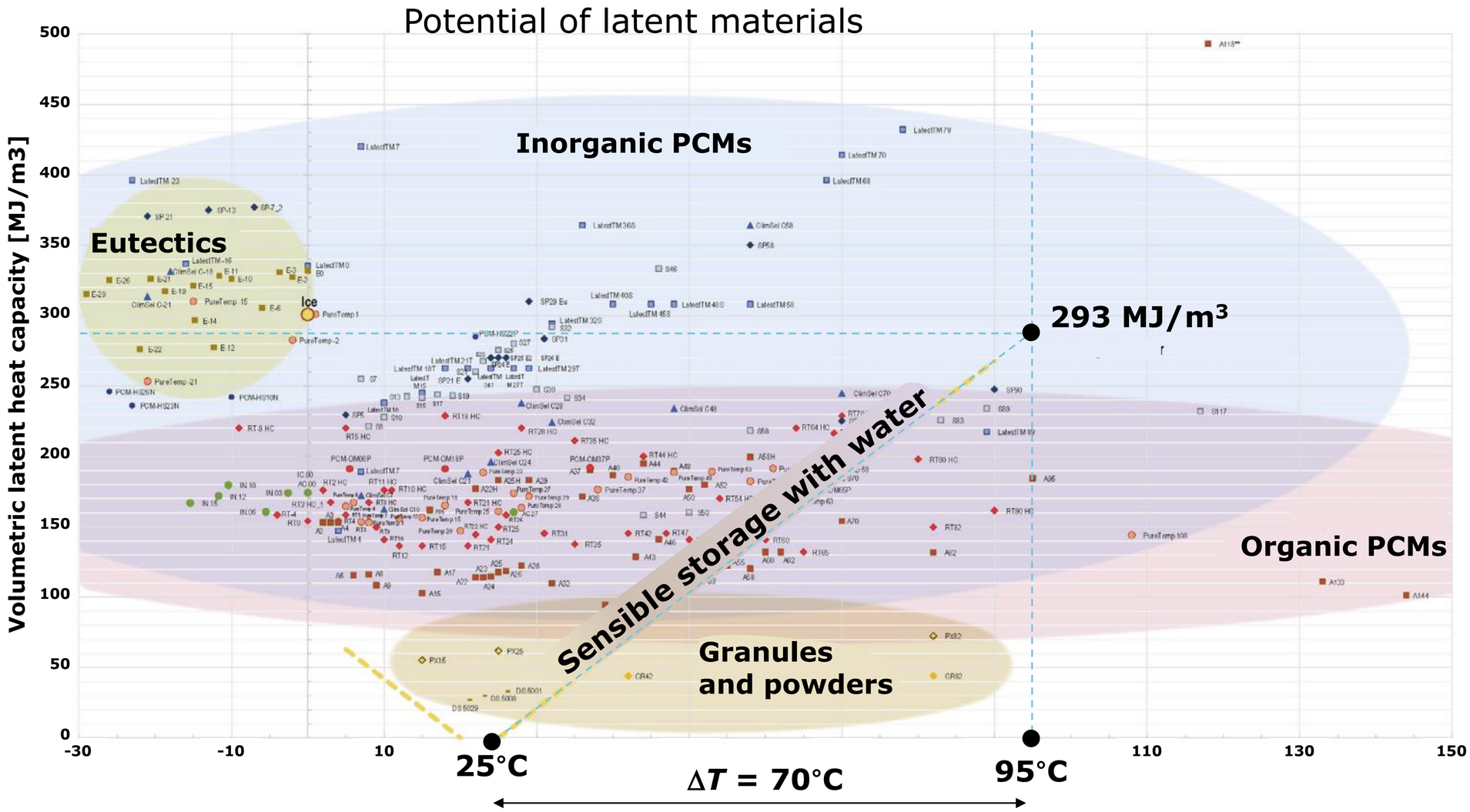
Importance of stratification and control algorithms

Key results:

- 40% reduction of storage volume through exergy-based optimization of control system
- Experimentally validated in-house model of thermally stratified water-based STES
- Vacuum-insulated double-wall storages feasible alternative to storages integrated inside buildings



Technological aspects of Seasonal Thermal Energy Storage (STES)

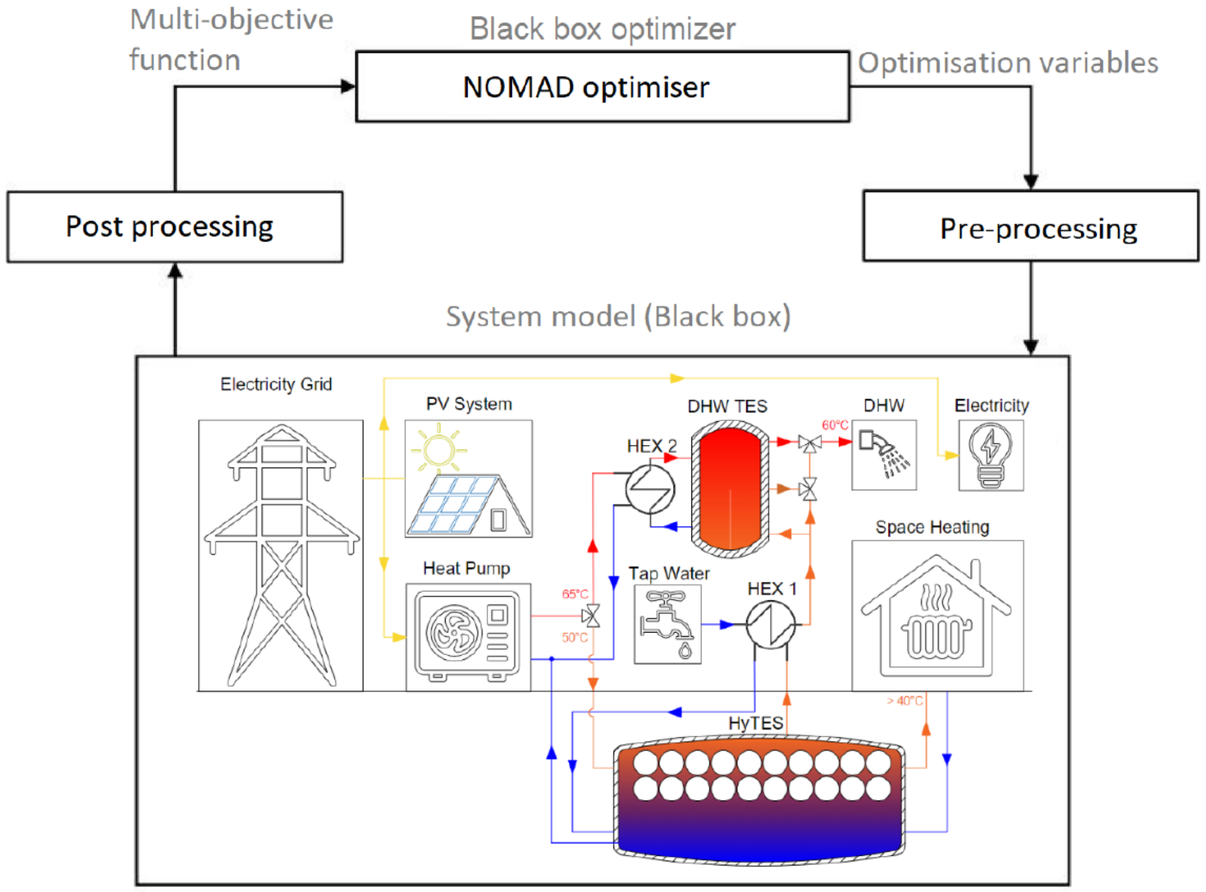


HSLU

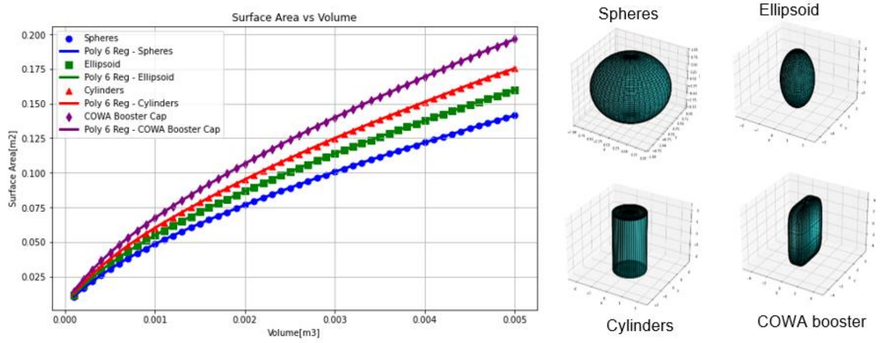
Lizana, J., *et al,* Advances in thermal energy storage materials and their applications towards zero energy buildings: A critical review. *Appl. Energy* 203, 219–239 (2017).

Technological aspects of Seasonal Thermal Energy Storage (STES)

Hybrid (sensible-latent) thermal energy storage models (HyTES) - Overview



W. Delgado Diaz et al (2024) (in preparation)



3 Storage Concepts:

Vacuum Insulated Tank **(VIT)**

Repurposed Basement Storage **(RBS)**

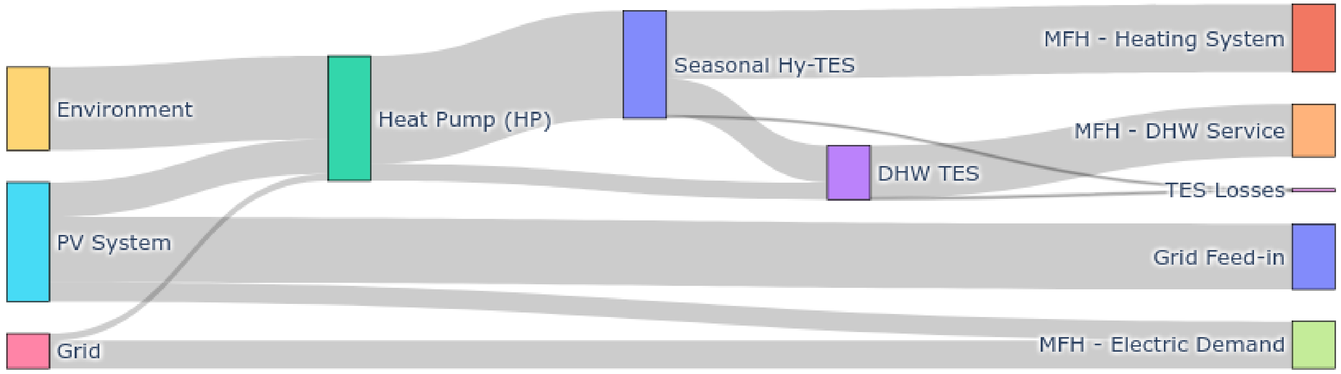
Spherical Storage Tank **(SST)**

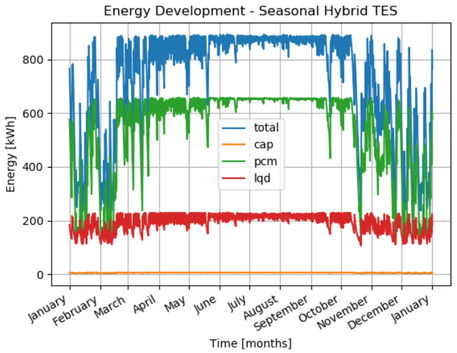
Technological aspects of Seasonal Thermal Energy Storage (STES)

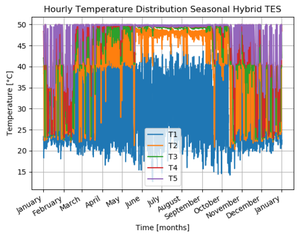
HyTES: Single run examples – Sensible vs Hybrid Comparison

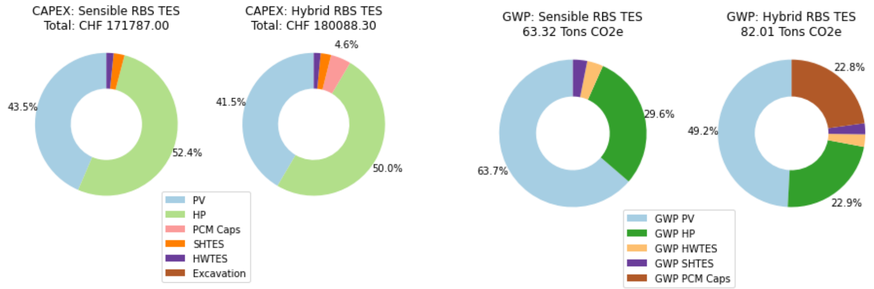
	Sensible SHTES	Hybrid SHTES
PV Power [kWp]	36.1	36.1
PV Azimuth [deg]	180	180
PV Tilt [deg]	45	45
HP power [kWe]	23	23
SHTES Volume [m³]	9.24	9.24
SHTES Height [m]	3	3
SHTES Diameter [m]	1.76	1.76
Total number of capsules [-]	-	2655
Capsule volume [L]	-	2
Capsule type [-]	-	COWA booster
PCM type [-]	-	PCM – 1
Total PCM mass [kg]	-	6335
Total PCM volume [m³]	-	4.9
Total Capsule mass [kg]	-	402
HWTES Volume [m³]	1.85	1.85
HWTES Height [m]	1.5	1.5
HWTES Diameter [m]	1.25	1.25

	Sensible SHTES	Hybrid SHTES
Self-Sufficiency Thermal [%]	79.9	84.6
LCOH [CHF/kWh]	0.325	0.334
GWP [CHF/kWh]	9.95E-03	1.18E-02
Self-Sufficiency Electric [%]	39.9	40.4
PV Self-Consumption [%]	42.5	44.2





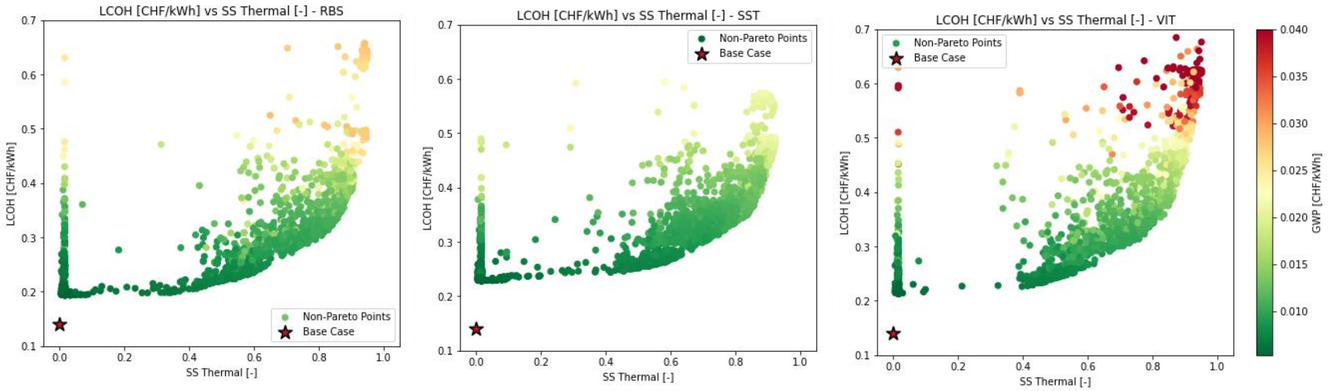


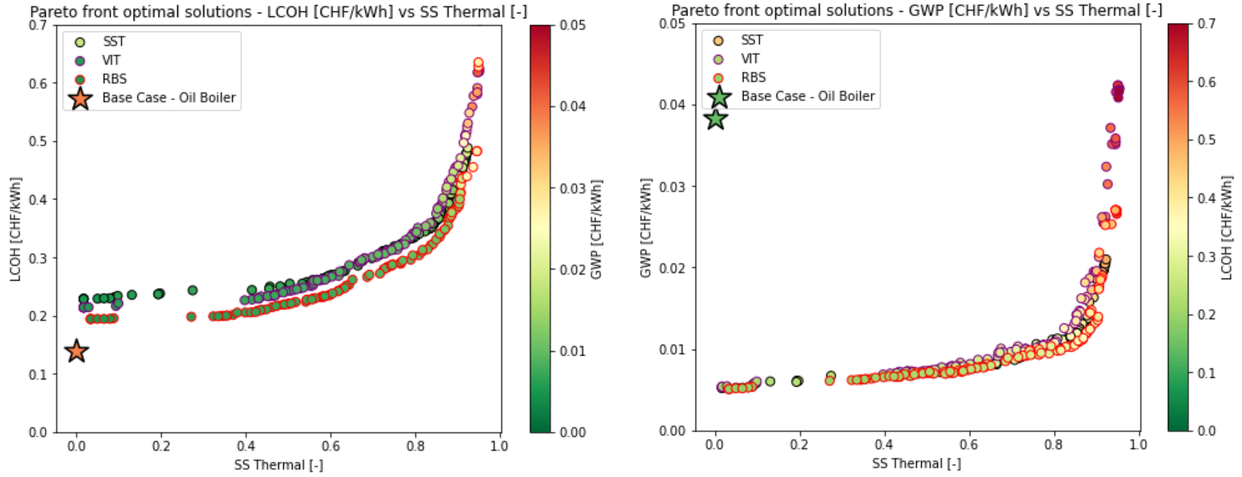


Technological aspects of Seasonal Thermal Energy Storage (STES)

HyTES: Optimization Results – Pareto Fronts and example configurations

SUMMARY	SST			VIT			RBS		
SS Thermal [%]	**70.8**	**85.0**	**92.4**	**69.9**	**85.3**	**95.6**	**68.6**	**84.9**	**94.9**
LCOH [CHF/kWh]	0.30	0.36	0.49	0.30	0.38	0.79	0.27	0.33	0.63
GWP [CHF/kWh]	0.009	0.012	0.021	0.010	0.013	0.042	0.008	0.010	0.027
SS Electric [%]	37.9	40.3	41.0	39.1	40.5	41.1	38.5	40.6	41.3
PV Self-Cons. [%]	45.7	45.3	47.8	38.6	44.3	48.3	43.4	44.8	49.6
Comfort level [%]	98.4	98.9	99.5	97.9	99.2	99.6	98.1	99.2	99.6
PV [kWp]	30.4	35.3	36.1	36.1	36.1	36.1	31.5	36.1	36.1
PV [m²]	146.0	169.7	173.3	151.4	173.3	173.3	173.3	173.3	173.3
PV Tilt [deg]	45	45	45	45	45	45	45	45	45
PV Azimuth [deg]	180	180	180	190	180	180	190	190	190
HP Peak Power [kWe]	8.5	15.5	24.5	7.5	16.5	24.0	7.5	15.5	23.0
SHTES Vol. [m³]	4.06	7.70	33.51	2.26	7.74	70.00	3.95	17.61	65.97
SHTES Height [m]	0.00	0.00	0.00	2.00	2.00	3.95	3.95	2.73	3.74
SHTES Dimension [m]	1.98	2.45	4.00	1.20	2.22	4.75	1.00	2.54	4.20
HWTES Vol. [m³]	3.07	2.45	3.07	2.38	2.61	3.07	2.18	2.27	3.07
HWTES Height [m]	2.50	2.00	2.50	2.50	2.23	2.50	1.78	1.97	2.50
HWTES Dimension [m]	1.25	1.25	1.25	1.10	1.22	1.25	1.25	1.21	1.25
PCM Rel. Height [%]	10	80	80	45	90	90	10	10	90
PCM Rel. Vol [%]	1.5	50.1	51.5	26.1	52.1	44.2	5.1	5.7	46.1
PCM Capsule Size [L]	1.10	1.70	0.10	2.55	2.25	0.10	0.10	4.20	0.10
PCM Capsule Index [-]	4	4	4	4	4	4	1	2	2
PCM material Index [-]	1	1	1	1	1	1	1	1	1



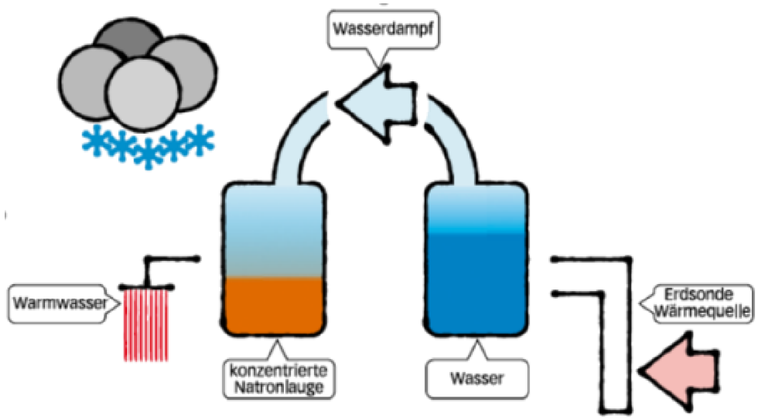


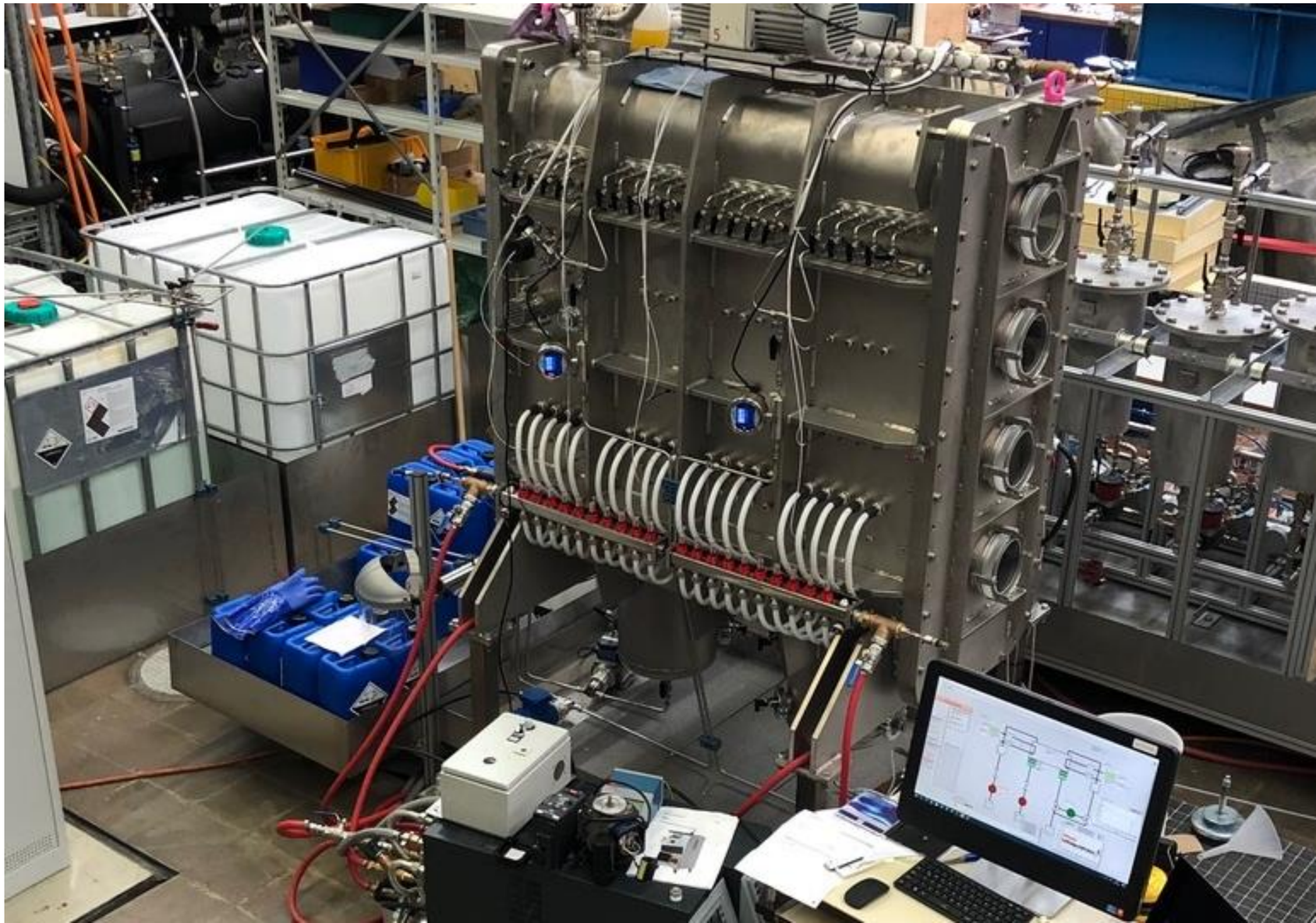
PATHFNDR

Technological aspects of Seasonal Thermal Energy Storage (STES)

Example of Thermochemical Storage

Sodium Lye Projects, HSLU, Empa, SFOE



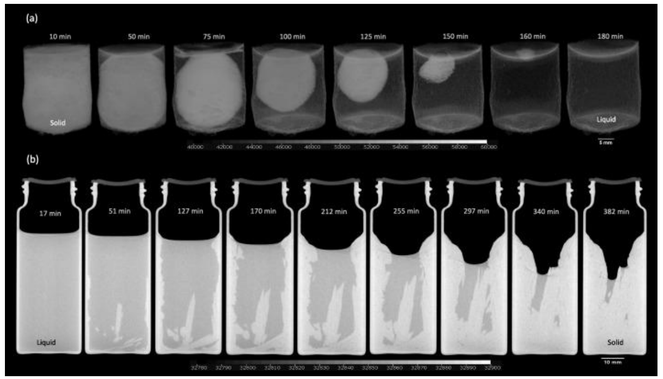


Technological aspects – next steps

Running Projects for in depth analysis of the research question
”How to increase compactness of thermal energy storage”

Segregation SNSF

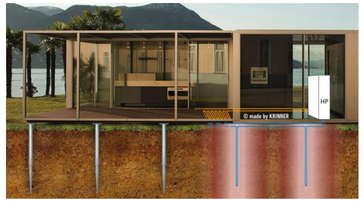
- Understanding the underlying mechanisms behind the segregation of salt hydrates
- How does local distribution of heat influence segregation?
- Develop well-established methodology to analyze salt hydrates with XCT
- Model liquid fraction of salt hydrates over time in multi-components mixtures



Melting of CaCl2*6H2O over time in XCT

Thermally Active Screw-foundation (TAS)

- Feasibility study
- Construction and operation of a test-setup on campus
- System modeling and optimization
- Support in design & testing
- Monitoring of pilot system



Euteq

- Development of two PCMs based on eutectic salt hydrate mixtures of 45°C "PCM45" and 65°C "PCM65‟ melting points (WP 3&4).
- Development of a prototype of a PV-driven heat pump system with a storage unit filled with COWA-Caps in an operational environment (real building).

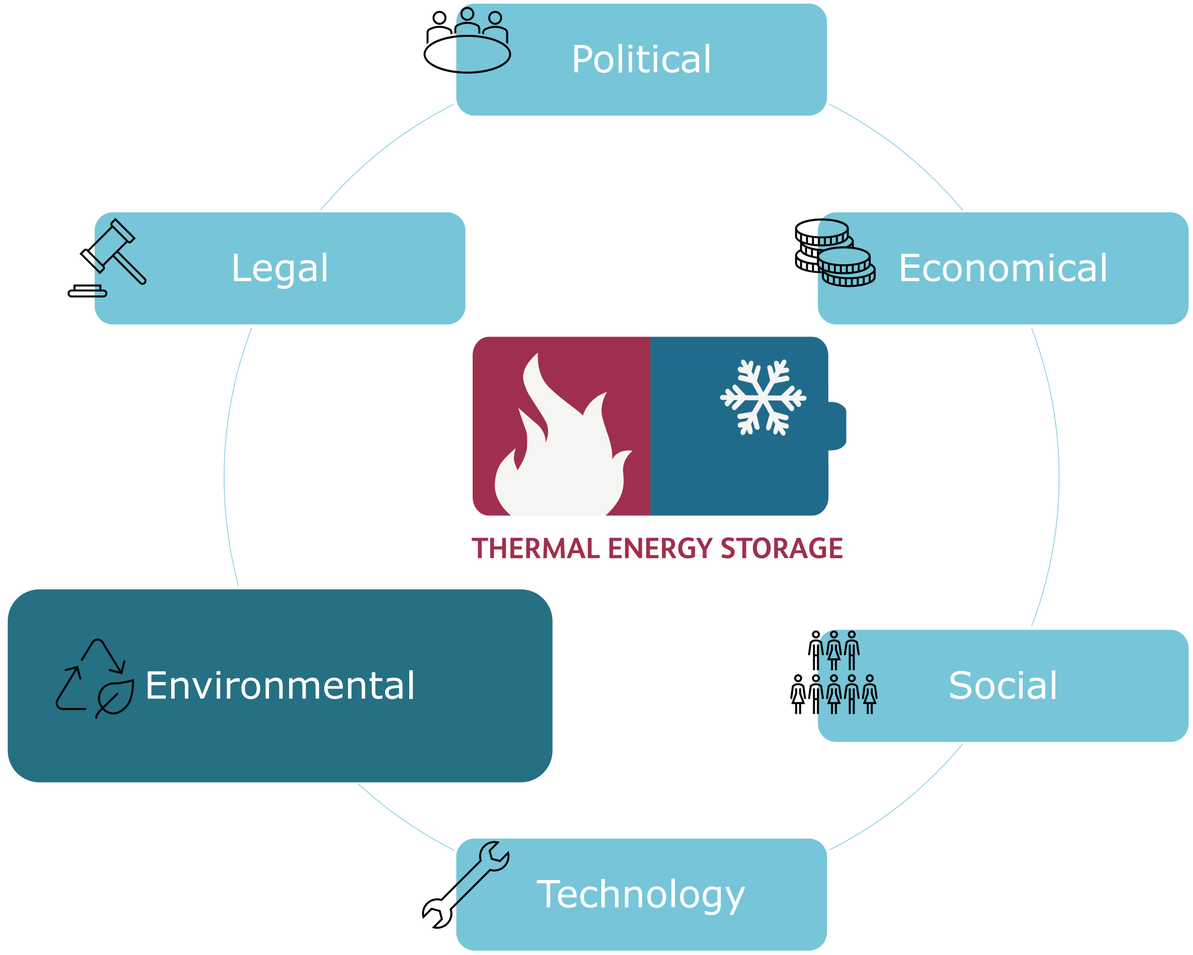
cowa
varmeco
ZAE BAYERN
eureka
eurostars

SwissSTES

PATHFNDR

Research Questions regarding Seasonal Thermal Energy Storage (STES)

How can sustainable use of resources be guaranteed when developing and using STES?



Quelle: IEA-ES Task 39 brochure Large Seasonal Thermal Energy Storage (STES)s for District Heating – Introduction

Environmental analysis of Seasonal Thermal Energy Storage (STES)

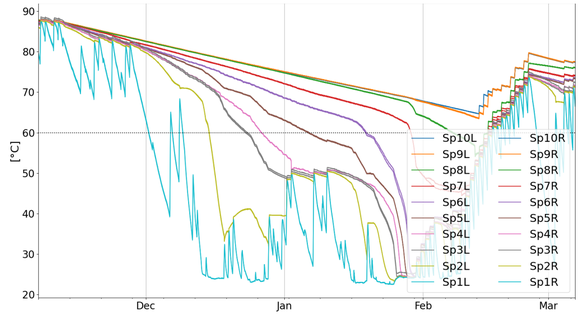
Project: 100 % solar

- Comparison and life cycle assessment of 3 concepts for 100% solar heated multi family housing:
  - Solar thermal (ST)
  - PV & heat pump (HP)
  - Mixed ST, PV & HP
- Contribution HSLU:
  - Monitoring and data analysis of a 100% solar heated multi family house in Huttwil
  - Technical expertise on STES

Conceptual illustration of the solar thermal system in the monitored MFH in Huttwil

Results:

- The systems are comparable to conventional HP-systems in terms of life cycle emissions and cost
- Mixed systems have the best environmental and economical performance



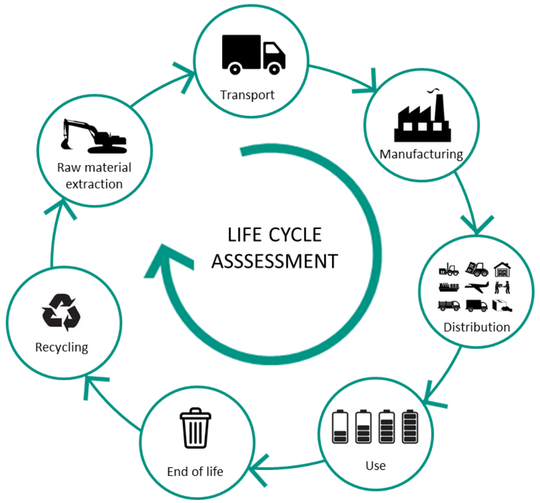
Parametric Cost Optimization of Solar Systems with Seasonal Thermal Energy Storage (STES) for Buildings, https://www.e3s-conferences.org/articles/e3sconf/abs/2021/22/e3sconf_hvac2021_03003/e3sconf_hvac2021_03003.html

Environmental analysis

Running Projects for in depth analysis of the research question *"How can sustainable use of resources be guaranteed when developing and using STES?"*

SOTES

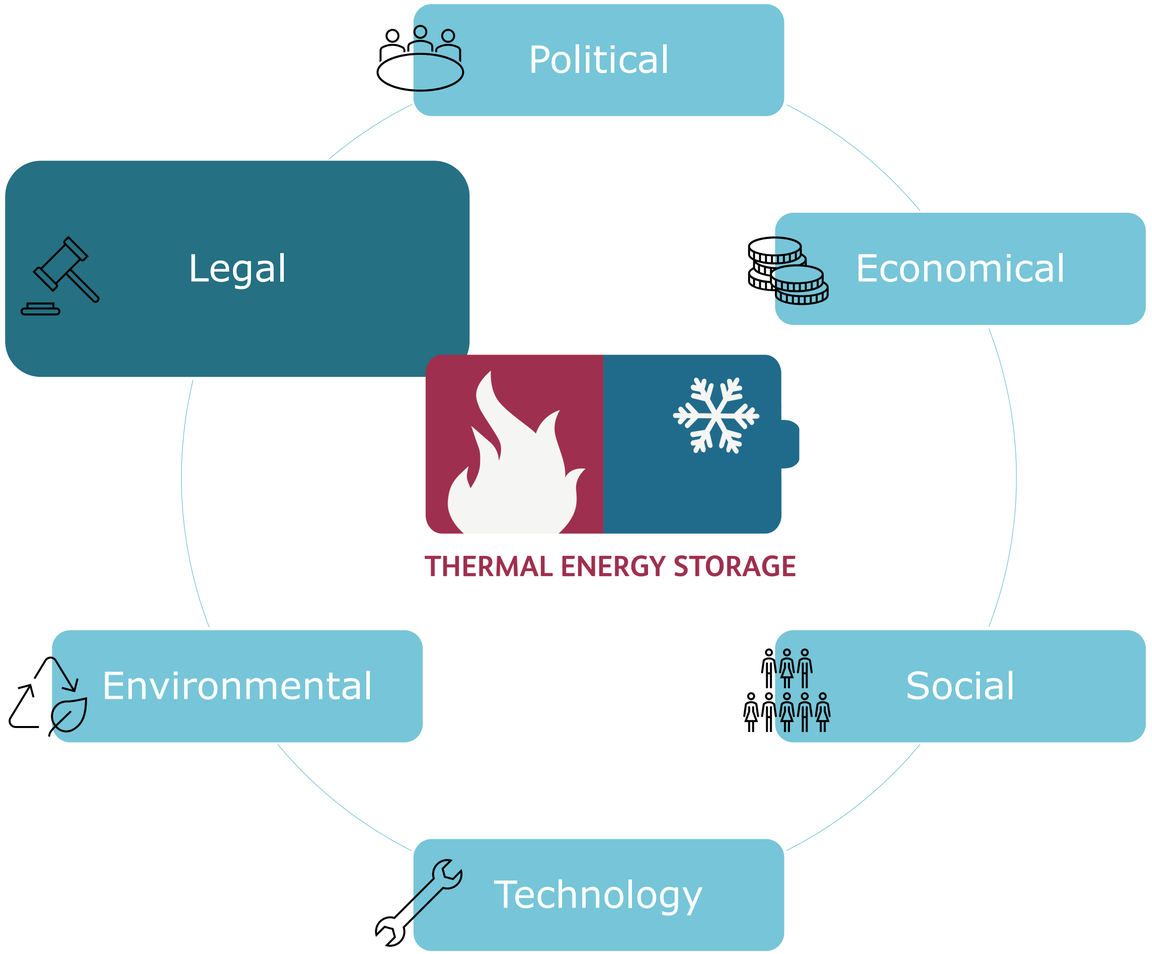
- LCA for all main STES technologies



https://cicenergigune.com/en/blog/life-cycle-assessment-key-sustainable-energy-storage

Research Questions regarding Seasonal Thermal Energy Storage (STES)

What legal measure accelerates the spread of Seasonal Thermal Energy Storage (STES)?



Legal aspects

Running Projects for in depth analysis of the research question *"What legal measure accelerates the spread of Seasonal Thermal Energy Storage (STES)?"*

SwissSTES

- Non-Technical Challenges

SP 3.1
Legal perspective

SP 3.2
Spatial planning perspective

SP 3.3
Social acceptance perspective

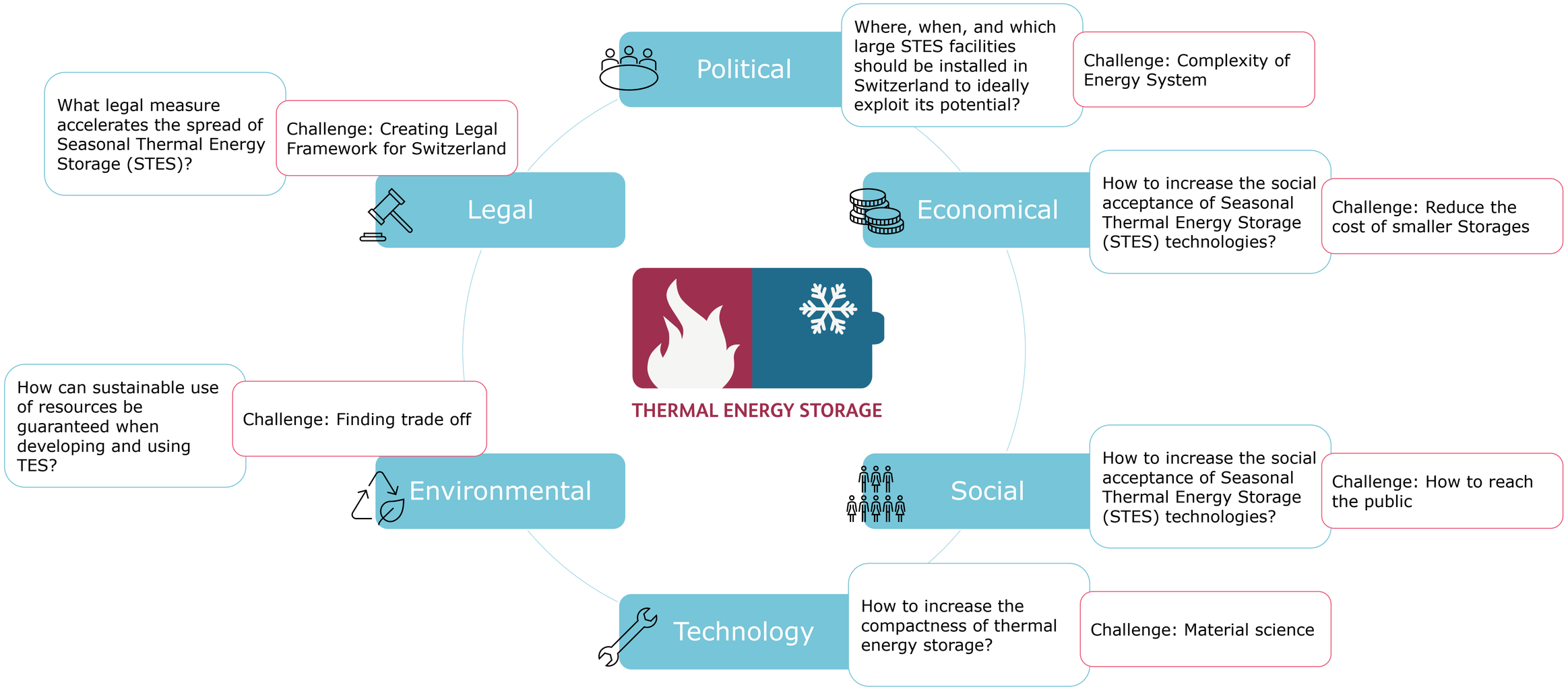
SP 3.4
Business model perspective

Rerates

Regulatory framework of thermal energy storage systems

- Clarification of the legal aspects
- Analysis of the competitive framework
- Synthesis of the legal framework for TES

Research Questions regarding Seasonal Thermal Energy Storage (STES) - Wrap up



Some links and Literature

Positionspapier des Forums Energiespeicher Schweiz: https://www.hslu.ch/de-ch/technik-architektur/ueber-uns/organisation/kompetenzzentren-und-forschungsgruppen/technik/thermische-energiespeicher/positionspapier/

SWISS-STES: https://www.hslu.ch/de-ch/hochschule-luzern/forschung/projekte/detail/?pid=6541 / https://www.zhaw.ch/de/forschung/forschungsdatenbank/projektdetail/projektid/6918/

LinkedIn: https://www.linkedin.com/company/cctes/

PhD summer School on thermal energy storage

- Cooperation between HSLU and University of Padova
- More Information and Registration: https://www.hslu.ch/de-ch/technik-architektur/ueber-uns/organisation/kompetenzzentren-und-forschungsgruppen/technik/thermische-energiespeicher/ltes-summer-school/

12th Swiss Symposium Seasonal Thermal Energy Storage (STES)

12th Swiss Symposium Thermal Energy Storage, 24th January 2025
Save the Date

- Research Sessions
- Industrial and Pilot Sessions
- Political Sessions

- Registration for 2025 soon
- More Information: www.hslu.ch/stes

Acknowledgement to the Team – www.hslu.ch/tes


Adina Hochuli


Adrian Müller


Anabel Palacios


Anastasia Stamatiou


Andreas Melillo


Benjamin Fenk


Curtis Meister

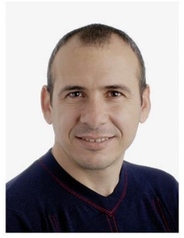

Damian Gwerder


Edward Lucas


Esther Linder


Eva Odermatt


Jörg Worlitschek


Jorge Martinez Garcia


Josua Hefti


Judit Tomás Verde


Julien Morel


Karina Jurt

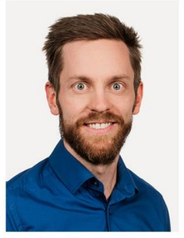

Lóránt Sztranyovszky


Louis Schibli


Luca Brauchli


Ludger Fischer


Malin Siegwart


Manuel Meyer


Maria Silveira


Matthias Eifert


Medine Ilbas


Núria Duran Adroher


Oliver Fellmann


Patrick Estermann


Patrick Meyer


Philipp Schütz


Priska Herzog


Rebecca Ravotti


Reto Hendry


Richard Lüchinger


Robin Studer


Robin Worreby


Sarah Schneeberger


Sebastian Ammann


Silvan von Arx

Sophia Sonnert

Ueli Schilt

William Delgado

Yannick Krabben

sweet swiss energy research for the energy transition

PATHFNDR

THANK YOU!

Contact Person:

Prof. Dr. Jörg Worlitschek
Co-Leader CC Seasonal Thermal Energy Storage HSLU
Institute Leader mechanical and energy technology (IME HSLU)
+41 41 349 39 57
Jörg.worlitschek@hslu.ch

Dr. Philipp Schütz
Leader Research Group Assessment of Thermal Energy Storage HSLU
+41 41 349 33 83
Philipp.schuetz@hslu.ch

Malin Siegwart
Co-Leader Research Group Seasonal Thermal Energy Storage HSLU
+41 41 349 31 97
Malin.siegwart@hslu.ch

PATHFNDR: www.sweet-pathfndr.ch
CC-TES Website: https://www.hslu.ch/de-ch/technik-architektur/ueber-uns/organisation/kompetenzzentren-und-forschungsgruppen/technik/thermische-energiespeicher/

HSLU ETH zürich Empa PAUL SCHERRER INSTITUT PSI zhaw HOCHSCHULE LUZERN UNIVERSITÉ DE GENÈVE EPFL TU Delft