IEA SHC Task 66: Solar Energy Buildings

Integrated solar energy supply concepts for climate-neutral buildings and communities for the "City of the Future"

Presentation of Final Results

Current and future technologies for Solar Energy Buildings

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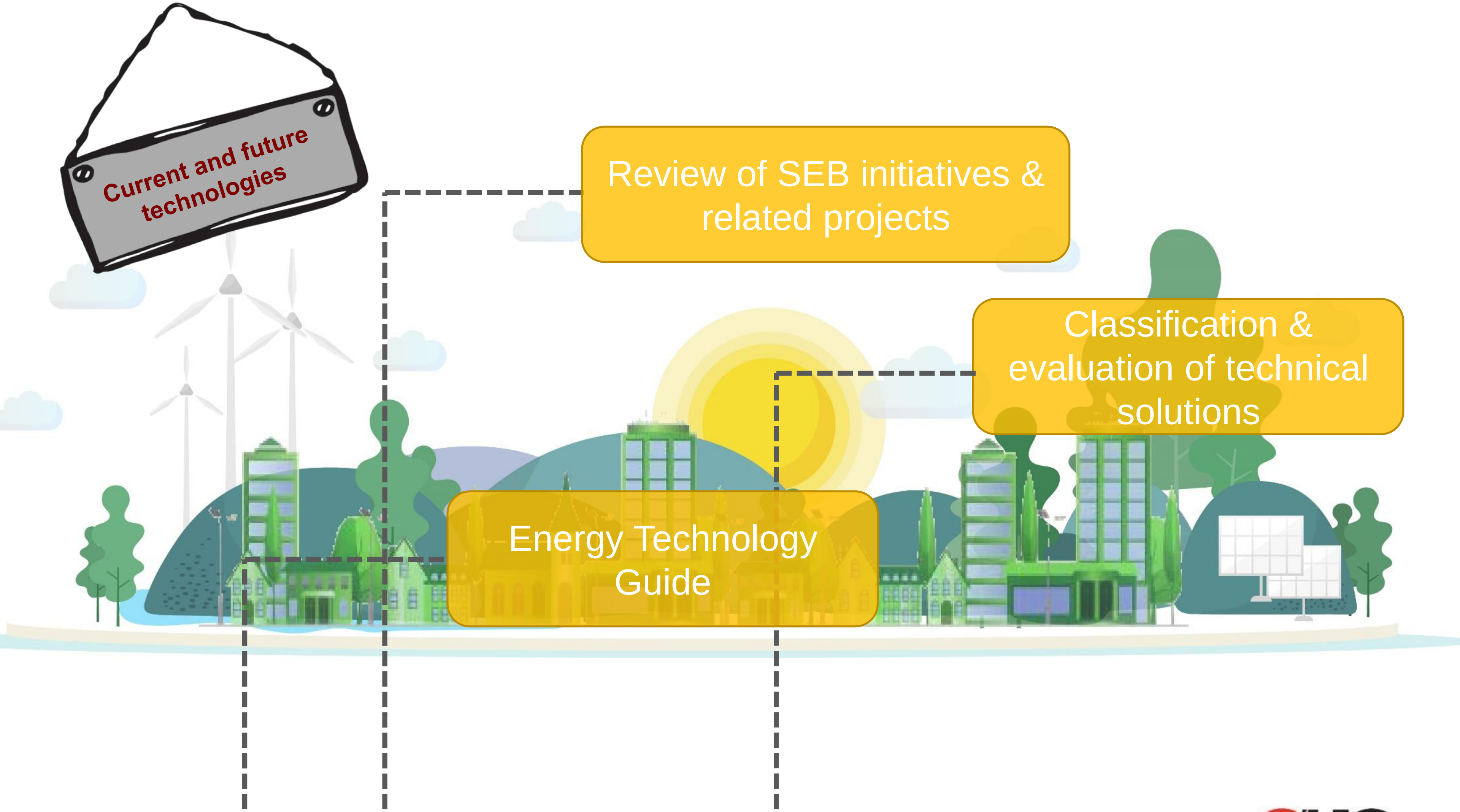
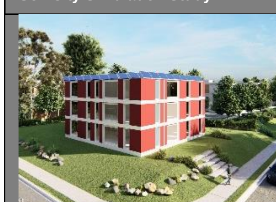
Task 66 Solar Energy Buildings
Subtask D



Review of SEB initiatives & related projects

Demo Cases from Task 66

- Stand alone buildings to city districts (+ lab sites)
- Very ambitions demonstration cases
- Emerging technologies
- Upgrading single technologies to be part of a larger system

MIXED USE by AEE INTEC Former Industrial complex (AT)	COMMERCIAL by DTU Ramboll Head Office (DK)	RESIDENTIAL by Simply Solar	RESIDENTIAL by IGTE Flying Space (DE)
			
SEB No.1	SEB No. 2	SEB No.3	SEB No.4
RESIDENTIAL by TU Freibg Apartment Buildings (DE)	TEST CHAMBERS by LNGE LNGE Campus (PT)	COMMERCIAL by AEE INTEC Orphange (PL)	RESIDENTIAL by SIZ energieplus Multi-family houses (DE)
			
SEB No.5	SEB No.6	SEB No.7	SEB No.8
RESIDENTIAL by AEE INTEC Sol4City-Simulation Study	RESIDENTIAL by SIZ energieplus Multi-family house (DE)	MIXED USE by (UIBK) An der Lan (AT)	RESIDENTIAL by (UIBK) Vögelebichl (AT)
			
SEB No.9	SEB No.10	SEB No.11	SEB No.12

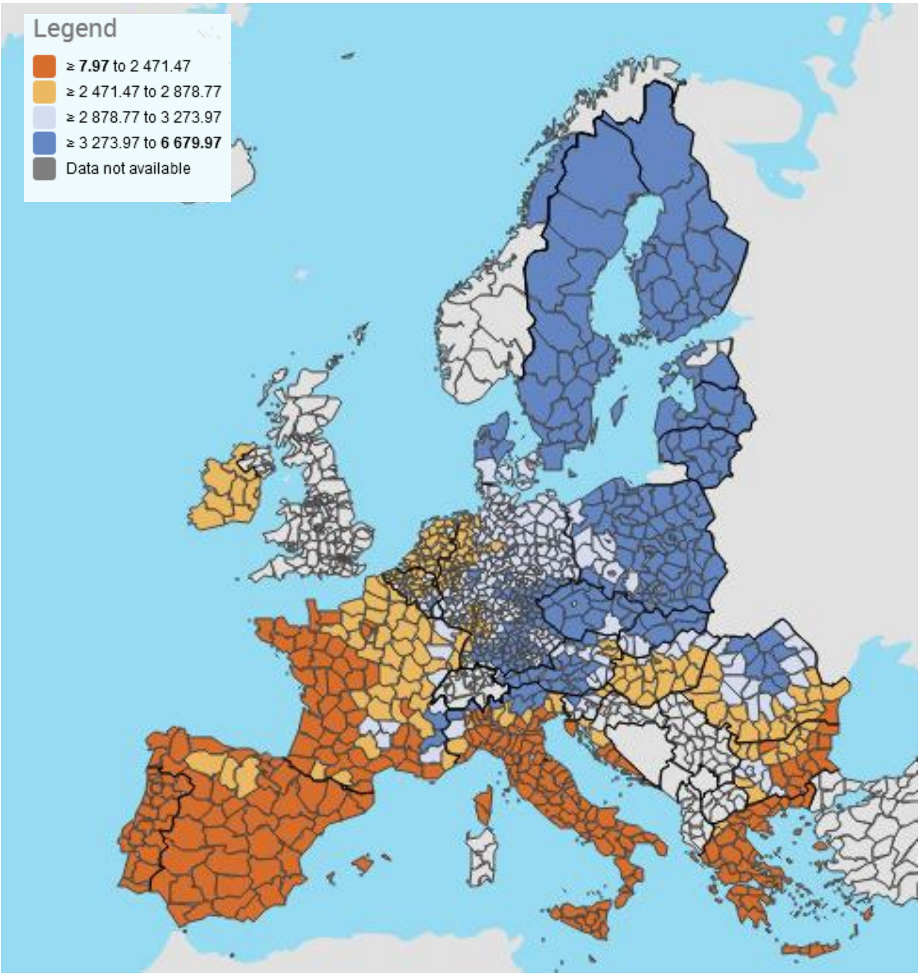
Review of SEB initiatives & related projects

126 SEBs in 17 countries

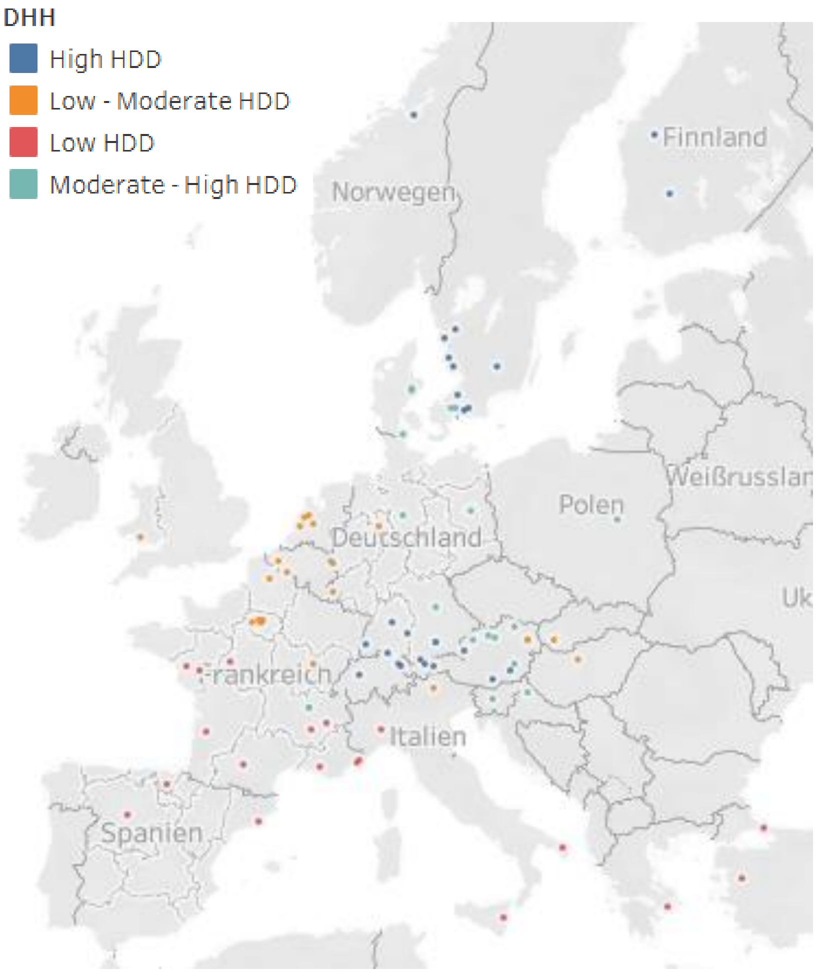
SEB No.	Name of SEB Example	Country	DHH	Link
1	Act2	Germany	Moderate - High HDD	Link
2	Act2	France	Low HDD	Link
3	Active office	United Kingdom	Low - Moderate HDD	Link
4	Aerem factory	France	Low HDD	Link
5	AquaTurm Water Tower Hotel	Germany	High HDD	Link
6	BEEM-UP	Sweden	High HDD	Link
7	BEEM-UP	Netherlands	Low - Moderate HDD	Link
8	BEEM-UP	France	Low - Moderate HDD	Link
9	BUILDSMART	Sweden	High HDD	Link
10	CITyFiED	Sweden	High HDD	Link
11	CITyFiED	Turkey	Low HDD	Link
12	CITY-ZEN	Netherlands	Low - Moderate HDD	Link
13	CITY-ZEN	France	Low HDD	Link
14	CLASS1	Sweden	High HDD	Link
15	Commercial Building Kobra	Slovenia	Moderate - High HDD	Link
16	Concert or Conference Hall "The House for All"	France	Moderate - High HDD	Link
17	Concerto AL Piano	Italy	Low HDD	Link
18	DIRECTION	Germany	Moderate - High HDD	Link
19	DIRECTION	Spain	Low HDD	Link
20	ECO-Life	Denmark	Moderate - High HDD	Link
21	ECO-Life	Belgium	Low - Moderate HDD	Link
22	Eco-Renovation of KTR France HQ	France	no information on exact location	Link
23	Education and Leisure Hub	France	Low - Moderate HDD	Link
24	EE-HIGHRISE	Slovenia	Moderate - High HDD	Link
25	Efficiency House Plus	Germany	no information on exact location	Link
26	Elithis Tower	France	Low - Moderate HDD	Link
27	Energy in Minds!	Sweden	High HDD	Link
28	Energy Positive Dwelling	Netherlands	Low - Moderate HDD	Link

Classification of SEBs

Geography and climate



Source: Eurobase Cooling and Heating degree days



Source: AEE INTEC

Classification of SEBs

Technologies

Generation Technologies → Storage Technologies → Thermal Grids → Buildings/ Communities

Technology ..	Technology	Sub-Technnology
Generation	Solar Electric	Photovoltaic systems (PV)
	Solar Thermal	Solar thermal collector (ST)
	Hybrid (solar thermal and solar electric)	Air PVT-collectors
		Concentraing PVT-collectors
		Covered water PVT-collectors
		Evacuated tube PVT-collectors
		Uncovered water PVT-collectors
		Uncovered water PVT-collectors with fin heat exchanger to incre..
	Sorption collectors	Charge Boost-sorption collector
	Heat pumps	Absorption heat pump
		Adsorption heat pump
		Air-source heat pump using heat recovery
		Ground-source heatpump with ground heat exchanger
		Ground-source heatpump with inclined or deep horizontal wells
		Heat pumps with (PV)T-collectors as heat source
		Heat pumps with direct solar evaporator
		High-temperatur heat pumps
		Metal hybrid heat pump
		Natural refrigerant heat pump
		Sate of the art air-to-air heat pump
		Synthetic methane heat pump
		Water to water heat pump
	Wind	Micro wind turbines
	Hybdro	Small hydropower plant
	Cogeneration	Fuel cell micro-CHP
	Biomass	Pellets burning stove and boiler
		Wood-burning stove
	Biogas	Biogas plants

Classification of SEBs

Technologies

Generation Technologies | Storage Technologies | Thermal Grids | Buildings/ Communities

Technology ..	Technology	Sub-Technnology
Storage	Electricity	Battery storage
		Community Battery storage
		Mobile electircal storage (E-mobility with vehicle to Grid)
		Redox flow battery
		Salt water battery
	Latent	Thermal storage- Latent (PCM)-solid-liquid ice storage
	Mechanical	Pumped storage
	Sensible	Hot water tanks
		Large scale sensibel storage
		Thermal activated building mass
		Thermal storage with vacuum insulation
	TCM (thermo chemical sto..	Null
	Ungerground thermal storage	Aquifer thermal energy storage
		Borehole thermal energy storage

Classification of SEBs

Technologies

Generation Technologies | Storage Technologies | **Thermal Grids** | Buildings/ Communities

Technology ..	Technology	Sub-Technnology
Thermal grids	Heating and Cooling	Absorption-heat exchangers
		Booster heatpumps
	System integration and operation	Anergy or ultra-low temperature networks
		Demand Side Management / Demand Response
		District cooling
		Integrated energy systems
		Integration of waste heat and low exergy sources
		Low temperature district heating grids
		Model predictive and adaptive Control Strategy for the Operatio..
		Solar thermal district heating
		Virtual power plant

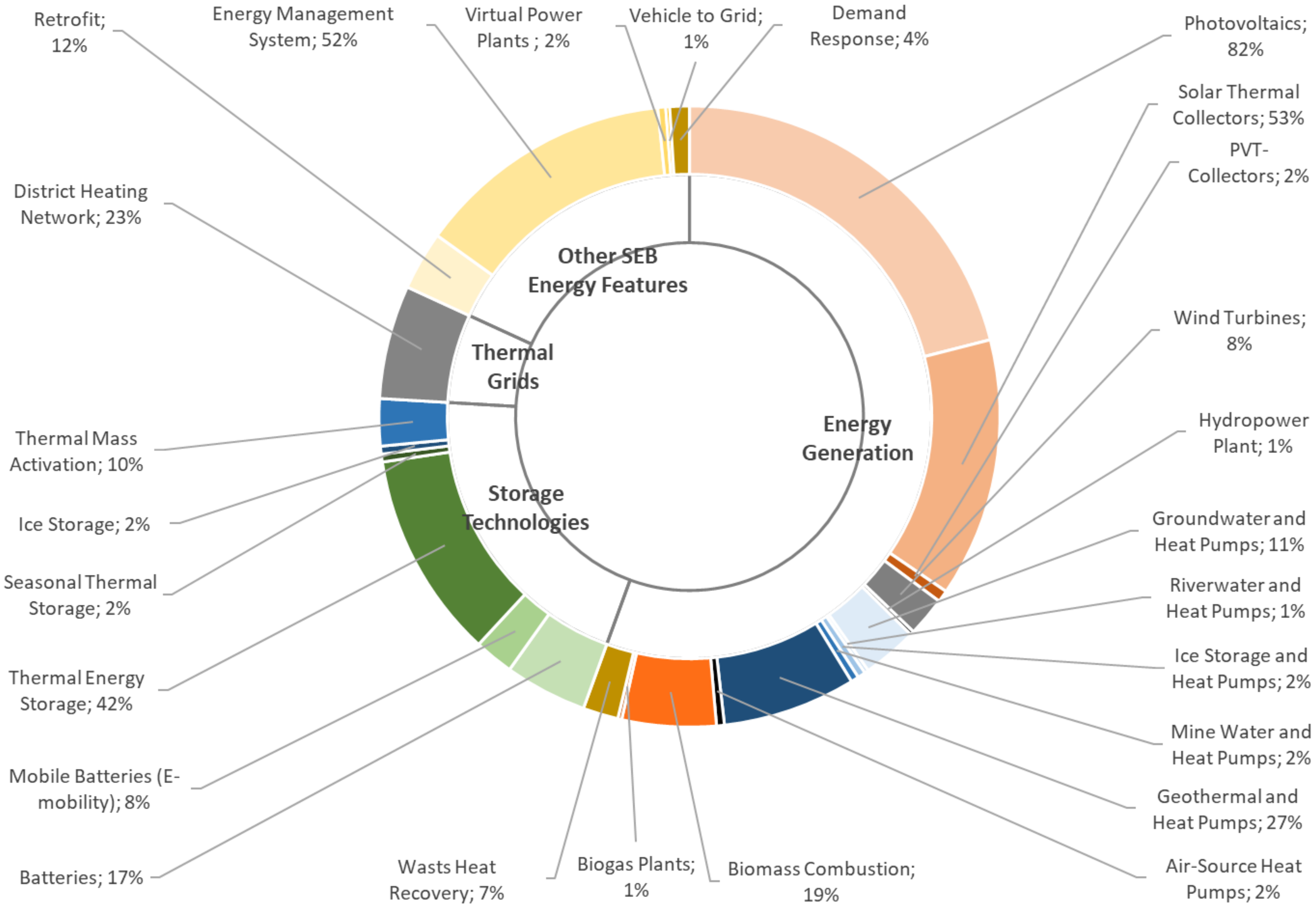
Classification of SEBs

Technologies

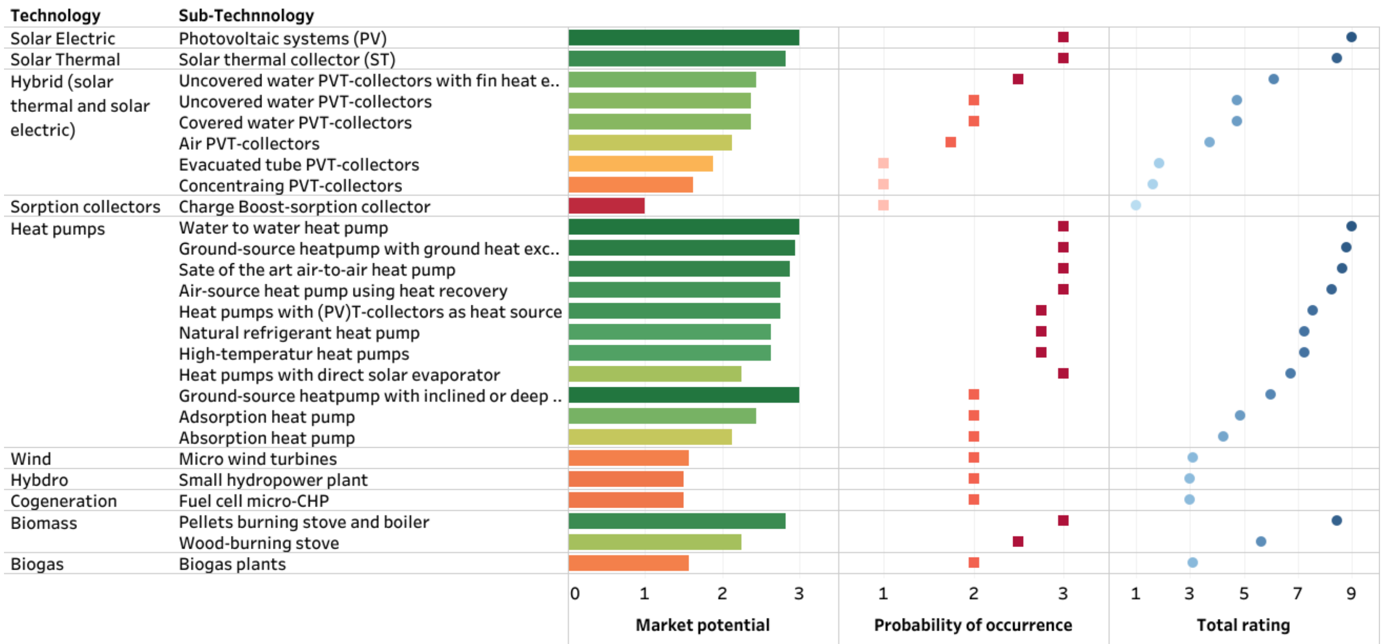
Generation Technologies → Storage Technologies → Thermal Grids → Buildings/ Communities

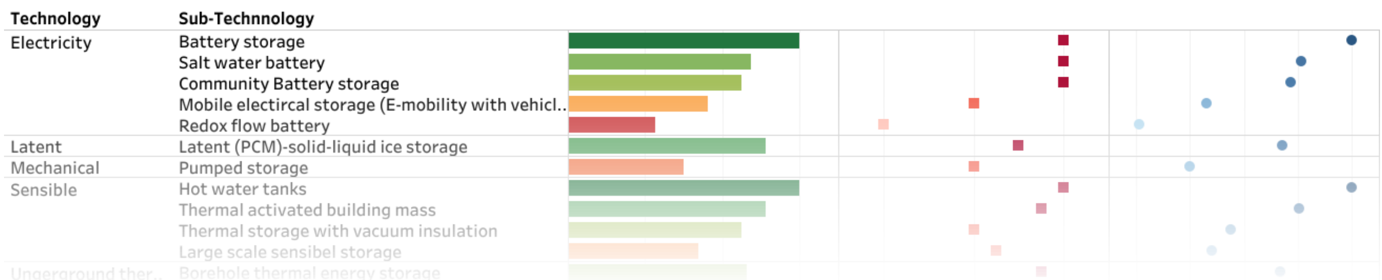
Technology Grouping	Technology	Sub-Technnology
Buildings/Communities	Heating and Cooling	Dynamic thermo-regulative walls/windows
		Energy active Facades
		Facade integrated mico heatpump
		Thermal building mass activation
		Thermal mass activation under building
	System integration and operation	Assisted fault detection & efficiency diagnostic system
		Demand (electricity, DHW, Space heatig space cooling) and gen..
		Demand response - Gamification devices
		Demand response - Virtual net metering
		Demand response- Open automated demand response
		Digital building (community) twins
		Smart Energy Management Systems
		User-centered pro-active building management system

Evaluation of technical solutions



Market potential of technical solutions

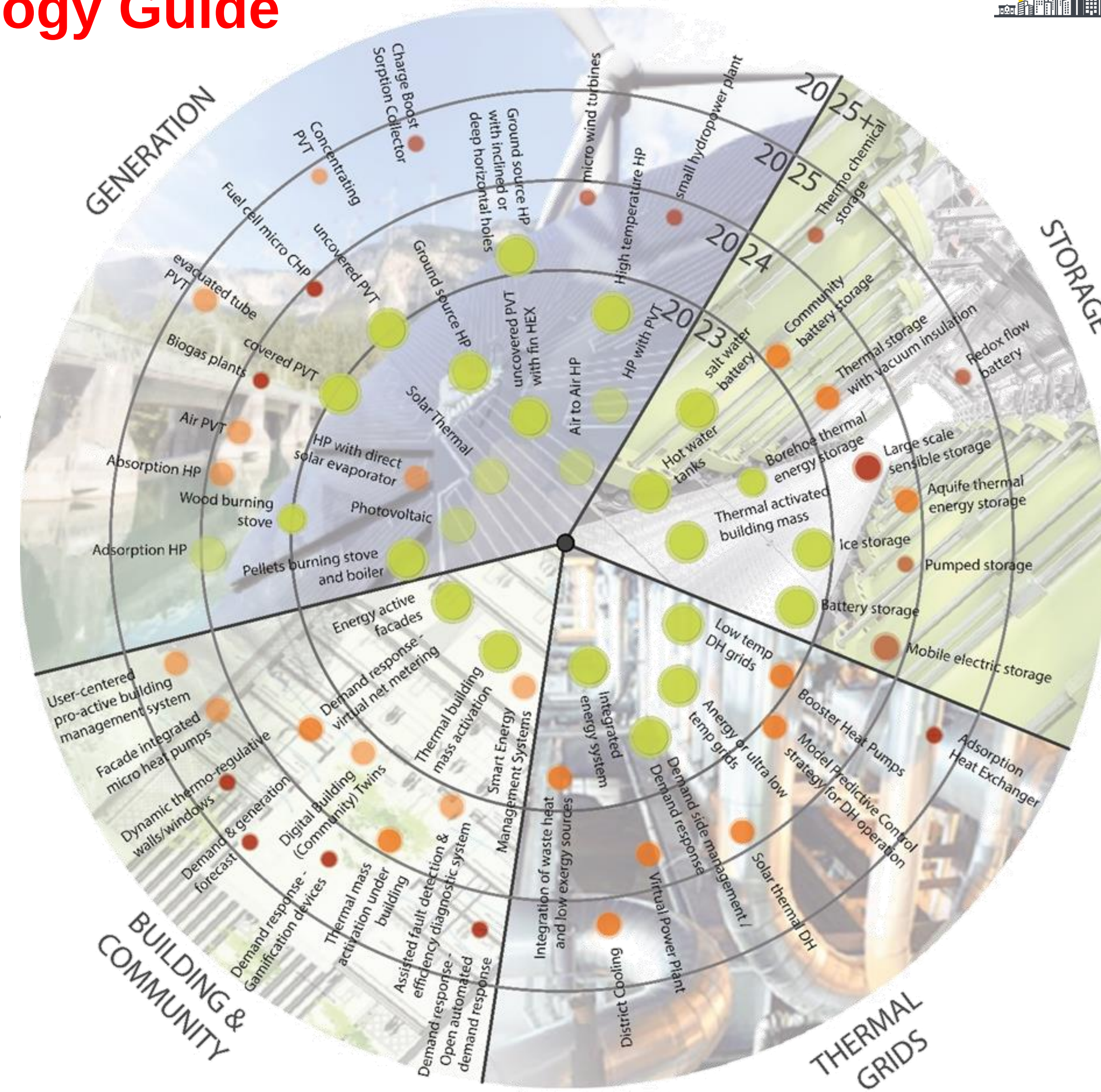




Energy Technology Guide

Clean Energy Technology Radar

Technologies and components across the whole energy system that contribute to achieve the goal of SEBs



Market Potential

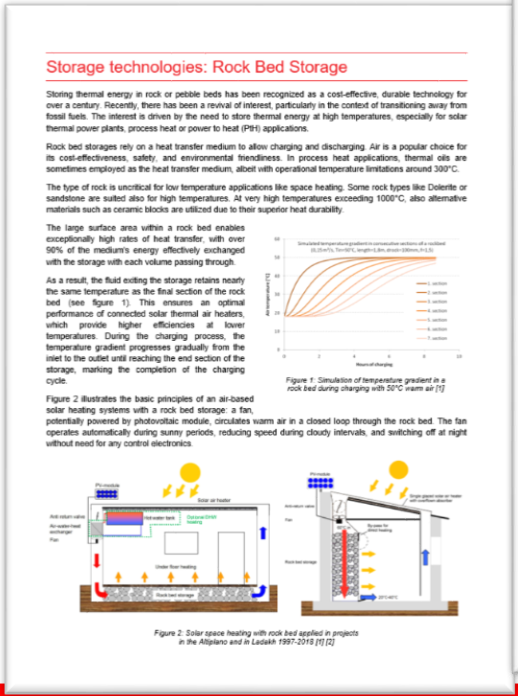
Low Middle High

Total Rating

Low Middle High

New technologies and components for Solar Energy Buildings

- The information about selected technologies are presented in Fact sheets
  - Description of the technology
  - Examples: Images of the application of solutions
  - References: scientific literature, journals, links to relevant documents and projects



Storage technologies: Rock Bed Storage

Storing thermal energy in rock or pebble beds has been recognized as a cost-effective, durable technology for over a century. Recently, there has been a revival of interest, particularly in the context of transitioning away from fossil fuels. The interest is driven by the need to store thermal energy at high temperatures, especially for solar thermal power plants, process heat or power to heat (PtH) applications.

Rock bed storages rely on a heat transfer medium to allow charging and discharging. Air is a popular choice for its cost-effectiveness, safety, and environmental friendliness. In process heat applications, thermal oils are sometimes employed as the heat transfer medium, albeit with operational temperature limitations around 300°C.

The type of rock is uncritical for low temperature applications like space heating. Some rock types like Dolerite or sandstone are suited also for high temperatures. At very high temperatures exceeding 1000°C, also alternative materials such as ceramic blocks are utilized due to their superior heat durability.

The large surface area within a rock bed enables exceptionally high rates of heat transfer, with over 90% of the medium's energy effectively exchanged with the storage with each volume passing through.

As a result, the fluid exiting the storage retains nearly the same temperature as the final section of the rock bed (see figure 1). This ensures an optimal performance of connected solar thermal air heaters, which provide higher efficiencies at lower temperatures. During the charging process, the temperature gradient progresses gradually from the inlet to the outlet until reaching the end section of the storage, marking the completion of the charging cycle.

Figure 1: Simulation of temperature gradient in a rock bed during charging with 50°C warm air [1]

Figure 2 illustrates the basic principles of an air-based solar heating systems with a rock bed storage: a fan, potentially powered by photovoltaic module, circulates warm air in a closed loop through the rock bed. The fan operates automatically during sunny periods, reducing speed during cloudy intervals, and switching off at night without need for any control electronics.

Figure 2: Solar space heating with rock bed applied in projects in the Altiplano and in Ladakh 1997-2018 [1] [2]

Building and Community: Energy active facades

The EU has committed to reducing its greenhouse gas (GHG) emissions by 55% by 2030 compared to 1990 levels. The building sector, responsible for 36% of GHG emissions, plays a crucial role in achieving these climate targets. Most notably, the existing building stock, which will still be 85-95% present in 2050, needs to be refurbished. Three-quarters of this stock are energy-inefficient and require comprehensive energy retrofitting and decarbonization over the next 20 years to enable climate neutrality. This will involve increasing the renovation rate to 3% and simultaneously transitioning to renewable heating/cooling systems.

Current standard renovations use External Thermal Insulation Composite Systems (ETICS), but their irreversible bonding to existing walls complicates material recycling and presents ecological disadvantages over their lifecycle. Long renovation times, including necessary scaffolding, pose significant barriers, affecting resident disruption and acceptance of the renovation process. Additionally, outdated energy distribution systems (heating distribution systems, radiators, etc.) pose risks due to leaks and demonstrate substantial improvement potential in terms of distribution losses and temperature levels. Modernizing heating distribution lines in existing buildings is often feasible only with significant construction efforts, thus incurring high costs and frequently necessitating resident relocation.

The ENERGY FACADE CEPA® was developed through collaborative research between SME Towern3000 and research institute AEE INTEC. It was conceptualized in a strategic sequence of preliminary projects. CEPA® represents both a radical and disruptive innovation in the energy retrofitting of existing buildings by combining the concepts of modular prefabricated facade elements and thermal component activation into a single approach.

1. Wall – Energy Storage (concrete, bricks…)
2. Heat emission system (heating/cooling)
3. Thermal insulation
4. Substructure
5. Ventilation
6. Facade cladding
7. Room

Figure 1: Exemplary system components of CEPA® energy facade, Source Towern3000

These large, highly insulated curtain façade elements can be manufactured in factories through standardized processes with high precision, reducing implementation errors in construction by 5-10%. The onsite assembly time for the approximately 20 m² facade module, using a mobile crane without scaffolding and involving about three personnel including HVAC components, can be reduced by up to 70%. One of the core elements is an active heat transfer layer, akin to a radiant heating system, integrated into the prefabricated facade element. By a patented concept, pressing the pipes or heat transfer surfaces onto the existing wall through the insulation in the facade module, the system's heat transfer capability significantly increases, roughly doubling the heat transfer performance and making the integration of heating layers in facade envelopes feasible.

By transferring heat from the outside, the thermal mass of the existing exterior walls is activated similarly to thermal component activation (TCA), facilitating load shifting and intelligent operation. The unlocked energy flexibility opens new markets and supports managing the increasing volatility in electricity markets driven by fluctuating renewable energies from solar or wind. In addition to monetary savings for portfolio managers or users, the "connectivity-market-friendly flexibility" plays a crucial role in the electrical economy by offering potentials for improved grid stability, grid security, and reduced investment needs in grid expansion. The ENERGY FACADE CEPA® addresses entirely new markets and customer groups.

The externally located TCA as a minimally invasive serial renovation concept with the potential for energy flexibility is seen as a game-changer. It aids property owners of large housing stocks not only in maintaining or increasing www.iea-shc.org

SHC
TASK 66
Solar Energy Buildings

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

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