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Keepin' it Cool (or Hot)

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U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
BUILDING TECHNOLOGIES OFFICE

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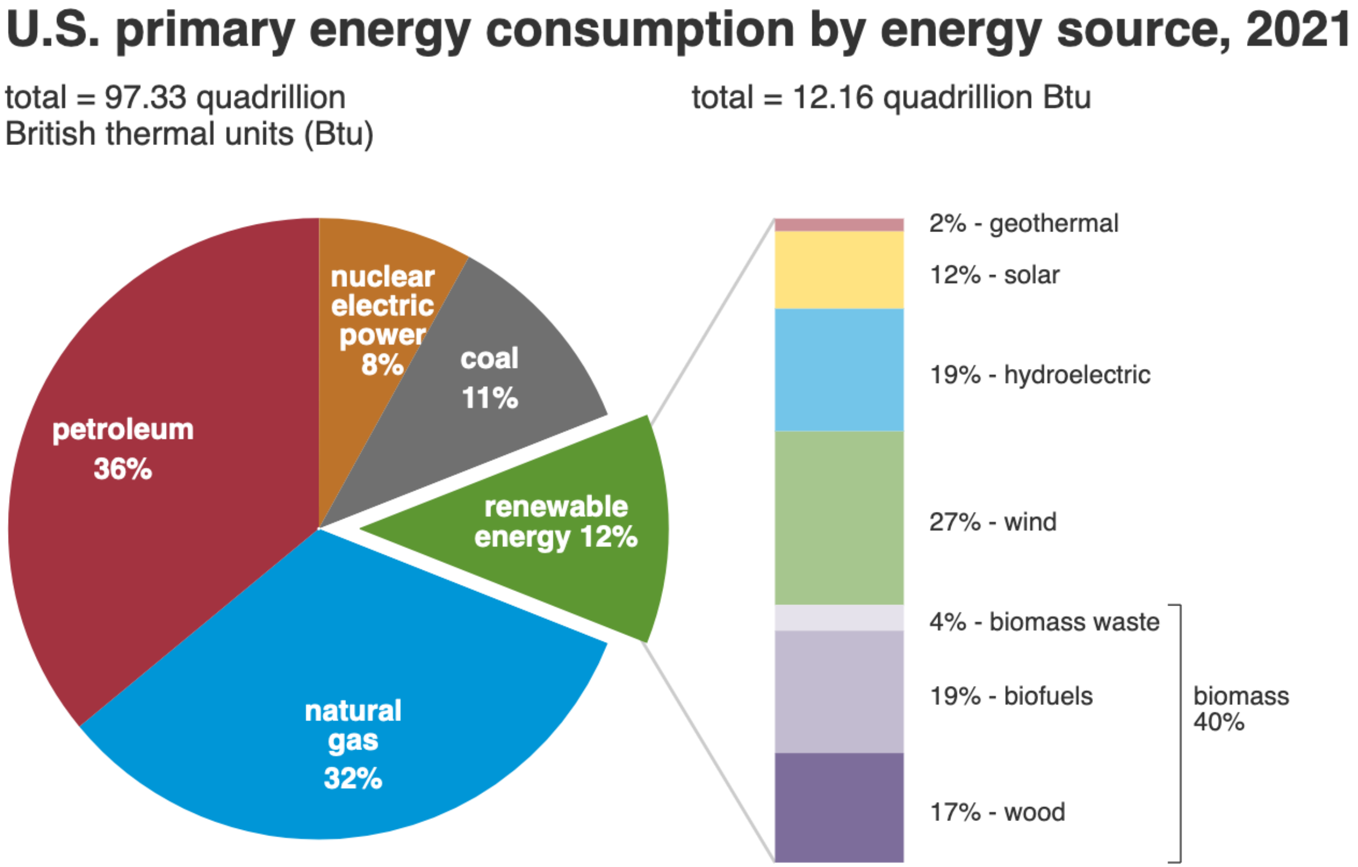
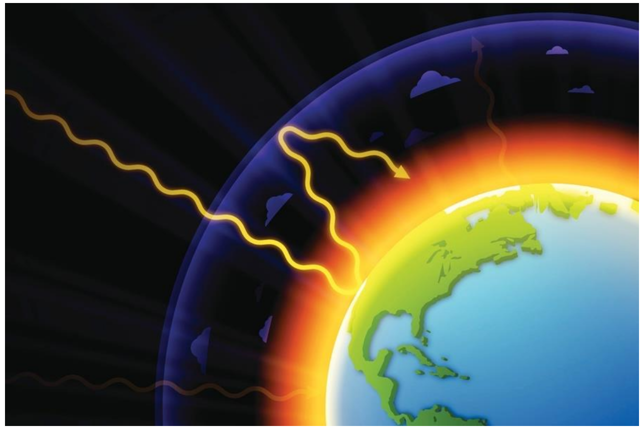
Context
Fossil Fuel Dominance



Oil, natural gas, and coal account for 80% of the U.S. energy consumption jump into STEM

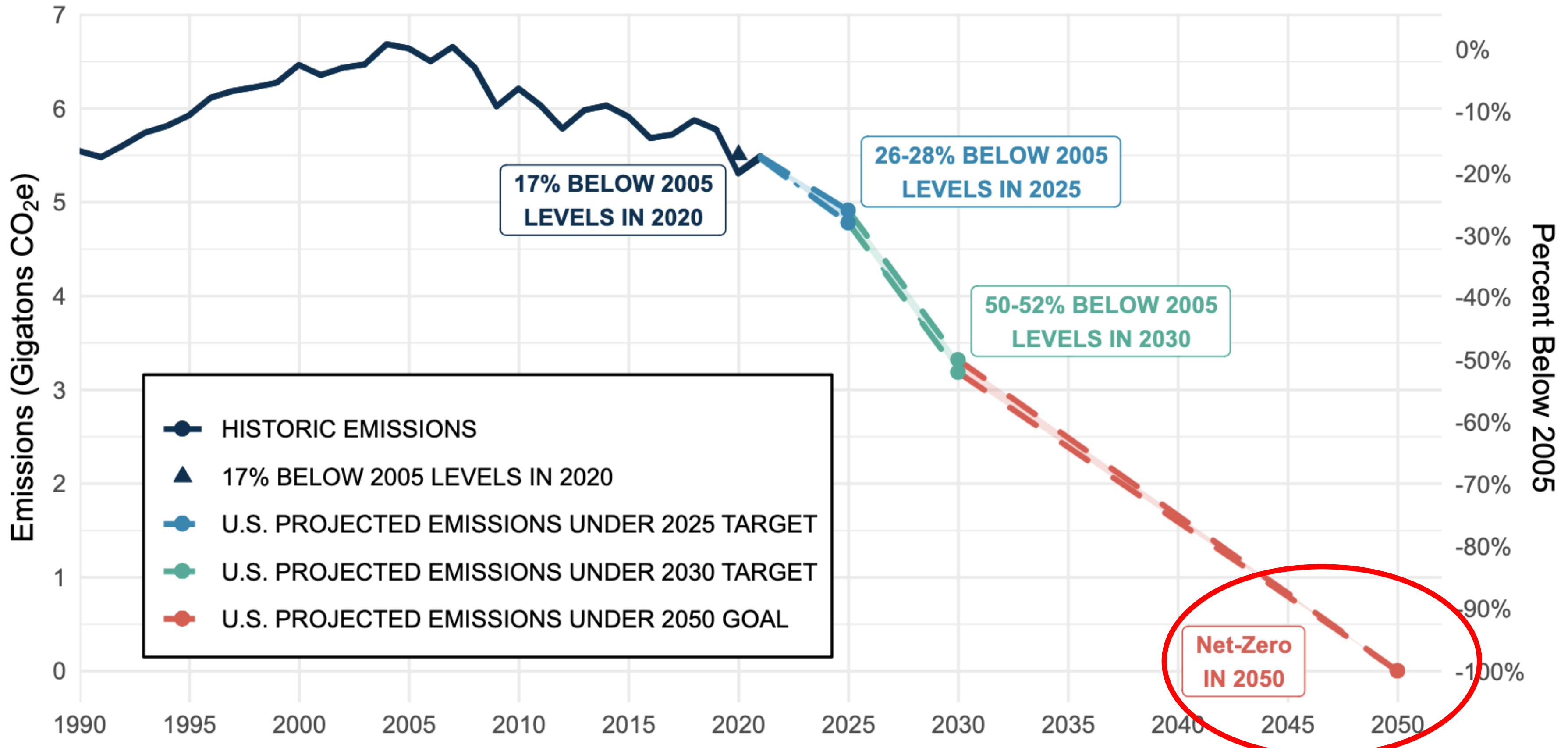
Context
Climate Change



Burning of fossil fuels for power generation, heating applications, and transportation → Excessive release of greenhouse gases into the atmosphere traps heat → More frequent and severe effects of global warming and climate change

Context

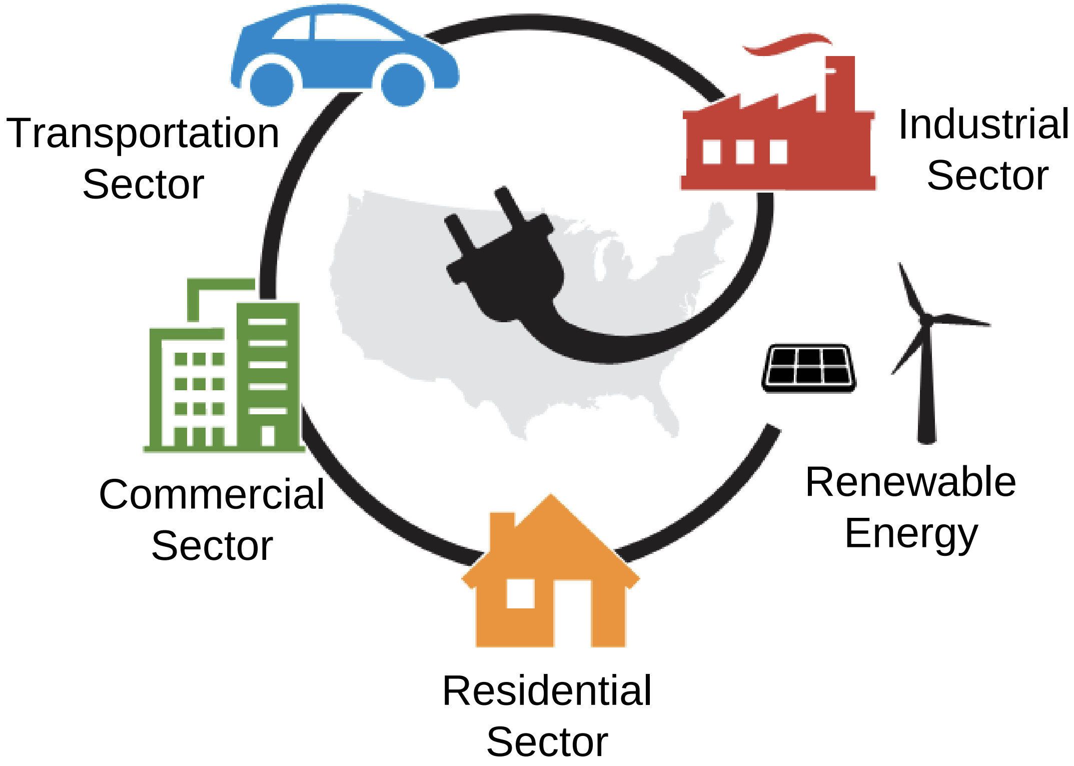
US Decarbonization Goals



U.S. historic emissions and projected emissions under the 2050 goal for net-zero.

Context
Transition to Renewable Energy

Electrification
Shifting from fossil-fuel based technologies to electricity-based technologies

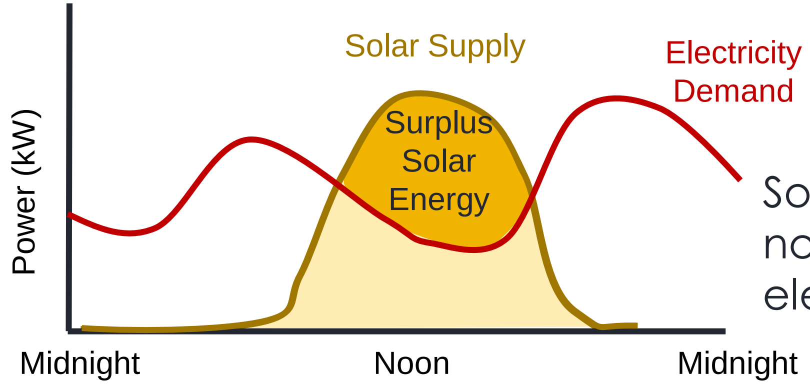


Economy-wide transition to renewable energy

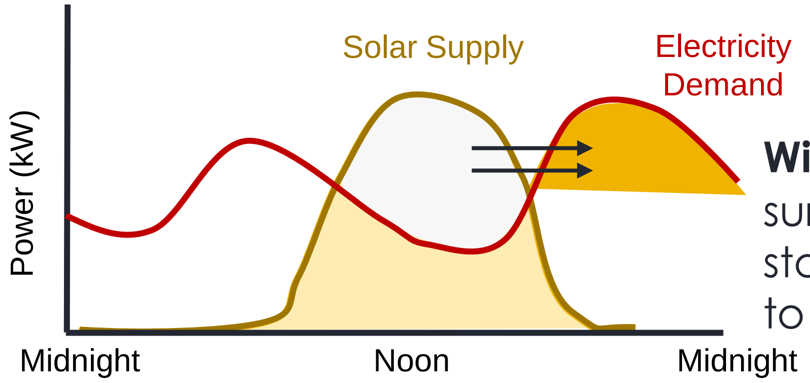
Clean electricity production
- Solar energy
- Wind energy
- Hydropower
- Geothermal energy
- Biomass energy

Context

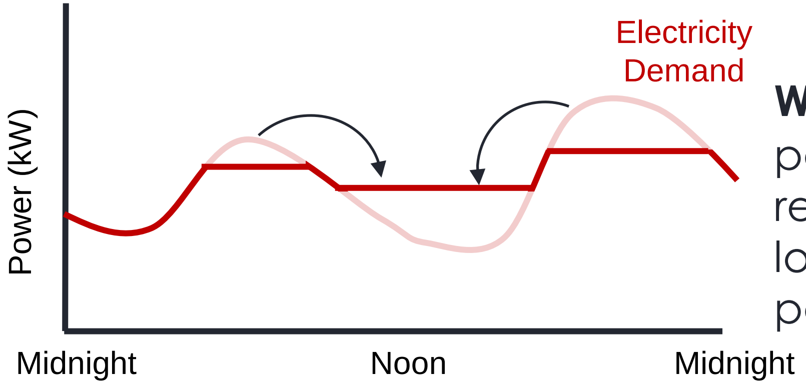
Role of Energy Storage



Solar energy supply not aligned with electricity demand



With energy storage, surplus energy can be stored and used later to meet the demand

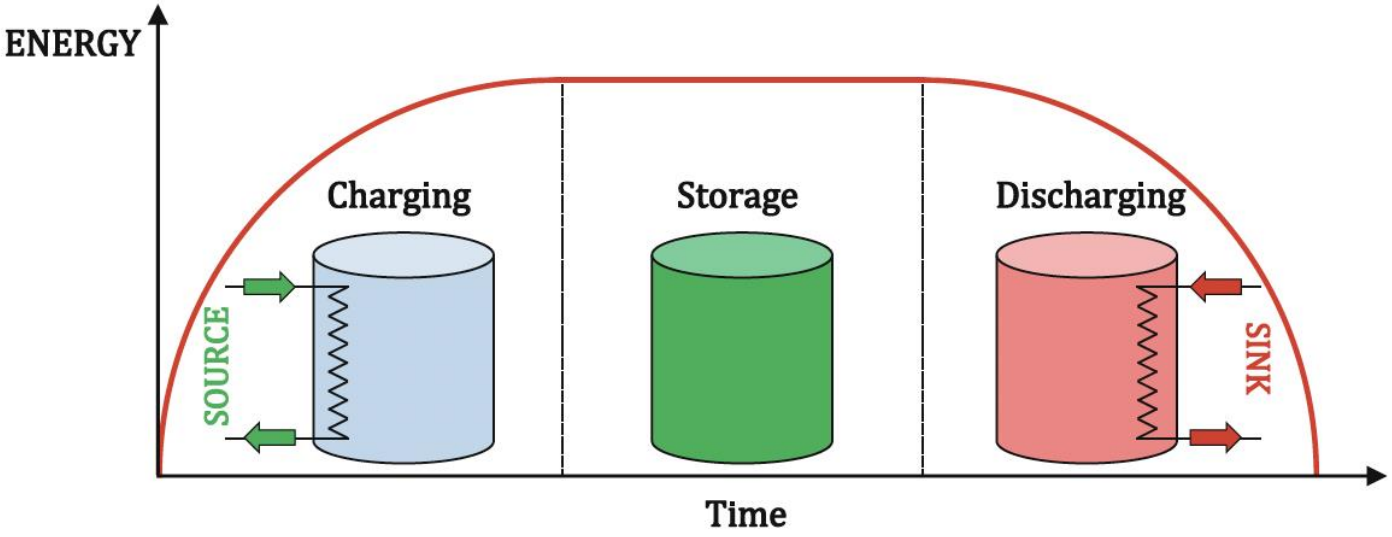


With energy storage, peak demand can be reduced by shifting loads to off-peak periods

Thermal Energy Storage (TES)

Types of Energy Storage

- Mechanical energy storage
  (e.g., compressed air storage)
- Electrical energy storage
  (e.g., capacitors)
- Electrochemical energy storage
  (e.g., batteries)
- **Thermal energy storage (TES)**
- Chemical energy storage
  (e.g., hydrogen storage)



A typical cycle of a TES unit

Classification of TES Technologies

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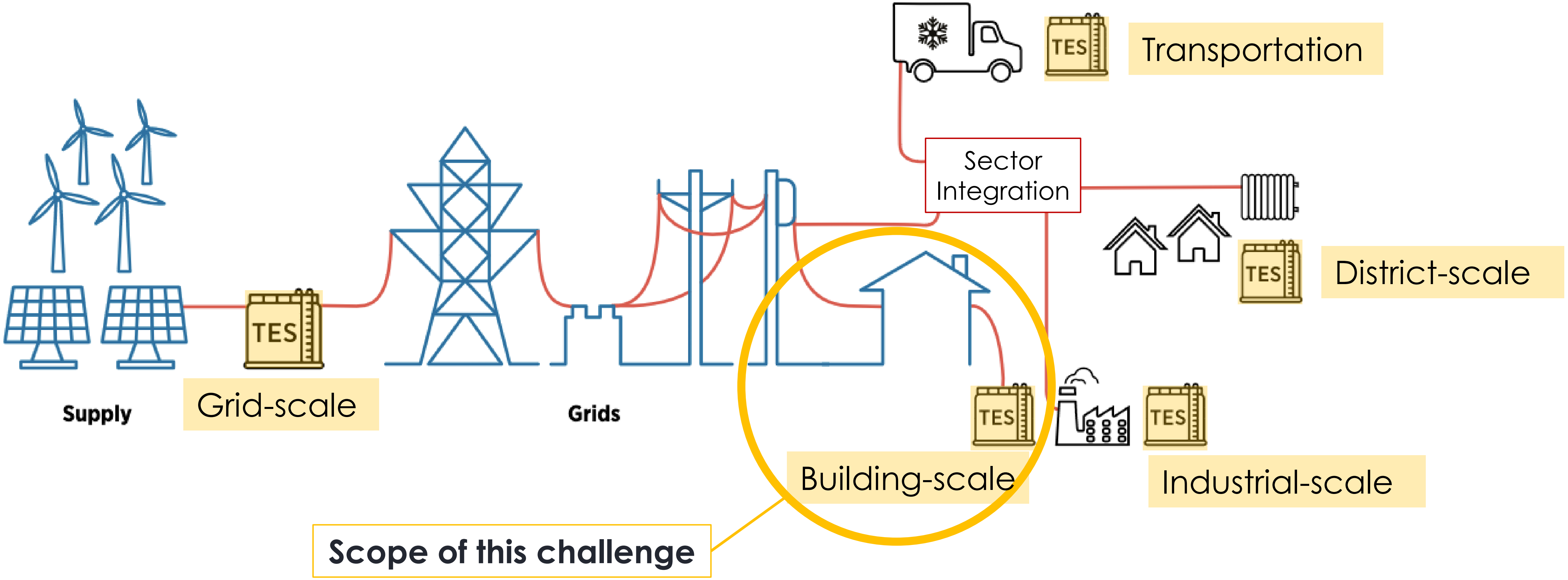
Types of Energy Storage

- Mechanical energy storage
  (e.g., compressed air storage)
- Electrical energy storage
  (e.g., capacitors)
- Electrochemical energy storage
  (e.g., batteries)
- **Thermal energy storage (TES)**
  - By storage mechanism
  - By storage temperature
  - By storage duration
  - By scale of application
- Chemical energy storage
  (e.g., hydrogen storage)

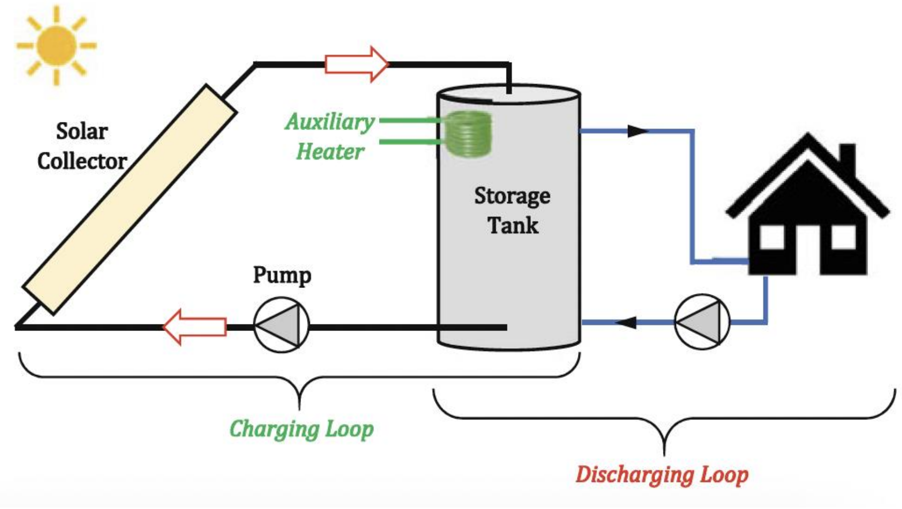
Classification of TES
By Scale of Application



Classification of TES
By Storage Temperature

High temperature storage (heat storage)

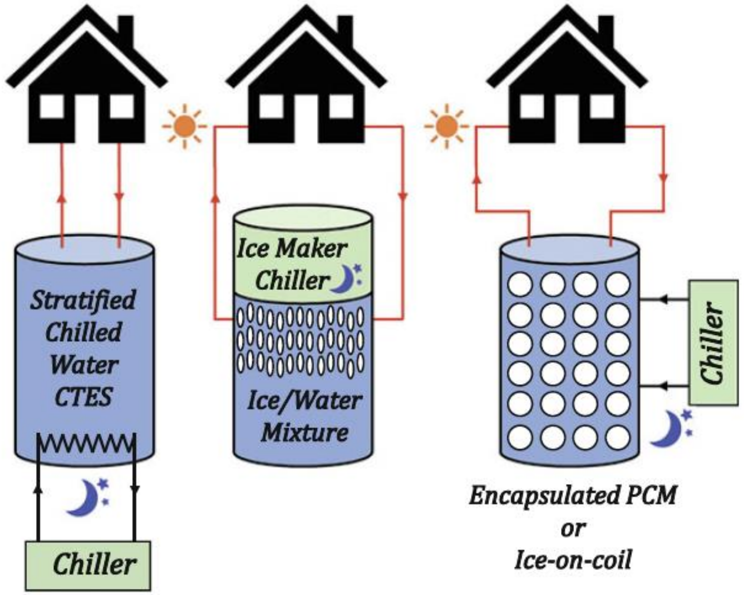
Building applications: space heating, water heating



High temperature TES for solar thermal system

Low temperature storage (cold storage)

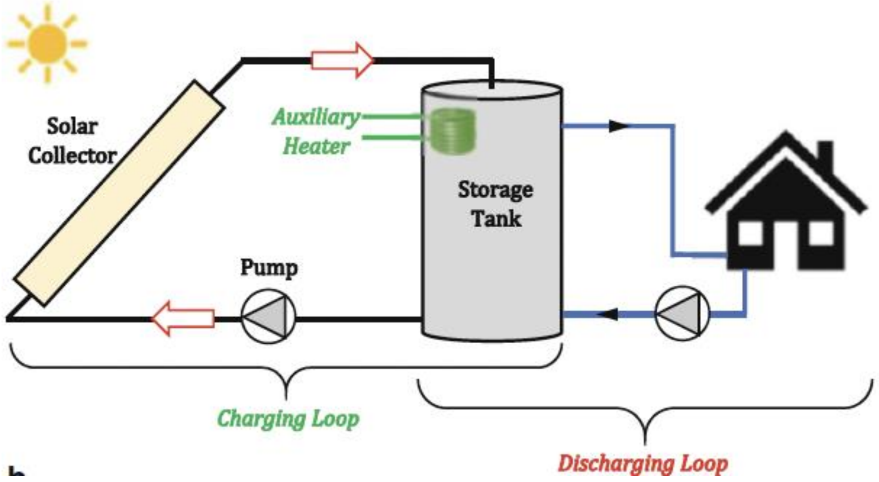
Building applications: space cooling, refrigeration



Low temperature underground TES

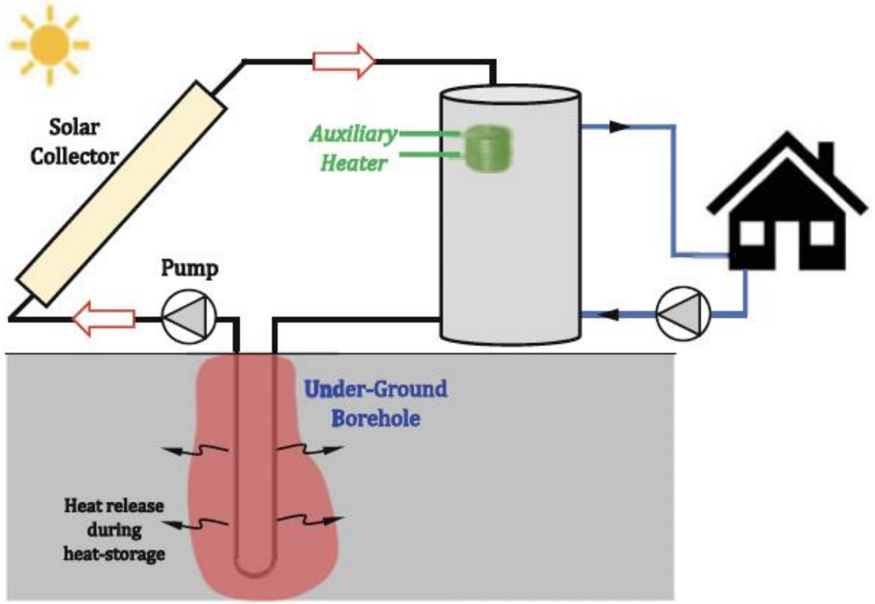
Classification of TES
By Storage Duration

Short-term storage (for few hours to few days)
Building applications: On-site renewable system integration, demand management, load shifting



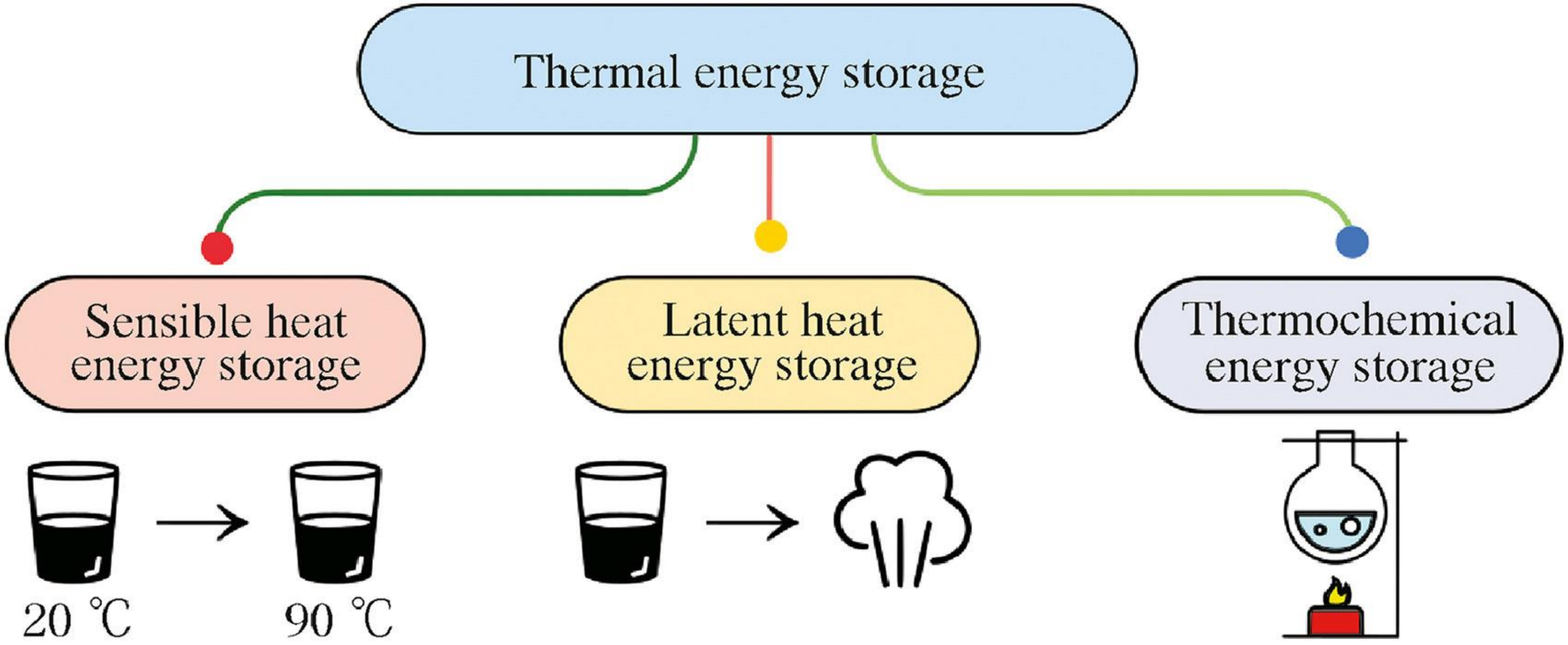
Short-term storage for space heating

Long-term storage (for several days, weeks, or months)
Building applications: On-site renewable system integration for space heating, space cooling, and water heating



Long-term storage for space heating

Classification of TES
By Storage Mechanism



Sensible heat storage medium (e.g., water tanks, concrete)

Phase change materials (PCM)

Reversible chemical reactions

Characteristics of TES Technologies

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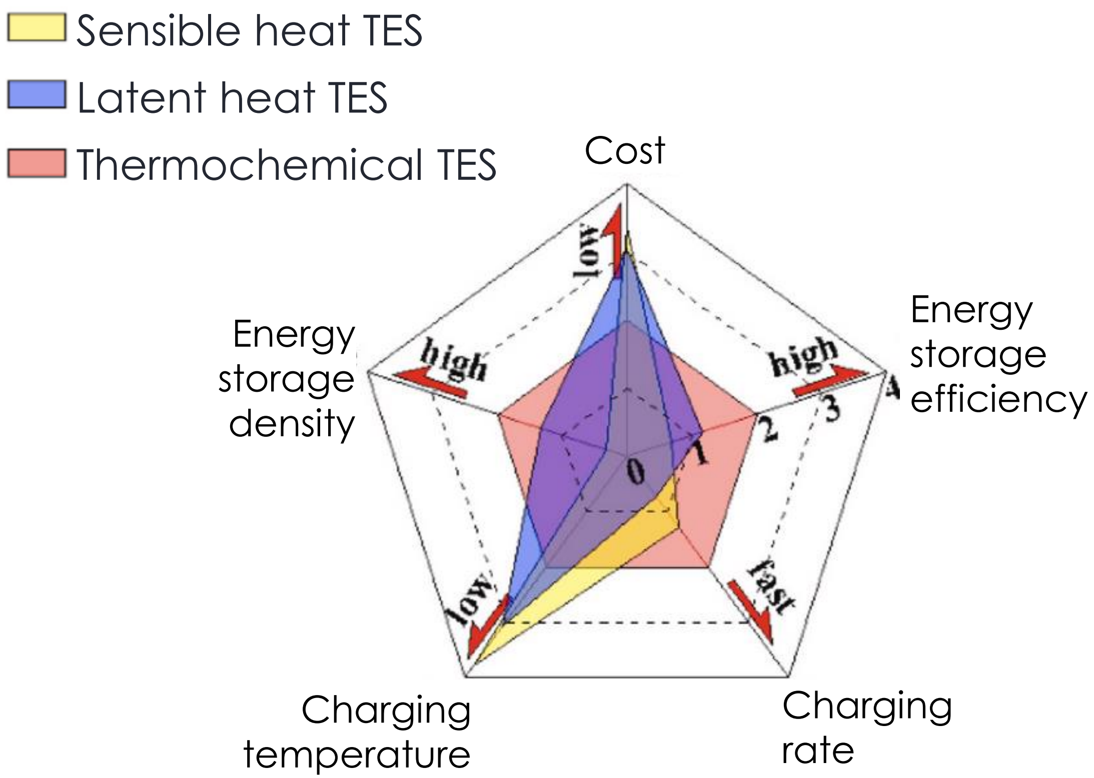
Basic TES technologies



TES technologies for enhanced performance

- Hybrid TES materials
- Hybrid TES system
- Advanced TES cycles
- Short-term + long-term storage

TES in Building Applications

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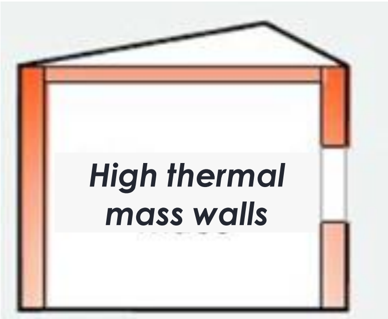
Passive applications



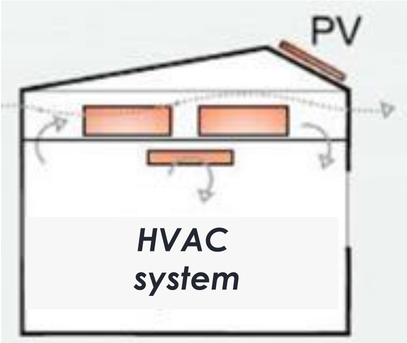
Storage in building structure

(with passive solar heating and/or night ventilation)

Active applications

Storage in building structure

(activation using air or water distribution)

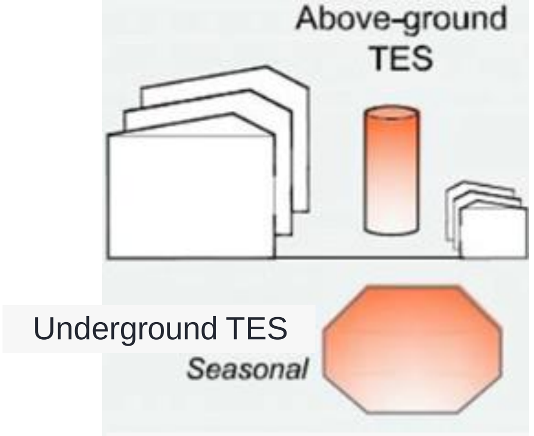


Storage in HVAC system

(cooling or ventilation system)

Solar thermal system

(water or water with PCM)



Storage in surrounding area

(borehole, aquifer, pits, water tanks)

The Challenge

Develop an innovative solution for TES for buildings to optimize energy use, enhance sustainability, and increase resilience. The solutions could involve (but are not limited to) the integration of materials, systems, and controls for the storage and release of energy. The cost for implementing TES should be affordable or recoverable from the benefits provided by the TES.

Examples

Building Type Specific Solutions

Design strategies for TES integration in buildings specific to

- Building type
  - Residential – single-family, multifamily
  - Commercial – office, retail, educational, heath care, food sales, etc.
- New construction vs existing building

Examples

Building System Specific Solutions

Innovative solutions for TES application in buildings that utilizes

- Building materials, components, or structure
- HVAC or water heating systems
- Renewable energy systems
- Waste heat in buildings

Examples

Advanced Controls

Cost-effective solutions to maximize the benefits TES by combining

- **Advanced controls to optimize TES operation** based on
  - real-time energy demand,
  - weather forecasts, and
  - occupancy patterns
- **Innovative business models**, such as
  - demand response programs
  - time-of-use pricing
  - TES-as-a-service
  - energy-sharing networks with neighboring buildings

Additional Resources

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R&D pathways for TES technologies

Department of Energy TES Subprogram Area. https://www.energy.gov/eere/buildings/thermal-energy-storage

Priorities and Pathways to Widespread Deployment of Thermal Energy Storage in Buildings. https://www1.eere.energy.gov/buildings/pdfs/80376.pdf

Fundamental Needs for Dynamic and Interactive Thermal Storage Solutions for Buildings. https://www.nrel.gov/docs/fy20osti/76701.pdf

Innovation Outlook: Thermal Energy Storage. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_Innovation_Outlook_TES_2020.pdf?rev=6950b7b9792344b5ab28d58e18209926

Role of Thermal Energy Storage in National Roadmap for Grid-Interactive Efficient Buildings. https://escholarship.org/content/qt78k303s5/qt78k303s5.pdf

TES application in buildings

Thermal energy storage in building integrated thermal systems: A review. Part 1. active storage systems. https://doi.org/10.1016/j.renene.2015.11.040

Thermal energy storage in building integrated thermal systems: A review. Part 2. Integration as passive system. https://doi.org/10.1016/j.renene.2015.06.064

Thermal Energy Storage: A State-of-the-Art. https://www.sintef.no/globalassets/upload/smartbygg/wp3/thermal-energy-storage.pdf

Adaptive dynamic building envelope integrated with phase change material to enhance the heat storage and release efficiency: A state-of-the-art review. https://doi.org/10.1016/j.enbuild.2023.112928

Energy flexibility of residential buildings using short term heat storage in the thermal mass. https://doi.org/10.1016/j.energy.2016.05.076

A review on phase change materials for thermal energy storage in buildings: Heating and hybrid applications. https://doi.org/10.1016/j.est.2020.101913

Data on commercially available TES materials

Advances in thermal energy storage materials and their applications towards zero energy buildings: A critical review. https://doi.org/10.1016/j.apenergy.2017.06.008

TES incentives

PG&E Thermal energy storage program. https://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/demandresponse/pls/TESFactsheet.pdf

Austin Energy. https://savings.austinenergy.com/commercial/offerings/cooling-and-heating/thermal-storage

TVA's Thermal Ice Storage Incentive. https://energyright.com/business-industry/incentives/thermal-storage/

Image Credits

Slide 2 (Fossil Fuel Dominance)

https://www.eia.gov/energyexplained/us-energy-facts/

Slide 3 left to right (Climate Change)

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https://news.mit.edu/2017/explained-greenhouse-gases-0130

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"Hurricane Katrina as seen by NOAA satellite" by NOAA Images is marked with Public Domain Mark 1.0.

Slide 4 (US Decarbonization Goals)

The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050. November 2021. https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf

Slide 5 (Transition to Renewable Energy)

https://www.nrel.gov/analysis/electrification-futures.html

Slides 7, 10, and 11 (Thermal Energy Storage; Classification of TES)

Dincer, I., and M.A. Ezan. 2018. Heat Storage: A Unique Solution For Energy Systems. https://doi.org/10.1007/978-3-319-91893-8

Slide 9 (Classification of TES: By Scale of Application)

IRENA. 2020. Innovation Outlook: Thermal Energy Storage, International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_Innovation_Outlook_TES_2020.pdf?rev=6950b7b9792344b5ab28d58e18209926

Slide 12 (Classification of TES: By Storage Mechanism)

Mitali et al. 2022. Energy storage systems: a review. Energy Storage and Saving 1(3):166-216. https://doi.org/10.1016/j.enss.2022.07.002

Slide 13 (Characteristics of TES Technologies)

Ding et al. 2021. Advanced/hybrid thermal energy storage technology: material, cycle, system and perspective. Renewable and Sustainable Energy Reviews 145 (July 2021): 111088. https://doi.org/10.1016/j.rser.2021.111088

Slide 14 (TES in Building Applications)

Lizana et al. 2017. Advances in thermal energy storage materials and their applications towards zero energy buildings: A critical review. Applied Energy 203 (1 October 2017): 219-239. https://doi.org/10.1016/j.apenergy.2017.06.008

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