Thermal Energy Storage Research at Energy Technology






TES Research in KTH- EGI

Advanced TES concepts using e.g. phase change materials (PCM) for high energy storage capacity for any temperature.

1. **PCM for TES- Material development**
   - Systematic Design of cheap PCM
   - Polyols as renewable and safe PCM
2. **TES Components Study**
   - TES Fundamental Modelling
   - Stratified TES Enhancement
   - PCM Heat Transfer Enhancement
3. **TES Systems Assessments**
   - Passive Building with Free Cooling
   - "Heat on Wheels": Mobile TES with PCM
   - TES for District Heating and Cooling
   - Thermal Microgrid with Advanced Storage for the Polygeneration

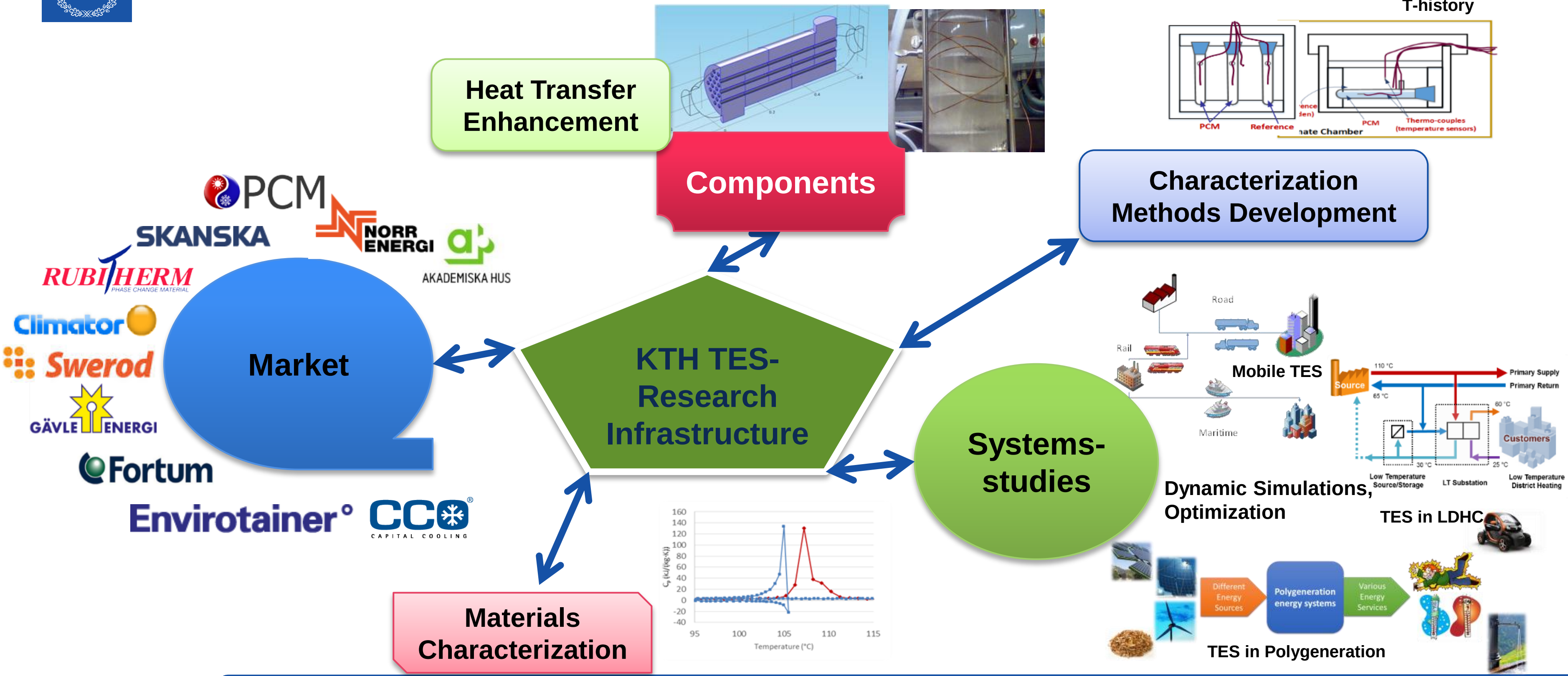
Participates in the IEA's implementing agreement on energy storage (IEA/ECES)

Annex 28: Integration of Renewable Energies by Distributed Energy Storage Systems

Annex 24, 29: Advanced Material Design for Compact TES+ contd with new annex

Annex 30: Thermal Energy Storage for Cost Effective Energy Management and CO_2 Mitigation

What Do We Do?



Heat Transfer Enhancement
Components
T-history
PCM
Reference
Thermo-couples (temperature sensors)
Characterization Methods Development
Market
PCM
SKANSKA
NORR ENERGI
AKADEMISKA HUS
RUBITHERM
PHASE CHANGE MATERIAL
Climator
Swerod
GÄVLE ENERGI
Fortum
Envirotainer
CCO
CAPITAL COOLING
KTH TES-Research Infrastructure
Road
Rail
Maritime
Mobile TES
Source
Primary Supply
Primary Return
Customers
Low Temperature Source/Storage
LT Substation
Low Temperature District Heating
Systems-studies
Dynamic Simulations, Optimization
TES in LDHC
Materials Characterization
Temperature (°C)
Different Energy Sources
Polygeneration energy systems
Various Energy Services
TES in Polygeneration

Current TES Projects at KTH

Materials (PCMs)

- Polyols, Alkanes
- **Systematic design of cost-effective blends using phase diagrams**, T-History
- 5 years (2012-2016)

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Components

- **Heat transfer enhancement**
- **Heat Exchangers**
- Single and multi-PCM design
- Experimental, theoretical
- 5 years (2016-2020)

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Applications

- **Heat on Wheels- Mobile TES with PCMs**
- TES applications with Heat Pumps
- Experimental, theoretical
- Techno-economic analysis, optimization
- 3 years (2014-2016)

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effsys EXPAND Resurseffektiva kyl- och värmepumpssystem samt kyl- och värmelager

Systems

1. **Low Temperature DHC**

- Theoretical, techno-economic analysis
- 4 years (2014-2017)

European Commission ERASMUS MUNDUS

2. Polygeneration with Thermal Microgrid

- Design and development of thermal microgrid and PCM storage by modelling
- 4 years (2016-2019)

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Systematic Design of Cost-effective Phase Change Materials

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PCMs for Thermal Energy Storage (TES)

Cheap PCM with sharp temperatures of phase change and no phase segregation

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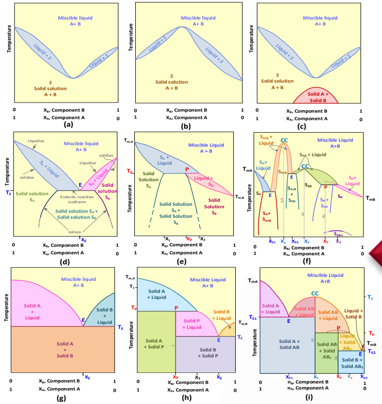
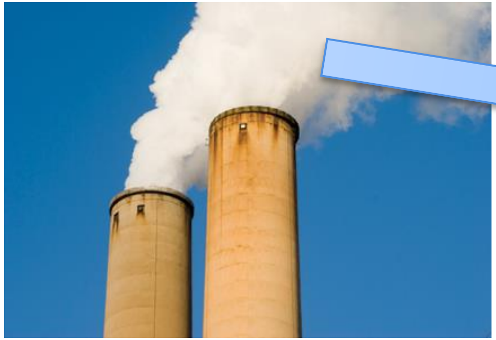
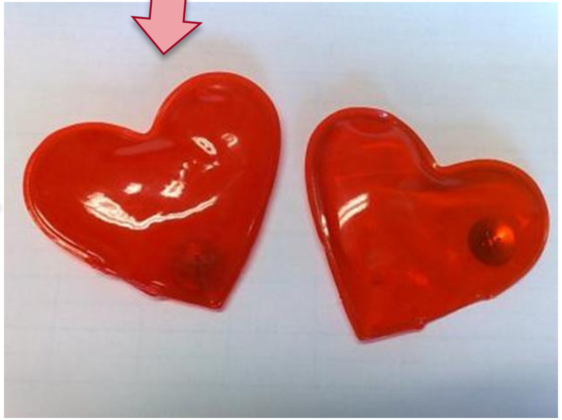
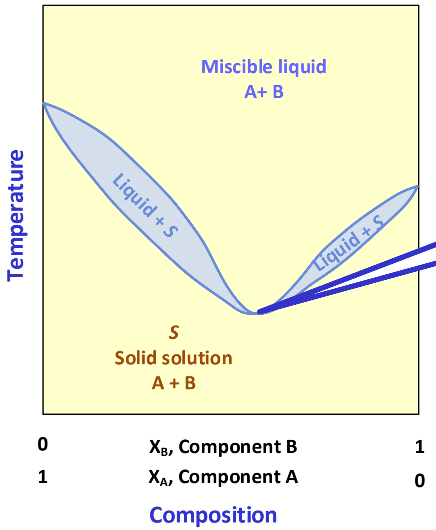




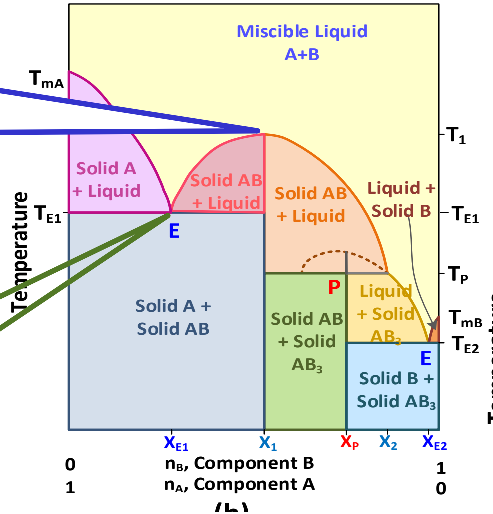


Blend PCMs Design → Phase Diagrams



Congruent Melting

Sharp temperature,
No phase segregation:
same density

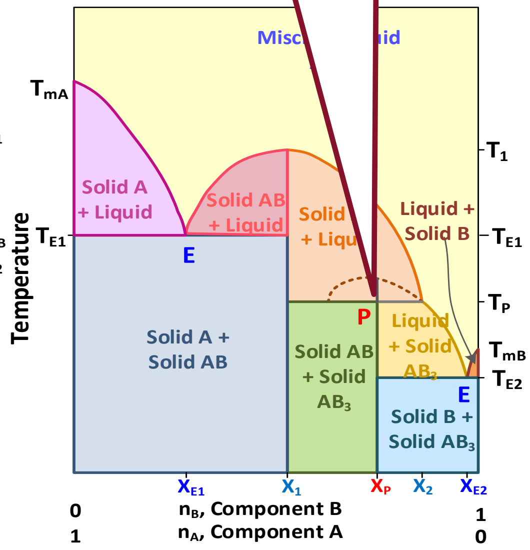


Sharp temperature,
No phase
segregation if no
supercooling

Eutectic

Peritectic

Coring, subcooling,
phase segregation



Polyols as Renewable and Safe PCM

Melting -15 to 245 ˚C

Fusion enthalpies

100-413 kJ/kg

Safe, renewable materials

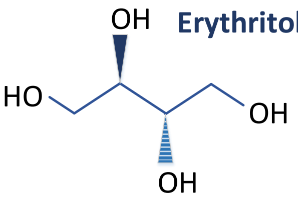
Rather expensive,

- potential to be cheaper

Complex behaviors

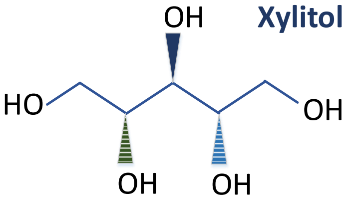
- Thermally activated change
- Glass transition

$C_4H_{10}O_4$



Erythritol

$C_5H_{12}O_5$



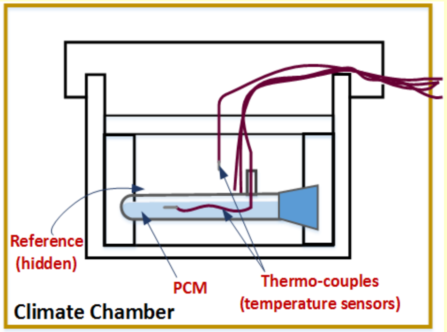
Xylitol

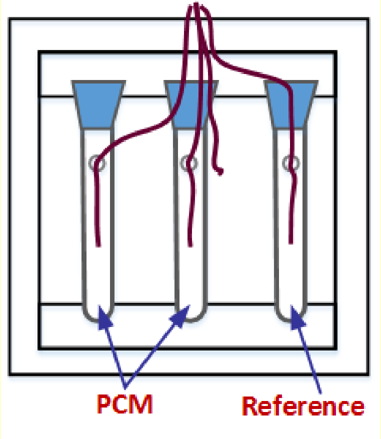
http://ecx.images-amazon.com/images/I/51V4cEcSymL.SX316_SY500_CR,0,0,316,500_PIbundle-3,TopRight,0,0_SX316_SY500_CR,0,0,316,500_SH20_.jpg, http://www.lawyersandsettlements.com/blog/tag/vitaminwater, http://thechalkboardmag.com/wp-content/uploads/2014/08/Chewing-Gum.jpg, http://www.cargillfoods.com/na/en/market-categories/dairy/index.jsp, http://www.climatetechwiki.org/sites/climatetechwiki.org/files/images/teaser/1576436_delta_cool1.jpg

Experimental Determination of Blends Phase Diagrams

- Armed, stainless steel test-tubes,
- Up to 7 samples, 1-2 references (Solid ETP Copper blocks)
- Hygross Climate Chamber
- T-type thermocouples

Temperature-History (T-History) Method





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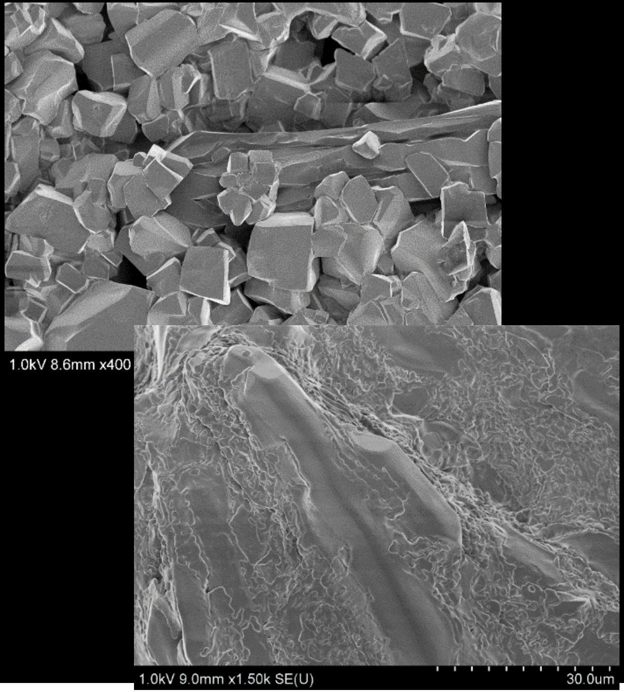
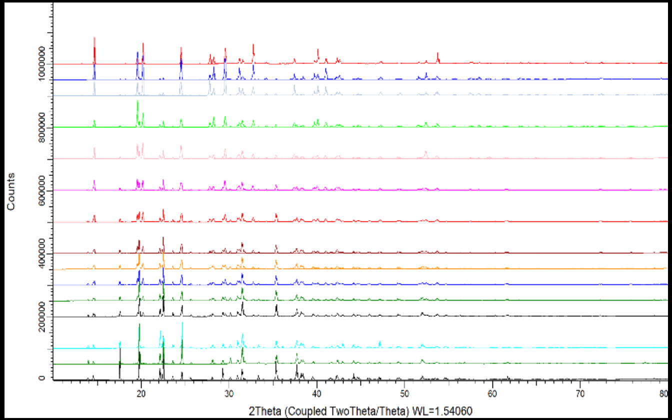
Erythritol-Xylitol Polyols Blend as PCM

T-history: Thermal Properties

SEM imaging

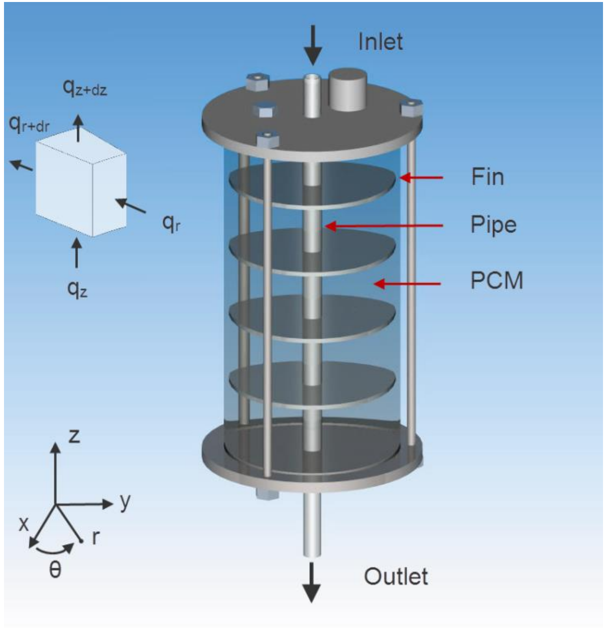


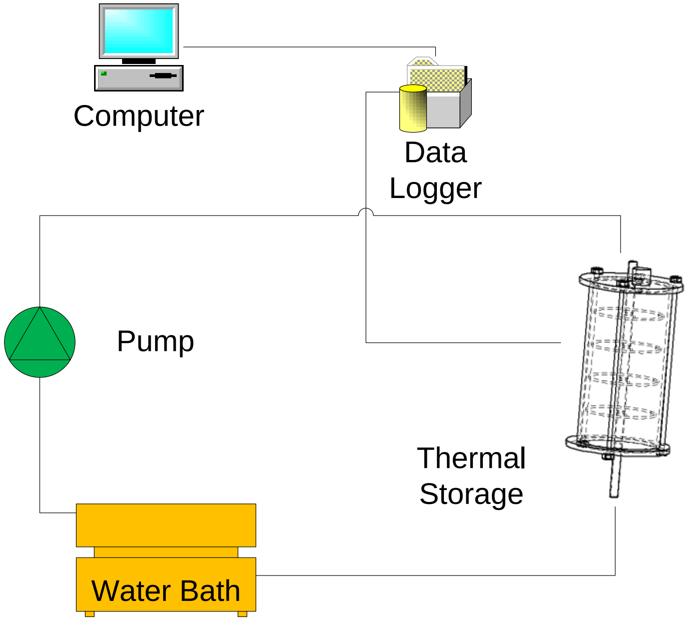
XRD analysis



2.1 TES Modelling and Experimentation

PCM Heat Transfer Model Verification





Energy Storage Stratification Enhancements

- Stratification of the water at very small differences in density.
- PCM can reinforce the thermocline and increase storage capacity slightly.

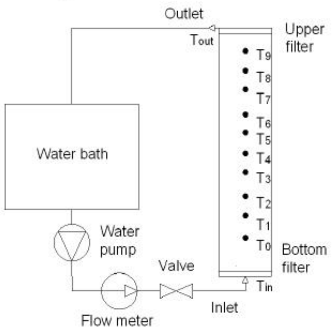
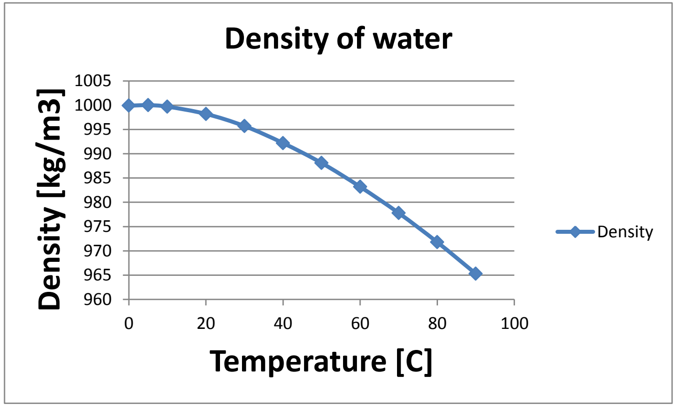
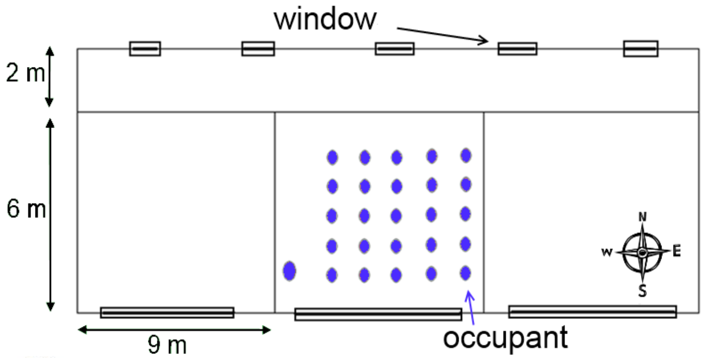


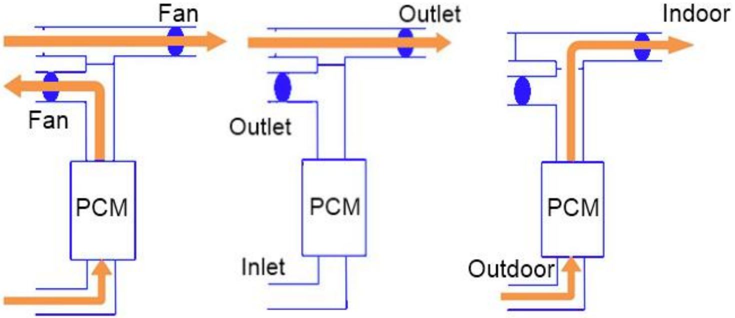
Fig. 1. Scheme of the experimental set up used in the experimentation.

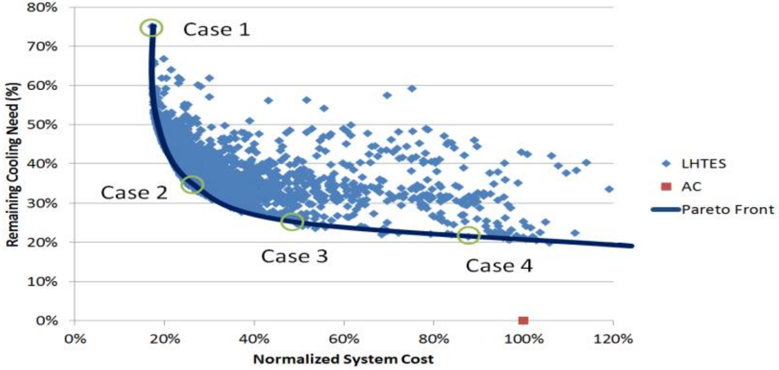
Fig 2. Storage tank filled with PCM [16].

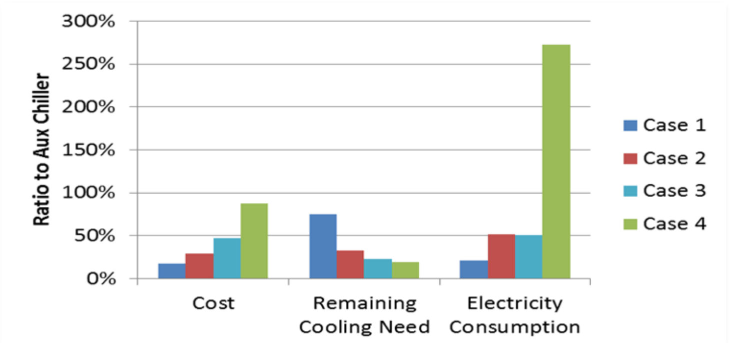


Techno-Economic Optimization of Passive Design









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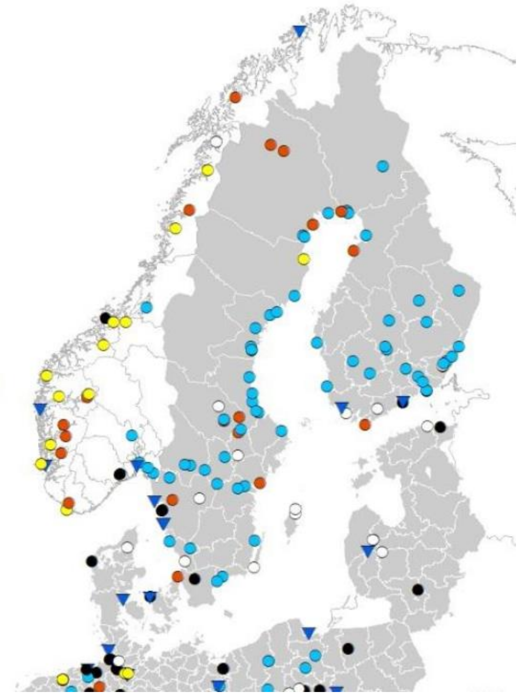
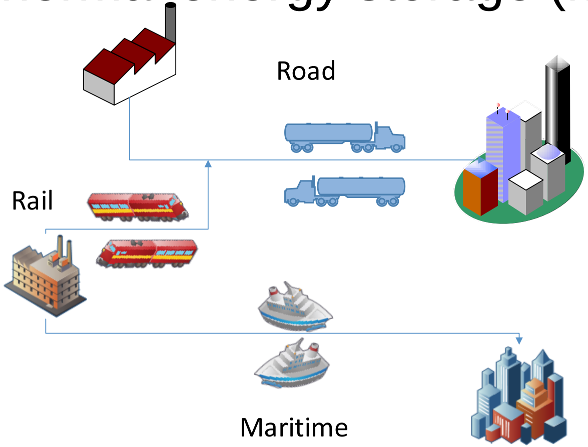
Reuse of Industrial Waste Heat



Industrial waste heat: 20% - 50%

Building sector heating and cooling: 40%

Use of waste heat in residential and service sector via mobile thermal energy storage (M-TES)



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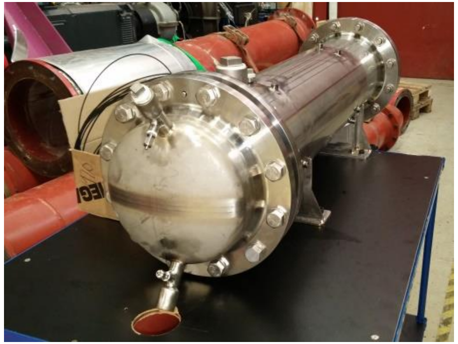
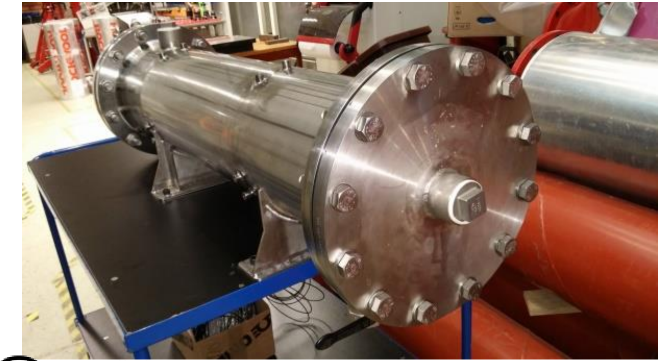
Experimental Validation





Tema VÄRME

Svenska industrier och fastigheter eldar fortfarande mycket för kråkorna. Det vill forskare och företag ändra på med hjälp av värmelagring i fasändringsmaterial. I laboratoriet på KTH i Stockholm startar nya experiment i höst.

TEXT MARIE GRANMAR FOTO FREDRIK STEHN

PCM ska ta vara på spillvärmen

Solen värmer fortfarande rejält den sensommardag då Energi & Miljö besöker KTH:s institution för energiteknik, avdelningen för kraft och värme. Längs promenaden från tunnelbanan syns klungor av studenter iklädda overaller eller vinröda kepsar. Nollningsaktiviteter pågår och snart börjar kurserna för framtidens ingenjörer.

I laboratoriet jobbar forskarna för fullt med sina experiment, för att hinna klart med så mycket som möjligt innan undervisningen drar igång. En trappa upp i tegelhuset på Brinellvägen 68 arbetar forskaren Justin Chiu med en testrigg för värmelagring i fasändringsmaterial. Målet är att visa hur spillvärme från industrier kan transporteras från en plats till en annan, exempelvis till ett fjärrvärmenät.

– 40 procent av Sveriges producerade energi används för värmning och kylning av byggnader. Samtidigt går nästan hälften av industrins producerade värme till spillo – så vi vill använda mer av den värmen! säger han.

En cirka två meter lång ståltub, försluten med kraftiga bultar i varje ände, står uppställd på en bänk. Snart kommer den att kopplas till en flödespump, mätare, dator och ett avrinningssystem, för att förhoppningsvis lämna de första resultaten om ett par månader.

Inuti värmeväxlartuben, med lagringskapaciteten 7 kWh, finns ett flertal smala tuber av rostfritt stål genom vilka vatten eller olja kan cirkulera. Utrymmet runt tuberna fylls snart med fasändringsmaterial, PCM, med känd smälttemperatur. Till att börja med sockeralkoholen erytritol som smälter vid cirka 120 °C.

– Men vi kommer att kunna testa många olika material, även salter. Värmen som kommer in i tuben ska ligga runt 140 °C och det som kommer ut ska hålla samma temperatur som fjärrvärmereturer, alltså 40, 50 eller 60 grader, säger Justin Chiu.

Målet för experimenten är att visa att det går att lagra så mycket värme som teorierna föreslår, och att det fungerar i 100-tals eller kanske till och med 1 000-tals cykler. Det är också viktigt att det går snabbt att lagra och plocka ut värmen.

– Vi kommer att testa energiuttaget per timme, minut eller sekund. Att få ut all energi ur den här lilla testriggen tror vi kommer att ta mellan 20 och 40 minuter, säger Justin Chiu.

En viktig poäng med testriggen är att den också är skalbar, så att det som mätningarna här visar går att räkna upp till större dimensioner och lagringskapacitet.

– I en verklig tillämpning kommer många sådana här tuber att ligga i en stor tank – i en lastbil,

Svenska PCM-lager

- Flera värmelager med fasändringsmaterial har installerats i Sverige sedan 1990-talet. Till de mest kända hör saltlager med aluminiumpåsar i biblioteket i Skövde och i Stockholms stadsmuseum, ett lager med salt i Boda Kvarn i Katrineholm samt ett lager med 1 000 saltfyllda plaststavar i en träningslokal i Borås.
- Vissa lagrar enbart spillvärme från lokaler, medan andra kombinerar med värme från solfångare. En viktig drivkraft i utvecklingen av PCM-teknik är att försöka få fram lager som är så kompakta och billiga som möjligt.

Saman Gunasekara, Viktoria Martin och Justin Chiu ska testa olika sorters fasändringsmaterial i en ny testrigg.

»

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2.2 Heat Transfer Enhancement in PCMs

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Main Objective

Developing PCM-based thermal energy storage with high capacity and power through fundamental studies of heat transfer mechanisms

Areas of Research

- **Conduction**: conductivity enhancement through adding nano-particles, metal foams, powders.
- **Convection**: enhancing forced and natural convection
- The use of different materials including nano-particles and metal foams
- Investigating new heat exchanger configurations

The research will be conducted by modeling and simulations. In parallel, experiments will be carried out to validate the numerical work.

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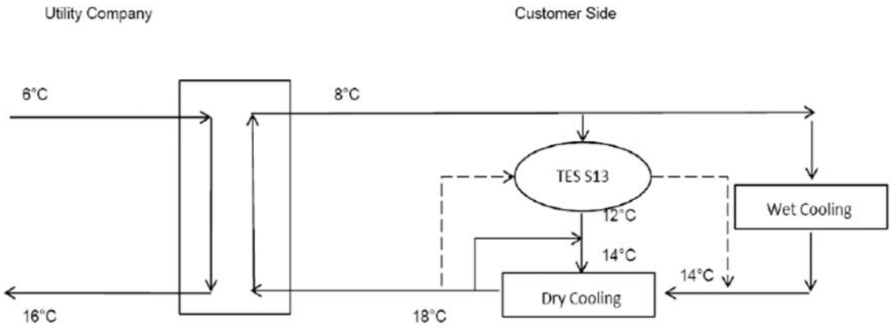
3.1 TES for District Heating and Cooling

Decentralized Cold Storage in Stockholm

One way to handle peak loads!

- During charging, it is not possible to return to 16 ° C, leading to a cost-based penalty under current pricing
- The proportion of cost-effective shaving of the peak load (power) depends on the load curve - this 10-30% cost depending on the PCM price.



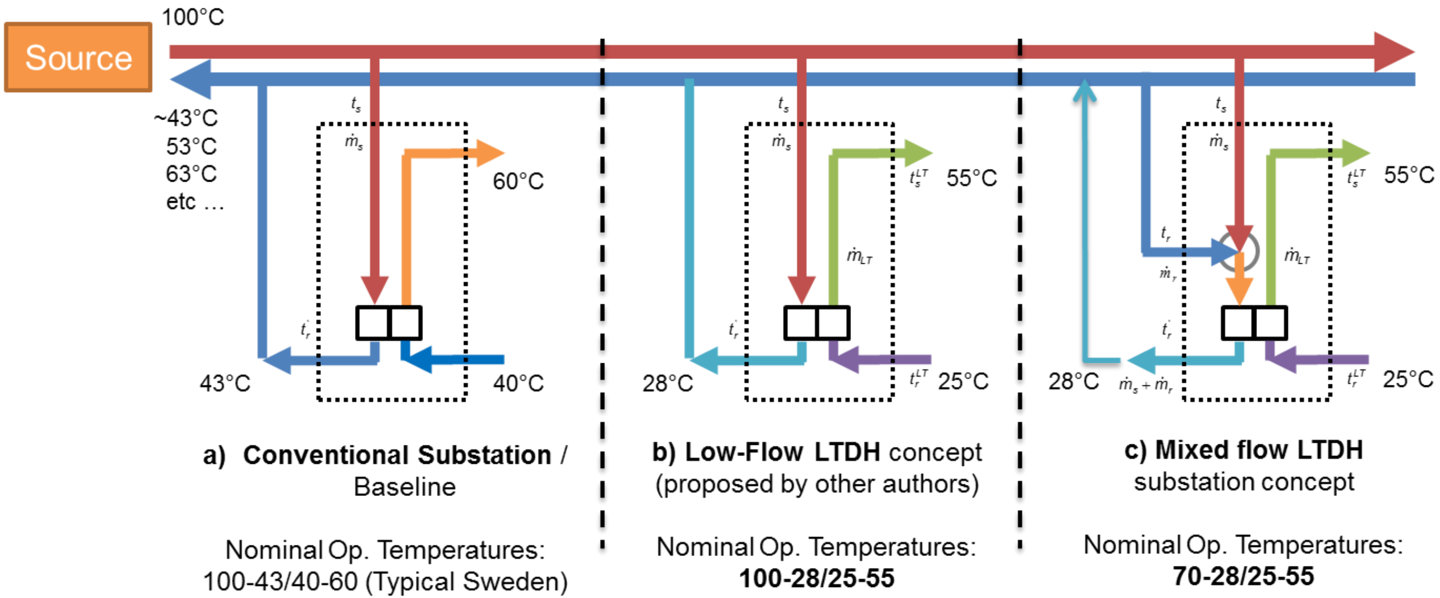
Chiu, 2013

Description

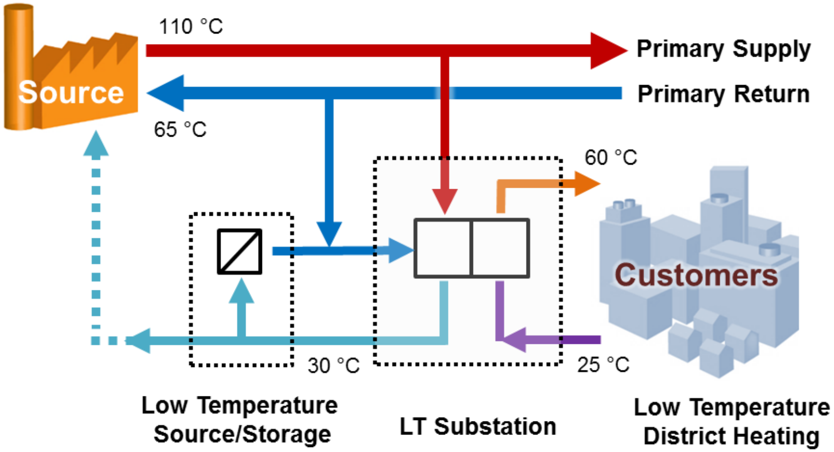
Comparison of impact of % penetration of LTDH subnets in a DH network

- Emphasis in savings and potential additional earning from heat/power generation

- Three types of substations compared:



Low-Temperature Substation



Schematic of the Low-Temperature substation with Primary and Secondary networks, and low temperature heat sources/storage

The low-temperature substation as **link** to connect the secondary network to the main network

It can use a **mix** of low-temperature heat resources:

- **Return flow** from the primary network (temperature cascading)
- **Solar thermal**, **Geothermal**
- **Industrial** surplus heat

Thermal energy storages (TES)

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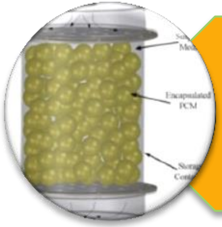
3.2 Design and Implementation of a Thermal Microgrid with Advanced Storage for the Polygeneration Lab

Background & Aims

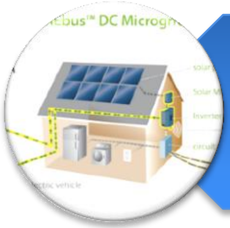
Aims

Designing and implementing a **Thermal Microgrid**, including a **Small Scale PCM Thermal Storage**, to ***effectively integrate*** different rigs in the Polygeneration lab (i.e., Micro Gas Turbine, Membrane Distiller, Stirling Engine, Fuel Cell, Gasifier), and ***balance out the system*** in order to reach its highest potential

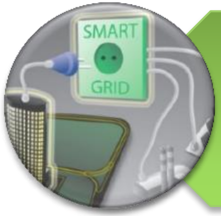
Project Focuses



Small Scale PCM Thermal Storage



Thermal Microgird



Integration of different energy components: Smart Control Strategies

Project Timeline

2016
- Mapping out problems and available solutions of collecting and utilizing waste heat in polygeneration systems
- Reviewing PCM technologies suitable for small scale applications

2017
- Designing the thermal microgrid and PCM storage by modelling
- Inter-correlations between different components of the polygeneration system are examined

2018
- Developing the thermal microgrid and PCM storage based on modelling results
- Control strategies and integration methods are evaluated

2019
- System testing and adjustments
- System assessment and sensitivity analysis

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