Thermal Energy Storage in industrial processes

Contribution to energy efficiency, energy flexibility and increasing the share of renewable energy

R. de Boer

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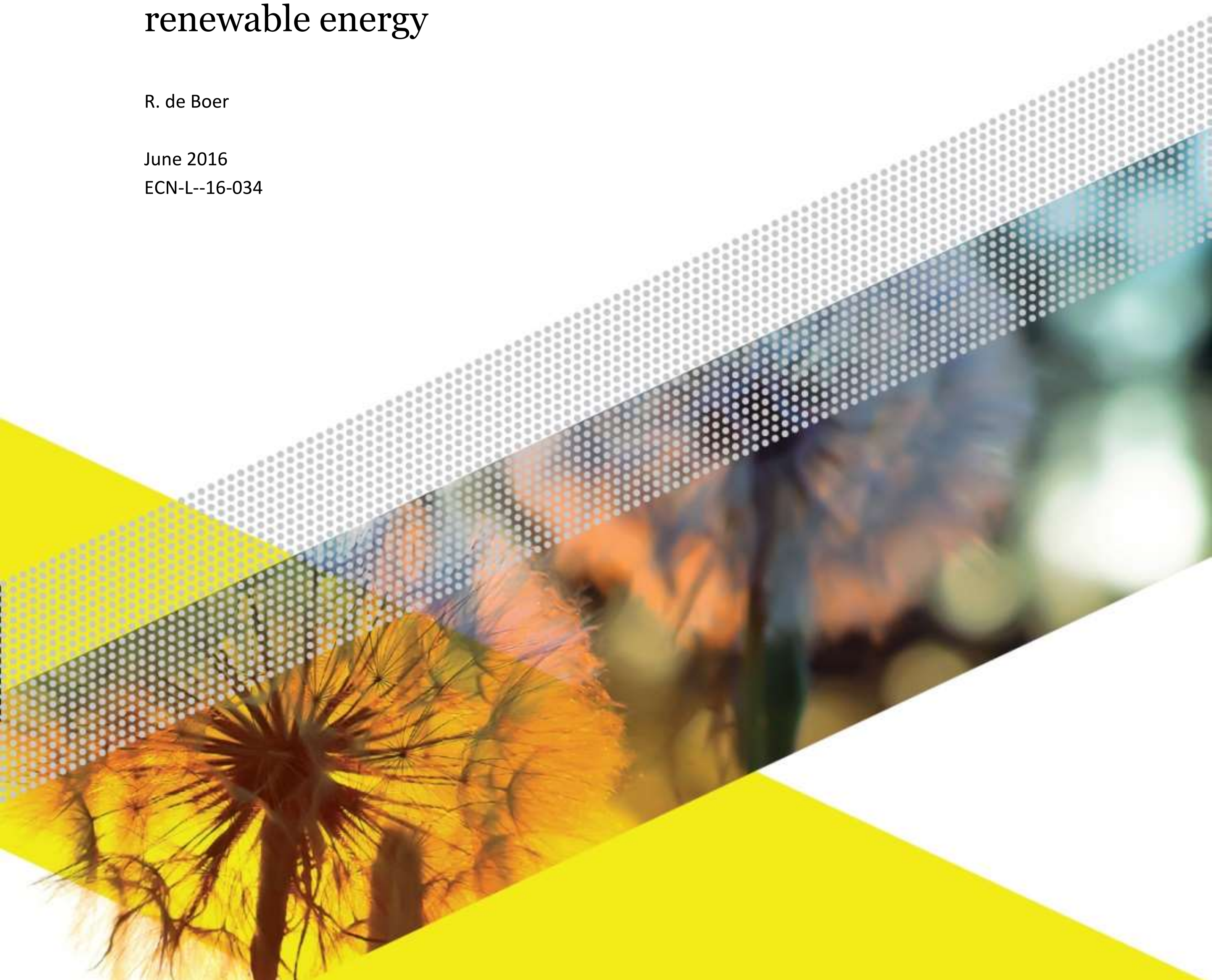

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and increasing the share of renewable energy

Robert de Boer
May 24, 2016

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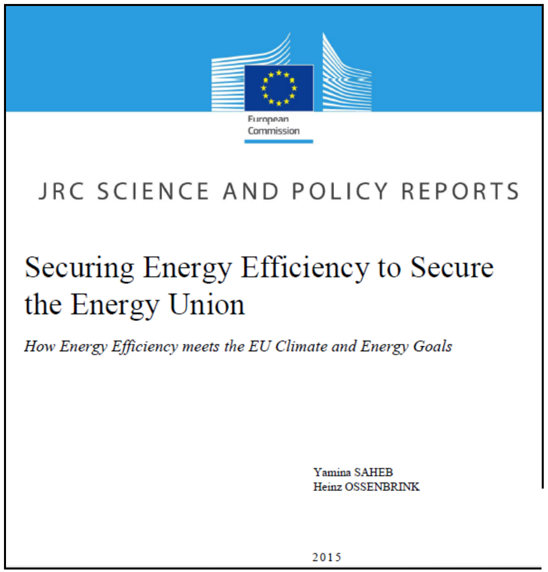
Recent advice to EU policy makers


European Commission

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Securing Energy Efficiency to Secure the Energy Union

How Energy Efficiency meets the EU Climate and Energy Goals

Yamina SAHEB
Heinz OSSENBRINK

2015

- **Energy saving as *first fuel* for Europe**
- **Energy saving should compete on equal terms with generation capacity**

Abstract

In line with the Energy Union strategy, the EU 2030 climate and energy policy framework sees energy saving as Europe's first fuel in 2030. Making energy efficiency the mechanism for delivering moderation of demand will enable the EU to meet its objectives in terms of security of supply, climate change, jobs, growth and competitiveness.

For decarbonisation to be made cost-neutral, a strong signal is required from the 2015 Paris Climate Summit (COP21) – giving a value to the carbon saved by pricing GHG emissions, so that energy saving become the niche fuel for investors. At EU level, a framework for "De-risking Energy Efficiency Investments (DEEI)" is needed to ensure that energy saving compete on equal terms with generation capacity. The framework should include setting-up guarantees for loans related to

Recent news in NL

Ten eerste

Overheid gaat bedrijven dwingen energie te besparen

Van onze verslaggever
Jeroen Trommelen

DEN HAAG Er komen voor het eerst maatregelen om afspraken over energieverbruik bij huishoudens en bedrijven af te dwingen. Met name energiebesparing bij grote industrieën blijft nu achter, maar ook particuliere huishoudens dreigen de doelen voor energiebesparing zonder wettelijke verplichting niet te halen.

Dat zegt Ed Nijpels (VVD), voorzitter van de commissie die de toeziet op het nakomen van afspraken uit het Energieakkoord. Dat akkoord werd in 2013 gesloten door een monsterverbond van 47 betrokken maatschappelijke partijen, milieubeweging en politiek.

Minister Kamp van Economische Zaken is bereid wettelijke verplichtingen moet in de woningen van huishoudens en kleine bedrijven binnen vier jaar 20 petajoule energie minder worden verbruikt. Dat is vergelijkbaar met het energieverbruik van 300 duizend gemiddelde huishoudens.

Er zijn twee manieren om dit te bereiken zonder de burger zelf te verplichten, stellen de commissie-Nijpels en minister Kamp. De eerste is om de energieleveranciers volledig verantwoordelijk te stellen voor daling van het energieverbruik. De andere is om

Voor particulieren komen er geen verplichte maatregelen

bruik van 135 duizend huishoudens – moet de komende vier jaar worden bereikt bij 111 grote, veelal internationale bedrijven die veel energie verbruiken zoals de staalindustrie en chemiebedrijven. Volgens eerdere afspraken zouden alle 111 daarvoor een eigen bijdrage leveren. Slechts twee hebben daarvan werk gemaakt en nog eens dertig hebben een voorstel gedaan. Als de sector voor oktober niet doet wat is afgesproken, overweegt de minister verplichte maatregelen voor iedereen.

Werkgeversvereniging VNO/NCW is een van de 47 partijen in het Energieakkoord en ondersteunt de aanpak, zegt een woordvoerder. 'Maar we gaan ervan uit dat de verplichting uiteindelijk niet nodig zal zijn en dat we er via maatwerk met alle 111 bedrijven uitkomen.'

Eigenaren van energie-onzuinige kantoorgebouwen worden verplicht om die kantoren in 2020 te laten vol-

Source: Volkskrant 18 May 2016

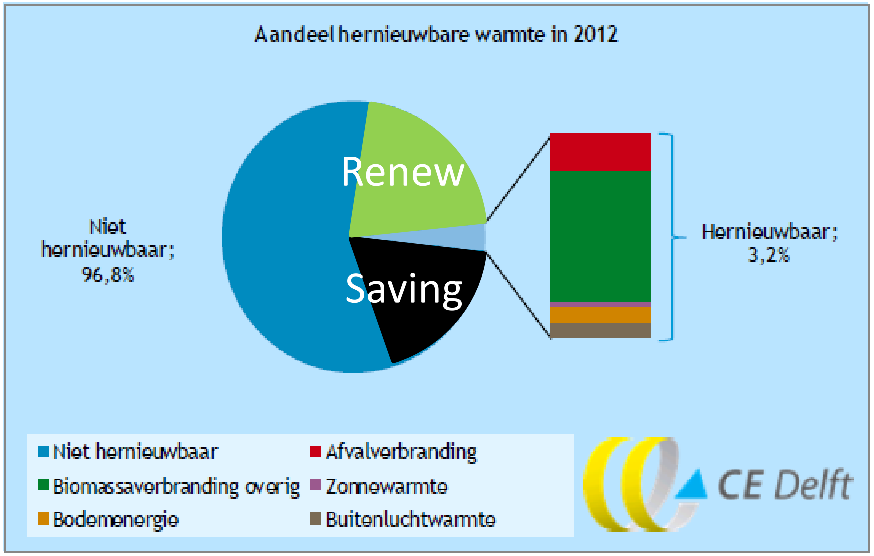
- **Dutch government threatens to enforce energy saving measures in energy intensive industries, in order to reach the targets of the Dutch national energy agreement**

- ***Speed up the implementation of energy saving measures***

Vision on thermal energy

- "… The demand for heat has a large share in the total energy demand. This means that reducing the heat demand as well as supplying thermal energy from renewable sources is crucial to achieve the transition towards a renewable energy system in 2050. ….”

Thermal energy in NL



Bron: CBS, 2012a.

- Primary energy use for heating: 1200 PJ
- Energy-saving potential for 2020
  - 260 PJ
    of which 166 PJ is cost competitive
- Renewable heat sources 2020
  - 282 PJ
    of which 86 PJ is cost competitive

Implementing the cost competitive options

	ΔCO_2-emissions	***share renewable***
Saving:	**- 14%**	**4%**
Renew:	**- 7%**	**10%**
Both:	**- 21%**	**12%**

Reuse of waste heat

What makes heat to be designated as waste heat?

Problem	**Solution**
Heat at wrong temperature	Convert it to the right temperature -> heat pump technology
Heat at wrong moment	Store it for use at the right moment -> heat storage technology
Heat at wrong place	Transport it to the right place -> heat transport technology

Applications for thermal energy storage

- Increase **energy efficiency** of industrial processes through the re-use of waste heat
- Increase the **share of renewable** energy based on Solar thermal
- Create new **energy flexibility** options for Combined Heat and Power and connect the electricity system to the heat system (power2heat)
- **Transport** of heat



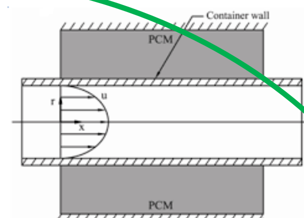


LOCOSTO
LOw COst STOrage of HEAT

- RVO - Joint Industry Project (JIP)
  - Stakeholders in the value chain involved
- Objective:
  - development of techno-economic feasible PCM heat storage solutions for industrial applications
- Innovation
  - Development of novel PCM, high energy storage density, T-range 100-250°C
  - New methods for integration of PCM's and heat exchangers, to obtain high thermal power PCM heat storage systems.

Approach and targeted results

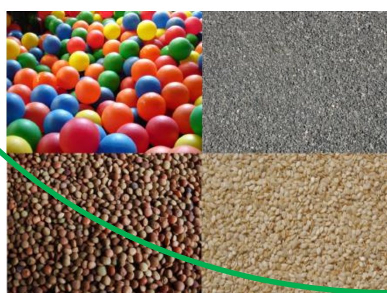
applications



PCM thermal model

economics

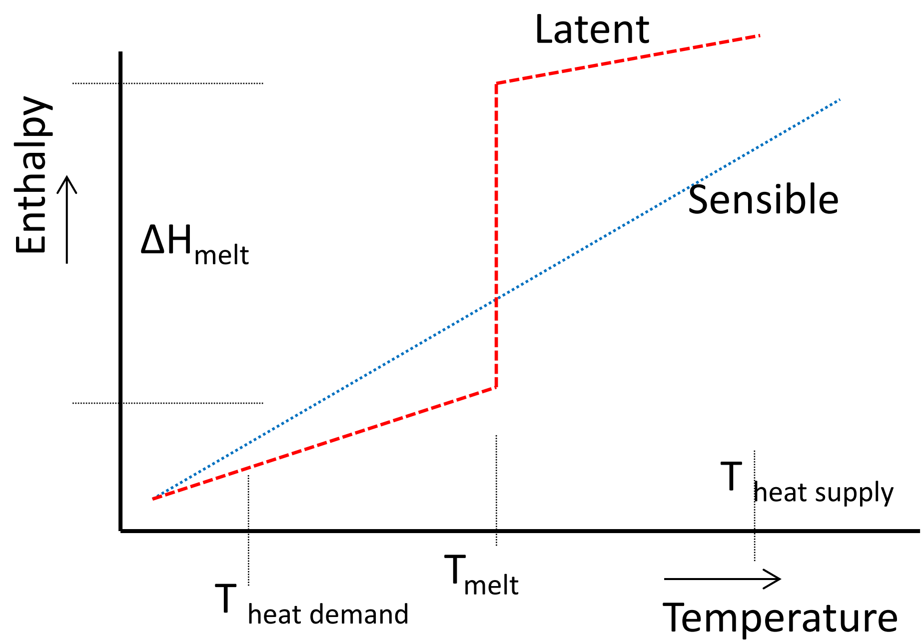
PCM lab prototype



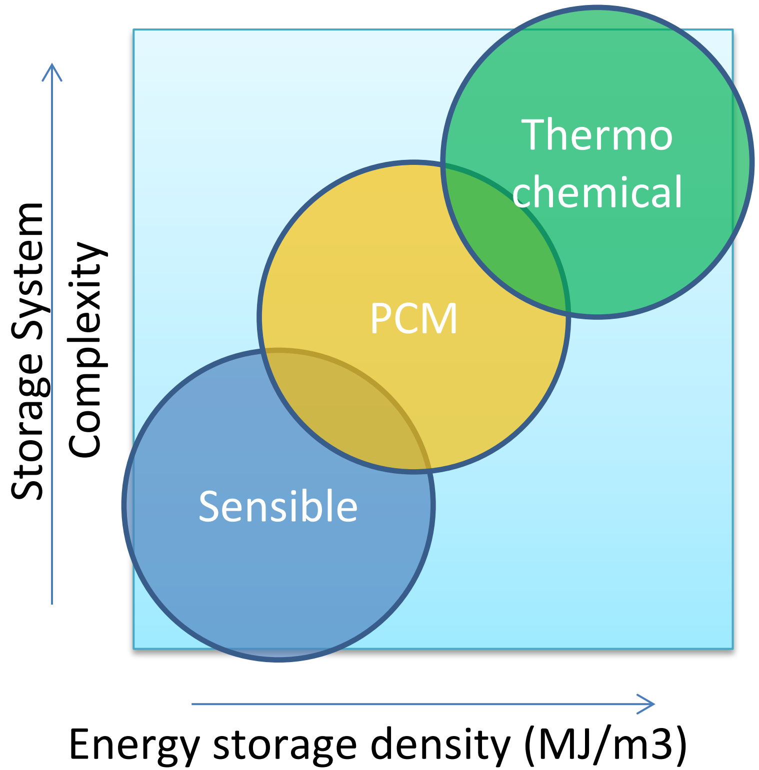
PCM materials

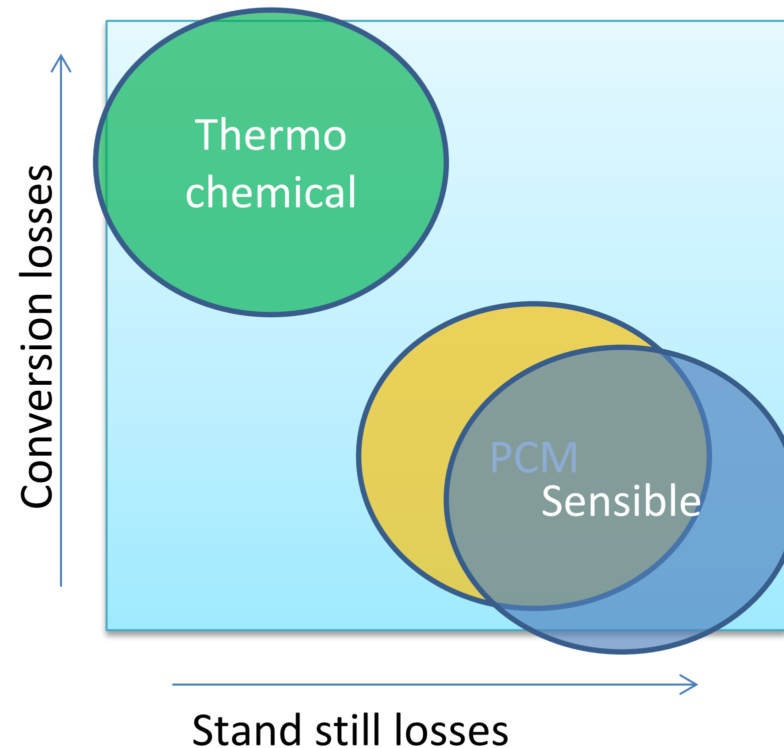
2017 →

Energy storage in Phase Change Materials



Thermal storage technologies



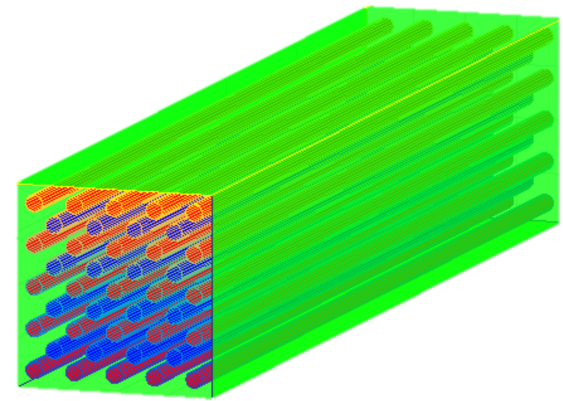


PCM heat storage: charge-discharge thermal powers

- Heat transfer rate in PCM systems is low
  - Low thermal conductivity of PCM's → Slow charge-discharge rates
- Solutions
  - Large heat transfer surface areas → short distances for heat transfer
  - Increase the thermal conductivity of PCM

Matlab tool LOCOSTO

Goal: performance calculations for a multi-tube PCM heat storage system



Characteristics:

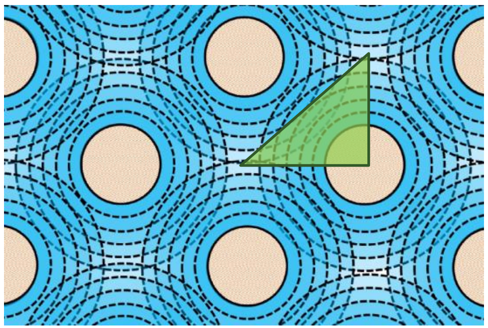
- Enthalpy based model
- Fixed 3 dimensional grid, variable time step
- Using software tool Matlab

Elements of model:

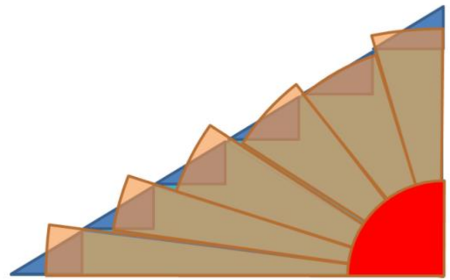
- Defining layout (tubes), PCM, heat transfer medium, initial conditions, …
- Calculating grid /mesh of tubes and PCM
- Dynamic calculations
- Visualization: design, grid, time plots, mesh plots, video

Grid definition

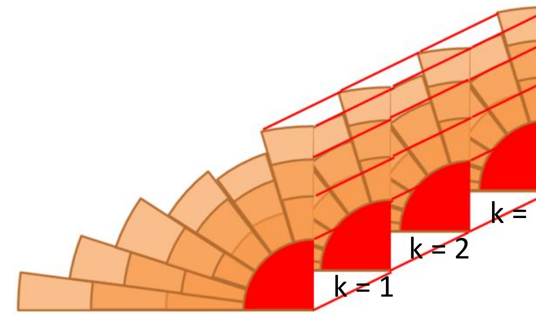
- Selection 'quarter' of tube:



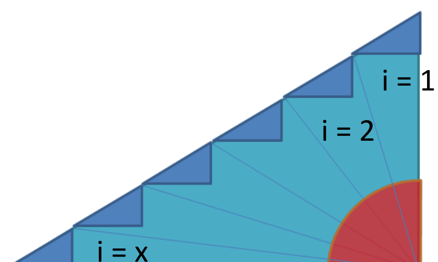
- Approach area of segment i with cake slice:



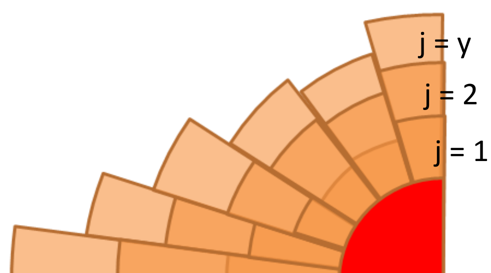
- Define segments k = 1 : z (tube length)



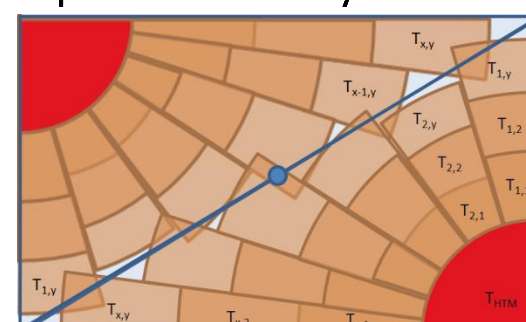
- Split triangle in x segments:



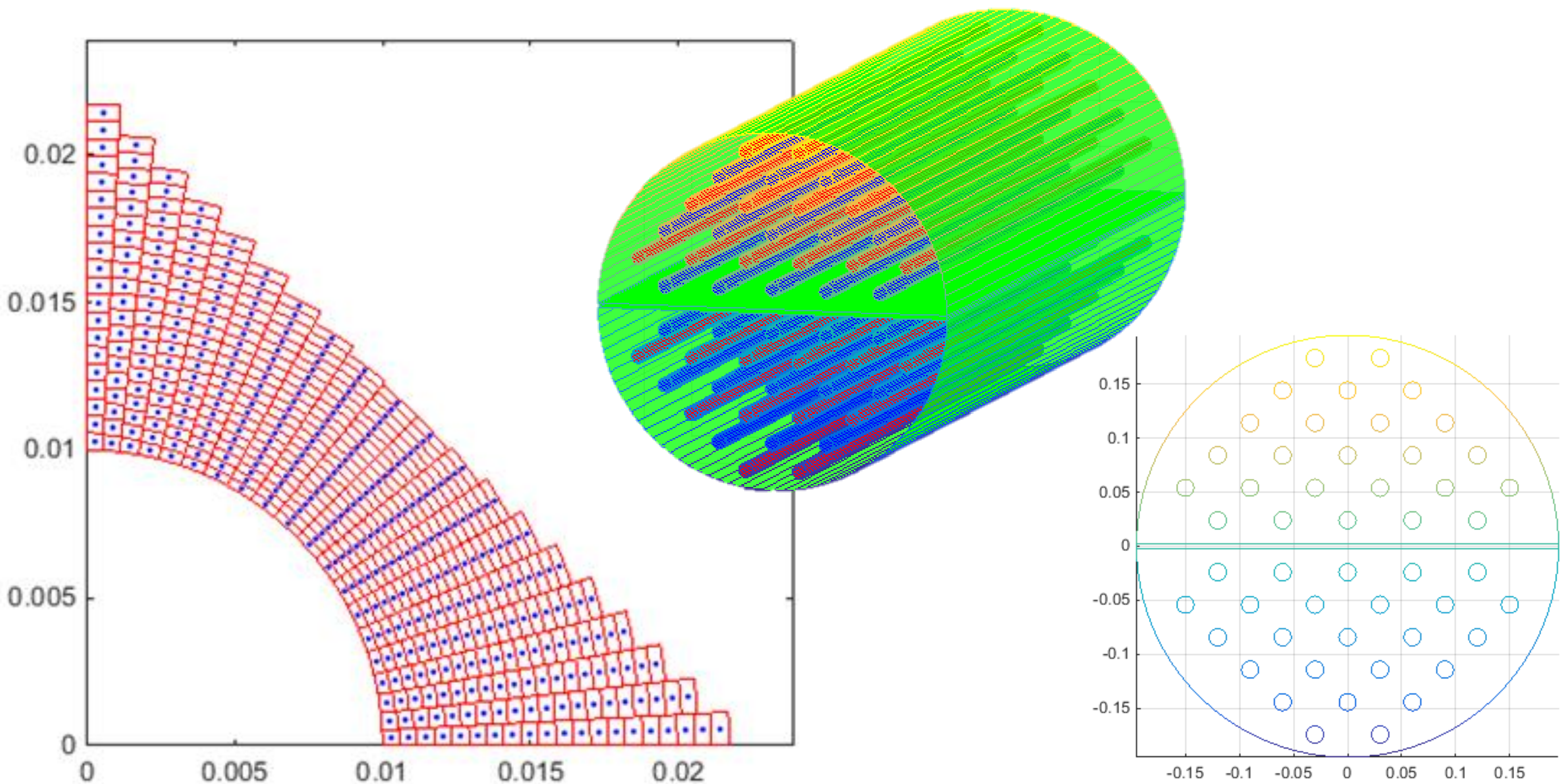
- Split each segment i in y parts of same length:



- Define wall conditions = point mirror symmetric:



Visualization grid / design



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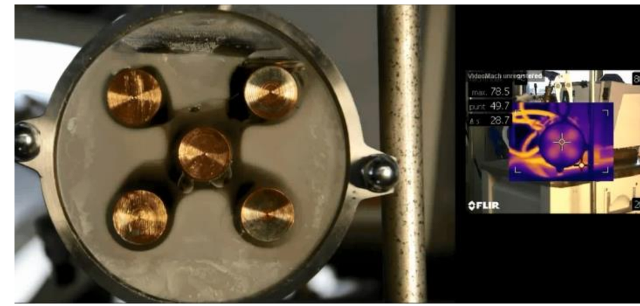
Heat transfer in PCM

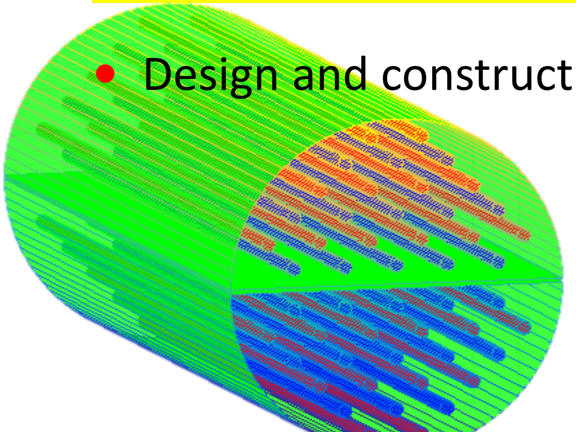
lab-prototype of
Shell & Tube PCM test system



Study of melting behaviour of a PCM storage concept, experiment + model

Heat transfer in PCM

- Design and construction of shell & tube concept for PCM heat storage



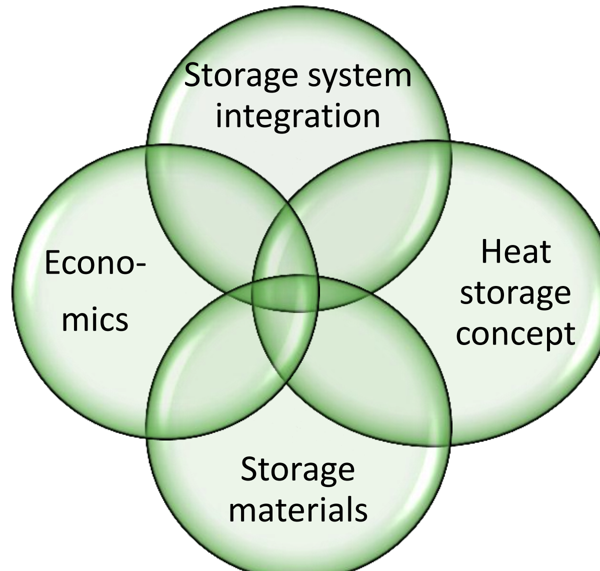
Summary

- Thermal energy has a substantial share in the overall energy system
- Re-use of waste heat has a large potential to enable thermal energy savings
- Heat storage technology contributes to:
  - energy saving
  - Providing flexibility to the energy system
  - Incorporate renewable heat sources (solar, geothermal)
- High thermal power density storage systems needed for industry applications: rapid charge and discharge

- Challenge to develop cost-efficient, high performance, robust and reliable thermal storage solutions

Outlook for PCM thermal energy storage

- Development of cost effective, stable PCM materials for T > 100°C
- Validate modelling tools with lab scale experiments
- Development of flexible storage concepts that match storage capacity and thermal power requirements as well as economic constraints
- Upscaling of HT-PCM storage concepts and test + demonstration in practical situations



Robert de Boer

Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 ZG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 4480

info@ecn.nl
www.ecn.nl

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Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 LG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ ecn.nl
www.ecn.nl