Grootschalige opslag voor een warmterevolutie in de gebouwde omgeving

David Smeulders

NNV Symposium, Utrecht 9 juni 2017

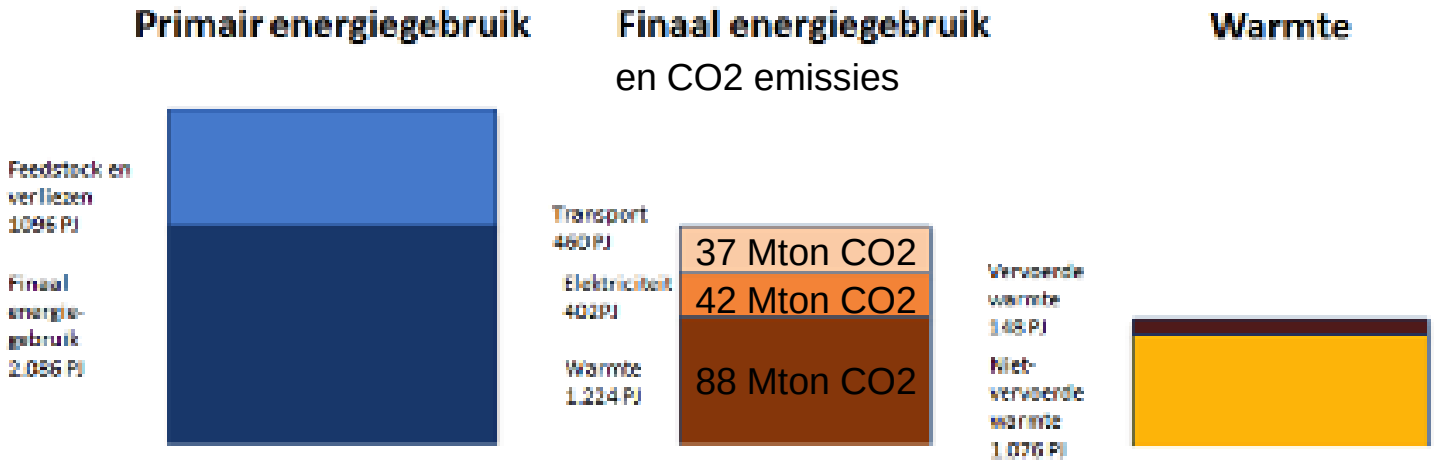
Technische Universiteit
Eindhoven
University of Technology

Where innovation starts

Het energieverbruik in Nederland

De samenstelling van het energieverbruik

De indeling naar gebruikssoort



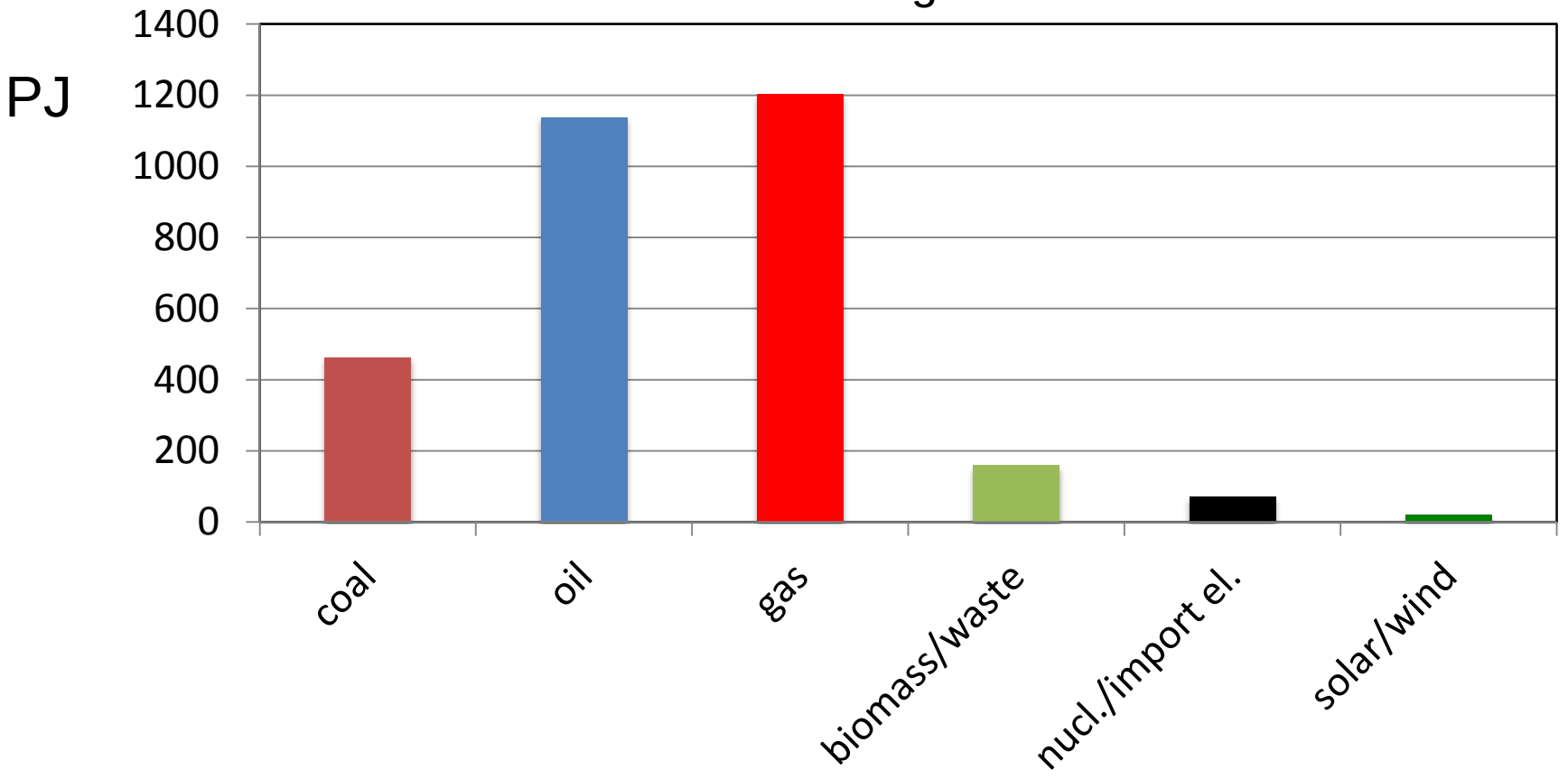
Bron: Ecorys 2016

Tussen het primaire energieverbruik en het finale energiegebruik is er een groot verschil. Bij opwekking en transport ontstaan immers verliezen. Warmte vormt een belangrijk onderdeel (ca. 59%) van het totale finale energieverbruik.

Van moleculen naar elektronen?

Energy supply NL 2015: 3054 PJ

Shifting from molecules to electrons?



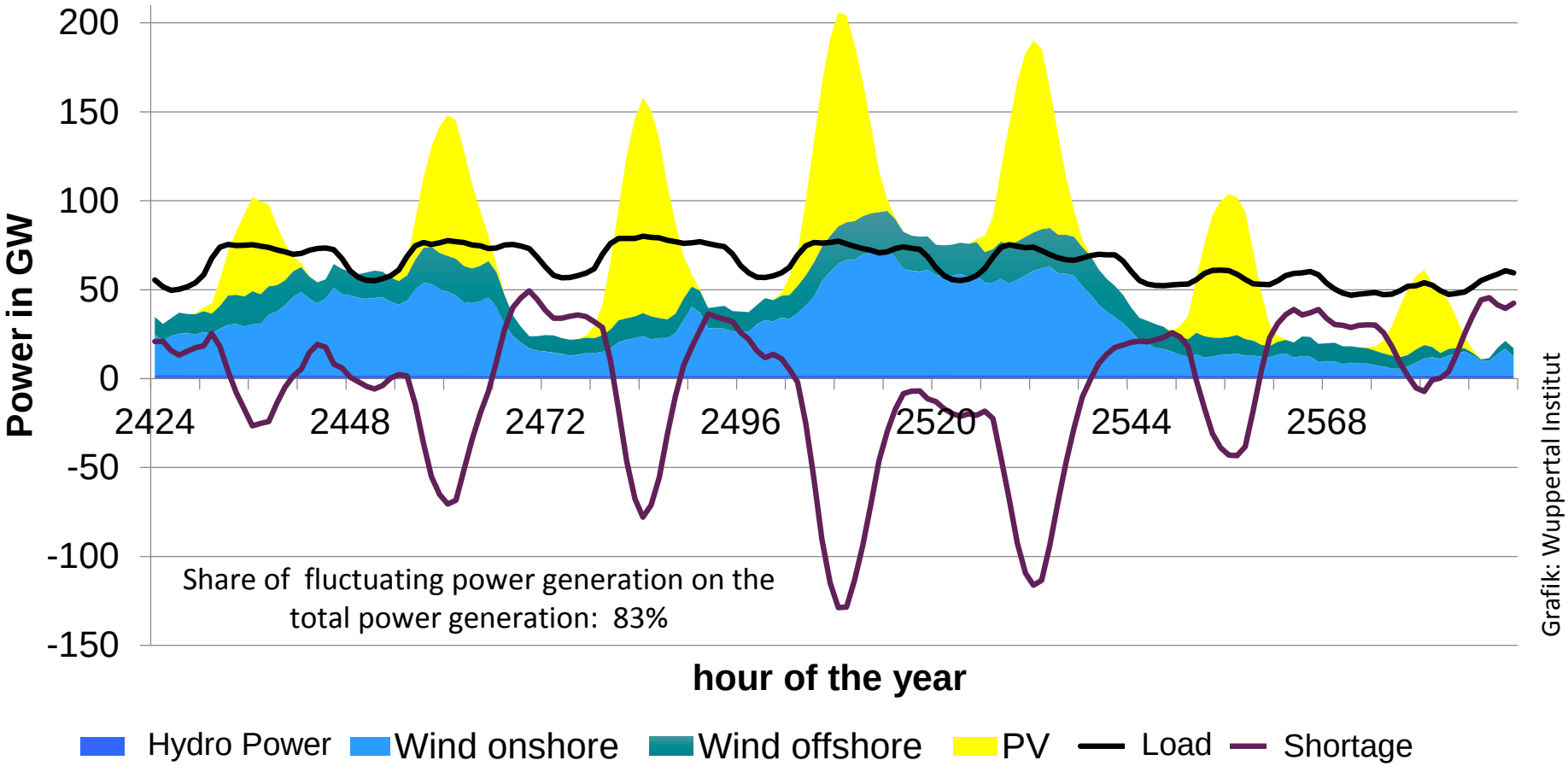
Source: CBS

Volledige elektrificatie huishoudelijke warmtevraag

- Gemiddeld verbruik per jaar: 1500 m^3 gas = 15.000 kWh
- Warmtepomp (met COP=3): 5.000 kWh/jaar
- 7,7 miljoen huishoudens: 38,5 TWh/jaar
- Huidig NL per jaar: 120 TWh/jaar met 19 GW opgesteld vermogen (40% overcapaciteit)
- 32% toename = 6 GW extra opgesteld vermogen =

  6 Uniper MPP3 centrales
- Alleen CO_2 winst bij 10 Gemini windmolenparken (of CCUS…..)
- Geluidsoverlast warmtepompen
- Renovatie woningvoorraad naar lage temperatuur warmte

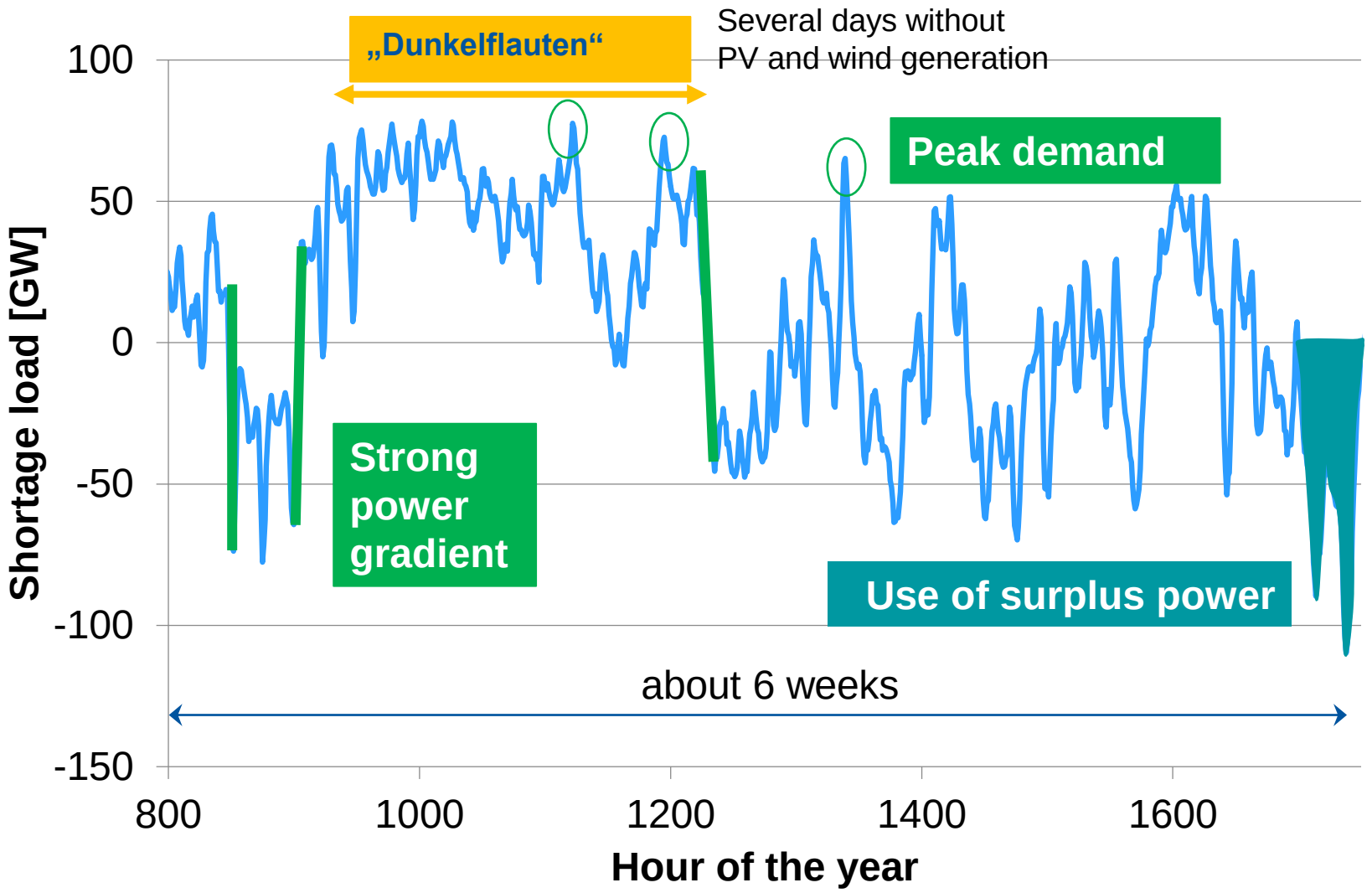
Renewables: German 2050 electricity scenario



Grafik: Wuppertal Institut

PV: 151 GW, Wind onshore: 82 GW, Wind offshore: 20 GW, Power consumption: 602 TWh/year

Future Energy Systems
3 main challenges*



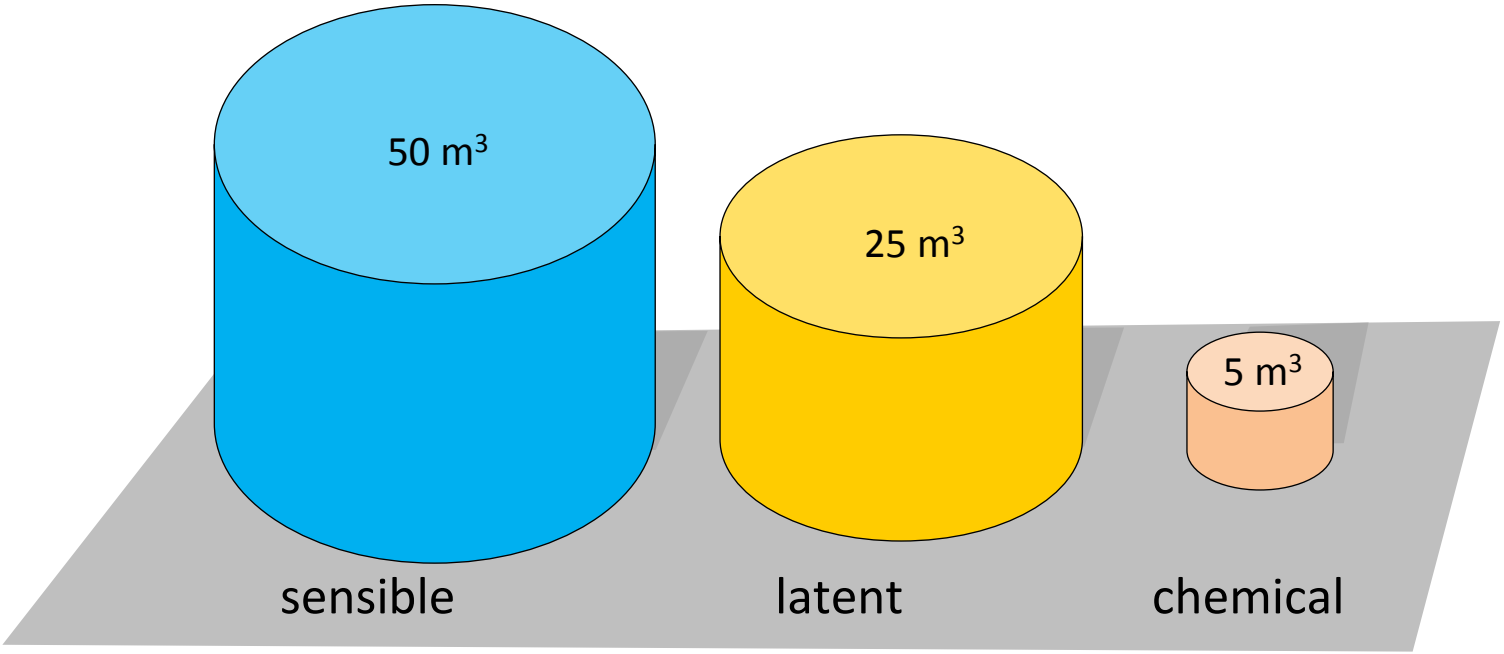
PV: 151 GW, Wind onshore: 82 GW, Wind offshore: 20 GW, Power consumption: 602 TWh/year, FEE-share: 83 %

*Besides other challenges

- Volledige elektrificatie is niet de oplossing
- Benut potentieel hoge temperatuur warmte (industriële restwarmte)
  - Transport van warmte
- Benut potentieel lage temperatuur warmte
  - Opslag van warmte

Vojens (DK): 37 MW zonnecollectoren met 200.000 m^3 opslag

Transport en opslag van warmte



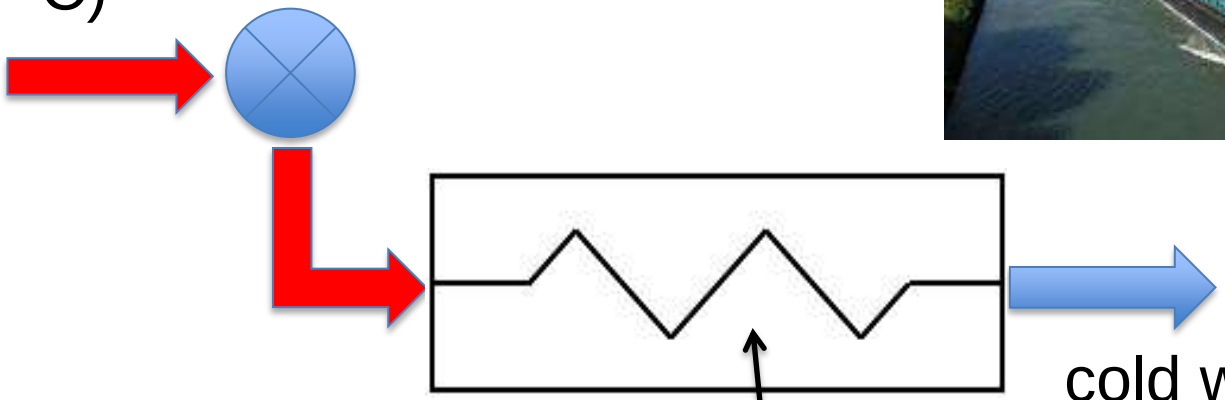
Water	PCMs	TCMs
0.2 GJ/m^3	0.4 GJ/m^3	2 GJ/m^3

Source: Abedin & Rosen, 2011

PCM heat battery (closed system)

Industrial waste heat (~130 ^{0}C)

Circulation pump

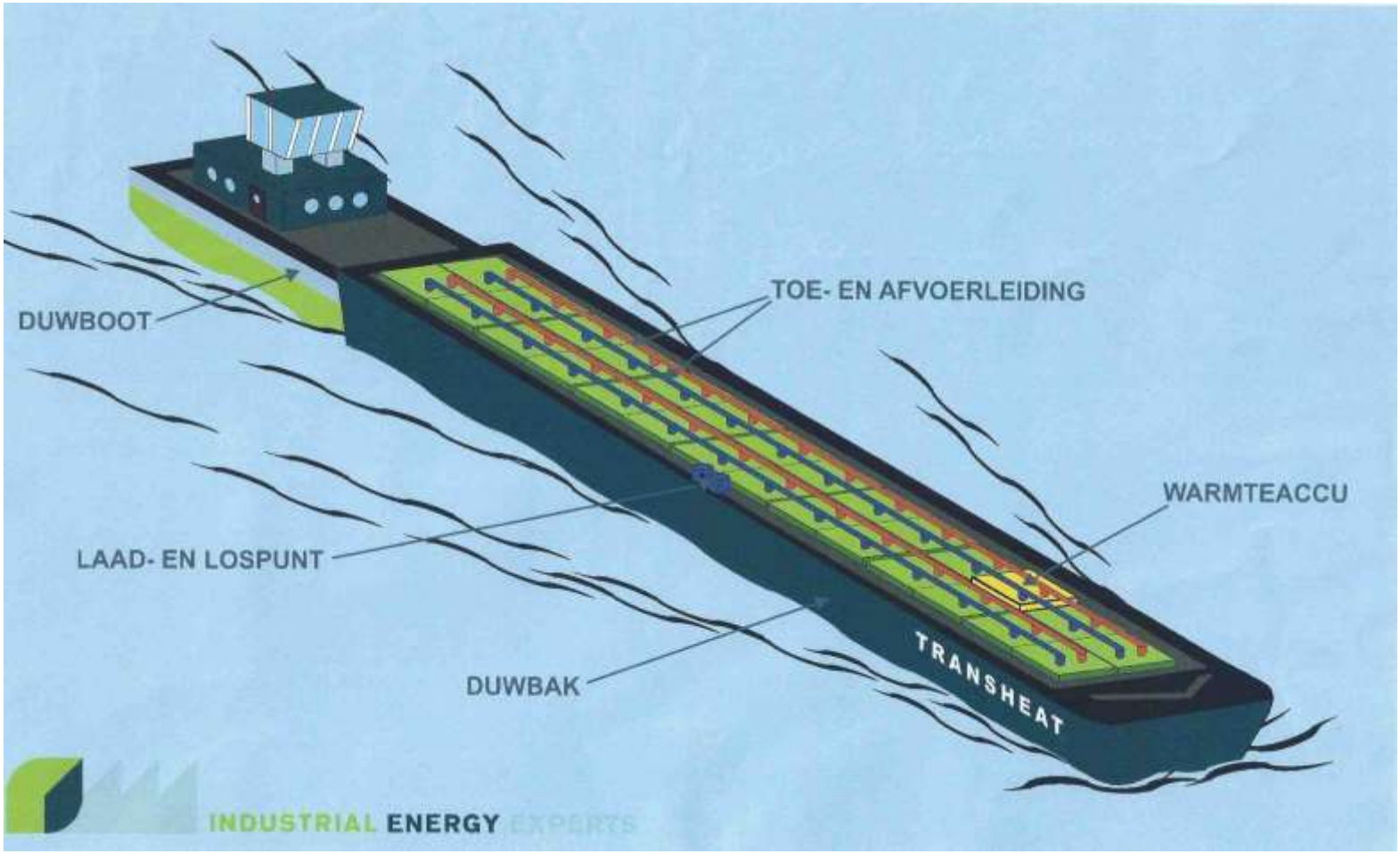


cold water

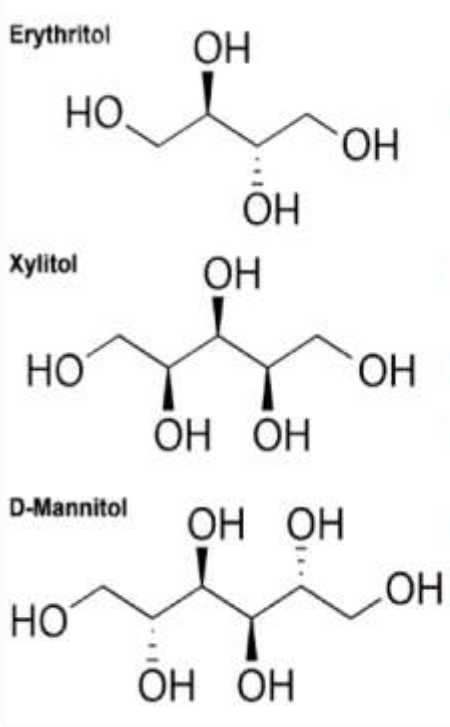
PCM melting at 90 ^{0}C

“switch”

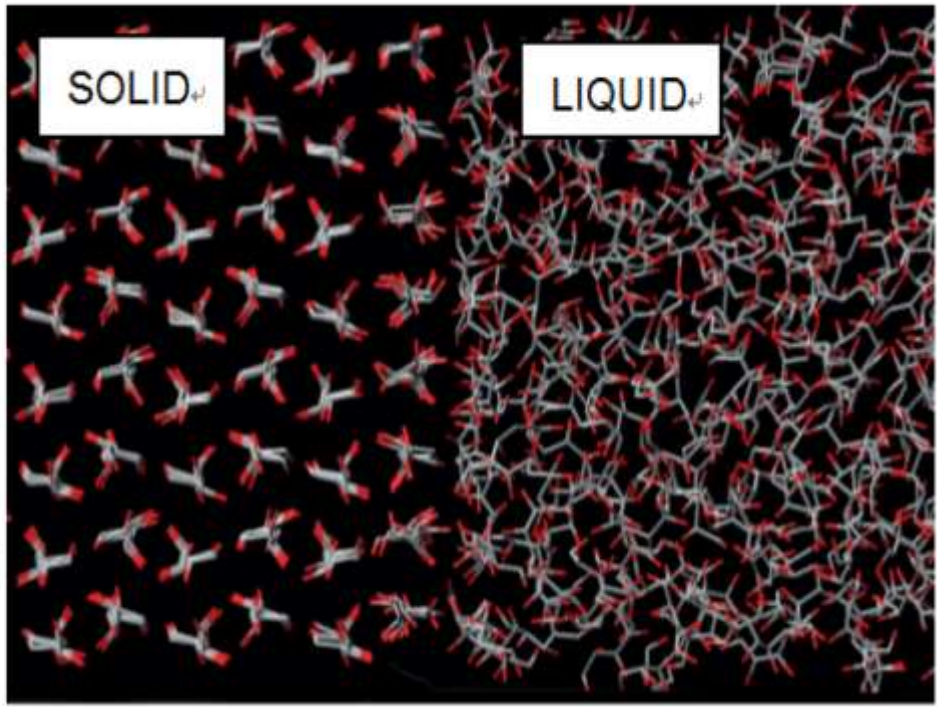
Transheat concept-IEE



PCM Molecular Dynamics simulations

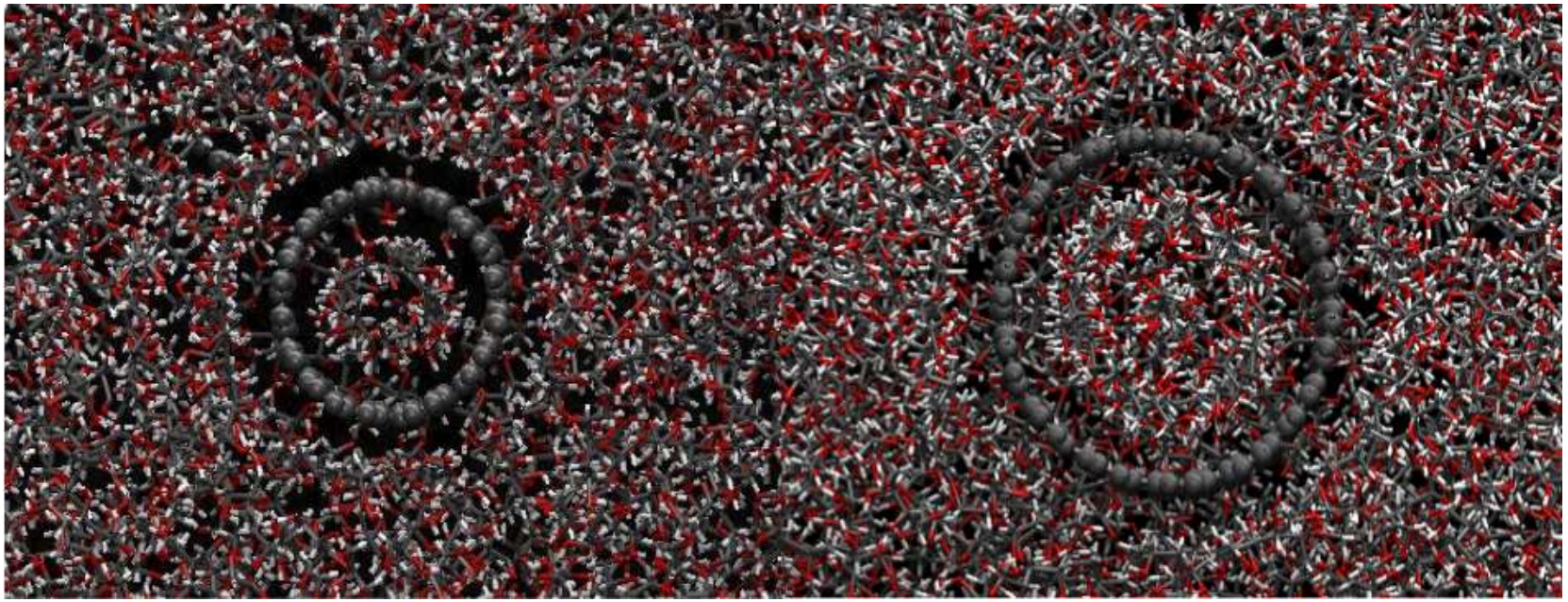


Sugar Alcohols



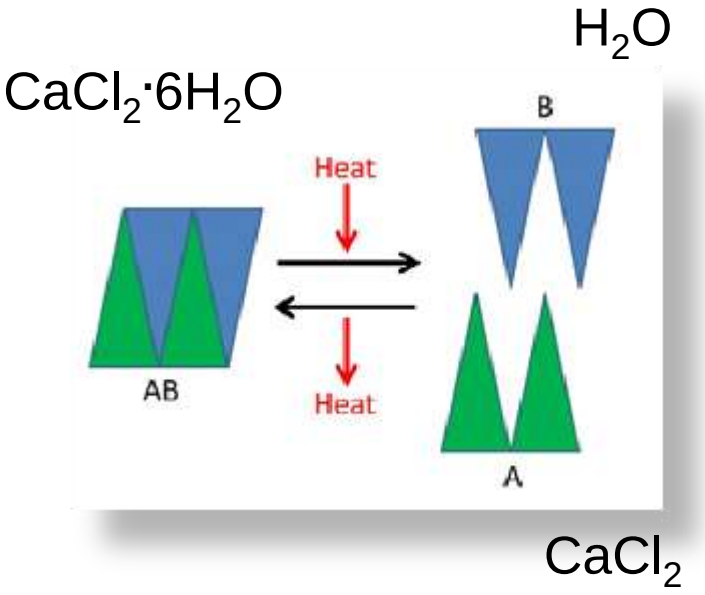
Xylitol crystallization (H. Zhang, S. Nedea)

Molecular Dynamics simulations



PCM: Xylitol with 1.36 nm diameter CNT (H. Zhang, S. Nedea)

Thermo-chemical materials (TCMs)



Exothermal chemical reaction between components H_2O en $CaCl_2$

Why salt hydrates?

- High energy density
- Appropriate window (*p, T*)
- Inexpensive materials

2nd generation salt hydrates: absorption mechanism

$$CuSO_4(s) + 2H_2O \leftrightarrow CuSO_4 \cdot 2H_2O(s) + \Delta H$$

White anhydrate

Blue salt hydrate

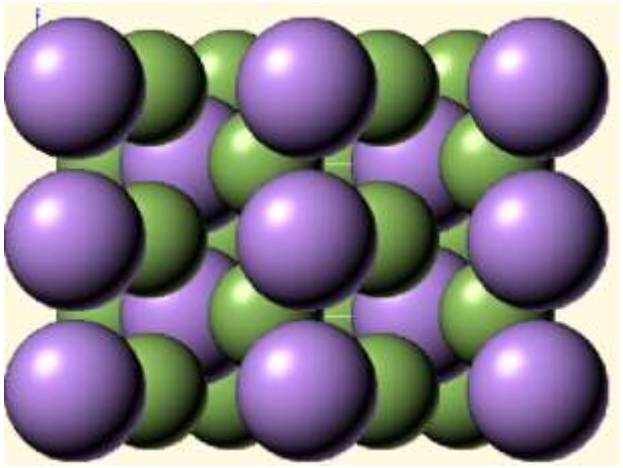
$$CaSO_4 \cdot \tfrac{1}{2} H_2O(s) + 1\tfrac{1}{2} H_2O \leftrightarrow CaSO_4 \cdot 2H_2O(s) + \Delta H$$

Hemi-hydrate

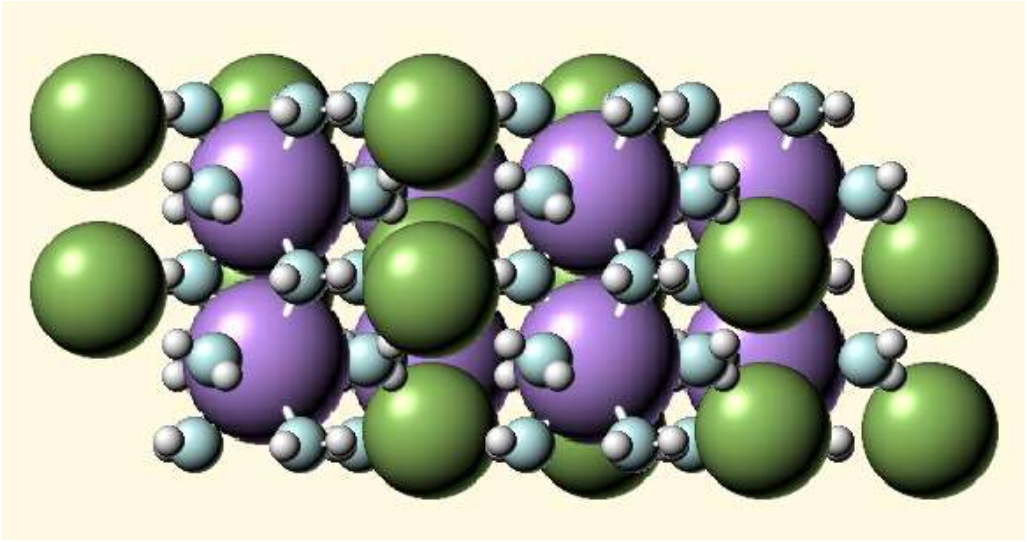
Di-hydrate: gipsum

Salt hydrates

$CaCl_2$



$CaCl_2.6H_2O$

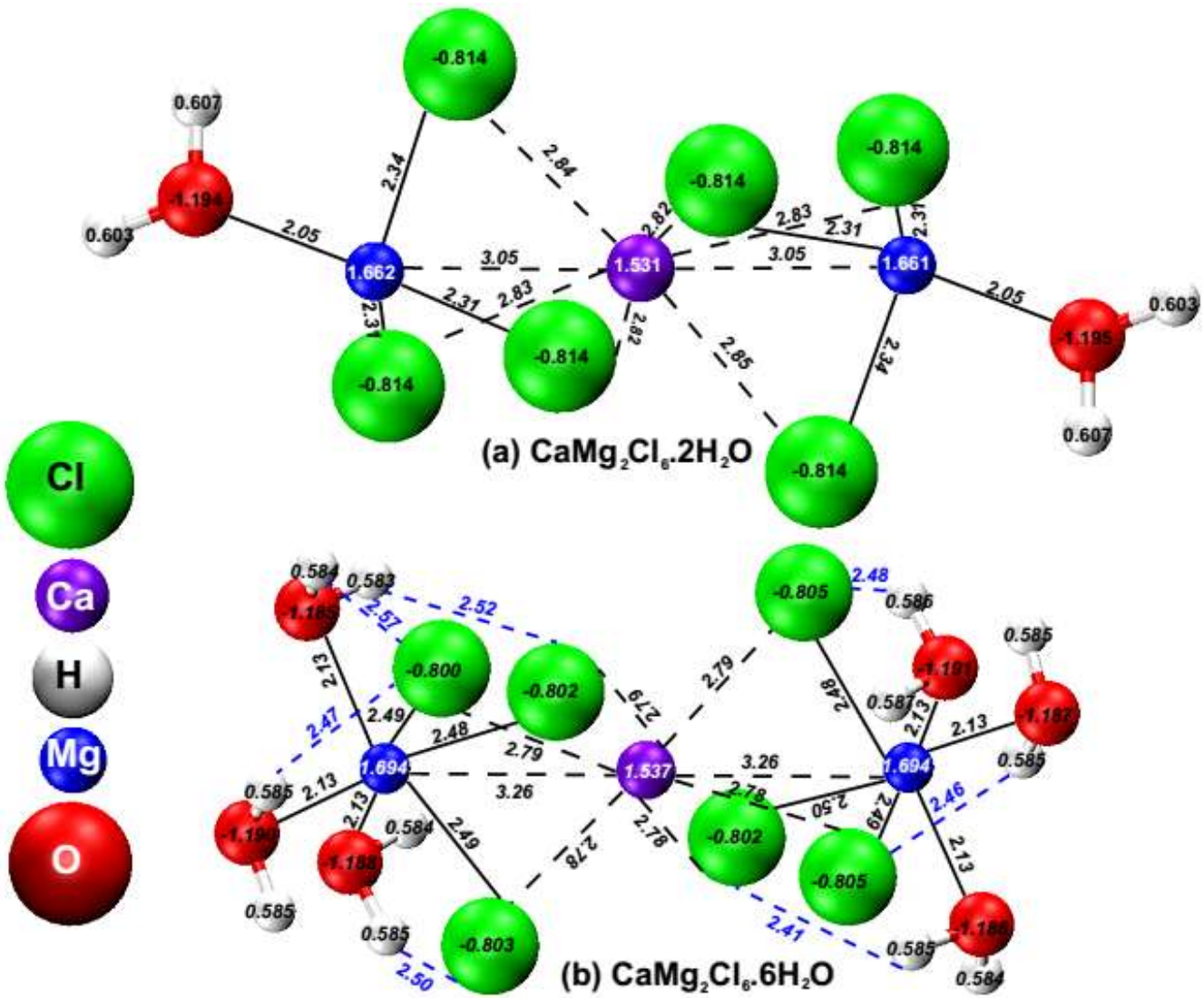


$MgCl_2$ en $CaCl_2$ hydraten

$MgCl_2$: Fast kinetics
Readily available
High storage density (2.6 GJ/m^3)
HCl formation

$CaCl_2$: Less expensive material
High storage density (2 GJ/m^3)
Better thermal and chemical stability
Gel formation after hydration

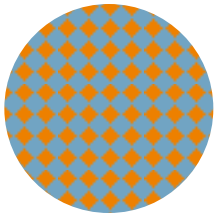
Molecular Dynamics: Mixed hydrates



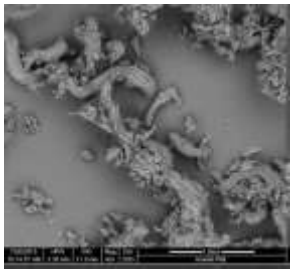
Stability enhancement: microencapsulation

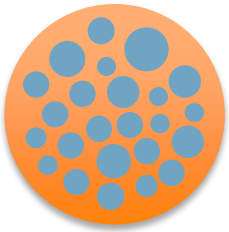
‘Microencapsulation’ is the process of making ‘microcapsules’.

Microcapsules: Hollow microparticles composed of a solid shell surrounding a core-forming space available to permanently or temporarily entrapped substances.

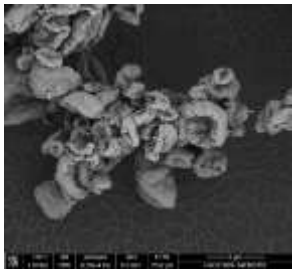


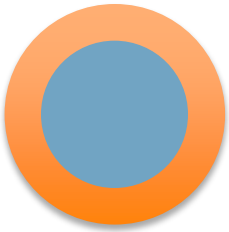
Matrix-type
Impregnatie
Wendelin



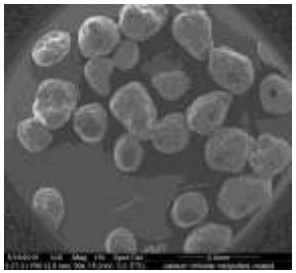


Multi-core/shell
Sproei-drogen
TNO



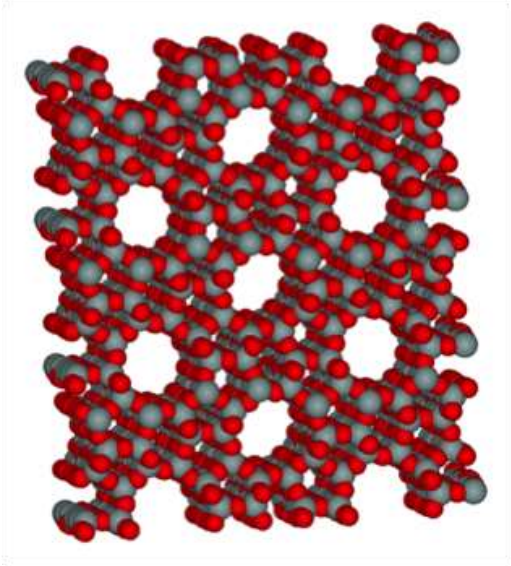


Core/shell
Fluid bed coaten
TNO

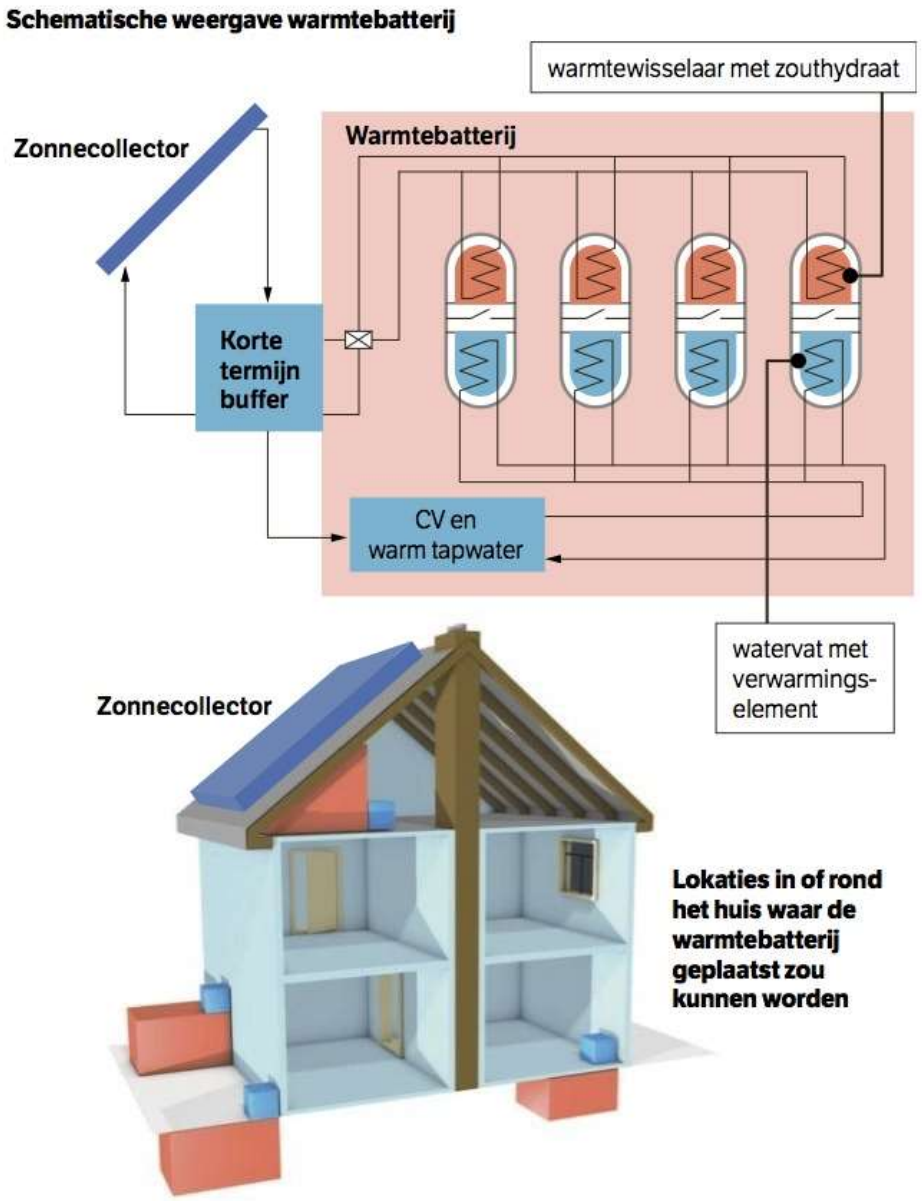


Reactor experiments: Zeolites (1st generation TCM: adsorption)

- Alumino-silicates: $NaAl(Si_2O_6)\cdot H_2O$
- Washing powder: absorb Ca^{2+} en Mg^{2+} ions
- Absorb water: heat storage



Zeolite 2 m3 reactor



Warmtebatterij

Bron: NRC 5 November 2016

Conclusies

- Opslag is essentieel bij meer zon/wind
- Vloeibare brandstoffen blijven een belangrijke rol spelen in de vervoersector
- Volledige elektrificatie van de warmtevraag vergroot opslagprobleem
- Warmtebatterij is essentieel voor de vergroening van de warmtevraag