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Evaluation of mobile storage systems for heat transport

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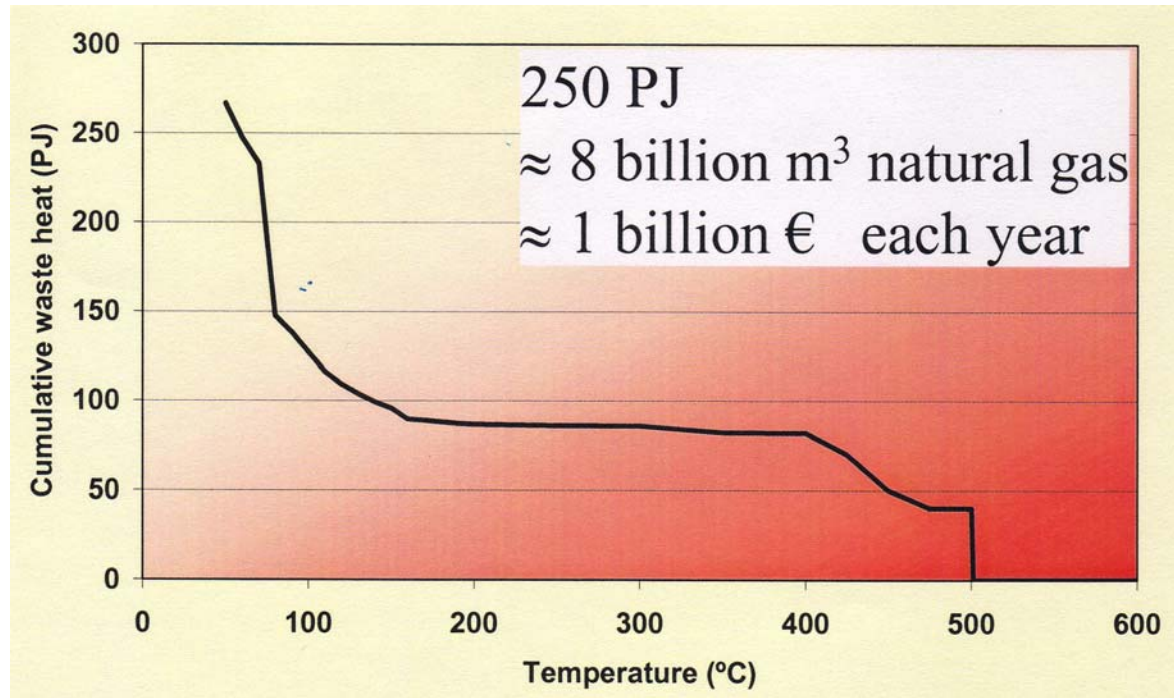


- Introduction
- Mobile Storage Units
- Case Studies: Setup
- Case Studies: Results

Motivation



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Obstacles :

- temperature level
- mismatch in **availability**
- mismatch in **place**

Cumulated waste heat in the Netherlands process industry.
Source: P. Bach, Energy Research Centre of the Netherlands



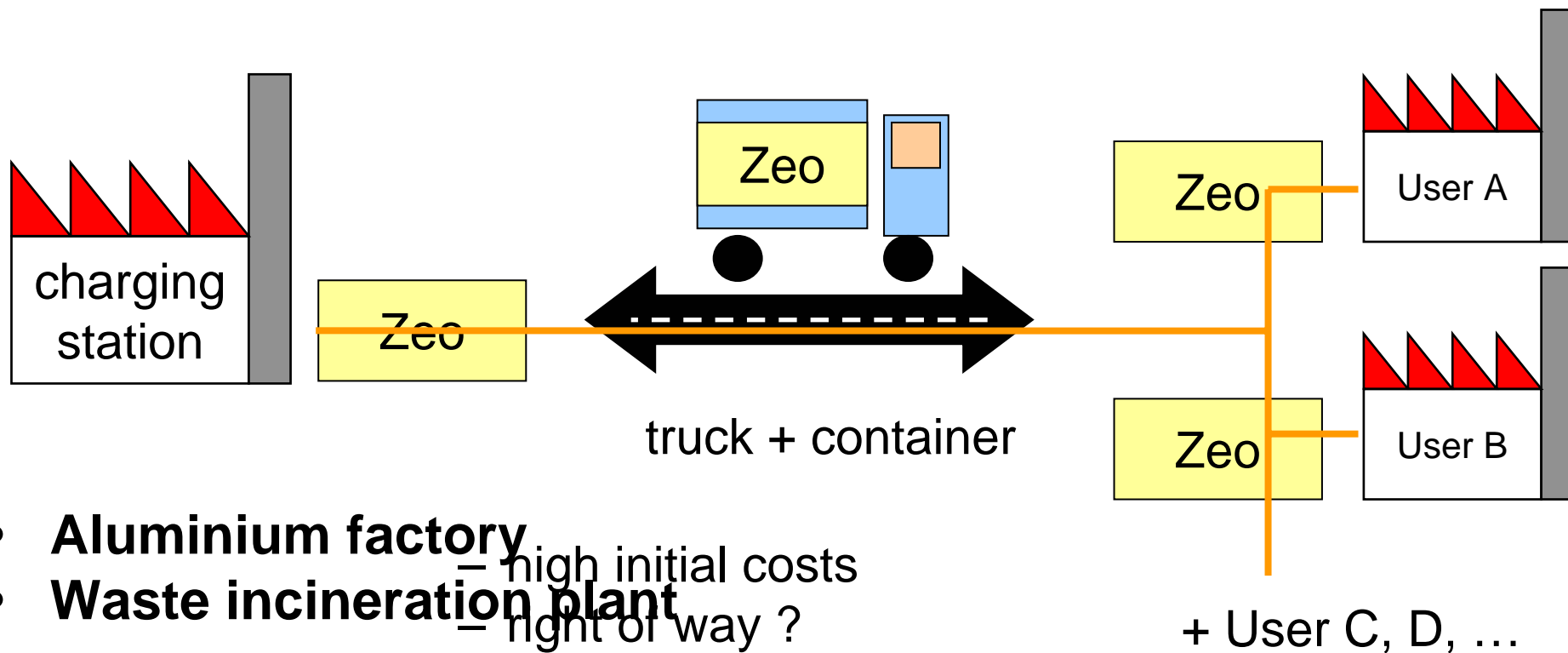
- Introduction
- **Mobile Storage Units**
 - Principle
 - Energy Storage in Zeolites
 - Other systems
- Case Studies: Setup
- Case Studies: Results

Concept



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Mobile storage units replace pipeline-bound system



- **Aluminium factory**
 - high initial costs
- **Waste incineration plant**
 - right of way ?
 - inflexible

Zeolite storage unit



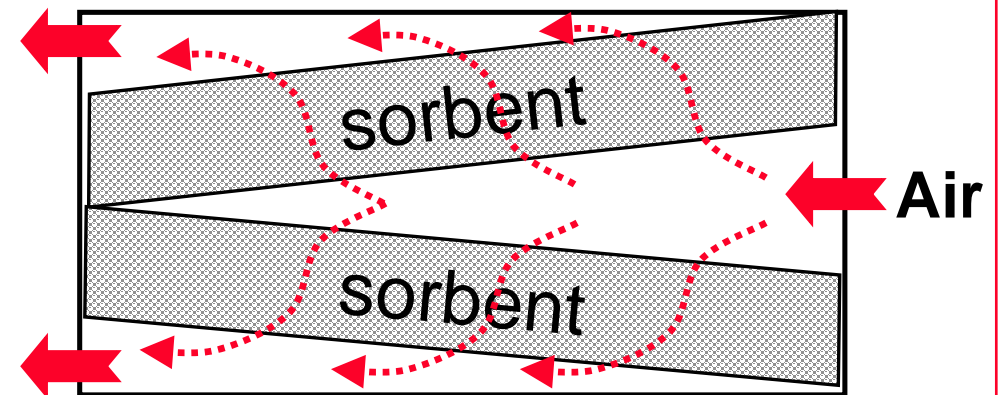
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Modified freight container:

zeolite volume	18,7 m ³
zeolite mass	15 t
bed height	0,8 m
bed cross section	23,2 m ²

maximum airstream 20.000 m³/h

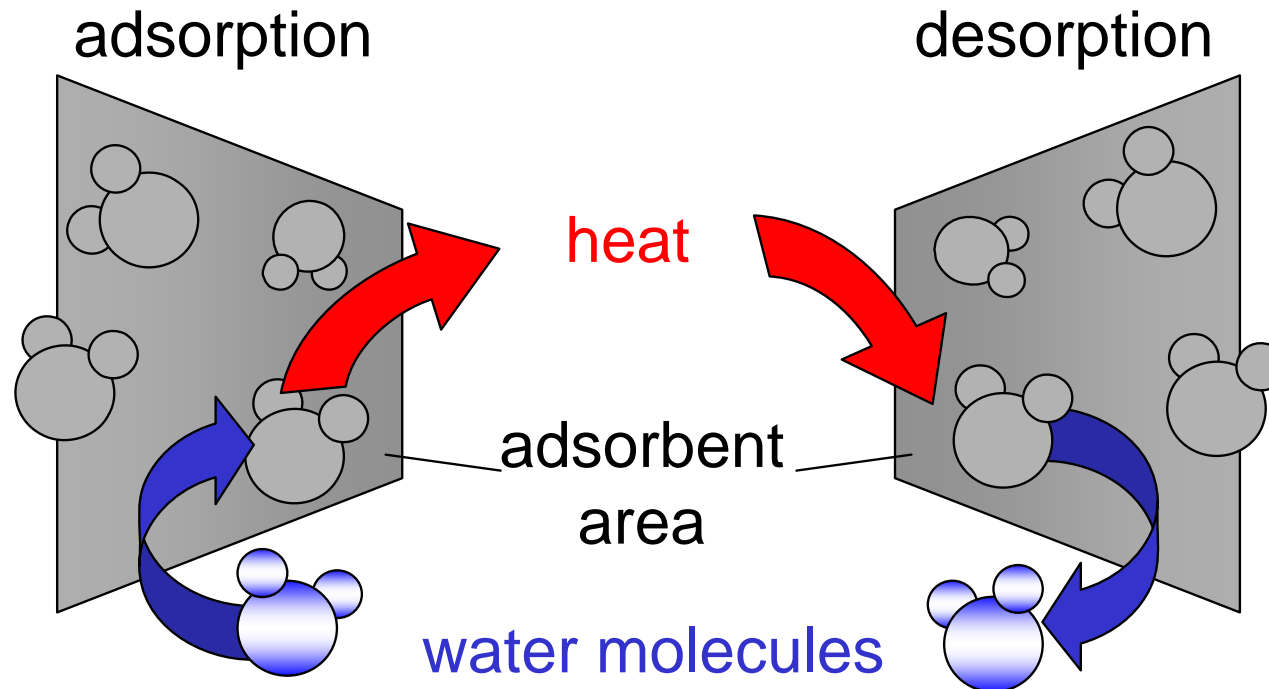
Energy storage capacity	max. 4.1 MWh
Charging power	max. 1 MW
discharging power	max. 750 kW



Principle of sorption heat storage



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Sorption processes combine

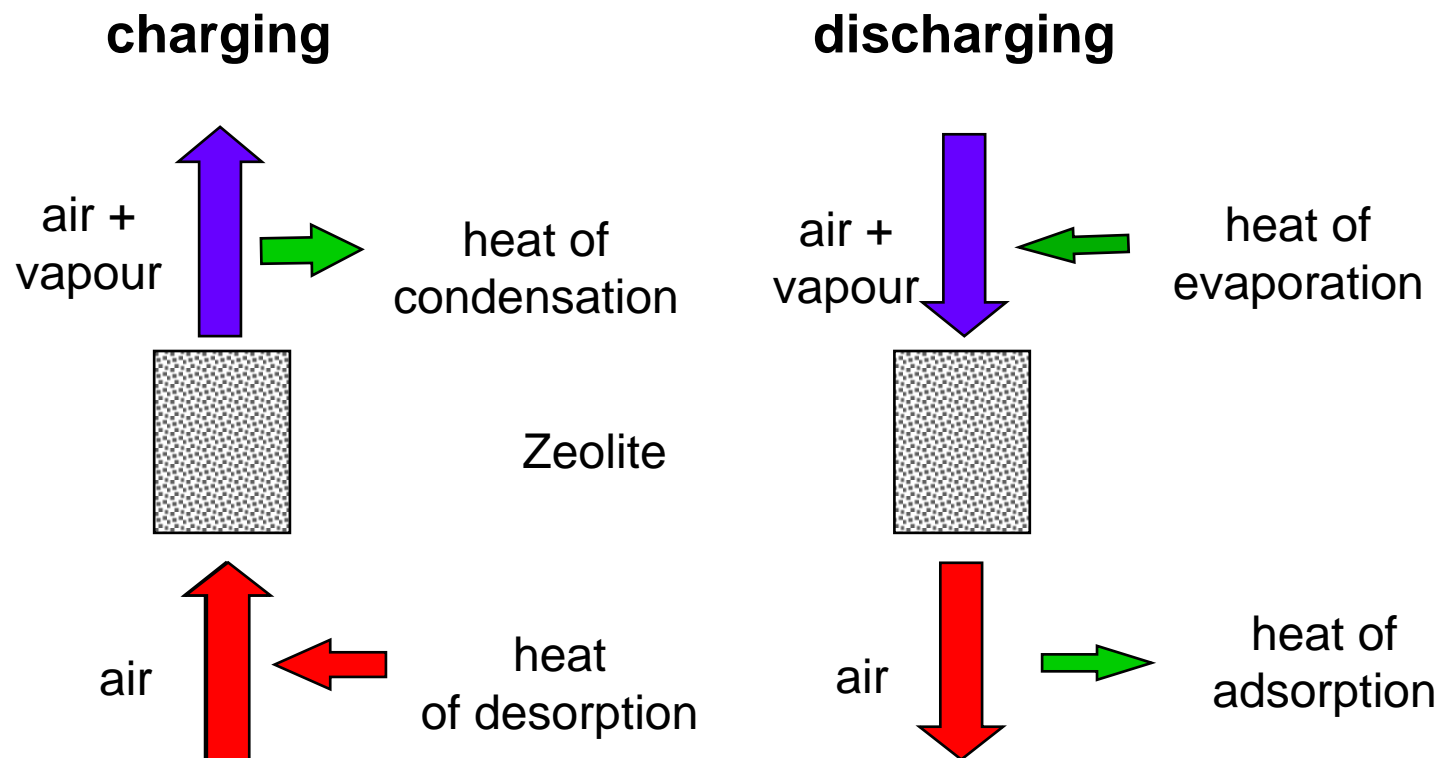
- high thermal turnover ($h_{ev,H_2O}=2440 \text{ kJ/kg}=0,68 \text{ kWh/kg}$)
- excellent repeatability
- low losses

Open sorption systems



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- water vapour / zeolite
- atmospheric pressure
- zeolite pellets in fixed bed
- air as carrier gas for heat- and mass transfer



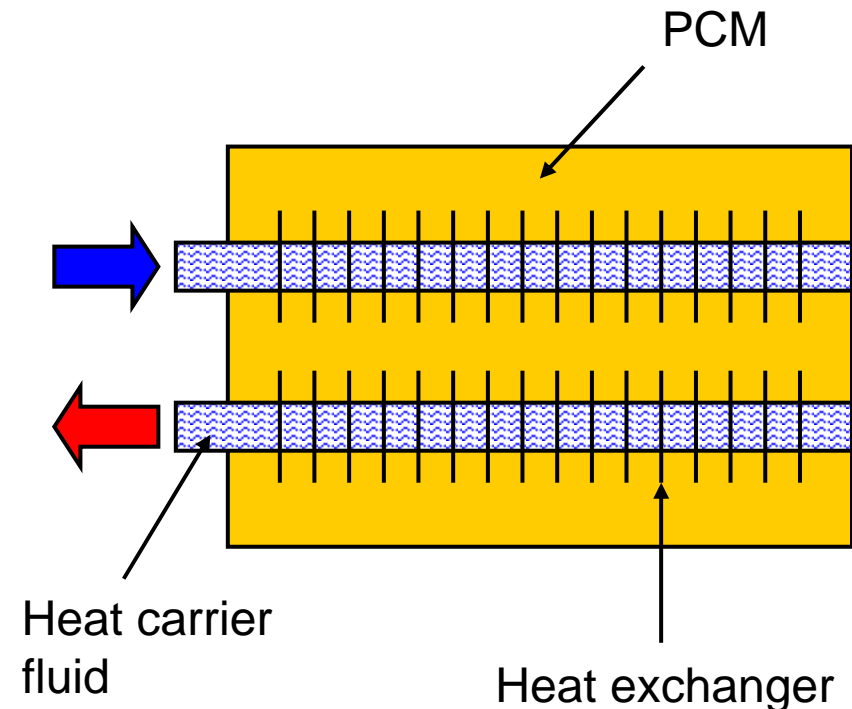
Alternative: PCM-Technology



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Sodium acetate tri-hydrate, melting point 58°C

PCM mass	22 t
unit total mass	26 t
energy stored / unit	2.4 MWh
thereof latent heat	1.6 MWh
typical charging power (90/70°C)	250 kW
typical discharging power (38/48°C)	125 kW
typical discharging power (25/40°C)	220 kW
energy losses	ca. 10 kWh in 24h



Other systems ?



- Introduction
- Mobile Storage Units
- **Case Studies: Setup**
 - Heat Sources
 - Potential Users
 - Parameters
- Case Studies: Results

Heat sources



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Aluminium factory

- Combustion of solvent-laden air
- 230°C
- Waste heat
- Only temporarily available



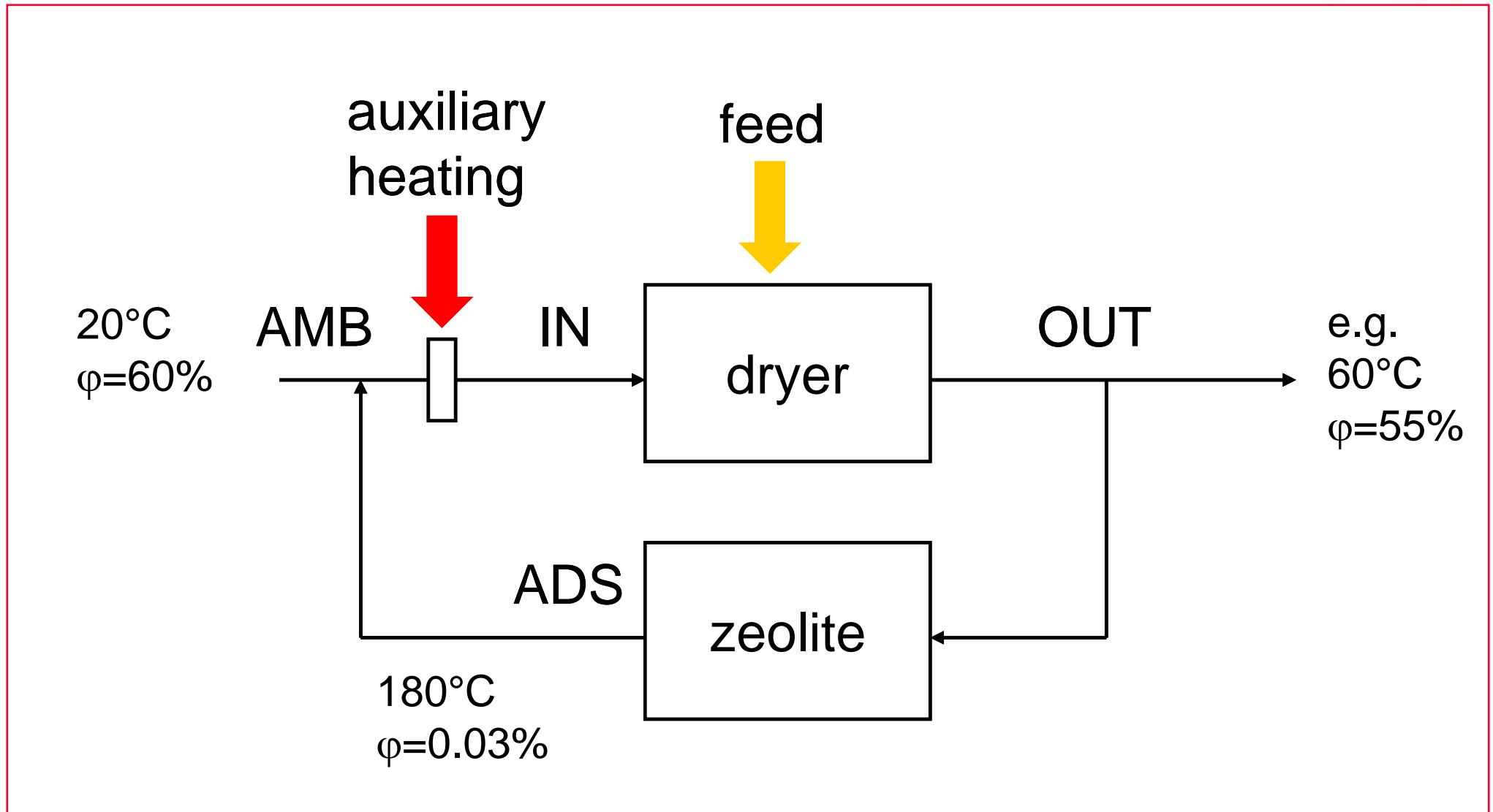
Waste incineration

- Steam from extraction turbine
- 150°C
- reduces electricity generation
- Non-stop operation

Discharging II: drying applications



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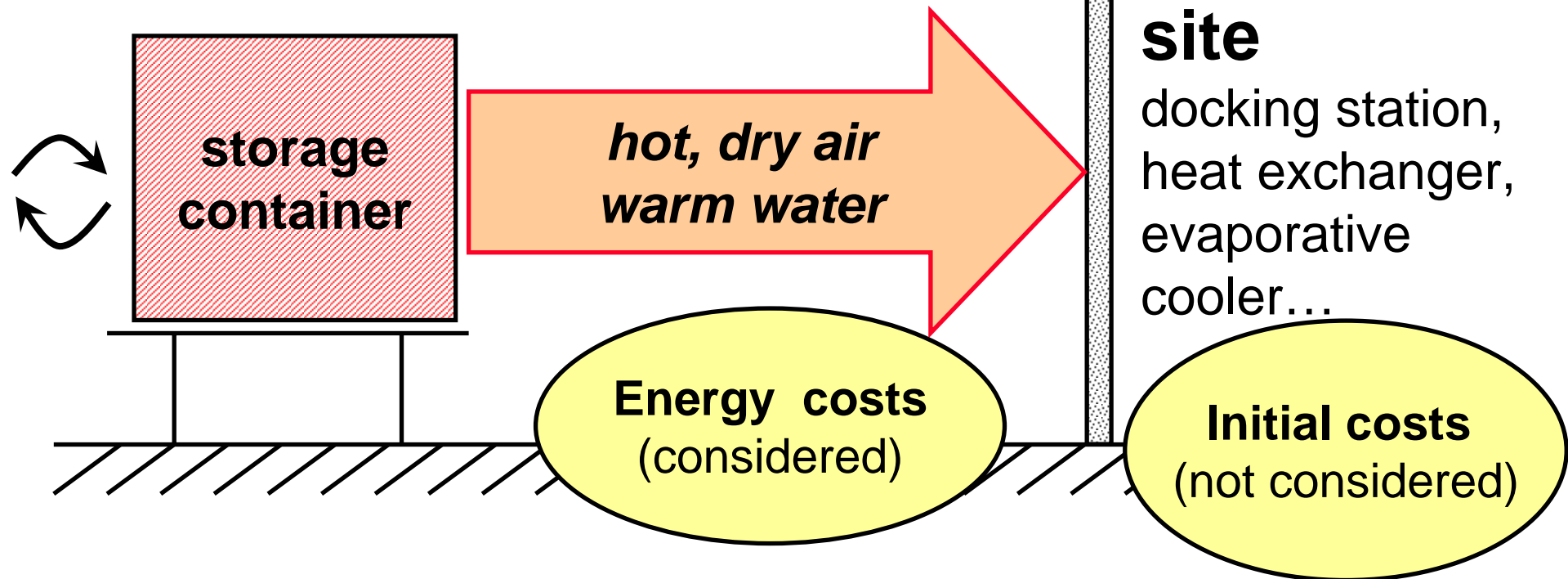
System boundary



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Mobile Storage

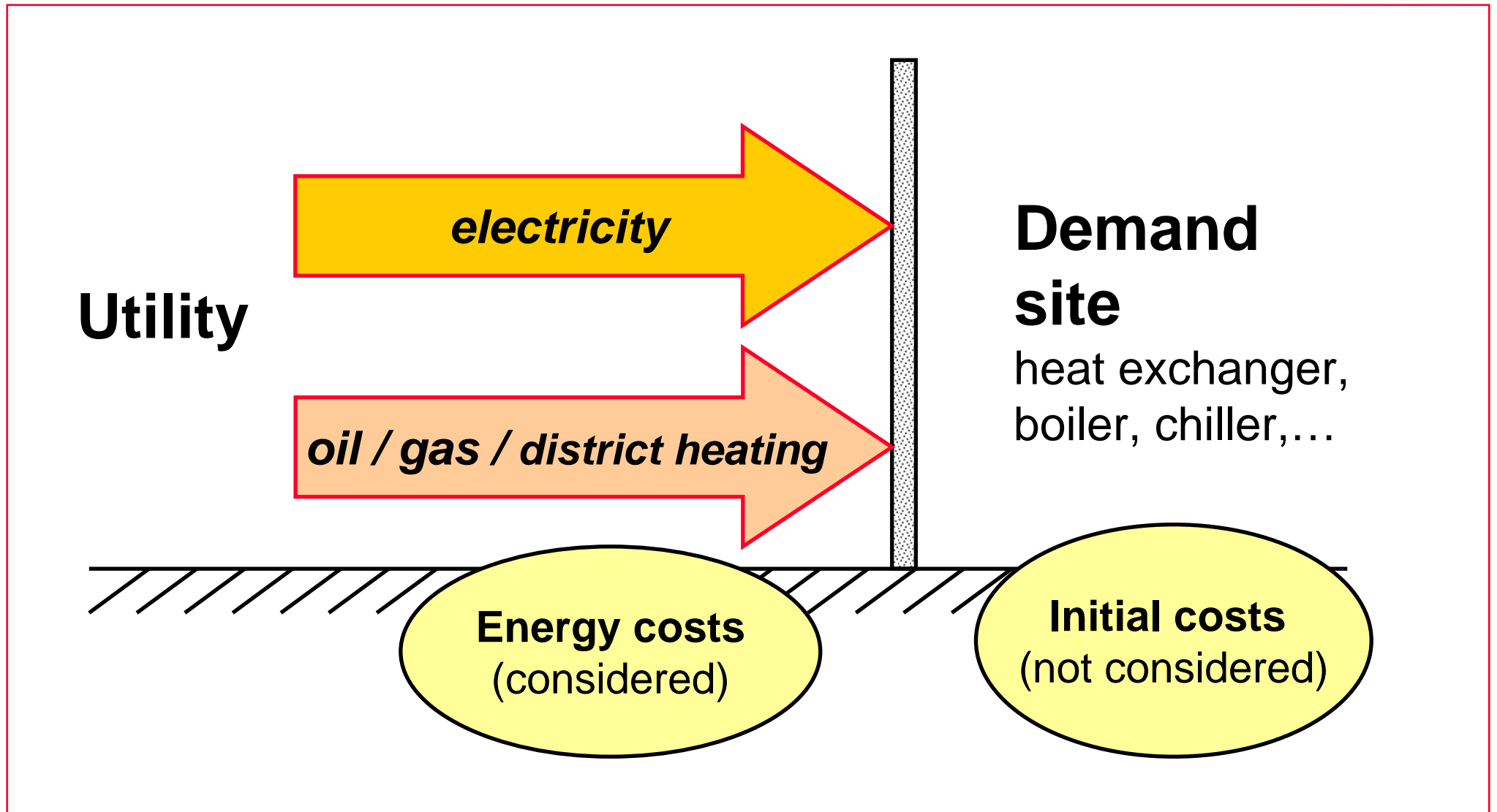
charging system, container,
truck, wages, fuel...



Reference System



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Parameter default values



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Parameter	alu +zeo	alu +PCM	waste +zeo	waste +PCM
Availability (uptime)	4380 h/a	4380 h/a	8320 h/a	8320 h/a
Internal heat costs	0	0	4.2 €/MWh	4.2 €/MWh
Storage capacity / unit	4.1 MWh	2.4 MWh	3.4 MWh	2.4 MWh
Charging time	5.5 h	9.3 h	5.8 h	9.3 h
One-way distance	10 km	10 km	7 km	7 km
Wages	40 €/h	40 €/h	28 €/h	28 €/h
Transportation costs per 100km	55 €	55 €	55 €	55 €
Driving speed	25 km/h	25 km/h	25 km/h	25 km/h
Auxiliary energy / unit	55 kWh	≈ 0	55 kWh	≈ 0

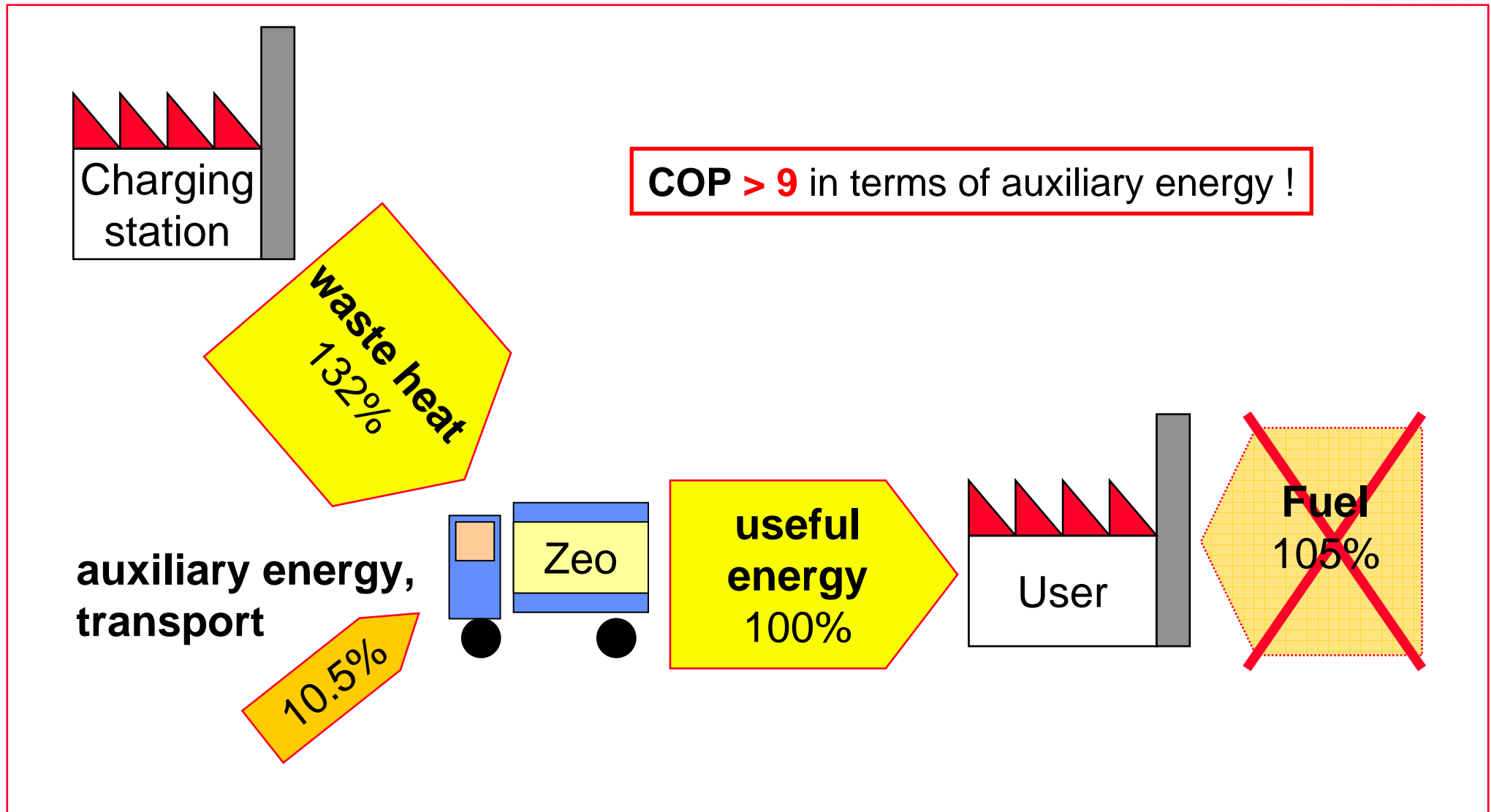


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(Primary) Energy Flow Diagram



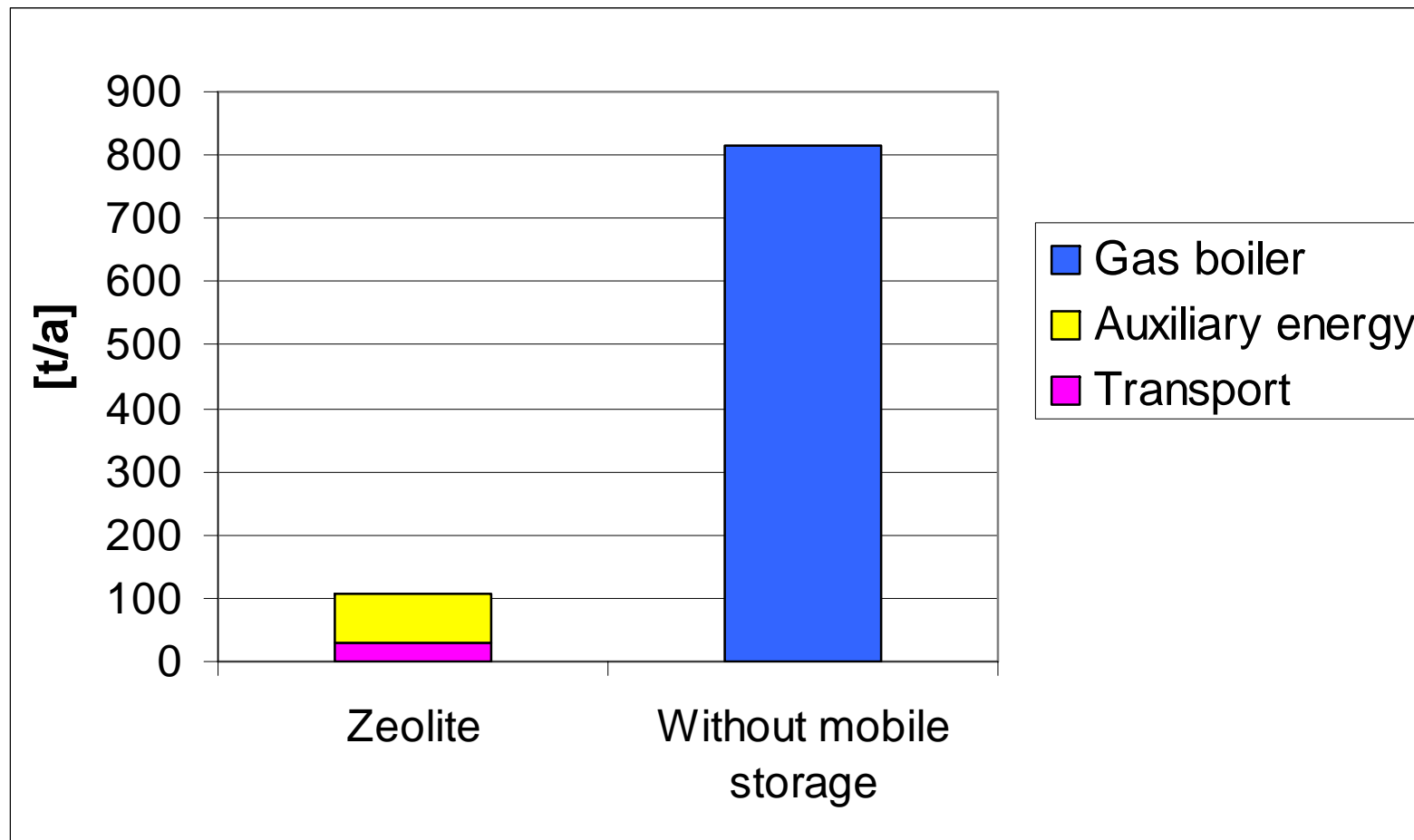
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Reduction of CO₂ emissions



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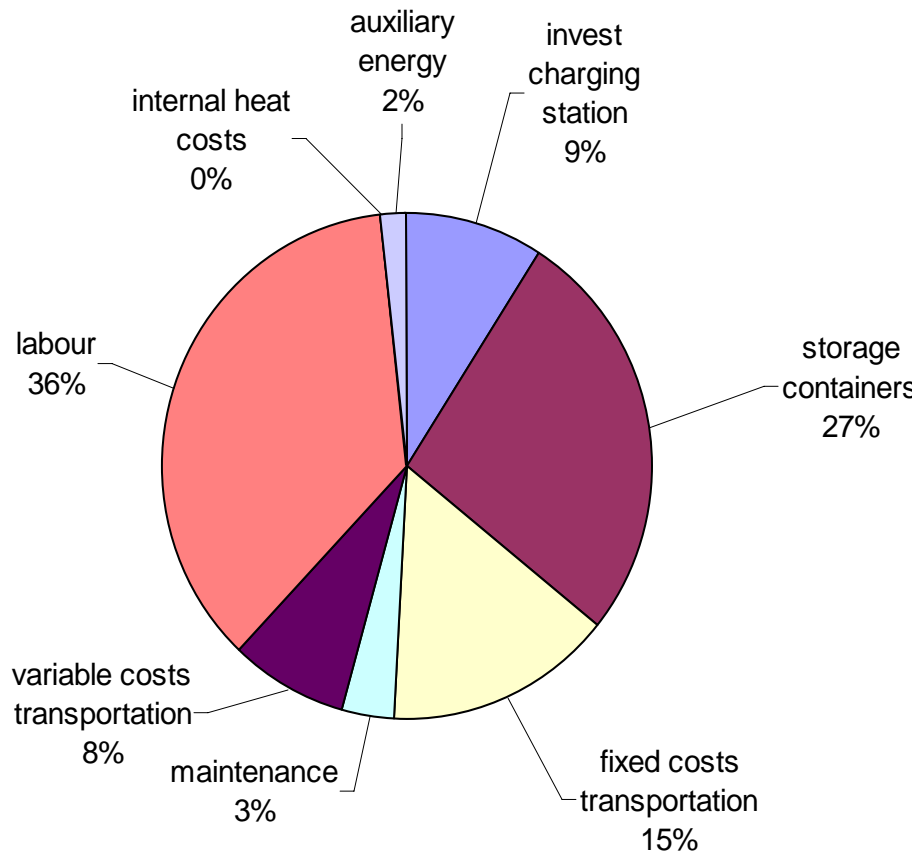


Cost distribution



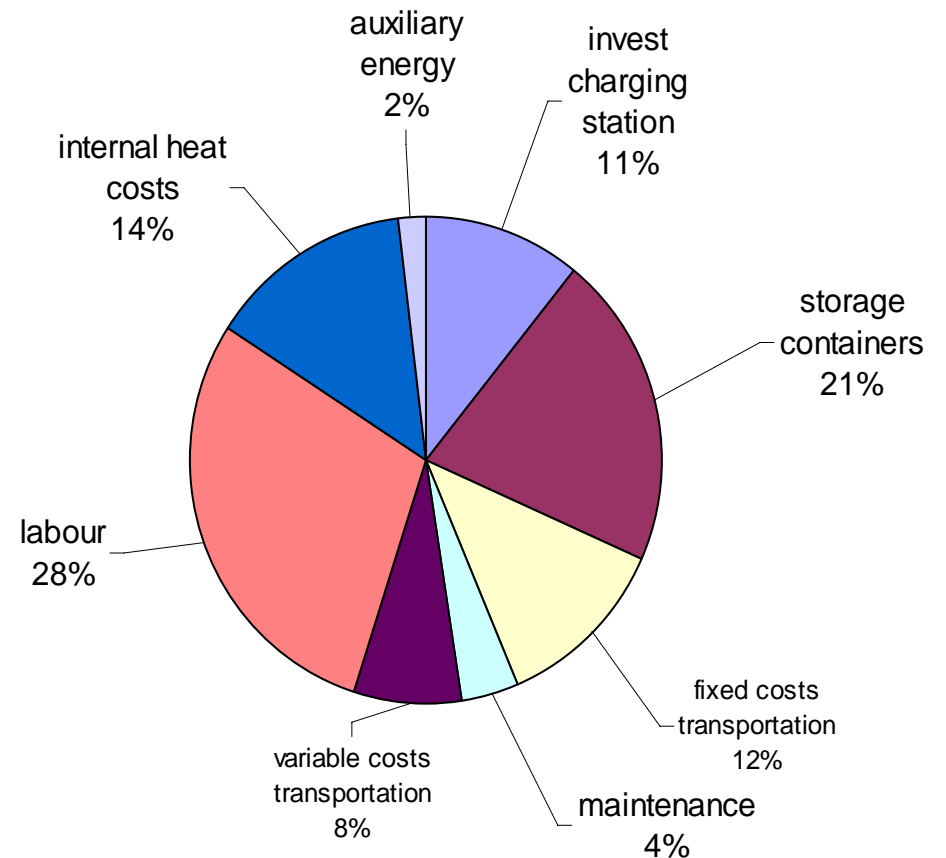
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aluminium factory + sorption



Sum: 114 000 €/a

waste incineration + sorption

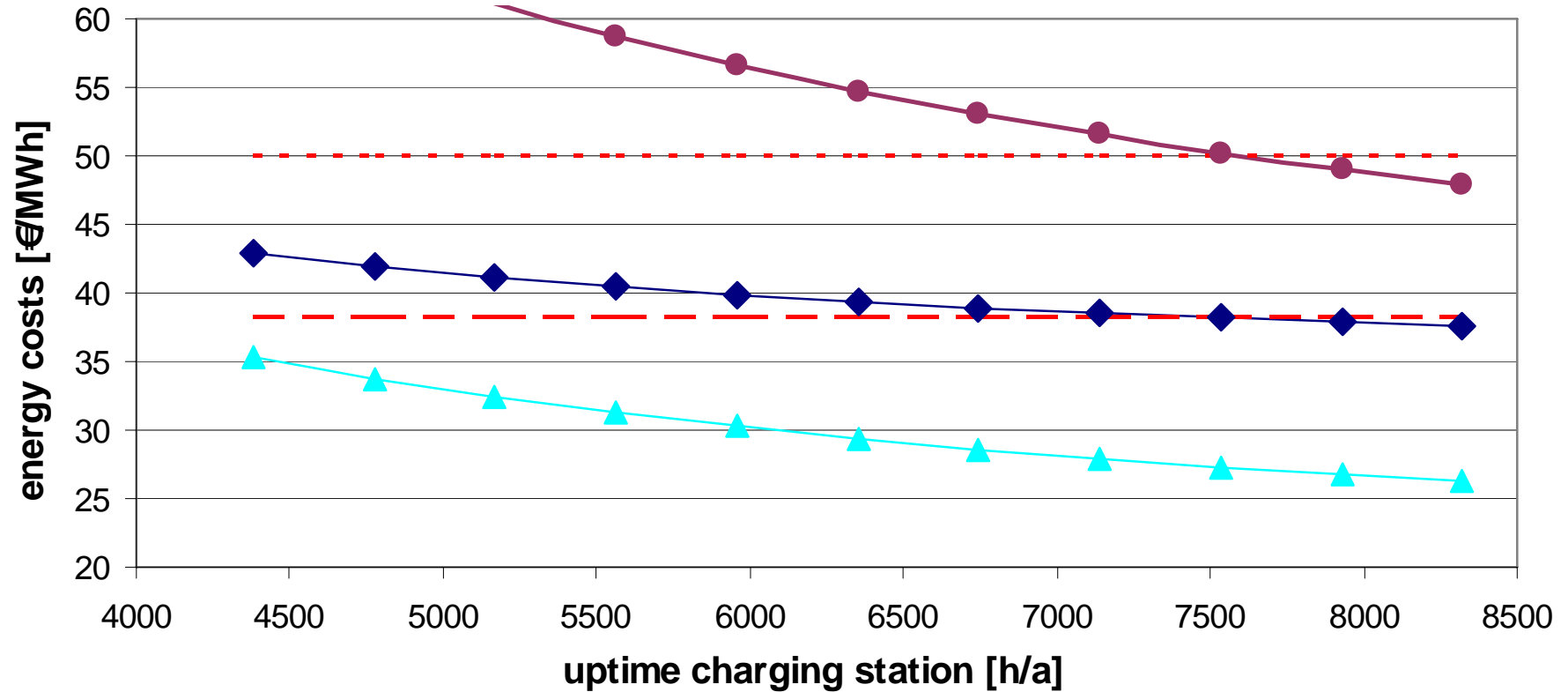


Sum: 146 000 €/a

Parameter study: uptime



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▲ sorption ● PCM ◆ water - - - oil - - - natural gas

- Energy transportation via mobile storage systems is *energetically sound*
- Topics for ongoing research on zeolite systems:
 - successful *demonstration*
 - *mechanical stability*
 - desorption with *flue gases*
- Economic performance depending on ratio *wages / energy costs*
- Ideal application: *industrial drying*

Acknowledgements



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We are grateful to

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*Thank **you** for your kind attention!*

Questions?