DTU

Smart Energy System 2019

Copenhagen

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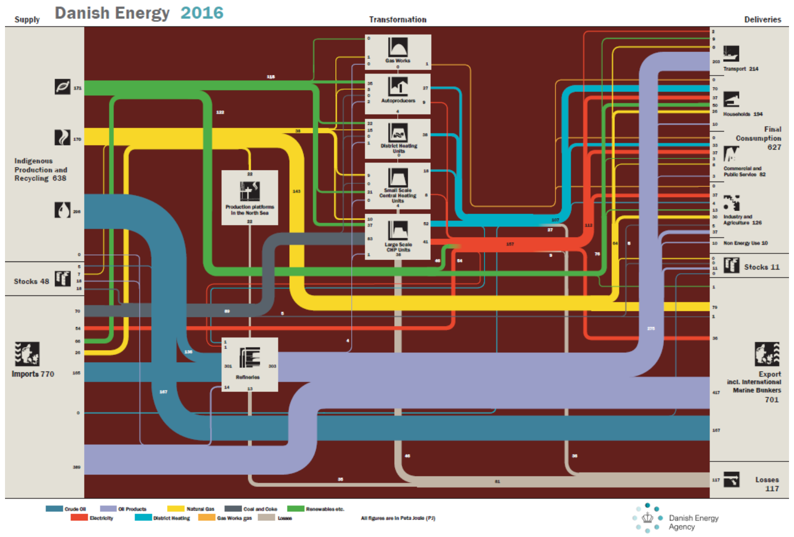
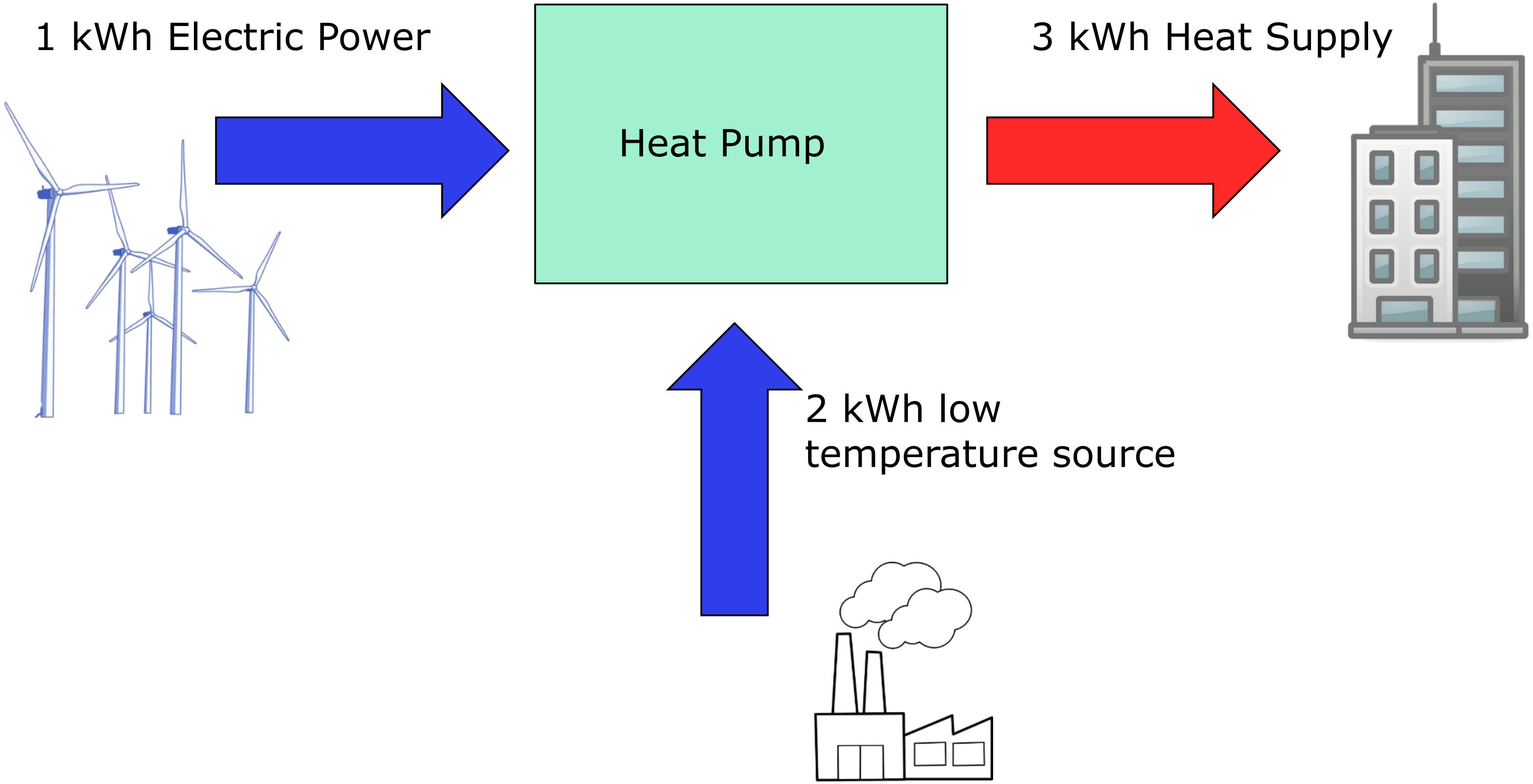
Modeling of heat pumps and excess heat sources in energy system models

Electrification – Heat Pumps

- Denmark 2050 Fossil fuel independence
- District heating
  - – Copenhagen 2035 ~150 MW heat
- Industry
  - – 20 % of energy demand



Excess heat integration



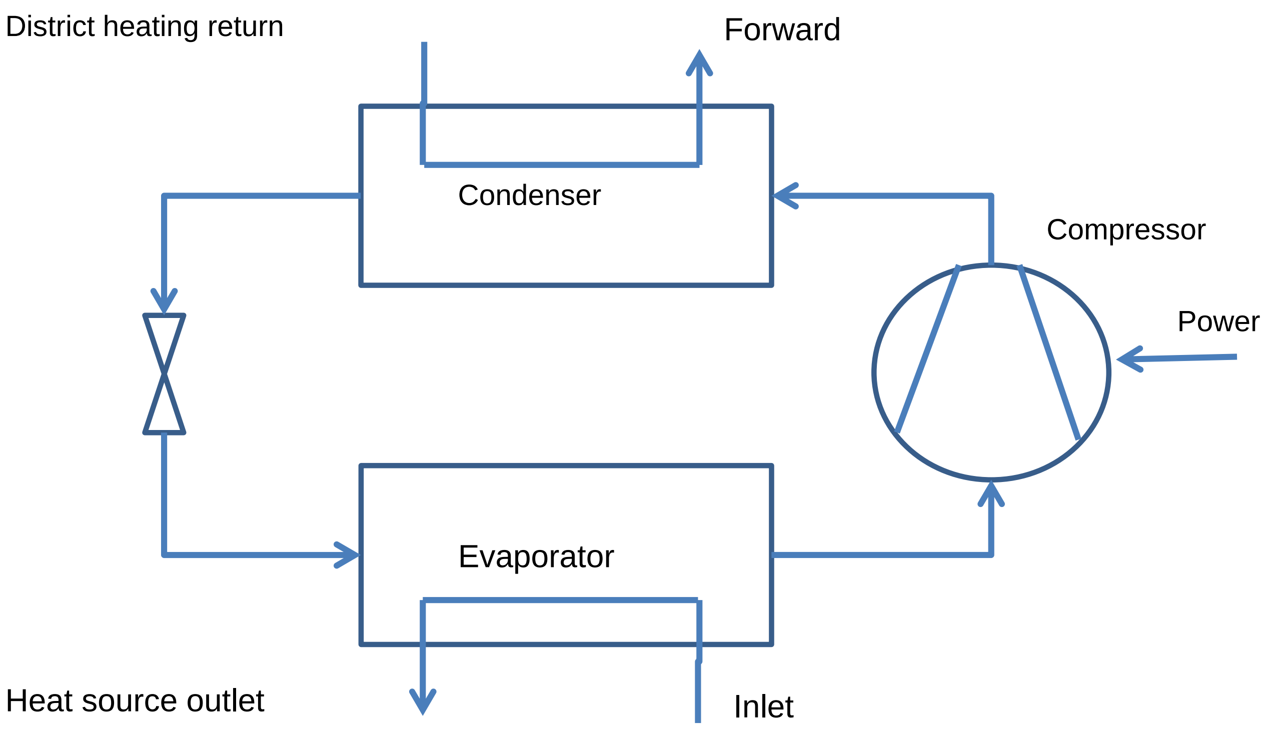
The Technology Catalogue

- Technology Data for Energy Plants for Electricity and District heating generation
- Accepted basis for planning models
  - TIMES-DK, Balmorel, EnergyPlan, …

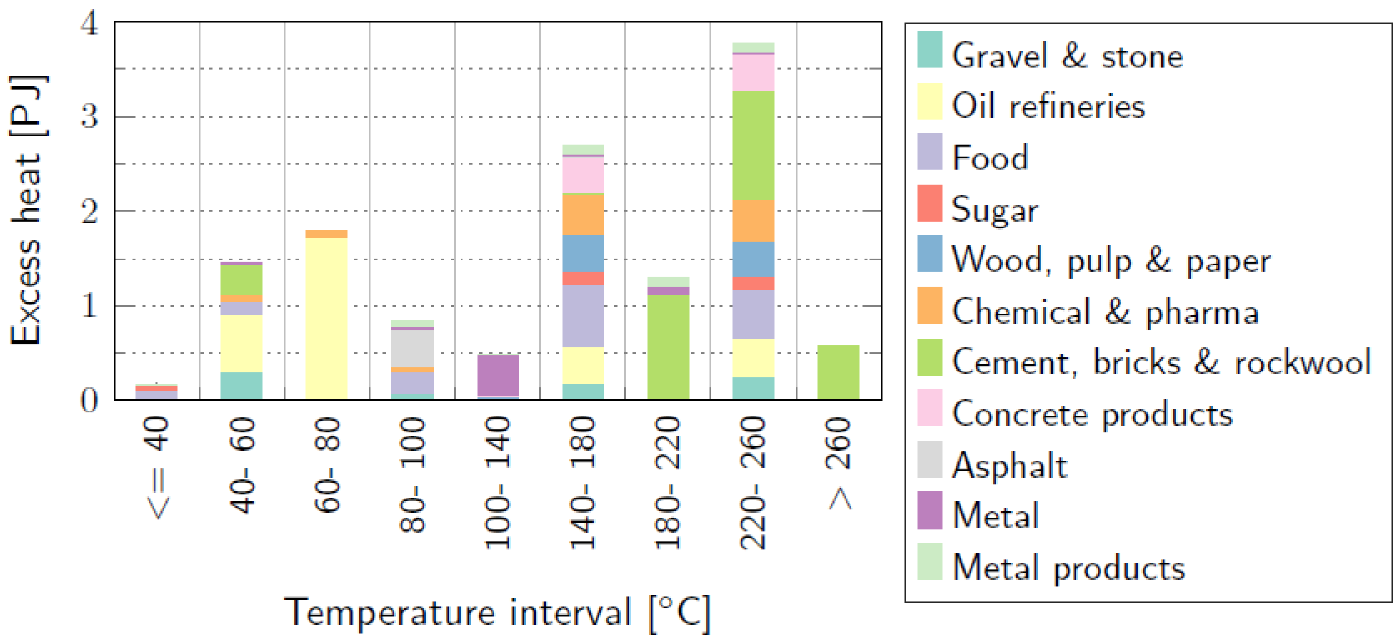
Data sheets

Technology	40 Electrical compression heat pumps - district heating									
	2015	2020	2030	2050	Uncertainty (2020)		Uncertainty (2050)		Note	Ref
Energy/technical data					Lower	Upper	Lower	Upper		
Heat generation capacity for one unit (MW_{heat})	4	4	4	4	3	6	3	10		3
Total efficiency, net (%), name plate	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Total eff., net (%), annual average, ambient heat source, no dev. in supply temp.	350	360	380	410	350	380	350	450	A, F, J, K	4
Total eff., net (%), annual average, ambient heat source, reduced supply temp.	350	400	480	600	350	450	350	700	A, B, F, J	3, 4
Total eff., net (%), annual average, waste heat 20° C, reduced supply temp.	440	500	600	740	440	600	440	850	A, B, F, J	3, 4
Total eff., net (%), annual average, waste heat 40° C, reduced supply temp.	700	900	1,200	1,800	700	1,200	700	2,000	A, B, F, J	3, 4
Electricity consumption for pumps etc. (% of heat gen)	2	2	2	2	1	4	1	4	I, M	3

Heat Pump characteristics



Excess heat potential in Denmark

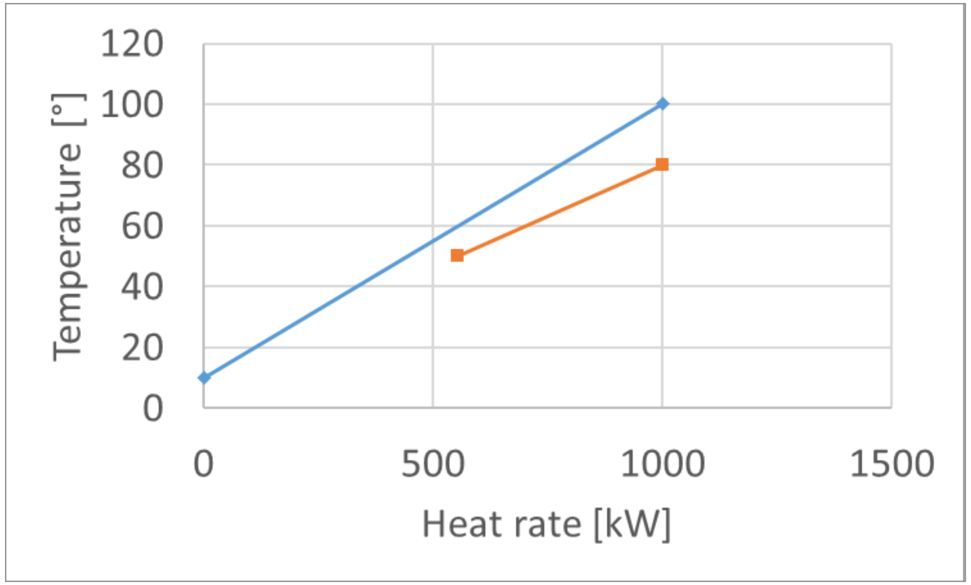


Excess heat in Denmark	212.0	PJ per year
↳ manufacturing industry	23.0	PJ per year
↳ thermal processes	12.6	PJ per year

Excess Heat High Temperature

1 MW @ 100 ℃

Sensible heat – utilized by cooling



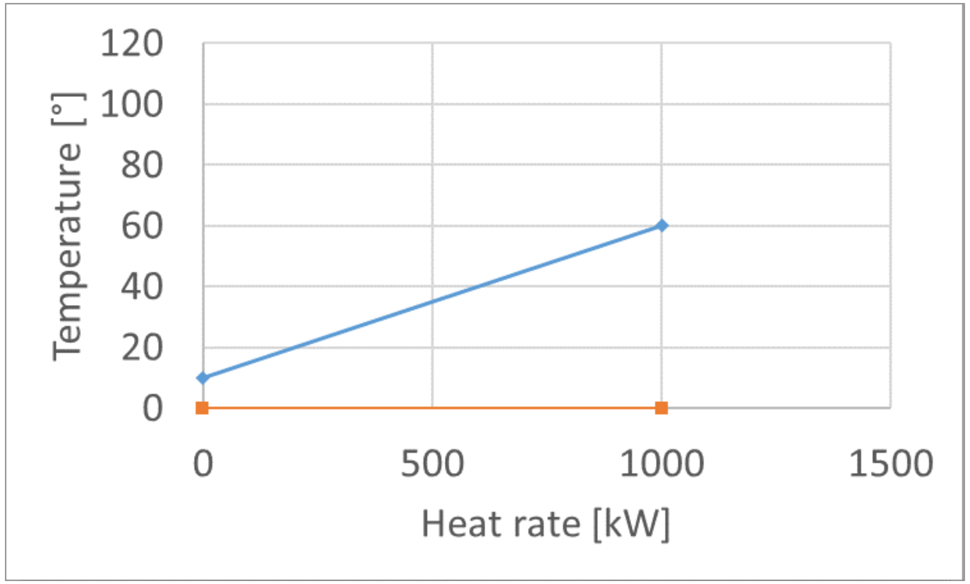
Direct integration – No heat pumping

Utilization – 44 %

Excess Heat Low Temperature

1 MW @ 60 ℃

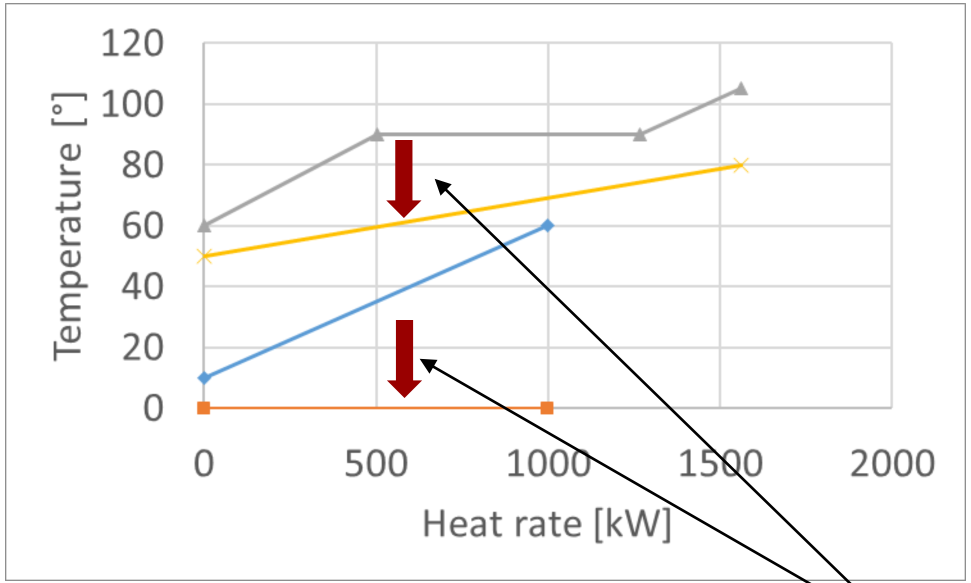
Sensible heat – utilized by cooling

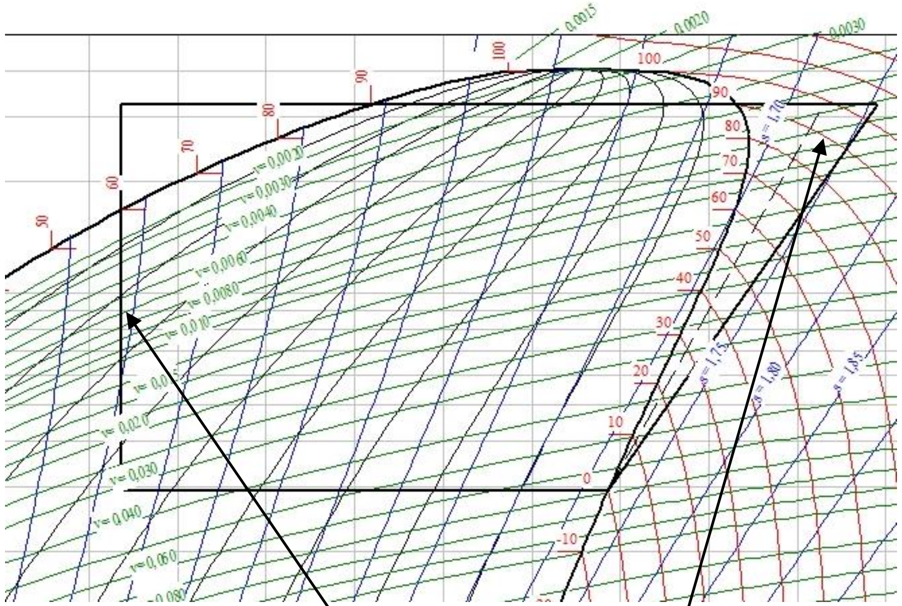


Direct integration not possible – heat pumping

Utilization up to 100 %

Heat Pump Integration





Heat transfer finite

Temperature difference

Non-isentropic compression

Non-isentropic expansion

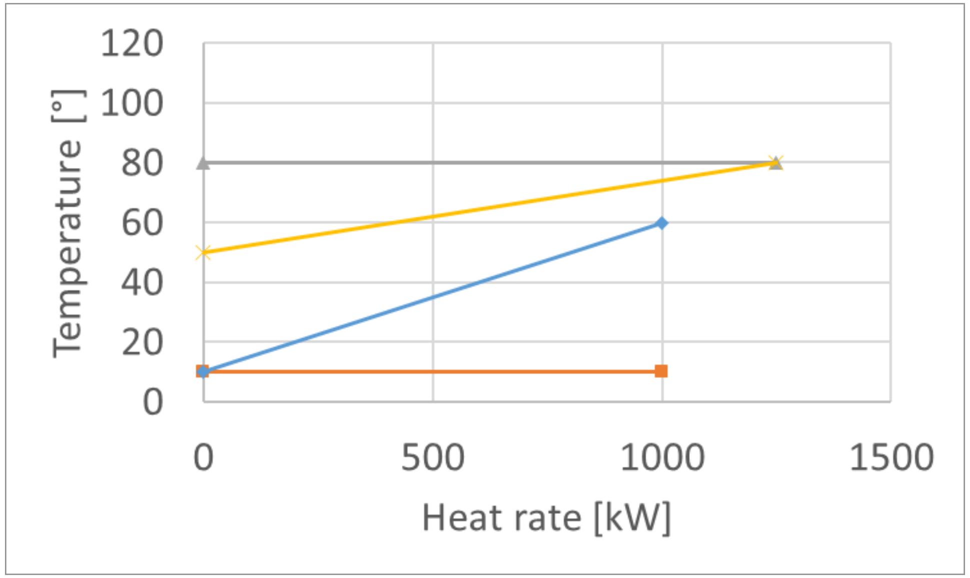
Pressure loss, motor, heat loss,…

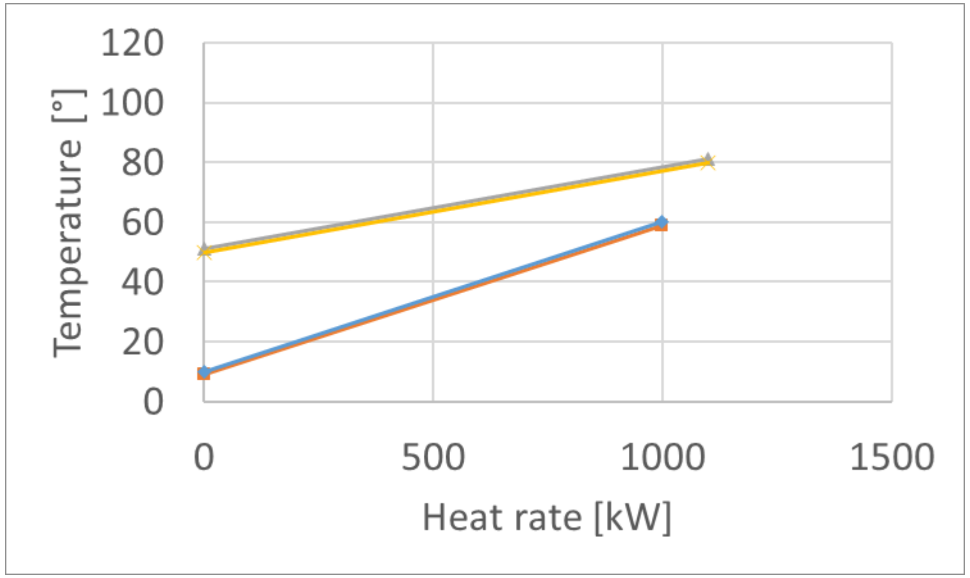
R134a example

COP 2,8

Heat production 1,6 MW

Carnot cycle v. Lorenz Cycle





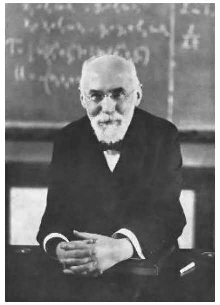
Carnot cycle integration
COP 5,0
Heat production 1,25 MW

No internal irreversibility

Lorenz cycle integration
COP 11
Heat production 1,1 MW

No internal and external irreversibility

Credit goes where credit's due



Hendrik Antoon Lorentz
(1853-1928) Netherlands

Lorentz transformation

Ludvig Valentin Lorenz
(1829 –1891) Denmark

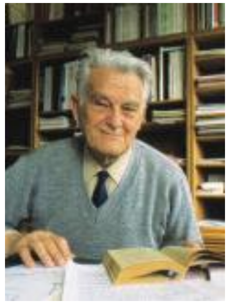
Refraction, conductivity

Edward Norton Lorenz
(1917-20 8) USA

Meteorolog , cha s theory

Hendrikus Albertus Lorentz
(1871-1944) Netherland

Explor



Gustav Lorentzen
(1915-1995) Norway

Transcritial CO_2 cycles, heat pump

Gustav Fredrik Lorentzen
(1947-2010) Norway

Engineer, musician

Hans Lorenz
(18 5-1945) German

Refrigerati n, thermo ynamics

A Lorenz
(ublished 1973-75) DDR

Refrigeration, zeotropic mixtures

Heat Pump performance

$$\mathbf{COP}_C = \frac{T_H}{T_H - T_L}$$

Sadi Carnot

$$\mathbf{COP}_L = \frac{T_{H,\mathrm{lm}}}{T_{H,\mathrm{lm}} - T_{L,\mathrm{lm}}}$$

Hans Lorenz

Lorenz efficiency

$$\eta_{\mathrm{Lorenz}} = \frac{\mathrm{COP}_{\mathrm{actual}}}{\mathrm{COP}_L}$$

Technology catalogue data

- COP from excess heat 40 ºC in 2050 : 18
- Lorenz limit: (273+45)/(45-25)=16
- Highly optimistic for some

Data sheets

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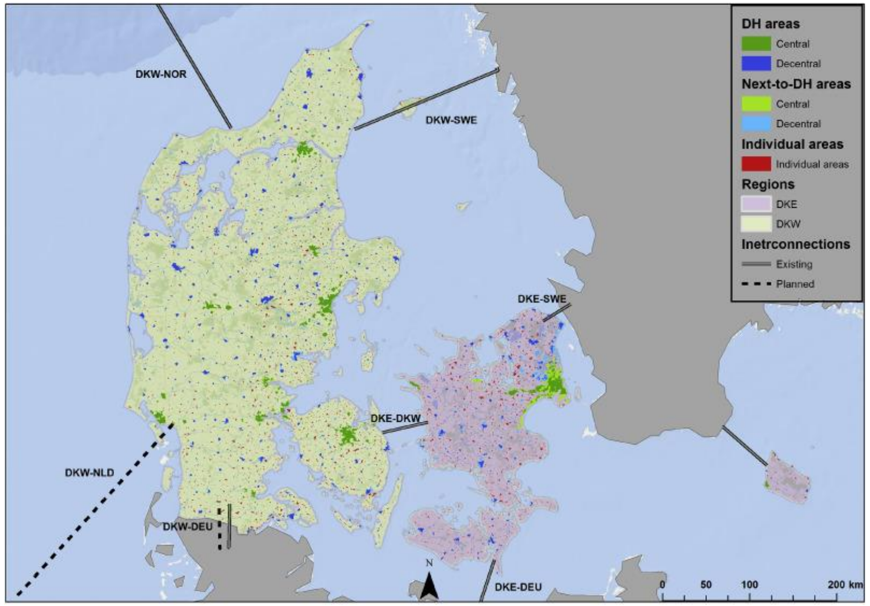
Analysis of impact TIMES-DK

- TIMES long-term analysis and planning of energy systems
- TIMES minimization of total system costs
- TIMES-DK covers all sectors
- Time-slices - non-chronological and not equal length
- District heating networks: Central and Decentral

36 Cases

- Carbon budget, Frozen Policy and High Risk Constant/Reduced DH temperature
- With/without transmission constraints
- 3 methods for calculating COP - Simple DEA, Corrected DEA, Advanced



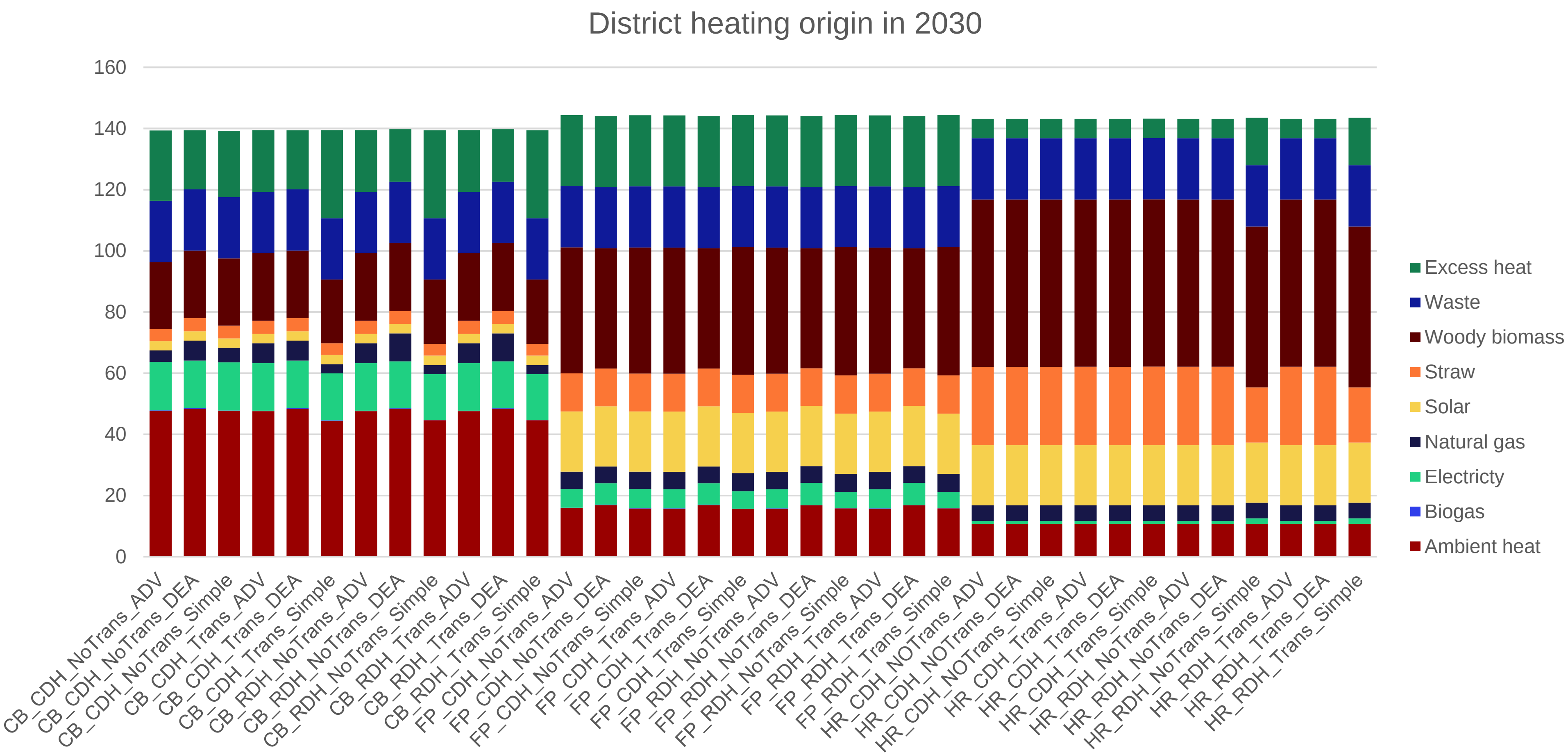
3 methods for calculating COPs

- Simple DEA
  - COPs directly from DEA Technology Catalogue

- Corrected DEA
  - Three temperature levels for excess heat: LT, MT, HT
  - HT direct integration
  - LT and MT with heat pump – re-evaluated COP

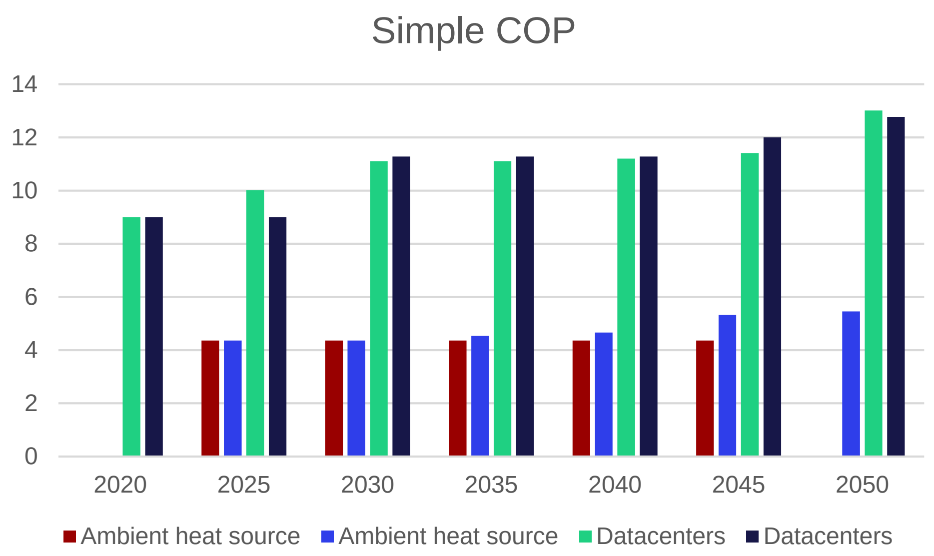
- Advanced
  - Three temperature levels for excess heat: LT, MT, HT
  - HT direct integration
  - LT and MT with heat pump – Lorenz efficiency 55 % - temperature differences

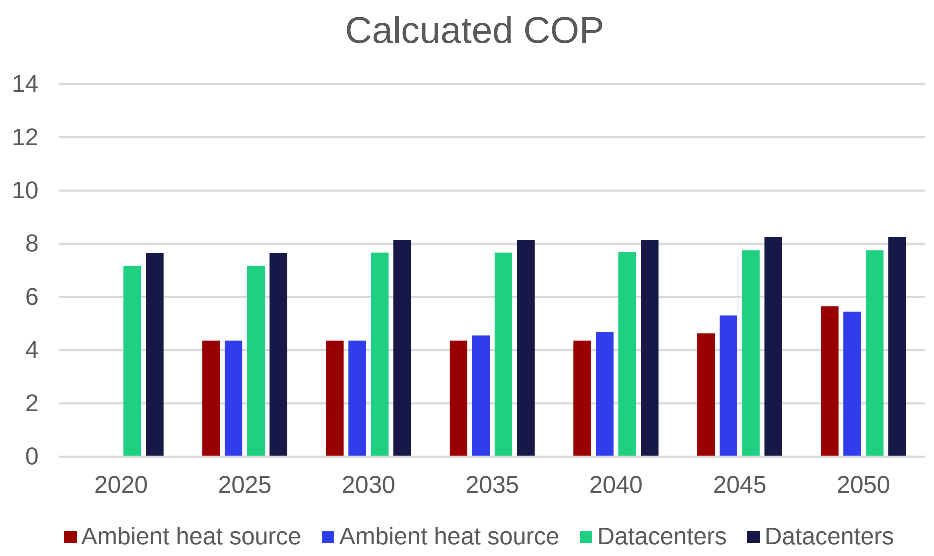
Results overall energy system



Difference in COP

- Annual average COP values as calculated by the TIMES-DK model
  - Simple approach
  - Advanced approach





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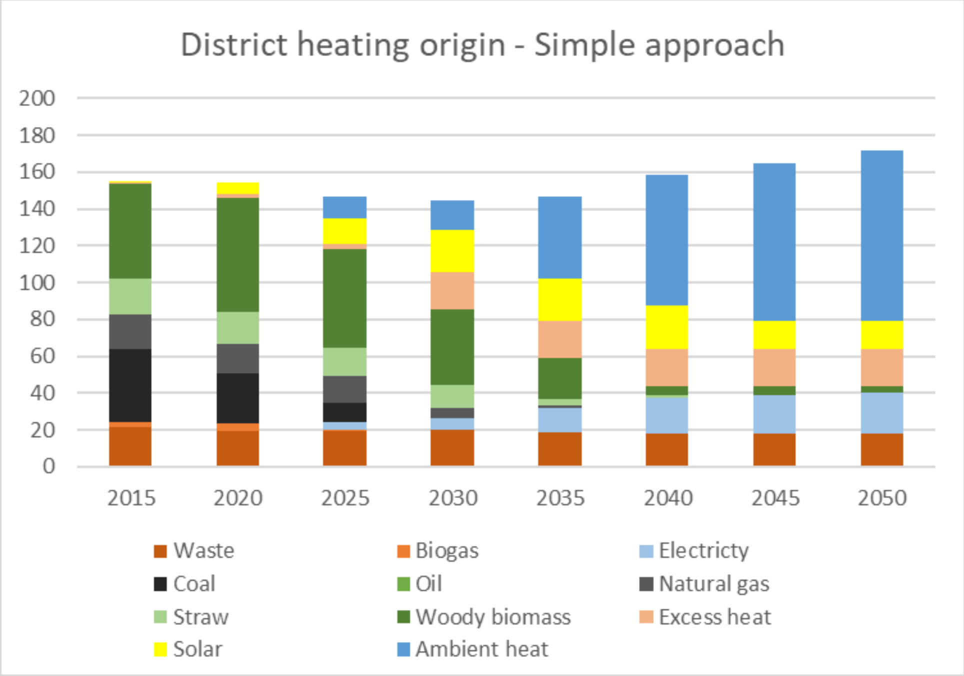
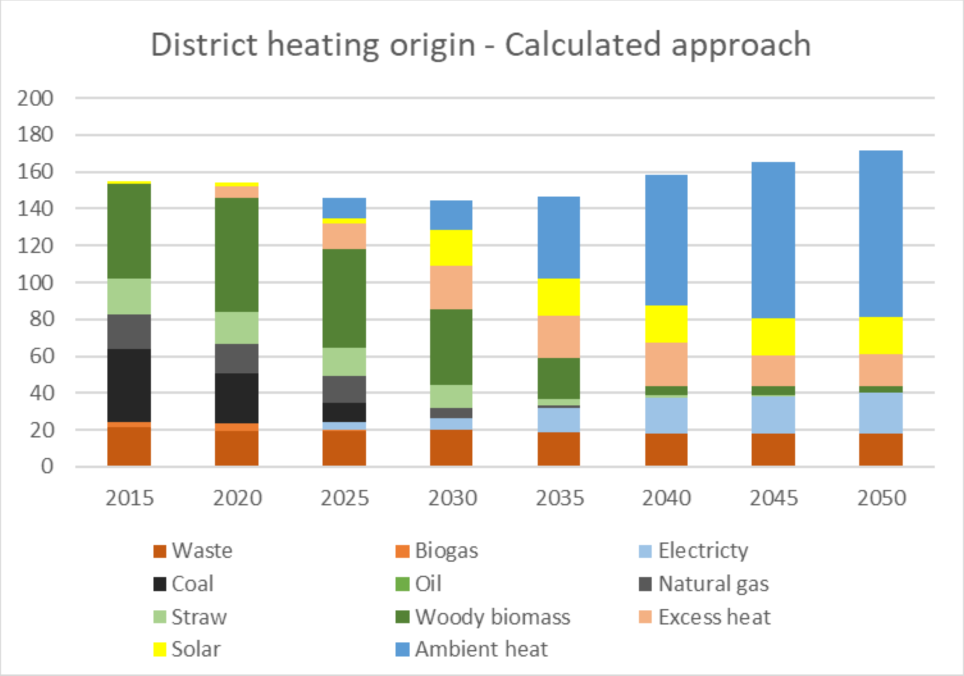
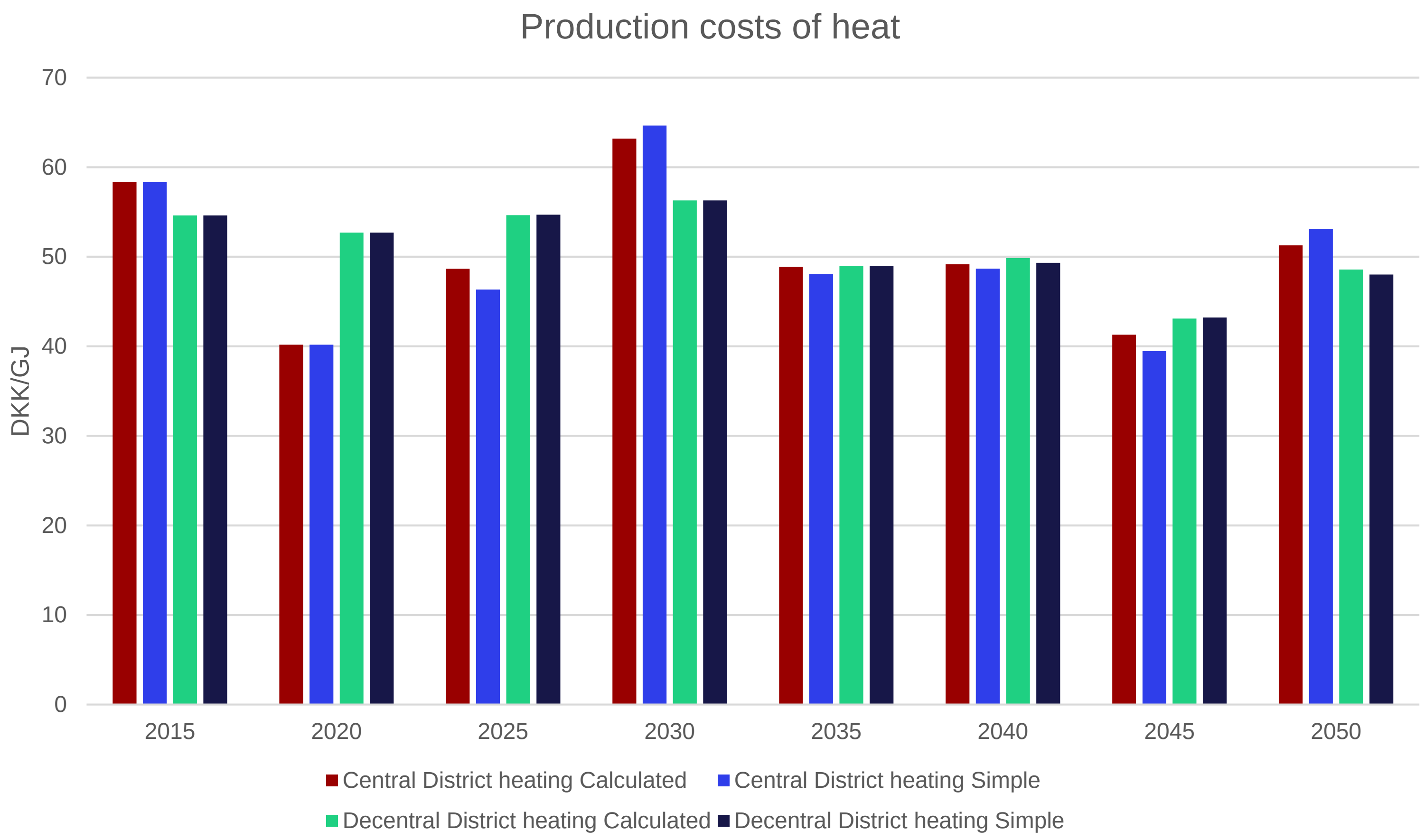
District heating Origin

- There are only a limited variation by using the two different approaches
- With a lower COP value, more solar heating appears at the cost of particular excess heat from datacentres





Annual average production costs of heat



Observations TIMES-DK

- Waste incineration and biorefinery excess heat are prioritized compared to heat pumps
- Data centers, biorefineries and high temperature excess heat in central areas
- Ambient source heat pumps in decentral areas
- No network investment is prioritized – data centers, ambient source
- Industrial excess heat with heat pumps has lowest priority
  – even if COP is highest – because of distance and network investment
- So under the given conditions and for the Danish system, the mistake by calculating the COP wrong is not so big. Only little industrial excess heat will be installed.

Conclusion

- Excess heat – Heat pump integration requires
  - Capacity
  - COP
  - May conflict

- COP estimates should account for thermodynamics

- Important for techno-economic analysis

- Excess heat-based heat pumps may be challenged socio-economically
  - High temperature excess heat – biorefineries
  - Network installation
  - Heat pumps using ambient sources in decentral grids

Heat pumps for the future energy system


TV2 / NYHEDER Seneste Politik Krimi Samfund Udland Business Penge Tech

SAMFUND

Regeringen vil sætte tryk på salget af varmepumper

17. feb. 2017, 07.02

af Ritzau

Energi-, forsynings- og klimaminister, Lars Christian Lilleholt. Foto: Emil Hougaard / Scanpix Denmark

MEST SETE PÅ TV2.DK

LOKALT Psykolog frataget autorisation: Sigtet for at have sex med klient

FODBOLD Bendtner kan være færdig på landsholdet, siger Toft

POLITIK Finansloven er ankommet - det ved vi om regeringens udspil

SAMFUND Vi er nogle af de største CO2-udledere i verden - hvordan kan du skære ned?


Ingeniøren

Nyheder Blogs Debat Jobfinder Avisen Mere Sektioner

VORES FOKUS SOLCELLEBALLADEN ENERGIFORLIG 2018 NYE SIGNALER TIL JERNBANEN ATOMSKROT SELVKØRENDE BILER FLERE

Lavere pris på elvarme skal sætte skub i små og store varmepumper

Jobfinder

RELATEREDE JOB

Machine Learning Engineer

Assistant or Associate Professor in Geotechnics


VORES FOKUS SOLCELLEBALLADEN ENERGIFORLIG 2018 NYE SIGNALER TIL JERNBANEN ATOMSKROT SELVKØR

Ny regering: Nu skal der gang i overskudsvarme og varmepumper

Jobfind

RELATEREDE JO

ORBICON

Ørsted

DHI

ORBICON


Berlingske Business

SOMMERKAMPAGNE Spar minimum 20.000 kr.* SE TILBUD

ENERGI

Danmark eksporterer vindmøllestrøm under markedspris

Fredag d. 31. oktober 2014, kl. 01.58

TOPNYHEDER

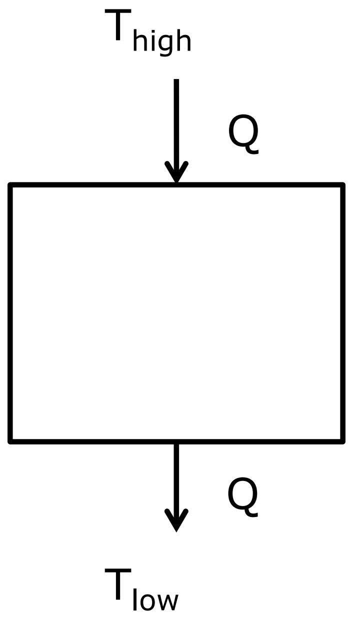
ØKONOMI 30. aug. Hackere fra Nordkorea forsøgte at bryde ind hos danske banker

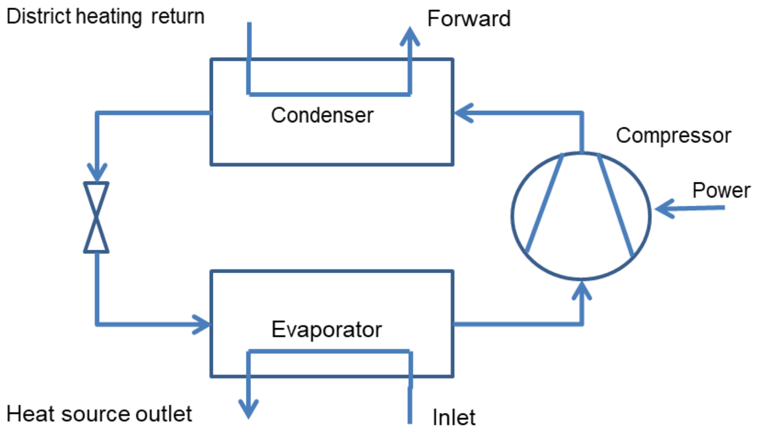
DIGITAL 30. aug. Vi har købt elektronik for næsten 13 milliarder kroner

FINANS 30. aug. På miniborsen med masser af risiko og anmærkninger fra revisor

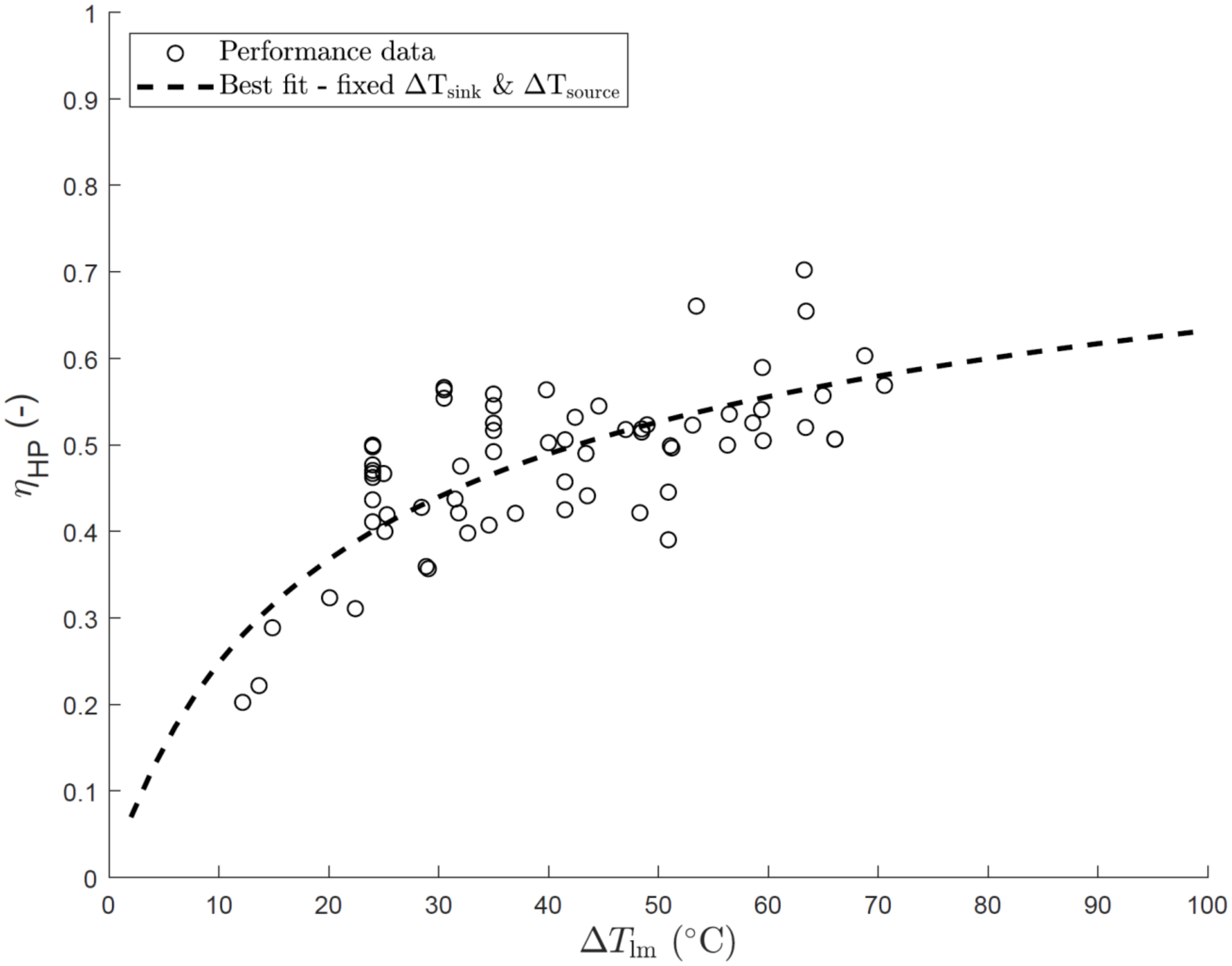
The Laws of Thermodynamics

- 1st Law: Energy is conserved – can only be transformed
- 2nd Law: Heat cannot pass spontaneously from a colder to a warmer body

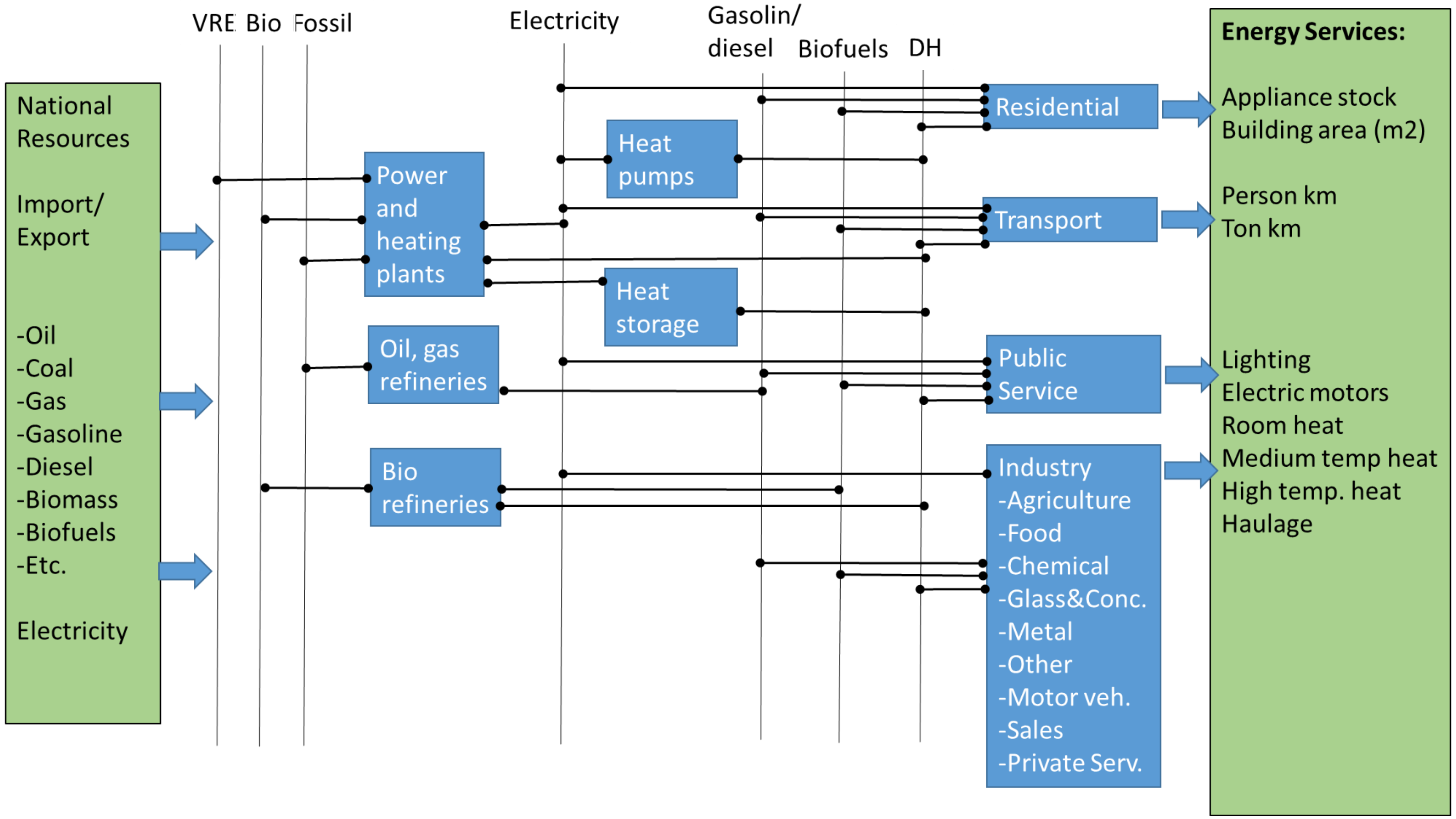




Heat pump realized performance



TIMES-DK model (if needed)



Comments on Brain's overall conclusions

I understand the overall conclusions are:

- So under the given conditions and for the Danish system, the mistake by calculating the COP wrong is not so big. Only little industrial excess heat will be installed.

I agree that the difference won't be so big. Some of the main explanations:

- Waste CHPs come in because we need to burn the waste
- Carbon budget scenarios put a big pressure on the transport sector, we need to produce biofuels, high temperature excess heat becomes available. The cost assumptions are that we build big biorefinaries and we assume that we can place them in the Central DH areas
- There is no big difference in total capacity of heat pumps, only in the sources. This is due to lack of alternatives - waste CHPs are almost fixed, biomass is need for fuel production, only heat pumps are left.
- The effect of COPs on the whole system (objective function for example) is very small - it is just one parameter in one of the sectors. Since heat pumps are always in (different sources), the only difference between the scenarios is the (average) COP. This can't affect the electricity price - it is determined by the neighboring countries. It can affect the electricity consumption, but the effect is minor. The DH price is mostly affected by the COP through the choice of sources for heat pumps. (For example, if the model chooses EH from biorefinaries, the DH price is lower than if the model chooses air-source.)

Discussion of TIMES-DK results

- How do we make sure that in particular decentral district heating grids have incentive to use heat pumps rather than biomass ressources.
- Excess heat from industries might be better utilised as a internal optimation process, in particular if heat pumps improve and become able to lift temperatures to 150-200 degrees.