Solar Thermal Plus Heat Pump

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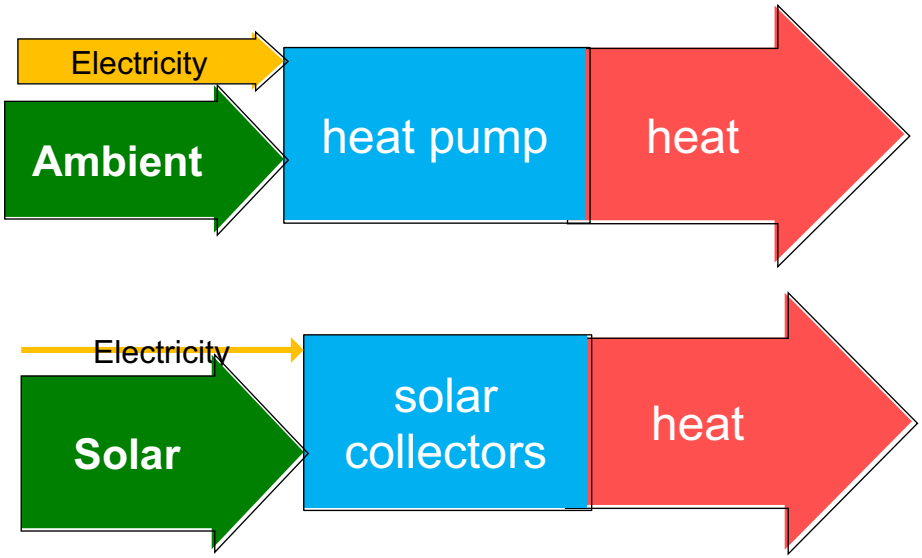
Solar and Heat Pump Systems - A Question of Technology?

Combination of Solar Thermal and Heat Pump

Key figure is the ratio of heat delivered [kWh] to electricity consumed [kWh] over the whole year

- Heat Pump:
  SPF ≈ **2.5 – 5**
  SPF = seasonal performance factor

- Solaranlage:
  Faktor ≈ **40 - 120**



But: 100% solar heating is costly!
Therefore:
- 100% Solar in summer, partially solar in autumn and spring
- the (big) rest is covered by the heat pump

1955: «The Heat Pump and Solar Energy»

E. R. AMBROSE

It has been demonstrated that the solar heat system can have an appreciably higher coefficient of performance than systems using only outdoor air as the heat source. The tests indicate that it is not unrealistic to expect coefficients of 6 to 8 on solar heat pump designs in the immediate future. Such performance values will not only provide a practical and effective way of using solar and sky radiation, but will also materially improve the competitive position of the heat pump with fuel fired heating systems.

Proc. of the World Symposium on Applied Solar Energy, The Association for Applied Solar Energy, 1955, Phoenix, US, p. 159–170.

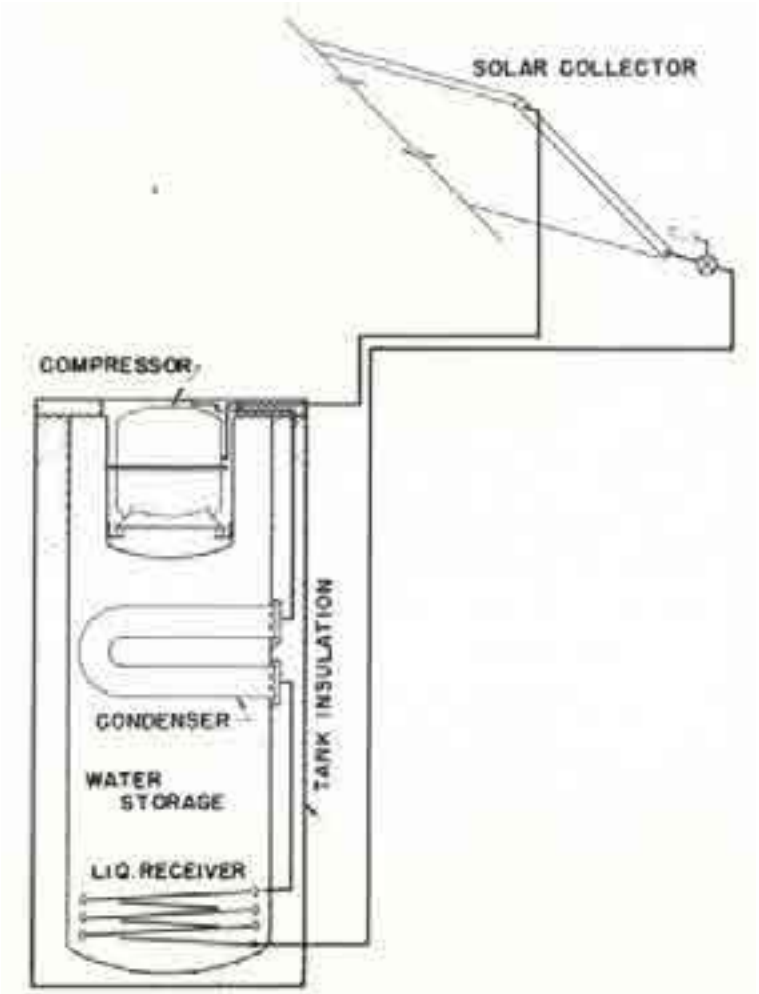
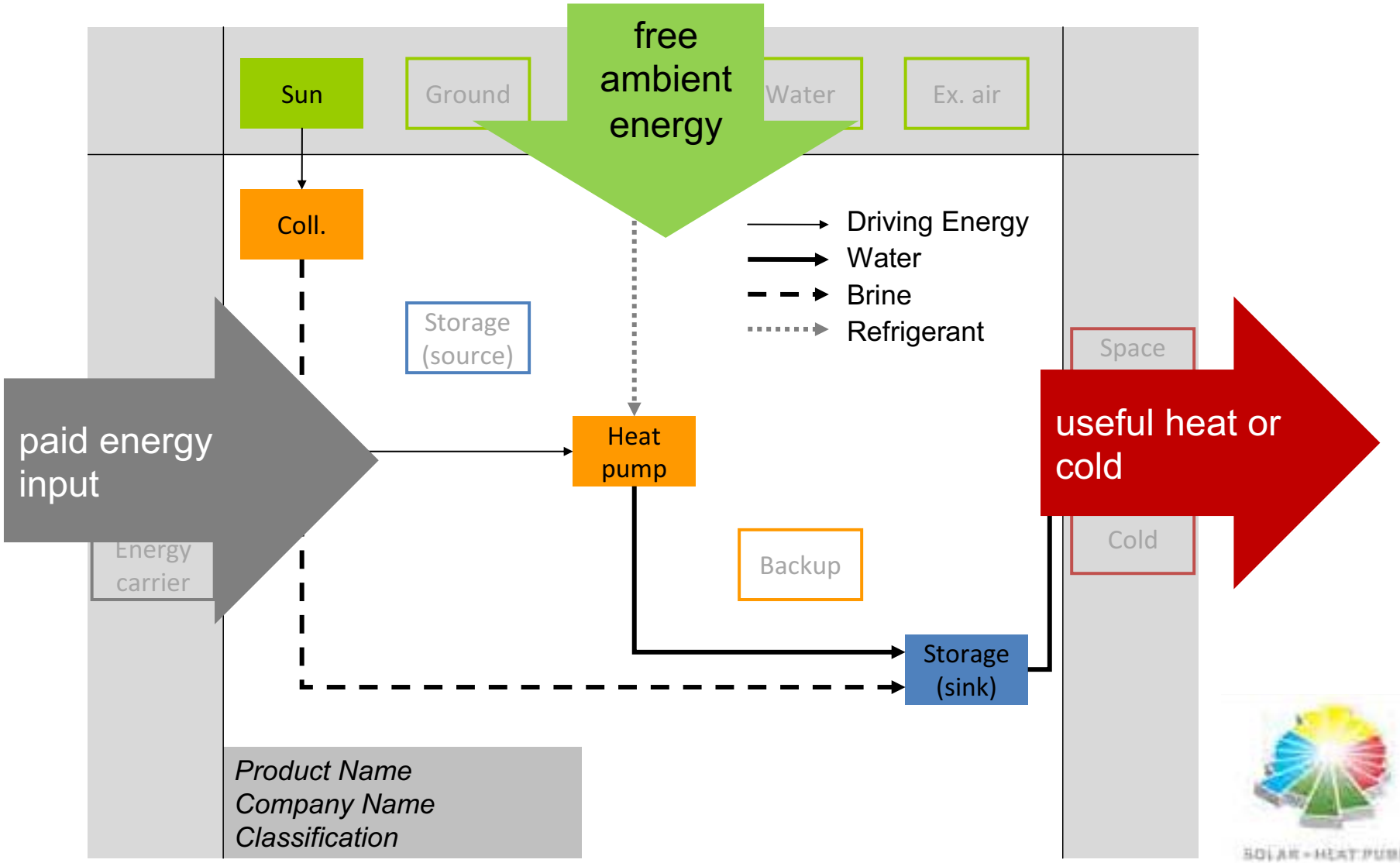
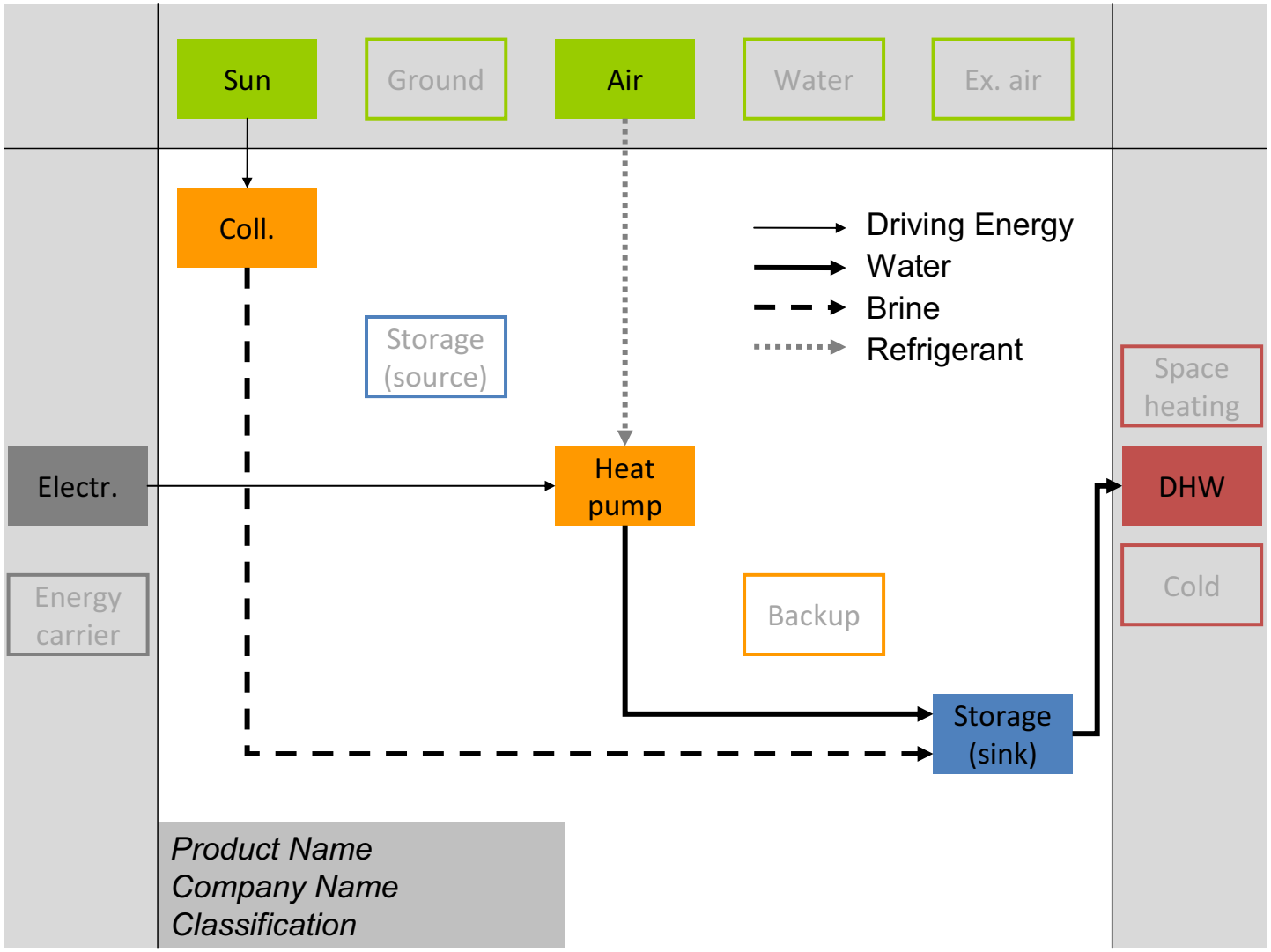


Fig. 12. Solar heat pump domestic water heater.

Systematic classification with the Energy Flow Chart



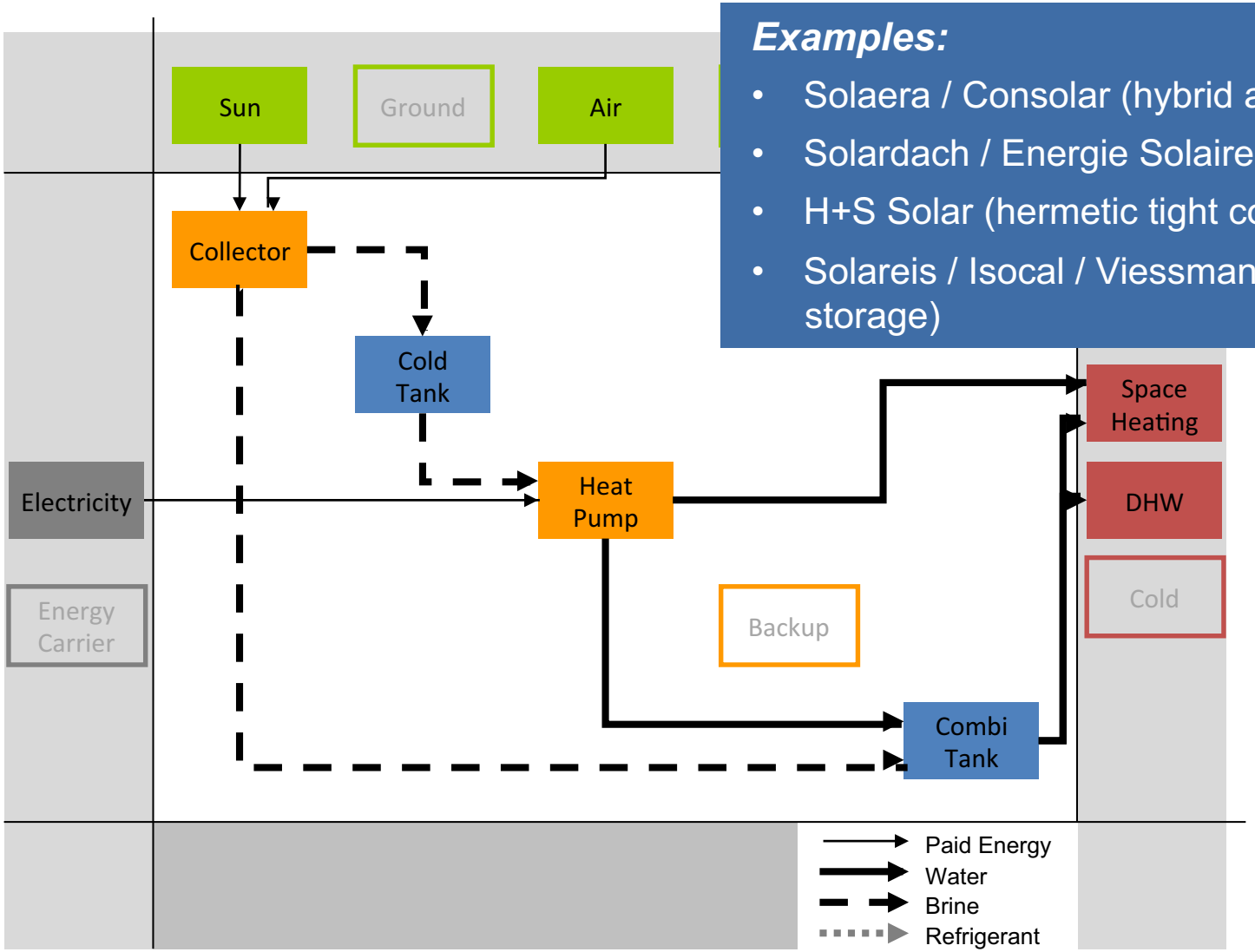
Classical «parallel» system



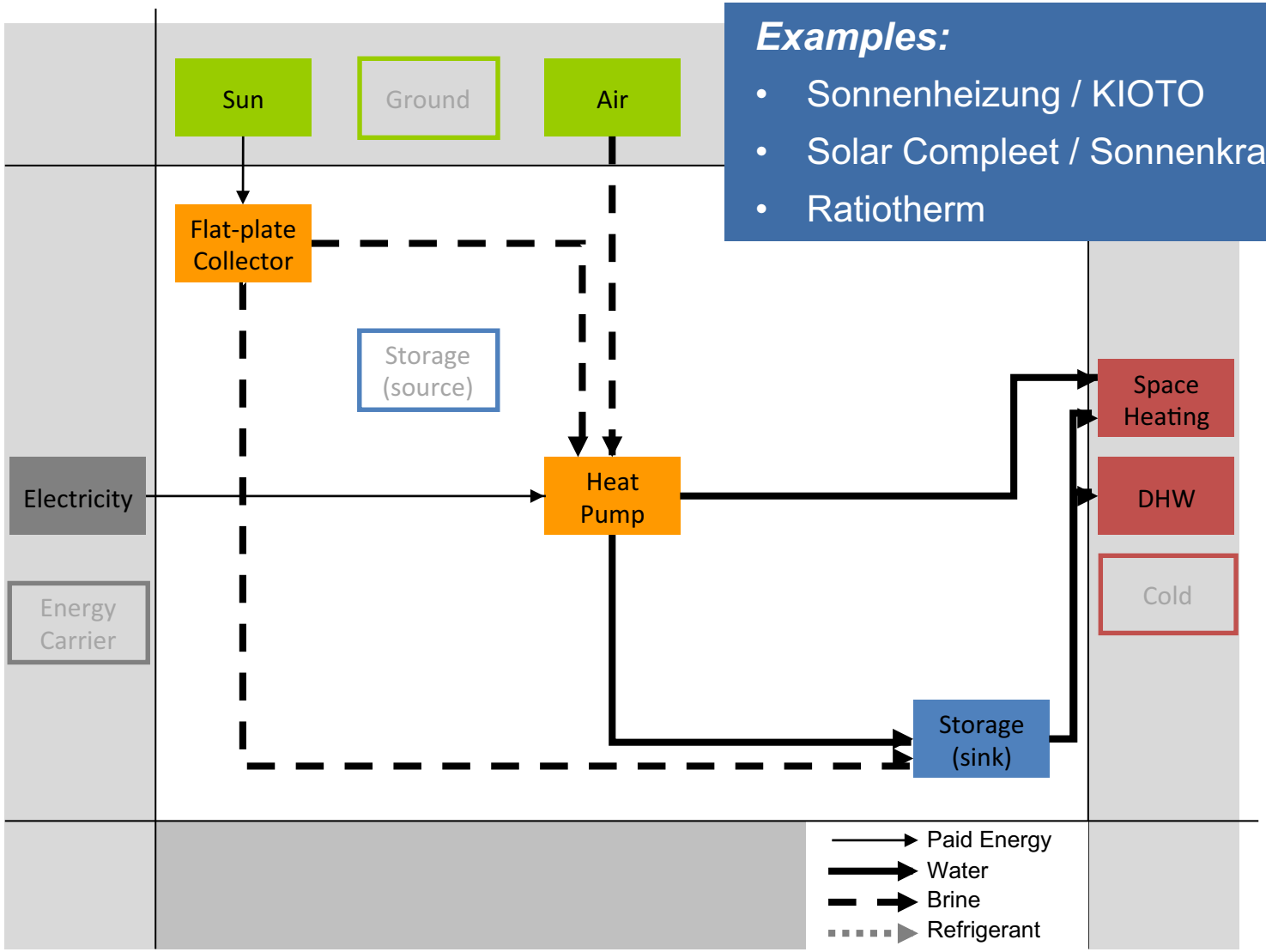
«Serial systems»: Solar heat for the evaporator of the heat pump

Examples:

- Solaera / Consolar (hybrid air-sun collector)
- Solardach / Energie Solaire (selective absorber)
- H+S Solar (hermetic tight collectors)
- Solareis / Isocal / Viessmann (ground buried ice-storage)



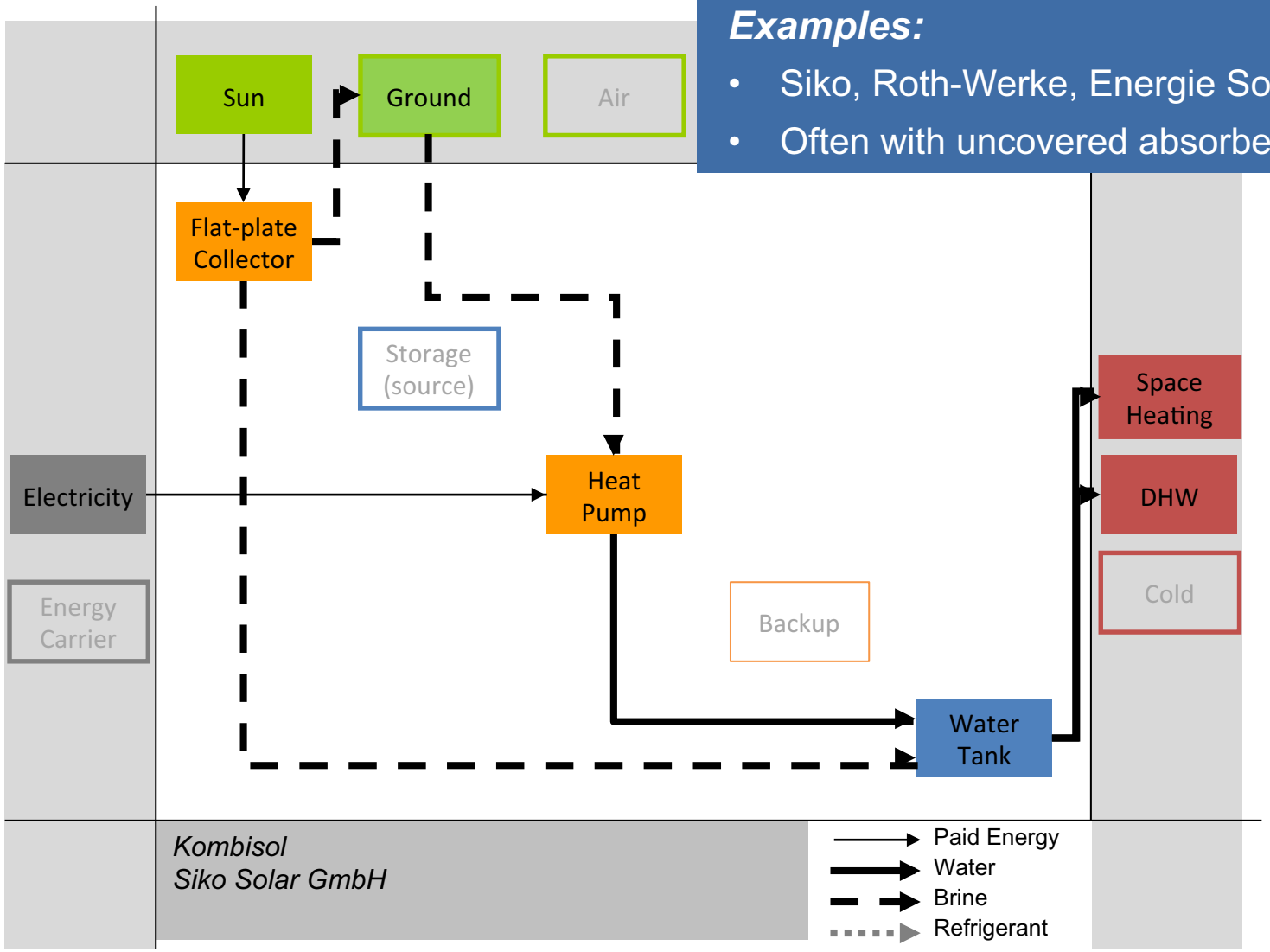
Serial systems without cold storage



Examples:

- Sonnenheizung / KIOTO
- Solar Compleet / Sonnenkraft
- Ratiotherm

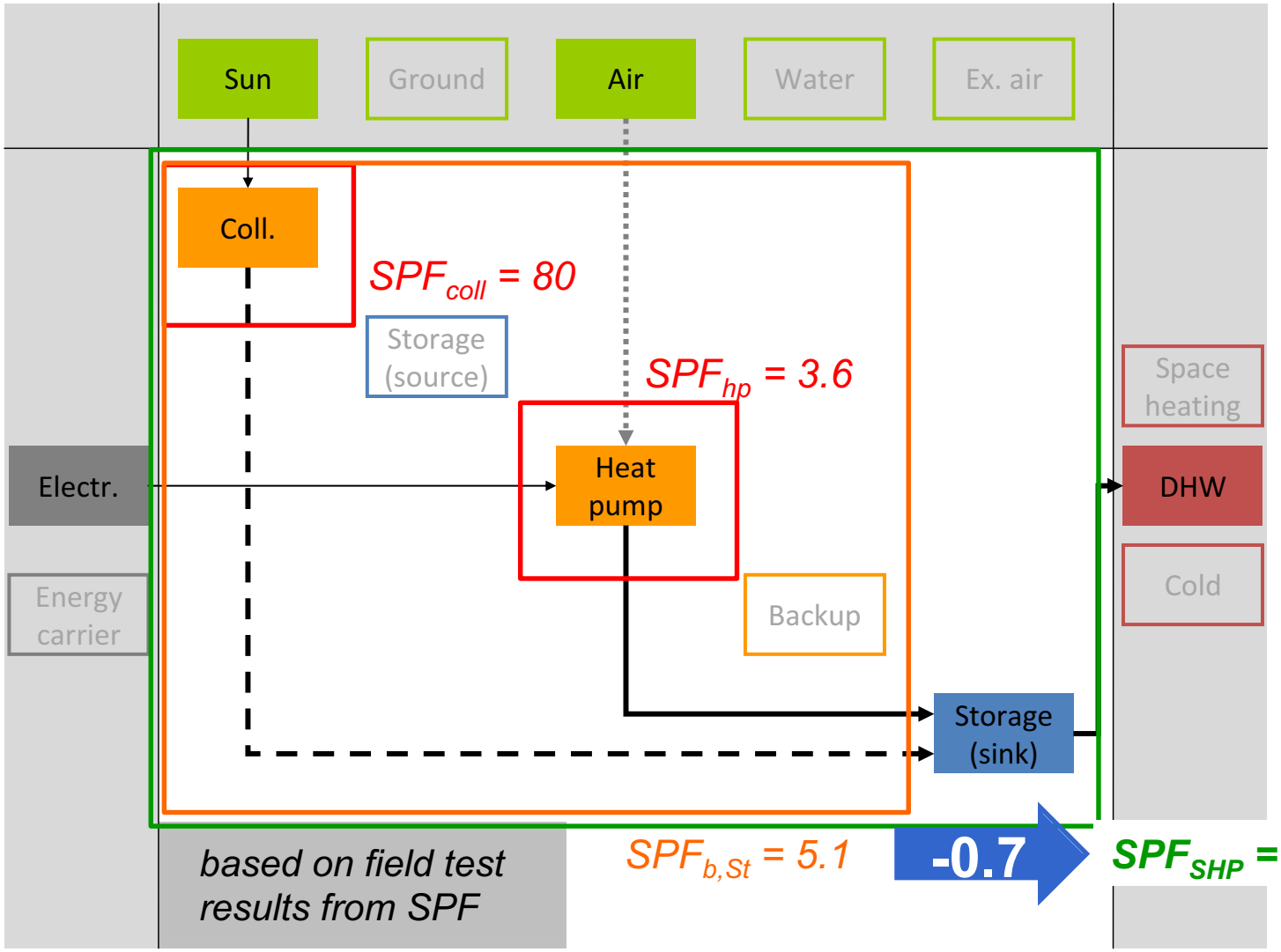
Systems with ground regeneration



Examples:

- Siko, Roth-Werke, Energie Solaire, Schüco
- Often with uncovered absorbers or PV/T collectors

The Seasonal Performance Factor (SPF) - Example



The Seasonal Performance Factor (SPF)

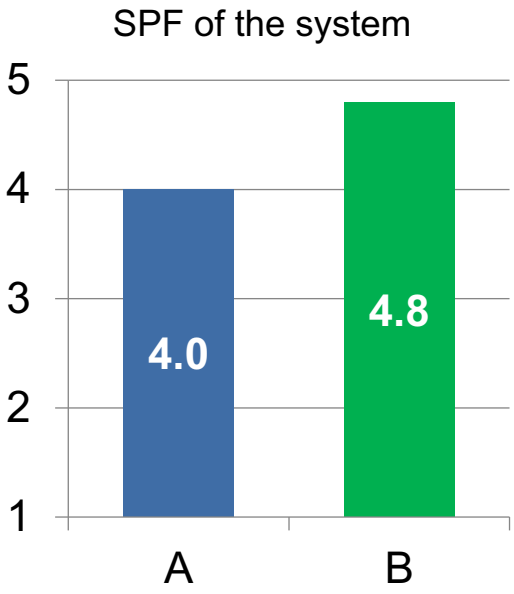
- Decrease in seasonal performance factors

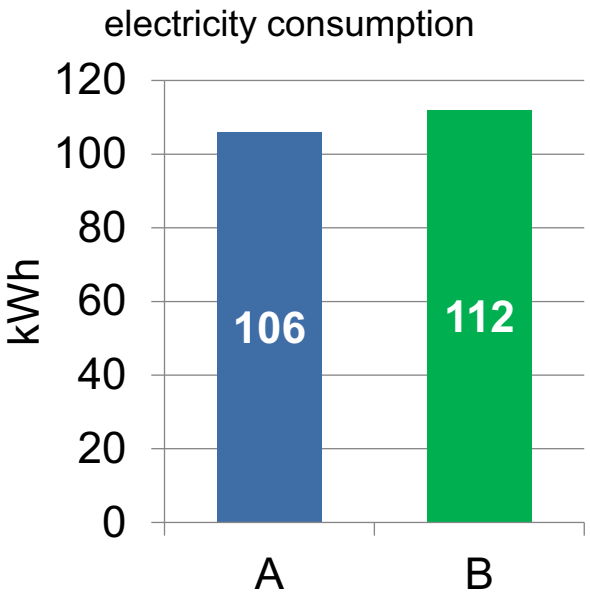
  from «before storage» to «system»

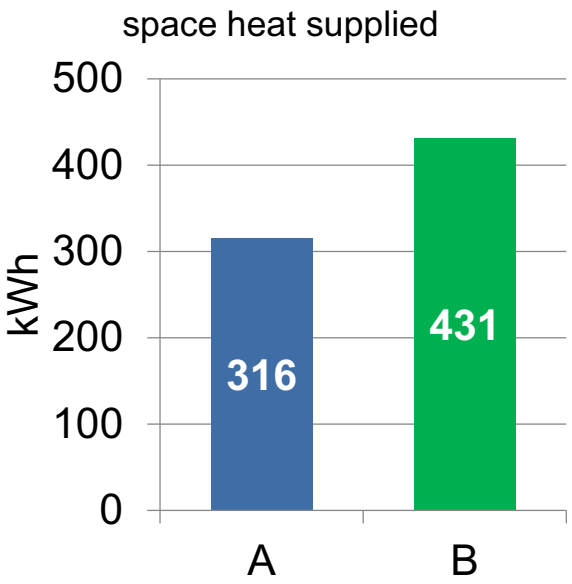
  - heat pump only: **0.2 - 0.5**
  - solar and heat pump: **0.4 - 1.0**

Seasonal Performance Factors may be misleading...

Test bench results of two solar and heat pump systems (same 12-day test)



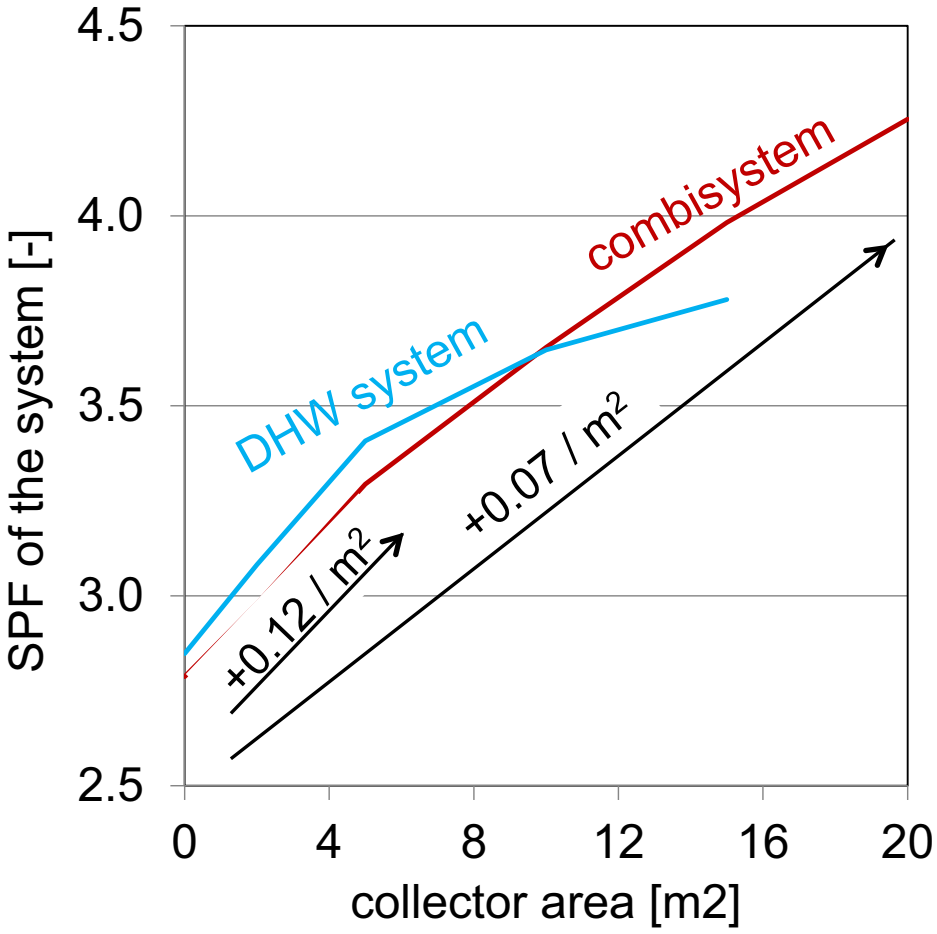




possible reasons: different settings for ***space heat control*** or ***no thermostatic valves*** may lead to increased (mostly useless) space heating at times where high COP can be achieved!

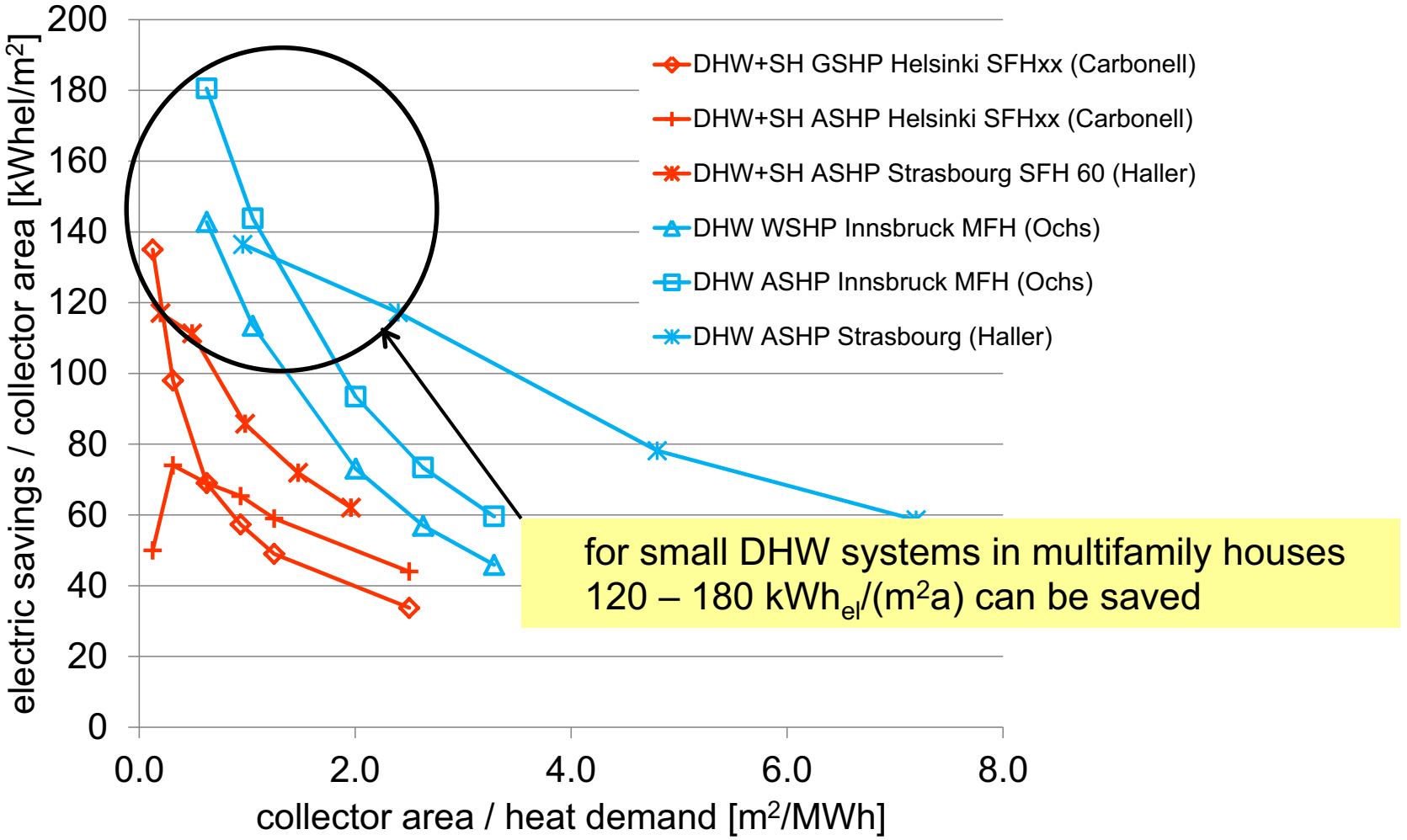
Increasing SPF of the System by Solar Thermal

- Example for a single family house with an air source heat pump
  ($Q_{space\ heat}$ = 8100 kWh/a (35/30), Q_{DHW} = 2100 kWh/a)



Electricity Savings by Solar Thermal

- Examples for different heat loads in central and Northern European climates



compared to PV...

- ***Electric savings per m² roof area*** are in the ***same range as PV yield*** (for the given location) assuming that PV yield can be used 100% (fed to the grid)
  - ***higher for*** small solar fractions of large ***DHW solar thermal systems*** (e.g. multifamily houses)
  - rather ***lower for*** solar ***combisystems***
- ***PV & heat pump*** is (and will be) a serious ***competitor*** for solar thermal and heat pump
  - It is not easy to do a fair comparison

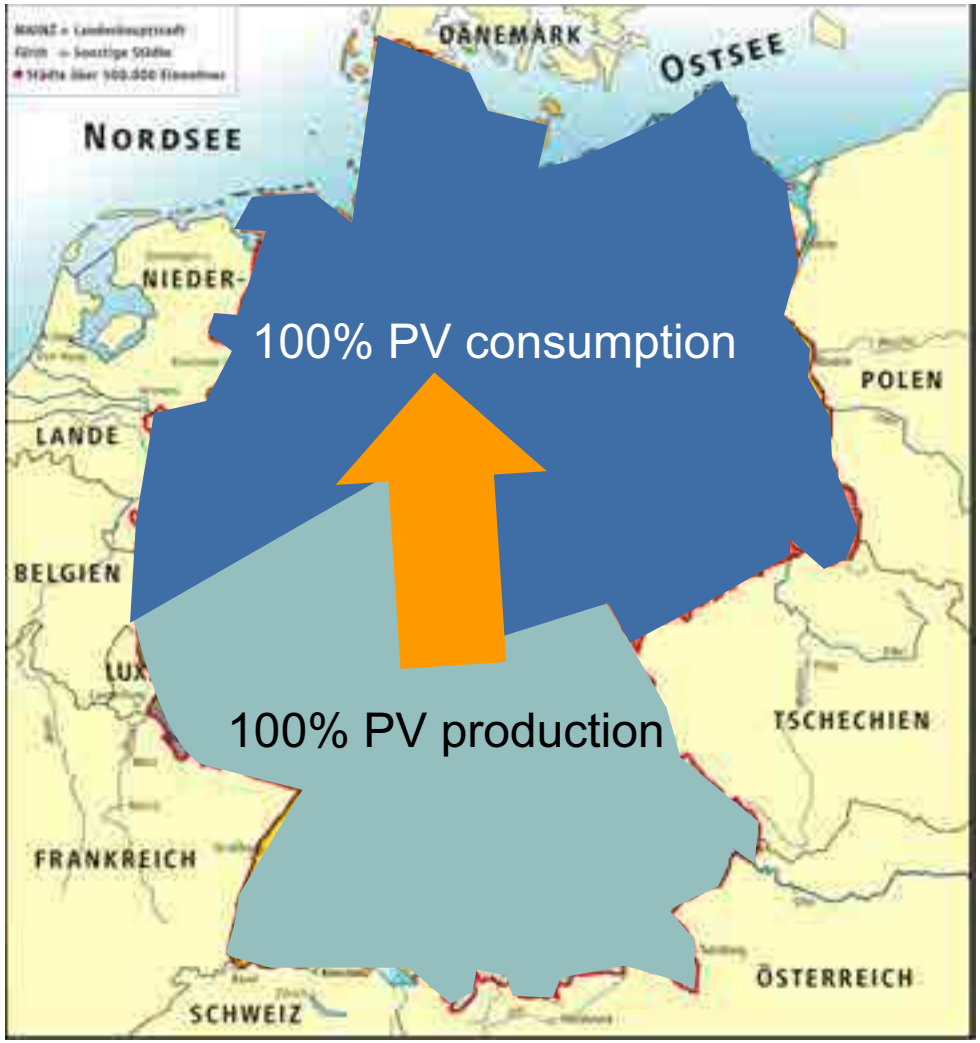
    → ***ST: storage included***

    → PV: storage or “grid” cost not included

    → what is a ***fair “free of subsidies” tariff for PV that is fed to the grid?***
  - ***Current subsidies are in favour of PV*** (KEV or 30% of installation cost)

    → we are ***comparing subsidies rather than cost effectiveness***

The PV miracle



source of map: http://www.weltkarte.com/europa/deutschland/deutschland-politisch.htm

- Let's assume 50% of Germany produces as much PV as it consumes electricity,...
- ...feeds this PV to the grid (sells it to the electricity trader)...
- ...the other 50% buys as much PV electricity as they consume electricity

and everybody is 100% clean (100% renewables) and happy...

??

Serial ST & HP systems -> special collector designs

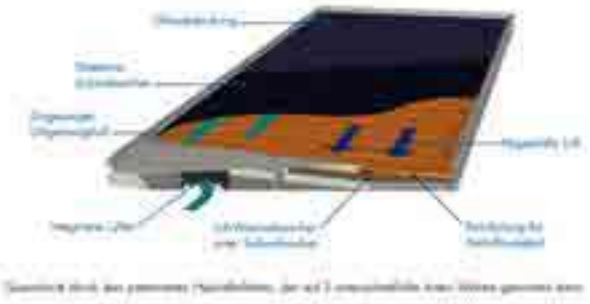
„only“ solar radiation

hermetic tight collectors

source: H+S Solar MULTIPANEL

additionally air as a heat source

covered with air fan integrated



source: Consolar SOLAERA

uncovered, selective

source: Energie Solaire SA „solar roof“

Requirements:

- hermetic tight or...
- ... insulation AND absorber coating compatible with condensation!

Collectors as a Source for the Heat Pump

- The ***electric savings may be higher*** (only may be!) than in parallel systems, but (for Central European applications) the ***increase in SPF compared to parallel systems is not much higher***!

  → doubling the collector yield does not double the electric savings!

- Makes more sense for ***high temperature applications*** (when there is a low COP of the heat pump):

  → domestic hot water (DHW)

  → «high» temperature heating systems (e.g. 50 °C)

- Is ***nonsense*** when there is a ***high irradiation on the collector field*** where a relatively high efficiency of direct (parallel) collector heat use can be achieved

- May be interesting for ***«low cost» uncovered absorbers***

PV/T & heat pump

uncovered

-> PV

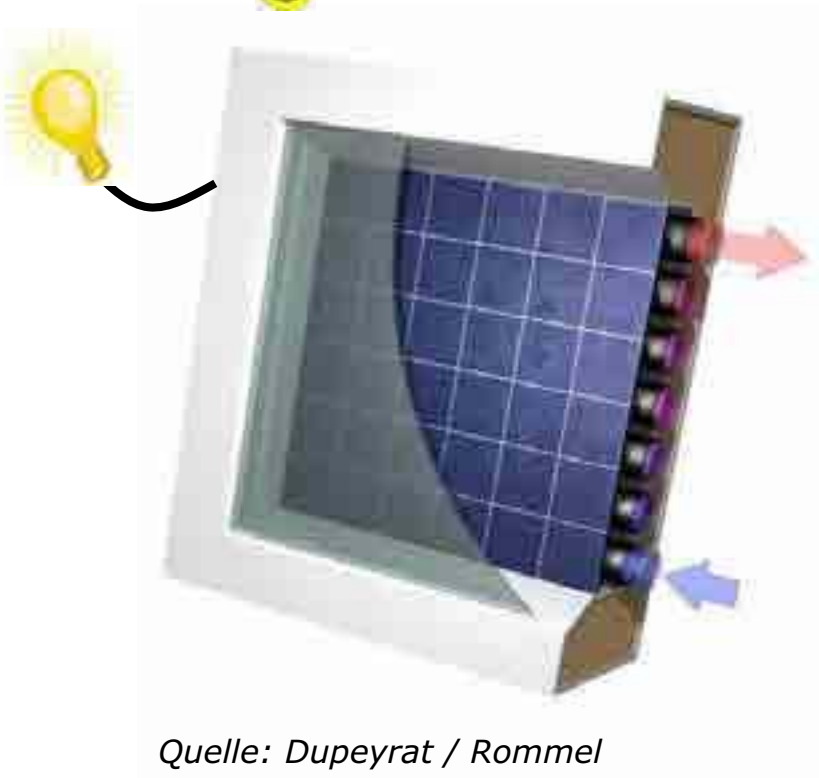
-> ST

covered

-> PV

-> ST

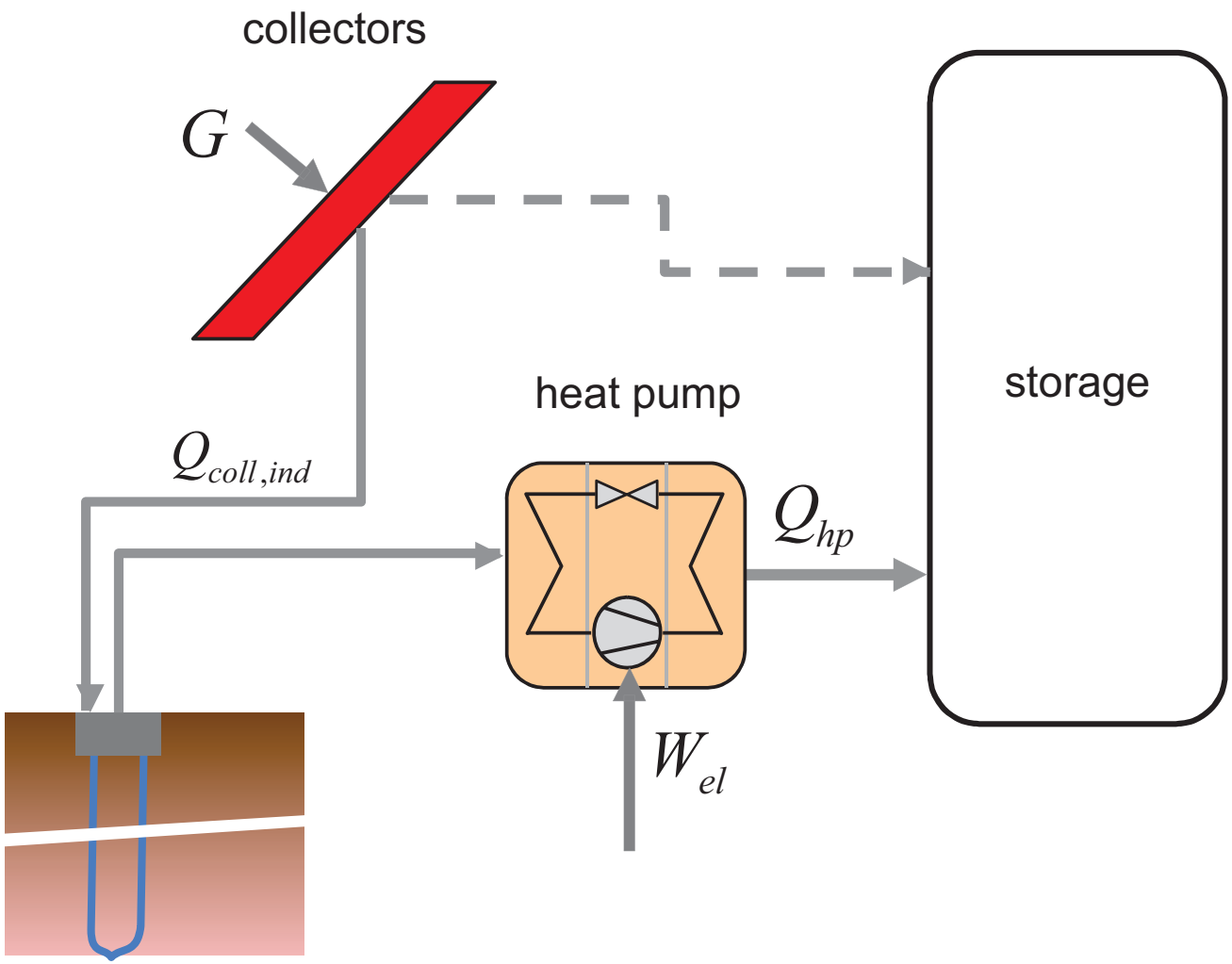
Quelle: Sonne Wind & Wärme



Quelle: Dupeyrat / Rommel

- *Attention: electric device must be protected from condensation!*

Regeneration of boreholes



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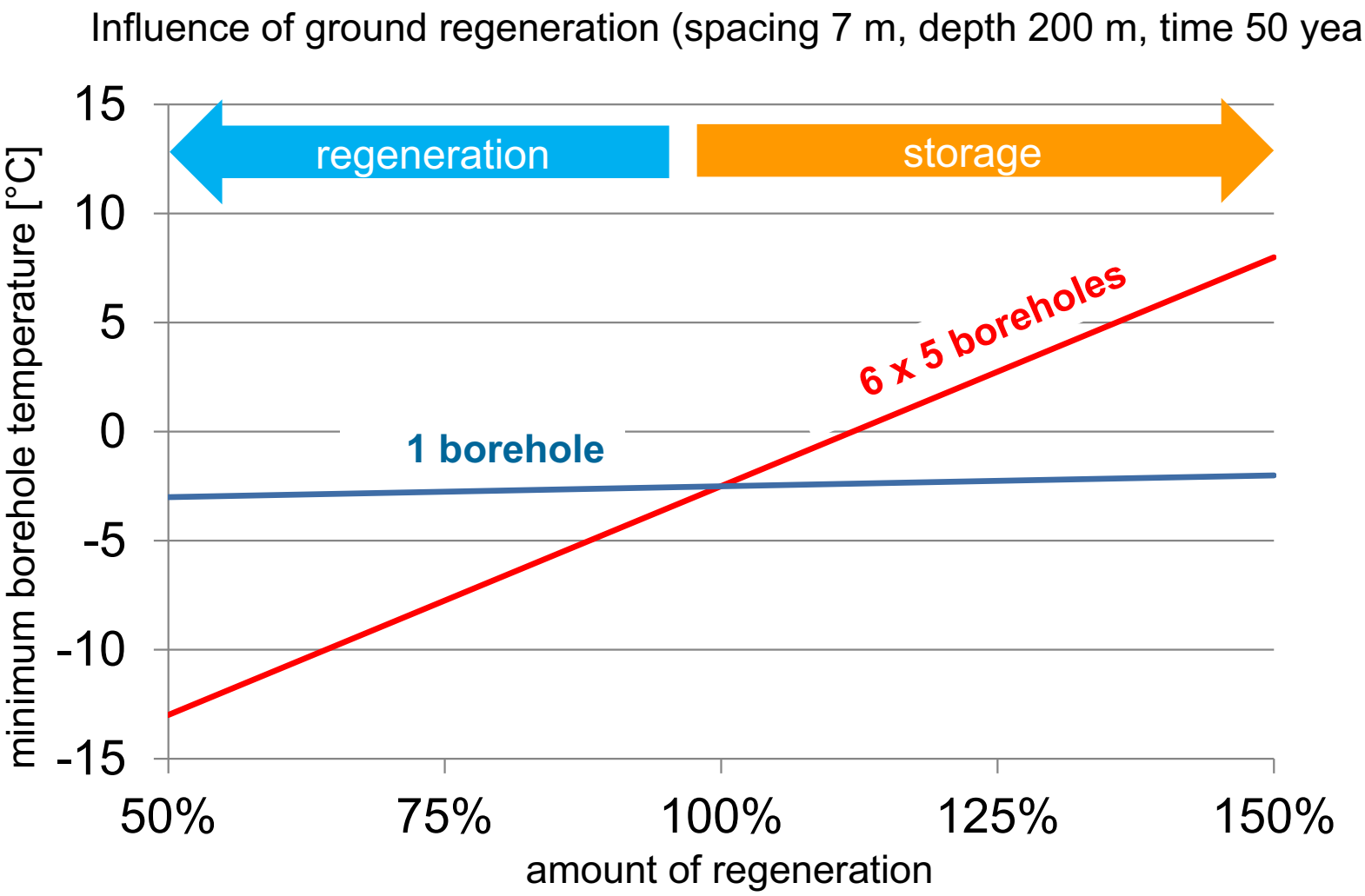
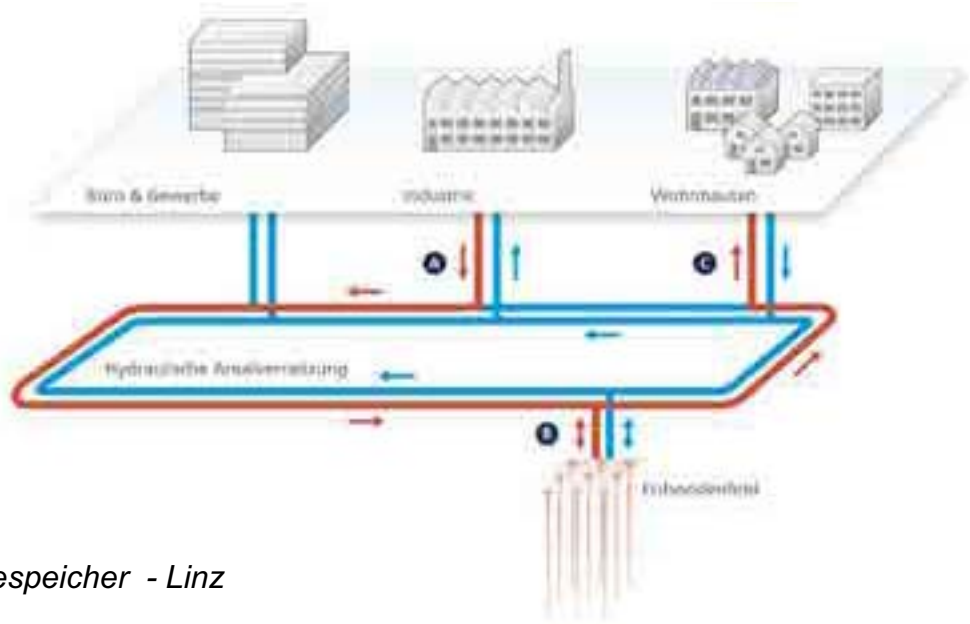


Based on Figure of Arthur Huber, www.hetag.ch

Low exergy networks for heat and cold

- Two circular loops at different temperature levels (4 – 25 °C, not insulated)
- Cooling: Fluid from «colder» loop is heated (by heat pump condenser) and fed to warmer loop
- Heating: the other way around (by heat pump evaporator)
- Mismatch is compensated by ***solar thermal (evt. PV/T)***
- Several pilot plants in Switzerland



Source: Amstein+Walthert, VDI-Forum 2012:
Neue Aspekte und Perspektiven thermischer Energiespeicher - Linz

Conclusions

- Collectors are more efficent than heat pumps (but usually not more cost-effective)
- ***Increase in SPF 0.07-1.2 per m^2*** collector area
  (for an exemplary single family home in Central Europe)
- ***Electric savings 100 – 180 kWh_{el} per m^2*** collector area (DHW for multifamily house)
- There are ***parallel concepts*** and serial concepts
  - There is evidence that serial concepts ***may achieve better system SPF*** than parallel concepts for certain boundary conditions / applications (extremely dependent on the boundary conditions (***solar irradiation in winter***, temperatures of heat sinks and heat sources of the heat pump)
  - There is ***NO evidence*** that serial concepts ***are MUCH*** better than parallel concepts (let alone much more attractive from an economic point of view)
- The ***advantage of serial concepts compared to parallel concepts*** is higher for:

  → Systems with ***higher temperatures of heat demand***
  (DHW, space heat distribution with 50 °C)

  → When there is ***low solar irradiation*** that is not used effectively by the collectors in parallel operation (e.g. also for uncovered collectors & PV/T)

... a matter of technology?

- **YES!**
  - There is a vast range of different concepts and components and little experience and Know-How for determining the ***SYSTEM performance***
  - ***Details play a major role for the SYSTEM performance***
    → hydraulic solutions, exergetic efficiency of storage
    → **quality assurance *on a SYSTEM* level** is currently insufficient
    → the successful saving of non-renewable electricity depends on this!
  - ***Competition with PV & heat pump will become more interesting*** when ***PV feeds the heat pump directly*** (time-synchronous) and/or stores excessive PV yield locally (battery or heat storage) → comparison will be fairer!
- **... and NO!**
  - Whether PV & heat pump or solar thermal & heat pump are installed may be...

...more a question of subsidies (politics) than a question of technology!

THANK YOU FOR YOUR ATTENTION!

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IEA SHC Task 44 / HPP Annex 38
Solar and Heat Pump Systems:
http://task44.iea-shc.org

Bundesamt für Energie BFE, Bern
Projekte SOL-HEAP, HIGH-ICE

EU FP7 project MacSheep:
http://macsheep.spf.ch

KTI-Projekt 10769.2
KTI-Projekt 12606.2