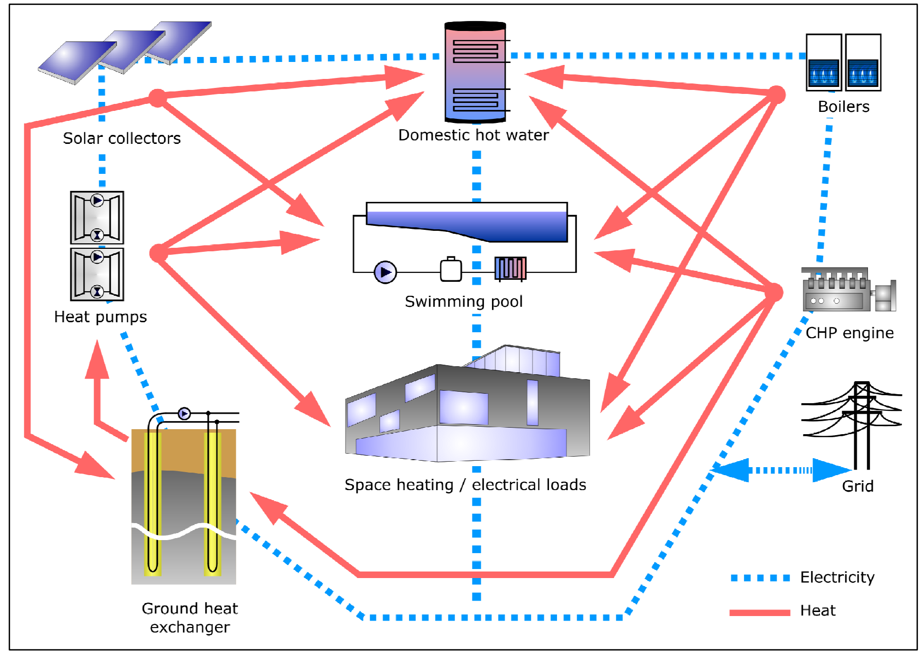
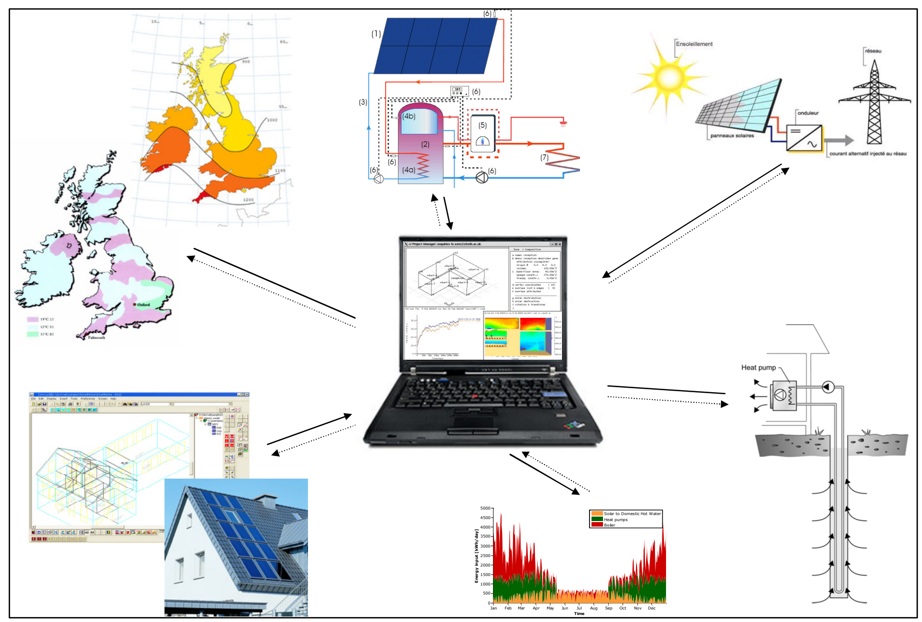
Optimising hybrid systems design and performance





Michaël Kummert

SESG / BRE seminar – Electric heating: yesterday's villain, tomorrow's saviour?

17 April 2008

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University of Strathclyde

Outline

- Who am I?
- Hybrid systems
  - What is a hybrid system?
  - Types of hybrid systems
  - Importance of control strategies
  - Hybrid systems on the rise
  - Hybrid systems and electricity
- Optimisation problem
  - Design, operation, lifetime performance
  - The role of simulation
- Case studies
  - Design optimisation: NZEH
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- Conclusions

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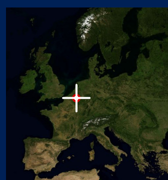

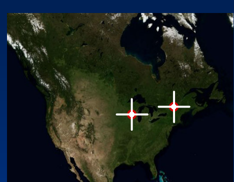

PhD in environmental sciences

- Passive/active solar buildings
- Model-based optimal control

Consulting engineer

- Low energy buildings, solar thermal systems

TRNSYS coordinator

- Modelling, simulation software development

Post-doc researcher / lecturer

- Net-zero energy houses, solar thermal, ground source heat pumps

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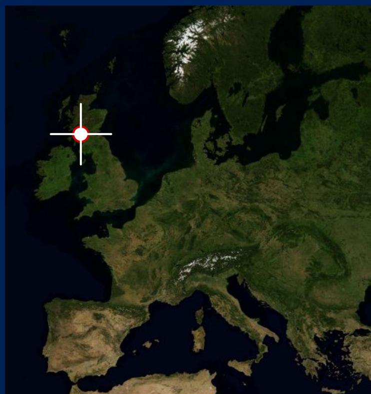

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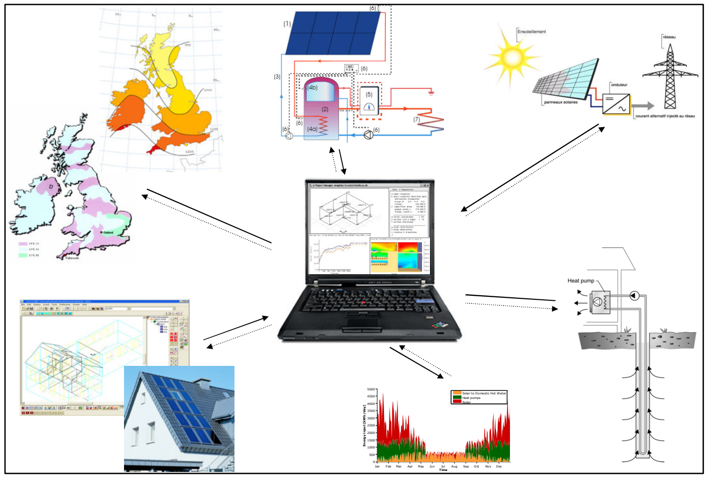
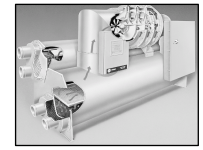
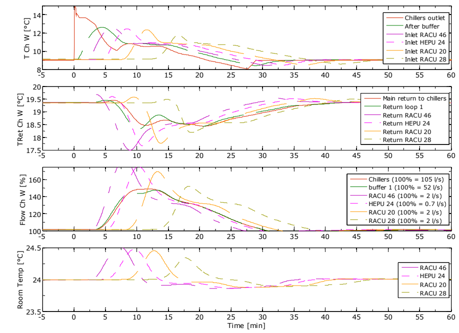
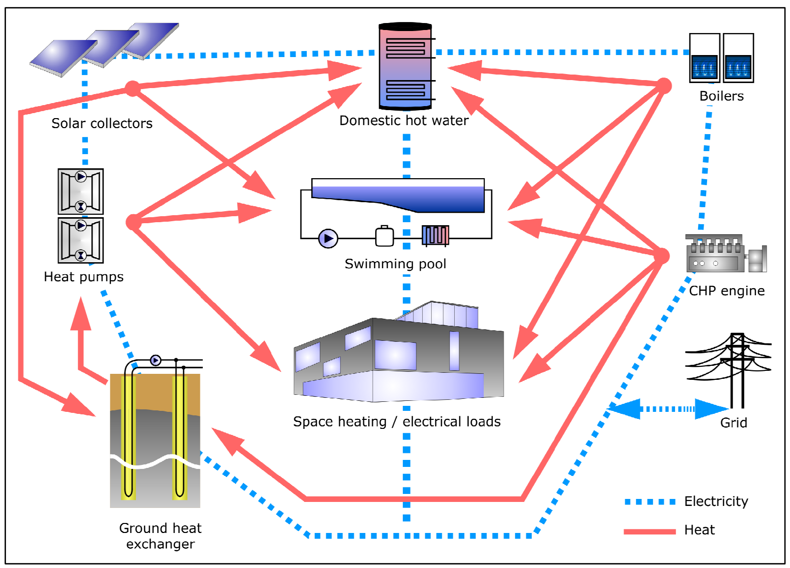
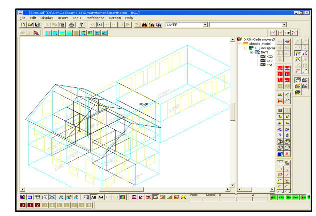
Lecturer

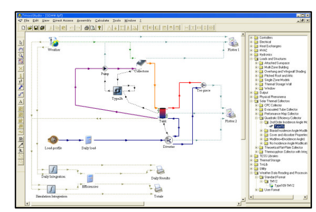












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Hybrid systems

- What is a hybrid system?

  "Something (as a power plant, vehicle, or electronic circuit) that has two different types of components performing essentially the same function"

  (Merriam Webster dictionary)

  2 (or more) ways to perform the same task

  ⇨ control decision

- Some examples (building services)
  - Hybrid heating system
    - Radiant underfloor heating + radiators
    - Radiators (gas boiler) + wood stove
    - Underfloor heating + electric baseboard
    - Etc.

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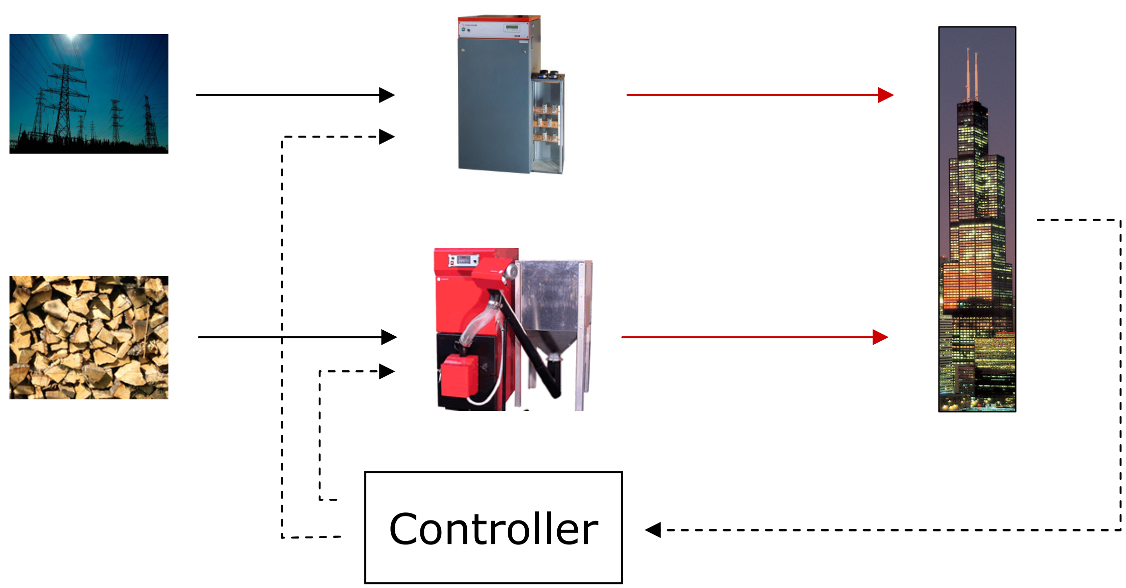
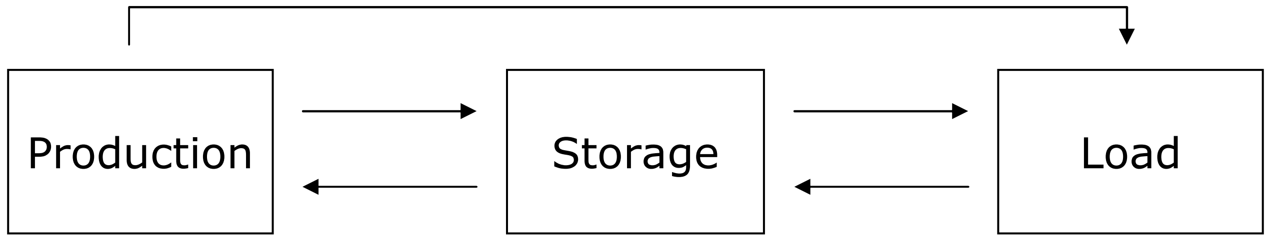
Basic control problem

- Which one of the 2, 3, … components to use and when?
  - Meet demand
  - Maximise efficiency
    - Cost
    - Environmental impact (CO_2, etc.)
  - Ensure sustainability and long-term performance

  ⇨ Predictive control (optimal, near-optimal, rule-based, etc.)



Energy storage



- Options
  - Meet load directly
  - Meet load from storage
  - Recharge storage
- Constraints
  - Manage storage state of charge
  - Maximise efficiency (minimise cost)

⇨ Similar control problem

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Types of hybrid systems

- Multiple energy sources
  - Gas / oil / etc. + electric
  - Renewables
    - Biomass + backup
    - Solar + backup
    - Heat pump + backup
- Storage
  - DHW storage
  - Buffer storage (building thermal mass!)
  - Ground source systems
  - Seasonal storage
- Multiple source / sink
  - Hybrid ground-source + boiler / cooler
- Multiple secondary systems
  - Undefloor + convectors, etc.
  - Desiccant / conventional AC systems

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Hybrid systems on the rise

- Higher energy prices and climate change concerns
  - Renewable energy systems requiring backup
    - Intermittent supply
    - Economic or technical constraints
    - Encouraged by policies
      - “Merton rule”: 10, 20% renewable
      - Grants for heat pumps up to x kW
  - Interest in micro-generation
    - Economic optimum often includes backup
  - Net-zero energy or carbon neutral buildings
    - Only realistic solutions involve hybrid systems
  - Storage systems
    - Reduce cost
      - Time-of-Use electricity rates
      - Free cooling

⇨ These systems need to be optimised

⇨ Importance of predictive control strategies

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Hybrid systems and electricity

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- Most hybrid systems involve electricity
  - Heat pumps
  - Small backup system
  - Storage
    - Time-of-Use pricing
    - Cooling system performance (free cooling)
- Future electric systems
  - Will be hybrid systems
    - Heat pump / resistance
    - Solar / immersion
    - Microgeneration
  - Will include storage
    - Off-peak rates / TOU

⇨ will require advanced control strategies

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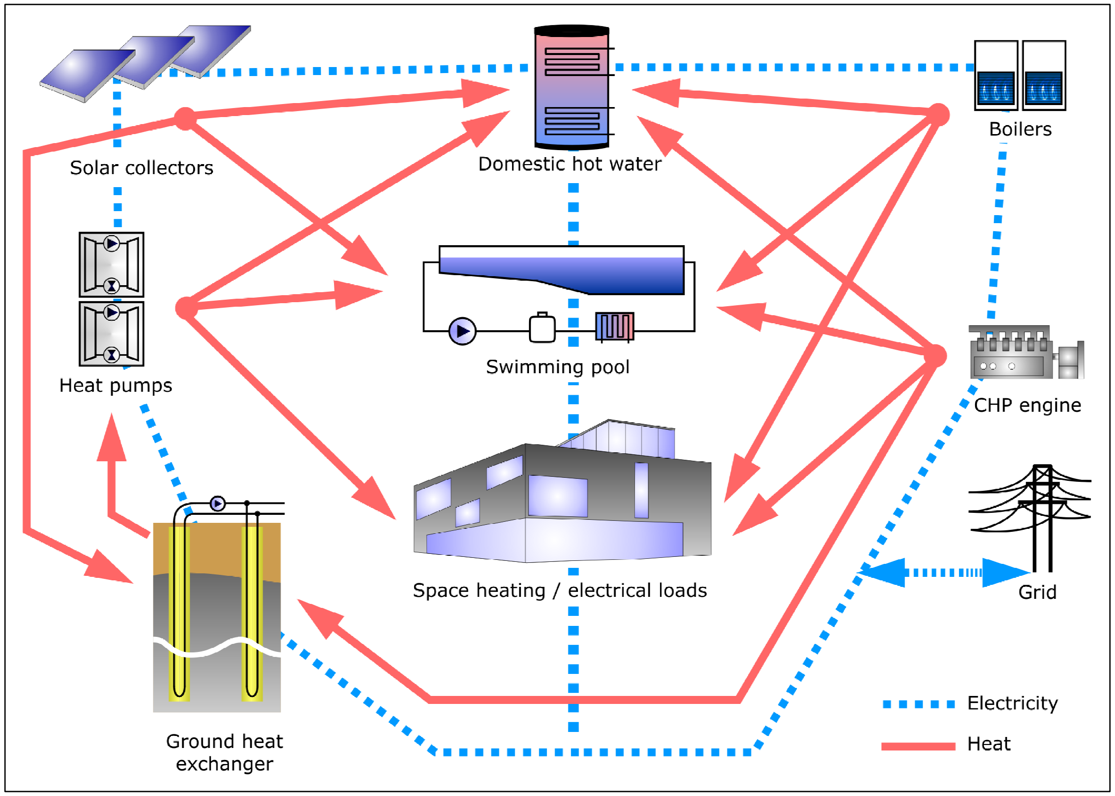
Optimisation

- What do we want to optimise?
  - Design
  - Operational costs (control strategies)
  - Lifetime performance
  - The 3 are interrelated



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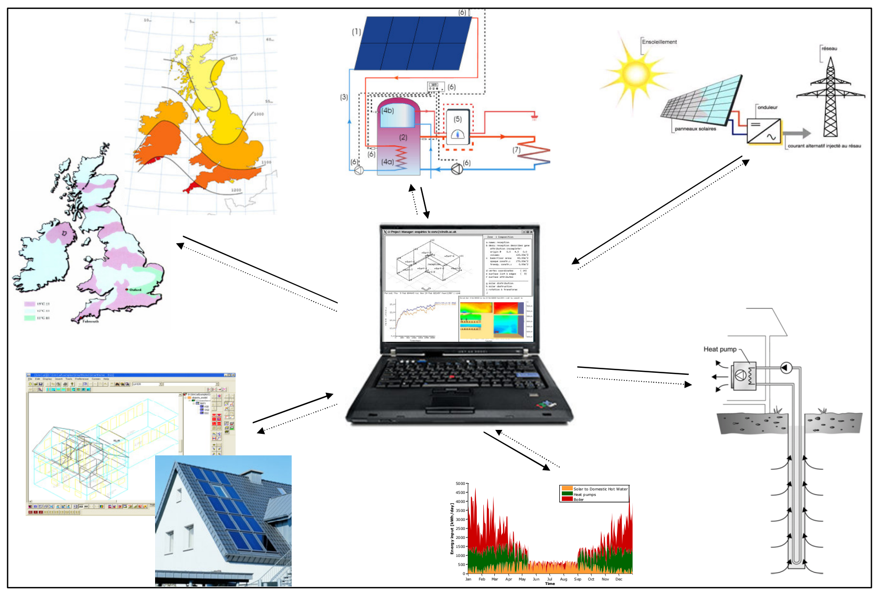
The role of simulation: combined optimisation

Optimised design parameters
System configurations
Control strategies (sets of rules)
Control setpoints, thresholds

Weather
Occupancy
Fixed design parameters
Energy rates
Etc.

Performance simulation

Investment cost
Operational costs
Occupant satisfaction
Life cycle performance



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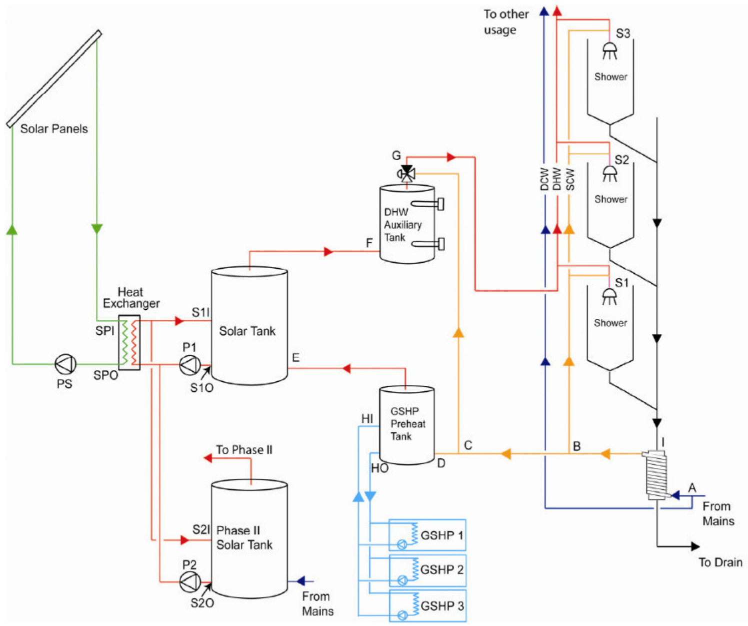
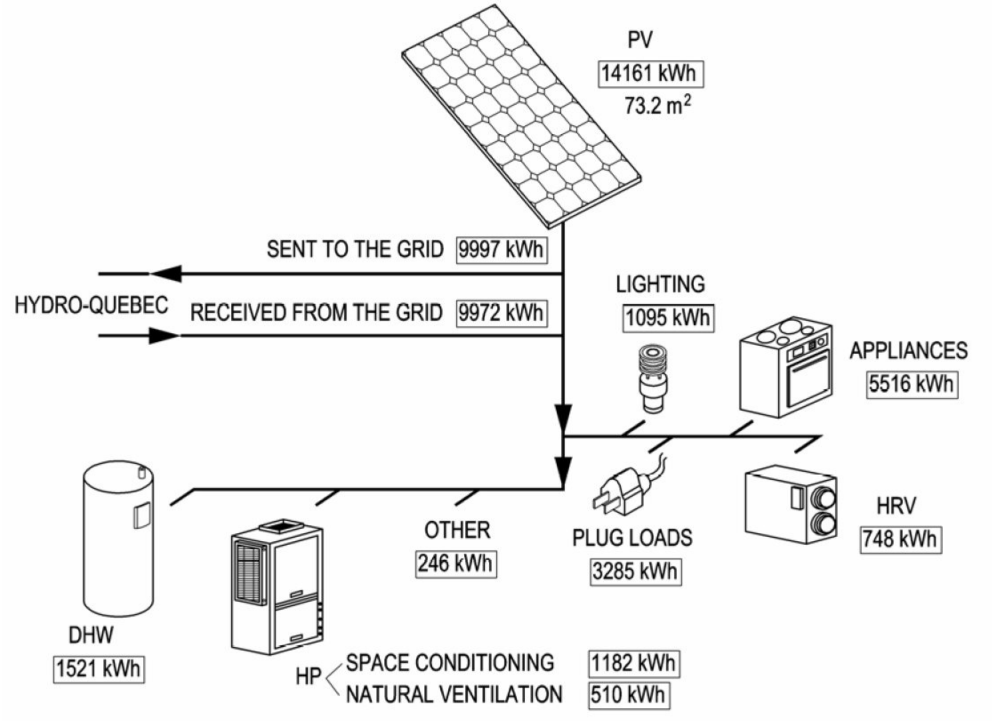
Design optimisation: NZEH





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The path to net-zero

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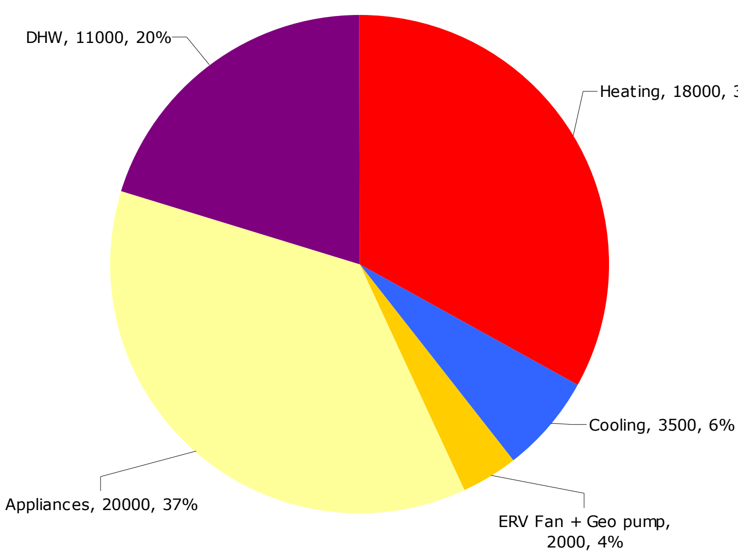
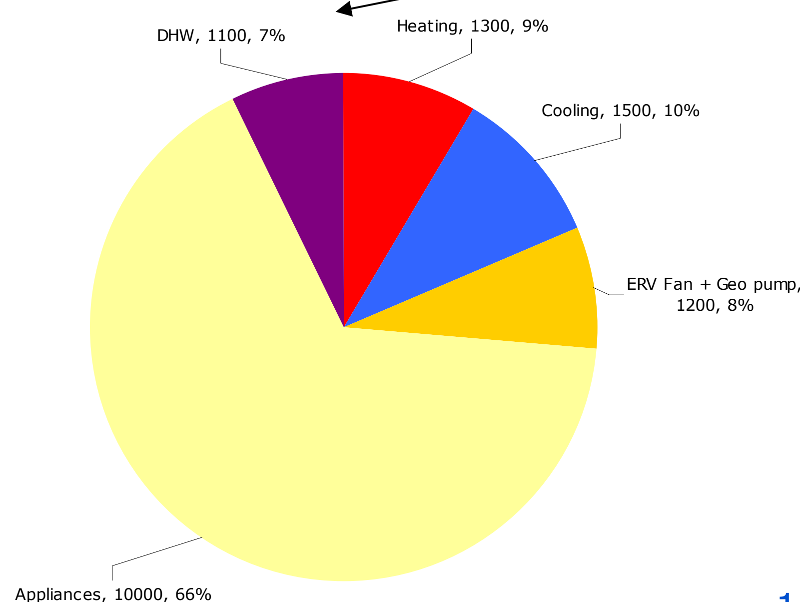
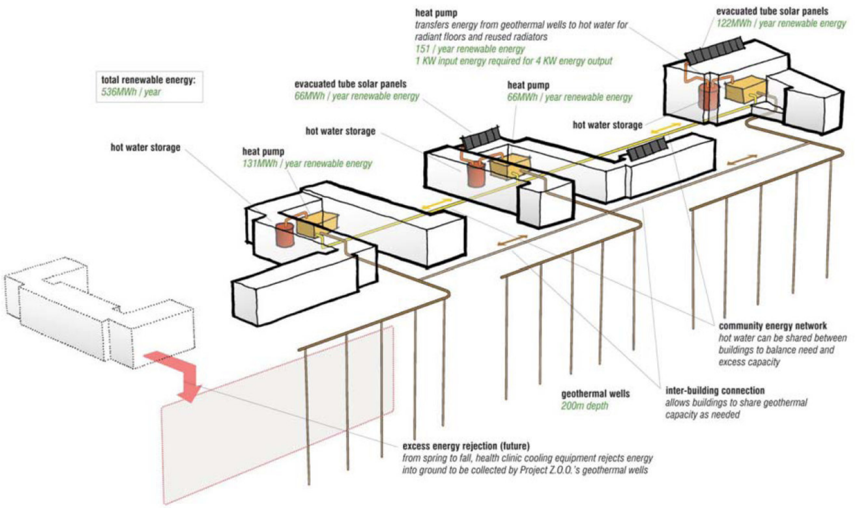
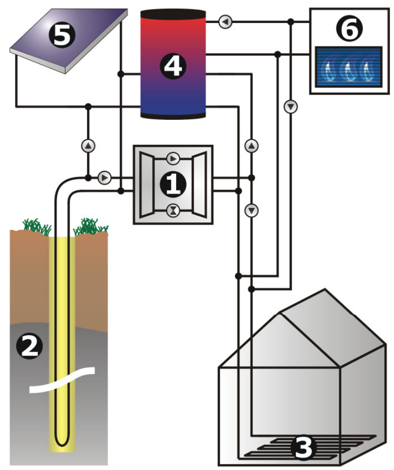
	MNECH 97	R2000	Super insulation	Geo on MNCEH97	Geo on R2000	Geo on Super Ins	SDHW 8 + GFX	SDHW 12 + GFX	SDHW 24 + GFX	R2000+Vent control 1/2	Energy Star Appl.	NAHB study appl.	R2000 + Geo + Vent control + SDHW 24 + GFX + NAHB Appl	Super + Geo + Vent control + SDHW 24 + GFX + NAHB Appl
Heating	18000	10000	4500	5000	2900	1300	18000	18000	18000	7500	18000	18000	2900	1300
Cooling	3500	4000	4000	1400	1500	1500	3500	3500	3500	4000	3500	3500	1500	1500
ERV Fan + Geo pump	2000	2000	2000	2500	2300	2200	2000	2000	2000	1000	2000	2000	1300	1200
Appliances	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	13000	10000	10000	10000
DHW	11000	11000	11000	11000	11000	11000	3300	2200	1100	11000	11000	11000	1100	1100
total kWh	54500	47000	41500	39900	37700	36000	46800	45700	44600	43500	47500	44500	16800	15100
%	100%	86%	76%	73%	69%	66%	86%	84%	82%	80%	87%	82%	31%	28%
Extra cost	0	5000	20000	22000	23000	35000	8000	12000	18000	23250	3000	10000	37000	51000
$/kWh saved, 25 y	N/A	0.027	0.062	0.060	0.055	0.076	0.042	0.055	0.073	0.085	0.017	0.040	0.039	0.052
Required PV [m²]	363	313	277	266	251	240	312	305	297	290	317	297	112	101
PV Cost [$]	381500	329000	290500	279500	264000	252000	327500	320000	312000	304500	332500	311500	117500	105500
PV cost savings [$]	0	52500	91000	102000	117500	129500	54000	61500	69500	77000	49000	70000	264000	276000
Total savings		47500	71000	80000	94500	94500	46000	49500	51500	53750	46000	60000	227000	225000

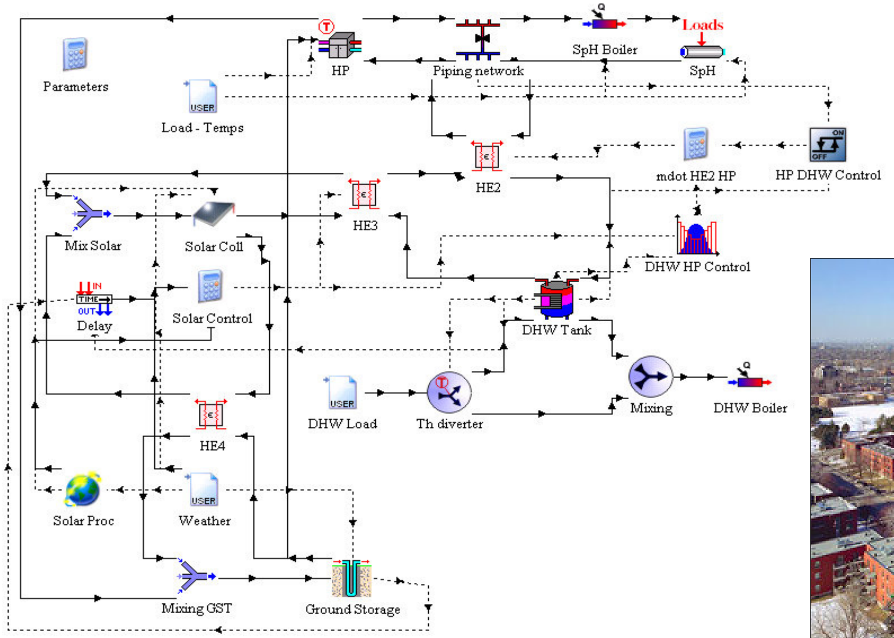




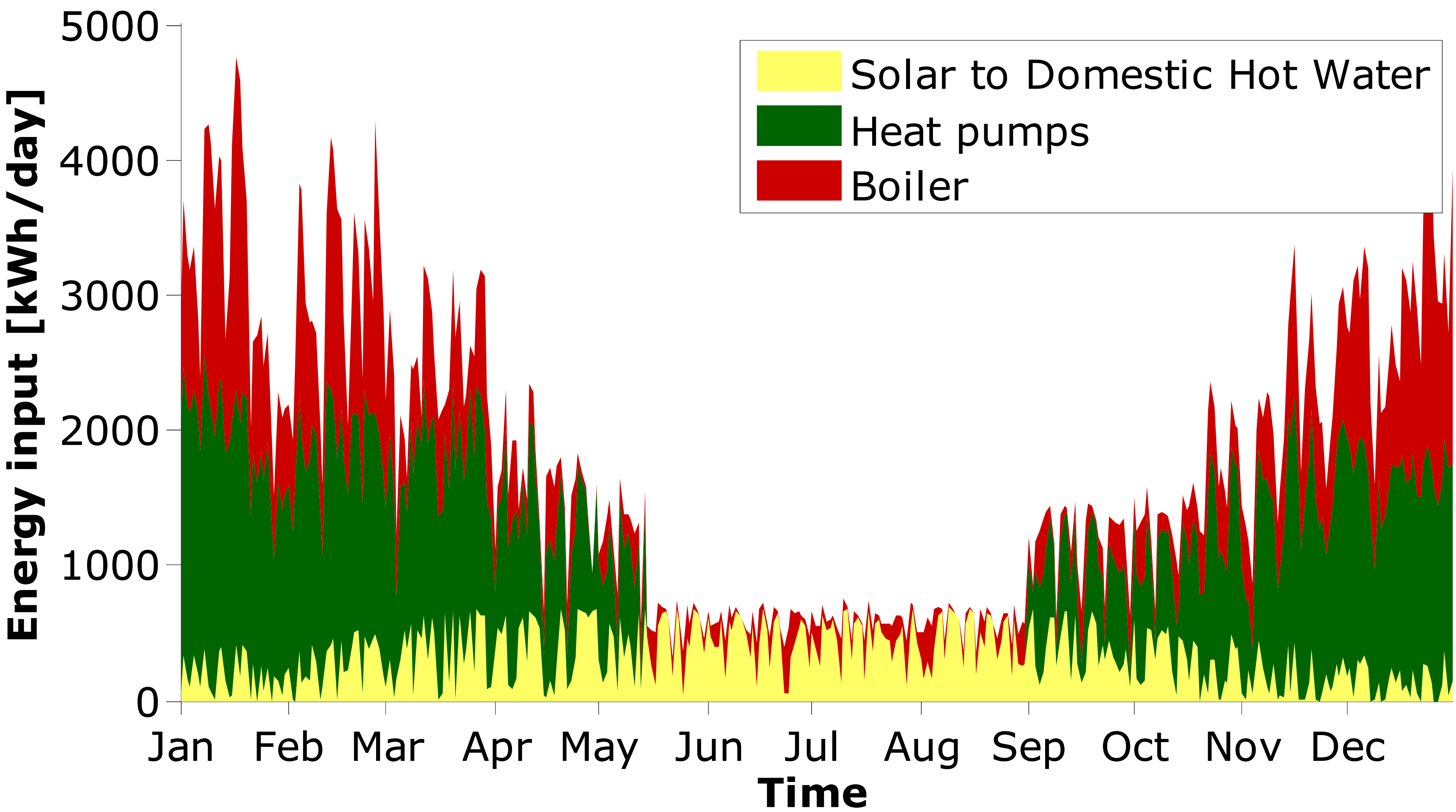
Design and control: Hy-GSHP





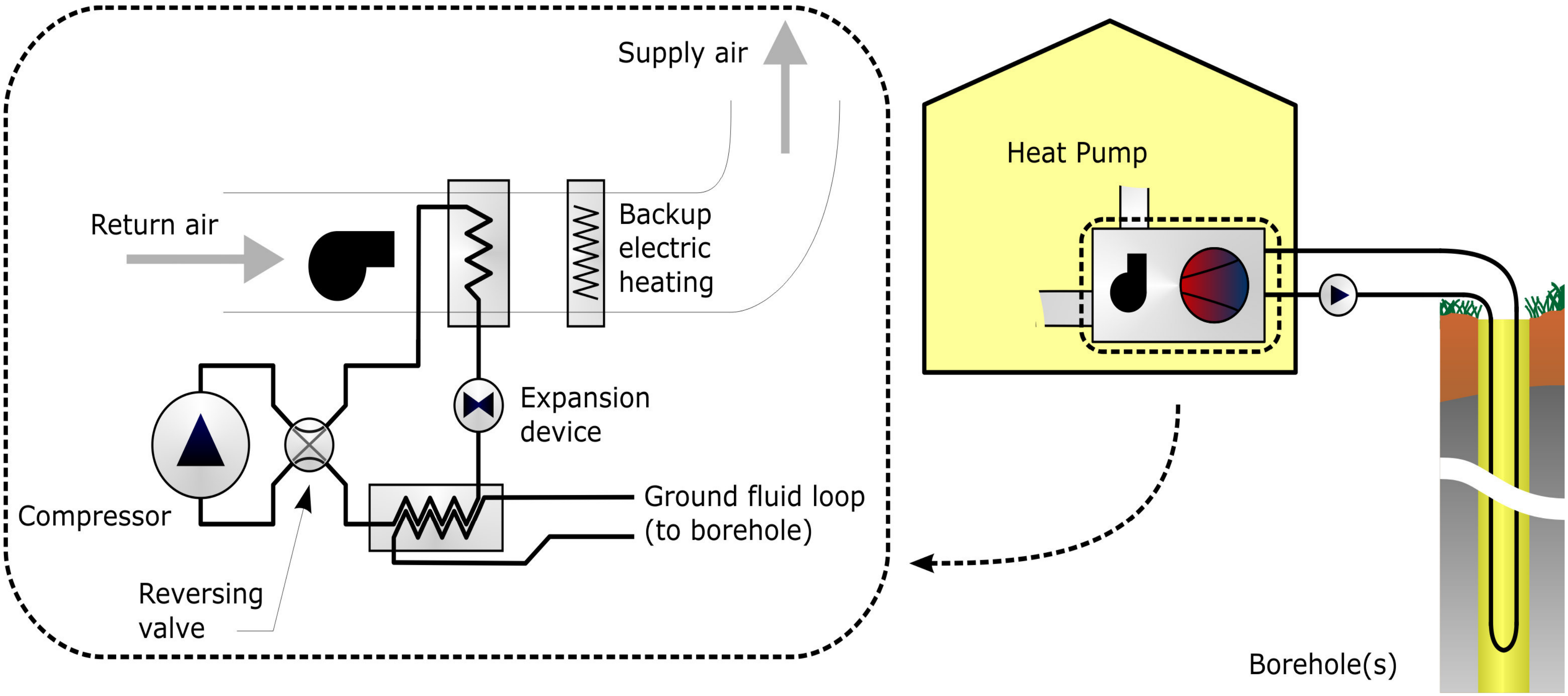


System performance

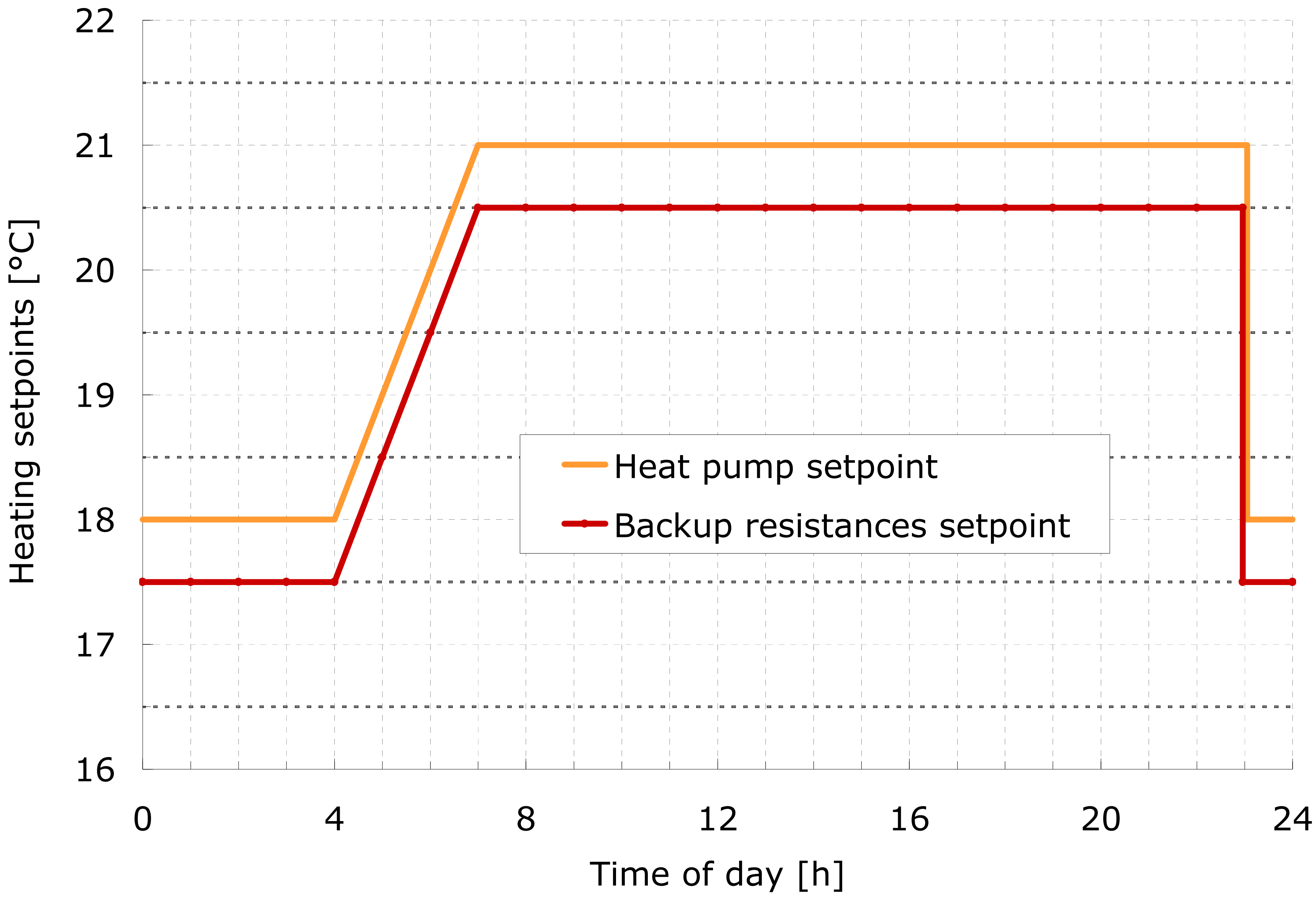


Building 1, **1st year** of operation

- GSHP system + backup resistance



Heating setpoint controller



Short time-step simulation (for 20 years!)

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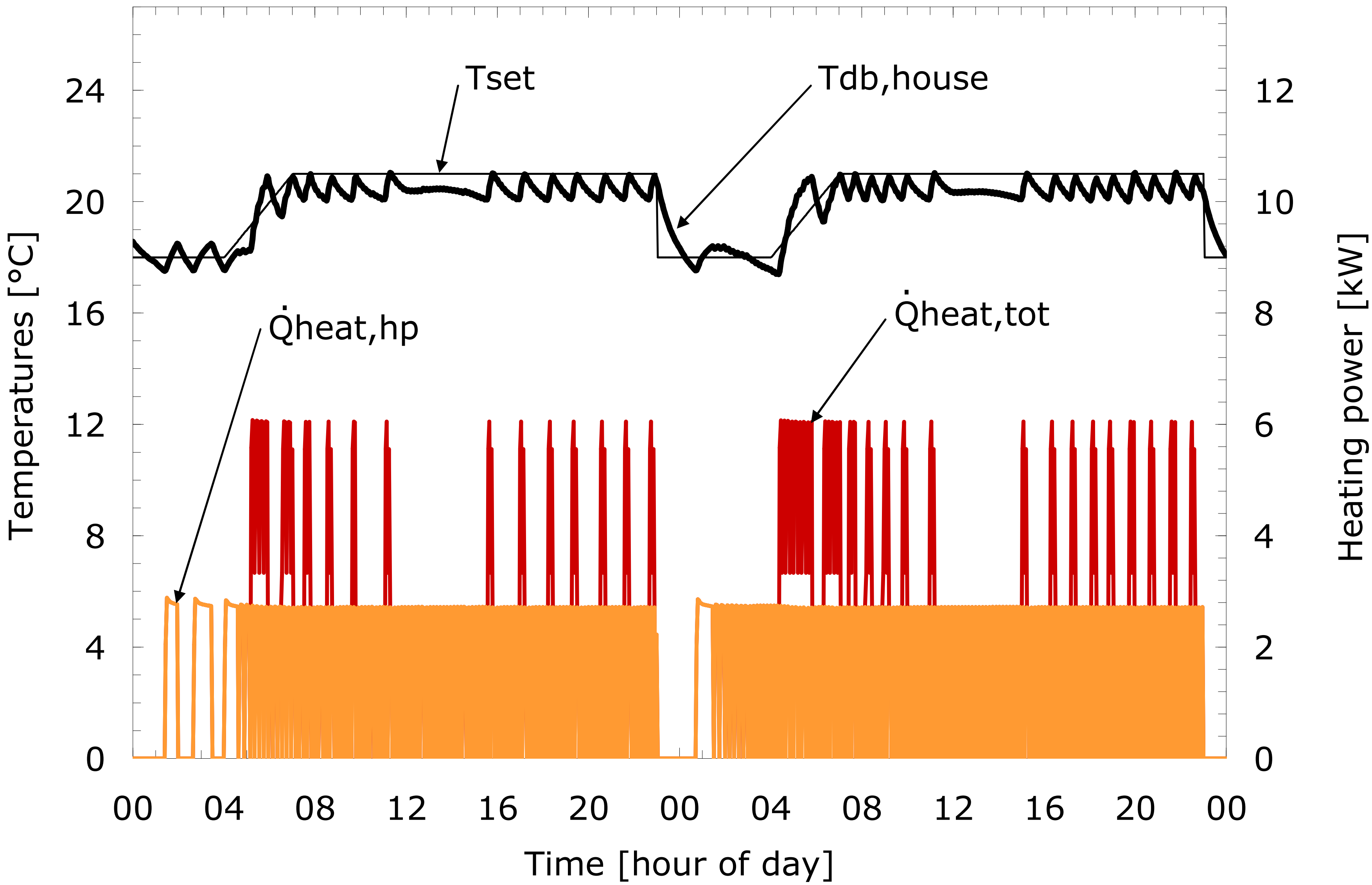
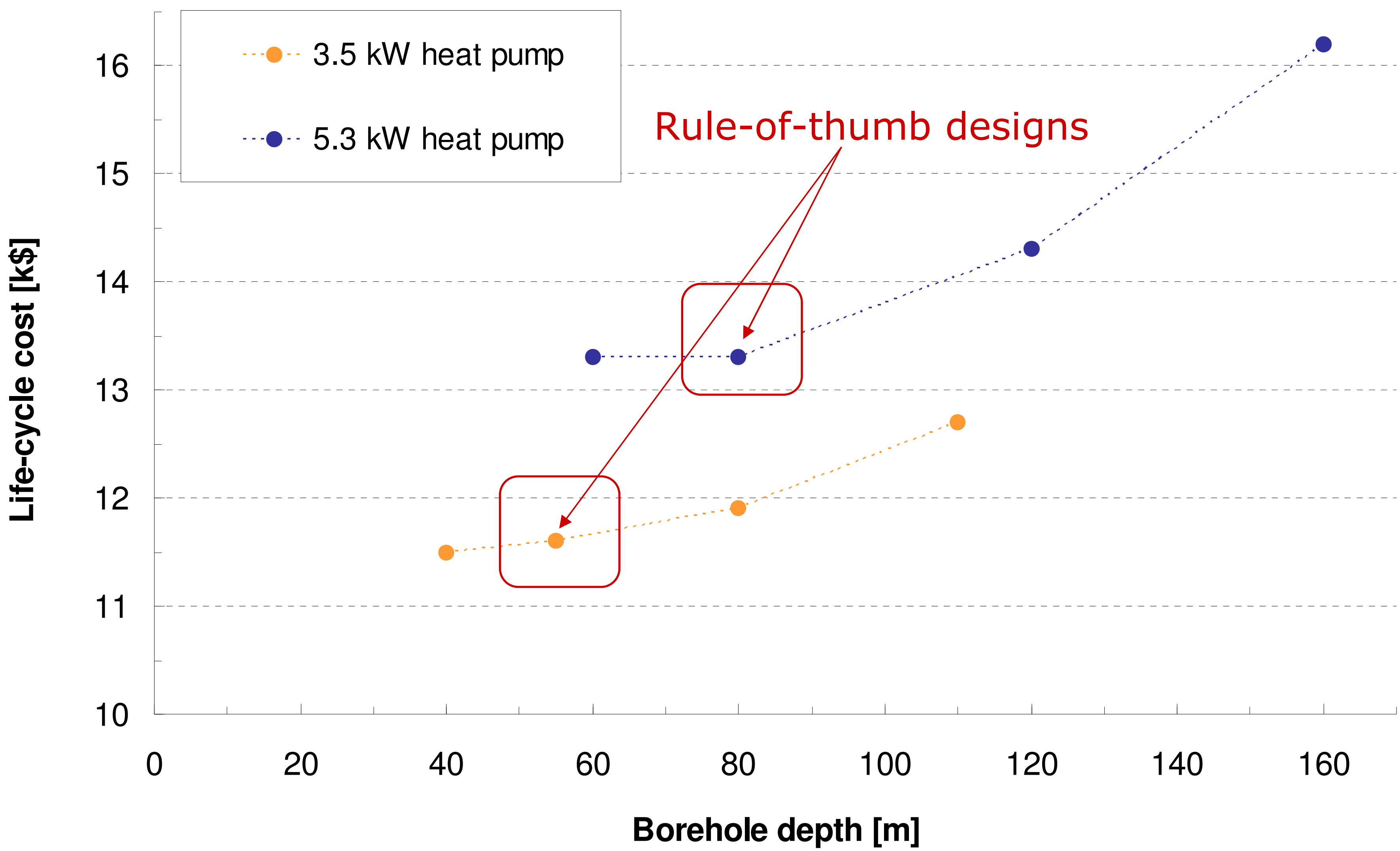


Life cycle analysis



Conclusions

- Hybrid systems are on the rise
  - Renewable energy + backup
  - Net-zero energy or carbon neutral
  - Storage (time varying electricity pricing)
- Optimisation:
  - Design
  - Operation (control)
  - Lifetime performance

  } interrelated
- Simulation can play a key role
  - Testing design configurations and variables, control strategies and setpoints/thresholds
- Electricity will play a key role in hybrid systems
- Future electric systems will be hybrid / have storage

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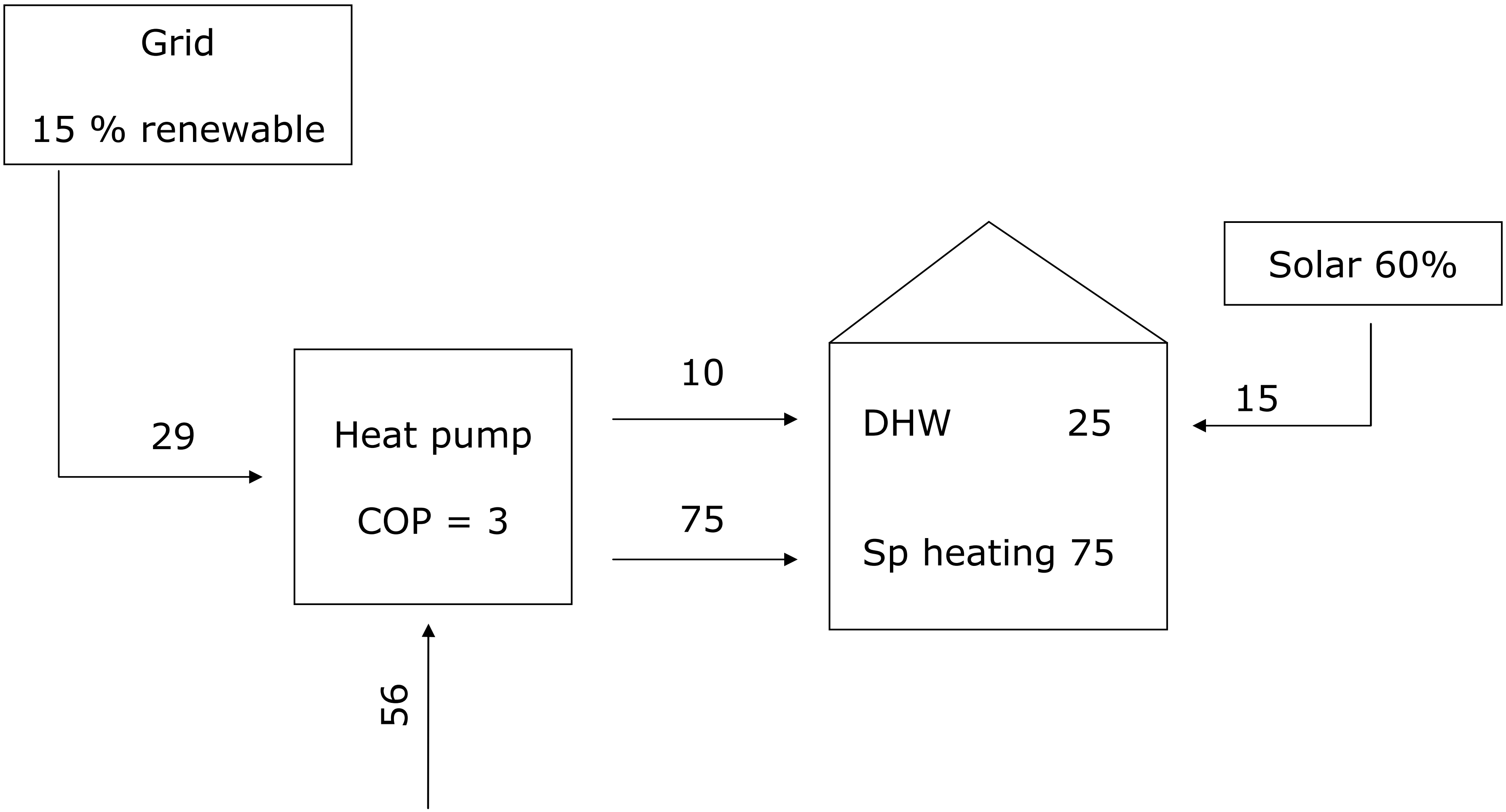
15 % renewable energy in dwellings



Total renewable fraction = 15 + 56 + 0.15*29 = 75 %

If 20% of dwellings, overall percentage = 15%