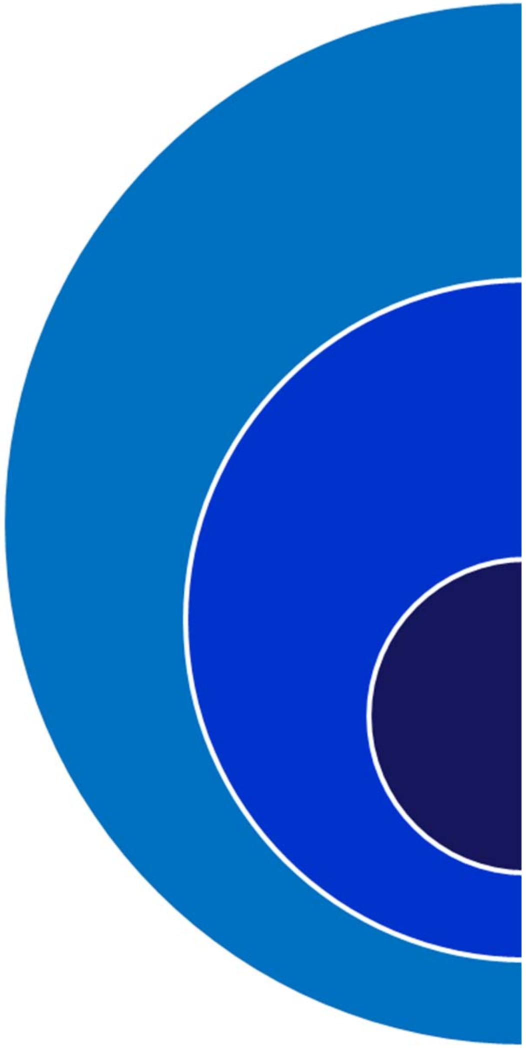
M7

The Right Scale for Each Energy Concept



Content

What is it good for?

MOTIVATION

1. Motivation

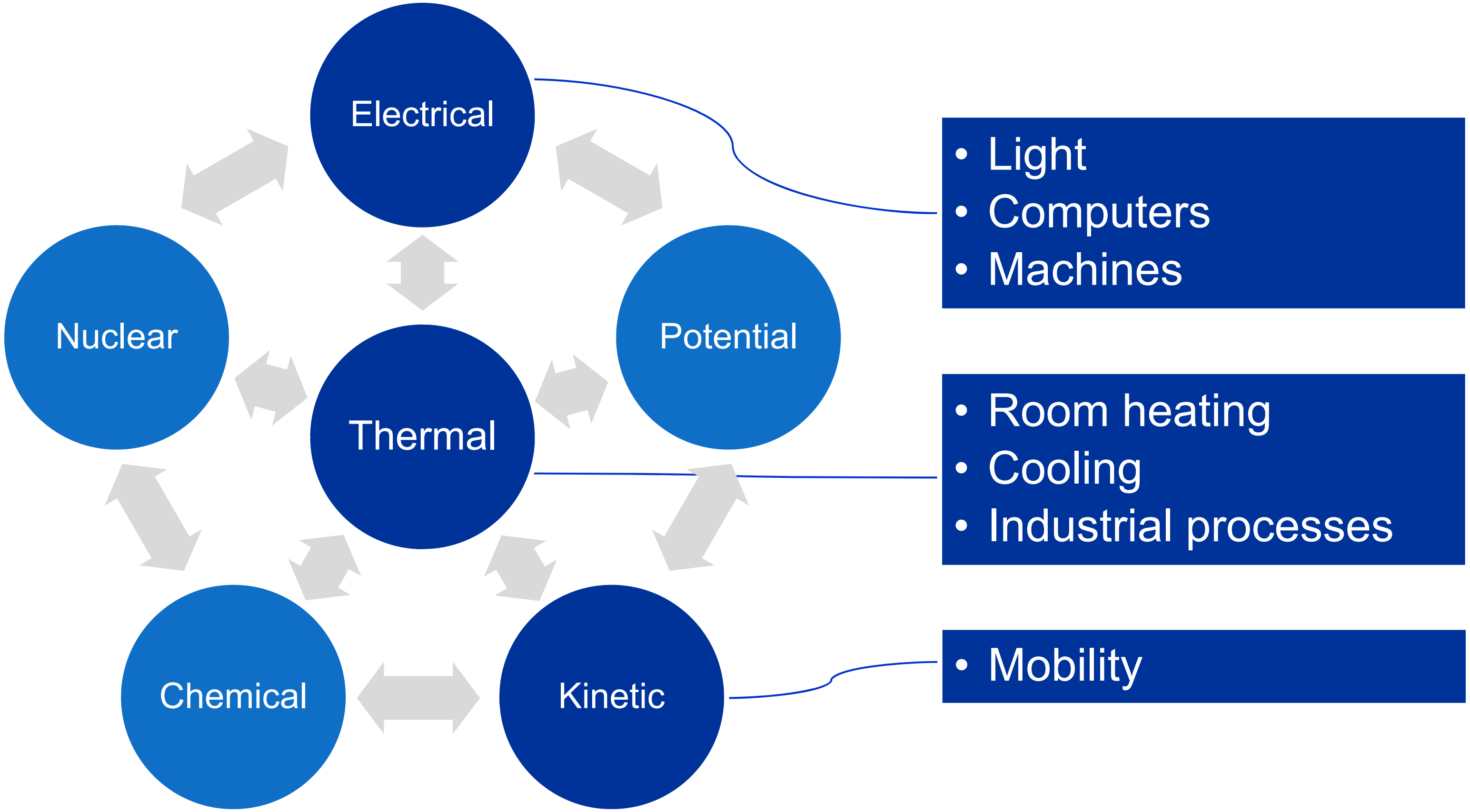
1.1. Energy is More than Electricity

- Physical definition: energy is the possibility to perform work.
- Six forms: electrical, potential, kinetic, chemical, nuclear and thermal.
- Law of energy conservation: energy can only be converted from one form to another, neither created nor destroyed.
- In nearly all technical energy conversion processes (e.g. fuel to electricity), some energy is inevitably converted to heat.

Energy form	Examples of occurrence
Electrical energy	Electric current, (sun)light, radio waves
Potential energy	Water in high reservoir, pendulum clock weight
Kinetic energy	Wind, carousel
Chemical energy	Fuel, food, battery
Nuclear energy	Uranium (fission), deuterium (fusion)
Thermal energy	Geothermal energy

1. Motivation

1.1. Energy Forms and their Use



- Light
- Computers
- Machines

- Room heating
- Cooling
- Industrial processes

- Mobility

1. Motivation

1.2. What is an Energy Concept?

- It is a plan for satisfying a given energy demand with certain energy sources.
- Its scope is variable: it can be global, international, national, regional, local and even individual.
- It incorporates several options, so that unfeasible or undesired measures can be avoided

Energy form	Energy sources	Energy use
Electrical energy	Solar radiation	Light, IT, machines
Potential energy	-	-
Kinetic energy	Wind, hydropower, tides	Mobility
Chemical energy	Fossil fuels, biomass	-
Nuclear energy	Uranium, deuterium	-
Thermal energy	Geothermal energy	Room heating/cooling

1. Motivation

1.2. Why an Energy Concept?

Status quo

- Fossil fuels are the backbone supplying our energy demands: electricity (coal), heat (gas) and mobility (oil).
- However, demand for fossil fuels will increase while supplies are limited.
- Reducing GHG emissions is necessary to limit global warming.

Hence

- Reducing energy demand is crucial.
- Increasing efficiency of energy use is required.
- Integrating new energy sources (i.e. renewables) is beneficial.

But where does money spent have most impact on which goal?

→ A structured approach is needed: an energy concept

1. Motivation

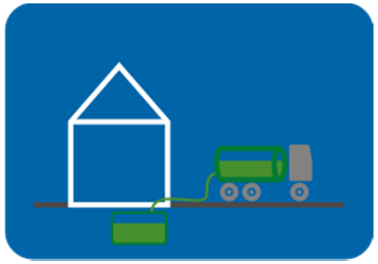
1.2. Development of Heat Supply (1/3)

Paradigm I
Energy carriers are burnt **on location** for heat generation **just in time**.

Wood	biogenic fuel	medium energy density	solid
Coal	fossil fuel	high energy density	solid
Oil	fossil fuel	high energy density	liquid

Wood

Coal



Oil

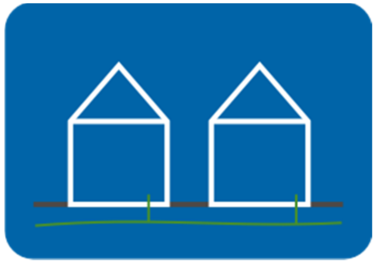
1. Motivation

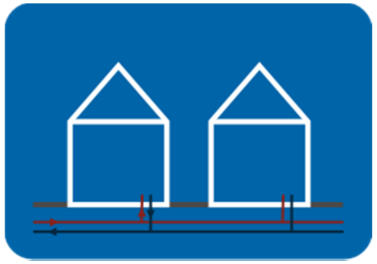
1.2. Development of Heat Supply (2/3)

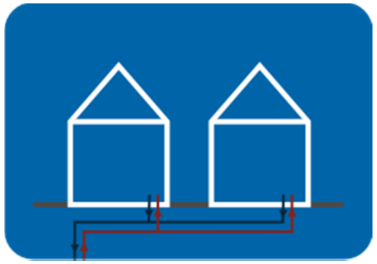
Paradigm II
Energy is no longer stored in every building, but an energy carrier (natural gas, hot water) **transports** energy **just in time** through a transport grid.

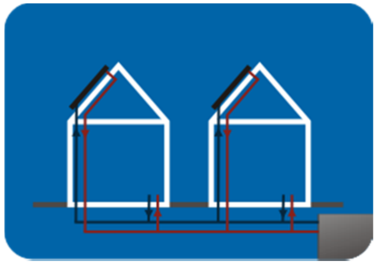
Natural gas	fossil fuel	high energy density	gas grid
District heating	fuel flexible (mainly natural gas)		liquid grid

Geothermal and **solar thermal** (local or individual)


Natural gas


District heating


Geothermal


Solar thermal

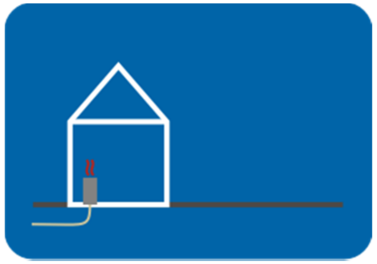
1. Motivation

1.2. Development of Heat Supply (3/3)

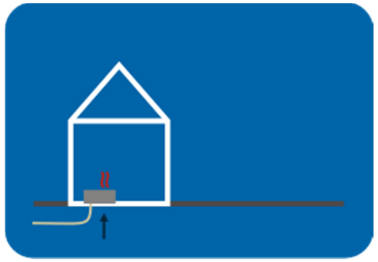
Paradigm III
Electrical energy is the most flexible in terms of generation and transport.

Energy sources for electricity production determine its ecological footprint
→ with today’s power fuel mix (mainly coal),
better to use fossil fuels in CHP for heat generation

Q Which option is *best* for a building, district, city?
A It depends on demand (density), environmental and economic constraints.



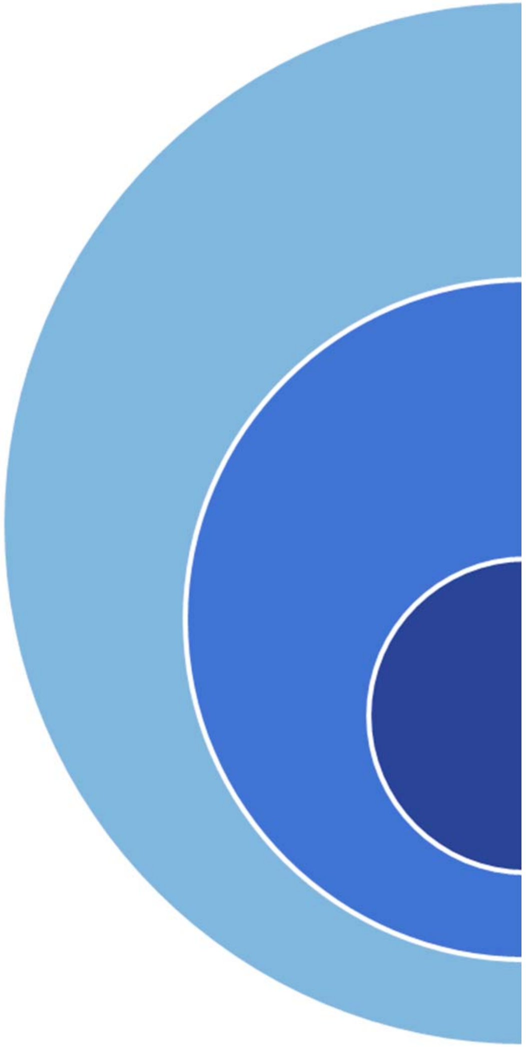
Electric heating



Heat pump

How is it done?

METHOD



2. Method

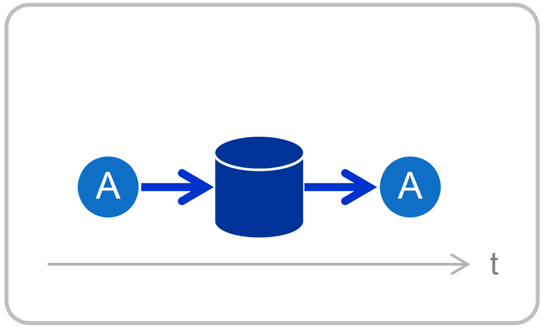
2.1. Why Scale is Important

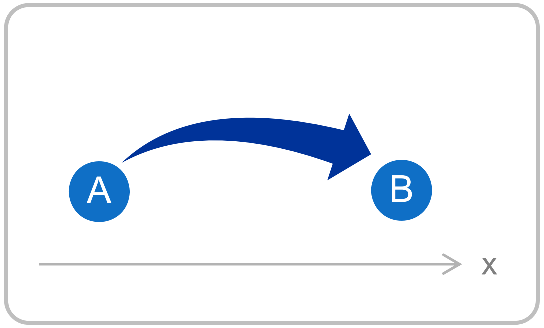
Energy must be provided at the **exact time and location it is needed**.

There are three options to satisfy this condition:

1. This can happen either by converting it just in time from **another energy carrier** that is carried along **as storage** (e.g. fuel in a car).
2. Or the required energy is **transported** over distance (e.g. electricity grid).
3. Or the desired energy form is **generated before, stored and released** when needed (e.g. hot water storage tank).

Scale determines which option is preferable for best efficiency.





2. Method

2.1. Spatial Scale (Transport)

- Fossil fuels
  - Pipelines: across continents
  - Ships: global
- Electricity
  - High voltage AC (altering current - state of the art): up to about 1’000 km
  - High voltage DC (direct current - emerging): several thousand kilometres
- Heat
  - cannot be transported for huge distances without major losses

Energy carrier	Mode of transport	Approx. loss per 1‘000 km
Fossil fuel (gas, oil)	Pipeline	0.1 %
Fossil fuel (coal, oil)	Ship	1 %
Electricity	High voltage AC	10 %
Heat	District heating pipe	100 %

2. Method

2.1. Temporal Scale (Storage)

- Fossil fuels
  - Coal, oil, gas in tanks. High energy density, easy to store indefinitely.
- Electricity
  - Pump storage plants (potential energy). Cheap and state of the art, but limited.
  - Batteries (chemical). Too huge and expensive for bulk storage.
  - Hydrogen (chemical). Promising candidate, but still low efficiency and maturity.
- Heat
  - Hot water tanks. Even seasonal storage is possible with thick insulation.

Energy carrier	Storage type	Approx. loss per 1 week
Fossil fuel	Tank	~ 0 %
Electricity	Battery	1-5 %
Heat	Hot water tank	< 1 %
Kinetic energy	Rotation wheel	100 %

2. Method

2.1. Consequences for a Municipal Energy Concept

- Electricity
  - Demand reduction and efficiency increase most important
  - Exploit favourable local conditions (wind, solar, hydro, biomass)
  - Strong autarky not desirable due to easy electricity transport
- Heat
  - Demand reduction and efficiency increase most important
  - Centralised heat generation, where demand cannot be reduced
  - Reduction of fossil fuel use in the long term, as heat generation will remain local
- Mobility
  - Demand reduction by changing usage
  - Efficiency increase by using technical improvements

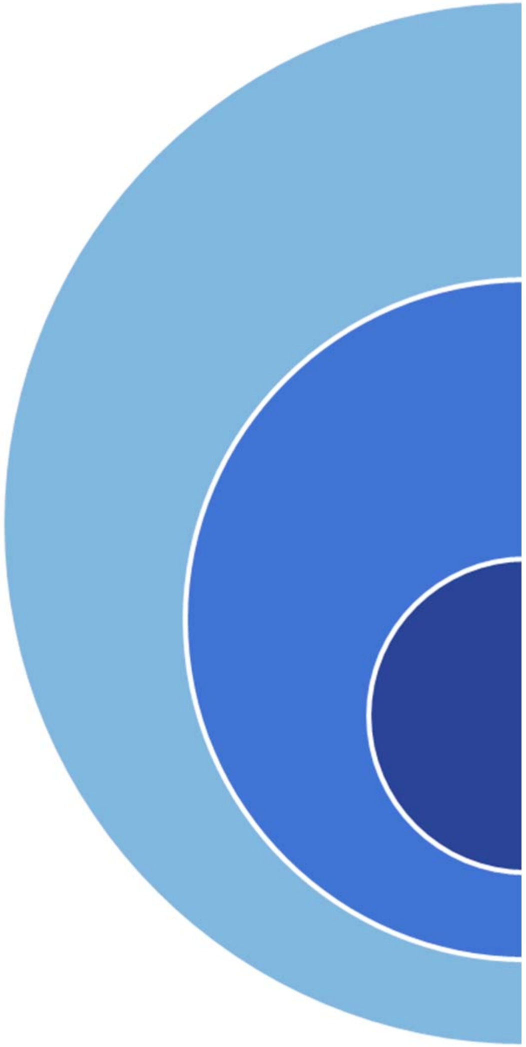
2. Method

2.2. Local Energy Concept in Three Steps

1. Quantify status quo
   - Energy demand for heat, electricity and mobility
   - Technical infrastructure for generation, transport and storage
2. Assess potential for
   - Demand reduction
   - Efficiency increase
   - Renewable energy use
3. Derive measures to realise those potentials
   - Technical
   - Behavioural

What needs to be known?

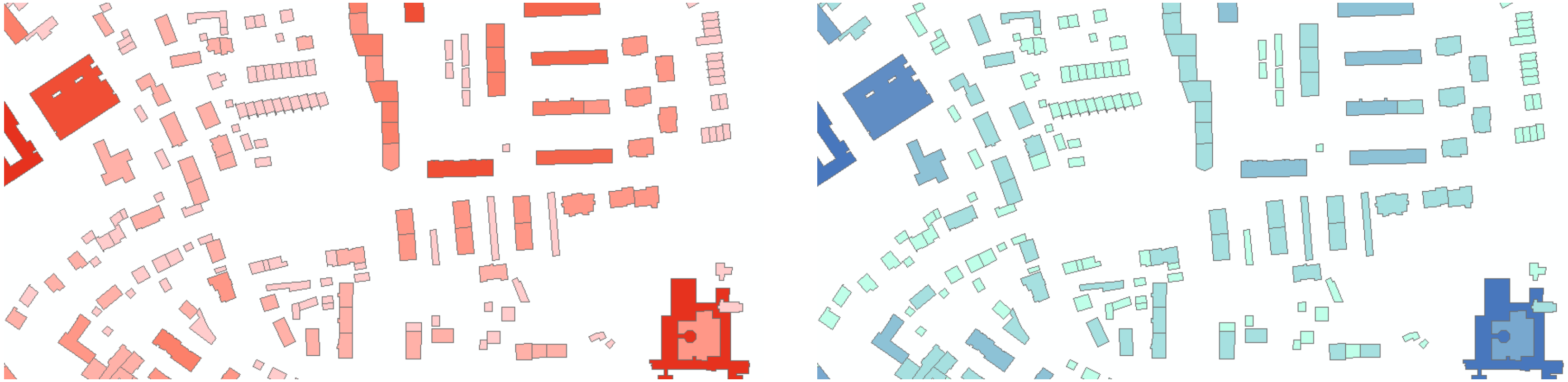
DATA



3. Data

3.1. Heating (and Cooling) Demand

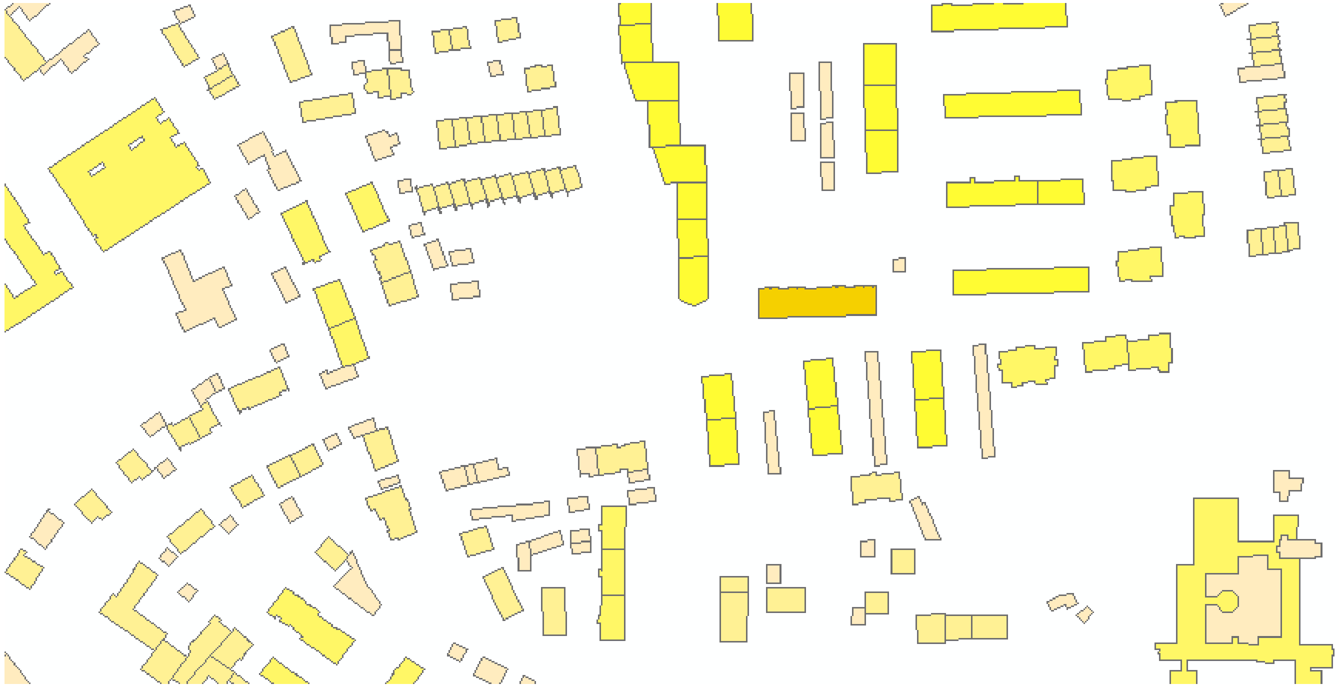
- Heating (and cooling) demand for space heating and hot water:
  - Peak (MW) and annual (MWh/a)
  - At building, building block or district level
  - If air conditioning in summer, collect data about annual cooling energy demand, also with spatial resolution.
- For (industrial) process heat demand, also note the temperature level.
- Collect data on buildings, their use, their age and level of renovation.
- Changes in building conditions can be mapped to changes in heat demand.



3. Data

3.1. Electricity Demand

- Electricity
  - peak (MW) and annual (MWh/a)
  - at building, building block or district level

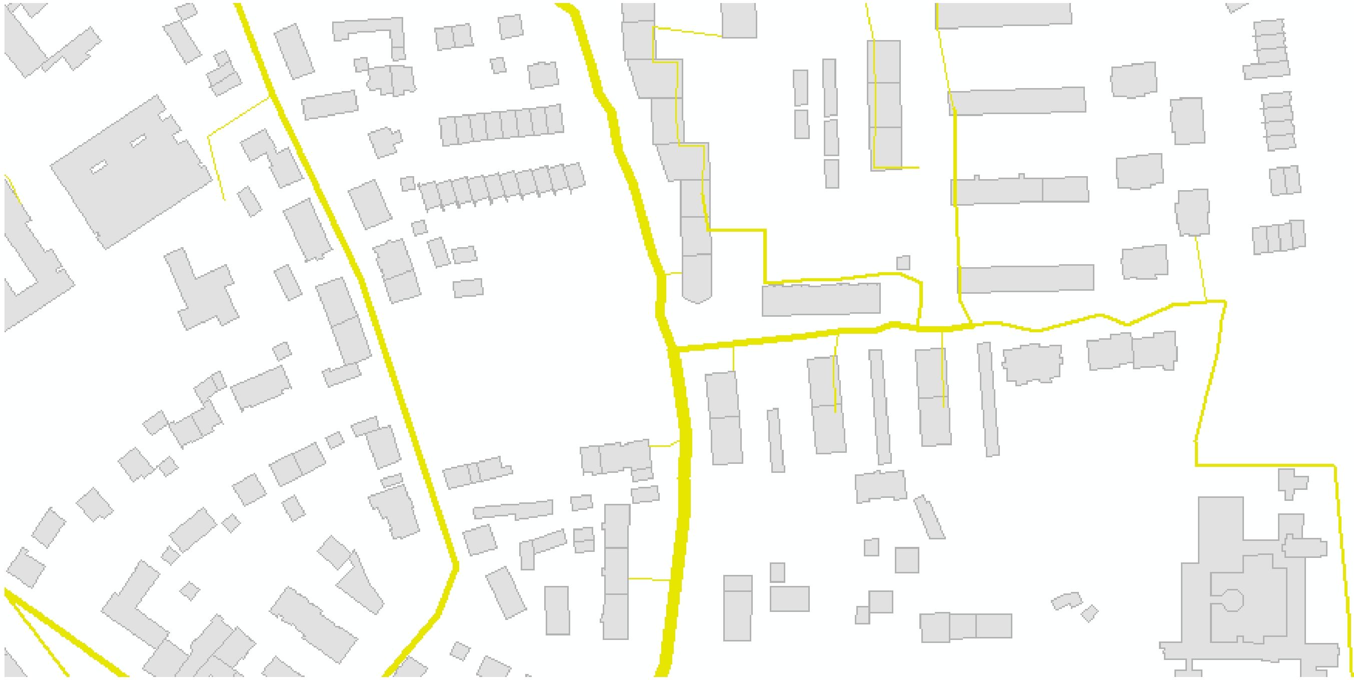


3. Data

3.1. Technical Infrastructure

- Inventory of energy infrastructure for

Generation	Power plants, local power units (if widespread)
Transport	Electricity grid, gas network, district heating network
Storage	Pump storage, hot water tanks, batteries



3. Data

3.1. Mobility

- Gather data to evaluate the current situation:
  - Transport performance by mode (Pkm, tkm per year)
  - Map of transport networks
  - Parking situation
  - Pedestrian zones, cycling roads
  - Location of sub-centres for day-to-day business

3. Data

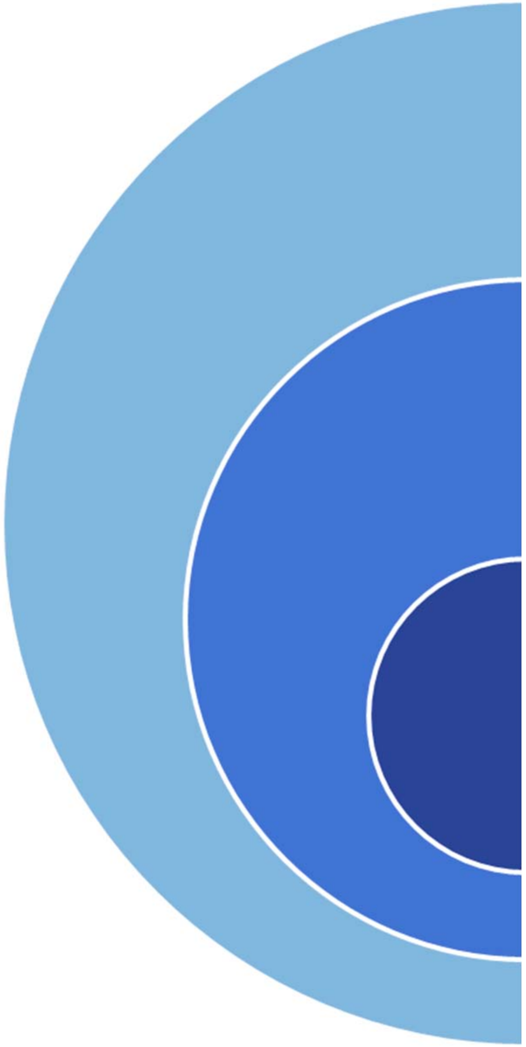
3.2. Local Heat Potential

- Solar heat
  - Uses direct solar irradiation
  - Suited to roof areas on heated buildings (flat and especially tilted)
- Waste heat
  - From industry
  - From waste water
- Geothermal energy
  - Near-surface
  - Deep

3. Data

3.2. Local Electricity Potential

- Wind power
  - Free land with high average wind speeds in 80-150 m above ground
  - Minimum distance to buildings
- Photovoltaic
  - Uses global solar irradiation
  - Suited for roof areas (flat and tilted)
  - Competition with solar heat
- Hydro
  - Rivers, where potential still remains
  - Ecological consequences
  - Alternative: modernisation of existing plants



How is data combined?

CONCEPT

4. Concept

4.1. Demand Reduction Potential

- Measures for demand reduction fall in two categories
  - Technical difficult to finance, medium impact, easy to quantify benefit
  - Behavioural difficult to initiate, huge impact, difficult to quantify success
- Both categories need to be addressed in an energy concept
- All energy forms must be included, not only electricity

Heating/cooling	Electricity	Mobility
Building arrangement	Energy-aware behaviour	Shorter ways
Building insulation	Less appliances	Public transport
Energy-aware behaviour		Bicycle use
		Fuel-efficient vehicles

4. Concept

4.1. Increase Efficiency of Energy Use

Heat

- Modernisation of boilers and turbines in central plants
- New heating systems (eg CHP) in municipal buildings
- District heating networks and/or heat storage (cf. next slide)

Electricity

- Energy-efficient appliances
- New lighting technology (eg LED)

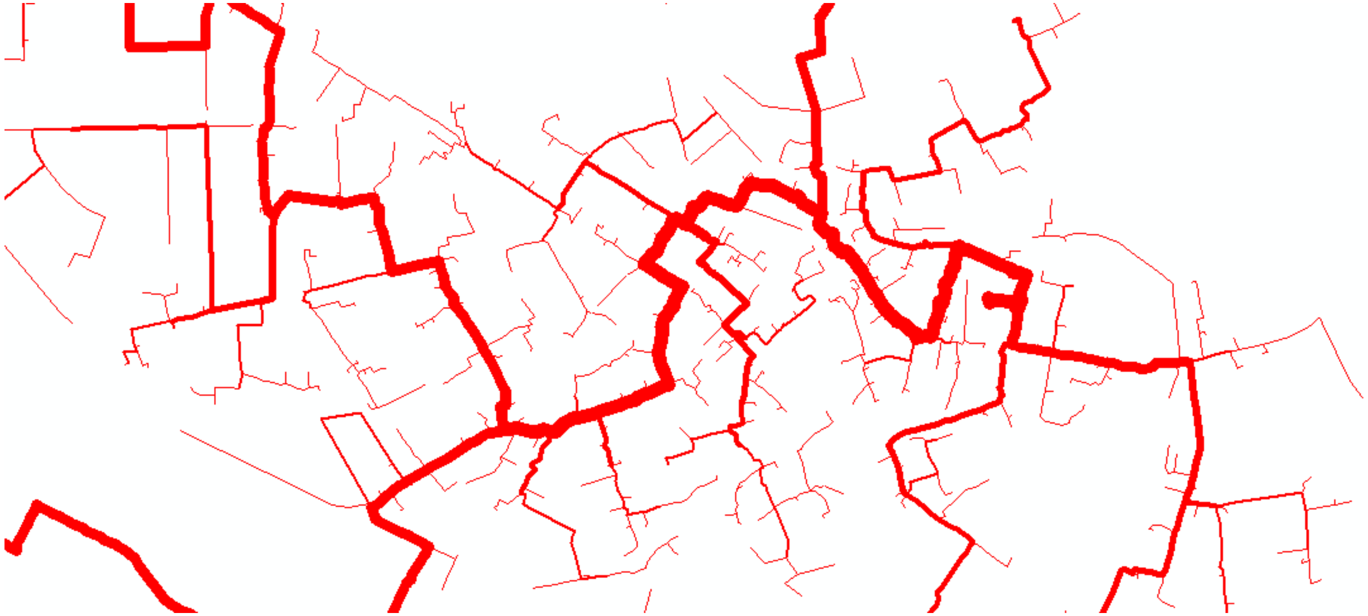
Both

- CHP (Combined heat and power)

4. Concept

4.2. Where to use DH Networks

- Aggregate heating/cooling demand data to heating/cooling density (MW/km²)
- Where density is high and cannot be reduced, consider investing in a local district heating (and/or cooling) network with central, optimised heat generation.
- If concentrated heat potential is available (waste heat, geothermal), use it for a local district heating network.



4. Concept

4.2. Use of Local (Renewable) Energy Potential

Heat

Generation

- Solar heat
- Geothermal energy
- Heat from biomass
- Waste heat
- Cooling with heat

Storage

- Hot water
- Molten salt

Electricity

Generation

- Solar power
- Wind power
- Water power
- Geothermics
- Biomass fuelled CHP

Storage

- Pump storage
- Compressed air
- Hydrogen

4. Concept

4.3. Mobility

- Structural decisions in urban planning influence how much travelling is needed in day-to-day life.
- Multi-use zoning shortens ways
- Intensification, i.e. high-density planning improves use of public transport
- Parking policies can regulate attractiveness of car use in city centres
- New billing concepts across different transport modes facilitate car-free living
- Behavioural awareness for alternatives to car use (walking, cycling, public transport, taxi, car sharing)

Beware of the ”paradox of intensification”: While intensification leads to an overall decrease in mobility demand, local traffic density in intensified areas increases. Additional measures have to be combined with increasing population density, in order to prevent local air and noise pollution.
<http://eprints.uwe.ac.uk/10555/2/melia-barton-parkhurst_The_Paradox_of_Intensification.pdf>

How can the concept be realised successfully?

IMPLEMENTATION

5. Implementation

5.1. Assess Practicality of Measures

- What is the possible impact of a proposed *local* measure? (Table below)
- Is it possible to implement the proposed action at a local scale?
  - Technical feasibility
  - Ecological viability
- Do stakeholders have interest in the action's success?
  - Local added value
  - (Non) financial incentives

Rough impact	**Demand reduction**		**Efficiency increase**		**Renewable energy**	
Heating/cooling	B ●●	T ●●●		T ●●		T ●●
Electricity	B ●●	T ●●		T●		T ●●
Mobility	B ●●●	T ●		T ●●		T ●

B = Behavioural changes T = Technical measures

5. Implementation

5.1. Initiate Measures or Create Suitable Conditions

- Direct municipal funding
  - Municipality operates plants itself or through an operating company
  - Financing of measures through credits and/or subsidies
- Contracting
  - Municipality calls for tenders for realising actions
  - Successful contractor must deliver promised performance
- Citizen initiatives
  - Citizens pool money to create an operating company
  - Success of this model is highly dependent on motivation

5. Implementation

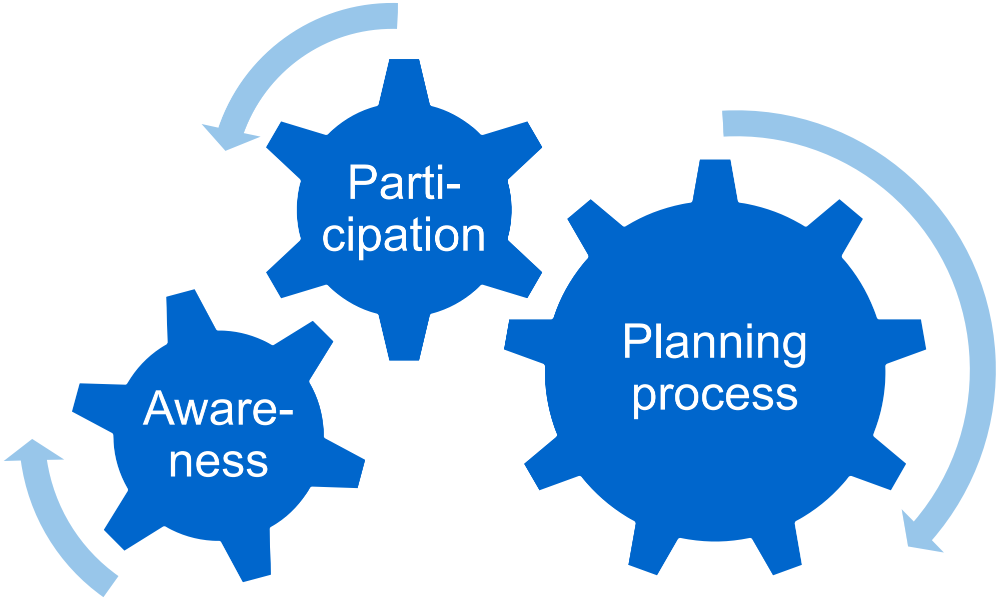
5.2. Identify Stakeholders and Their Potential

- Public
  - Interested valuable source of suggestions and critique
  - Passive should be informed too
  - Opposing must not be ignored and objections should be taken seriously
- City utilities
  - Technical expertise
  - Owner and operator of infrastructure
- Major and special energy consumers
  (industry, hospitals, swimming pools, schools, universities)
  - Enable favourable combinations with residential consumers
  - Consumers for or providers of waste heat
  - Financial participation possible in case of mutual benefit

5. Implementation

5.2. Public Awareness and Participation

1. Citizen committee with mandate (and responsibilities) for concept creation
2. Regular dissemination on both planning progress with possibility for feedback
3. Publication of finalized energy concept
4. Official commitment to energy concept contents
5. Implement measures, including visible flagship projects
6. Evaluate progress



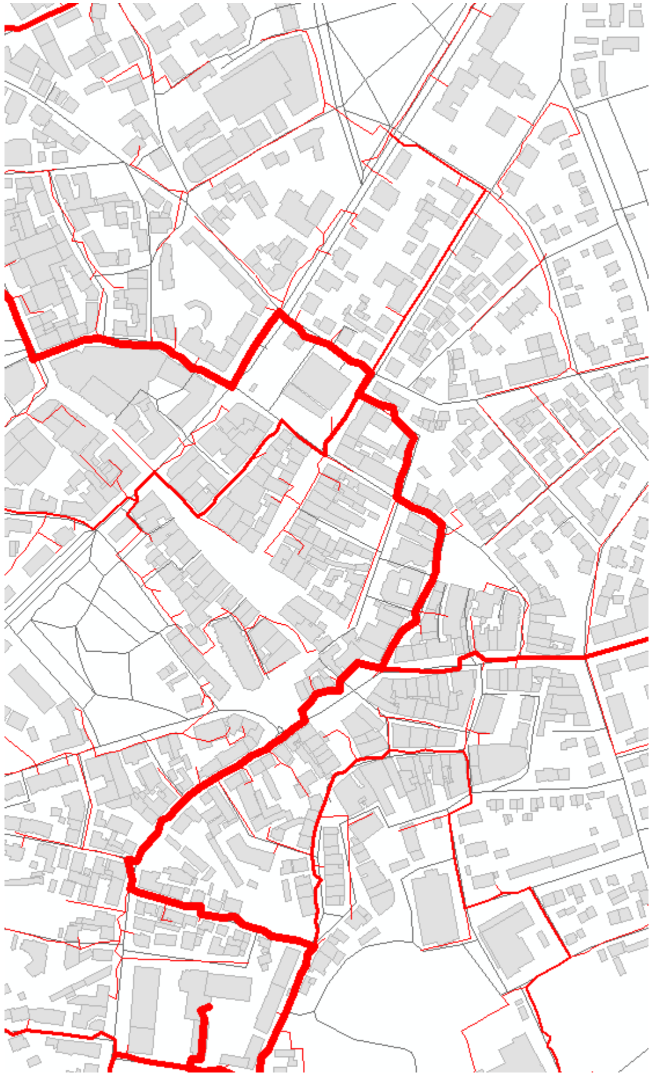
5. Implementation

5.3. Conclusion

- Each measure has a scale at which it is effective

- There are three priorities for measures in an energy concept:
  1. Demand reduction
  2. Efficiency increase
  3. Renewable energy use

- Two group of changes
  - Behavioural changes
  - Technical changes



The UP-RES Consortium

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- **United Kingdom: BRE Building Research Establishment Ltd.**
  www.bre.co.uk
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