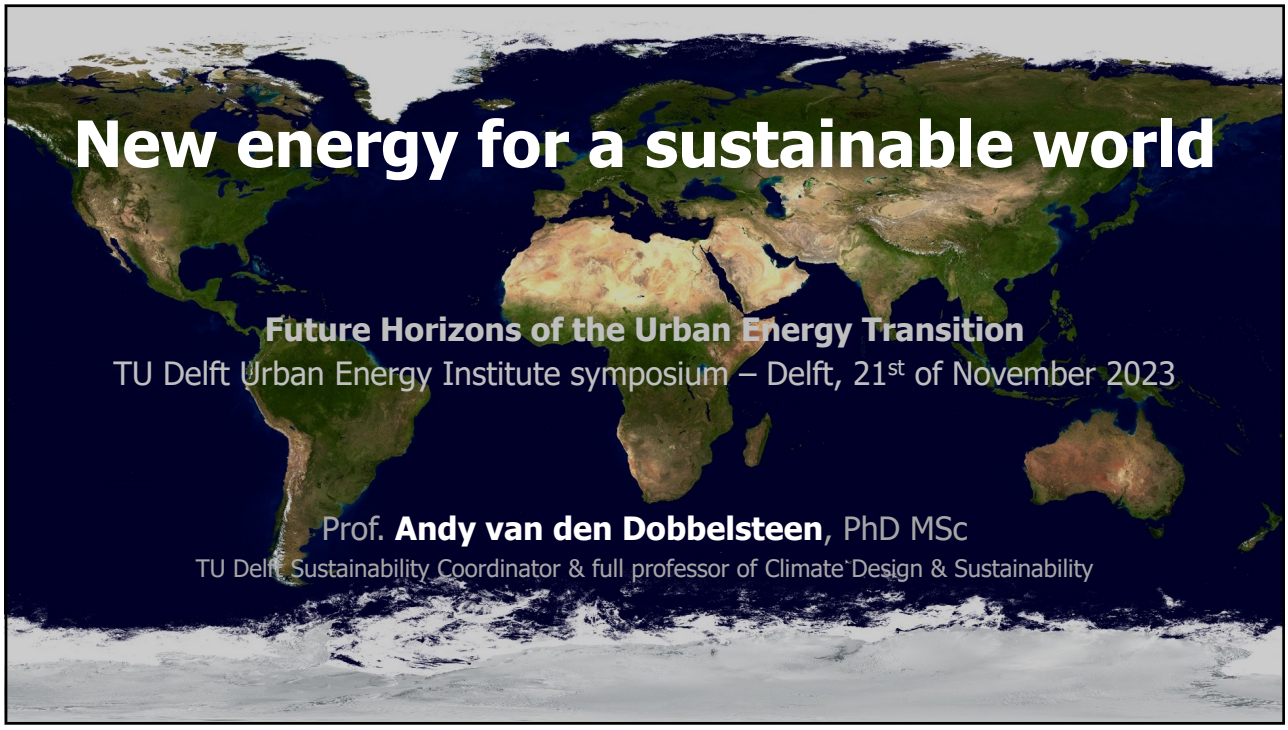

New energy for a sustainable world
Future Horizons of the Urban Energy Transition
TU Delft Urban Energy Institute symposium – Delft, 21st of November 2023
Prof. Andy van den Dobbelsteen, PhD MSc
TU Delft Sustainability Coordinator & full professor of Climate Design & Sustainability

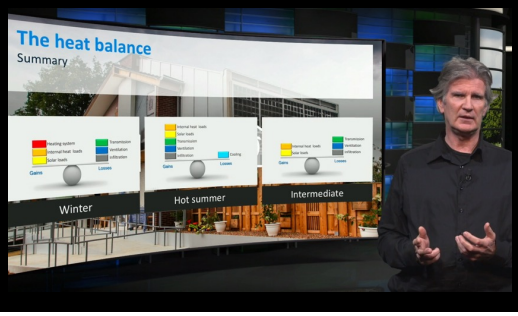
1


Energy slaves
Winner of a Gouden Reiger
(Dutch Oscar for commissioned films)
Visible on youtube
→ Share it!

2

# Zero-Energy Design

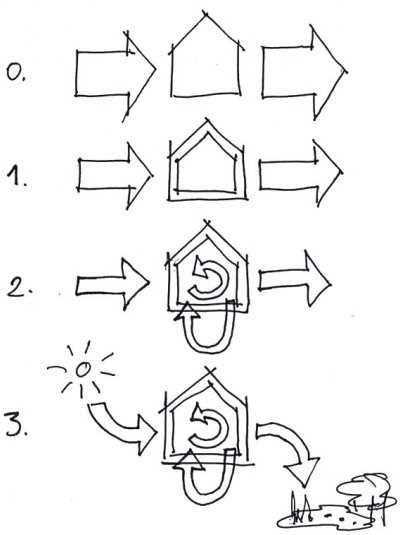
Winner of the 2020 EdX Prize (best online course worldwide)




Free **MOOC**
open in January
@ EdX Online


3

# Steps towards a zero-energy built environment




0 **research: study the local circumstances**

1 **reduce: reduce the demand**
- passive, smart bioclimatic design

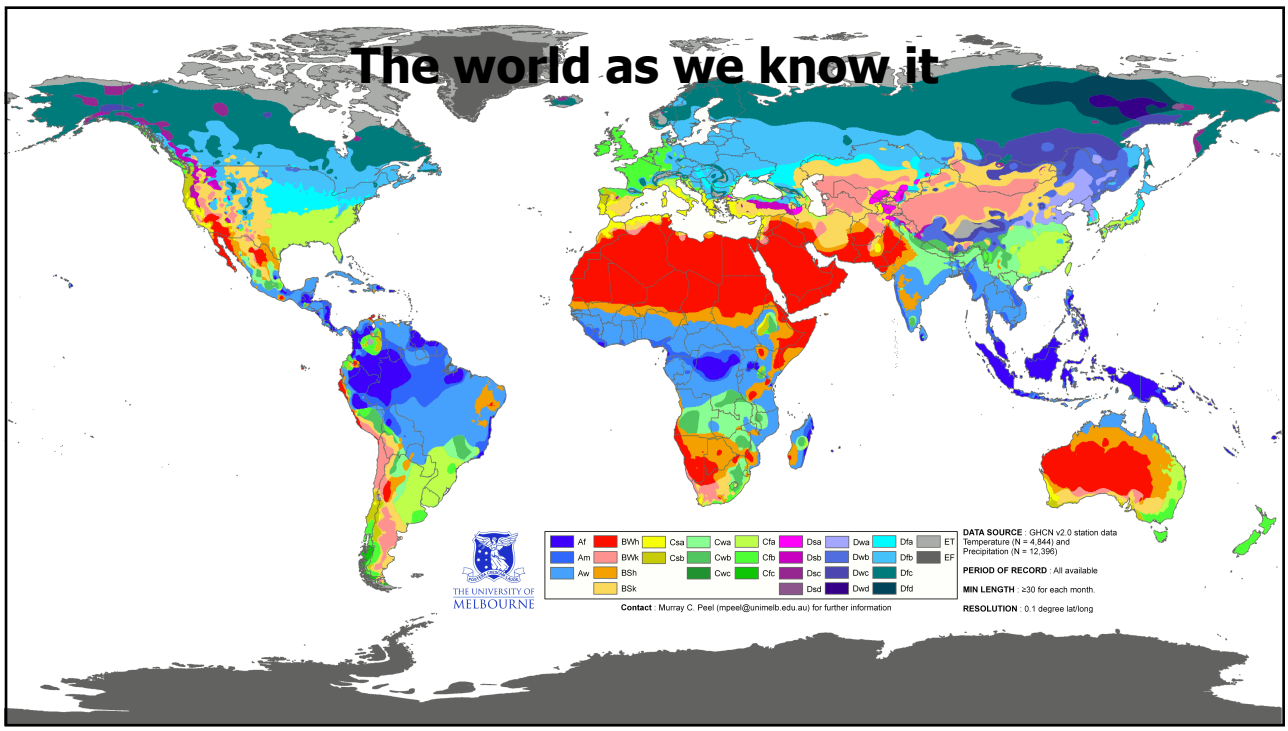
2 **reuse: use residual flows**
- wastewater, waste material, waste heat/cold
- in closed or connected cycles

3 **produce: generate renewable energy**

4


Step 0: **Research**

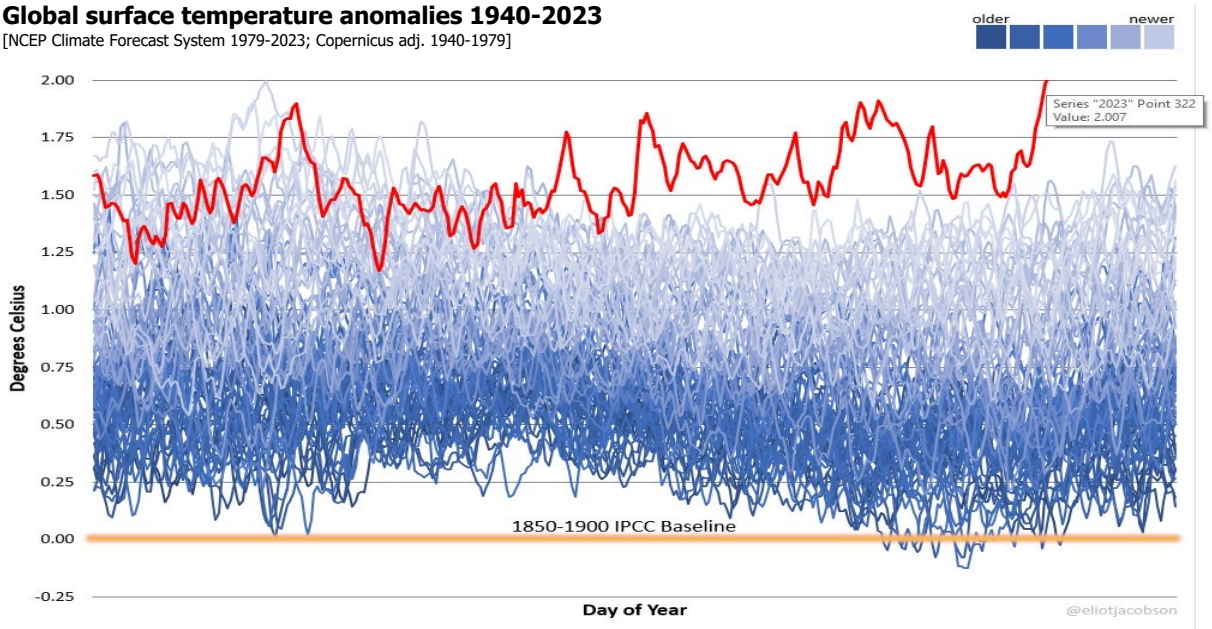
5


The world as we know it
THE UNIVERSITY OF MELBOURNE
Af BWh Csa Cwa Cfa Dsa Dwa Dfa ET
Am BWk Csb Cwb Cfb Dsb Dwb Dfb EF
Aw BSh Cwc Cfc Dsc Dwc Dfc
BSk Dsd Dwd Dfd
Contact : Murray C. Peel (mpeel@unimelb.edu.au) for further information
DATA SOURCE : GHCN v2.0 station data
Temperature (N = 4,844) and
Precipitation (N = 12,396)
PERIOD OF RECORD : All available
MIN LENGTH : ≥30 for each month.
RESOLUTION : 0.1 degree lat/long

6

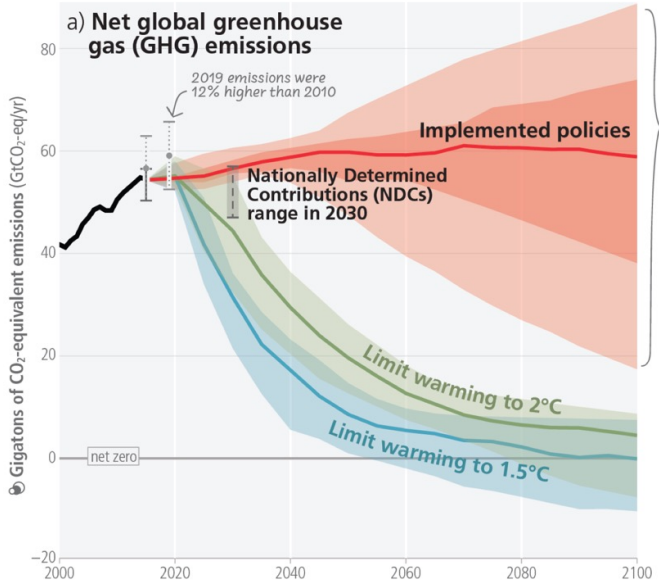
# Houston, we have a problem…

**Global surface temperature anomalies 1940-2023**
[NCEP Climate Forecast System 1979-2023; Copernicus adj. 1940-1979]




7

# Radical action is needed




**Limiting global warming to 1.5ºC and 2ºC involves rapid, deep and in most cases immediate greenhouse gas emission reductions**
Net zero $CO_2$ and net zero GHG emissions can be achieved through strong reductions across all sectors [IPCC 2023]

*Implemented policies result in projected emissions that lead to warming of 3.2°C, with a range of 2.2°C to 3.5°C (medium confidence)*

Key
- Implemented policies (median, with percentiles 25-75% and 5-95%)
- Limit warming to 2°C (>67%)
- Limit warming to 1.5°C (>50%) with no or limited overshoot
- Past emissions (2000–2015)
- Model range for 2015 emissions
- Past GHG emissions and uncertainty for 2015 and 2019 (dot indicates the median)

8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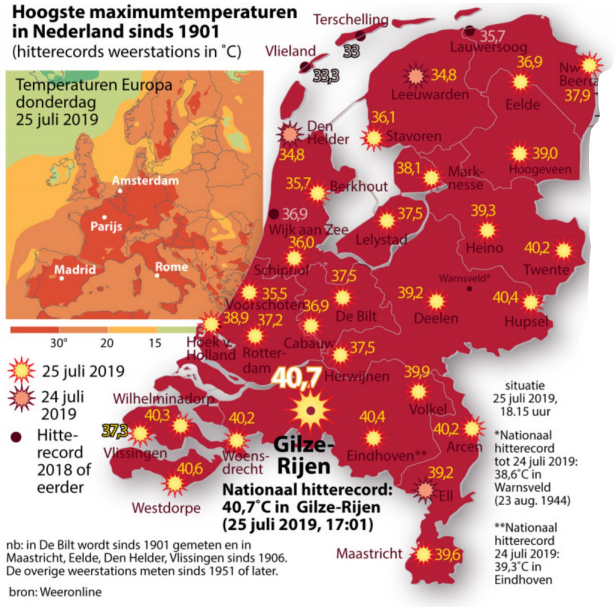
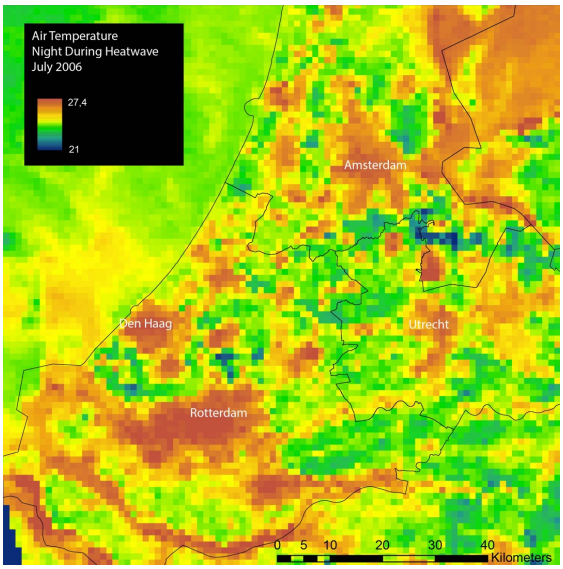
## Extreme temperatures, even higher in urban areas

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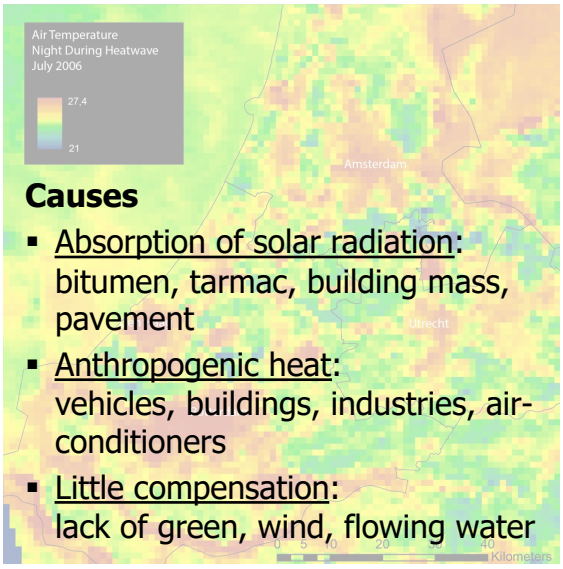
# Causes of extreme urban heat

The **urban heat island (UHI) effect** is the phenomenon that urbanised areas are significantly warmer than their rural countryside.

[Wandl & Hoeven, 2014]




**Causes**

- Absorption of solar radiation: bitumen, tarmac, building mass, pavement
- Anthropogenic heat: vehicles, buildings, industries, air-conditioners
- Little compensation: lack of green, wind, flowing water

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# Bring nature back into the built environment

- **Absorbing $CO_2$**
- **Filtering fine dust** and other pollutions
- **Retaining** (in the substrate layer) **rainwater**
- **Humidifying the air**
- **Cooling**, by shadow and evapo-transpiration
- **Stabilising the temperature** in buildings
- **Increasing biodiversity**
- **Basic psychological need** of humans

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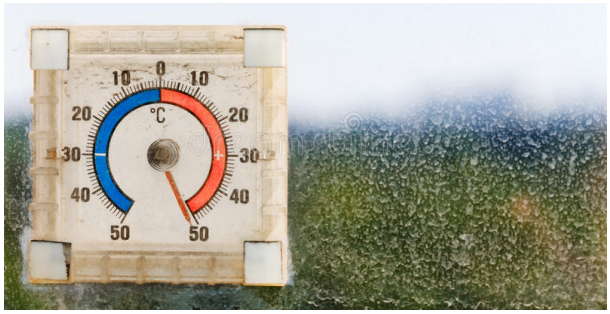
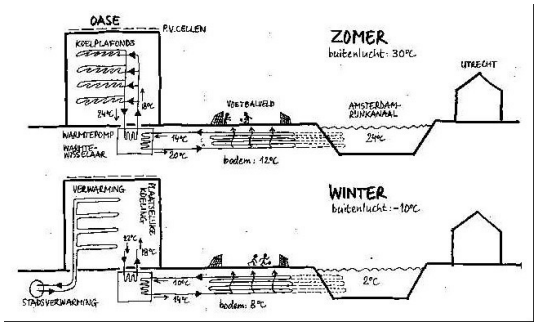
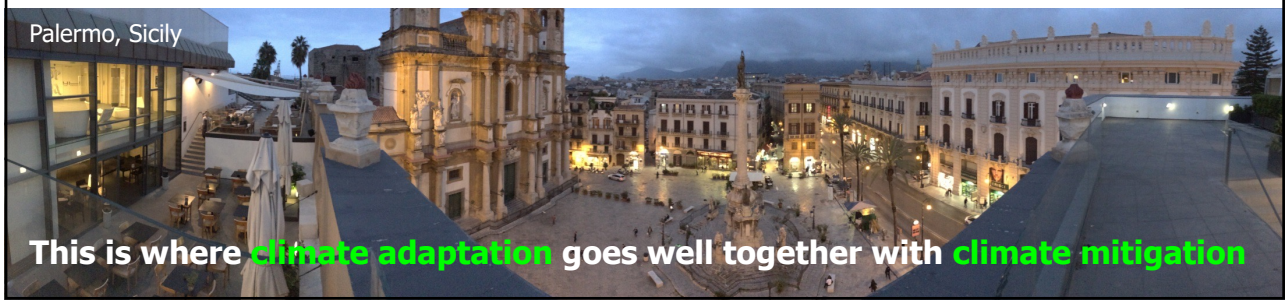
## Also needed: active cooling of hot urban surfaces

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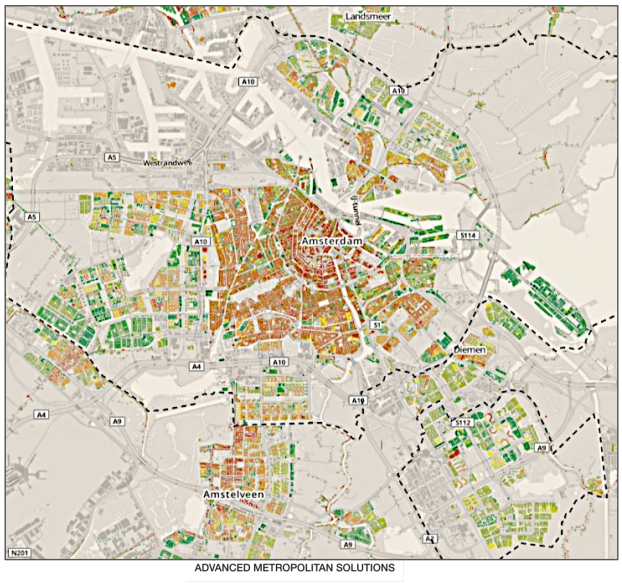
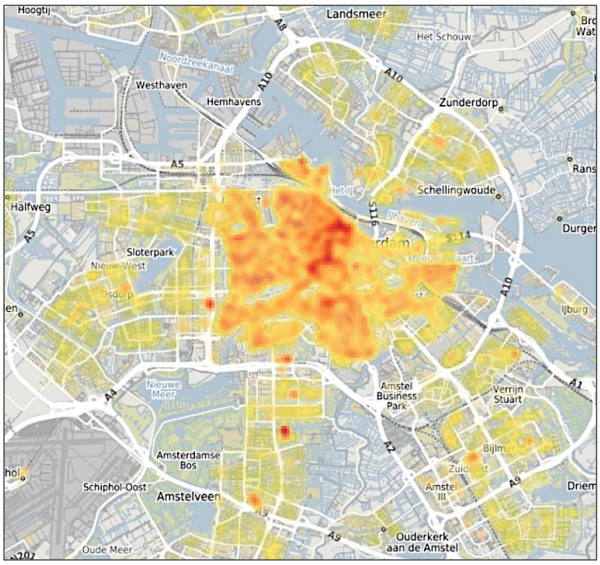
# Energy labels and gas use [City of Amsterdam]

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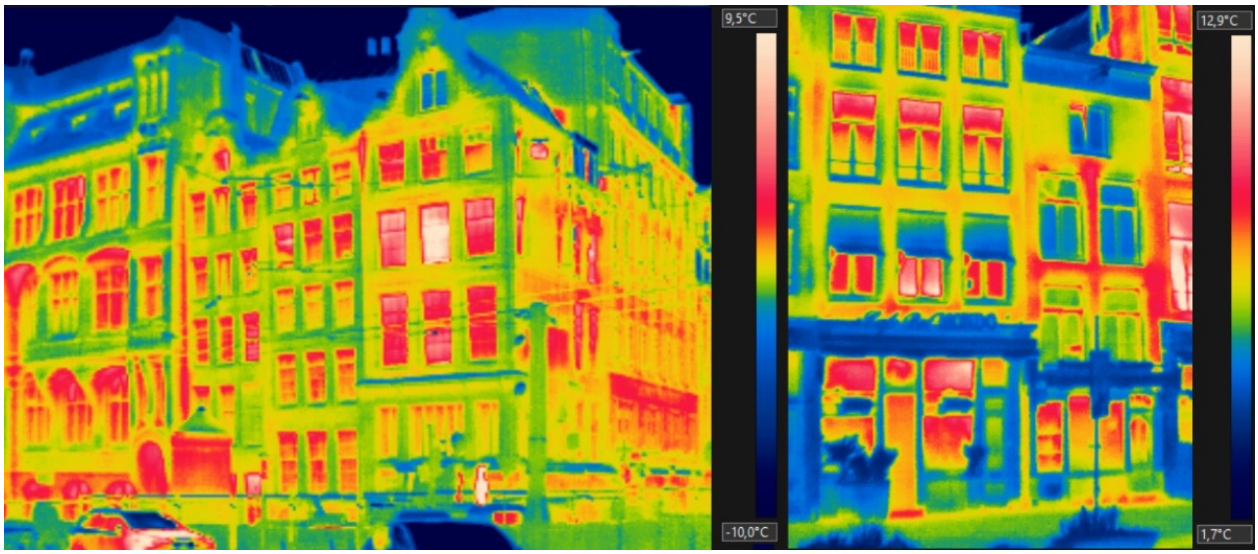
# Great energy losses still…

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# So, it always starts with reducing the demand

| | |
|---|---|
| Urban plan | ▪ Avoidance of energy users |
| Building orientation | ▪ **LED lighting** |
| Building geometry | ▪ **Energy-efficient tv** |
| Building layout | ▪ **Energy-efficient fridge** |
| Zoning | ▪ **Energy-efficient freezer** |
| Compartmentalisation | ▪ **Energy-efficient washing machine** |
| Daylight access | ▪ **Natural drying** |
| Use regime | ▪ **Thermostat taps** |
| Thermal mass | ▪ **Thermostat shower** |
| **Thermal insulation** | ▪ **Smart meters** |
| **Insulating glass** | ▪ **Kill-button** |
| **Sunshading** | ▪ **Building management system** |

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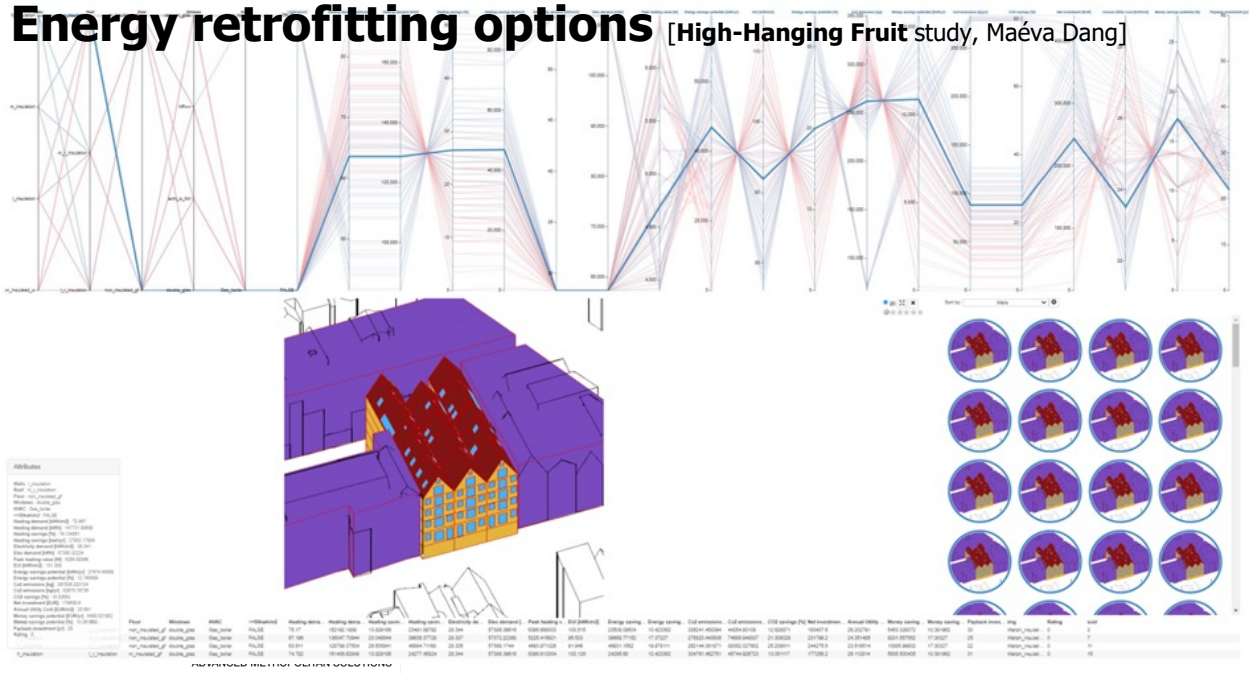
# Energy retrofitting options [**High-Hanging Fruit** study, Maéva Dang]



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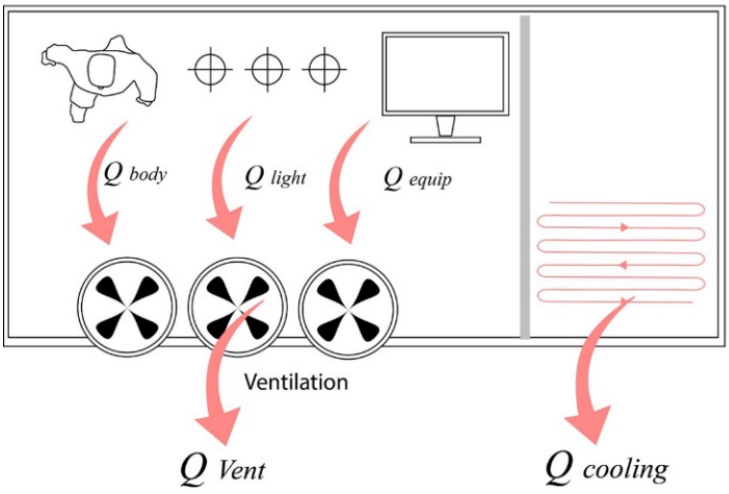
## Common exhaust air is a source of waste heat




$Q_{cooling} = Elec_{avg} \times A_{floorElec_{avg}} \times Cooling_{\%} \times (COP + 1\ )$

$Q_{vent} = Q_{body} + Q_{light} + Q_{equip} = \Delta T_{in-out} \times V_{flow} \times HC_{air} \times T_{month} \div 3600$

$Q_{wasteheat} = Q_{vent} + Q_{cooling}$

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# Heat recovery systems

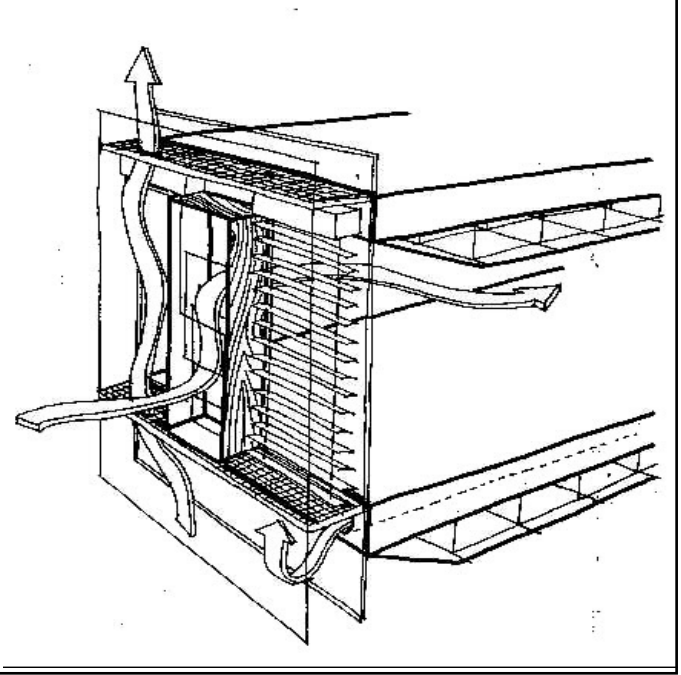
**Exhaust air**

- Direct, e.g. via concrete core slabs
- Heat exchanger, air-air
  *(heat wheel, cross-flow exchanger)*
- Heat exchanger, air-water
  *(direct use or store in the soil)*
- Heat pump, air-water
  *(direct use or store in a tank)*

**Waste water**

- Shower (~ 35°C)
- Sewage (~ 25°C)
- Kitchen sink (varies)

(tubular exchangers)



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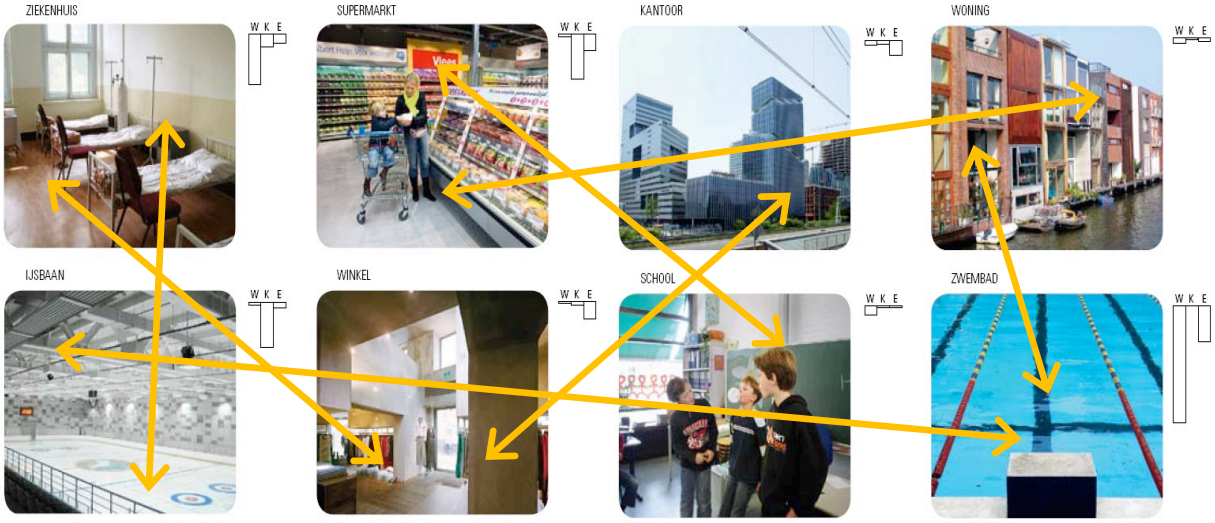
# Different energy patterns → smart exchange




**W = heat** ('warmte'); **K = cold** ('koude'); **E = electricity** ('elektriciteit'), all **per m²** of gross floor area

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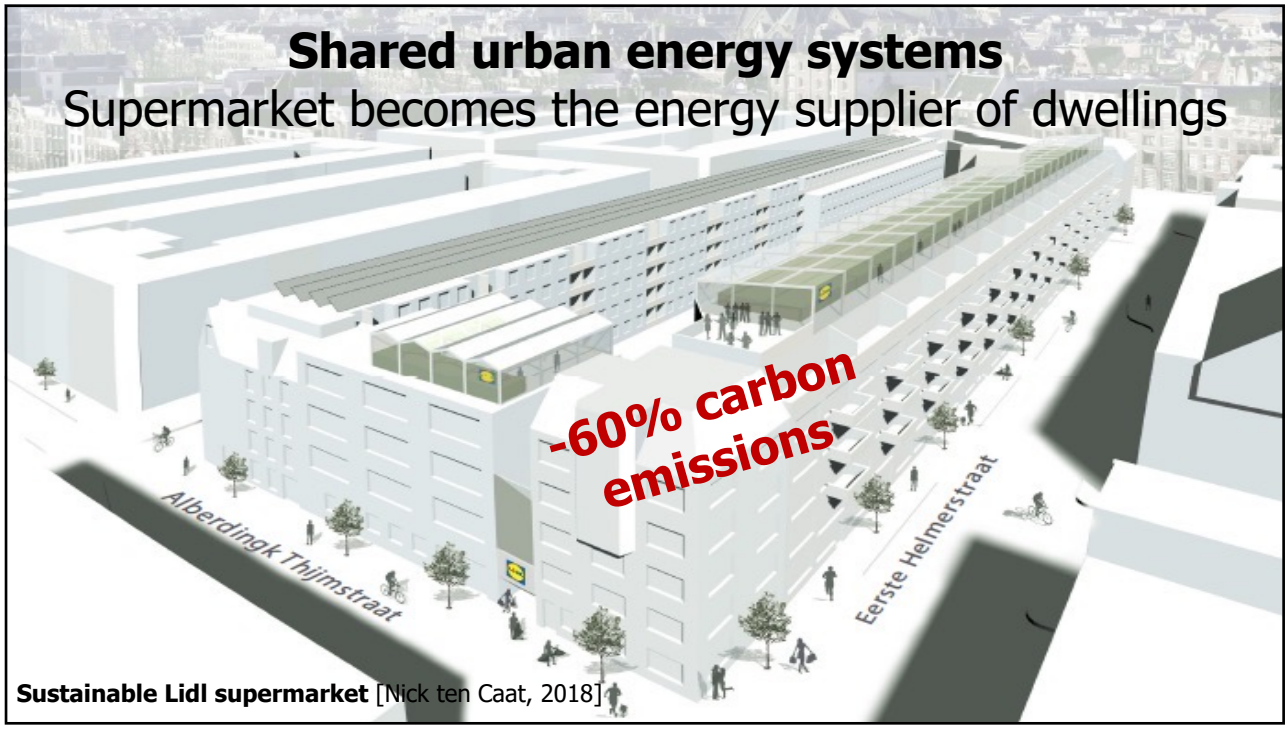
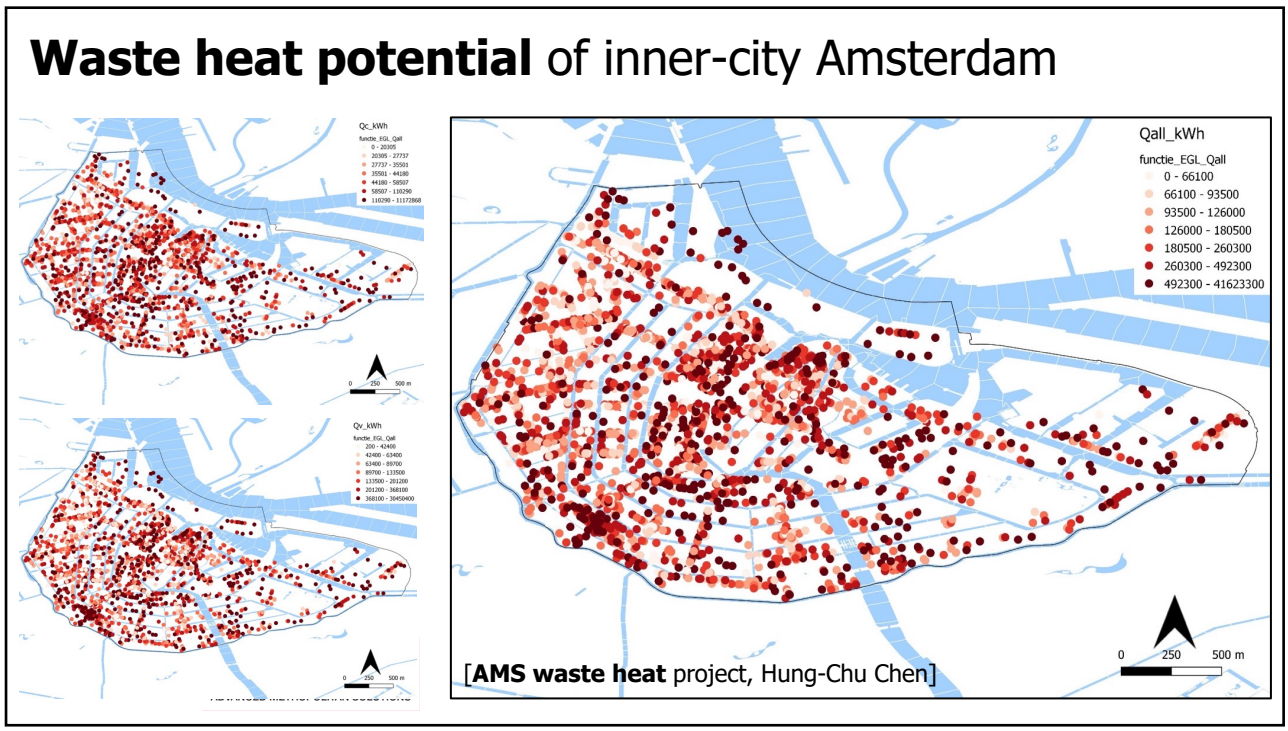

Shared urban energy systems
Supermarket becomes the energy supplier of dwellings
-60% carbon emissions
Alberdingk Thijmstraat
Eerste Helmerstraat
**Sustainable Lidl supermarket** [Nick ten Caat, 2018]

23


**Waste heat potential** of inner-city Amsterdam
Qall_kWh
functie_EGL_Qall
0 - 66100
66100 - 93500
93500 - 126000
126000 - 180500
180500 - 260300
260300 - 492300
492300 - 41623300
0 250 500 m
[**AMS waste heat** project, Hung-Chu Chen]

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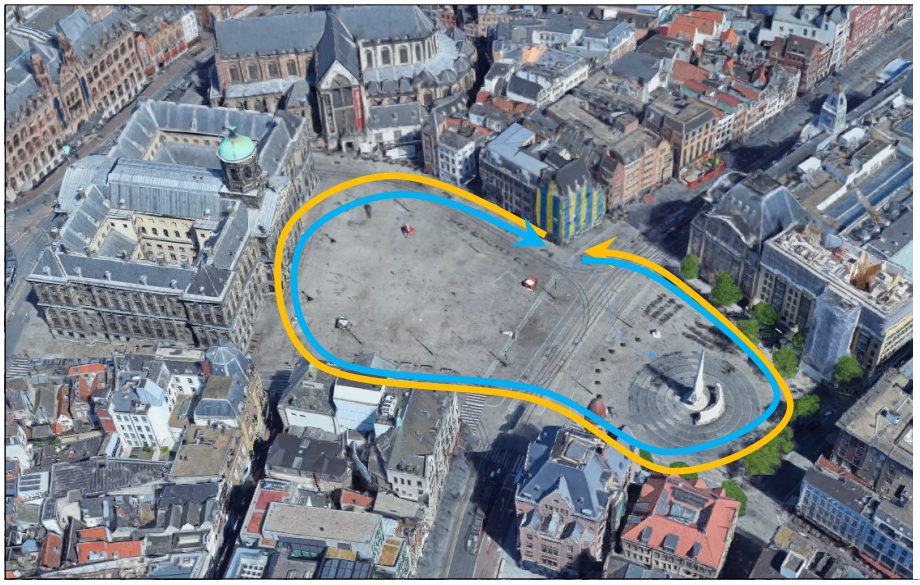
# **LT heat** (& cold) **network fed by multiple sources**



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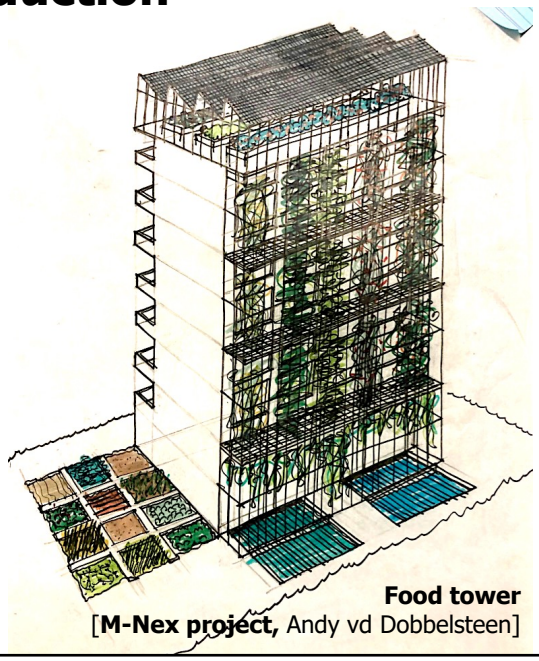
# Synergy with urban food production

- Rainwater from the roof to the plants
- **Electricity from PV cells to the building**
- **Heat from the greenhouse to the building**
- Nutrients from wastewater to the plants
- $CO_2$ from the building to plants



**Food tower**
[**M-Nex project,** Andy vd Dobbelsteen]

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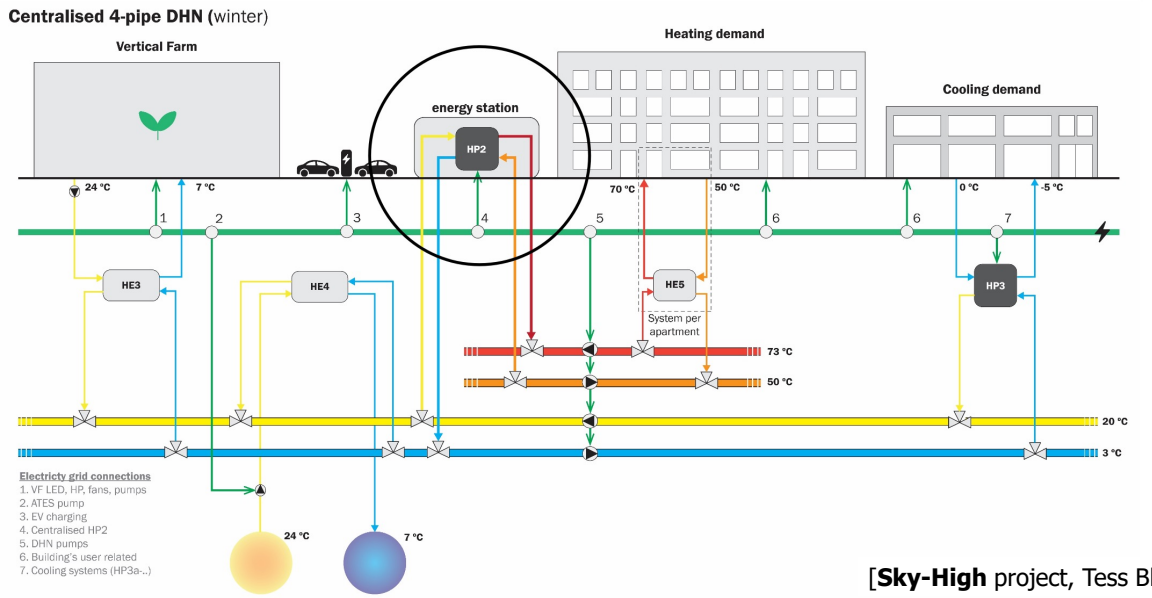
# Vertical farms as heat source and energy balancer




[**Sky-High** project, Tess Blom]

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## Producing your own energy, maximum, not optimal


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## Problem: storage of redundant summer electricity

- **Batteries**
  - Short-term storage, high performance
  - Requires a lot of (rare) material
- **Hydrogen**
  - Seasonal storage, <50% performance from electricity → gas → electricity
  - Special infrastructure, equipment and tanks
- **E-fuels**
  - $CO_2$ + $H_2O$ turned into carbon hydrates (petrol, diesel, kerosine) with electricity
  - Seasonal storage, performance still low, expensive
- **Or: design differently**

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# Vertical solar panels: many advantages

- Larger surfaces
- Low sun angles
- Winter produce
- Diurnal spread

Social zero-on-the-meter housing (Best)

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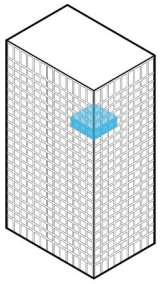
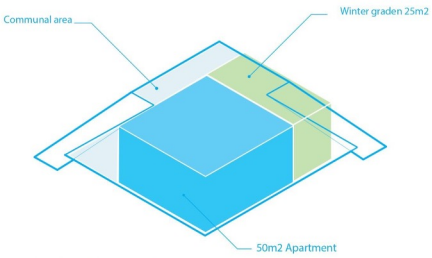
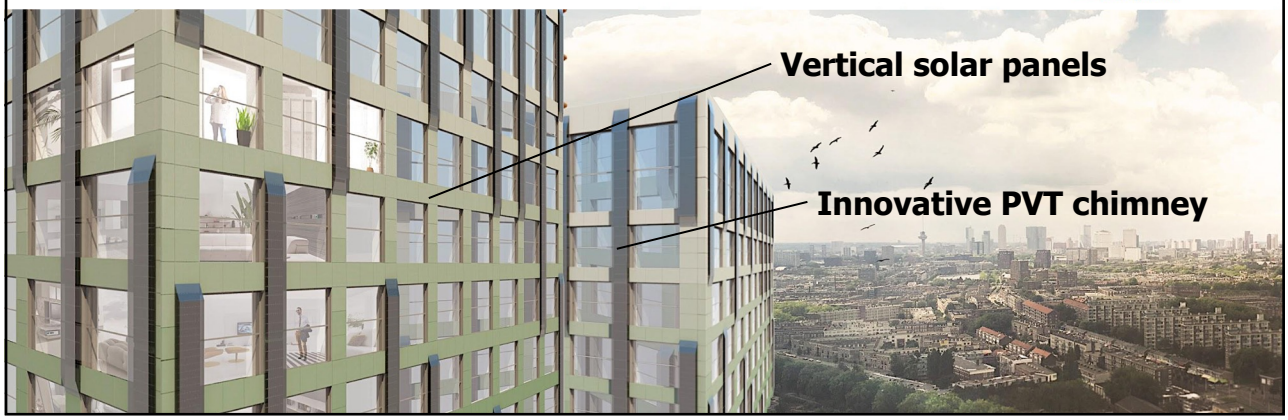
# Coloured PV panels



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## This is a power plant

**Solar Decathlon Europe 2019** [**MOR**: Modular Office Renovation]

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# Local energy potentials of inner-city Amsterdam

| category | source/technology | electricity | | | heat | | | cold | |
|---|---|---|---|---|---|---|---|---|---|
| **solar** | roofs | 8,999 | MWh | OR | 20,831 | MWh | | | |
| **wind** | turbines | 126 | MWh | | | | | | |
| **biomass** | waste (fermentation) | 167 | MWh | OR | 251 | MWh | | | |
| **water** | surface | | | | 31,680 | MWh | OR | 31,680 | MWh |
| | sewage | | | | 2,055 | MWh | OR | 2,055 | MWh |
| | drinking | | | | 1,370 | MWh | OR | 2,466 | MWh |
| **geothermal** | deep | | | | 494 | MWh | | | |
| | ultradeep | - | | | - | MWh | | | |
| | **TOTAL** | 9,292 | MWh | | 56,680 | MWh | | 36,201 | MWh |

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# Added value of aquathermal energy

→ better water quality (algae, bacteria)
→ cooling in summer
→ greater probability of ice in winter

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# It works!


Aquathermal system Gerrit Hiemstra, Balk, 02-03-2021

**Andy van den Dobbelsteen**
Sustainability Coordinator bij TU Delft
3w • Edited •

Vanochtend demonstreerde het warmtepompsysteem van **Gerrit Hiemstra** hoe **#aquathermie** kan worden gebruikt voor het vergroten van de kans op ijs in de **Provincie Fryslân**: er ligt ijs waar de wisselaar warmte onttrekt, open water op andere plekken.

Zoals Gerrit zelf opmerkt: er spelen andere factoren een rol, zoals het verschil in waterdiepte, stroming versus geen stroming, verschil in beschutting, eenden. Maar alle beetjes helpen.

Onderzoek moet uitwijzen hoe groot het effect is op de watertemperatuur, waterkwaliteit en ecologie, mate van stedelijke verkoeling, condities voor ijsvorming en natuurlijk de energieprestatie.

Het gaat om een paar graden afkoeling, dus een koude winterperiode is nog steeds nodig, maar in geval van veel aquathermieprojecten kan de **#Elfstedentocht** zo toch ooit weer komen!

**Wetterskip Fryslân MEFA GROUP Plushuis Unilever Ivo Pothof Phil Vardon Jakob Haverkamp Frits Kuus Koninklijke Oosterhof Holman Sybrand Frietema de Vries Bram Hulsman Arjan van den Hoogen Lucek Wolthekker Gemeente Noardeast-Fryslân Gemeente Súdwest-Fryslân Gemeente Leeuwarden Gemeente**

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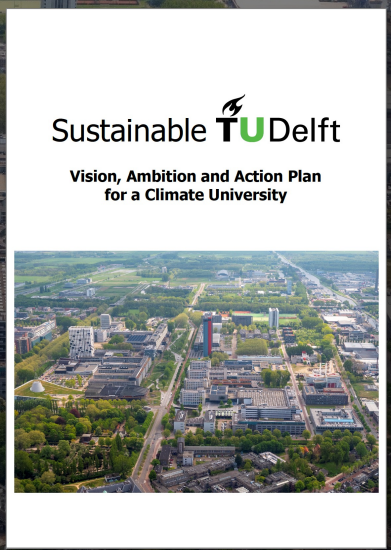
## TU Delft: practise what we teach & preach

- **Carbon neutral, by 2030**
  related to all activities done on and from the campus
- **Circular, by 2030**
  referring to all resource and waste flows through the campus
- **Climate-adaptive, by 2030**
  dealing with heat, drought, rain, floods, extreme weather
- **Contributing to quality of life**
  aiming at biodiversity, safety, health, inclusiveness, happiness
- **Exposing & testing sustainability**
  accommodating and demonstrating living labs and innovation

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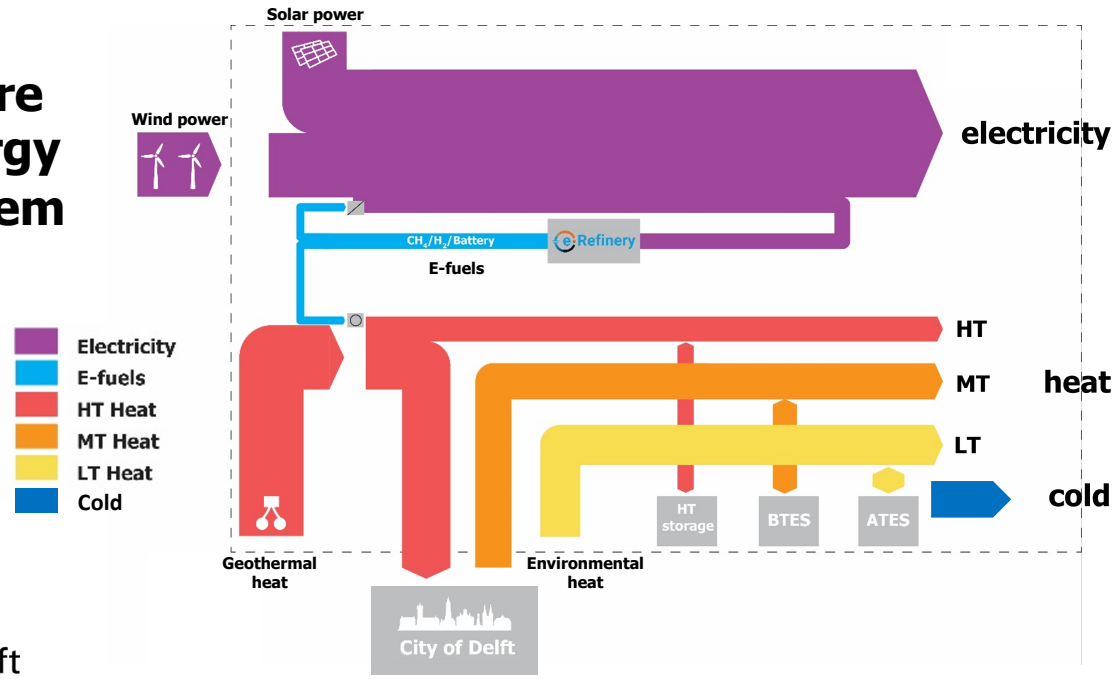
# The future energy system

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# Deep renovation of large faculty buildings



**Applied Physics** (22)
**Mech. Engineering** (34)



**Civil Engineering** (23)
**Electr. Engineering** (36)

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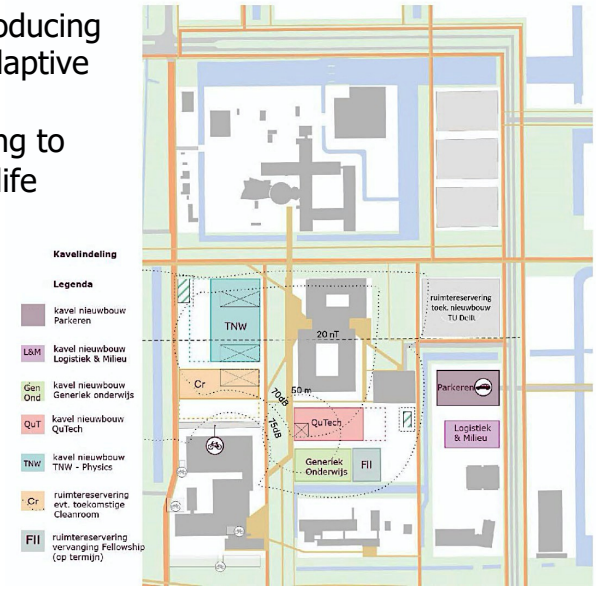
# Low-temperature energy system on Campus South

- Energy producing
- Climate adaptive
- Circular
- Contributing to quality of life

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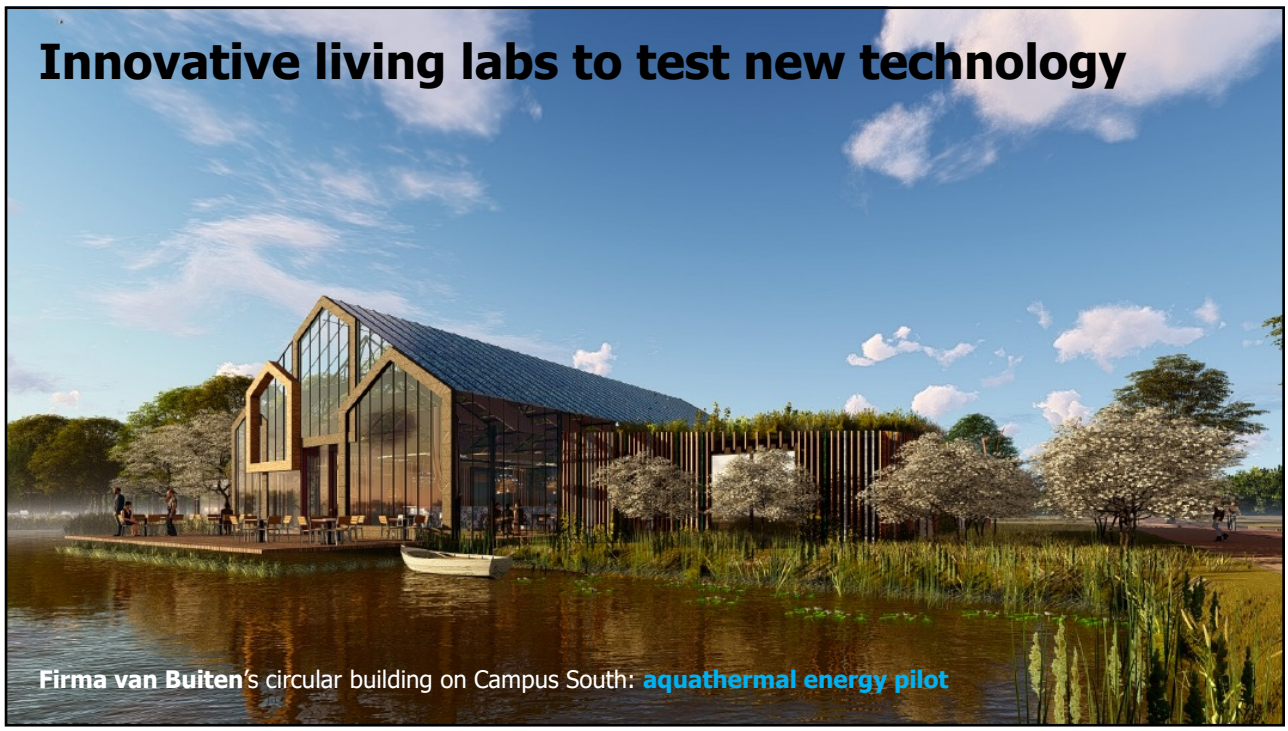
# Innovative living labs to test new technology



**Firma van Buiten**'s circular building on Campus South: **aquathermal energy pilot**

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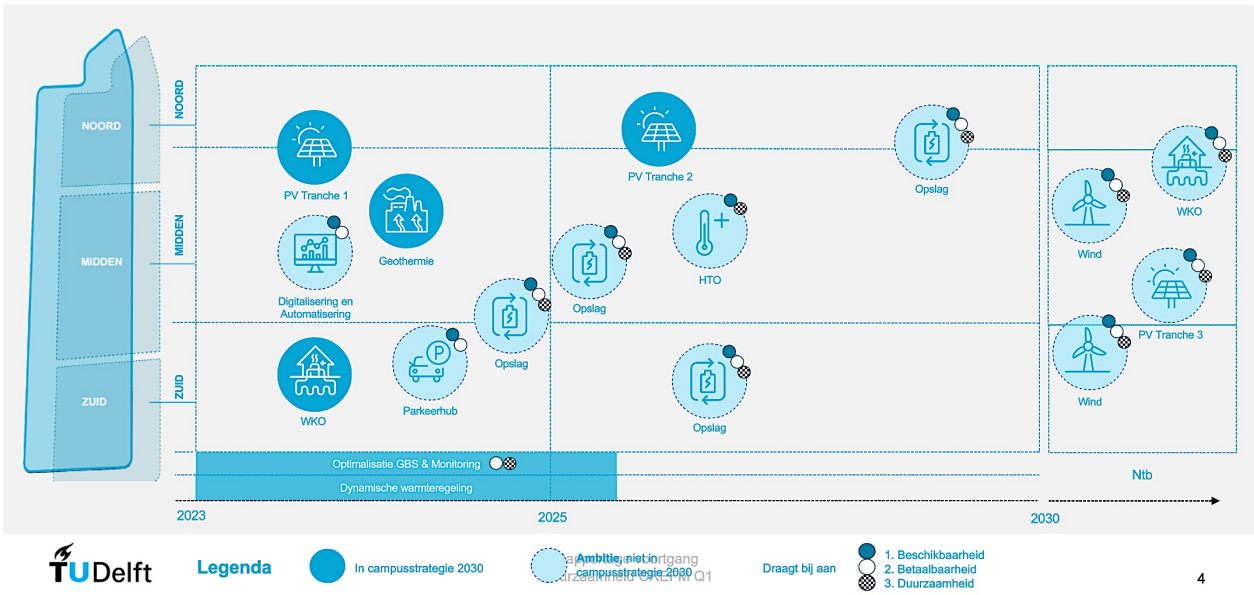
# Energy roadmap towards zero carbon

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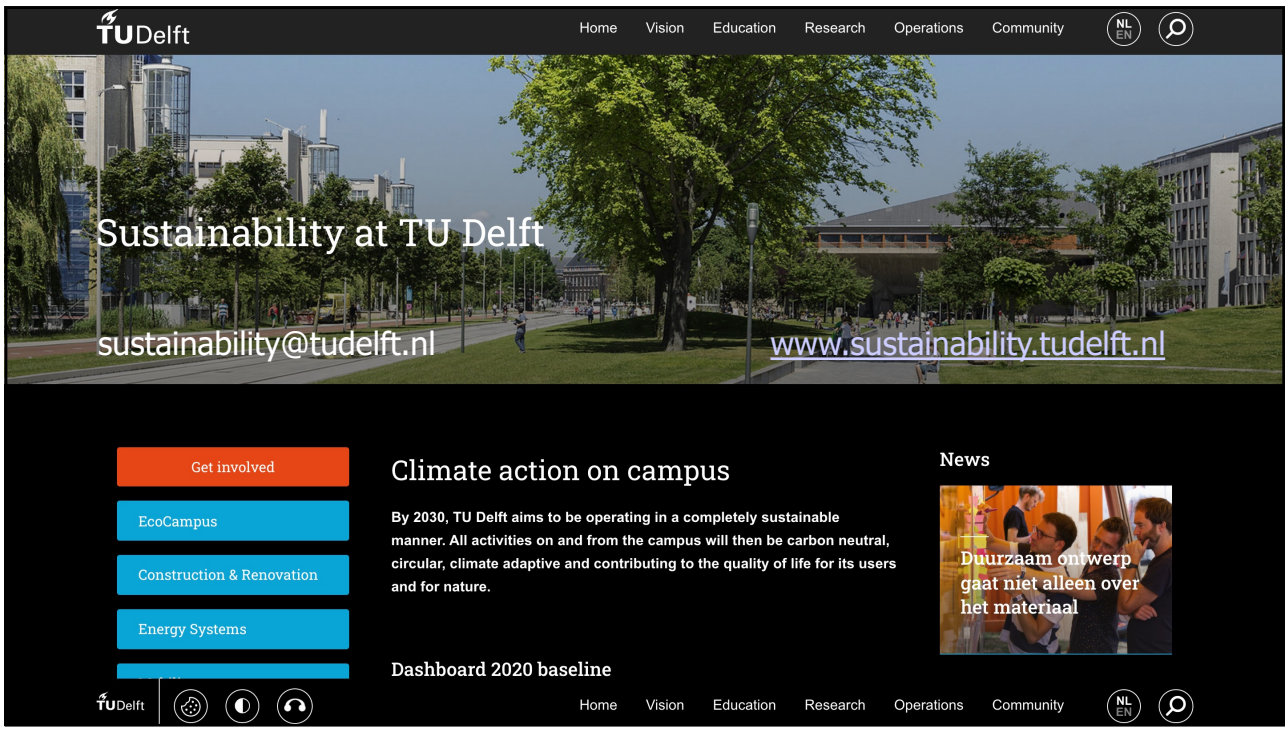


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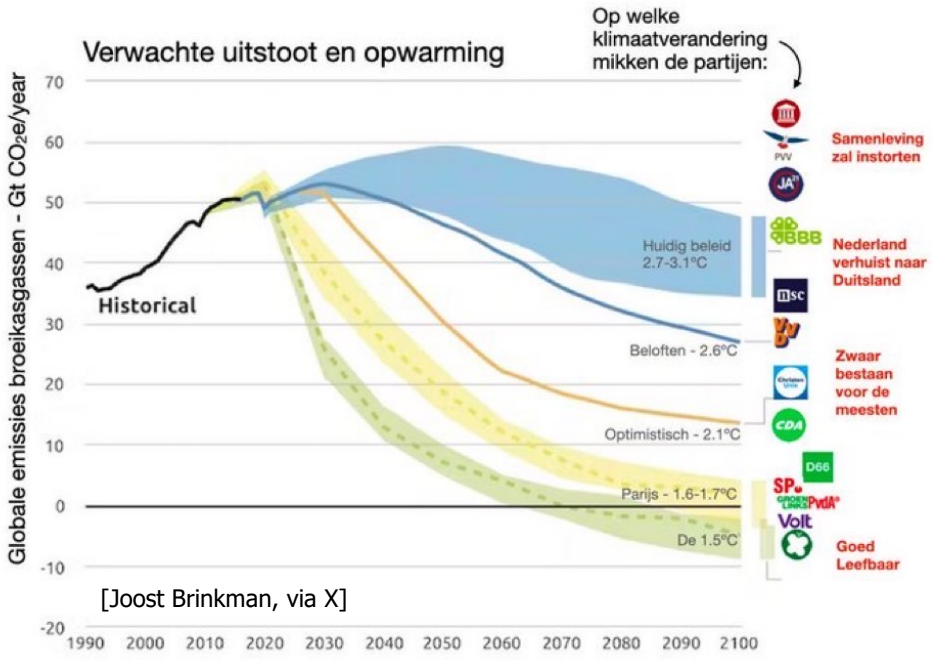
**There is something to vote for tomorrow…**




[Joost Brinkman, via X]

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