Roadmapping For Sustainability in Best

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Abstract

Roadmapping is a tool to visualize and concretize a strategy, using a timeline. The development of sustainability is a huge endeavour with many stakeholders at a global scale, making it highly complex. A roadmap is a means to keep overview in such complex problems, helping the wide variety of stakeholders to communicate and to share a vision on how to achieve sustainability. The roadmap sets the context for concrete action plans. This presentation shows an example from a Dutch town Best.

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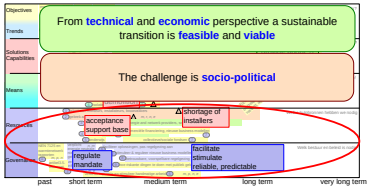
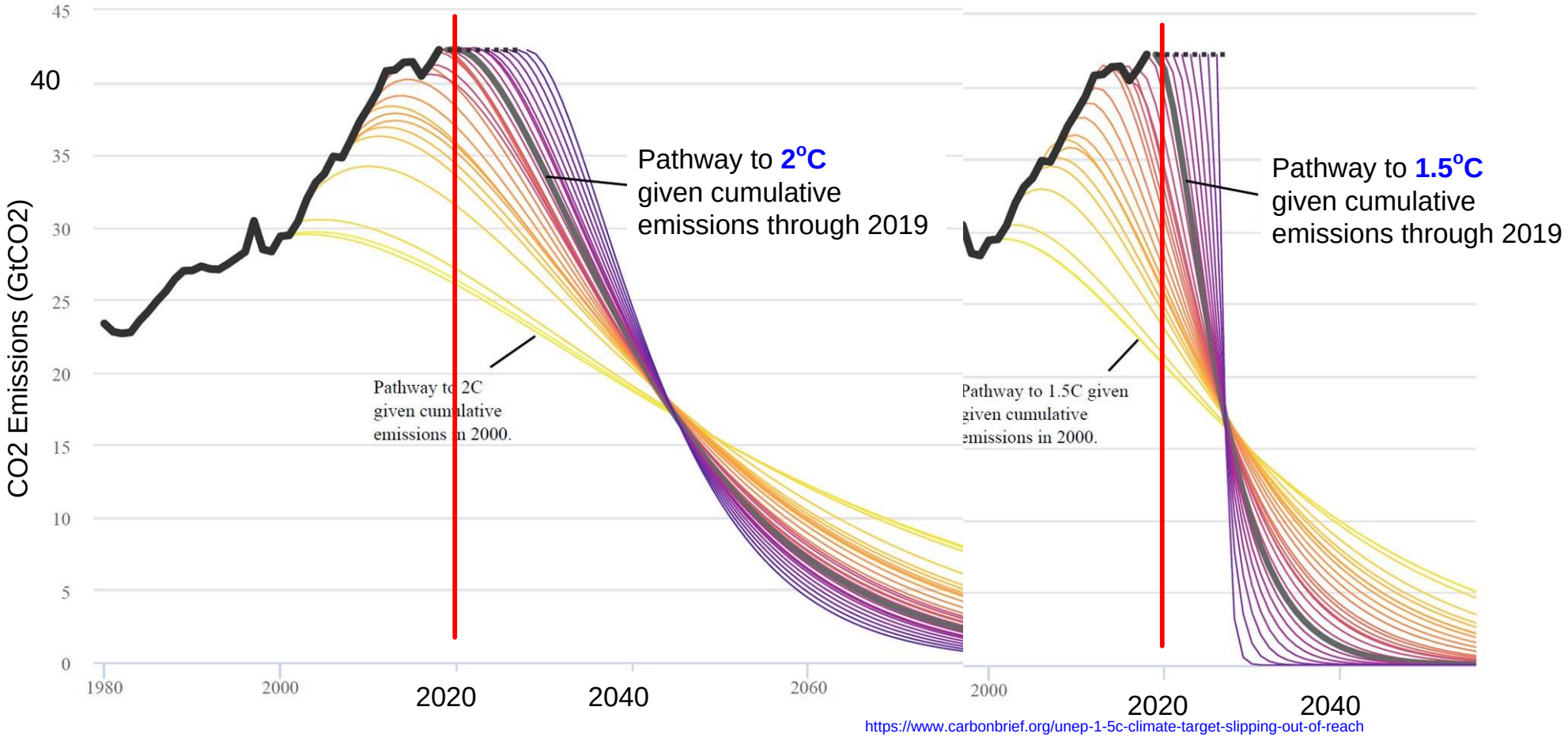
version: 0



Global Sustainability Goals

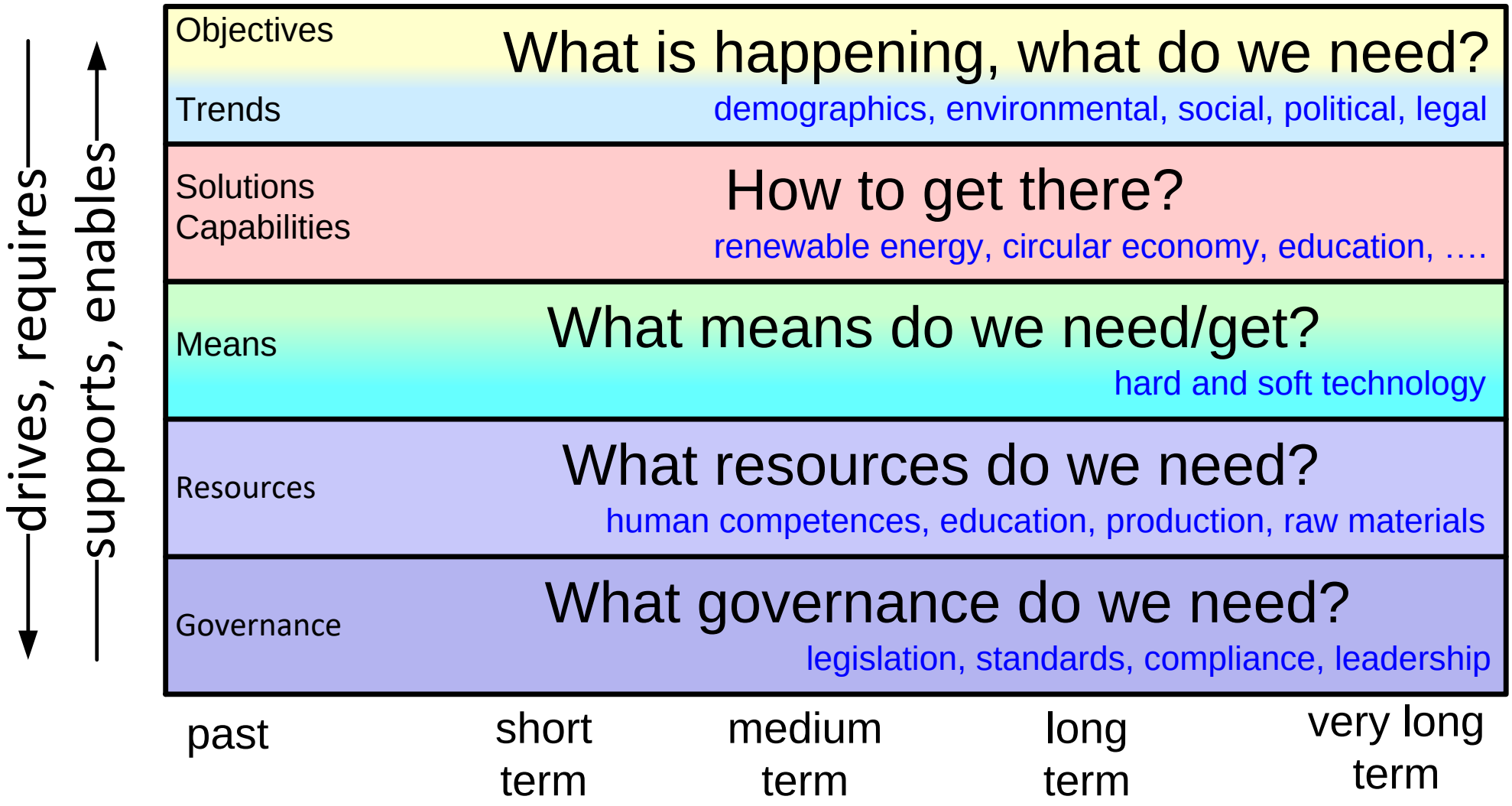
Time is Running Out Fast



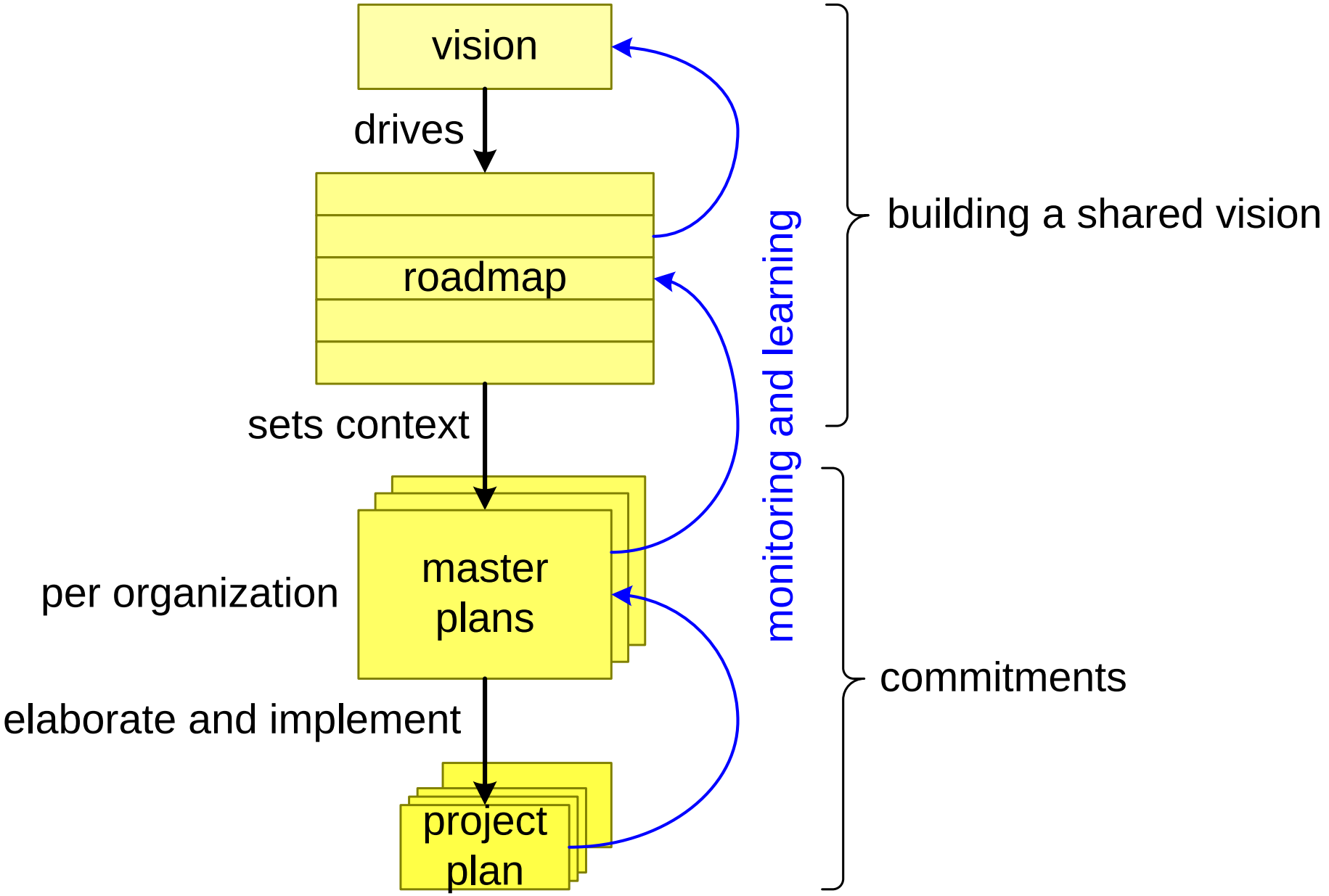
https://www.carbonbrief.org/unep-1-5c-climate-target-slipping-out-of-reach

Source: Historical CO2 emissions from the Global Carbon Project. 1.5C carbon budgets based on the IPCC SR15 report. Original figure from Robbie Andrews. Chart by Carbon Brief using Highcharts.

Integrated Roadmap Layers



Strategy and Planning Tiers



Roadmap for Sustainability for Best

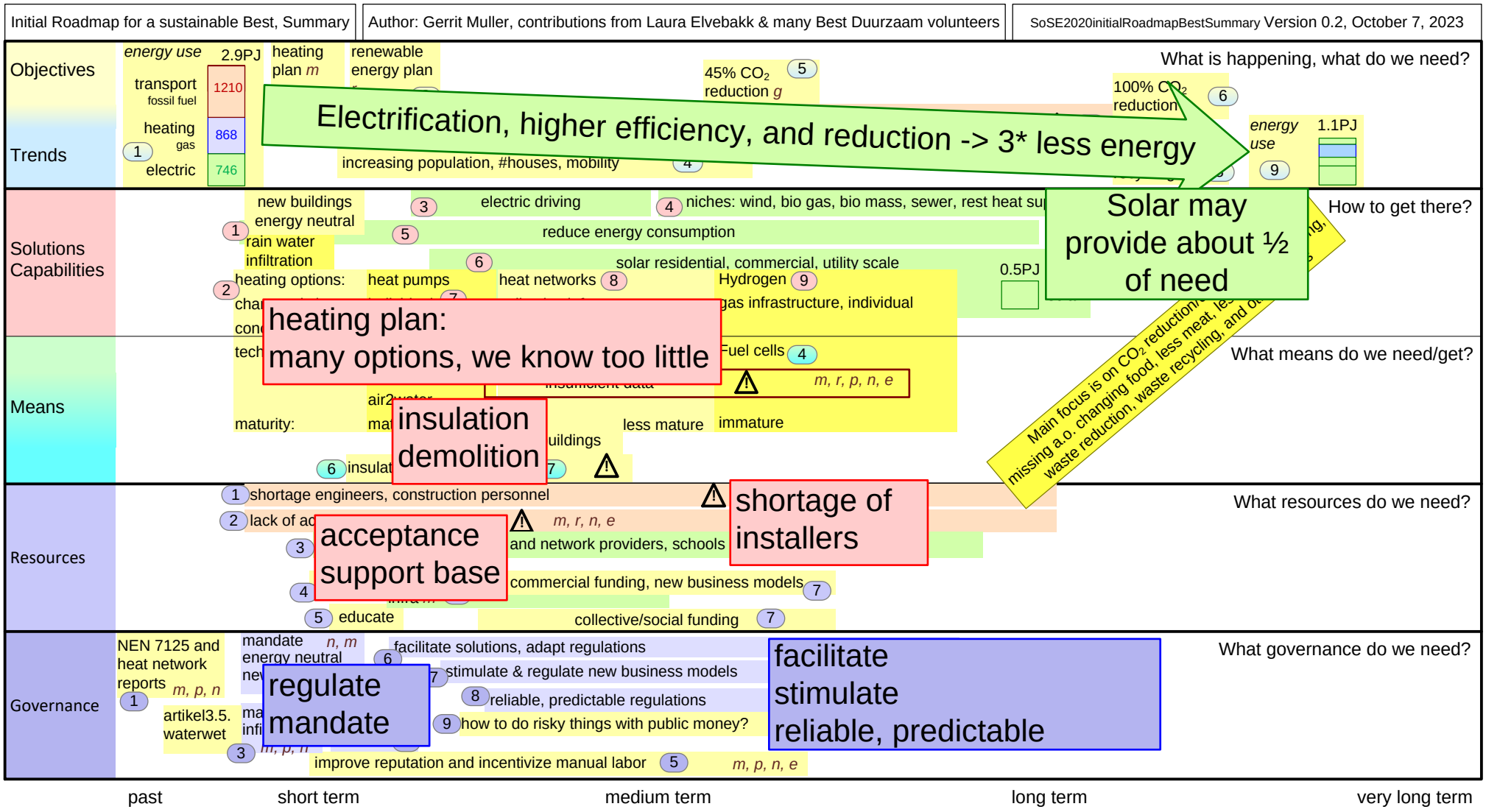
Laura Elvebakk

30K inhabitants in Best

Cooperation Best Duurzaam

- Local initiative
- Promote Sustainability
- 360 members and 40 active volunteers
- Consultant and mediator role

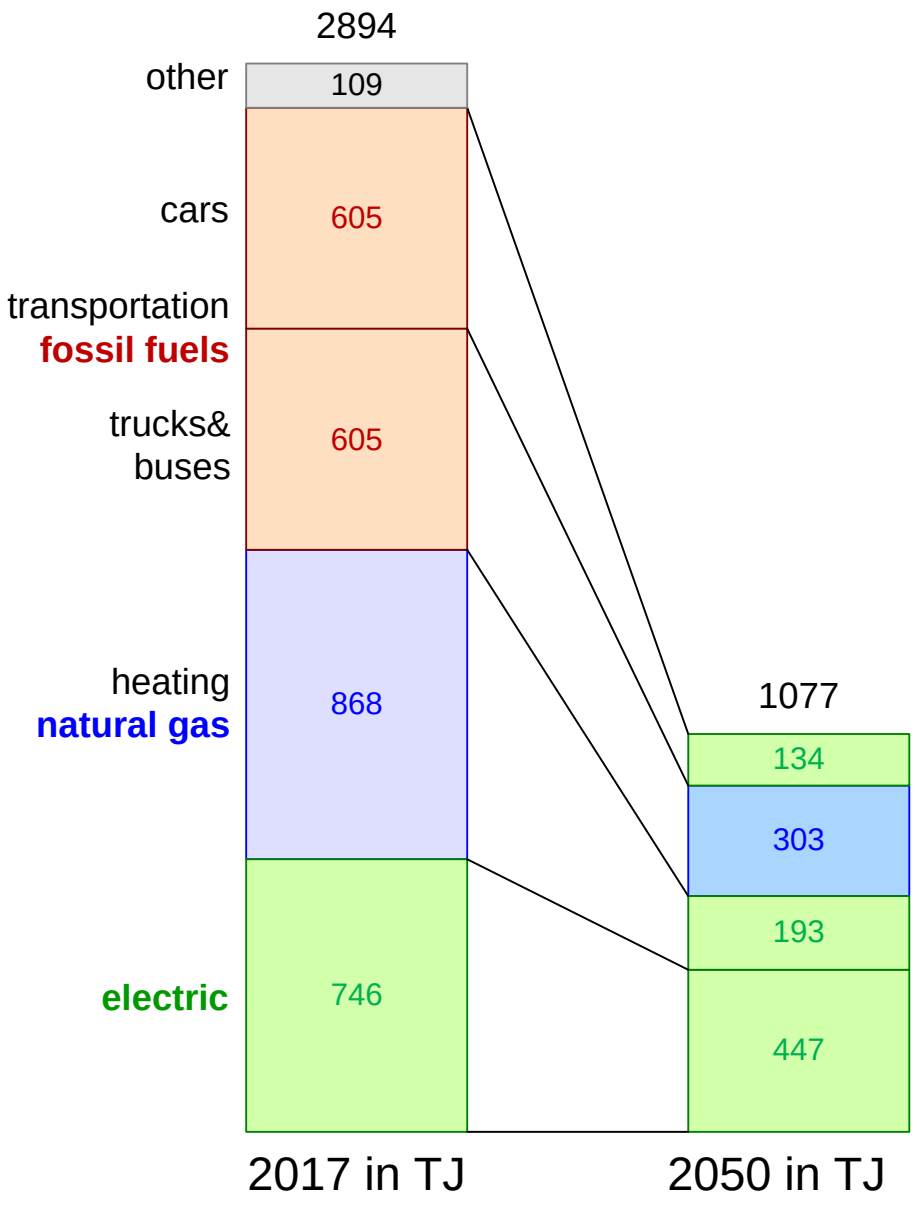
Summary of Roadmap for Best



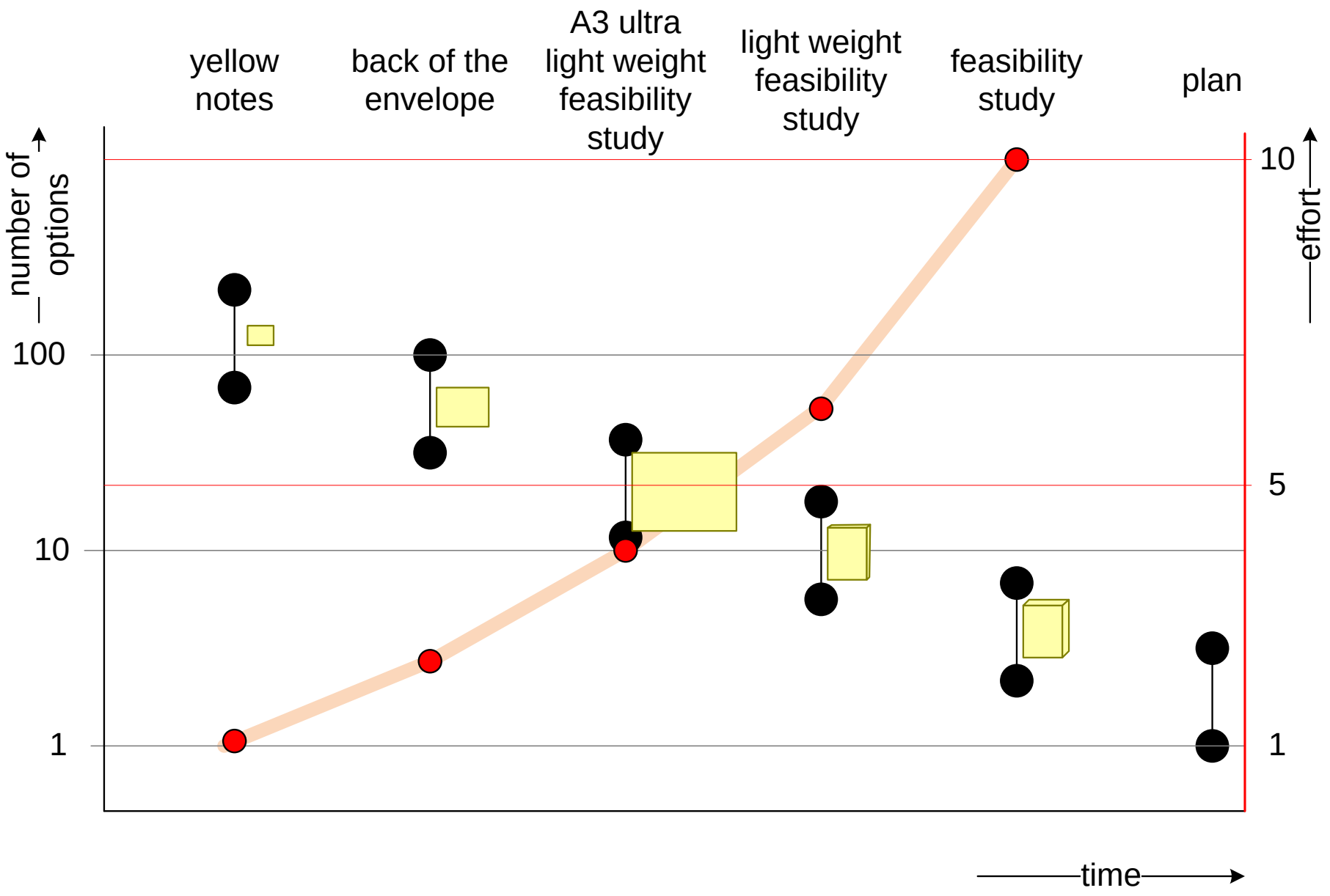
Energy Consumption: Reduction and Electrification

Best Energy use https://klimaatmonitor.databank.nl/dashboard/Dashboard/Energiegebruik/Totaal-bekend-energiegebruik--41/

	fossil fuels	gas	electric	*2017 TJ/yr*
Buildings				
residential		566	141	702
commercial		130	328	427
public		45	38	82
total buildings		**739**	**507**	**1247**
Traffic				
on roads	1146			1146
mobile equipment	49			49
ships	4			4
rail (diesel only)	11			11
total traffic	**1210**			**1210**
Industry and construction				
industry		103	211	312
construction		9	5	14
total industry & construction		**112**	**217**	**329**
Agriculture		**16**	**22**	**38**
Renewable energy				**68**
Other				**41**
	1210	**868**	**746**	**2894**



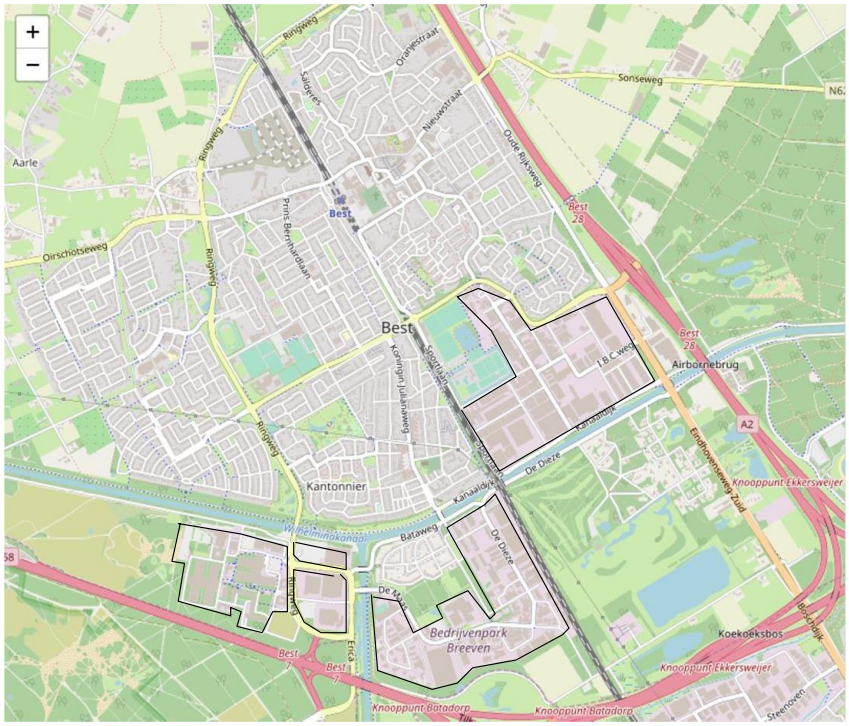
Funnel from Ideas to Decisions



Solar options Commercial, Residential, and Countryside

Best Duurzaam Solar Opportunities	Author: Gerrit Muller, contributions from many Best Duurzaam volunteers	BDRA3solarOpportunities Version 0.1, September 29, 2019

Solar PV commercial and residential areas

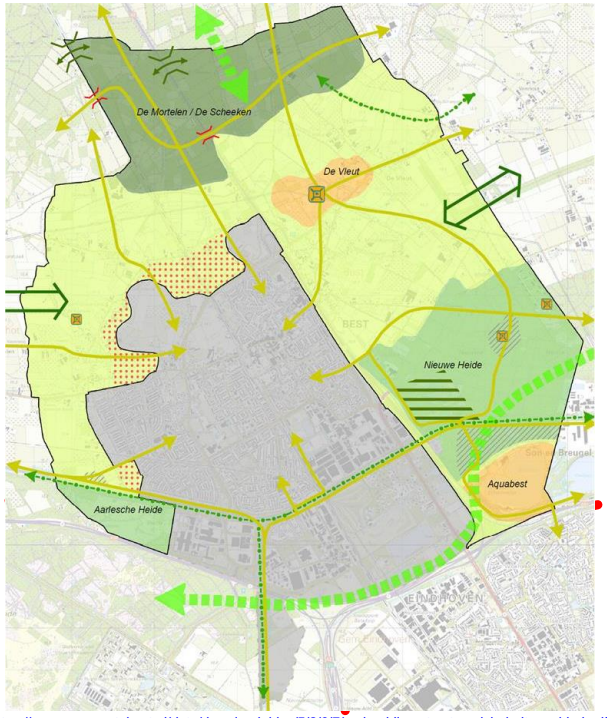


Commercial ca 1.5 km^2			
building area			25%
parking area			10%
used for solar			50%
km^2	MW$_{peak}$	GWh	TJ
0.26	52	43	155

Residential ca 6 km^2			
building area			15%
used for solar			50%
km^2	MW$_{peak}$	GWh	TJ
0.45	90	74	267

alternatively (Reinier ten Kate)
12500 houses, 20 m^2/house 0.25 km^2

Solar PV utility scale and country side



https://www.gemeentebest.nl/data/downloadables/5/8/6/7/verbeelding-structuurvisie-buitengebied.pdf

Utility scale			
Best has about 10km motor way			
assume that 200 m at both sides is a good option for utility scale solar.			
assume that only 2.5% is usable			
km^2	MW$_{peak}$	GWh/yr	TJ/yr
0.1	20	16.5	59

Country side			
Rough count of larger sheds and stables			50
roof area per building			250 m^2
assume that 50% is usable			
km^2	MW$_{peak}$	GWh/yr	TJ/yr
0.006	1.3	1.0	4

input data	
W$_{peak}$	0,2 kW/m^2
W$_{peak}$ to kWh/yr	0.825

all numbers are coarse estimates and need validation and refinement

Total potential solar PV TJ/yr	
Commercial	155
Residential	267
Utility scale	59
Country side	4
Total	486

Much More than Technical

Political

Economic

Social

Technical

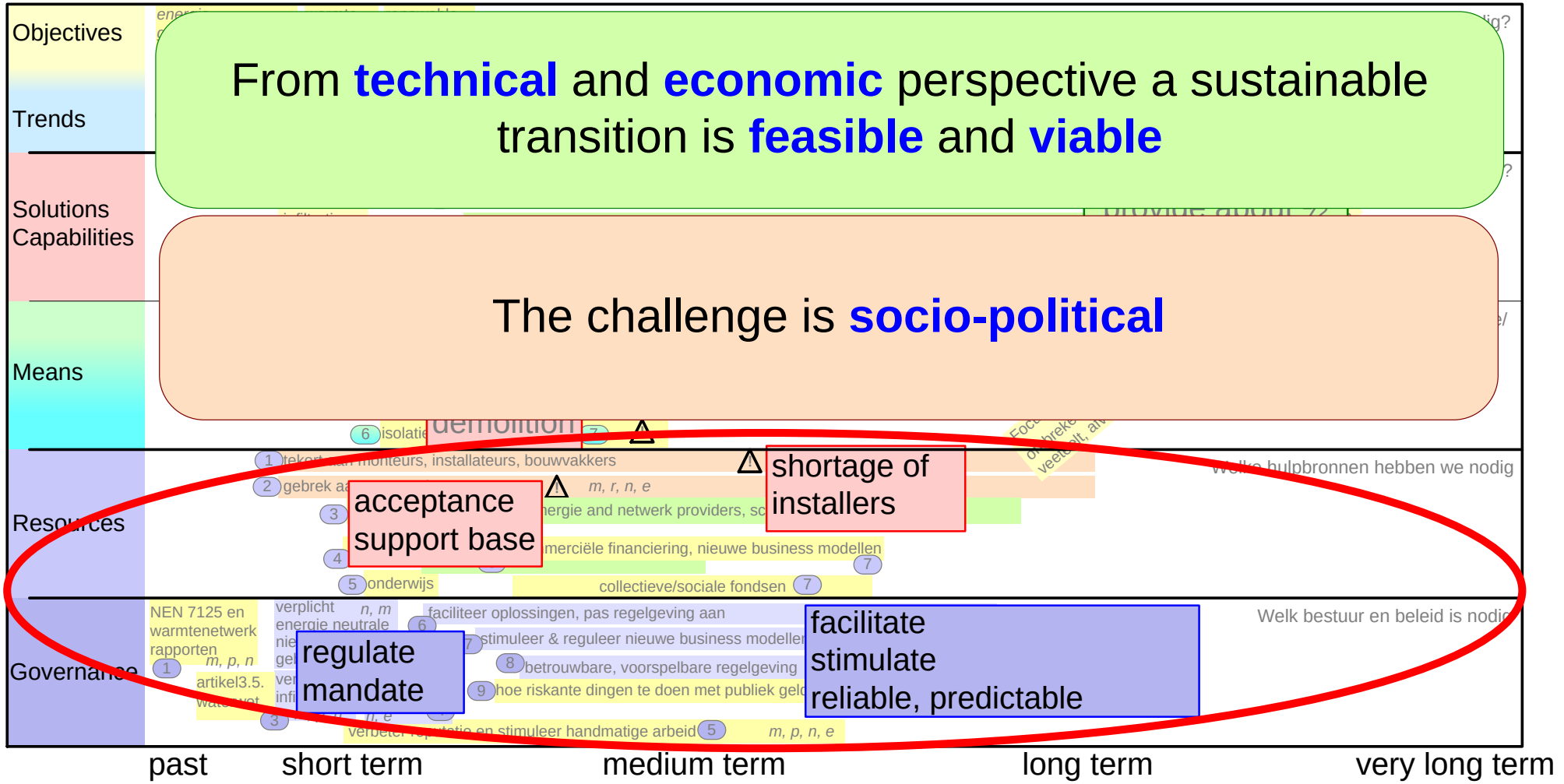
Environmental

Legal

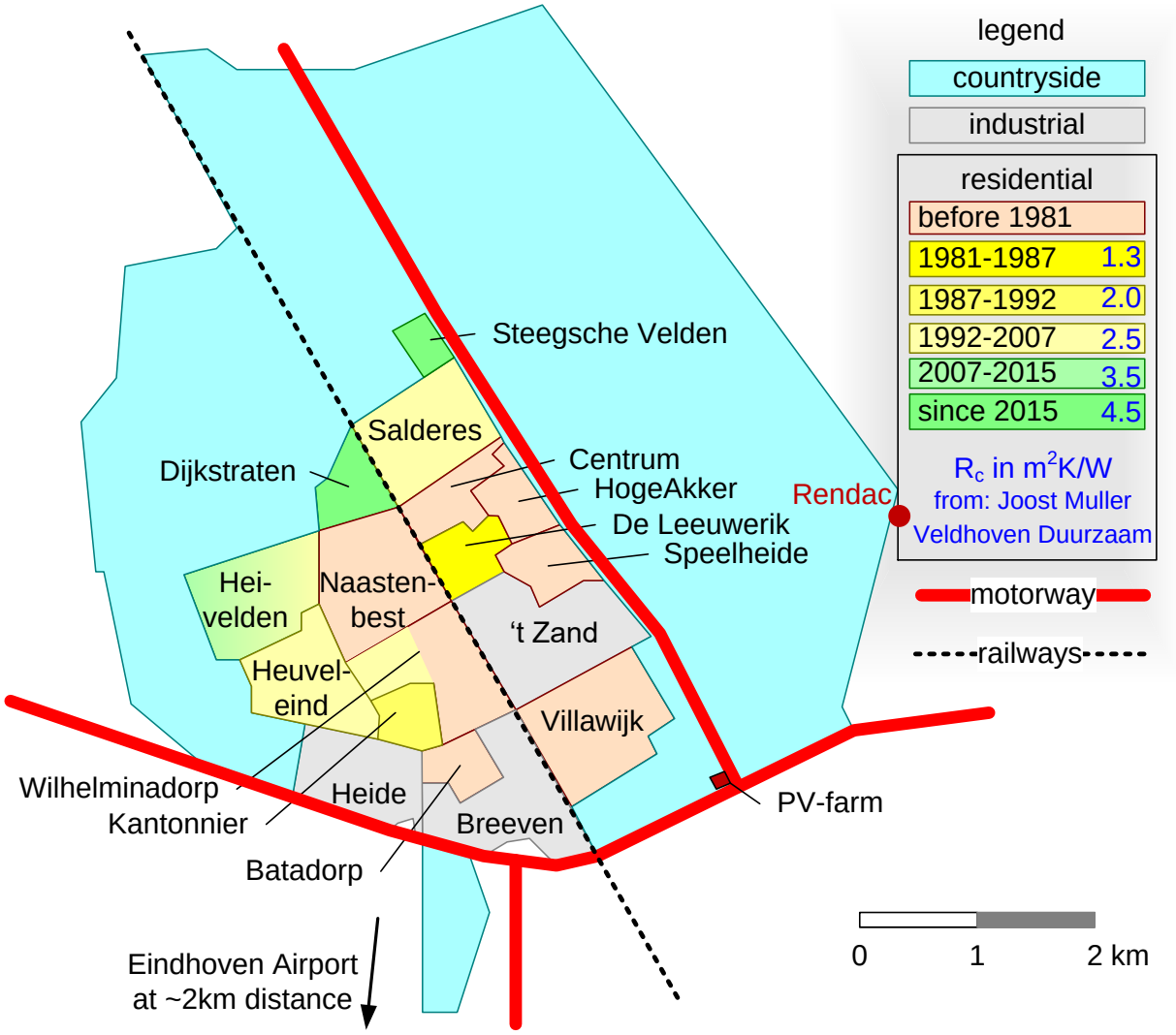
Political	Economic	Social
	• CAPEX • OPEX • time to deployment • life time • risks • viable business model	• affordable for all • participation by all • disruption of deployment • side effects (e.g.noise)

Technical	Environmental	Legal
• readiness level • complexity • competence level • effectiveness/ performance • robustness	• foot print • impact on flora and fauna	• fits in current legislation

(Jumping to) a Conclusion



Neighborhoods in Best



Example Back of the Envelope Estimate

cost/house	cost in k€ incl. install incl VAT
16kW heat pump	18
insulation	4
PV system with 16 solar panels, 5.4kWp	7
miscellaneous	1
total	30

heat pump in&out	11
mounting material	1
installation	6
total	18

16 panels 340kWp	3.7
optimizers	0.7
inverter	1.0
mounting material	1.0
installation	1.0
total	7.4
excl VAT	

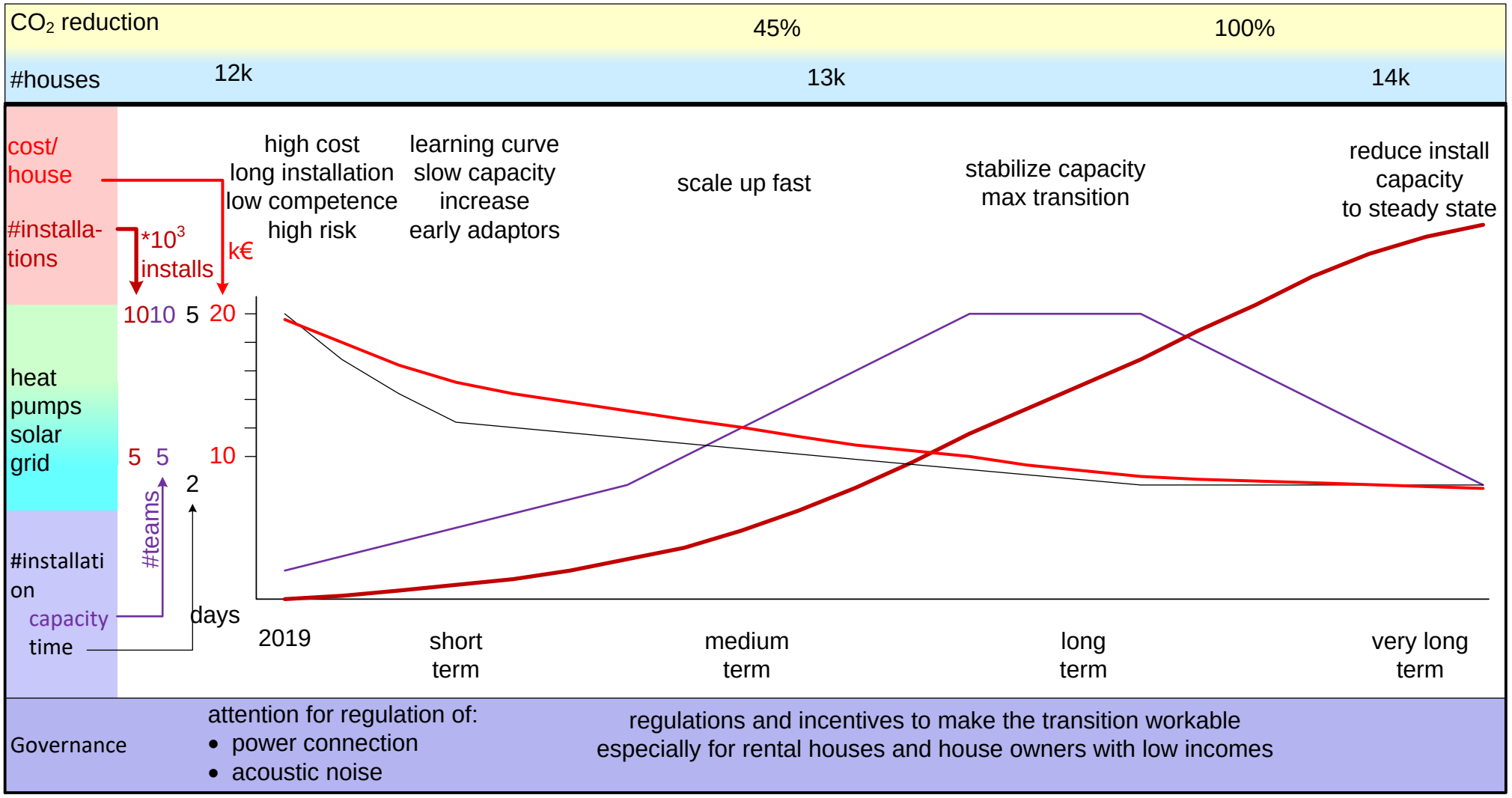
cost for all houses in Best

12k houses
30 k€/house
360 M€

assumptions:
prices 2018
effort 2018
VAT return on solar
no infrastructure cost

this is a very coarse estimate, e.g. +/- 50%

Example Heating Scenario



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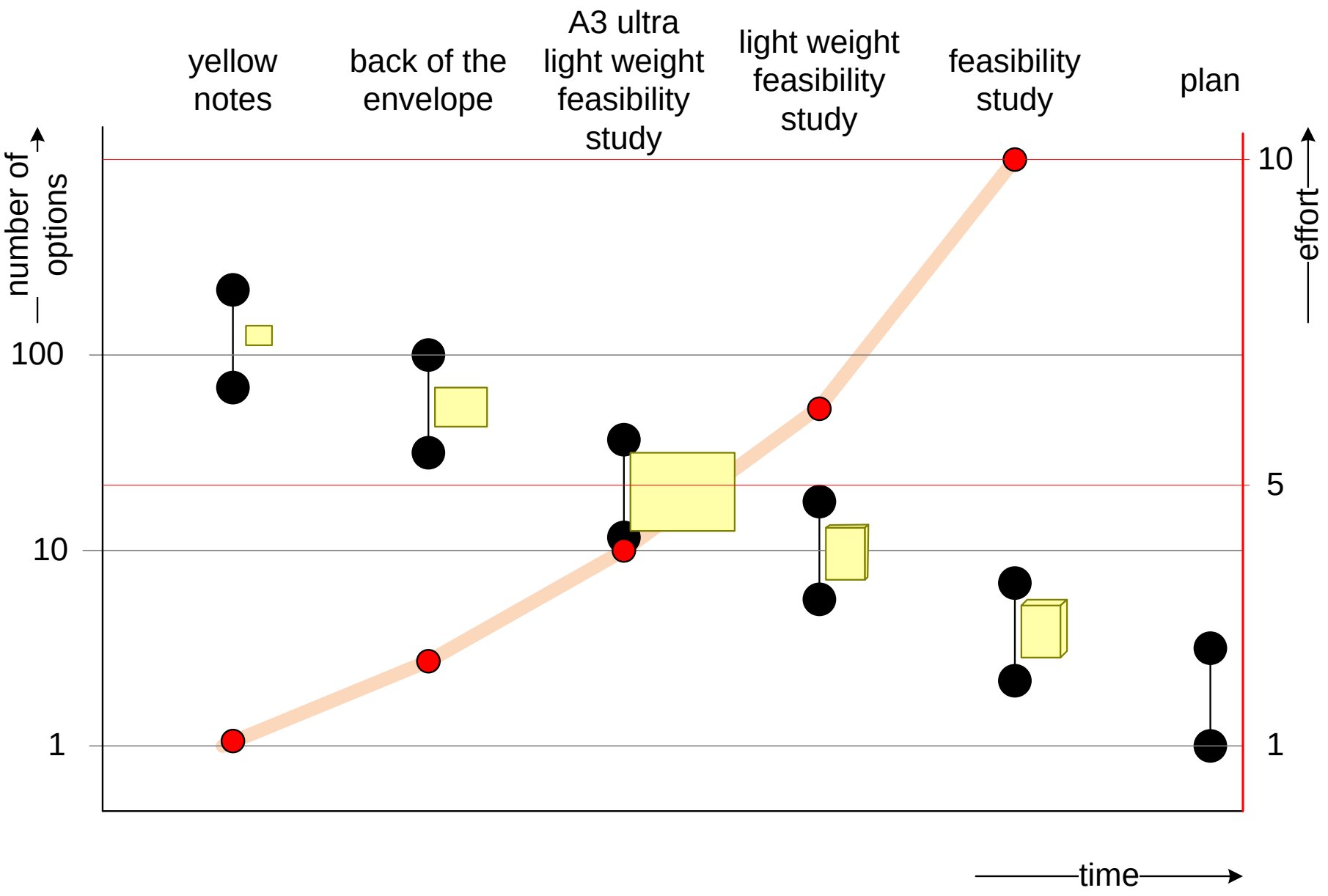
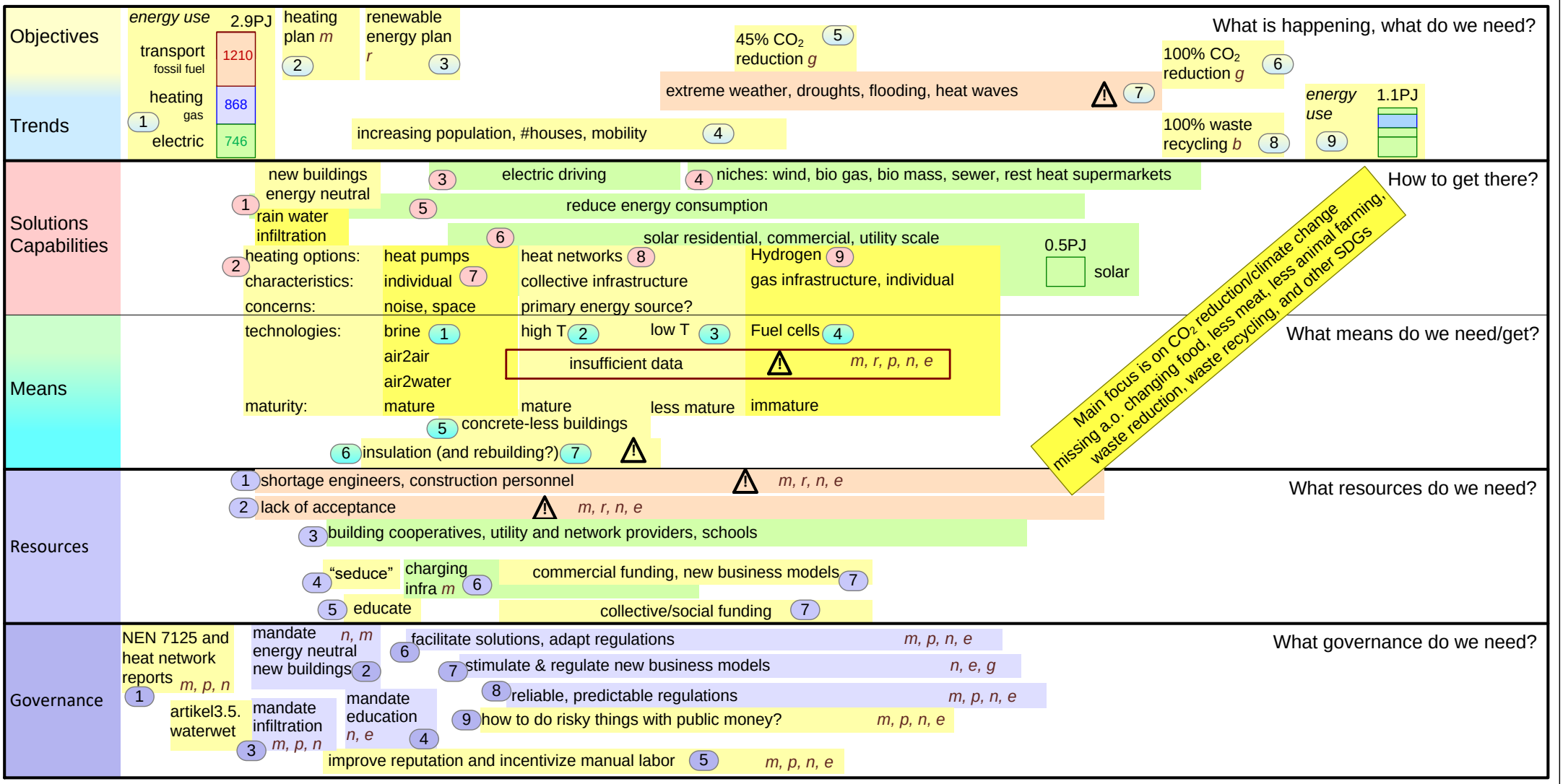


Initial Roadmap for a sustainable Best	Author: Gerrit Muller, contributions from Laura Elvebakk & many Best Duurzaam volunteers	BDRA3initialRoadmapBest Version 0.7, May 8, 2019



1 energy use 2017
2 mandatory 2020 heating plan per neighborhood
3 mandatory 2021 regional
4 small increase per year
5 IPCC 2018
6 IPCC 2018
7 may increase energy use
8
9 energy use after full electrification and some reduction

1 make all new developments sustainable
2 selection of options for heating plan
3 transport is major CO_2 producer
4 niche solutions in Best
5 reducing energy consumption is must
6 all forms of solar may result in 0.5 PJ/yr
7 mature; noise, space is concern
8 few rest heat sources; large collective infrastructure investment
9 long-term option; re-use gas infra

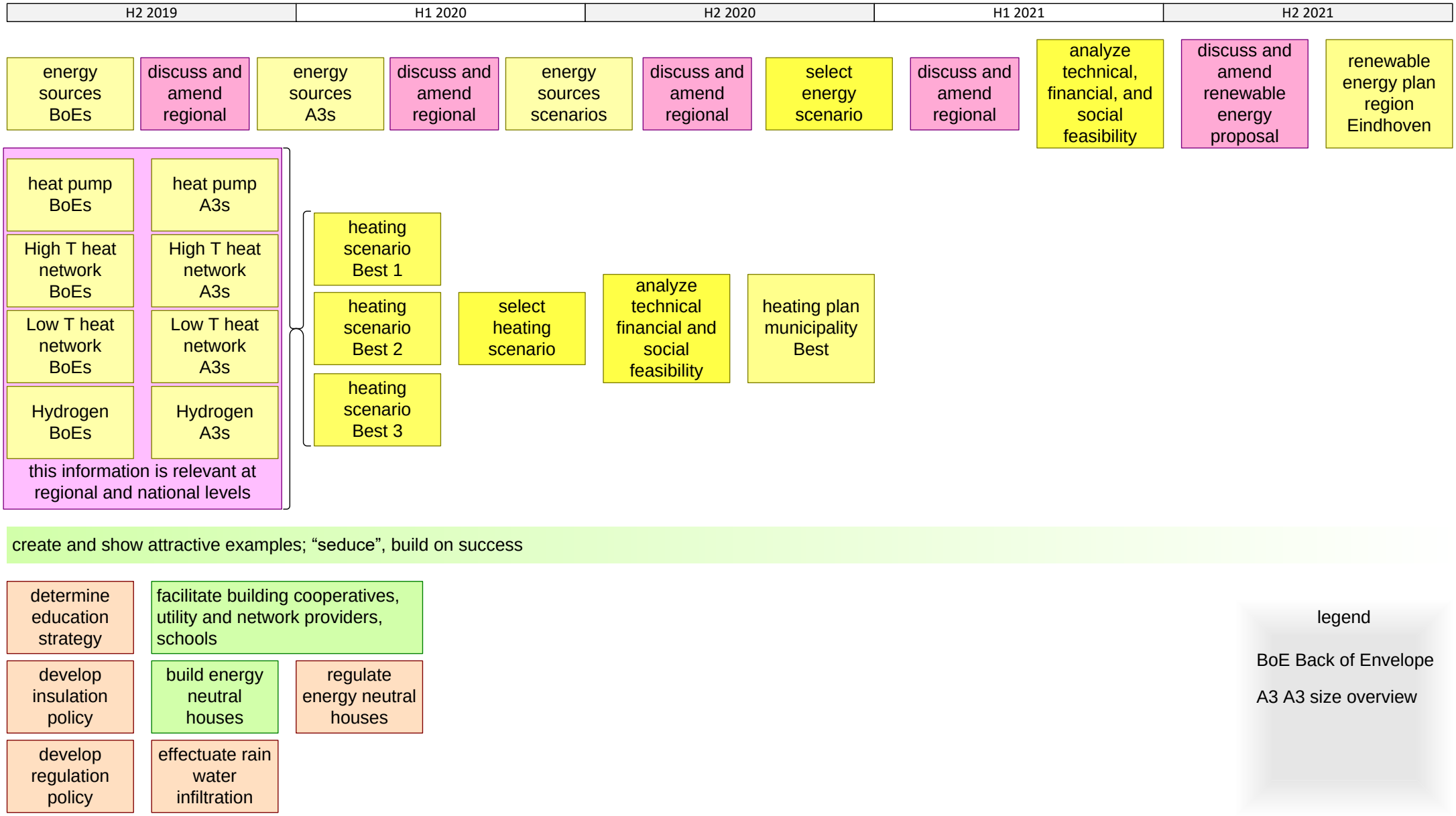
1 air2air for heating is efficient; how to get tap water?
2 compatible with older houses; challenge data is not public due to commercial interests
3 efficient allows re-use of any rest heat; storage is the big challenge
4 source to use little efficient; solves seasonal storage; production infrastructure expensive
5 concrete is major CO_2 producer
6 insulation is first step; external insulation needed?
7 when is rebuilding better (justified and acceptable)

1 action plan to attract and educate
2 involve, engage, seduce, incentivize
3 roadmap and master plan to coordinate
4 more effective than enforcement
5 primary, secondary schools; avoid overload
6 enable electric driving
7 be creative to get economy and funding working

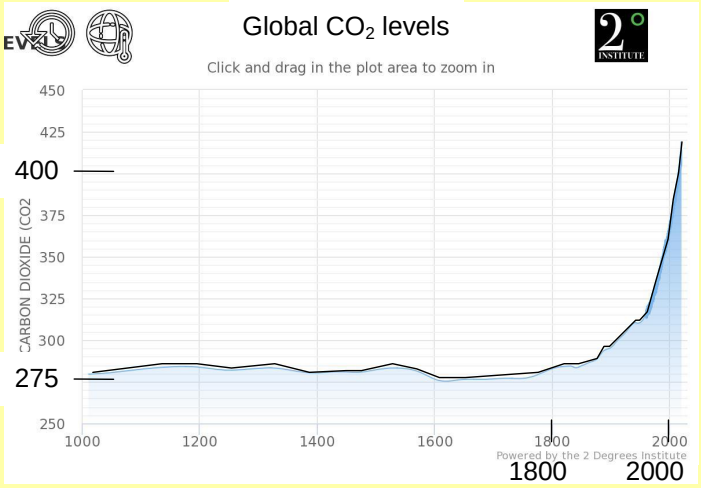
1 7125 and reports overrate sustainability of bio mass and rest heat sources; lack absolute data
2 ASAP! waiting increases problem
3 vng.nl/3-gemeentelijke-watertaken; should be standard operation when maintaining streets
4 how to do this effectively?
5 culturally ingrained
6 agile (fast response) governance
7 facilitate and regulate
8 past pitfall; blocks investments
9 major dilemma for 6, 7, and 8

legend
b Best Duurzaam
m municipality
r regional
p province
n national
e Europe
g global

Initial Master Plan Sustainable Best	Author: Gerrit Muller, contributions from many Best Duurzaam volunteers	BDRA3masterPlan Version 0, April 23, 2019



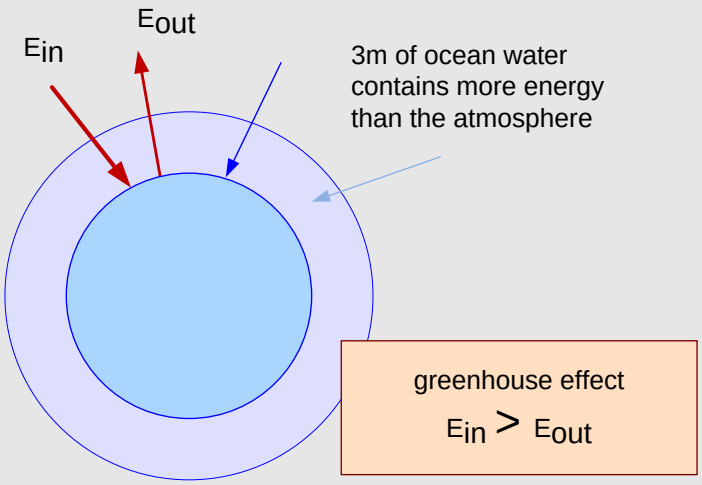
1 *CO2 ppm*



CO2levels.org

CO_2 levels started to increase with the industrial revolution
The rate of change is very high on cosmic time scale

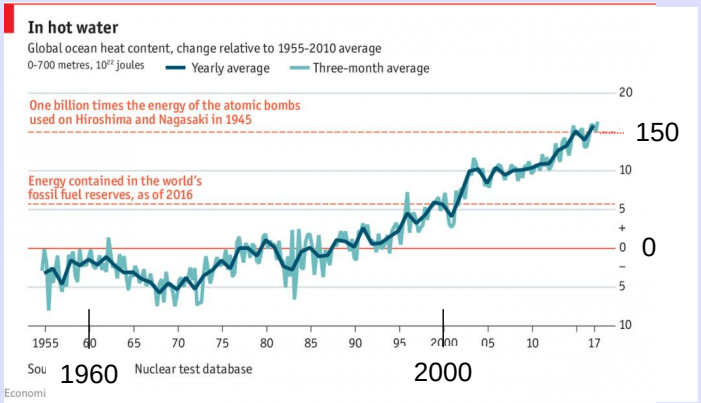
2 *physics/nature of earth*



High CO_2 levels cause the greenhouse effect. Earth warms up because more energy from the sun comes in then the amount of energy that can escape the atmosphere

3 *Global Ocean Heat Content **Change***

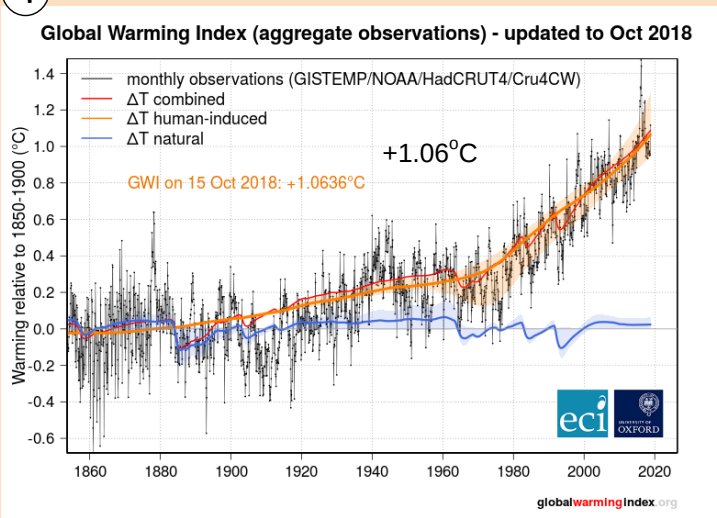
in 10^{21} Joules (=10^6 PJ; NL uses 3 PJ/yr))



sources; NOAA; BP, Nuclear test database
https://www.economist.com/graphic-detail/2018/03/12/the-temperature-of-the-ocean-is-rising

The oceans act as buffer for accumulating energy surplus. The amount of energy that oceans absorbed in past decades is huge

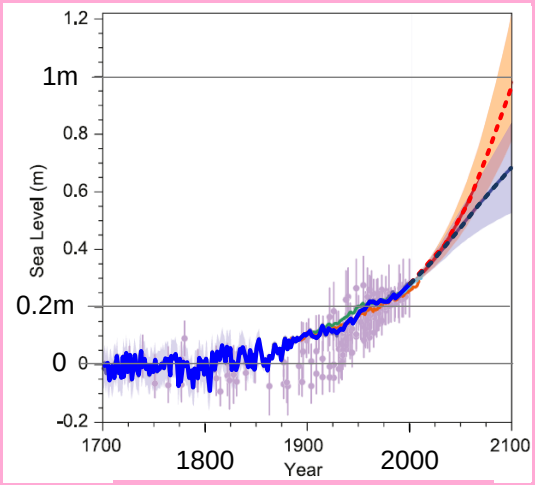
4 *temperature on earth*



globalwarmingindex.org

The average temperature on earth has been rising. This rise has accelerated since the 1960s. Local temperature changes vary a lot. The arctic areas have warmed much more

5 *sea water level*

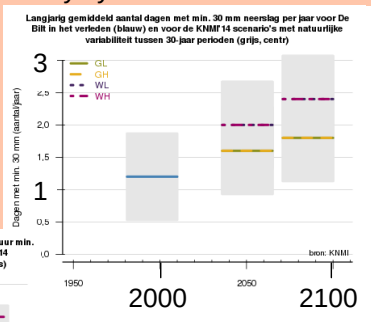


5th IPCC report via realclimate.org

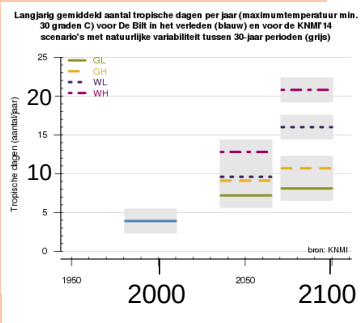
Combination of smelting land ice and increasing see water temperature will increase see water level. In a few centuries this increase can be tens of meters

6 *extreme weather*

#days/year with >30mm rain



#days/year with T>30°C



klimaatscenarios.nl

Oceans affect the local climates to a large degree. We can expect more extreme weather, e.g. droughts & tropical rain

Best Duurzaam Background data energy consumption	Author: Gerrit Muller, contributions from many Best Duurzaam volunteers	BDRA3backgroundData. Version 0.1, May 8, 2020

Best Energy use https://klimaatmonitor.databank.nl/dashboard/Dashboard/Energiegebruik/Totaal-bekend-energiegebruik--41/

	fossil fuels	gas	electric	*2017 TJ/yr*
Buildings				
residential		566	141	702
commercial		130	328	427
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total buildings		**739**	**507**	**1247**
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Renewable energy				**68**
Other				**41**
	1210	**868**	**746**	**2894**

fossil fuels **1210** | gas **868** | electric **746**

Best estimate of energy need

transportation

efficiency gains
- cars (electric) 3[1]
- trucks&buses (hydrogen) 2[2]

assuming cars become electric, heavy transport becomes Hydrogen

ratio car/trucks&buses: rough estimate 50/50

assuming energy reduction (lower speed, lighter and smaller vehicles)
- electric 30%

0.5 * 1210 / 3 * 0.67 + 0.5 * 1210 / 2 = 437

heating/gas

efficiency gain using heat pumps 3

reduce consumption by improving insulation 30%

868/3 * 0.67 = 193

electricity

efficiency gain using modern equipment 1.5

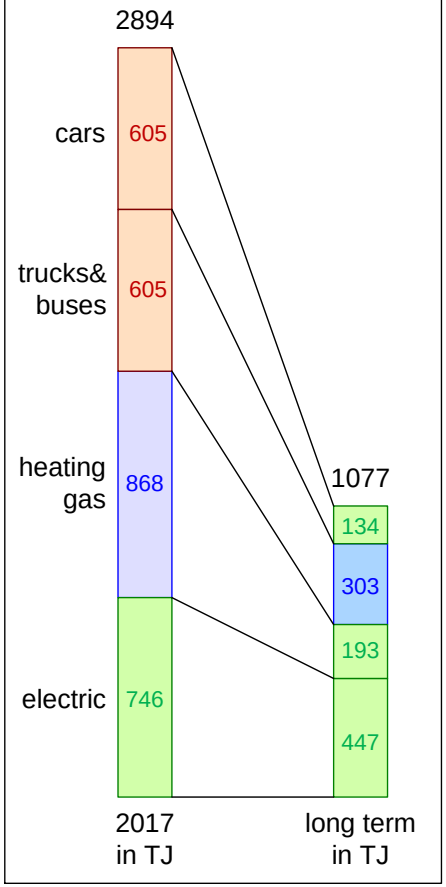
reduce consumption 10%

746 / 1.5 * 0.9 = 447

energy need after transition and full reduction 1077 TJ/yr

[1] https://www.fueleconomy.gov/feg/evtech.shtml
efficiency gasoline (excluding well to pump) ~19%, electric ~58%, H_2 ~45%
[2] https://www.deingenieur.nl/artikel/hydrogen-car-wins-over-electric-car

energy transition

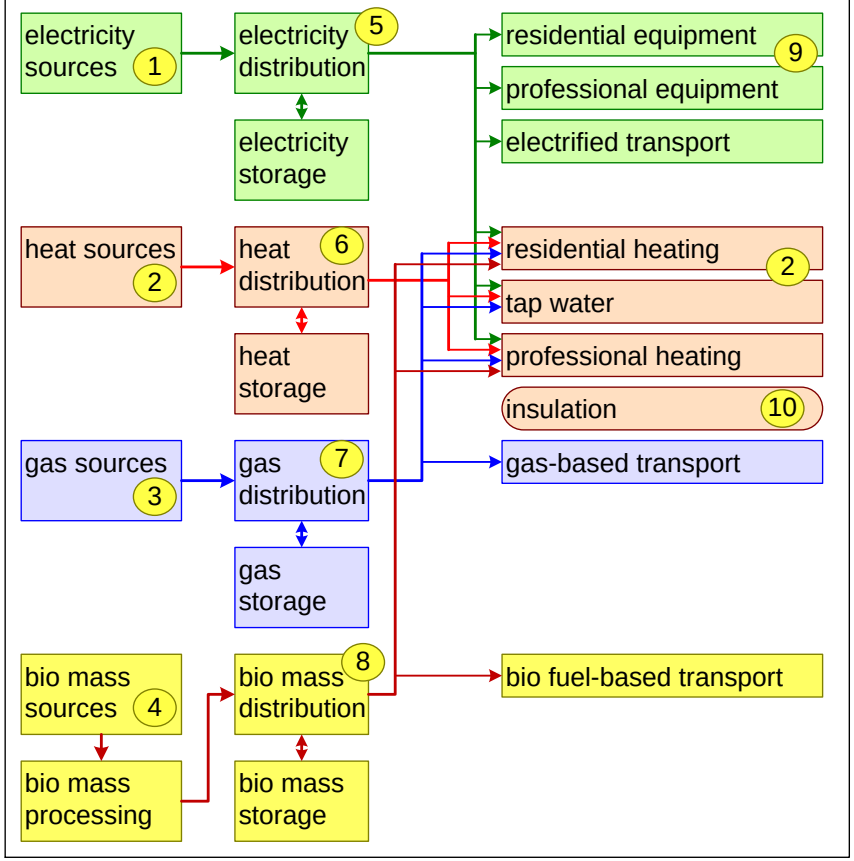


Best Duurzaam Roadmap Options

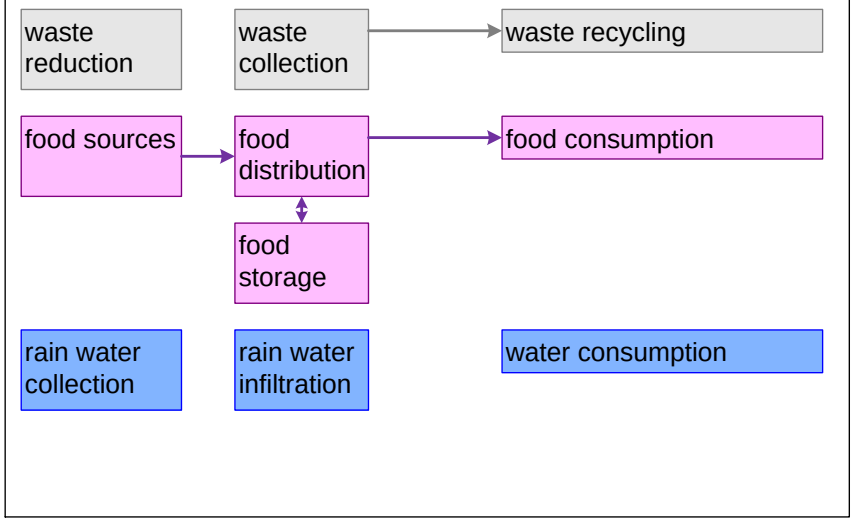
Author: Gerrit Muller, contributions from many Best Duurzaam volunteers

BDRA3roadmapOptions Version 0, March 24, 2019

Energy functions and options



Other sustainability functions and options



electricity sources 1

- solar PV panels
  - residential
  - cooperative
  - utility scale
- wind
  - small turbines
  - large turbines

heat sources, heating 2

- industrial rest heat
  - Rendac
- heat pumps
  - air to air
  - air to water
  - water to water
- Geo Thermal
- Co-generation
  - fuel cells
  - gas generator

gas sources 3

- hydrocarbons (biogas)
  - garden waste
  - agriculture waste
  - farm manure
  - sewer
- Hydrogen
  - local production
  - large scale production

bio mass sources 4

electricity distribution 5

- behind the meter
  - residential
  - professional
- local network Enexis
- HV network Tennet

heat distribution 6

- high temperature heat network
  - Source to Best
  - to consumers
- low temperature heat network

gas distribution 7

- existing infrastructure Enexis
- feed-in for new sources

bio mass distribution 8

electricity consumption 9

- reduction
- car charging
  - residential
  - public
  - high speed

insulation 10

- internal
- external wrapping
- demolishing and rebuilding

Best Duurzaam Concept Assessment	Author: Gerrit Muller, contributions from many Best Duurzaam volunteers	BDRA3conceptAssessment Version 0, March 24, 2019

Assessment Criteria

PESTEL

- Political
- Economic
- Social
- Technical
- Environmental
- Legal

Political

Economic

- CAPEX
- OPEX
- time to deployment
- life time
- risks
- viable business model

Social

- affordable for all
- participation by all
- disruption of deployment
- side effects (e.g.noise)

Technical

- readiness level
- complexity
- competence level
- effectiveness/ performance
- robustness

Environmental

- foot print
- impact on flora and fauna

Legal

- fits in current legislation

Concepts that need assessment

- solar PV panels
- wind
- industrial rest heat
- heat pumps
- Geo Thermal
- high T heat network
- low T heat network
- internal insulation
- external wrapping
- demolishing and rebuilding
- hydrocarbons (biogas)
- Hydrogen
- bio mass

Best Duurzaam Back of the Envelope estimates | Author: Gerrit Muller, contributions from many Best Duurzaam volunteers | BDRA3backOfTheEnvelope Version 0.1, May 12, 2019

Heat Pump

cost per house — in k€ incl. install incl VAT

heat pump in&out	11
mounting material	1
installation	6
16kW heat pump	18k€

average gas consumption per house in Best
1430 m^3/yr
~13 MWh/yr

electricity consumption to replace gas
(SCOP 3)
~4.3 MWh/yr

advantages:
- energy efficiency
- independent of other houses

disadvantages:
- installation effort
- initial cost
- acoustic noise
- space for equipment

High T heat network

advantages:
- compatible with old houses
- low cost/house
- low space use

disadvantages:
- costly infrastructure
- limited individual control
- efficiency?

Low T heat network

advantages:
- compatible with old houses?
- individual control
- energy efficient

disadvantages:
- costly infrastructure
- immature
- cost/house
- space for equipment

GeoThermie

1 doublet, 2km depth, 300 m3/hr salt water of 80^{0}C up 20^{0}C down
construction costs 15 a 20 M€
plus construction heat network

heat production:
300 * 10^6 g/h * 60 ^{0}C * 4.2 J/g/^{0}C
~=80 GJ/hr ~= 24*365*80 GJ/yr
~= 700 TJ/yr

unknowns
energy consumption of pumps
OPEX
environmental impacts

advantages:
- compatible with old houses

disadvantages:
- costly infrastructure
- immature
- corrosion

https://www.nrc.nl/nieuws/2019/06/14/een-waterput-om-je-huis-te-verwarmen-a3963783

residential Solar PV system

cost per house — in k€ excl VAT incl. install

16 panels 340kWp	3.7
optimizers	0.7
inverter	1.0
mounting material	1.0
installation	1.0
PV system with 16 solar panels, 5.4kWp	7k€

electricity production ~4.5 MWh/yr

~26 m^2 roof space
yearly energy production solar:
173 kWh/m^2/yr

Hydrogen

advantages:
- compatible with gas infrastructure
- individual control
- seasonal storage

disadvantages:
- very immature
- cost/house
- space for equipment

Bio mass

energy density (dry) wood: 5.3 kWh/Kg
https://nl.wikipedia.org/wiki/Energiedichtheid

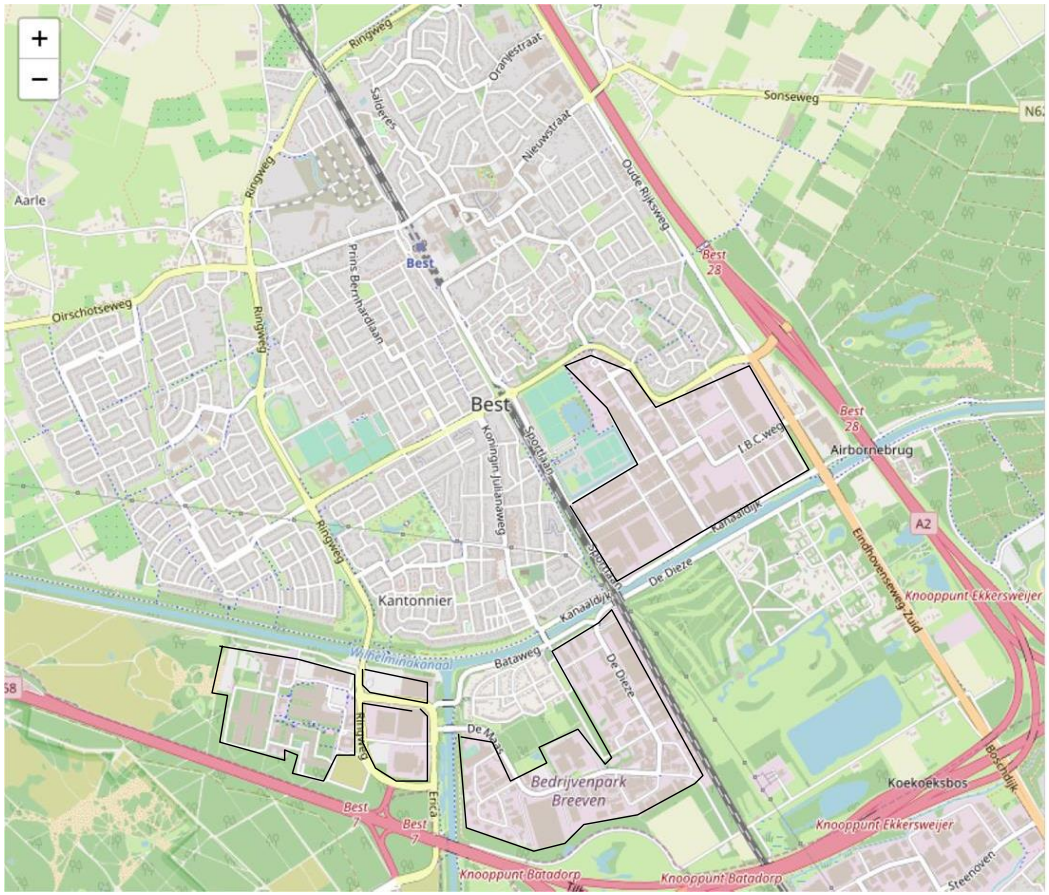
wood production 1.1 to 1.5 Kg/m^2/yr
https://www.agriholland.nl/dossiers/biobrandstoffen/agrarischesector.html#hout

yearly energy production wood:

~7 kWh/m^2 (4% of solar)

Best Duurzaam Solar Opportunities	Author: Gerrit Muller, contributions from many Best Duurzaam volunteers	BDRA3solarOpportunities Version 0.1, September 29, 2019

Solar PV commercial and residential areas



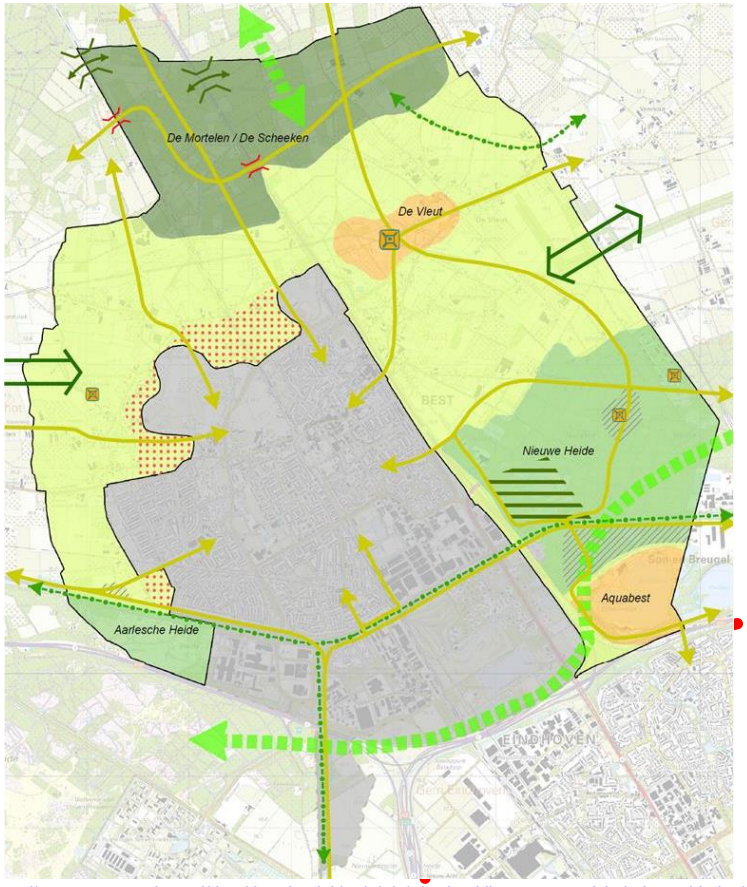
Commercial ca 1.5 km^2			
building area			25%
parking area			10%
used for solar			50%
km^2	MW$_{peak}$	GWh	TJ
0.26	52	43	155

Residential ca 6 km^2			
building area			15%
used for solar			50%
km^2	MW$_{peak}$	GWh	TJ
0.45	90	74	267

alternatively (Reinier ten Kate)
12500 houses, 20 m^2/house 0.25 km^2

input data	
W$_{peak}$	0,2 kW/m^2
W$_{peak}$ to kWh/yr	0.825

Solar PV utility scale and country side



https://www.gemeentebest.nl/data/downloadables/5/8/6/7/verbeelding-structuurvisie-buitengebied.pdf

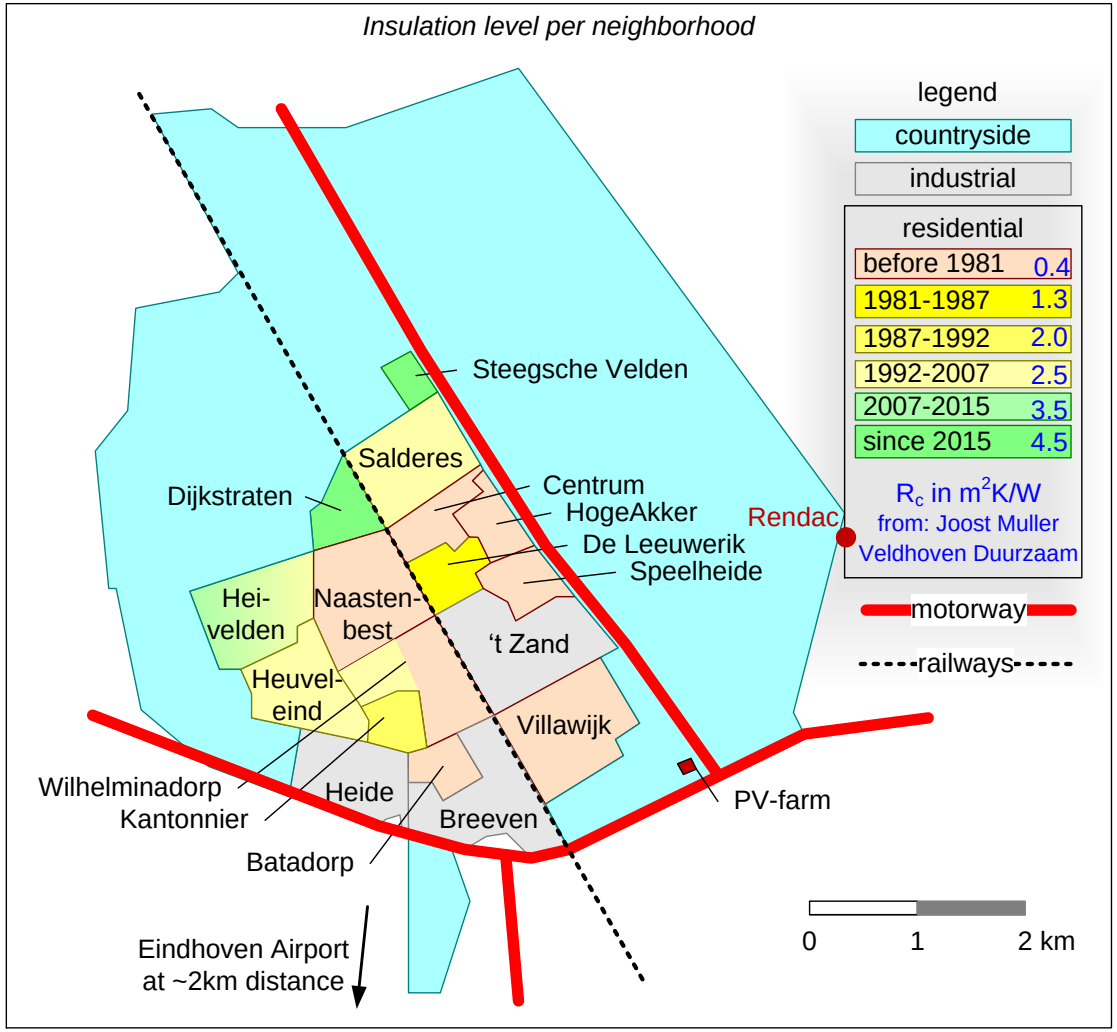
Utility scale			
Best has about 10km motor way			
assume that 200 m at both sides is a good option for utility scale solar.			
assume that only 2.5% is usable			
km^2	MW$_{peak}$	GWh/yr	TJ/yr
0.1	20	16.5	59

Country side			
Rough count of larger sheds and stables			50
roof area per building			250 m^2
assume that 50% is usable			
km^2	MW$_{peak}$	GWh/yr	TJ/yr
0.006	1.3	1.0	4

all numbers are coarse estimates and need validation and refinement

Total potential solar PV TJ/yr	
Commercial	155
Residential	267
Utility scale	59
Country side	4
Total	486

Best Duurzaam Insulation	Author: Gerrit Muller, contributions from many Best Duurzaam volunteers	BDRA3insulation Version 0, March 26, 2019

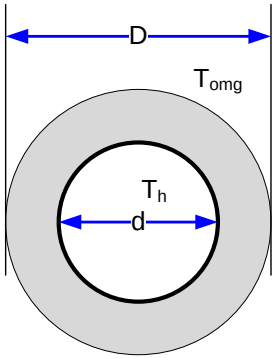


Heat Network Fundamentals	Author: Gerrit Muller, contributions from many Best Duurzaam volunteers	BDRA3heatNetworkFundamentals Version 0, April 21, 2019

heat loss in isolated pipe

$Qv = (2*\pi*\lambda*(T_h-T_{omg})) / (\ln(D/d))$

Q_v	heat loss (W/m)
λ	isolation factor (W/mK)
T_h	water temperature (°C)
T_{omg}	environmental temperature (°C)
D	pipe outside diameter with isolation (mm)
d	pipe diameter without isolation (mm)



http://www.humsterlandenergie.nl/Energiebesparingsopties/Warmteverlies%20leidingen/

example, Johan Brouwerstraat

38 houses
240 m thick pipe
114 m thin pipe
average heat loss per house:
354m/38 *(13.6+6.8) ~=
190 W/house ~=
1660 kWh/yr/house
(using input pipe of 60°C, return 35°C same length)

average gas use:
corner house 1540 m^3 gas/yr
middle house 1350 m^3 gas/yr
total 38 houses:
53960 m^3 gas/yr ~= 485 MWh/yr
12.8 MWh/yr/house
13% heat loss at street level.
www.cbs.nl data from 2017

all numbers are coarse estimates and need validation and refinement

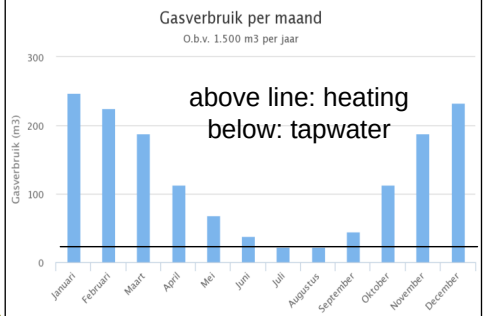
typical heat loss in isolated pipe in numbers

T_{hot} network		T_{return} network	
λ	0.03 W/mK	λ	0.03 W/mK
T_h	60°C	T_h	35°C
T_{omg}	10° C	T_{omg}	10° C
D	100 mm	D	100 mm
d	50 mm	d	50 mm
Q_v	**13.6 W/m**	Q_v	**6.8 W/m**

http://www.ekbouwadvies.nl/tabellen/lambdamaterialen.asp

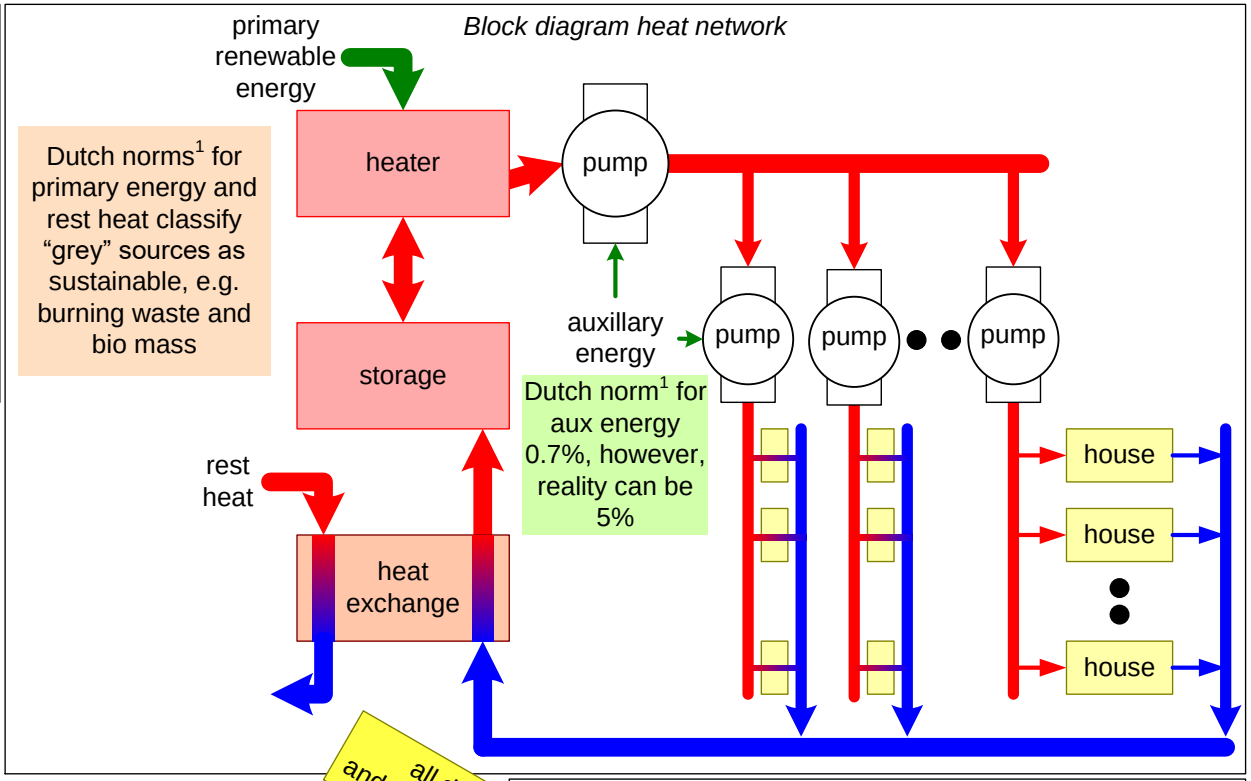
gas consumption per month

in summer time the energy loss, to heat tap water only, is 50 to 100%



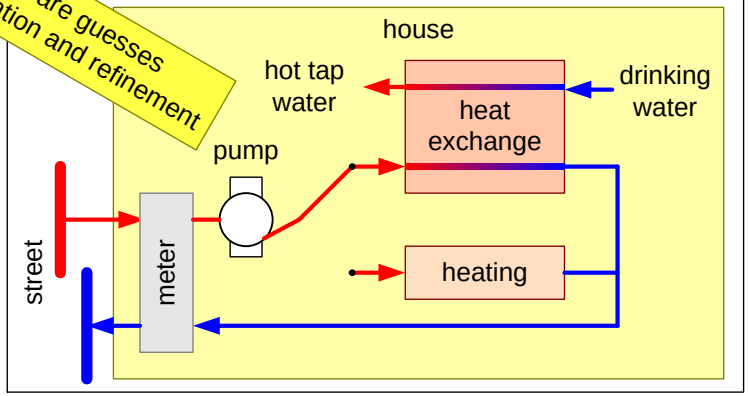
https://www.energiesite.nl/veelgestelde-vragen/wat-is-een-gemiddeld-gasverbruik/

Block diagram heat network



all diagrams are guesses and need validation and refinement

Block diagram single house



background documentation

[1]Energiemaatregelen op gebiedsniveau (EMG), NEN 7125 https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels-gebouwen/nieuwbouw/energieprestatie-epc/energiemaatregelen-op-gebiedsniveau-emg

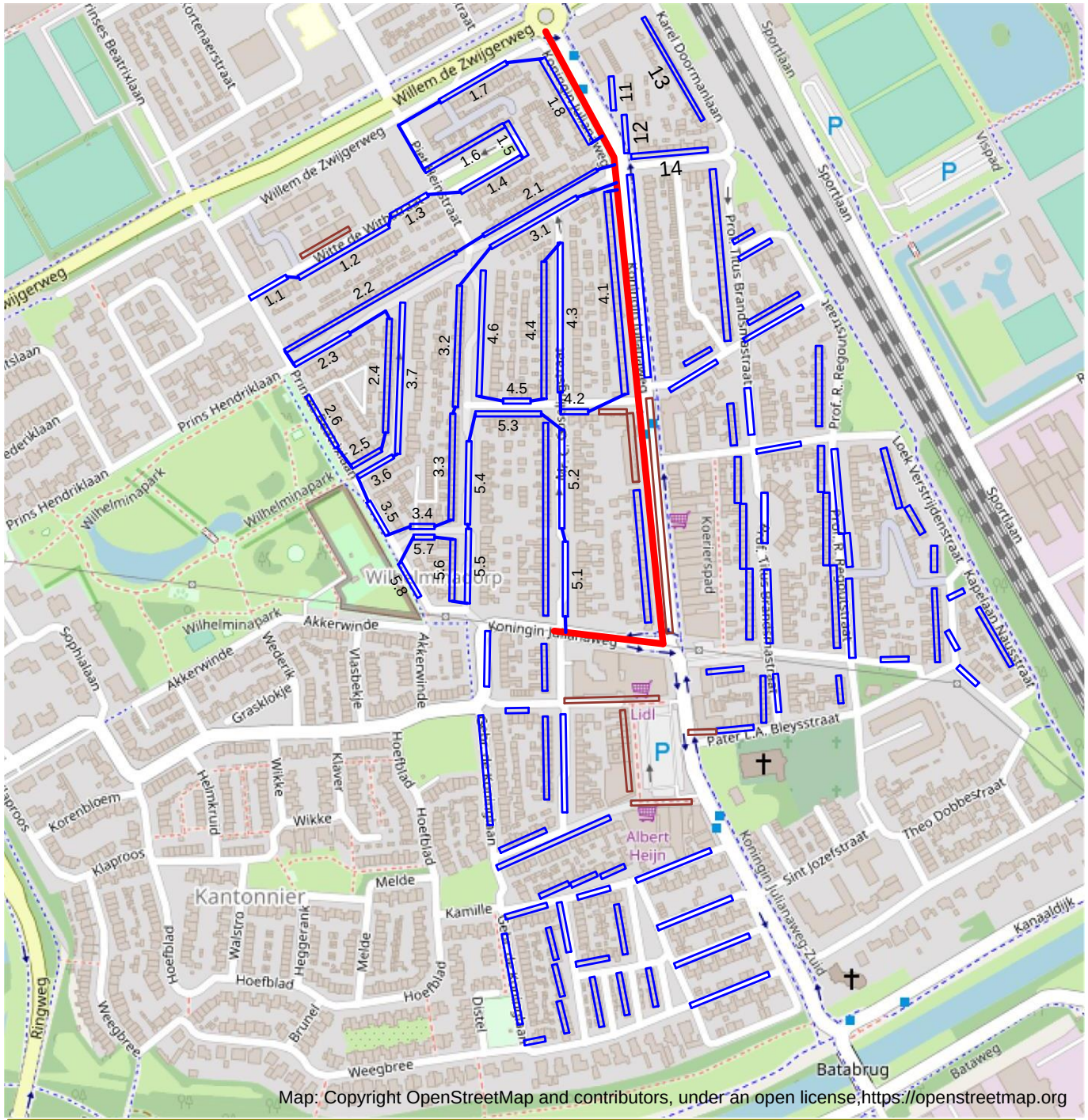
Aansluiten op warmtenetten Handreiking April 2018 https://www.ce.nl/publicaties/download/2564

Ketenemissies warmtelevering; Directe en indirecte CO2-emissies van warmtetechnieken https://www.ce.nl/publicaties/download/2069

Collectieve warmte naar lage temperatuur: Een verkenning van mogelijkheden en routes https://projecten.topsectorenergie.nl/storage/app/uploads/public/5aa/012/b89/5aa012b8926fd834673493.pdf

Heat Network Scenario Wilhelminadorp	Author: Gerrit Muller, contributions from many Best Duurzaam volunteers	BDRA3heatNetworkScenarioWilhelminadorp Version 0.1, April 28, 2019

section	total houses	total thick pipe (m)	total thin pipe (m)	energy for heating and tapwater MWh/yr	total loss/yr/ house MWh/yr	loss as percentage
1.total	48	677	249	1053	1,99	16%
2.total	38	689	258	1093	1,97	15%
3.total	40	685	249	1049	2,01	16%
4.total	31	728	276	1171	1,95	15%
5.total	35	609	255	1062	1,82	15%
total	192	3388	1287	5428		

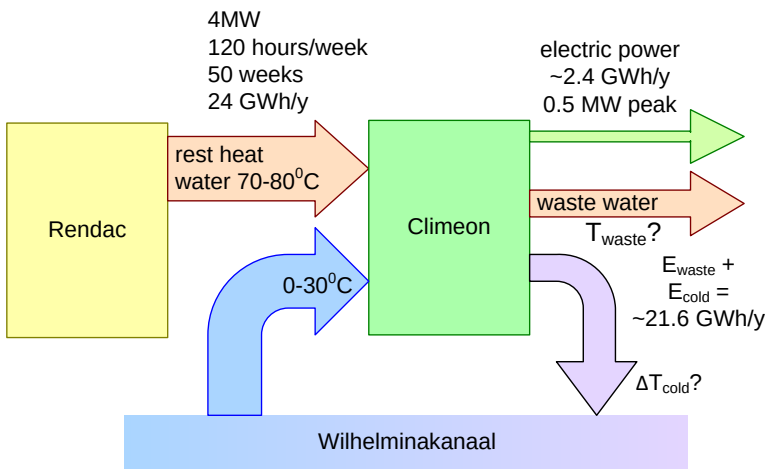


Darling-Rendac, exploration of using Climeon to transform rest heat into electricity

Author: Gerrit Muller, contributions from many Best Duurzaam volunteers

Version 1.1, January 19, 2019

1 System level block diagram

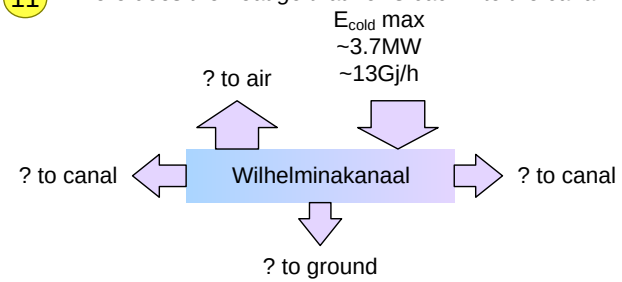


10 Assumptions, limitations

ignored:

- Operational cost
- effect of climate change (higher temperatures)
- warming up of Wilhelminakanaal
- energy use of auxillary systems
- potential subsidies

11 Where does the heat go that flows back into the canal?

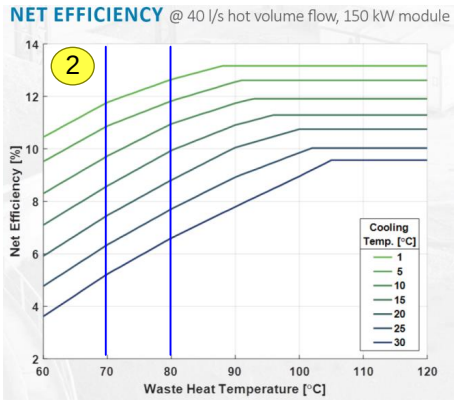


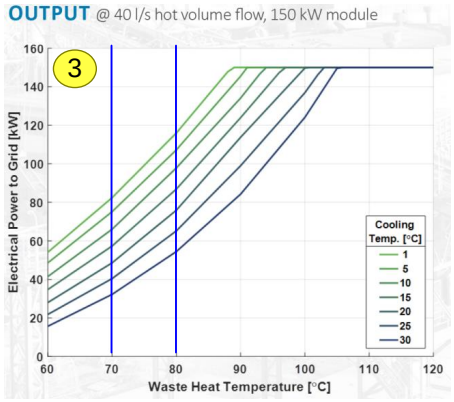
Explanations

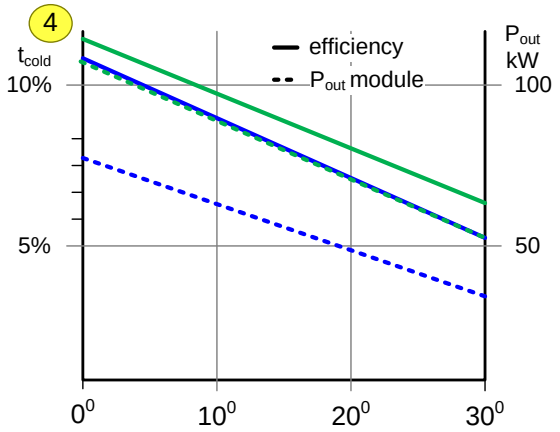
This A3 explores how the Climeon system may transform rest heat into electricity at Rendac in Son. Purpose is to understand this option and to find out what questions we need to ask. Feedback is welcome. Blame Gerrit for mistakes.

1 provides a high level block diagram of the concept
How does the rest heat leave the system? How much is hot waste water, how much is the cold water warmed up?
2 the efficiency of the Climeon system depends on t_{hot} and t_{cold}
3 the P_{out} also depends on t_{hot} and t_{cold}
4 We need the efficiency and P_{out} @ t_{hot} = 70..80^{0}C as function of t_{cold} between 0 and 30^{0}C, we derived a linear relation from 2 and 3
5 KNMI.nl provides the temperature per month for the regio Eindhoven we assume that the water temperature follows the air temperature
6 Combining 4 and 5, with the data from 1 gives the energy per month
7 cumulating all months in 6 gives the produced electric energy per year
8 we use 4 to calculate the required #modules at worst case conditions, which is when t_{cold} = 30^{0}C; it also shows E_{month} @ 30^{0}C
9 cost = #modules * cost/module + installation cost
income per year = E_{year} * $price_{kWh}$
ROI = cost / income per year
10 we have simplified a lot, here are some limitations
11 warming up of the canal has a big impact on environment and efficiency of the solution. Where does all the remaining heat go?
12 to get a feel for the impact, we estimate how much a stretch of 100m of the canal gets warmer per hour or per day, if all rest heat stays in the that part of the canal.
13 shows the impact of canal water that is 3^{0}C warmer than the average air temperature

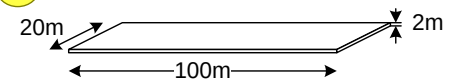
Climeon data from https://climeon.com/wp-content/uploads/2017/04/Climeon-Tech-Product-Sheet.pdf







12 Estimate of warming of canal water



V_{water} = 100 * 20 * 2 = 4000 m^3
m_{water}= V_{water} * 1000 kg/m^3
c_{water} = 4.2 J/gK
E_{in} = 3.7 MW/h * 3600 = 13.3 GJ
$\Delta T = P_{in} / m_{water} * c_{water}$

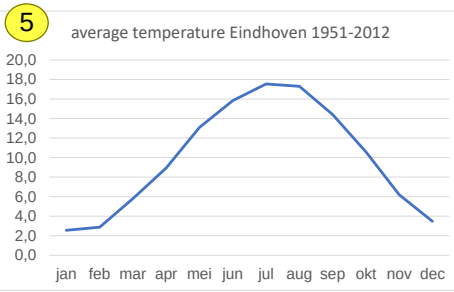
= 13.3 * 10^9 / 4 * 10^9 * 4.2

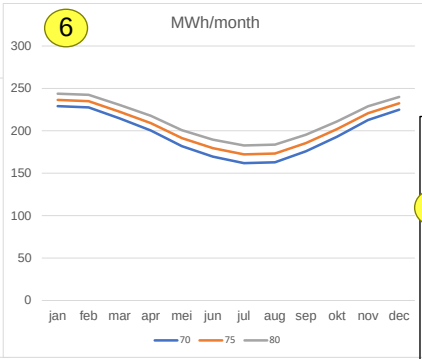
~= 0.8 K

this stretch of the channel would heat
0.8 K /hour if no heat escape or 20^{0}C/day

It is crucial to understand how the heat dissipates via the waste water, or from the canal to air, the rest of the canal, and the ground.

Electricity production in Eindhoven area





t_{hot}	7 MWh/y
70	2354
75	2460
80	2566

#modules, E_{month} @ worst case

8 (t_{cold}=30^{0}C)

t_{hot}	#mod	MWh/m
70	7	106
75	6	119
80	5	132

9 Cost and Income

Cost/module 350 k€

install cost (wild guess GM) 300 k€

electricity price 0.05€/kWh

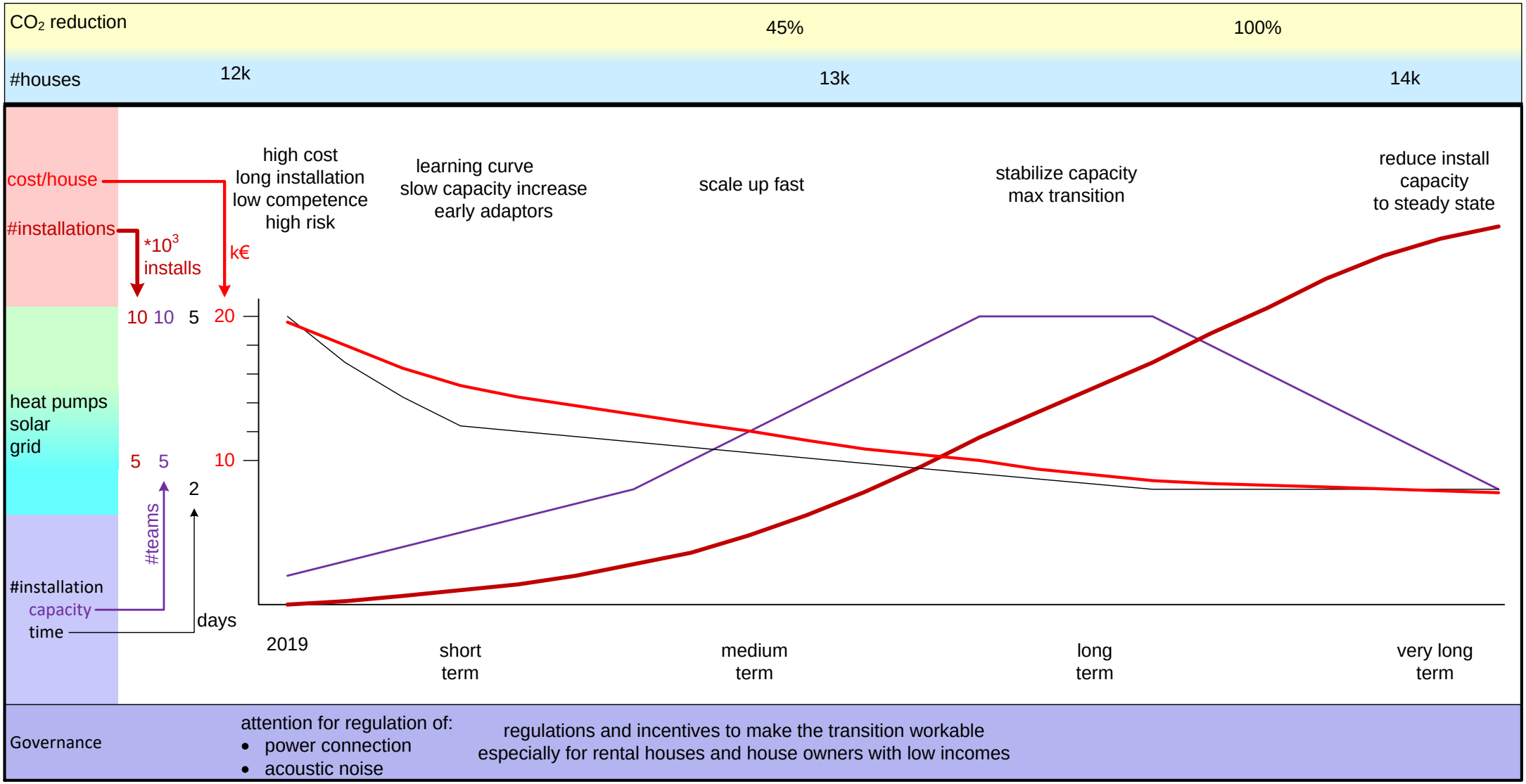
t_{hot}	#mod	cost k€	income k€/y	ROI years
70	7	2750	118	23.3
75	6	2400	123	19.5
80	5	2050	128	16.0

What if t_{cold} is 3 degrees warmer?

13

t_{hot}	MWh/y	income k€/y	ROI years
70	2193	109	25.2
75	2306	115	20,9
80	2402	120	17,1

Heat Pump transition scenario for Best	Author: Gerrit Muller	BDRA3heatpumpHeatingTransitionScenario Version 0.1, May 9, 2019



Solar PV cost and efficiency evolution

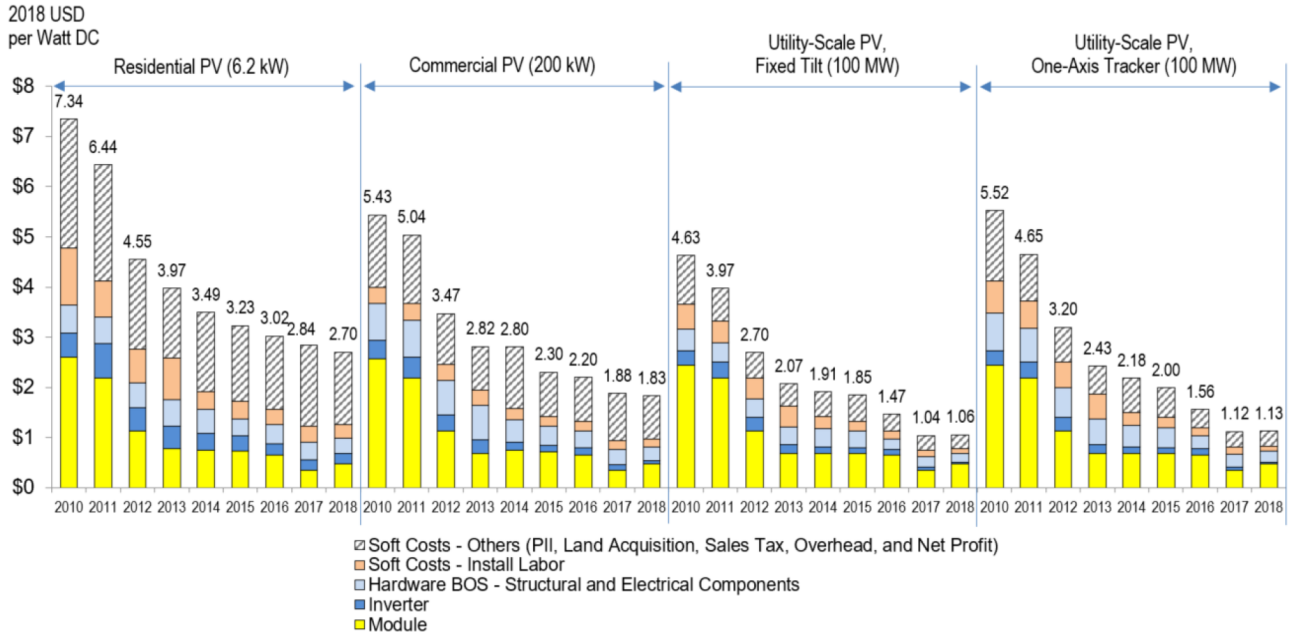
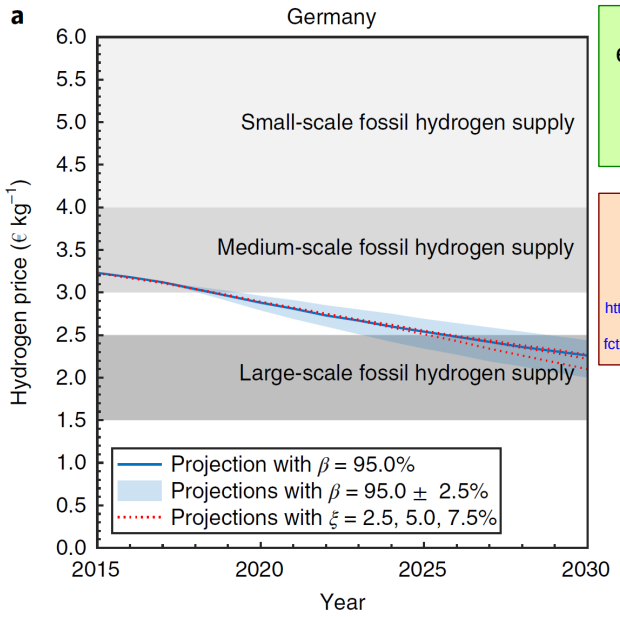


Figure ES-1. NREL PV system cost benchmark summary (inflation adjusted), 2010–2018

U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018 https://www.nrel.gov/docs/fy19osti/72399.pdf

Hydrogen cost evolution



energy content of 1 Kg H_2 = 33.3 kWh

fuel cell efficiency 40..60%
https://www.energy.gov/sites/prod/files/2015/11/f27/fcto_fuel_cells_fact_sheet.pdf

Fig. 3 | Prospects for renewable hydrogen production
The break-even price of renewable hydrogen for Germany relative to the benchmark prices for fossil hydrogen supply.
from: Economics of converting renewable power to hydrogen
Gunther Glenk and Stefan Reichelstein
Nature Eneregy https://doi.org/10.1038/s41560-019-0326-1

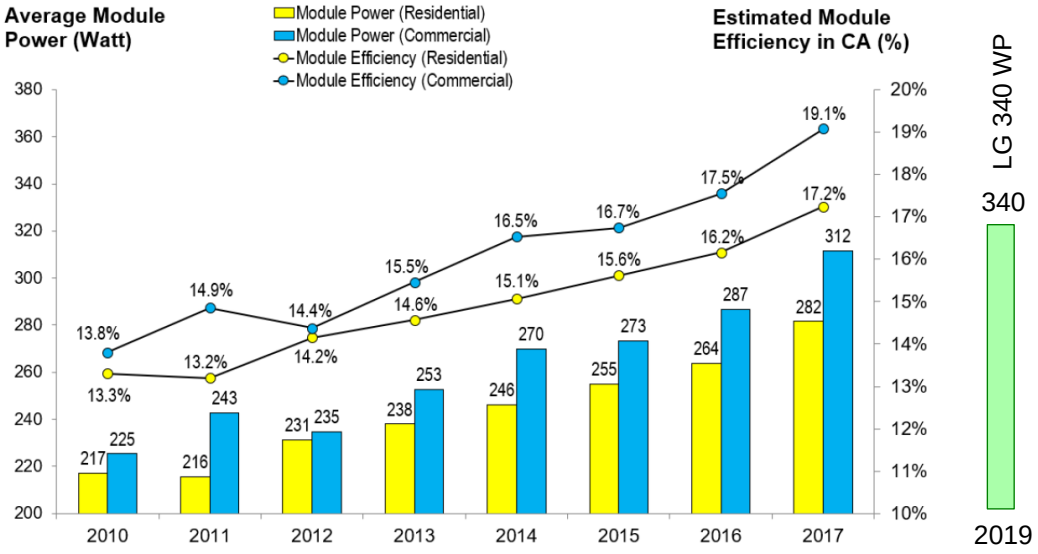
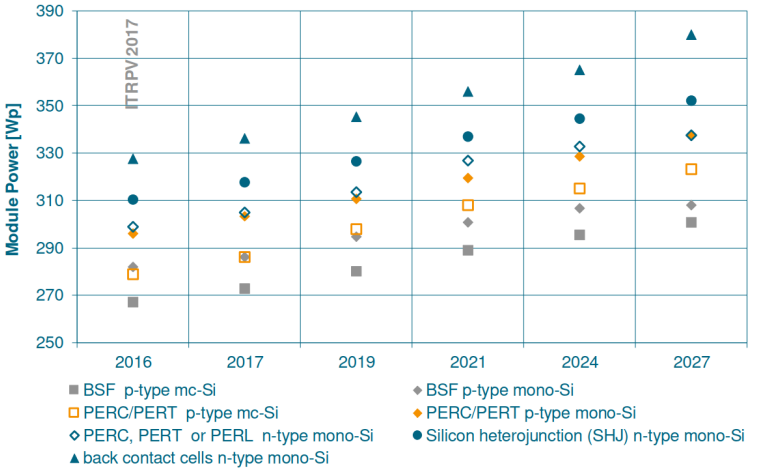


Figure 3. Module power and efficiency trends from the California NEM database (Go Solar CA 2018), 2010–2017

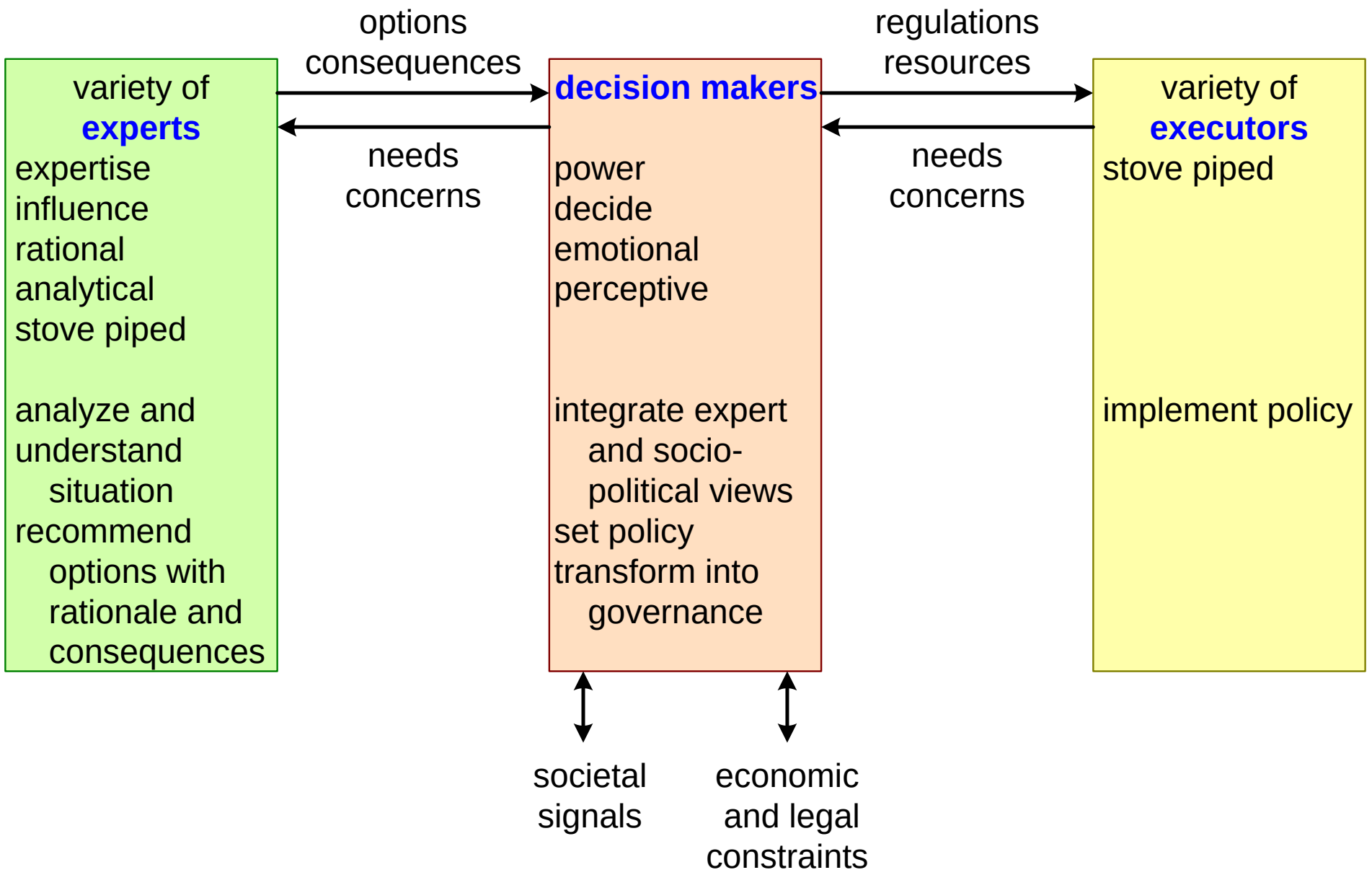
LG 340 WP
340
2019



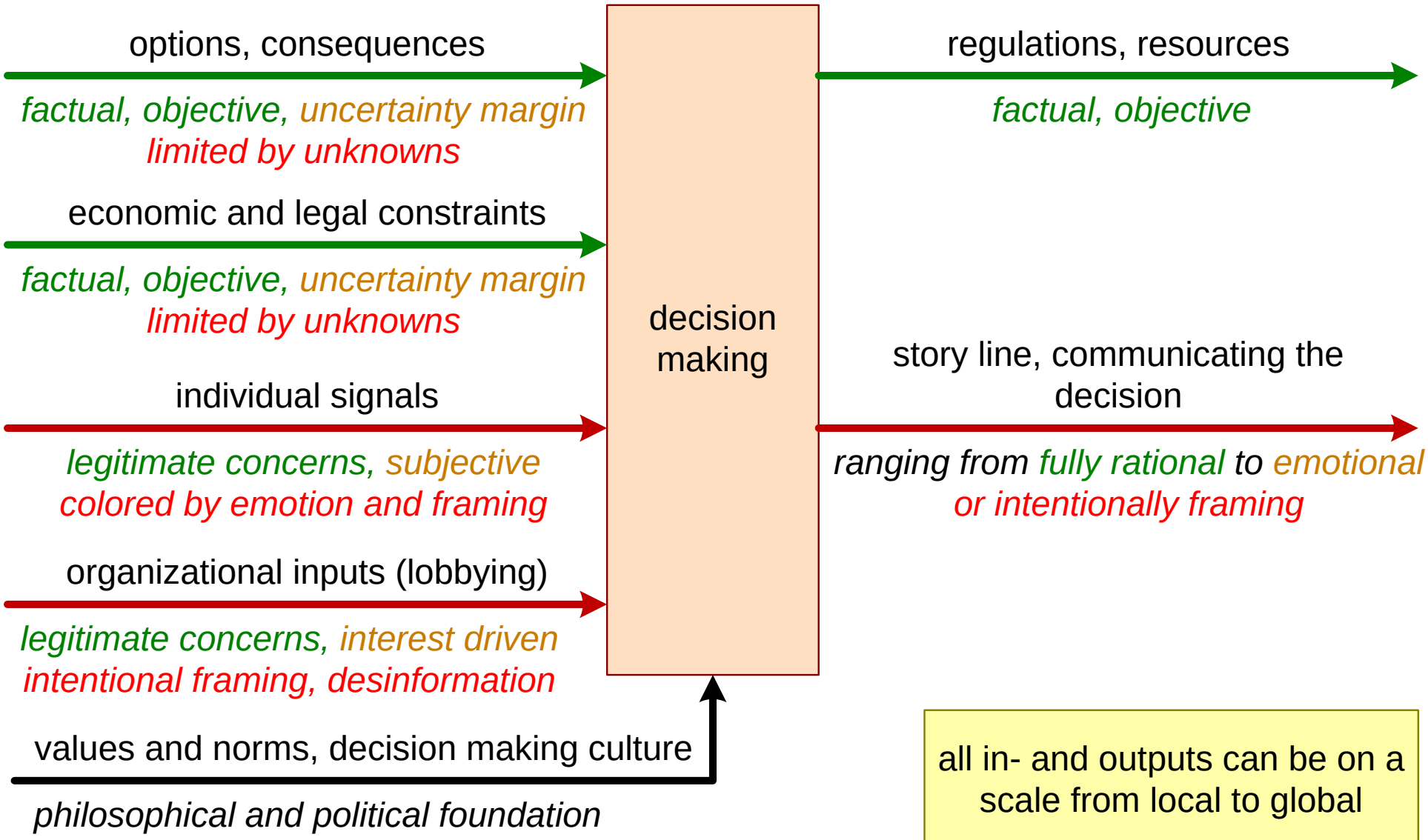
https://cleantechnica.com/2017/08/15/efficient-will-solar-pv-future-10-year-predictions-industry/

warning: none of the numbers are for Best or the Netherlands!

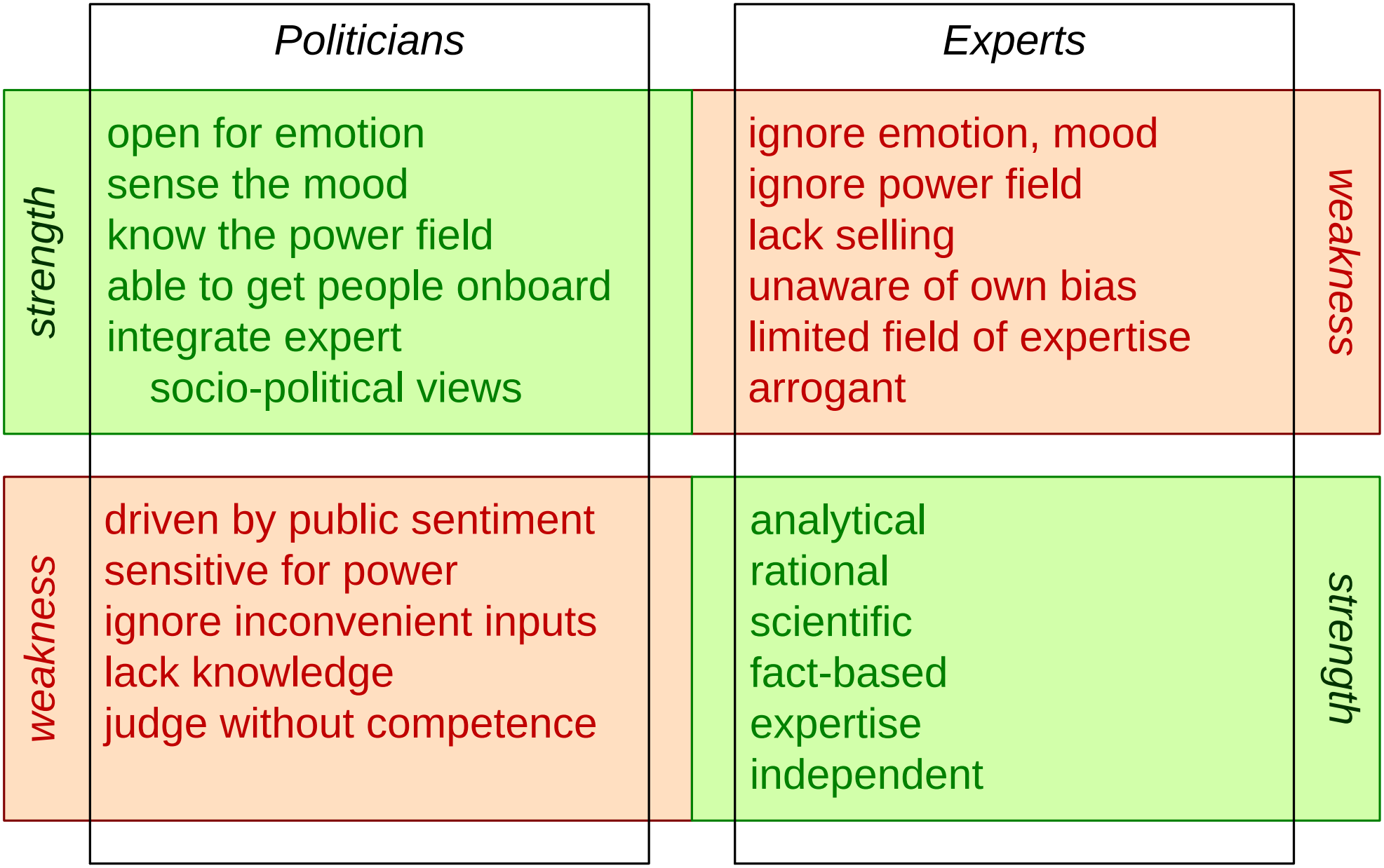
Roles in the Decision Making Process



Decision Making Inputs and Outputs



4 Quadrant Model Politicians and Experts



The Role of the Academic (Opinion of Gerrit)

	characteristics	*behavior*
Academic	analytical rational scientific fact-based expertise limited field of knowledge	researching educating ignoring emotion and power without selling
Member of society	responsibility ownership *personal norms and bias*	contributing with expertise striving for appropriate action communicating clearly humble and listening *taking a position* *counterbalancing power*