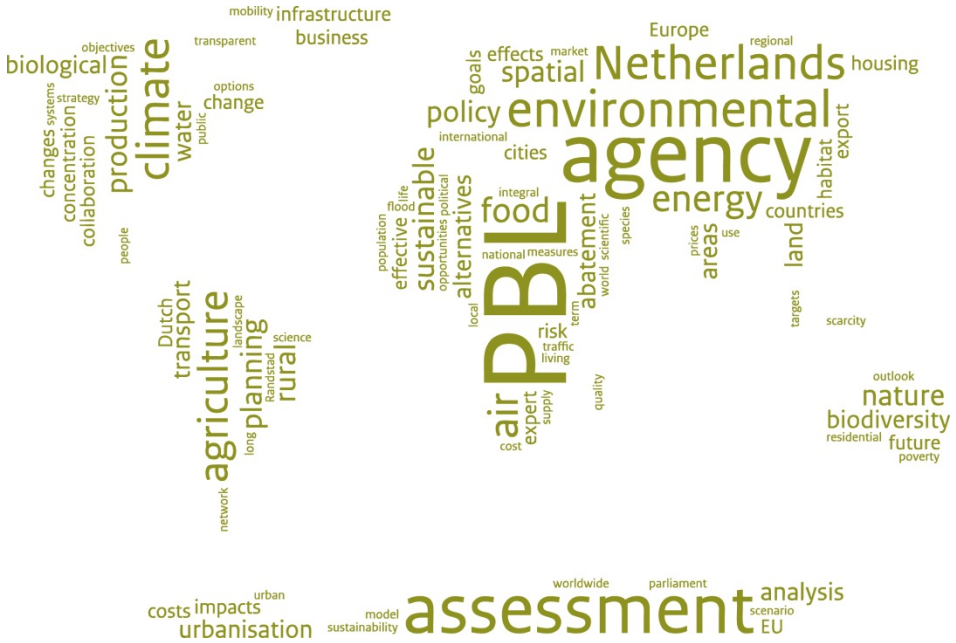
PBL Netherlands Environmental Assessment Agency

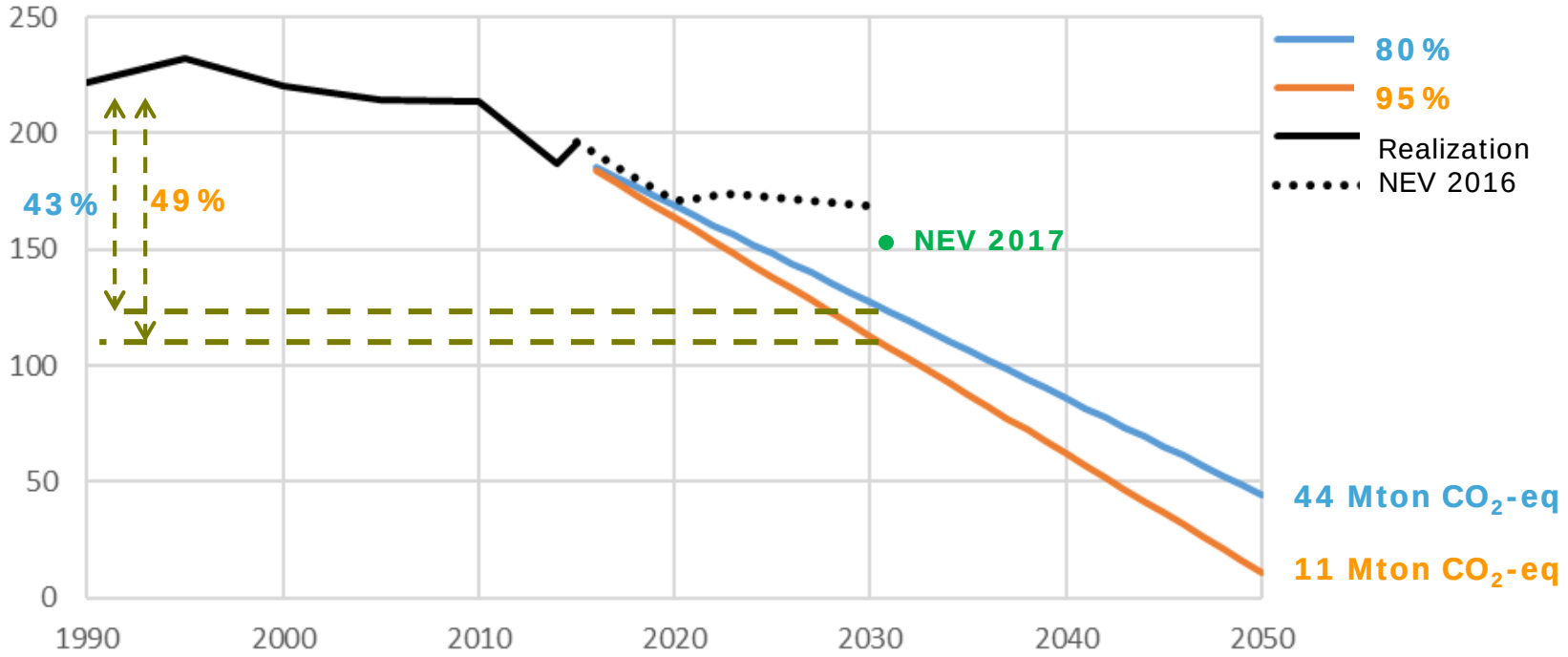


System integration, business and governance

Pieter Boot, Netherlands

Conference on Electrochemical Conversion&Materials, Den Haag, June 29th 2018

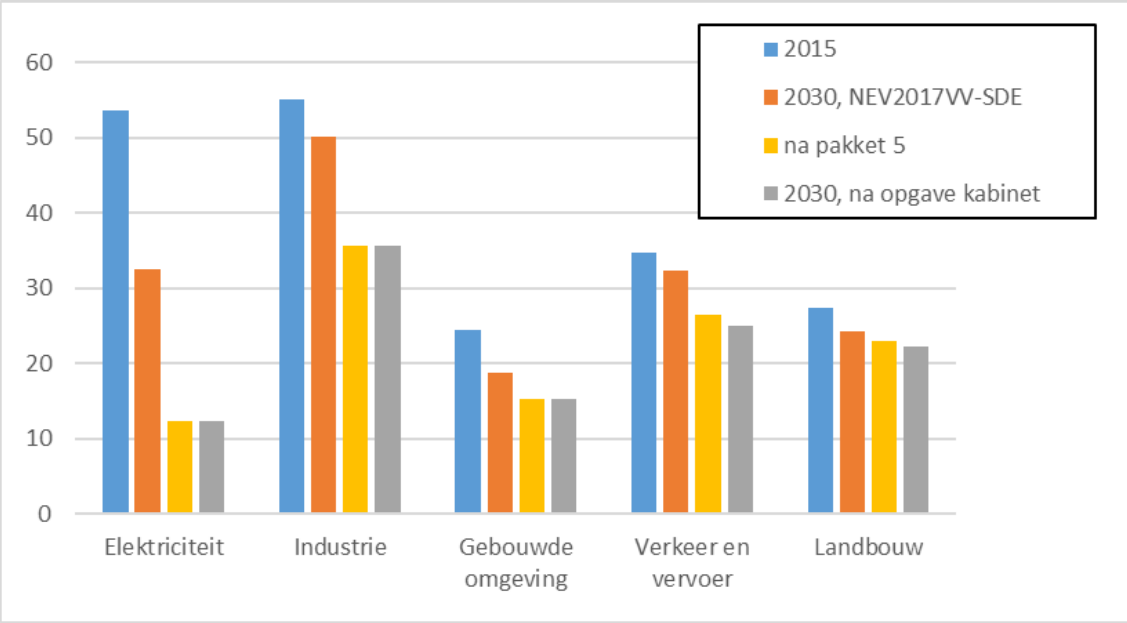
Greenhouse gas emissions in the Netherlands (Mton CO2-eq)



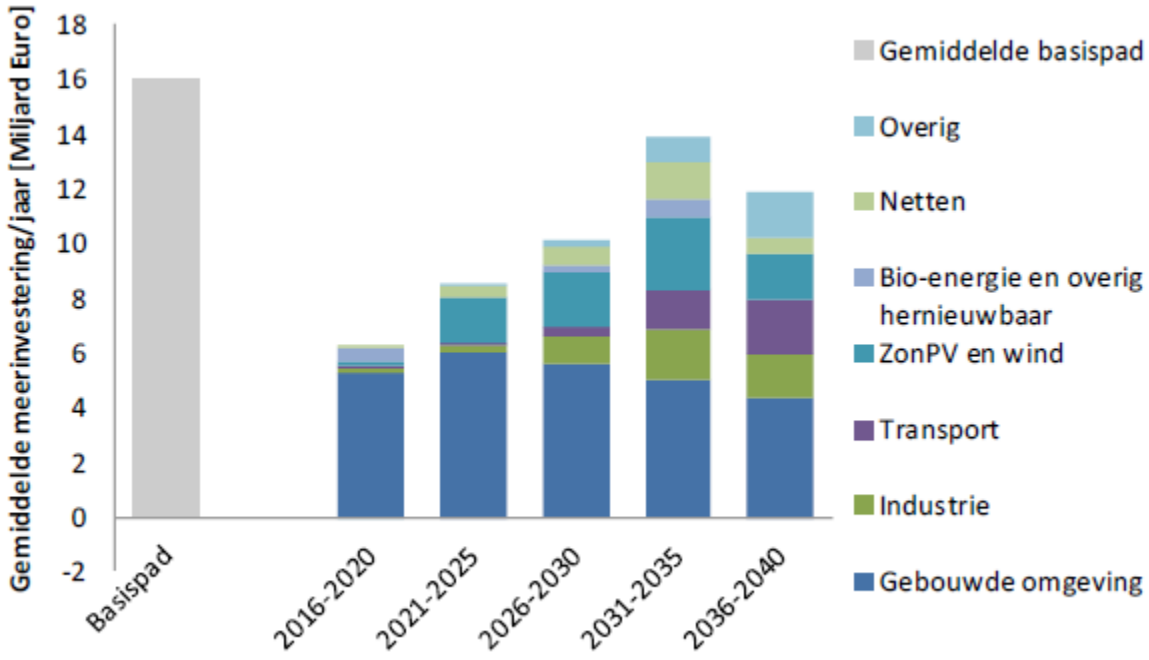
Example of challenge and costs

Package attaining 49% reduction, incl. LULUCF	Emission 2015 (Mton)	Emission 2030, reference (Mton)	Emission reduction package (Mton)	Emission 2030 after packaget (Mton)	National costs (Meuro)
Power generation (Netherlands)	52.8	32.6	20.2	12.4	1140
Manufacturing	55.1	50.0	14.3	35,7	890
Buildings	24.4	18.7	3.4	15.3	1210
Transport	35.5	32.4	5.9	26.5	-100
Agriculture	27.4	24.2	1.4	22.9	40
LULUCF	6.1	6.9	3.8	3.1	110
Total, without LULUCF	195.1	158.0	45.0	112.9	3180
Total, including LULUCF	201.2	164.9	48.8	116.0	3290

Emissions 2015 en 2030



Additional investments to attain 80% GHG reduction



Bron: PBL, Investeringen energietransitie en financierbaarheid, 2017

Robust parts of PBL analysis

Additional to reference path:

- Some onshore wind
- A lot of offshore wind
- Both large scale and rooftop solar-PV
- More process efficiency manufacturing
- Electrification in manufacturing
- CCS in several manufacturing sectors
- Efficient appliances, lighting
- Standards for cars and trucks; electric cars
- Start with additional policies in buildings

Main parts climate agreement to be expected soon

Several aspects of system integration

- Control of power system
  - now 15% wind/solar, increases to more than 70% by 2030
  - quality of system
  - sufficient back-up?
  - high level of interconnection
  - more flexibility needed
- Demand and supply
  - increase of offshore wind vs electrification
  - what happens in neighbouring countries?
- Now main energy carrier gas. Which future for molecules?

More interconnection to be expected

	2016	2020	2030
NL-D	2450	4250	5000
NL-B	1400	1400/2400	3400
NL-DK	0	700	700
NL-GB	1000	1000	1000
NL-N	700	700	700

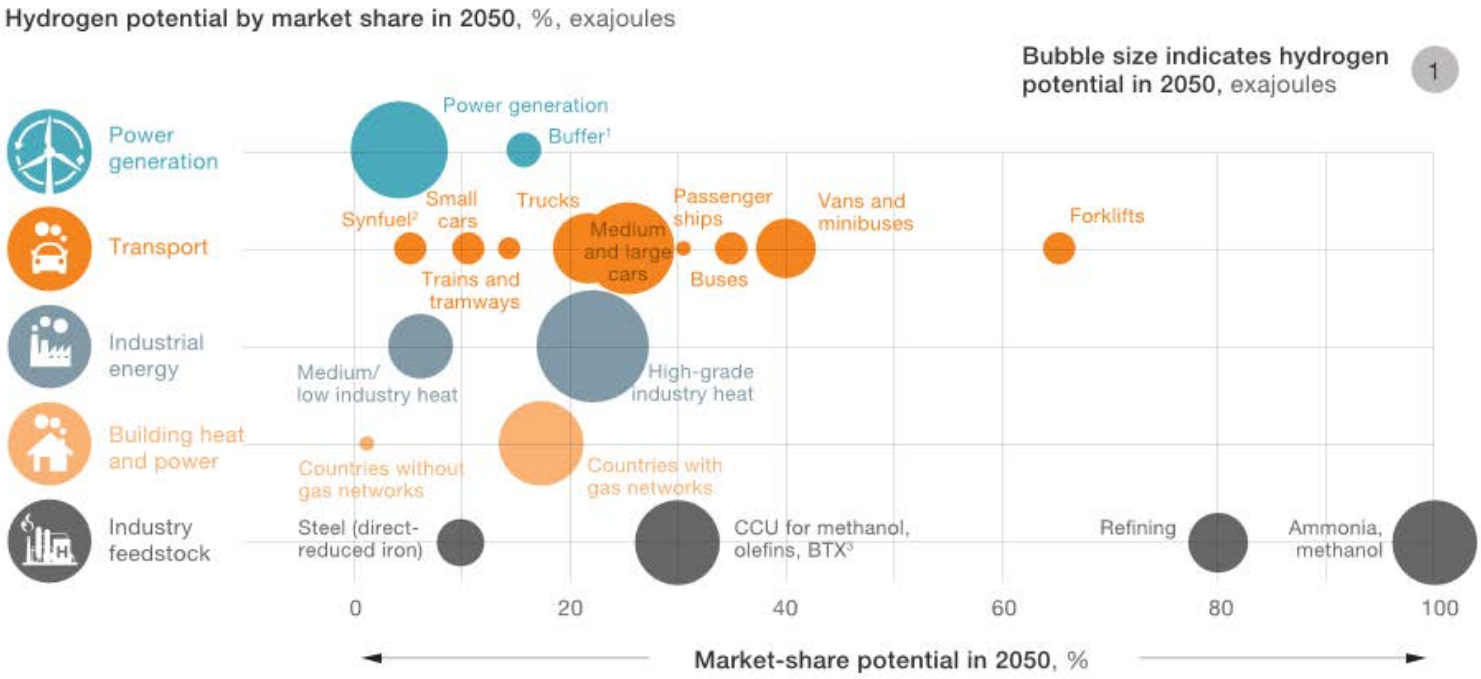
Bron: ECN,PBL, Nationale Energieverkenning 2017; Tennet

Electrons and molecules

- Three ways to use hydrogen:
- feedstocks
- different time or place of generation and use (flexibility)
- decarbonisation of sectors without alternatives (e.g. high grade industry; trucks; international shipping and aviation)

- Three types:
- Grey (existing in chemical industry)
- Blue (from natural gas with CCS, comp. Magnus plant project)
- Green (from clean electricity, comp. possible 20 MW plant Delfzijl)

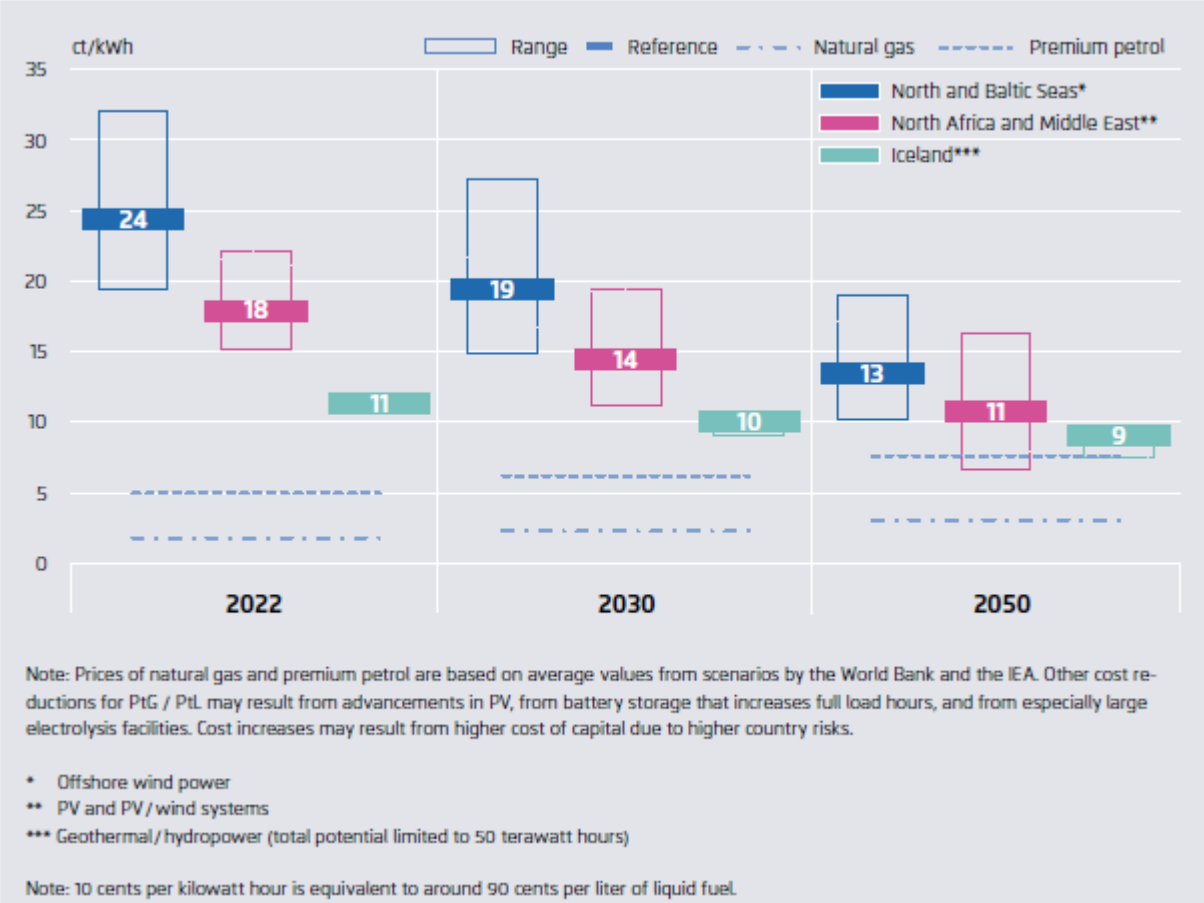
Hydrogen can play a critical role globally



[1]% of total annual growth in hydrogen and variable renewable-power demand.
[2]For aviation and freight ships.
[3]Carbon capture and utilization; % of total methanol, olefin, and benzene, toluene, and xylene (BTX) production using olefins and captured carbon.

McKinsey&Company | **Source:** Survey and interviews with Hydrogen Council member companies

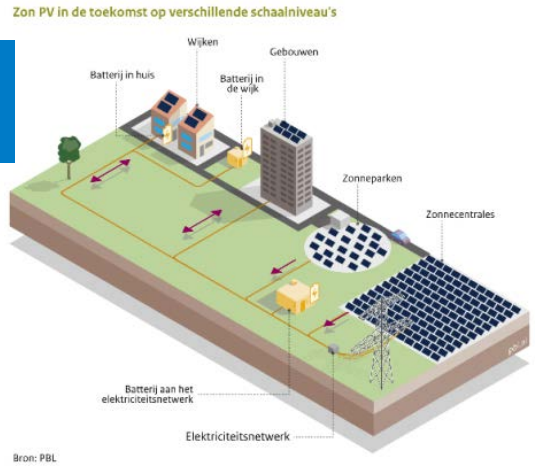
But green hydrogen costs have to decrease considerably



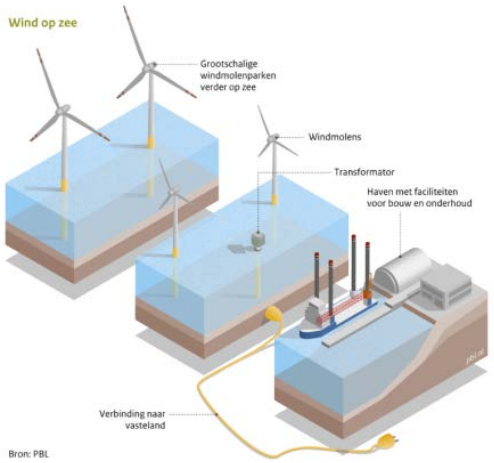
Agora, The future cost of electricity-based synthetic fuels, 2018. Costs in ct/kWh final product without network costs

Power production 2050: increase with 100/200%

Solar-PV 10-25%

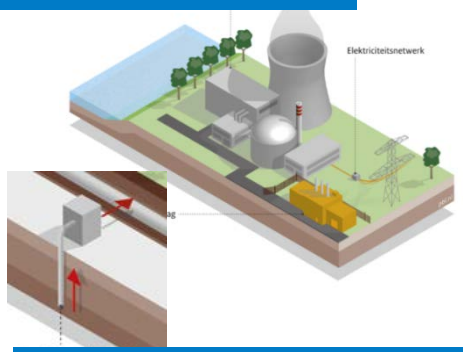


Wind off-shore 50-80%



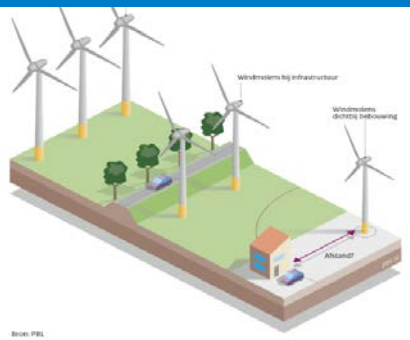
Gas (CCS) 1-20%

Nuclear 0-25%

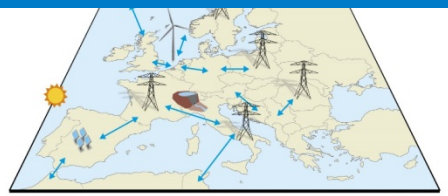


Geothermal 0-4%

Wind on shore 7-11%

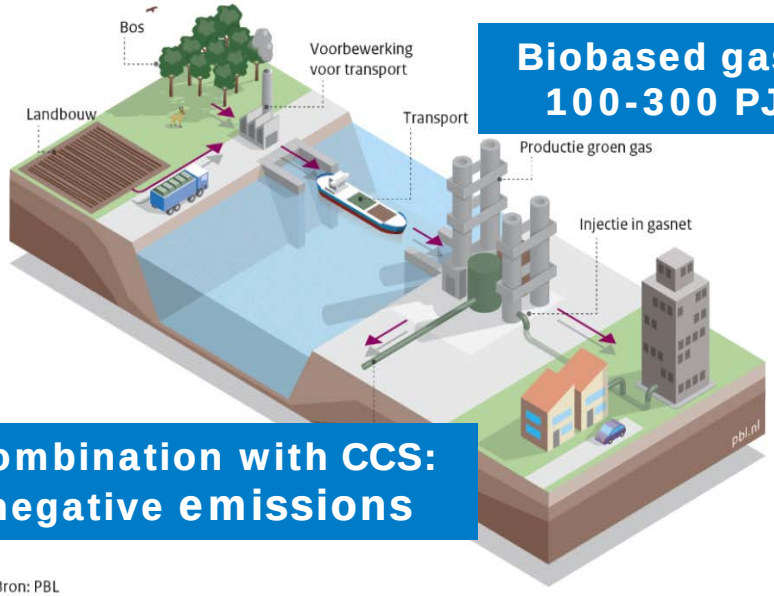


Interconnection



Green fuels: option in all sectors

Biobased fuels: important for transport

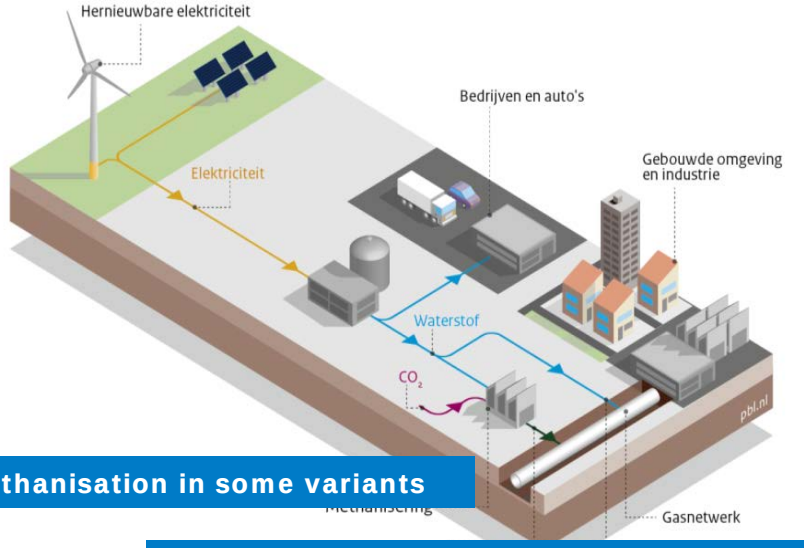


Biobased gas: 100-300 PJ

Combination with CCS: negative emissions

Bron: PBL

Power-to hydrogen (+ hydrogen from gas/CCS)



Methanisation in some variants

Bron: PBL

Addition of H2 in the gas grid

Manufacturing

Biomass (feedstock and fuel)

Extra saving

CCS 6-34 Mton

Electrification of processes and heat production

Demand side management

Energy transition challenge for all involved

- Government
  - EU — Broad targets, Regulation
  - Central — Climate Law
    Policy instruments: legal, finance, convincing
  - Local — Strategic Energy Plans, Heating plans: spatial

- Business and Civilians — Investments, behaviour

- Infrastructure companies — Investments (gas, power, heating grids, CCS, hydrogen)

Main conclusions

- GHG reduction is main challenge of energy/climate policy and all parties involved
- Main additional reduction in 2030 in power generation and manufacturing, but large steps needed everywhere
- Additional costs modest, but more investments needed (Capex vs Opex)
- Several aspects of system integration: power system quality/flexibility, supply/demand, electrons/molecules
- Even up to 2050 elements of transtion paths become clear, but shares uncertain
- Transition will succeed if all parties contribute sufficiently.