Building a CO_2 free energy system

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Many reports have been written already on the future energy supply

However most of them report only qualitative trends and are rather short term

Moreover very little attention is given to the hourly dynamics of the system

Essential is to have a workable model
of the hourly behaviour of the energy supply and
how to match the variability in the supply with the variability in the demand.

Many issues need clarification but :
this talk is focussed on the consequences for the electric grid.

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During 2016 and 2017 KIVI organized several seminars titled EnergyNL2050

- Many experts were invited to give their view on the expected energy system for the Netherlands around 2050

- A small group of KIVI engineers used this valuable information to make a design of an energy system with zero CO2 emission (without CCS)

- It has been documented and published in a white paper

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The design of a complete energy system

We analyzed the energy demand in detail

- we used the system generally used by experts

- included ALL energy demands (except international aviation and shipping) but also including hydrogen for industry, steel manufacturing,…

- it is divided in 4 parts
  low temperature heat, high temperature heat,
  transport, classical electricity demand

- our conclusion is that electricity and hydrogen can be used for all demands except for aviation

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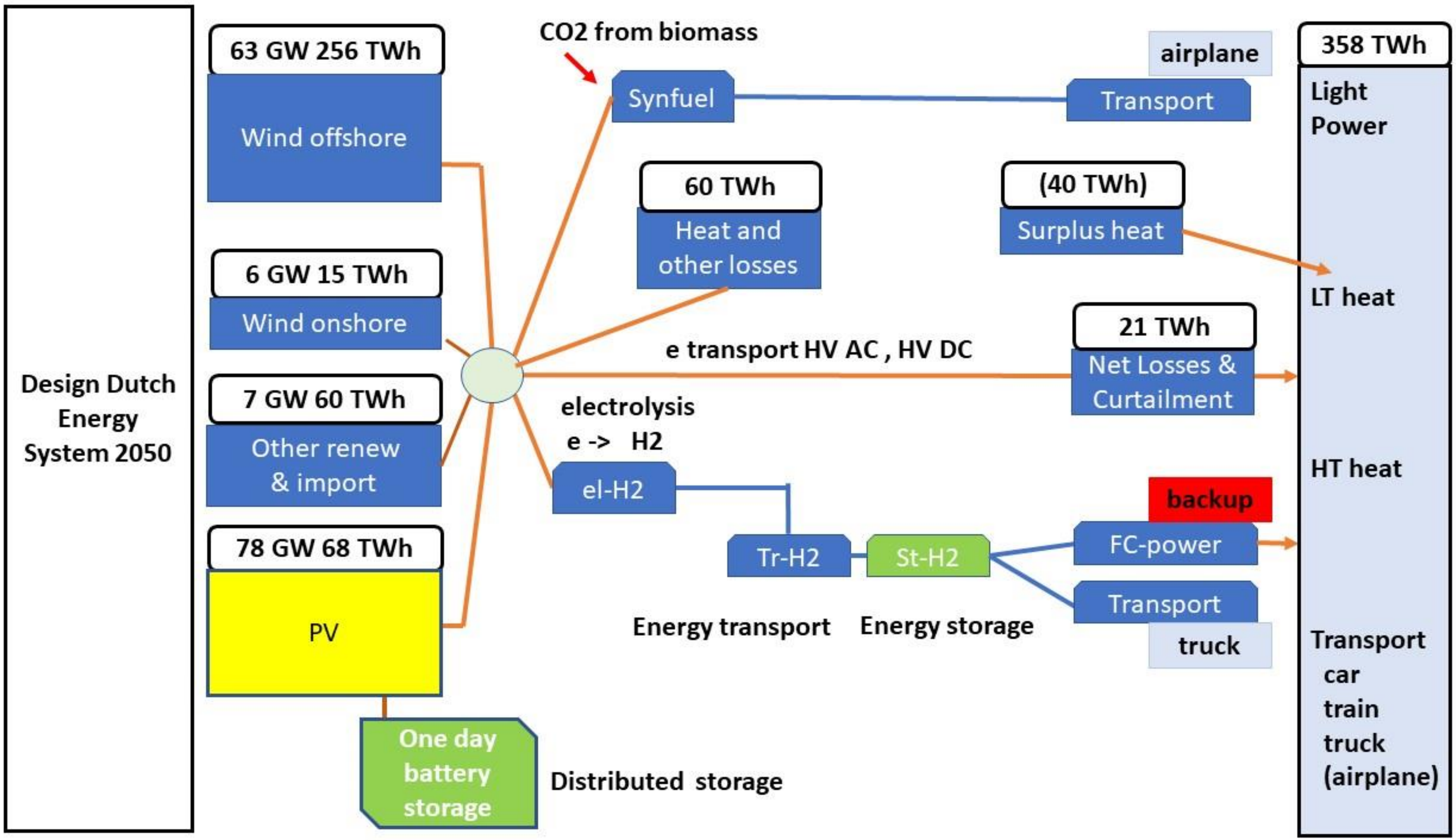
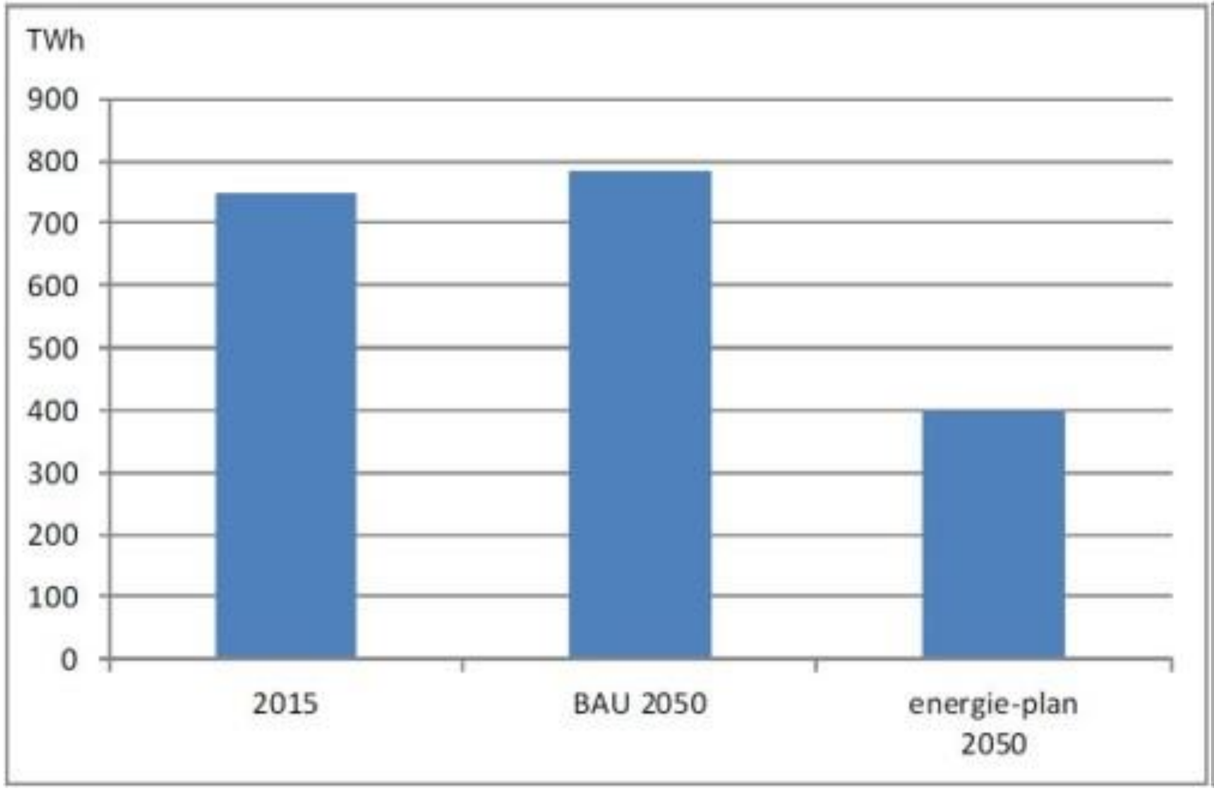
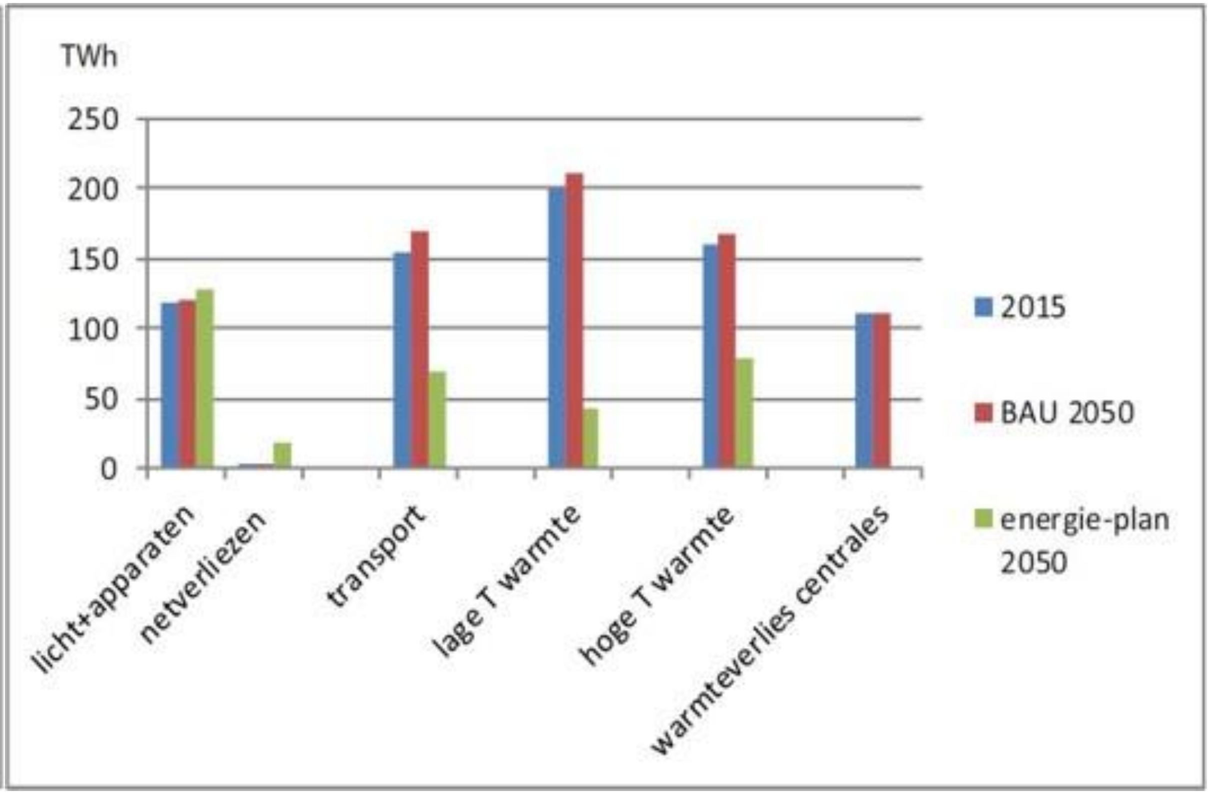
System overview

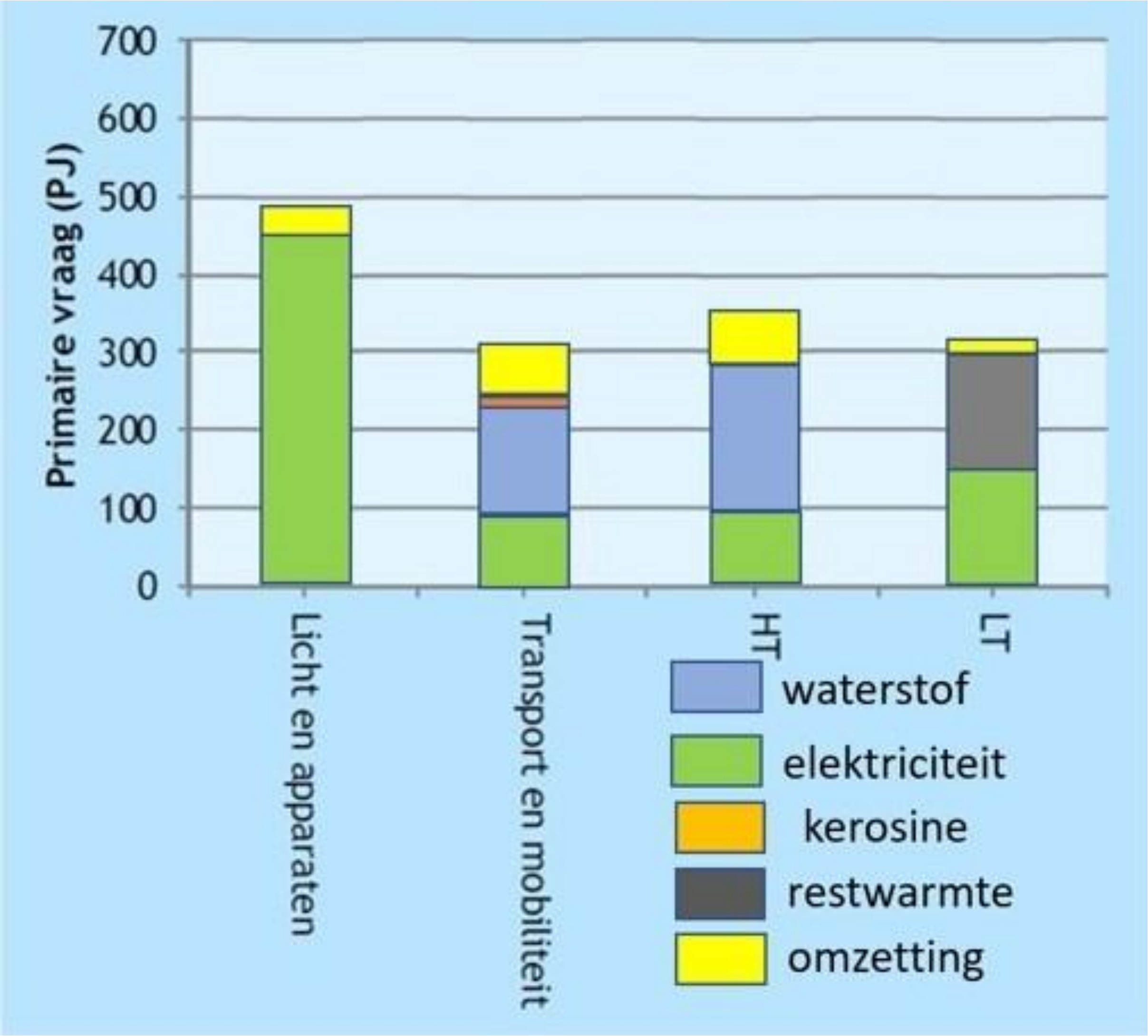


Energy savings





Energy Mix



Primaire vraag (PJ)
700
600
500
400
300
200
100
0
Licht en apparaten
Transport en mobiliteit
HT
LT
waterstof
elektriciteit
kerosine
restwarmte
omzetting

The goal is to design a system with zero CO_2 emission

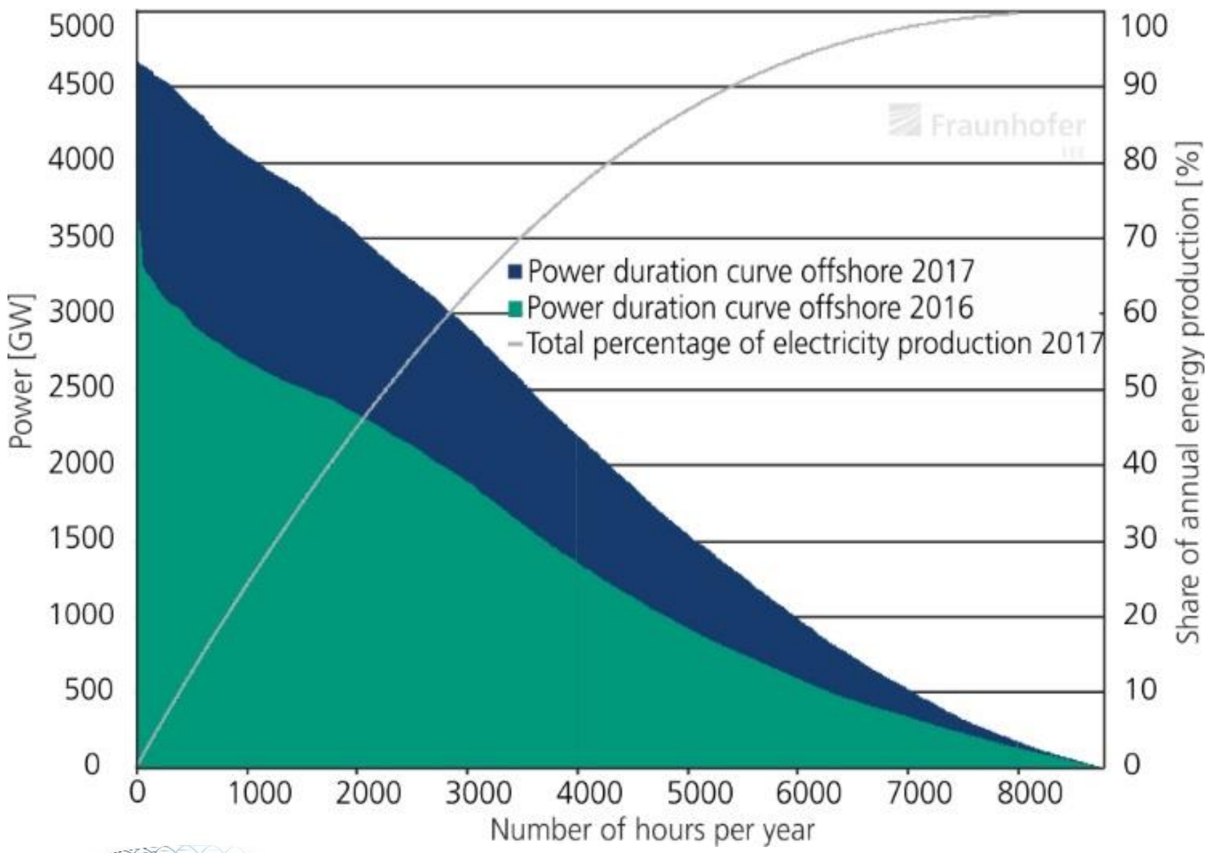
To achieve this the main sources of energy will be wind (turbines) and sun (PV)

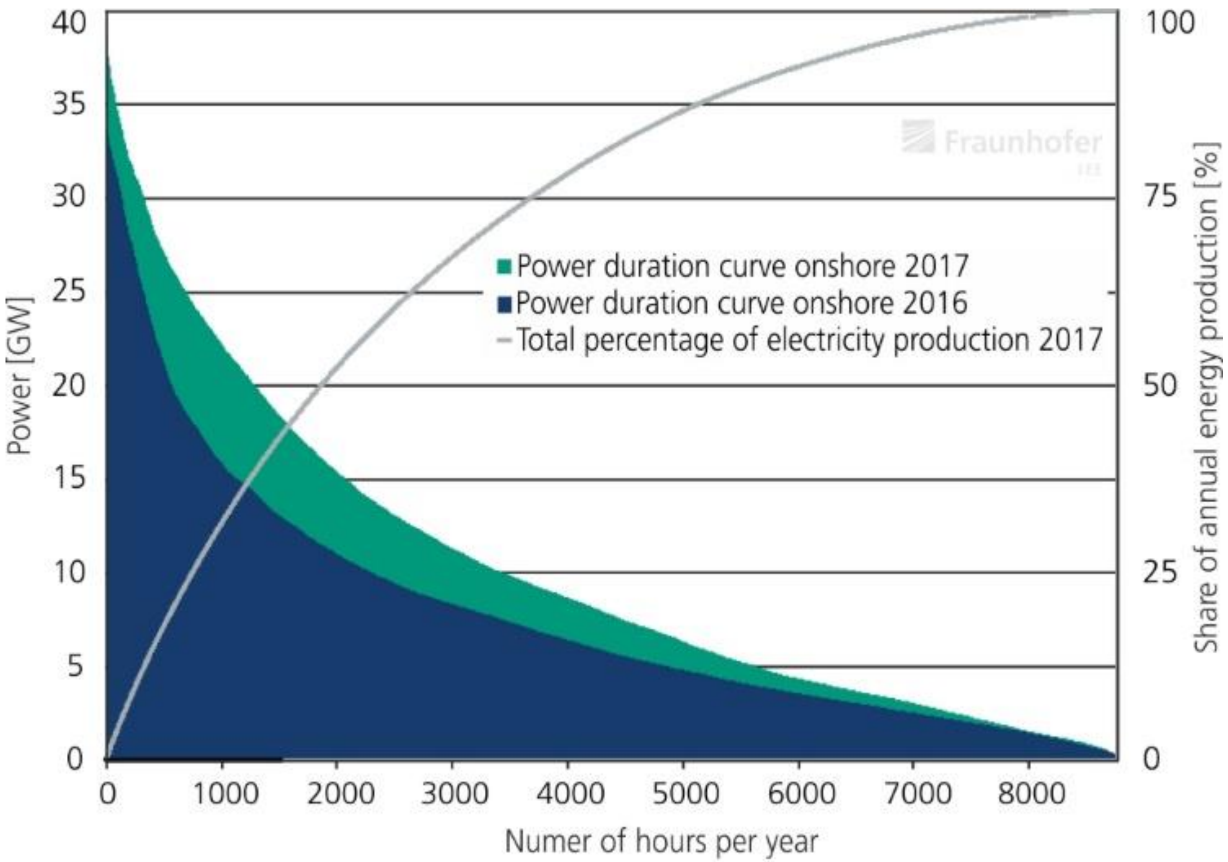
From those sources Wind at sea will be the main contributor. Followed by PV.

We make use of a basic concept called P(ower) D(uration) C(urve)

The PDC of wind at sea and wind at land

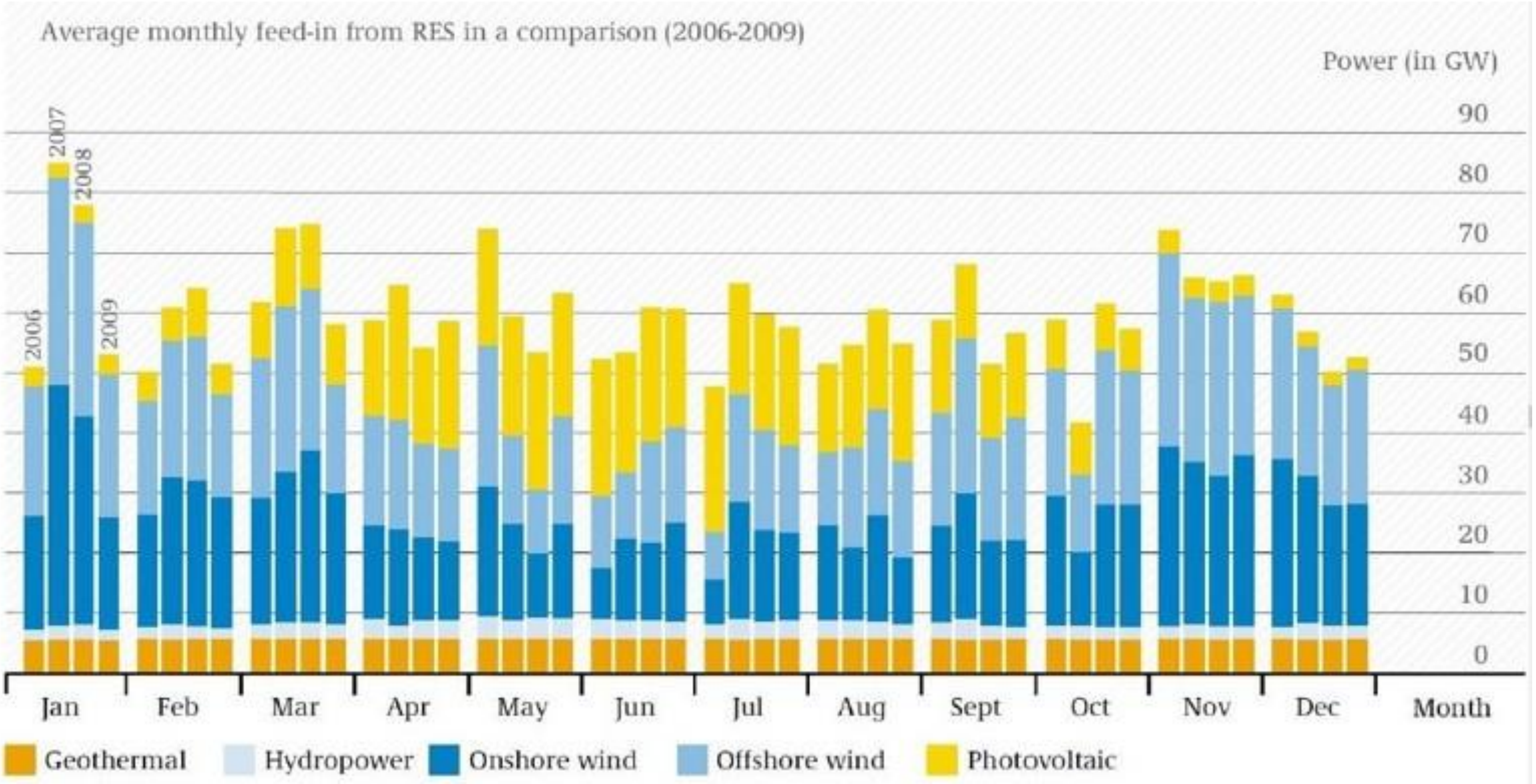
http://windmonitor.iee.fraunhofer.de/windmonitor_de/





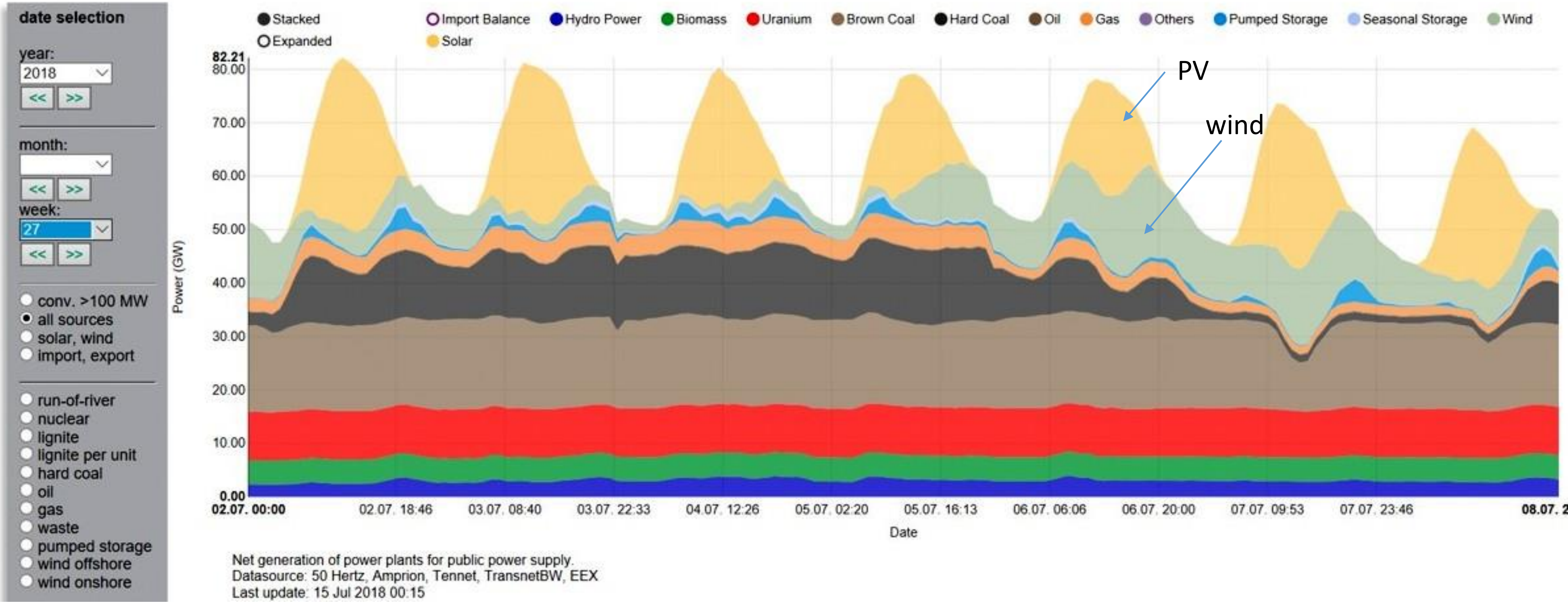
From this it can be seen that wind at sea is preferable

A suitable mix of Wind and PV



Based on this we have chosen a ratio 4 for wind energy / PV energy

Electricity production in Germany in week 27 2018



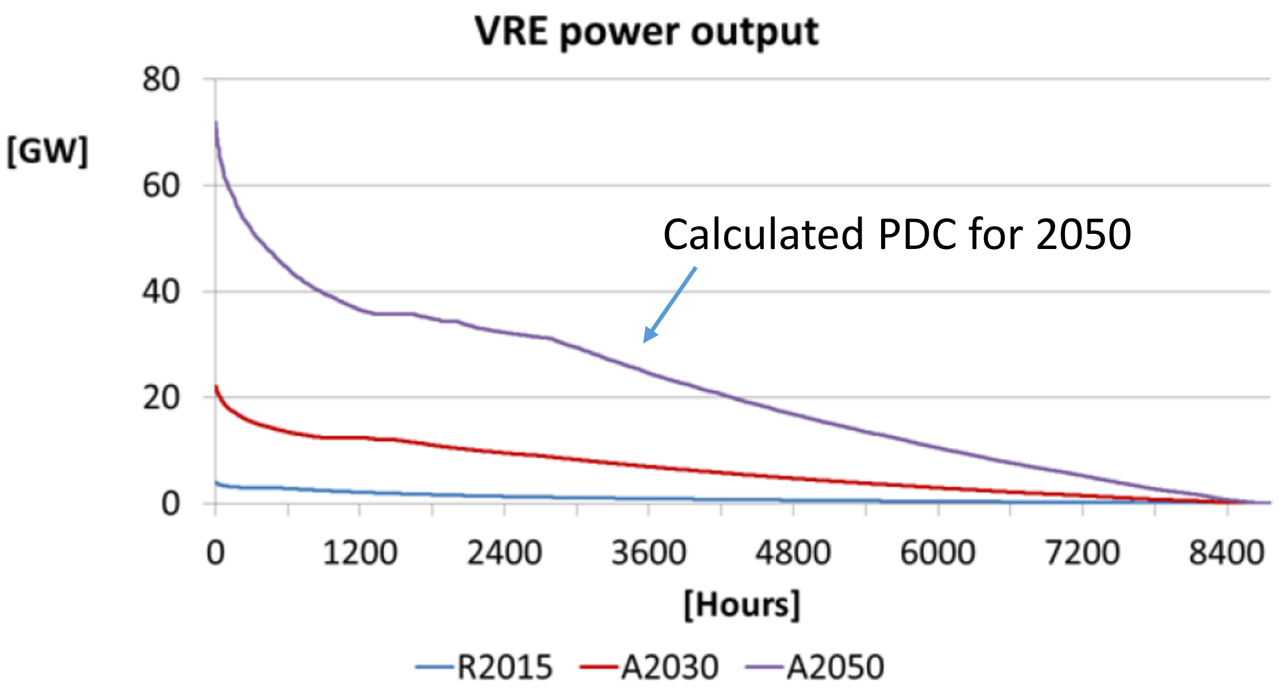
https://www.energy-charts.de/

How to merge the PV energy with wind energy into a combined PDC

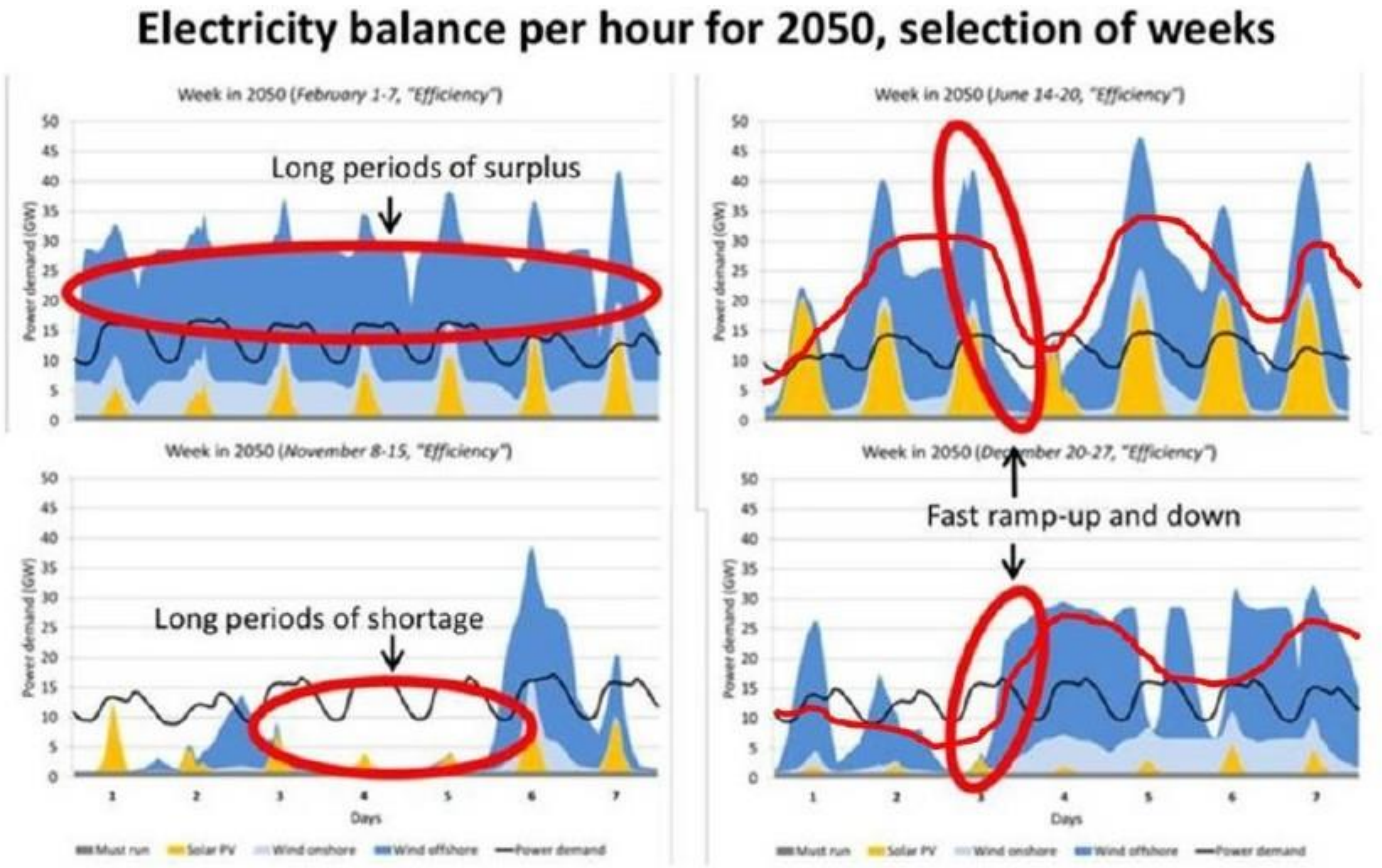
The PDC of PV energy has a very large peak due to the maximum irradiation at noon every day

Duration curve

ECN

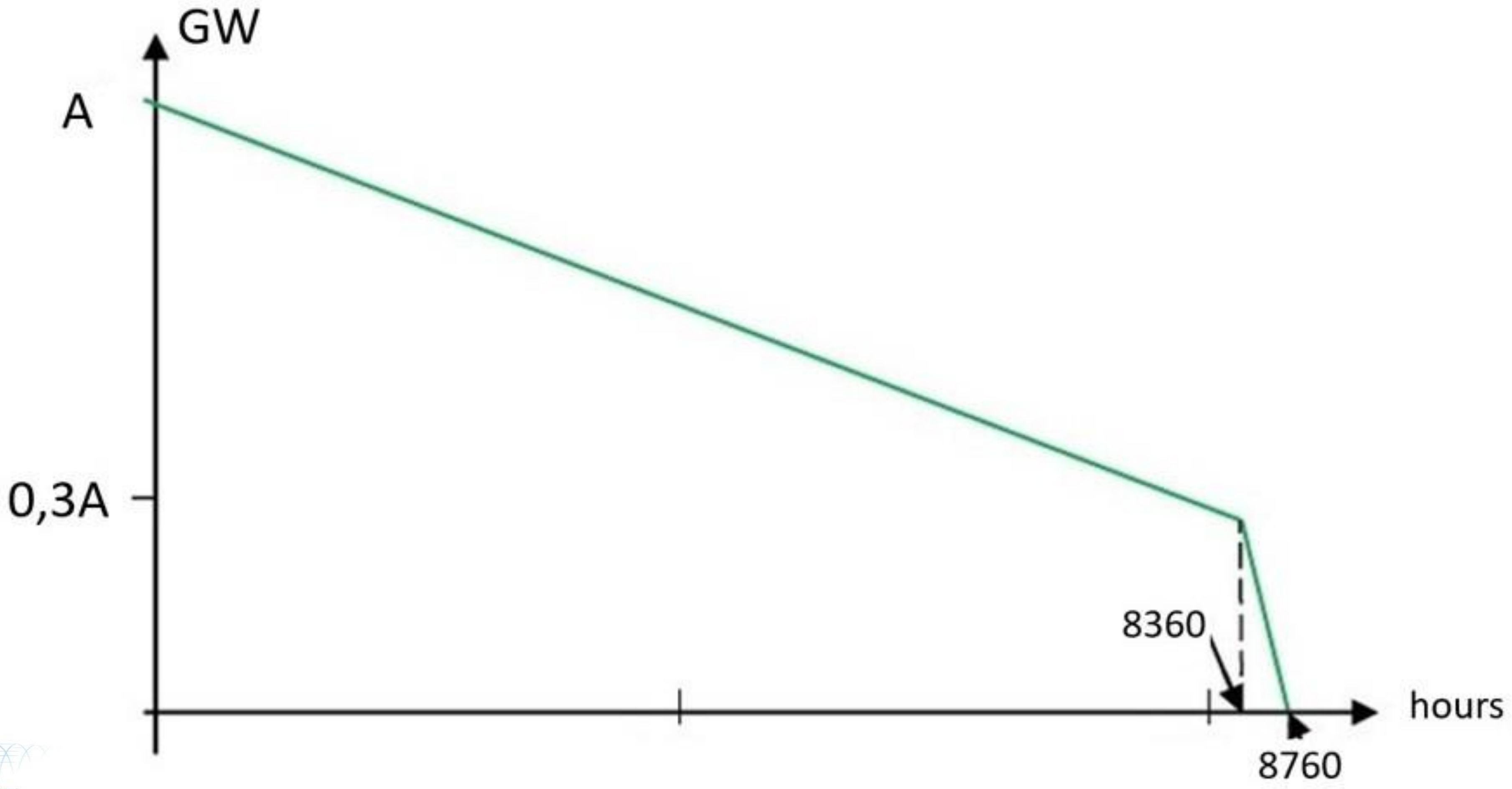


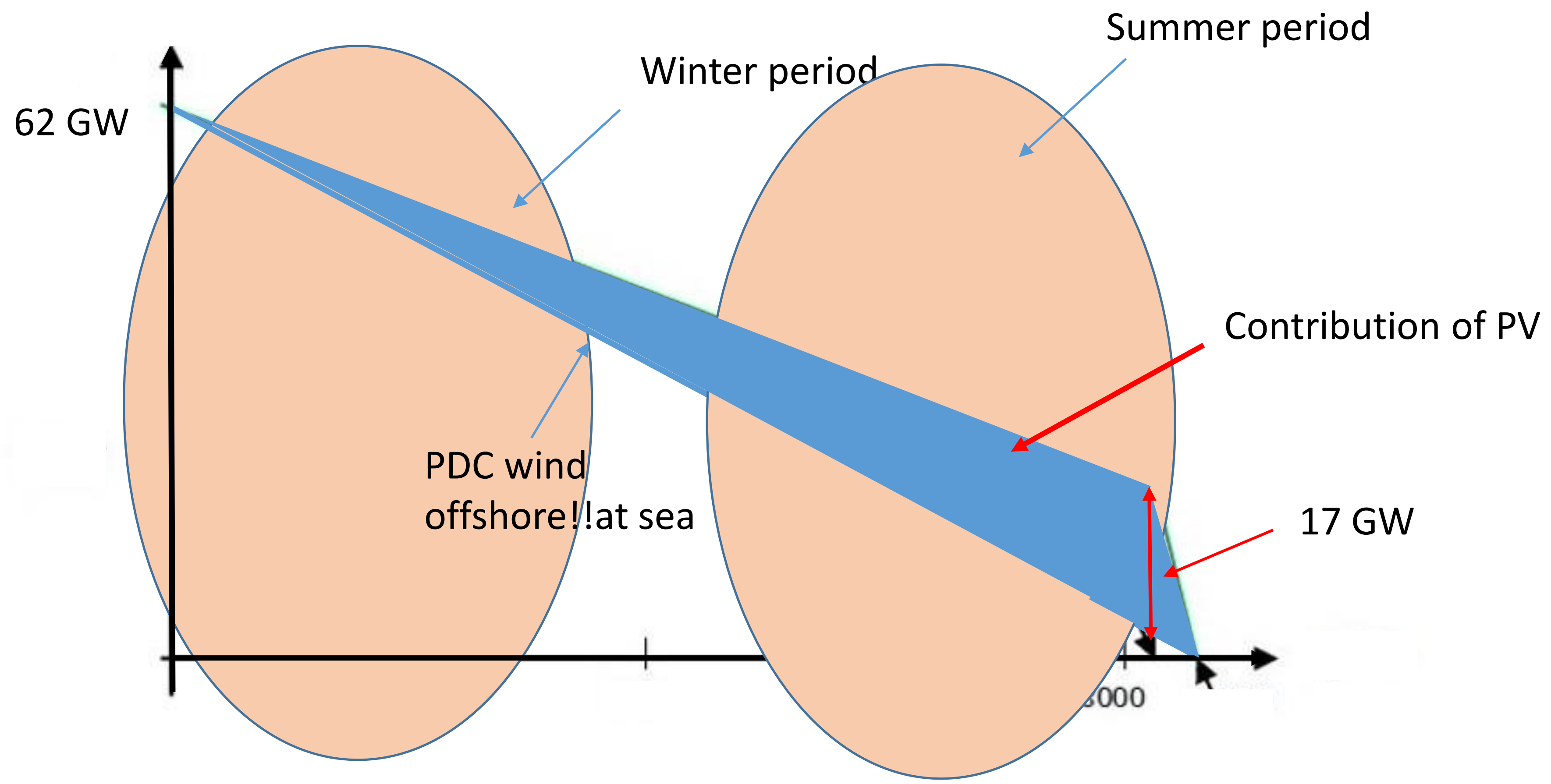
Introduction of a one day storage system



yellow = PV, light blue = wind onshore, dark blue = wind offshore, black = demand curve, red is curve with response including one-day storage.

The resulting PDC




Summer period
Winter period
62 GW
Contribution of PV
PDC wind
offshore!!at sea
17 GW

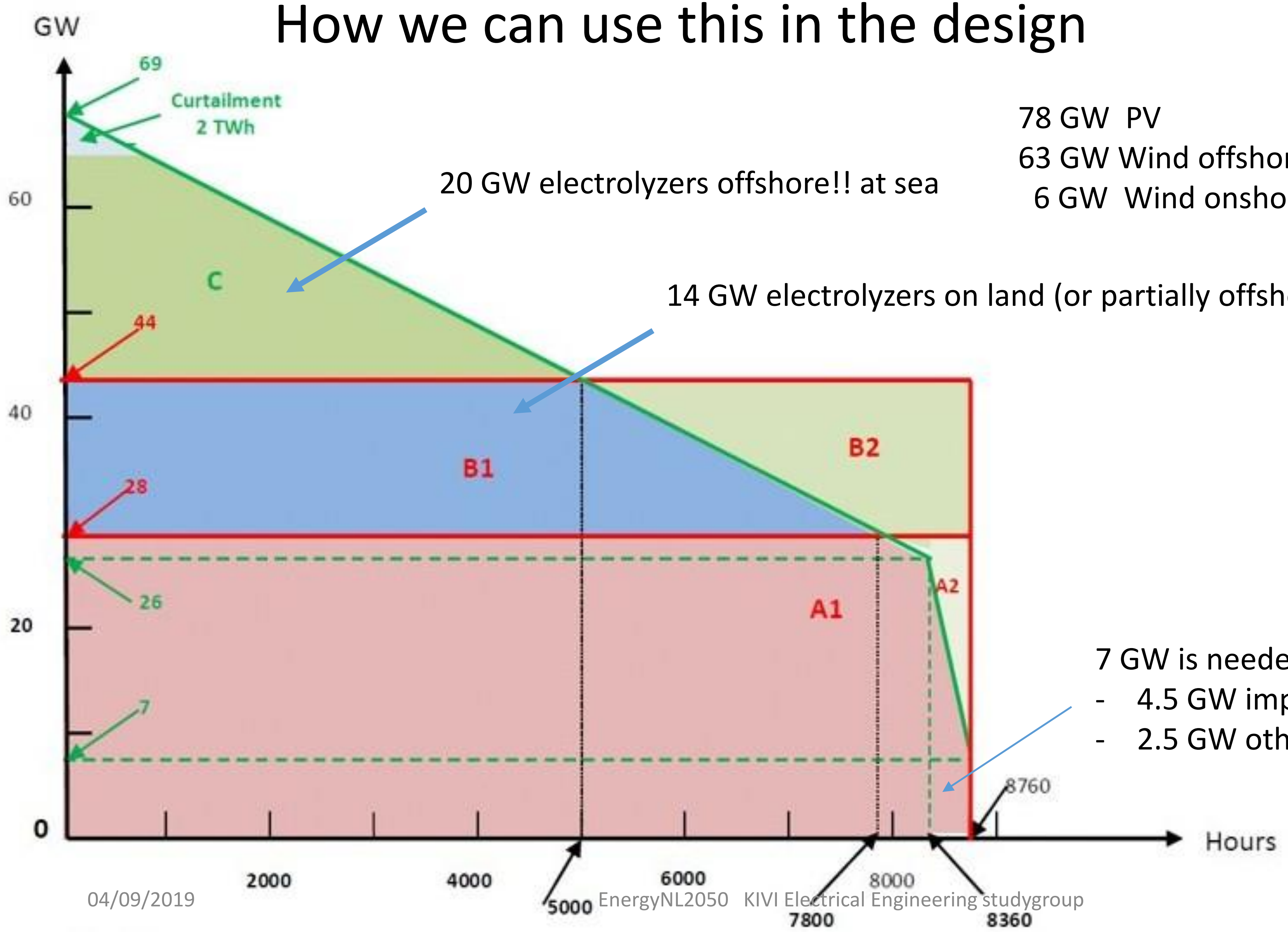
How we can use this in the design

78 GW PV
63 GW Wind offshore!! at Sea
 6 GW Wind onshore!! on land

20 GW electrolyzers offshore!! at sea

14 GW electrolyzers on land (or partially offshore!! at sea)

7 GW is needed
- 4.5 GW import
- 2.5 GW other renewable



Analysis of the energy demand 2050

1. **Economic growth 1% annualy** **Energy savings 1% annualy**

   Energy demand 2050 about equal to current demand (2015)

2. **Electrification and hydrogenation basis for the energy 2050 demand realization:**

. Low Temp Heat: heat pump (COP=4) + distributed heat net with surplus heat
. High Temp Heat: heat pumps + electrical burners + hydrogen gas burners
. Transport: Fully electric or combined with hydrogen plus fuel cells
for all transport sectors including shipping
but except aviation

Due to the much higher efficiency of heat pumps and electrical transmission a strong energy 2050 demand saving is realized, resulting in a 2050 demand of 358 TWh, for the 4 energy functions, delivered by electricity and hydrogen only:

electricity:	222 TWh + netlosses 19 TWh
hydrogen:	93 TWh (=3 Mton H2)
synth kerosine	3 TWh
surplus heat demand:	40 TWh

Avoiding Power peaks on the Dutch electricity network

Supply side

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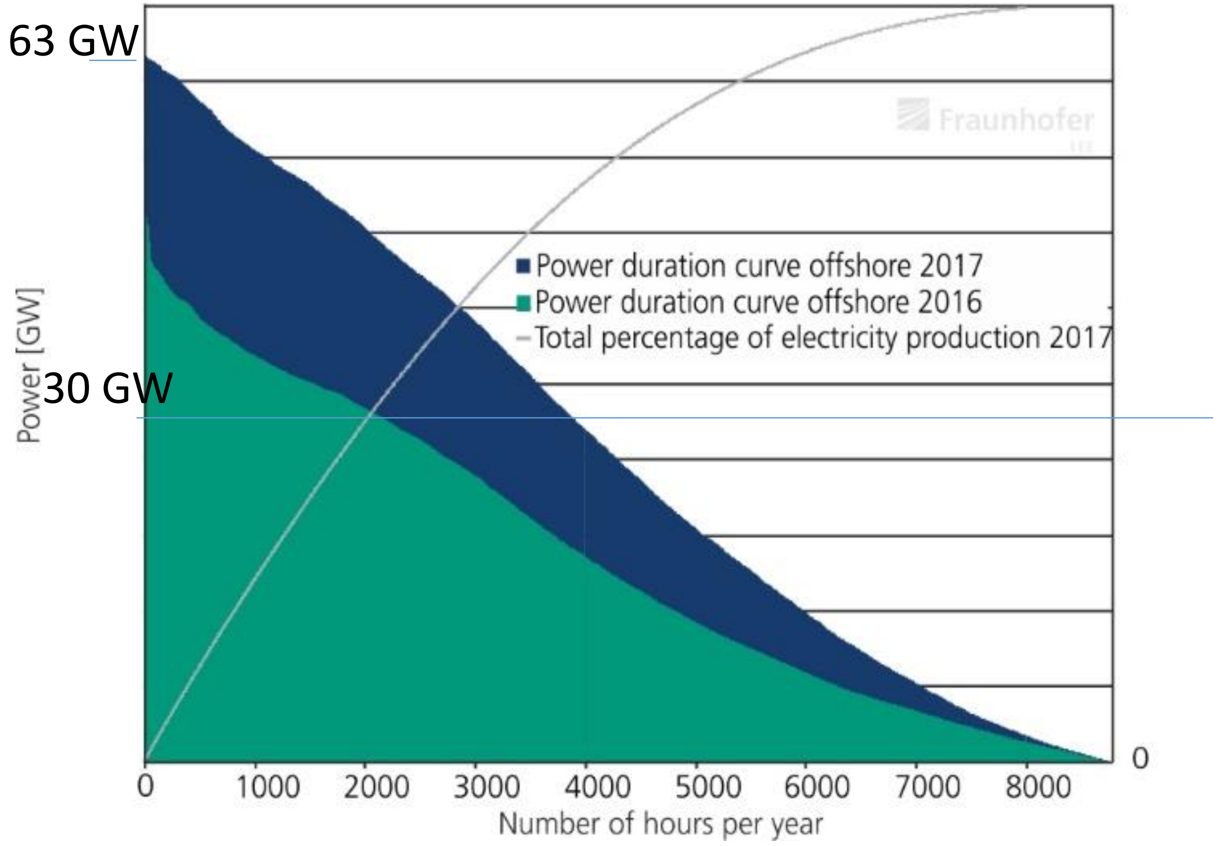
Wind at sea – avoid 30 GW power on Dutch network

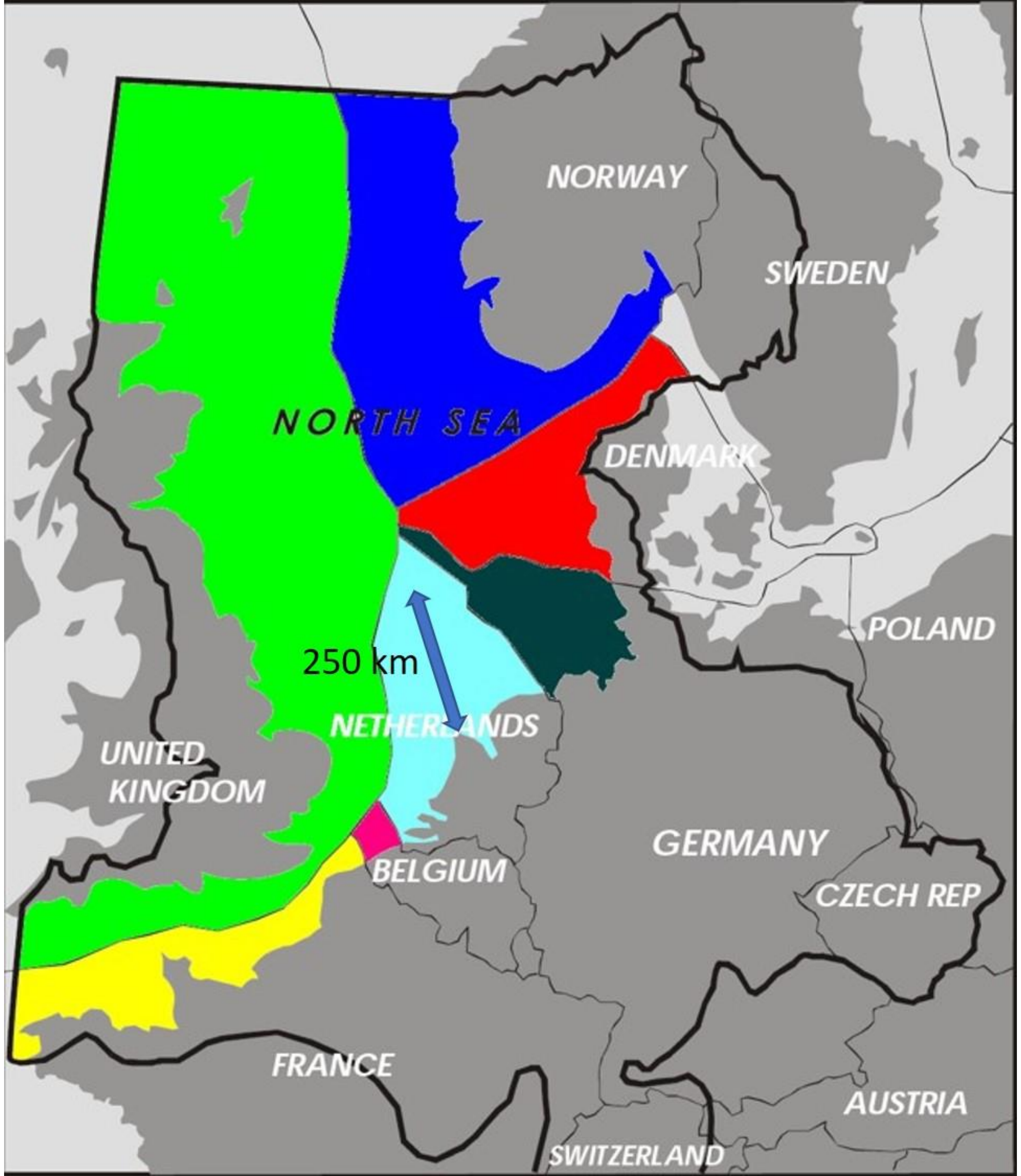


256 TWh is generated at sea (75% transmitted by cable)
Question : how to use the remaining 25 %

Option 1 : electrolyzers at sea
+ less cable costs
- loss of generated heat
- needs transport of very pure water

Option 2 : electrolyzers at sea coast
- higher cable costs
+ use of heat for heating homes

Option 3 : other ways to use excess electricity ?

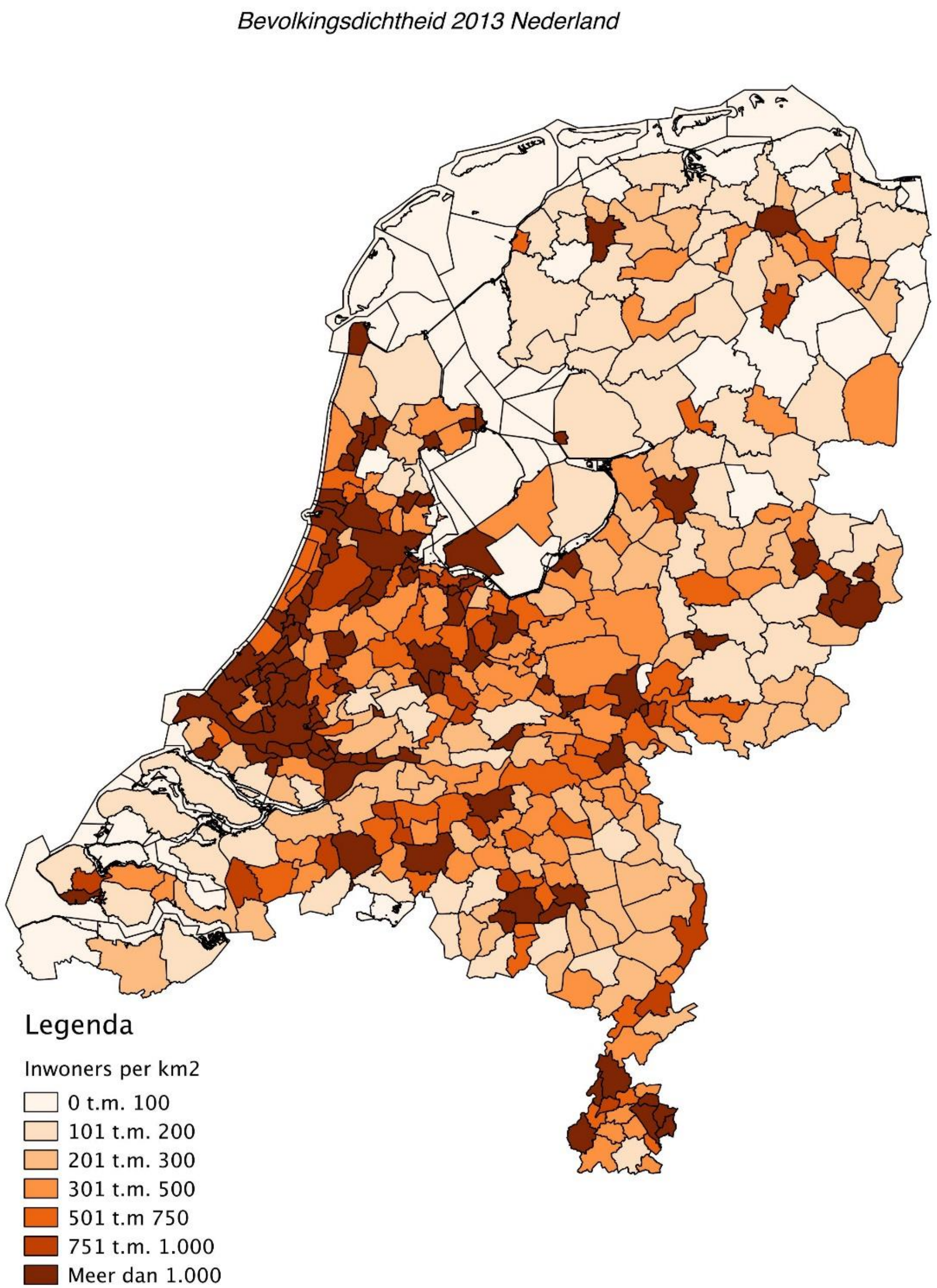


Cable cost

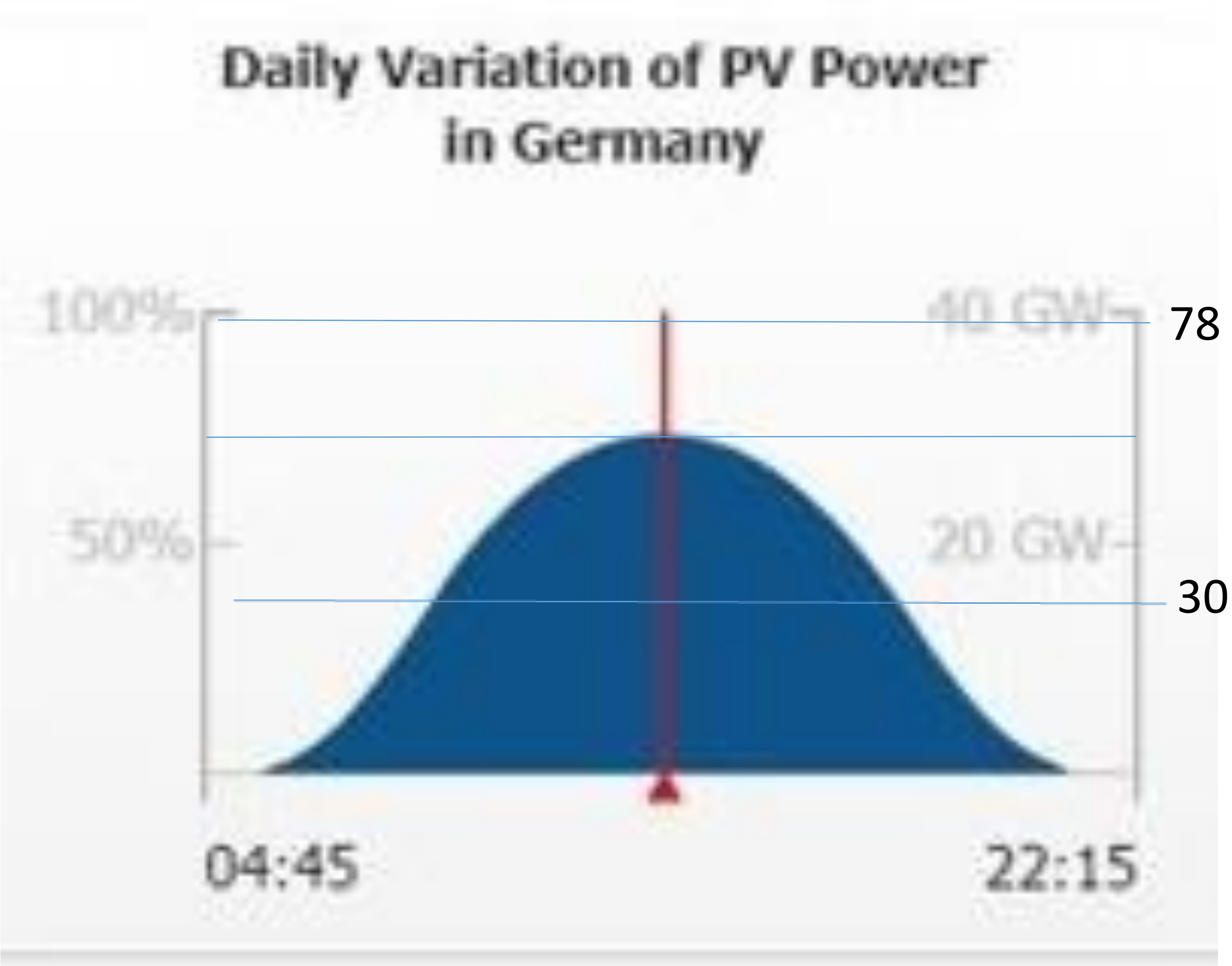
600.000 euro for 1 GW across 250 km

30 GW connection

18 Billion Euros


Bevolkingsdichtheid 2013 Nederland
Legenda
Inwoners per km2
0 t.m. 100
101 t.m. 200
201 t.m. 300
301 t.m. 500
501 t.m 750
751 t.m. 1.000
Meer dan 1.000

78 GW PV power



78 GW

30 GW

Store energy above 30 GW in batteries

How much is needed? About 200 GWh

Now 8.5 million passenger cars

In 2050 each one with 70 KWh battery

Total = 600 GWh

Important to place panels in East/West direction

Note : batteries can also be used for
other important purposes.

Needs better investigation!

Avoiding Power peaks on the Dutch electricity network

Demand side

Heat pumps

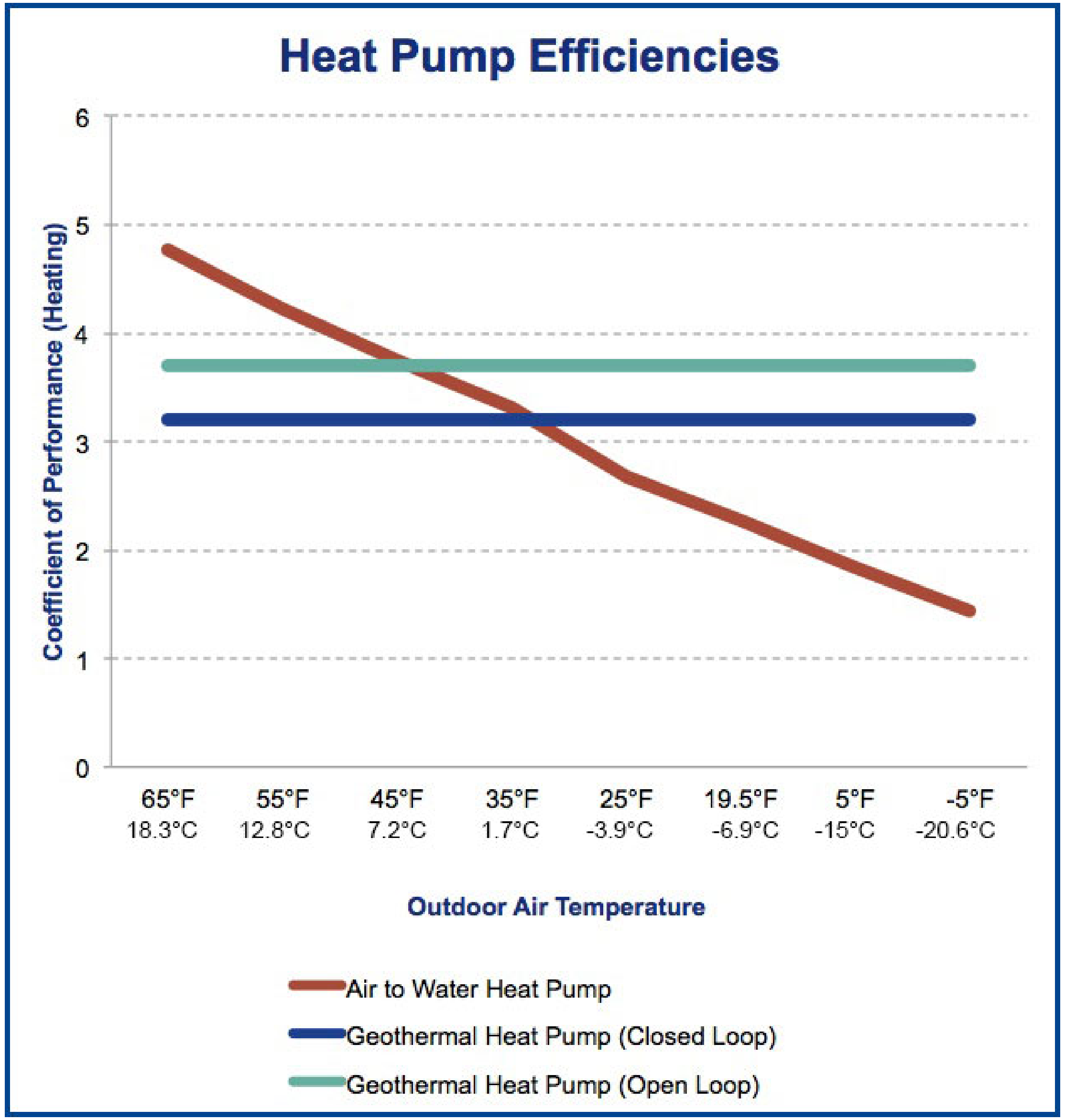
We assumed average COP = 4

Winter 2012-2013 long cold period
COP around 1.5

What would the increase in power be?
Needs careful analysis.

An estimate :
assume 4 million homes with heat pumps
Extra power 3 KW > 12 GW extra

Can homes be kept warm by other means?



EV charging stations

The demand for fast charging will increase!!

Charging stations with 350 KW already in use.
500 KW stations announced

Charging time around 30 minutes.
If several cars charge at the same moment (ex. After work driving home) the following may happen

2000 cars at the same time = 1 GW

Needs analysis : maybe batteries are needed at those stations

AIRCO’s

Summers with more than 40 degrees will happen more often

Homes are well insulated against cold weather but keep warmth inside!!

An airco requires 4 KWatt……..

Again : needs careful analysis

Back up power generation

Back up power generation

About 21 GW fast backup power is needed.

We prefer fuel cells as the solution

At the moment we have about 100.000 heavy trucks in Holland

We expect them to use fuel cells in the future, each with a power of 250 Kwatt.

That is a total of 25 Gwatt.

That is similar to the back up requirements.

Other important issues

Where to get sufficient heat to feed heat networks?
geothermal heat is limited and not garantueed.

Lifetime of electrolyzers and fuel cells under fast variable load

More investigation is needed