Energy/smart grid solutions in arable and dairy farming

Results PPS Energie & landbouw

Andries Visser 24 April 2024

Potential agriculture

- Part of the Dutch energy ambition on renewable energy must be realised through the Regional Energy Strategy (RES: Total 35 TWh on land)
- Rough estimation of contribution of agriculture

Berekening van de potentiële energieproductie uit zon

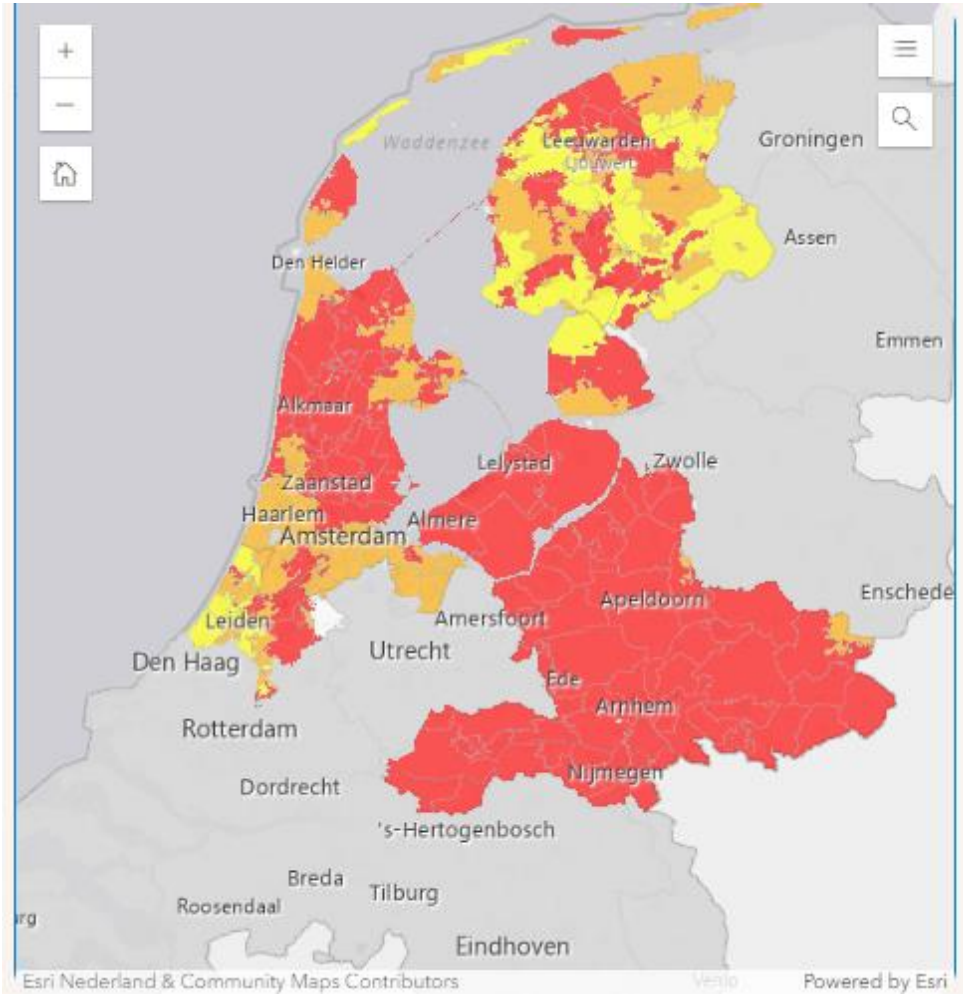
Oppervlakte dak (m²)	1.000
Aantal zonnepanelen	625
Totale opwek per 1.000 m² (KWh)	208.000
Aantal agrarische bedrijven	53.200
Totale opwek bij 1.000 m² per bedrijf (TWh)	11,06

Berekening van de potentiële energieproductie uit kleine windmolens bij verschillende windsnelheden

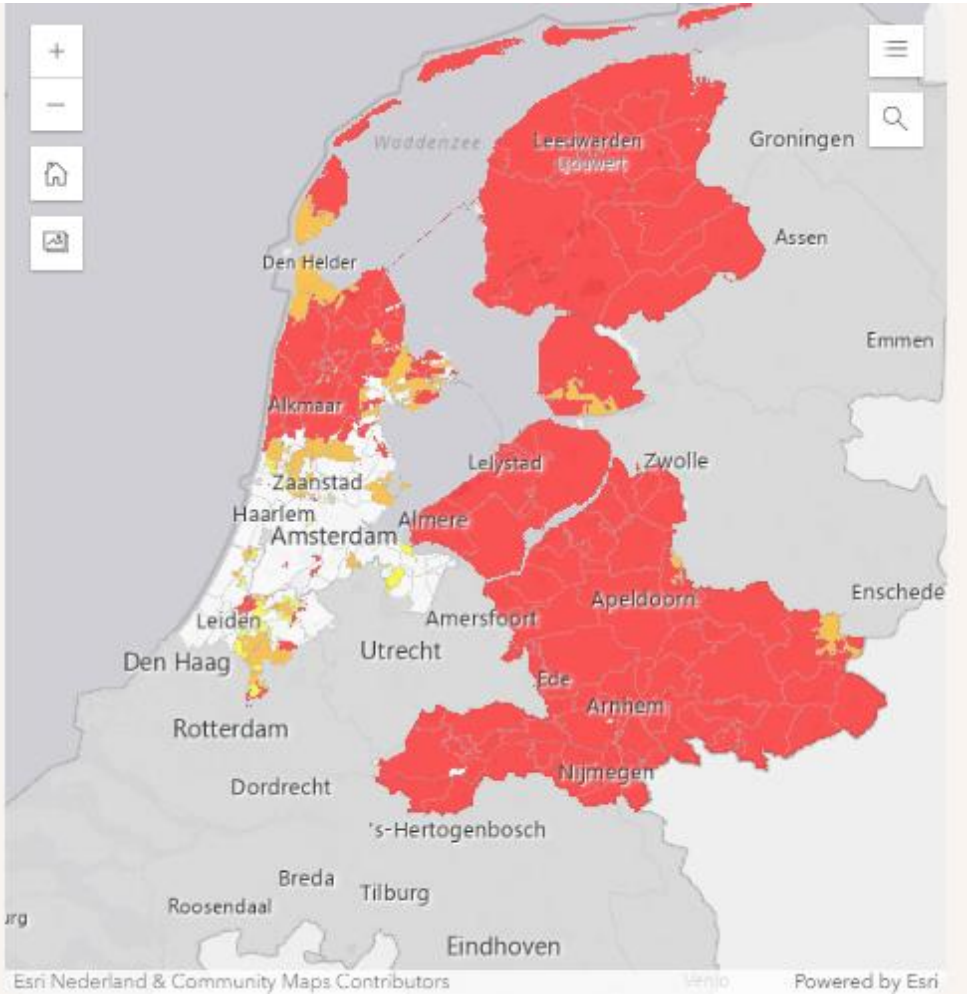
Aantal agrarische bedrijven 53.200	Windsnelheid		
	4m/s	5m/s	6m/s
1 windmolen per bedrijf (KWh)	44.600	72.600	98.100
Ieder bedrijf 1 windmolen (TWh)	2,37	3,86	5,21

Uptake and delivery of energy (high consumption connection)

Availabilty energy uptake



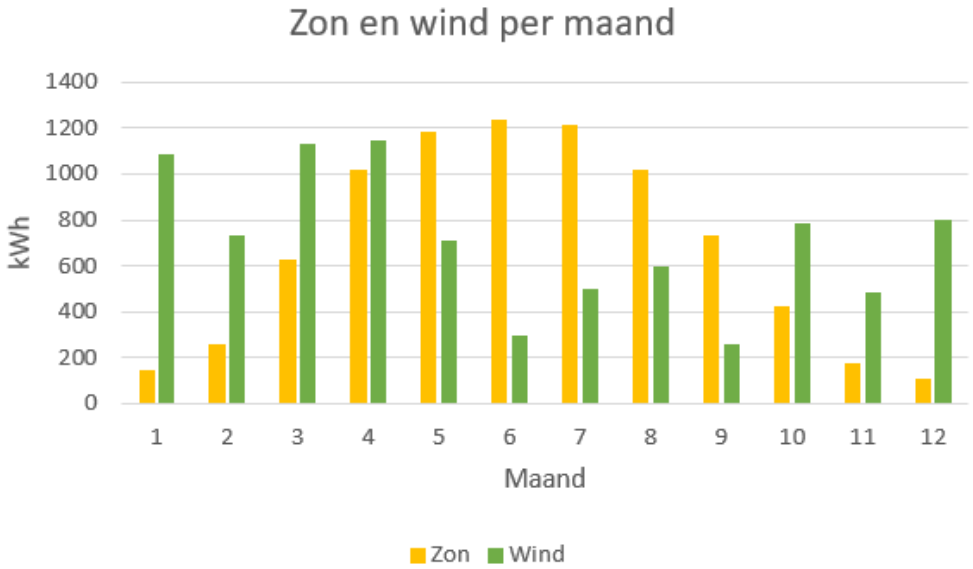
Availability energy delivery

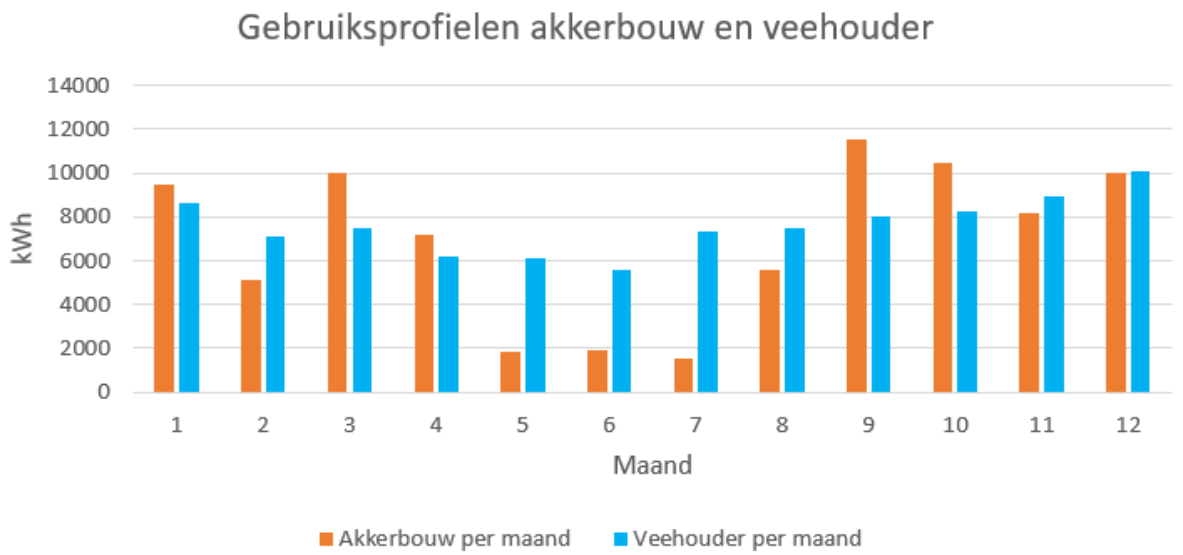


Energy generation through wind en solar PV

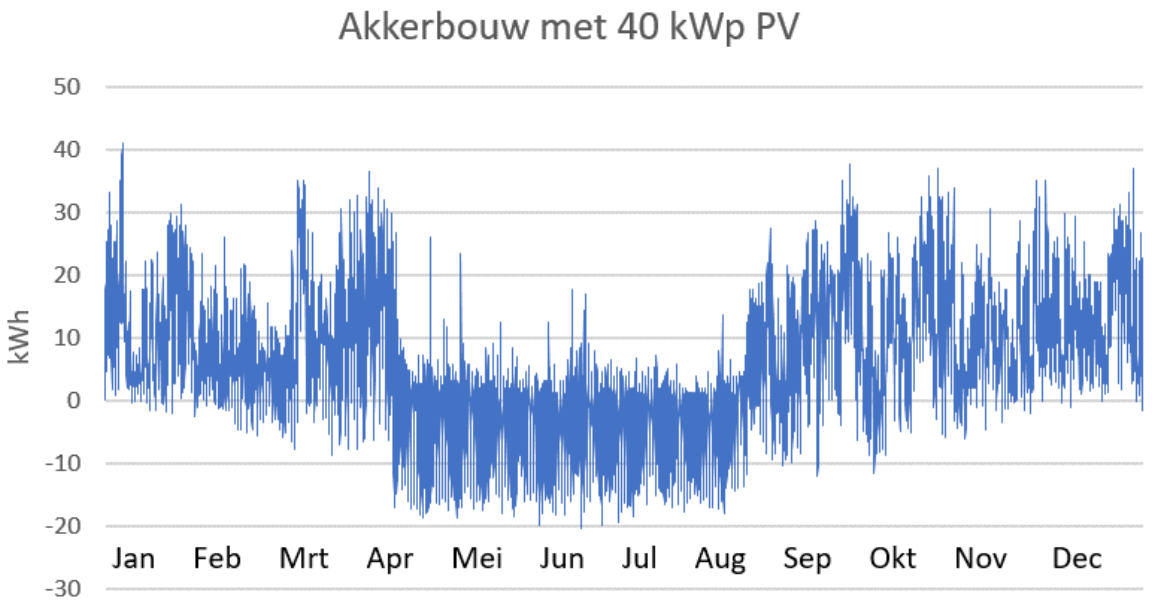
- Solar panels: already very interesting, short ROI.
- With small consumer connection (up to 3x 80A), you can in principle always supply energy to the grid
  - Max 55kW Peak = about 130 panels 420W Peak
- Supply is interesting, use in own company as well:
  - Lower energy costs
  - Reduction farm's CO2 footprint

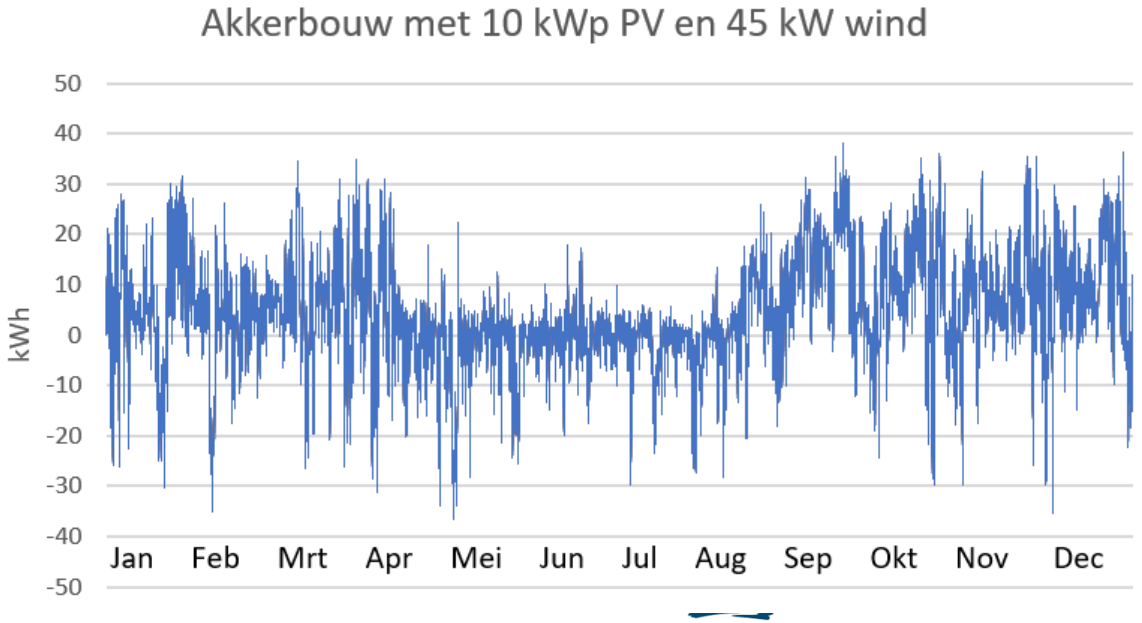
Importance of small windturbines for own energy consumption on a farm





Purchase -& supply profile PV & PV + wind





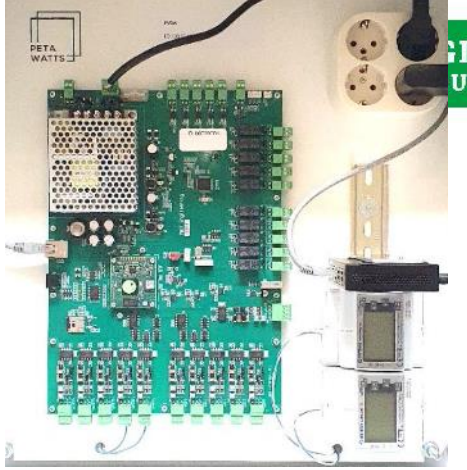
Conclusion

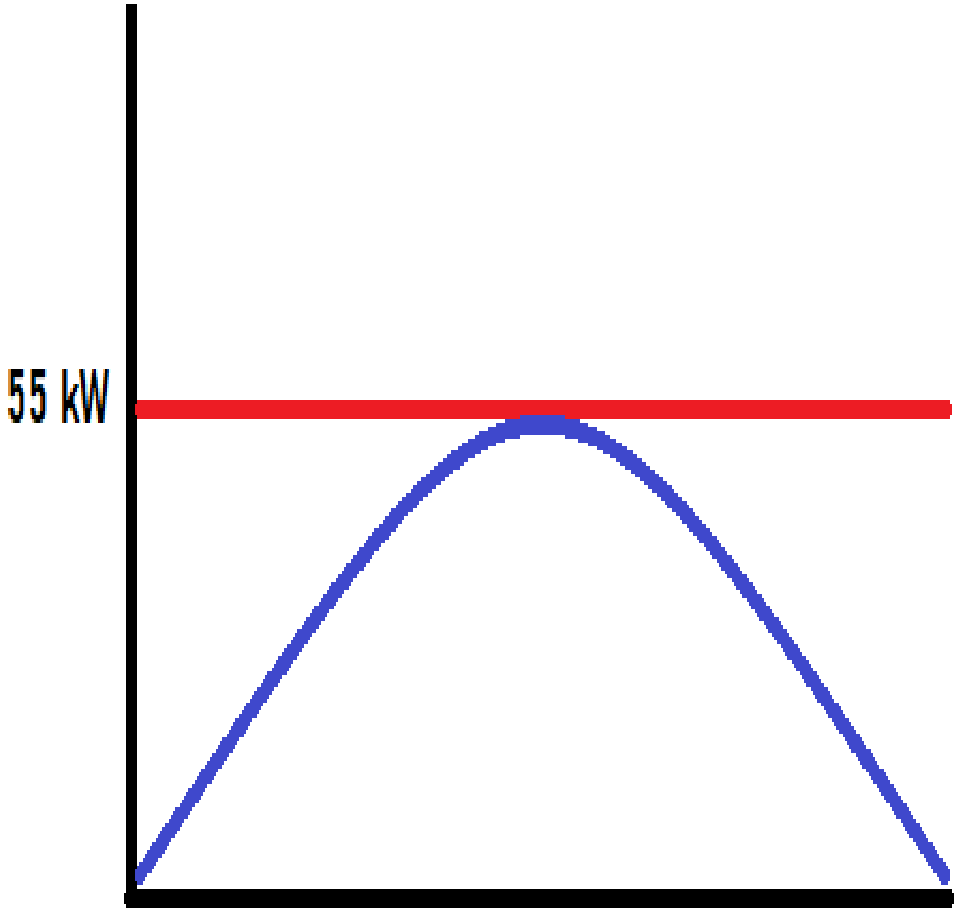
Energyflows in arable and dairy farms:

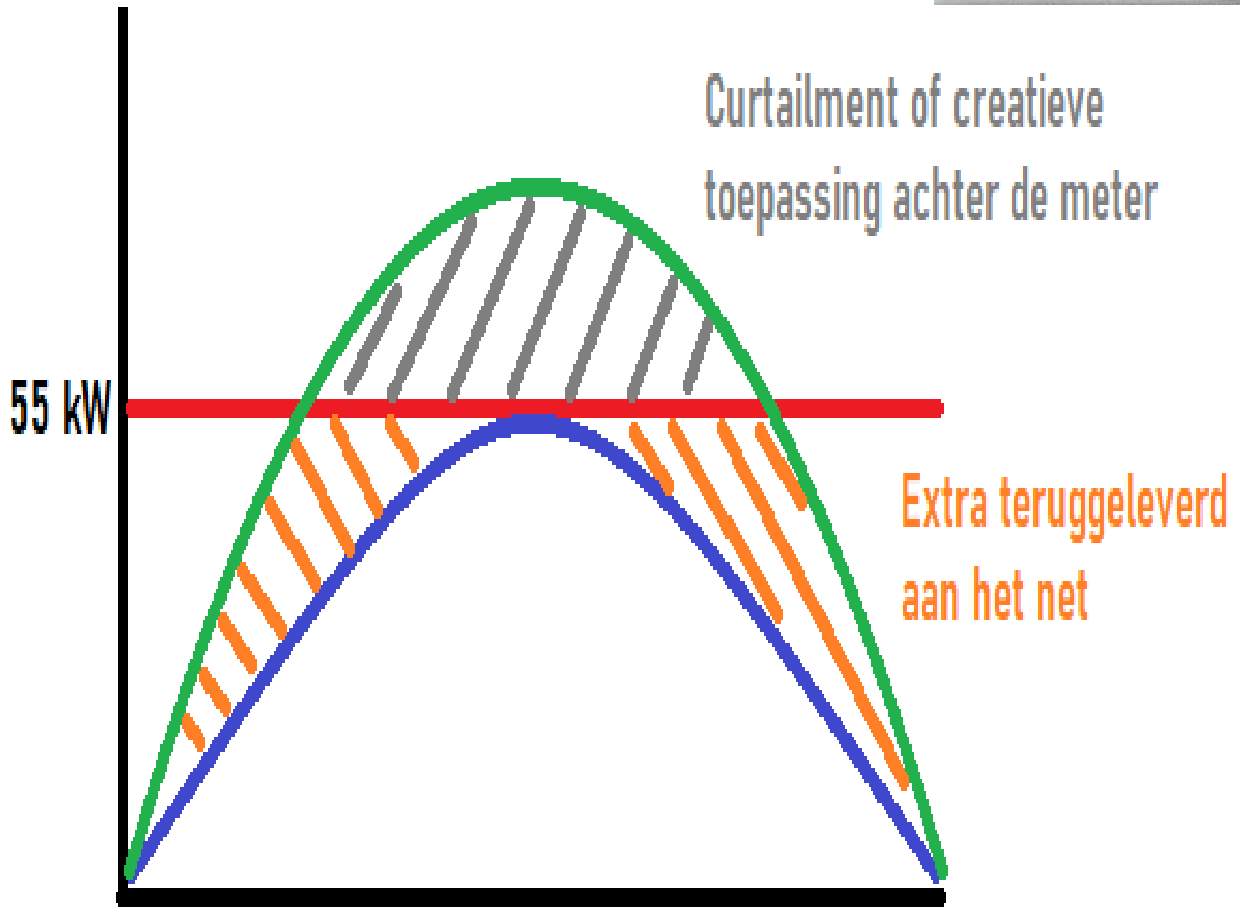
	Akkerbouw Alleen 40 kWp PV	Akkerbouw PV en Wind	Veehouderij Alleen 40 kWp PV	Veehouderij PV en Wind
Elektrabehoefte	83.000 kWh	83.000	91.000	91.000
Zelf opgewekt en direct gebruikt	16.500	43.750	25.000	60.500
Percentage direct gebruikt	20%	53%	27%	66%
Elektra ingekocht bij het net	66.500	39.250	66.000	30.500
Elektra terug geleverd	16.000	34.250	7.000	40.500

- Installation of small wind turbine results in better energy profile linked to own use

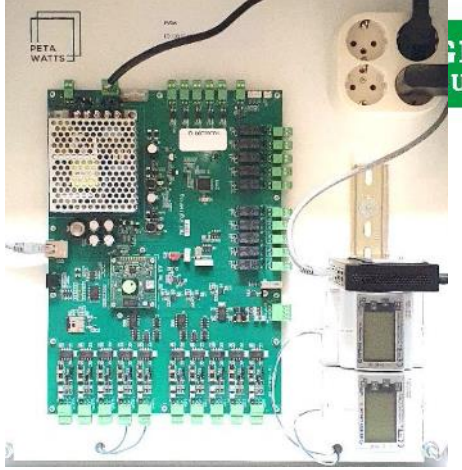
Business models behind the meter







Business models behind the meter



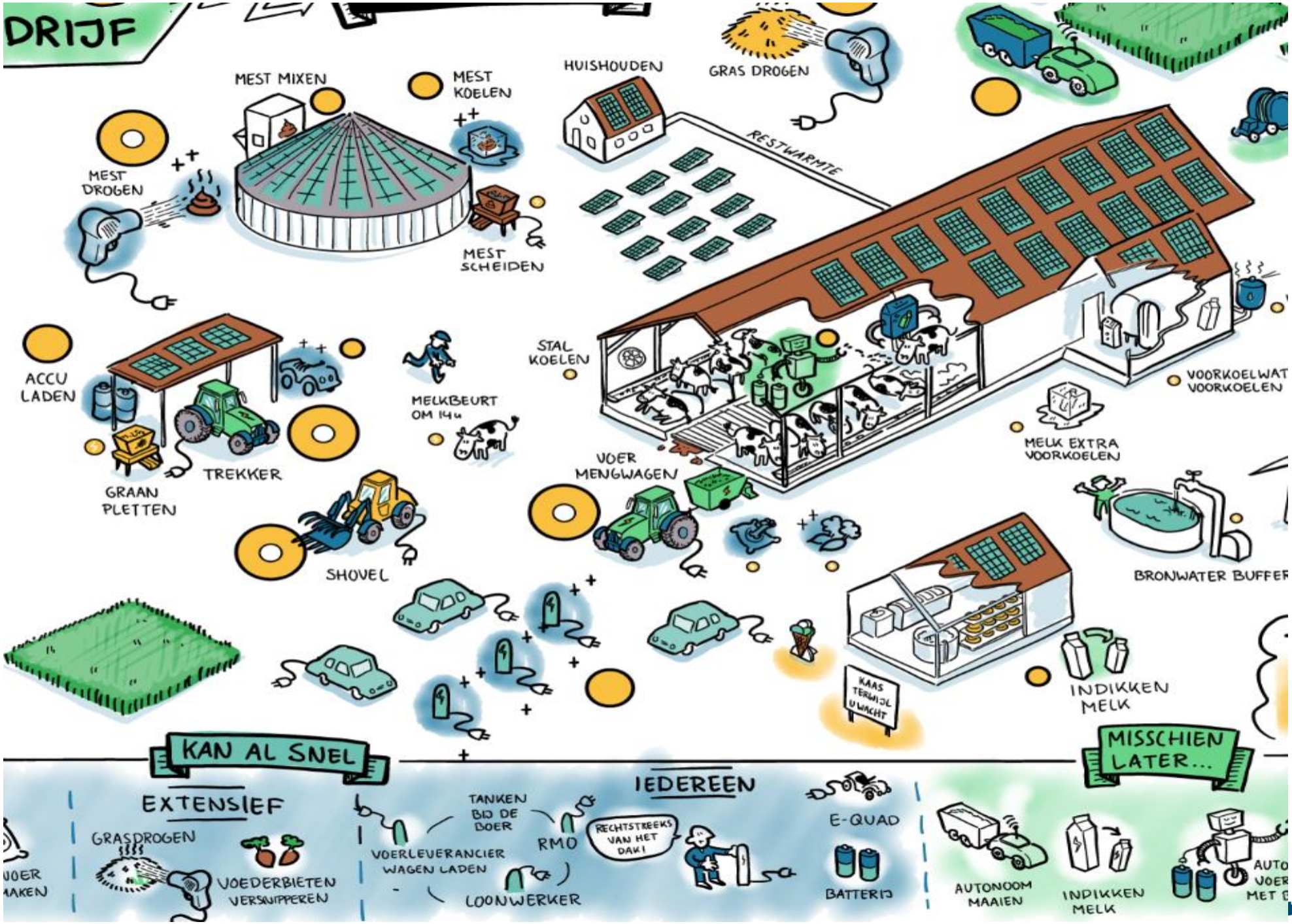
- With 3x 80A connection 6 times as many solar panels (330KW peak)
- Supplying more to the grid outside peak times
- Switching off at peaks (>55kW)
- Surplus to be used for other processes, the more use, the shorter payback period
- Storage & energy management system incl. response to flexible prices
- Return on investment after +- 5-7 years, decreases as residual energy (over 100,000kWh) can be used for other processes

Optimising energy system on the farm: flexible power behind the meter

1. Shift own electrical energy use to peak times production (11 -15 hours)

1. Electrifying processes (replacing diesel, e.g. electric sprinkling)

2. Adding processes (e.g. grass drying, manure cooling, barn cooling, H2 production, processing)Grid operator also seeks flexible power


DRIJF
MEST MIXEN
MEST KOELEN
MEST DROGEN
MEST SCHEIDEN
HUISHOUDEN
GRAS DROGEN
RESTWARMTE
ACCU LADEN
GRAAN PLETTEN
TREKKER
MELKBEURT OM 14u
STAL KOELEN
VOORKOELWAT VOORKOELEN
MELK EXTRA VOORKOELEN
VOER MENGWAGEN
SHOVEL
BRONWATER BUFFER
KAAS TERWIJL U WACHT
INDIKKEN MELK
KAN AL SNEL
EXTENSIEF
GRASDROGEN
VOEDERBIETEN VERSNIPPEREN
IEDEREEN
TANKEN BIJ DE BOER
VOERLEVERANCIER WAGEN LADEN
RMO
LOONWERKER
RECHTSTREEKS VAN HET DAK!
E-QUAD
BATTERIJ
MISSCHIEN LATER...
AUTONOOM MAAIEN
INDIKKEN MELK

ENERGIE IN BOERENBEDRIJF

AKKERBOUW NU:

Renewable energy self-use: Electric irrigation

- Interesting as flexible power:
  - Deployment when there is a lot of sun
  - Grid relief at peak times

Comparison of energy use and related emissions at farm level (2018)

Tabel 2. Beregening: energiebehoefte, economisch, CO_2-uitstoot en NO_x-emissie

Op bedrijfsniveau	Diesel	Elektrisch	Zon-PV
Energieverbruik	855 liter	8.030 kWh	8.030 kWh
Economisch[1]	€ 940,-	€ 370,-	€ 160,-
CO_2-uitstoot[2]	2.760 kg CO_2	1.115 kg CO_2	110 kg CO_2
NO_x-emissie[3]	15 kg NO_x	-	-

[1]: EUR 1,10 liter en EUR 0,14 kWh en EUR 0,06 kWh voor Zon-PV (KWIN 2018)

[2]: Op basis van 3,23 kg CO_2/liter uitstoot diesel en 0,413 kg CO_2/kWh uitstoot elektriciteit (CO_2-emissiefactoren.nl) en 0,042 kg CO_2/kWh voor zonne-energie op daken (Schlömer *et al.*, 2014)

[3]: Op basis van 3,3 gram/kWh (stage IIIB) op basis van Aerius.nl.

- Lower energy costs with electric irrigation
- CO2 emissions down by 60%, 95% with own solar PV

Surplus of energy using in storage

	Hoeveelheid ton	Bewaarduur weken	Besparing € / jaar
Aardappelen, cons.	508	28	€ 1,294
Aardappelen. Poot	624	32	€ 1,625
Zaaiuien	477	32	€ 1,836
Winterpeen	639	27	€ 1,588

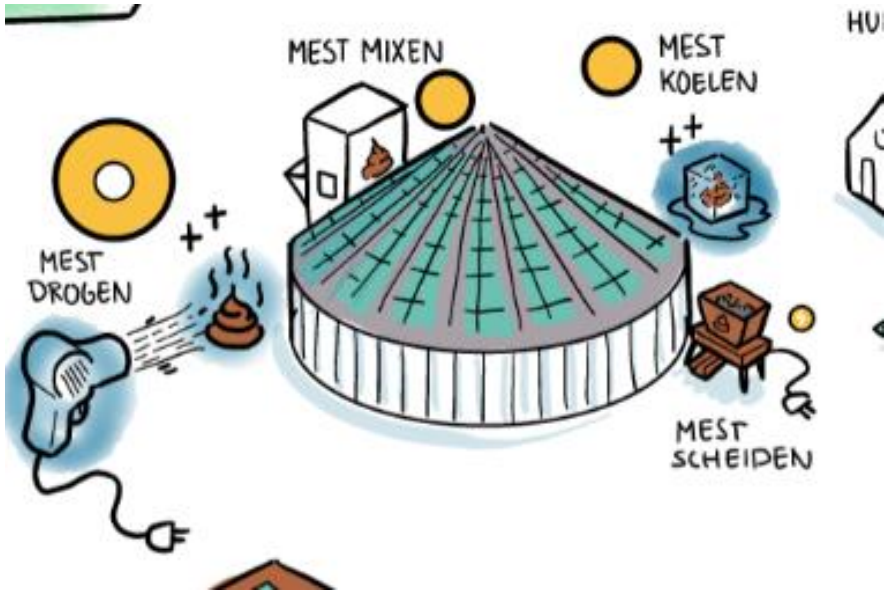
Manure cooling

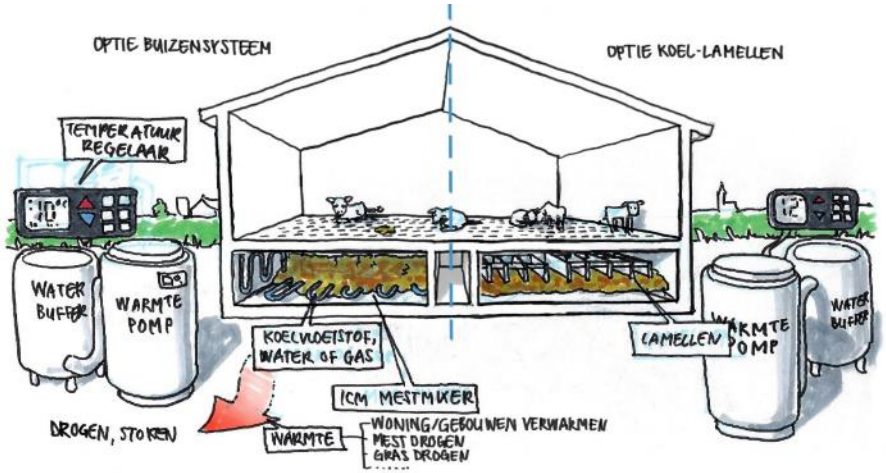
Benefits:

- Expected reduction in ammonia and methane emissions from manure
- Additional methane production from fermentation ('fresh' manure)
- Heat from manure for home or other processes
- Relatively high electricity consumption
- In combination with existing digester, positive financial result expected due to additional biogas revenues

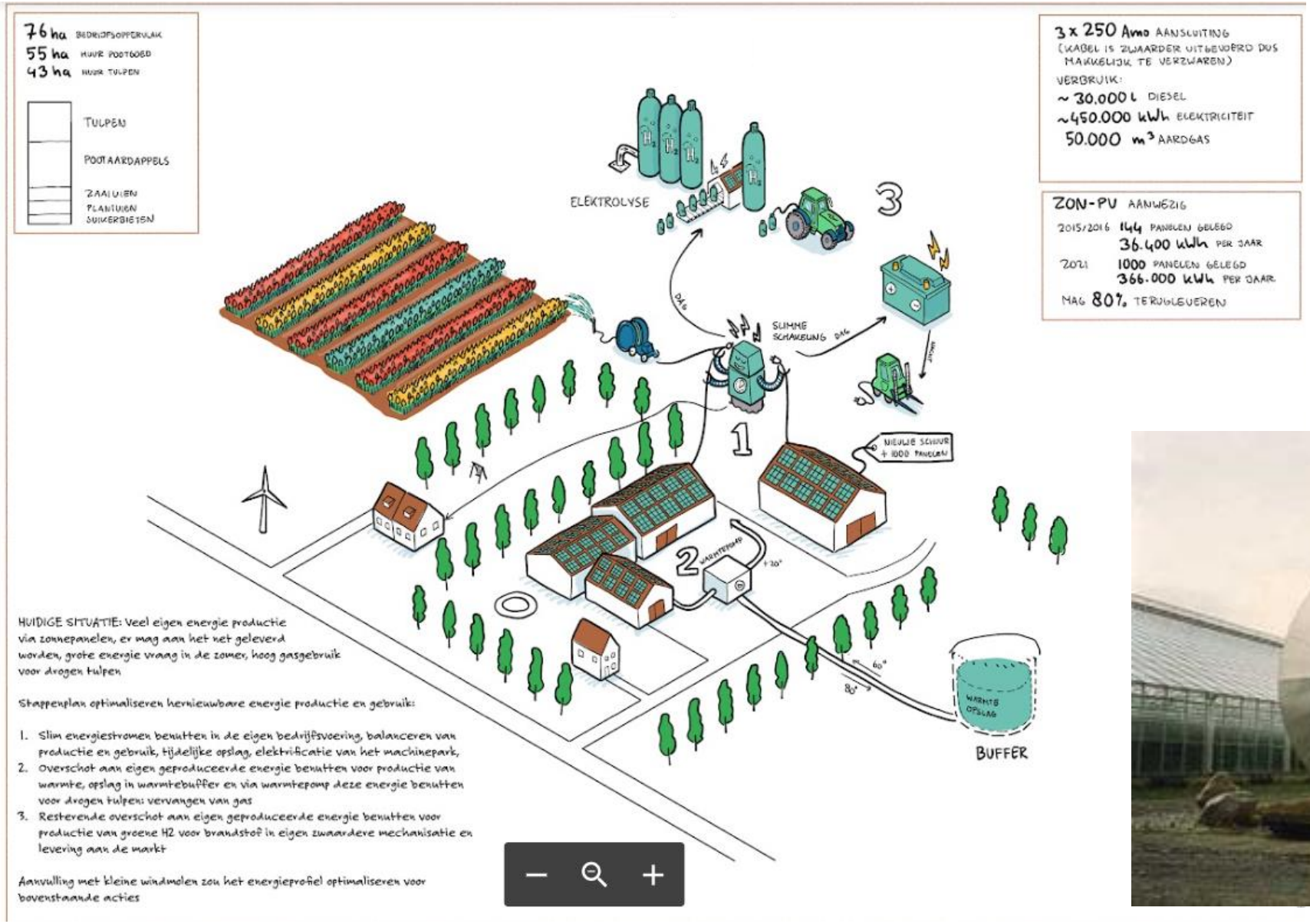
Disadvantages

- Technology under development
- Electricity consumption year-round
- Heat production in summer





Heat storage / heat pump (bulbs)



Grass drying

- Use grass or grass pellets partly as replacement for feed concentrates
- Electricity use can be relatively high depending on the installation chosen/with or without pre-drying
- Drying season coincides with solar peak moments

Small consumer package

Installation

- 150 kWp (±375 panelen) pv
- Battery 50 kW/ 150 kWh
- Trade & control box (Peta watts)
  - Onbalans markt
  - Epex
- Dynamic energy contract

Calculation example

Arable farm with potato storage- 50 ha

Contract: **Fixed** contract
Consumption: 100.000 kWh
Production: -

Connection: 3x80A (55 kW)
Solar PV: -
Battery: -

Kosten - Energiecontract

Consumptie		
Afname van het net	**100.000**	**kWh**

Productie		
Levering aan het net	**-**	**kWh**

Energiekosten		
Kosten afname (12,5ct)	€	12.500,00
Netvergoeding	€	6.000,00
Energiebelasting	€	7.249,30
Energiekosten zonder PV	**€**	**25.749,30**

Calculation example
Arable farm with potato storage- 50 ha

Contract: Dynamisch+
Consumption: 100.000 kWh
Production: 130.004 kWh

Connection: 3x80A (55 kW)
Solar PV: 150 kWp
Battery: 50 kW / 150 kW

Kosten/opbrengsten Zon + Batterij + Box

Consumptie				**Productie**			
Afname van het net		**84.950**	**kWh**	**Levering aan het net**		**99.252**	**kWh**
Prijs afname	€	0,08	/ kWh	Prijs levering	€	0,10	/ kWh
Kosten afname	**€**	**6.736,76**		**Opbrengsten levering**	**€**	**9.971,94**	

Energiekosten		
Kosten afname	€	6.736,76
Netvergoeding	€	-
Energiebelasting	€	-
Kosten Agem (0,6ct / kWh)	€	1.105,21
Kosten Peta Watts (100 pm)	€	1.200,00
Opbrengsten levering	€	(9.971,94)
Totaal Energiekosten	**€**	**-929,96**

Verlaging energiekosten pj	**€**	**26.679,26**

Calculation example
Arable farm with potato storage- 50 ha

Investments

Invesment	€150.000
EIA 11%	€ 16.500 -
Investment incl EIA	**€133.500**

Own financing

Investment	€133.500
Annual saving	€ 26.679

ROI: **5,0 year**

External financing

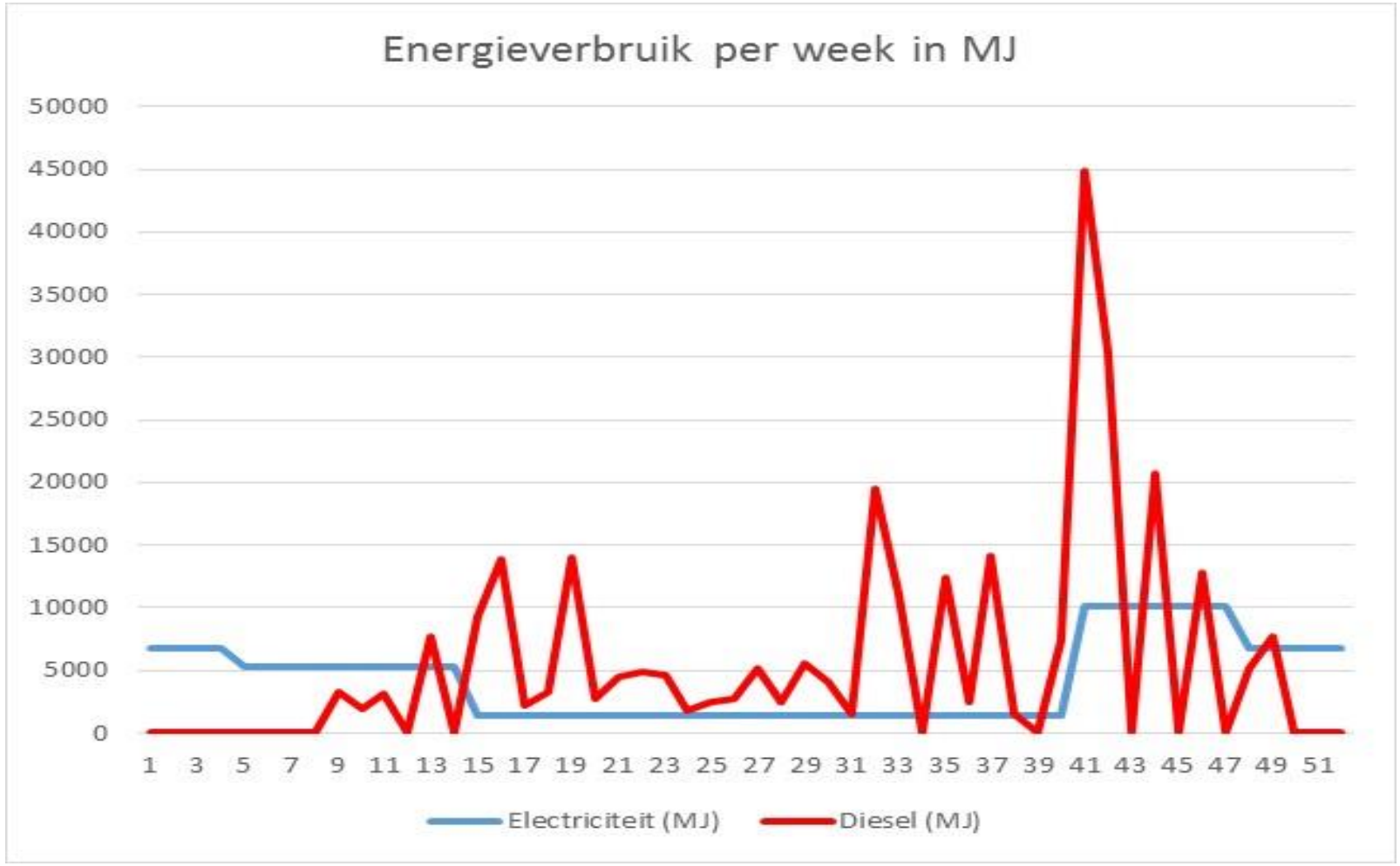
Investment		€133.500
Annual saving	€ 26.679	
Total interest		€ 3.505 -
Cost reduction		€ 23.674

ROI: **5,6 jaar**

Notes:

- Possible subsidy for batteries on solar panels (€3,000 - 6,000) not yet included.

Model Arable farm 60 ha



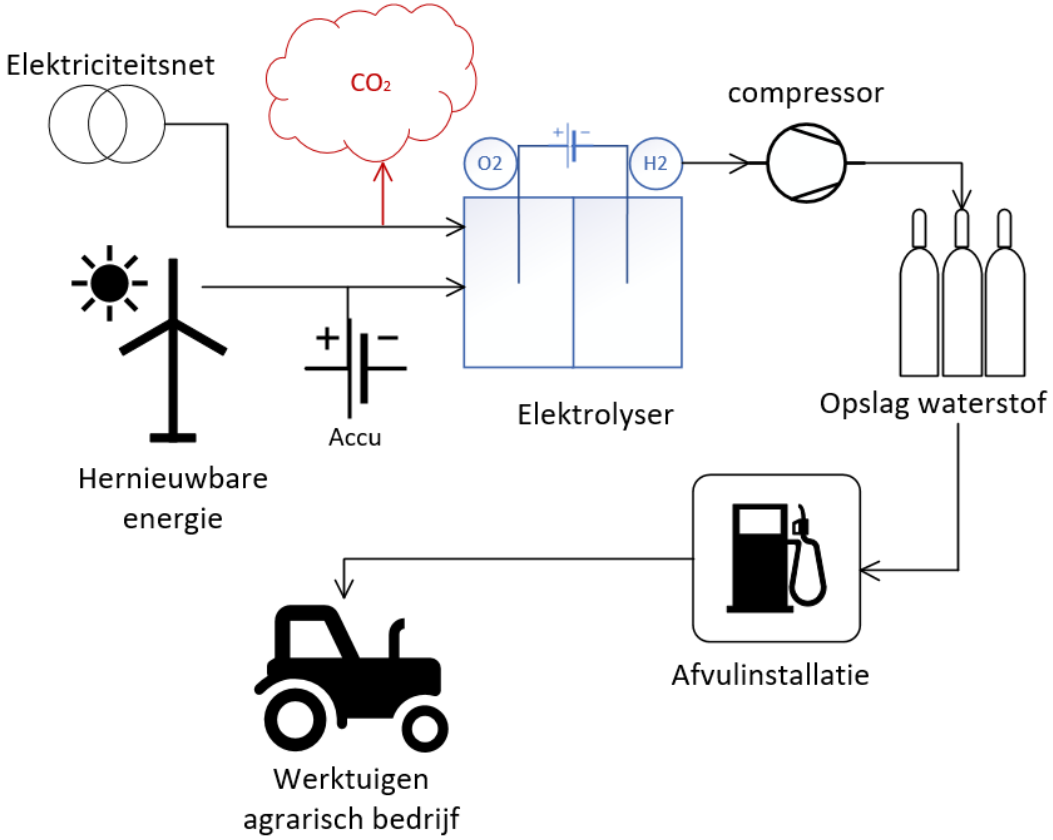
Challenge: - replacement of diesel with renewable energy

- imbalance production & use: Hydrogen

Challenge transition to H2 in agriculture

- Affordable agricultural mechanisation on H2
- Availability green H2

Businesscase Arable farm

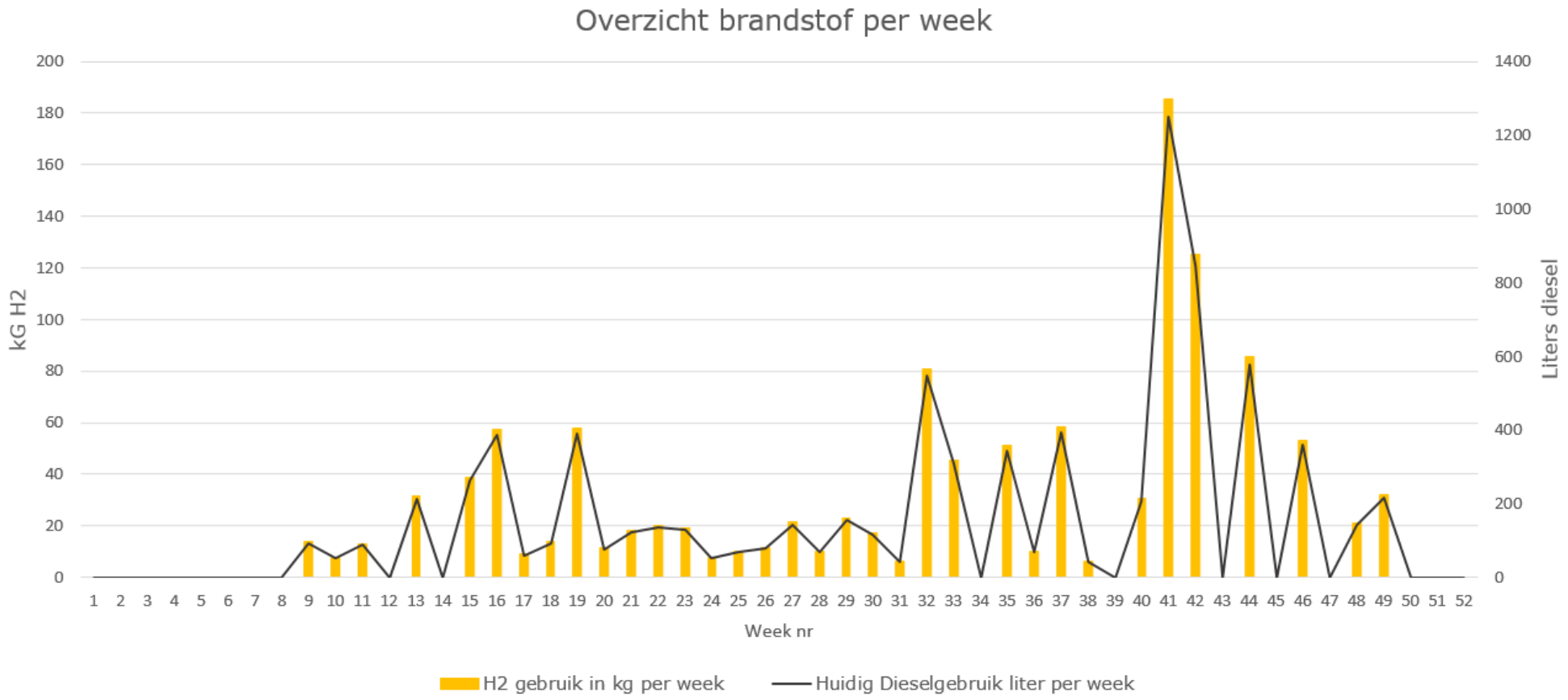


- Calculation of diesel use on basis of KWIN
- 1 kg H2 equivalent to 6,58 liter diesel (fuelcell)

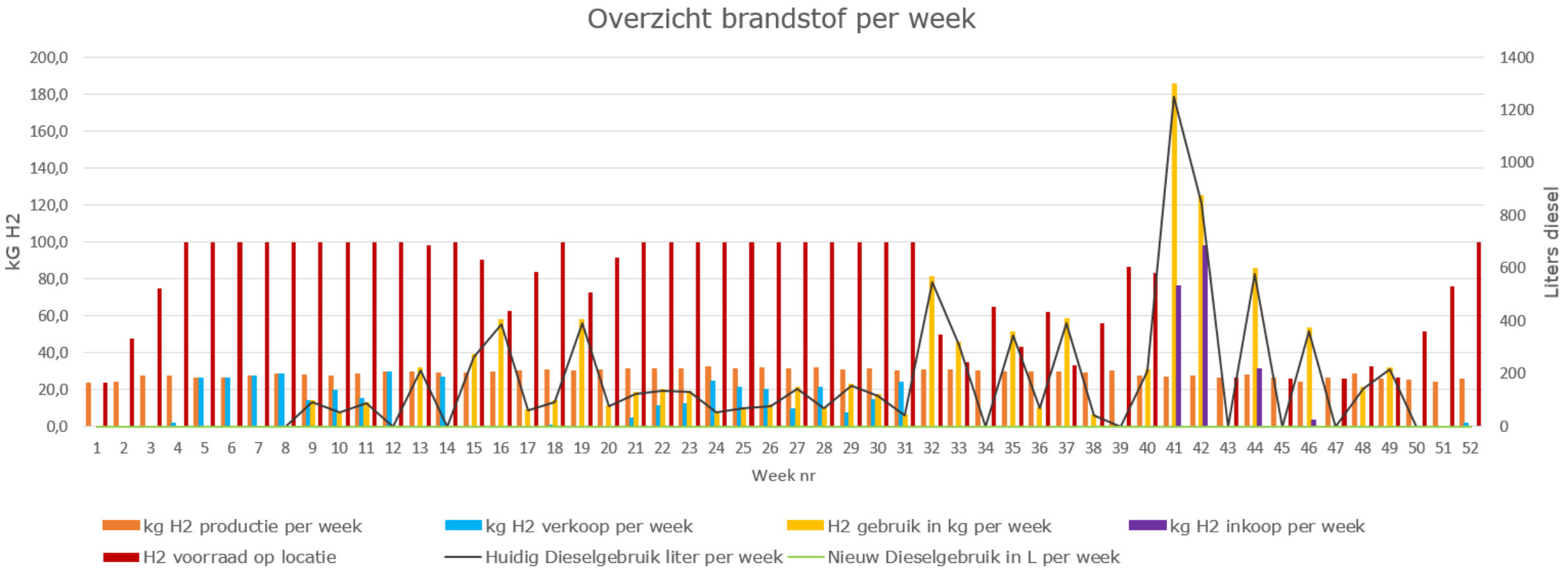
  Chang, C.C., P.C. Huang, J.S. Tu, 2019. "Life cycle assessment of yard tractors using hydrogen fuel at the Port of Kaohsiung, Taiwan." Energy, no. 189: 116222.
- If 1 liter diesel = €1,50 , costprice of 1 kg H2 max €9.87/kg

Diesel use 1 farm

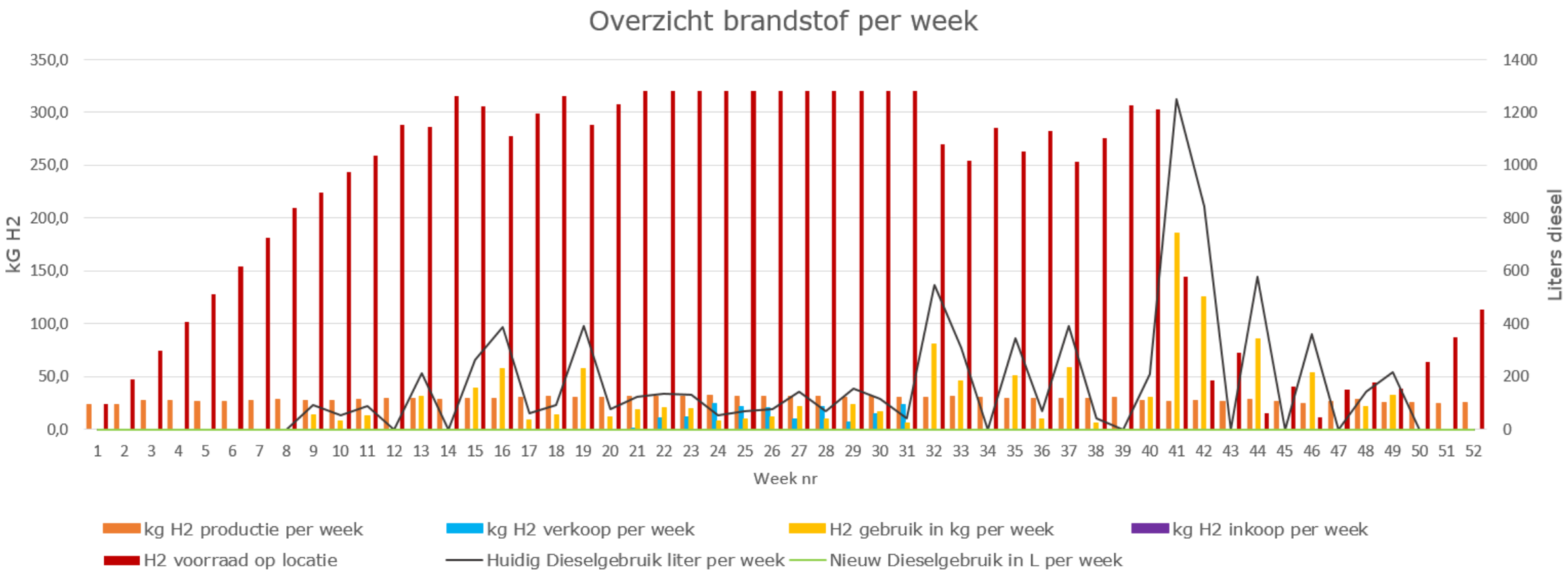
Arable farm Ca. 60 ha (South West rotation scheme) : Ca. 8100 liter diesel per year



Small storage



Larger storage



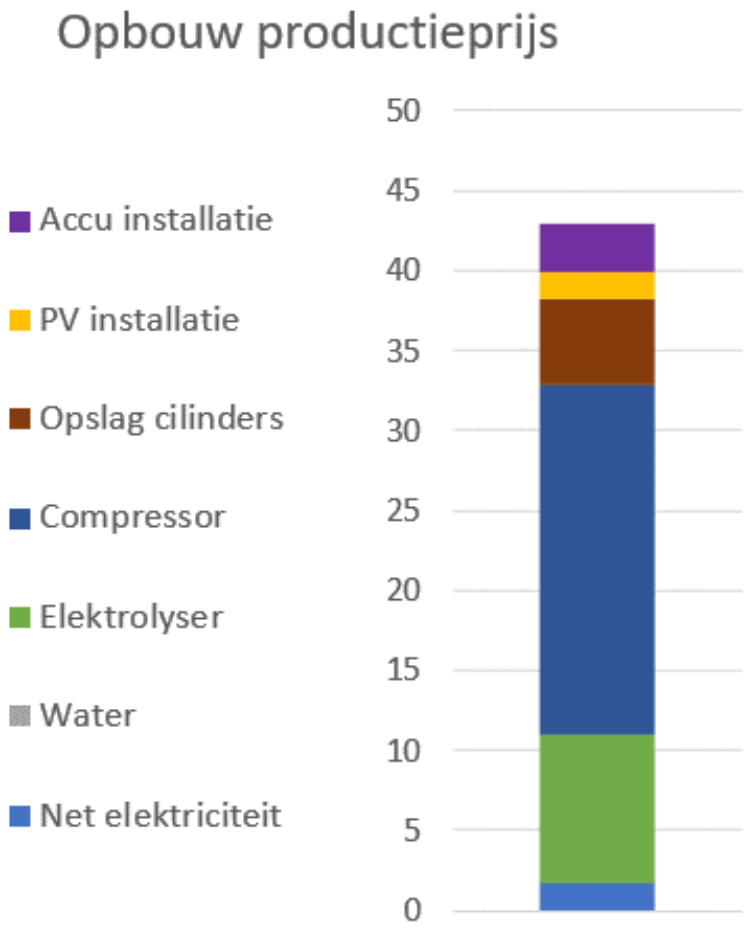
Price built-up

Dimensions

- 12 kW electrolyser
- 300 kWp PV panels
- 50 kW / 50 kWh battery
- 29.6% power from grid
- 320 kg hydrogen storage capacity

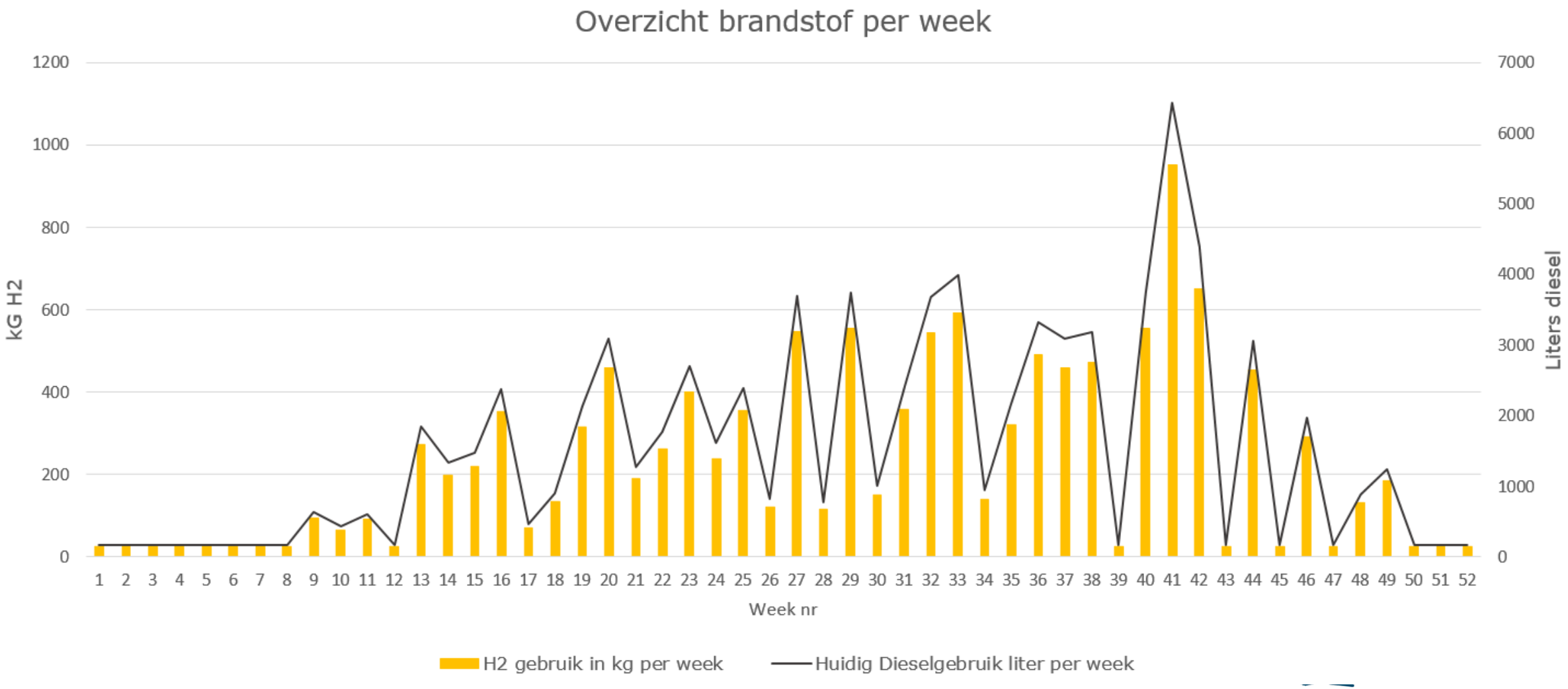
Results:

- Approx. 1200 kg H2 use per year
- 7000 Full load hours
- Production price: €42.97 /kg.
- Excl.
  - Licensing procedure
  - Filling station
  - Hydrogen tractor



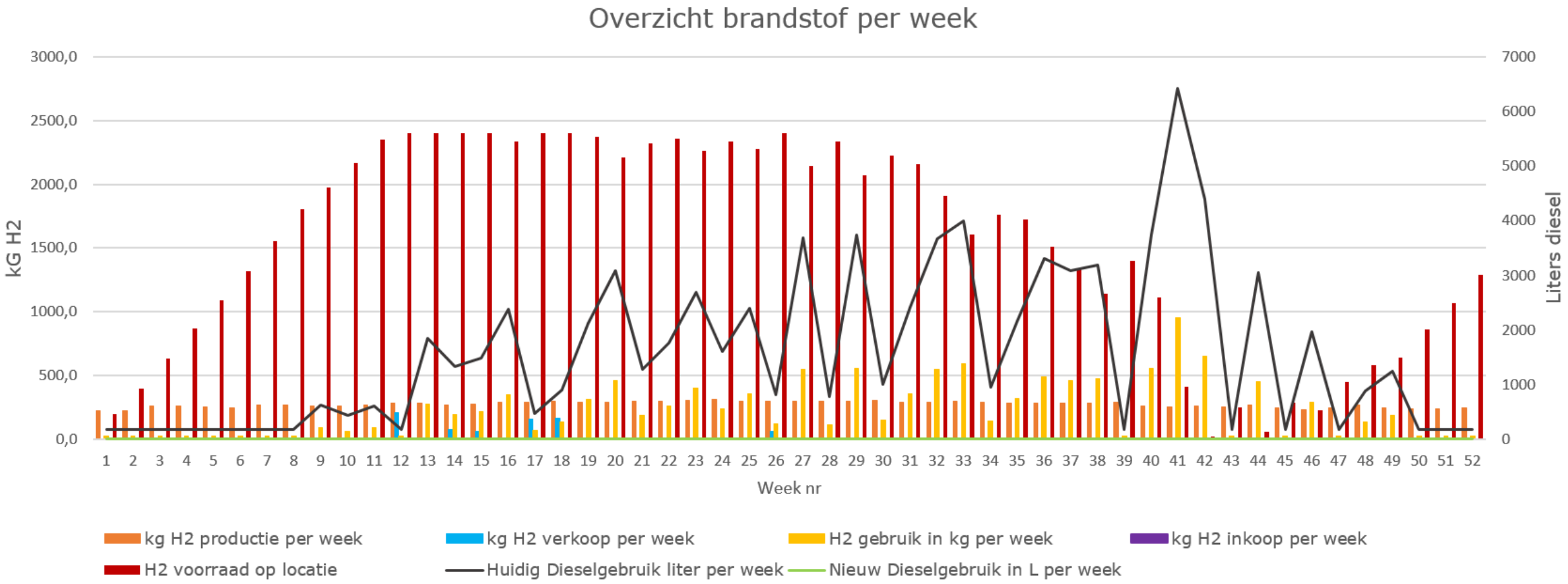
Diesel use 10 farms

- 5 Dairy farmers and 5 arable farmers; 82,000 litres of diesel per year



Large storage facility

- 5 Dairy farmers and 5 arable farmers

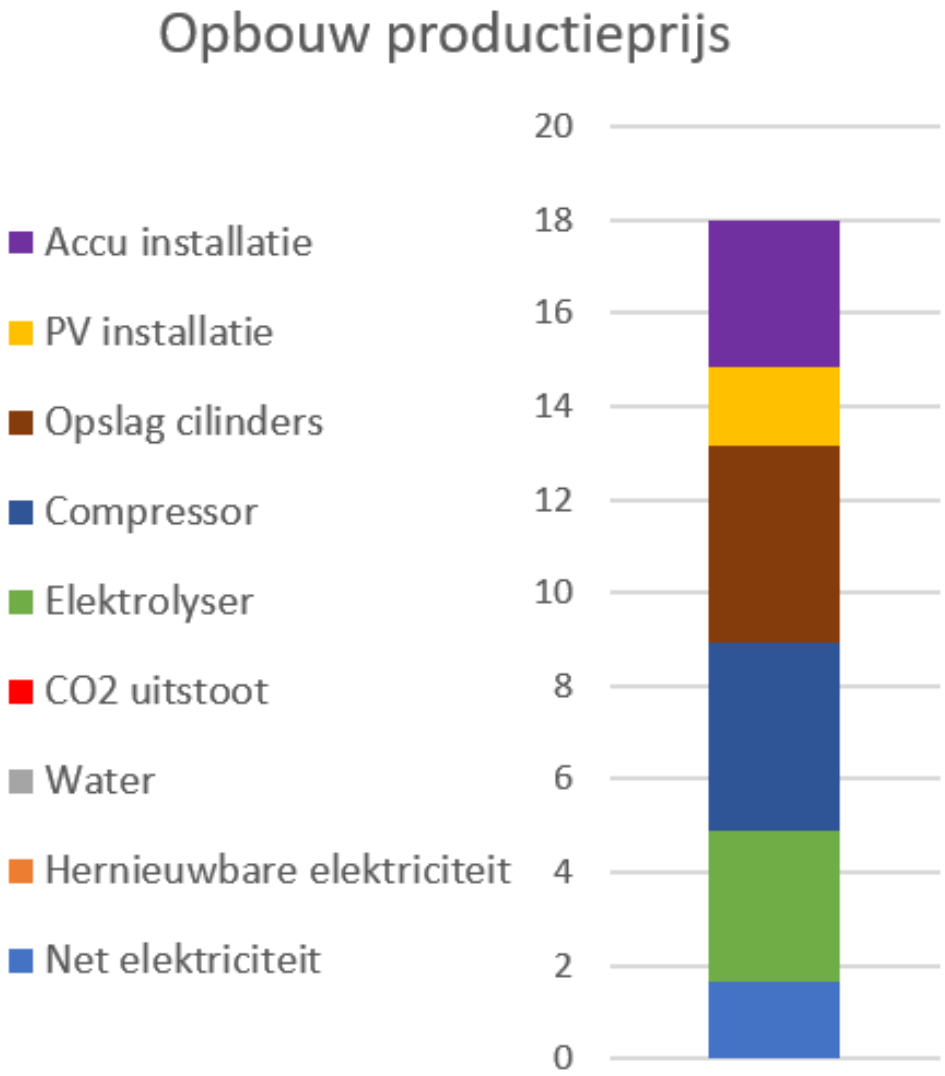


Mogelijke waterstoftoepassingen

Dimensions
115 kW electrolyser
3,000 kWp PV panels
500 kW / 500 kWh battery
28.5% power from grid
2,400 kg hydrogen storage capacity

Results

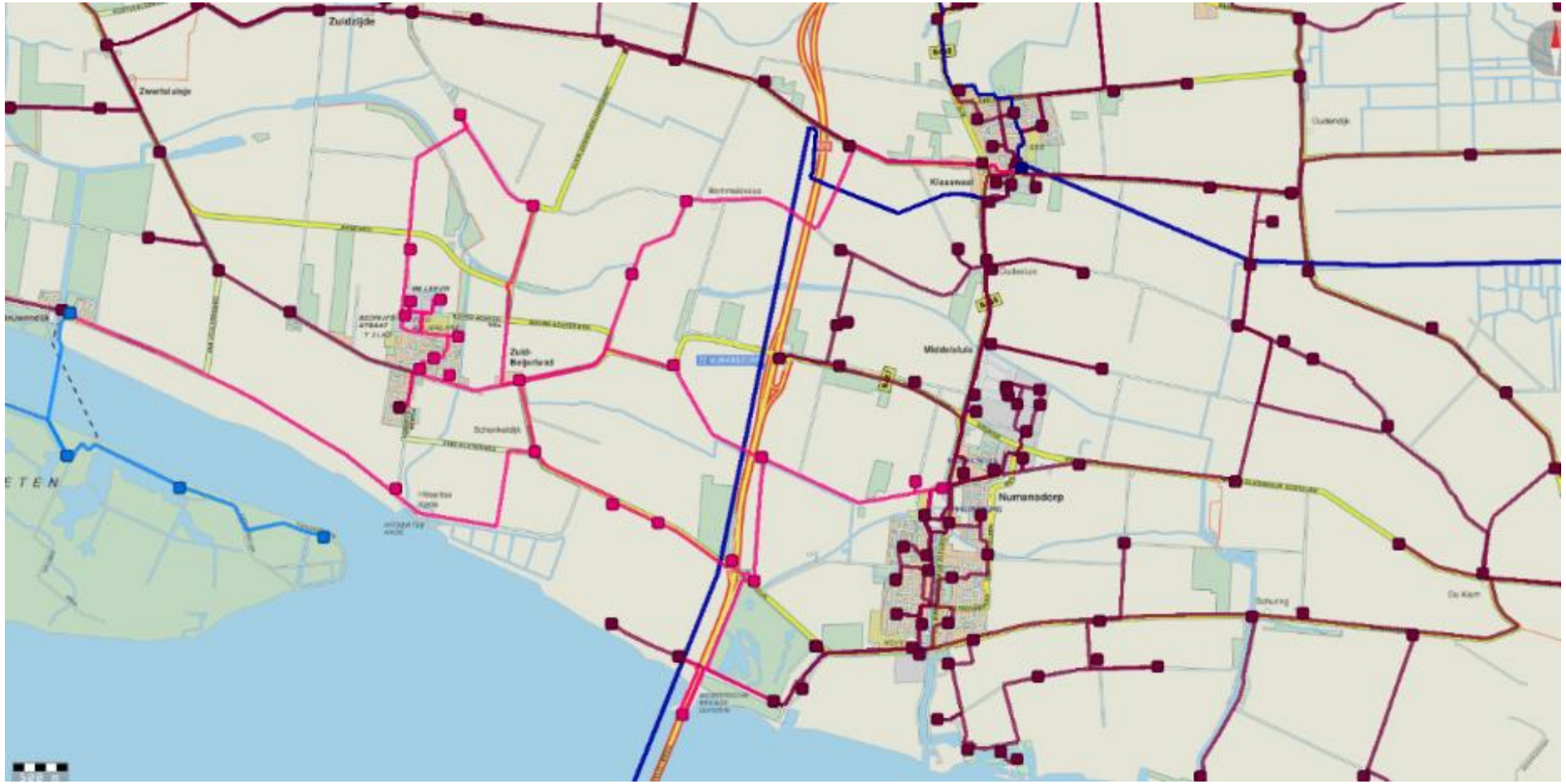
- Approx. 12,200 kg H2 use per year
- 7,350 Full load hours
- Production price: €18.00 /kg.
- Excl.
  - Licensing procedure
  - Filling station
  - Hydrogen tractor



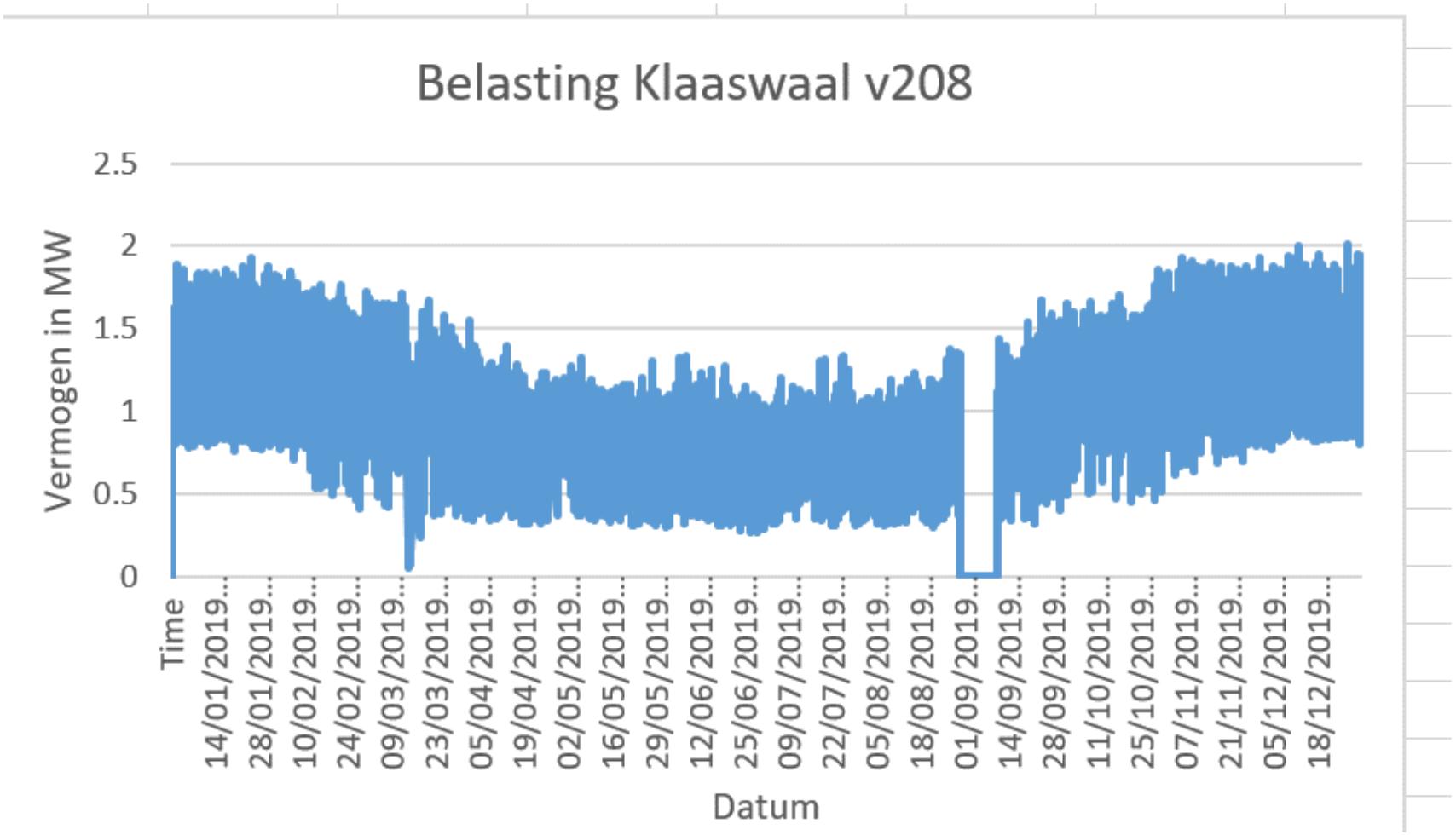
Comparison

	10 individual H2 installations	1 H2 installation for 10 farms
H2 storage capacity	3600 kg H2	2400 kg
Elektrolyser capacity	120 kW	115 kW
H2 production price	~ €44/kg	€18/kg

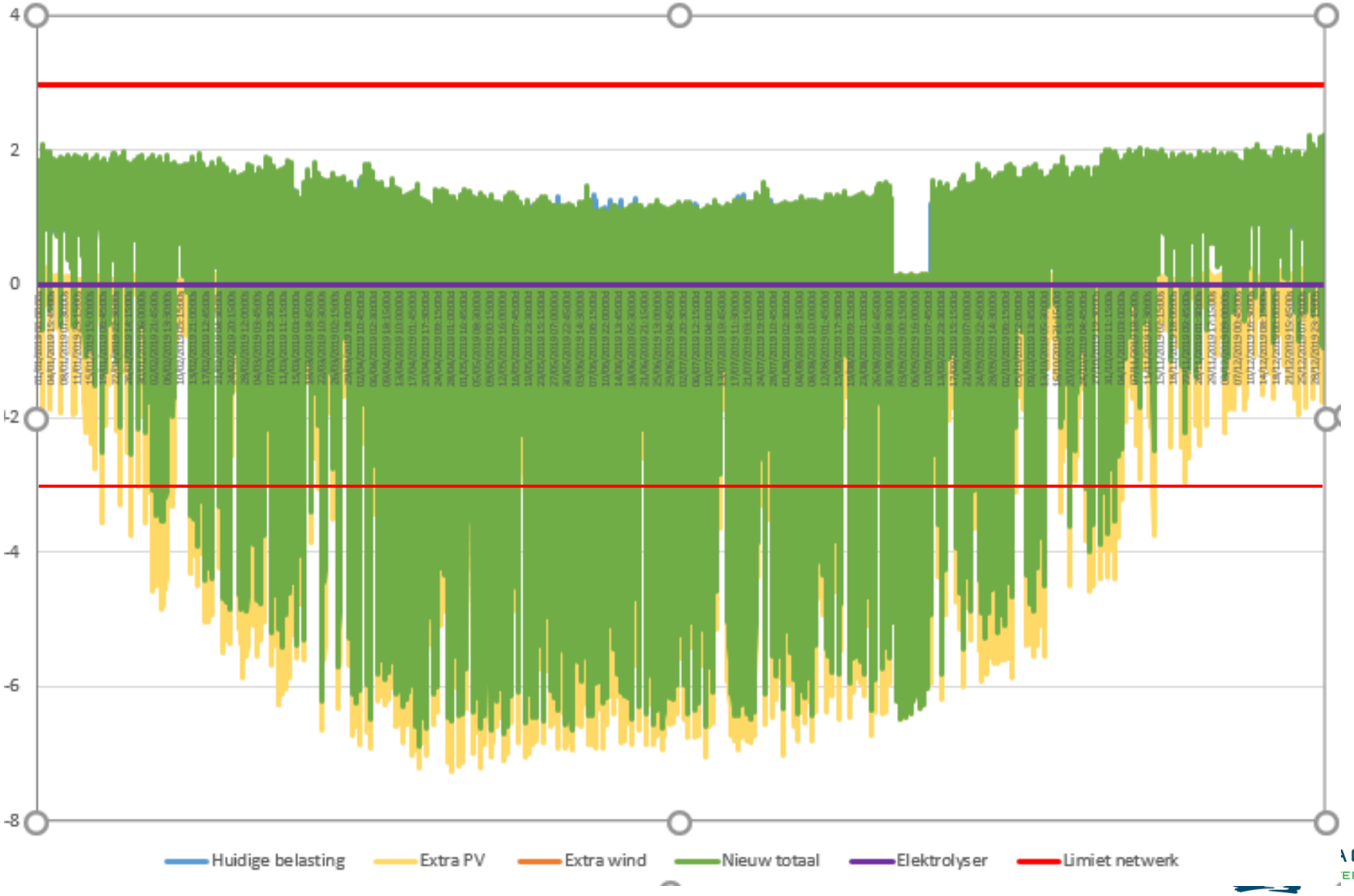
Streng Klaaswaal (v208)



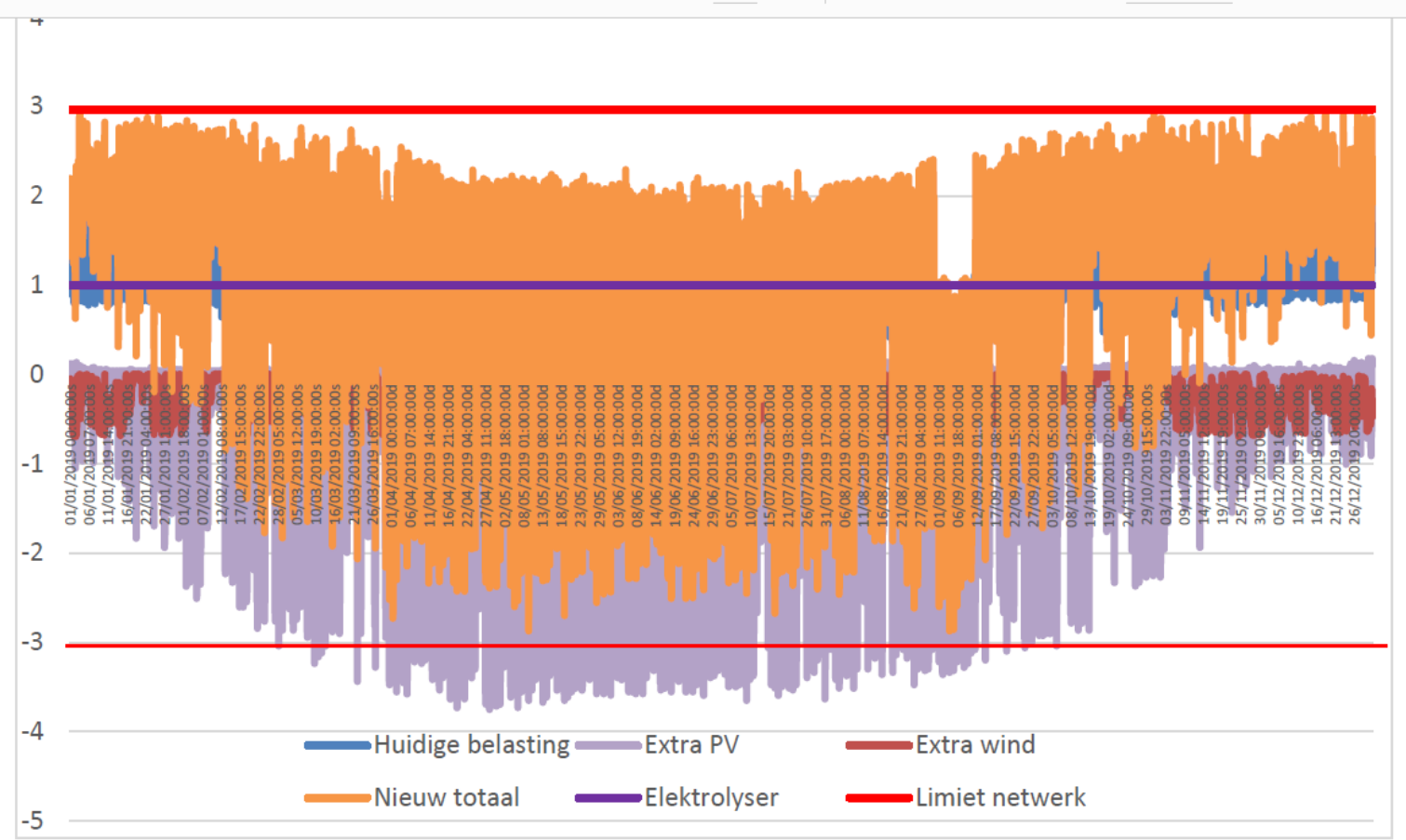
Energyprofile Klaaswaal (v208)



Potential 7.256 kW (available roofsurface)



Combining solar pv, wind, elektrolyser



Afbeelding 2: Effect van meer zonnepanelen, wind en een elektrolyser op het elektricteitsnetwerk (bron: Stedin)

Adding elektrolyser to MS grid

1500 kW electrolyser	8050 full-load hours
Investment (incl. compression and storage untill 300bar)	**3M Euro**
Yearcosts	**1.34 M Euro**
Cost price	**6.30 euro per kg H2**
Production	**213.700 kg H2**
	1,4M liter Diesel
Agricultural use	**10,000 ha diesel**

- 173 landbouwbedrijven van 60 ha

Summarizing:

- Still room for more renewable energy production in Agriculture despite overloaded power grid
- Opportunities to produce a large part of own energy use on farms, more independent of energy prices
- Renewable energy production can accelerate the development of sustainable farm systems.
- By organising flexible power behind the meter, contribution to grid stabilisation (grid services)
- All with attractive business models for the farmer

Thanks for your attention!