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TNO-report

TNO 2018 M11473 | Final report

Presentation ideation challenge 2018 - Energy neutral greenhouses

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Projectnaam	5.5346 - Ideation challenge 2018 – energy neutral greenhouses
Projectnummer	060.33975

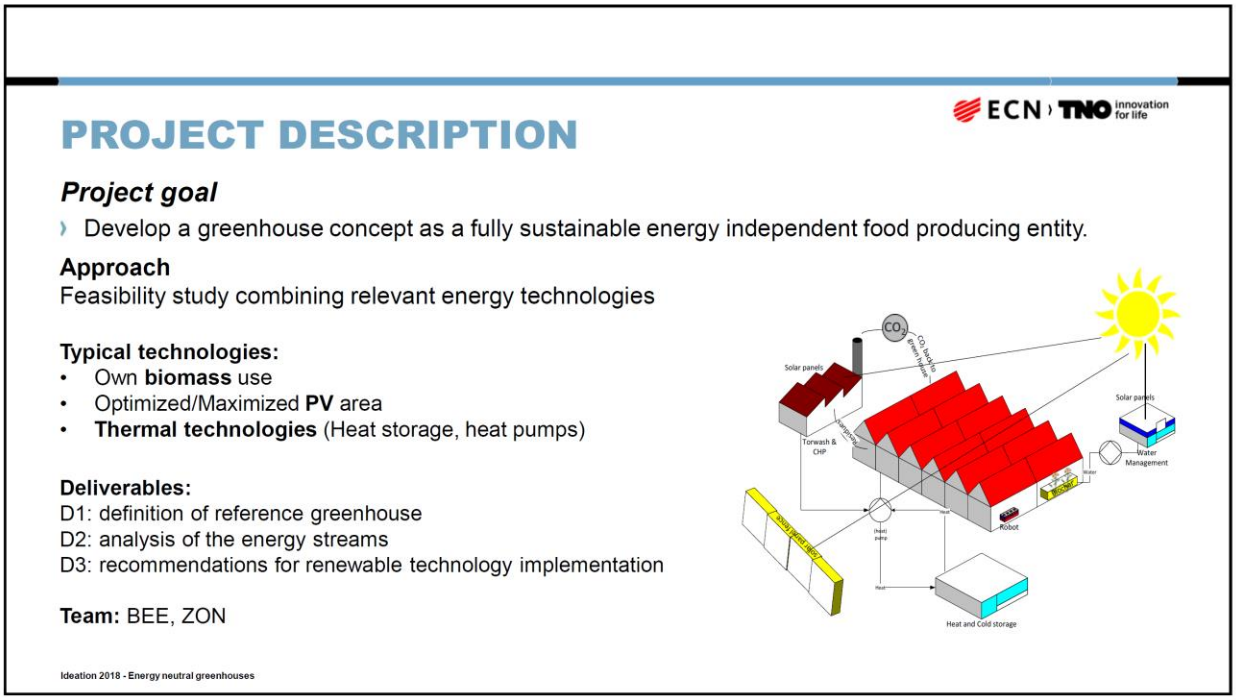
TNO PUBLIC

Acknowledgement

This report presents the results of the TNO project 060.33975 “Ideation challenge 2018 – energy neutral greenhouses”. This project was originally started beginning 2018 (before the merger of ECN and TNO) as ECN project 5.5346 “ideation 2018 - Towards energy producing greenhouses”.

This report has been structured in the form of a slide deck.


IDEATION 2018 - ENERGY NEUTRAL GREENHOUSES
Herbert Zondag, Jaap van Hal, Bonna Newman.
ECN › TNO innovation for life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PROJECT DESCRIPTION
Project goal
› Develop a greenhouse concept as a fully sustainable energy independent food producing entity.
Approach
Feasibility study combining relevant energy technologies
Typical technologies:
• Own biomass use
• Optimized/Maximized PV area
• Thermal technologies (Heat storage, heat pumps)
Deliverables:
D1: definition of reference greenhouse
D2: analysis of the energy streams
D3: recommendations for renewable technology implementation
Team: BEE, ZON
Solar panels
Torwash & CHP
Solar panels
Water Management
Robot
Heat and Cold storage
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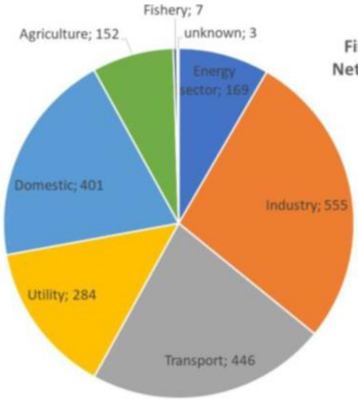
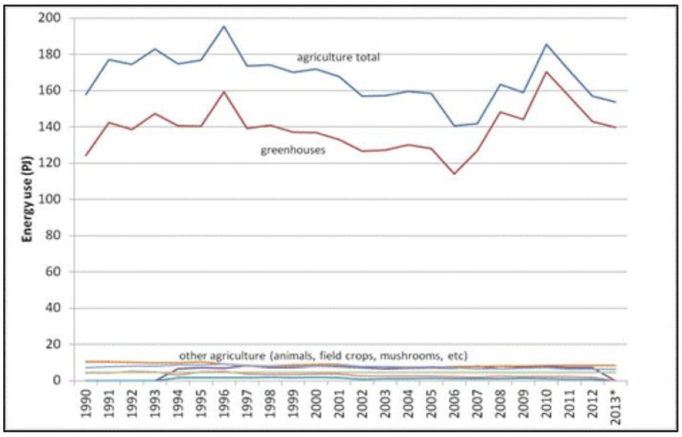
GREENHOUSES ARE LARGE ENERGY USERS



Final energy use Netherlands (PJ/yr) CBS, 2017



Agriculture ~8% Dutch energy use

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CONVENTIONAL GREENHOUSE

- **Main energy use in greenhouses:**
  - Heating
  - Lighting
  - CO_2 as fertilizer (150% atmosphere)

  Conventional technology: gas-fired CHP
- **Present project:**
  - Focus on heating and electricity demand
  - CO_2 demand covered by industry (piping network)

OCAP network as planned (expansion ongoing
CO_2 from Shell & Abengoa to greenhouses

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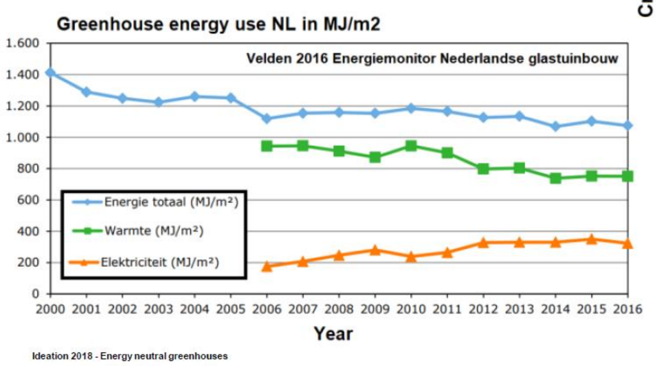
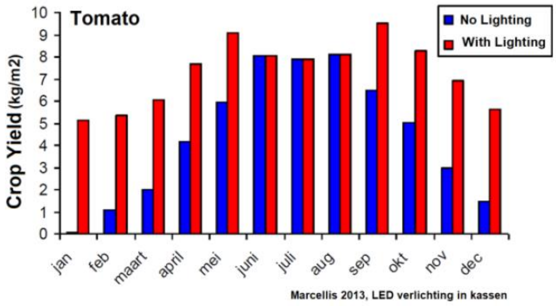
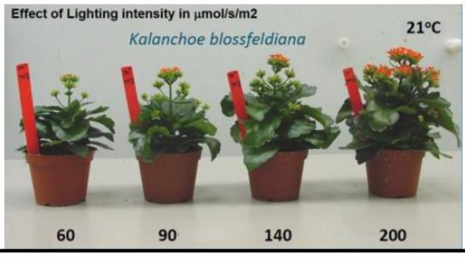
TRENDS IN ENERGY USE

- Reduction in gas use for heating
- Increase in lighting







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D1: GREENHOUSE DEFINITION

Tomato selected as reference crop =>
Typical greenhouse conditions: ~20°C, 2200 hours of lighting
Heating typcal 35-30 $m^3{}_{gas}/m^2{}_{greenhouse}$, best practise 25 m³/m².

Tomato	**Heating demand**	**Electricity demand**
	Conventional (best practise)	Conventional (best practise)
	GJ HHV/m2	GJ/m2_greenhouse
with lighting	1.2-1.1 (0.9)	0,95 (0,6)
Without lighting	1.1 (0.5)	

Selected reference greenhouse:

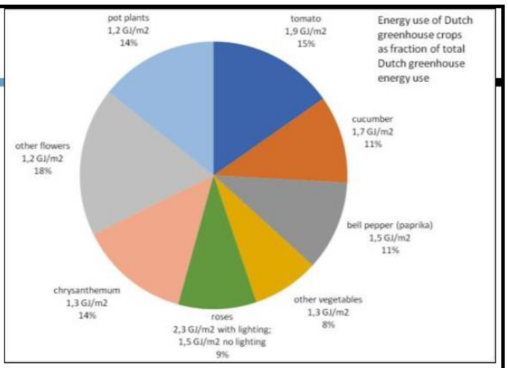
- Heating demand 1.2 GJ/m²/yr
- Lighting demand 0.75 GJ/m²/yr LED+SON-T

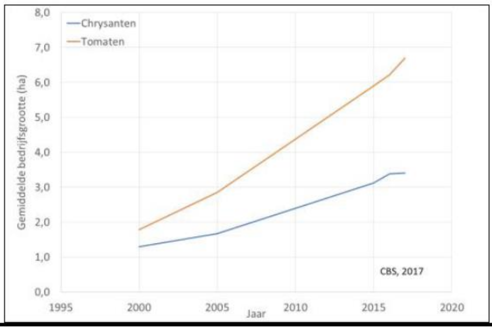
(50% LED 2.7 µmol/J; 50% SON-T 1.75 µmol/J, together 200 µmol/s/m²)

Typical tomato greenhouse 6 ha (2016):

- Annual Heating demand: 72 TJ
- Annual Lighting demand: 45 TJ = 12.5 GWh (5,5 MWel)

All tomato greenhouses ~ 21 PJ/yr





D2: ANALYSIS ENERGY

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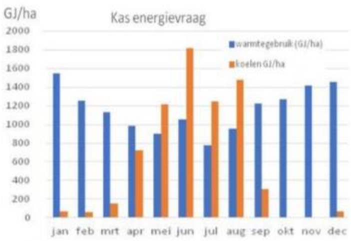
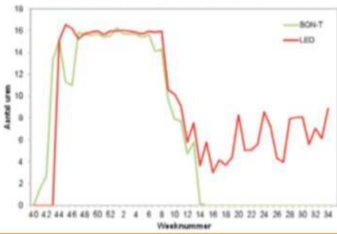
Monitored data

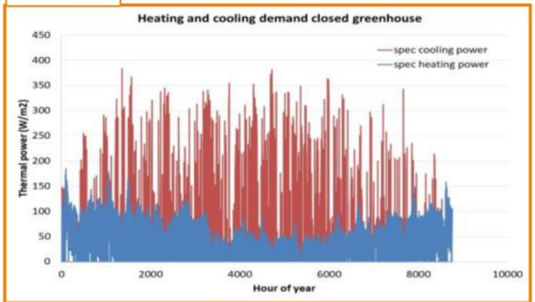
Heating

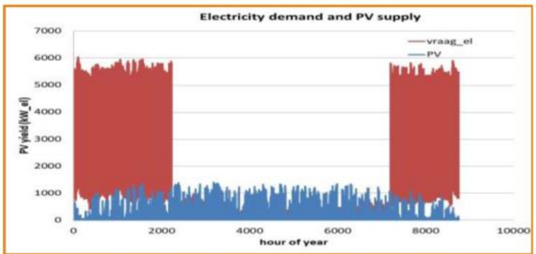


Lighting



Model





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D3: RENEWABLE TECHNOLOGY - BIOMASS

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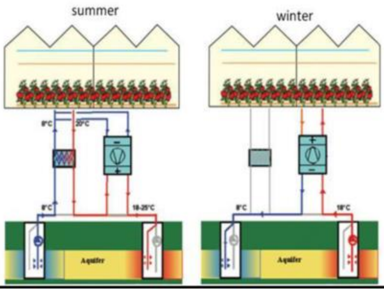
Greenhouse Heating demand: 1.2 GJ/m²/yr

Own Biomass:

- Total tomato area 420 ha greenhouses gives 10,000 ton/yr tomato waste
  - => 1,600 ton dry matter (16% dry fraction)
  - ⇒0,38 kg/m²_greenhouse => ~0.01 GJ/m² **=> insignificant for heating**

For heating: find alternative renewable heating solutions=>

- Use external biomass streams
- Use deep geothermal heat (~2km deep)
- Use heat pump for heating + aquifer (~100 m deep)
  - additional electricity required



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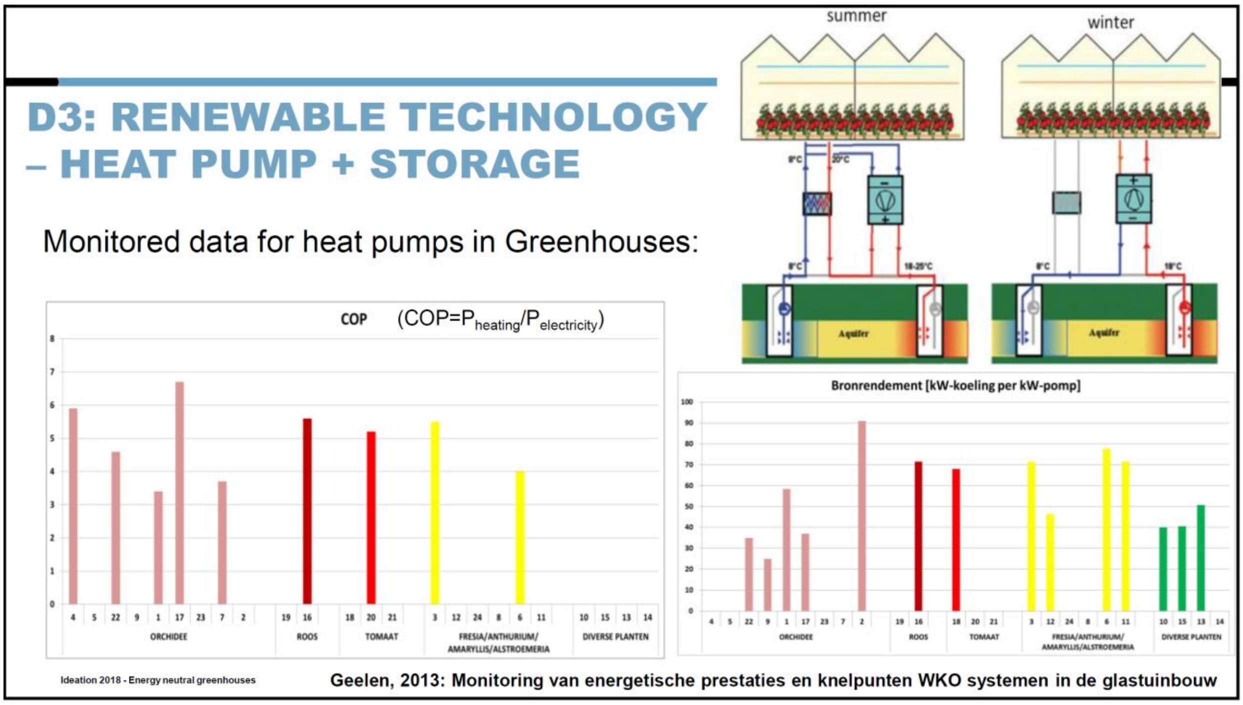
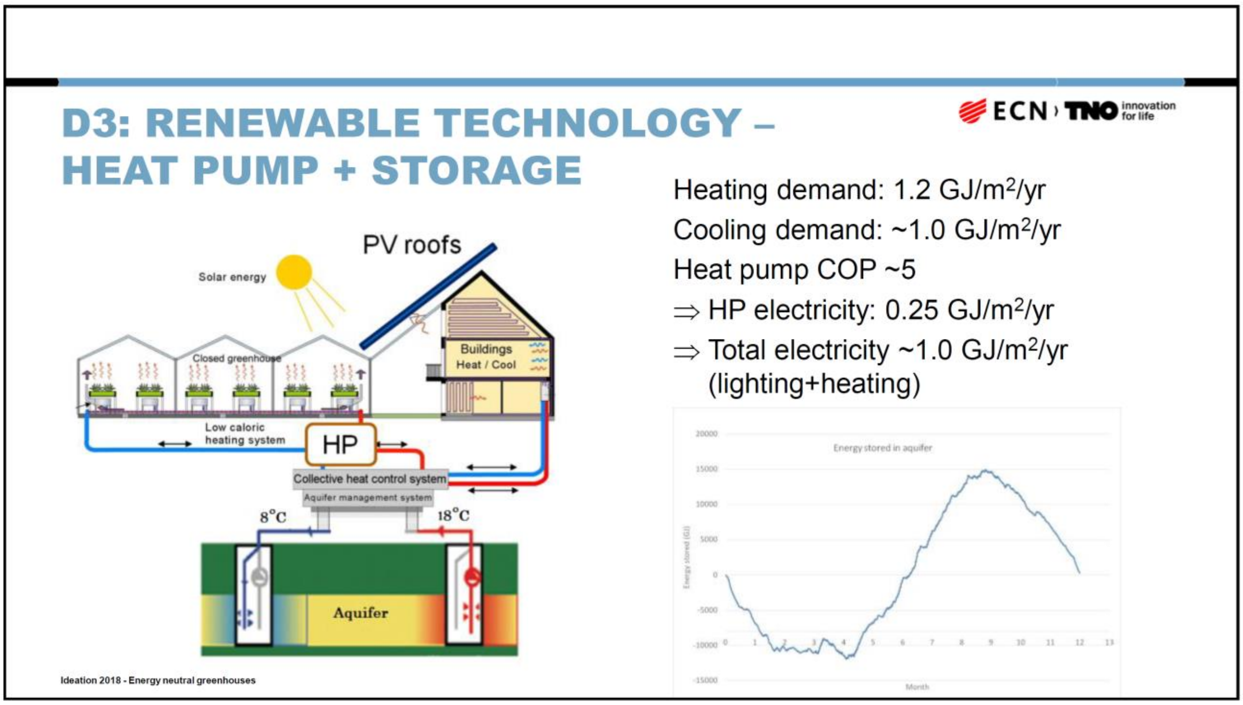

D3: RENEWABLE TECHNOLOGY – HEAT PUMP + STORAGE
Monitored data for heat pumps in Greenhouses:
COP (COP=P_heating/P_electricity)
ORCHIDEE
ROOS
TOMAAT
FRESIA/ANTHURIUM/ AMARYLLIS/ALSTROEMERIA
DIVERSE PLANTEN
summer
winter
Aquifer
Bronrendement [kW-koeling per kW-pomp]
Ideation 2018 - Energy neutral greenhouses
Geelen, 2013: Monitoring van energetische prestaties en knelpunten WKO systemen in de glastuinbouw


D3: RENEWABLE TECHNOLOGY – HEAT PUMP + STORAGE
ECN TNO innovation for life
Heating demand: 1.2 GJ/m²/yr
Cooling demand: ~1.0 GJ/m²/yr
Heat pump COP ~5
⇒ HP electricity: 0.25 GJ/m²/yr
⇒ Total electricity ~1.0 GJ/m²/yr (lighting+heating)
PV roofs
Solar energy
Closed greenhouse
Buildings Heat / Cool
Low caloric heating system
HP
Collective heat control system
Aquifer management system
8°C
18°C
Aquifer
Energy stored in aquifer
Month
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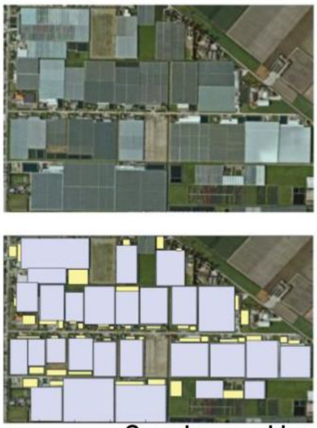
D3: RENEWABLE TECHNOLOGY - PV



Greenhouse = blue
other = yellow

PV area estimate

Report WUR[1] on typical available area for PV

- Area non-greenhouse constructions (buildings, water basins)
  - **10% of greenhouse area**
- Area on greenhouses (shading, transport path)
  - **4-5% greenhouse area**

⇒ **In total about 15% of greenhouse area available**

Type PV model	Module Efficiency	Performance ratio	Orientation Factor	Fraction of Greenhouse Area %	Annual Yield (kWh/m2)	Annual Yield (GJ/m2)
Standard	18%	90%	100%	15%	26,73	0,10
Bifacial	22%	90%	90%	15%	29,403	0,11
High-Efficinecy	21%	90%	100%	15%	31,185	0,11
Semi-transparent (IR)	14%	90%	80%	15%	16,632	0,06
			Average Specific Yield NL (South Facing, 45°)		1100	kWh/kWp/year

Electricity demand 1.0 GJ/m²/yr (LED+HP) => **PV coverage ~6-11%**

[1]Zwart et al., 2011, Benutting van zonne-energie in de tuinbouw – een strategische verkenning

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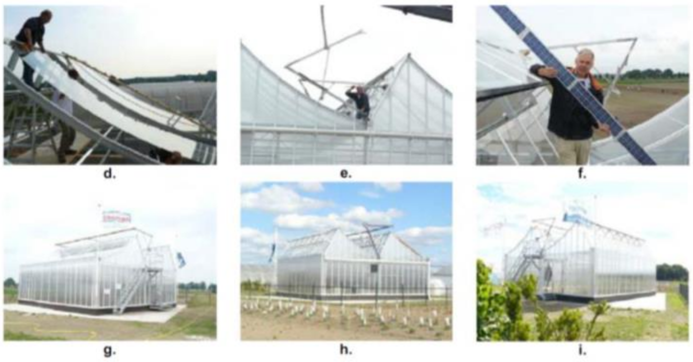
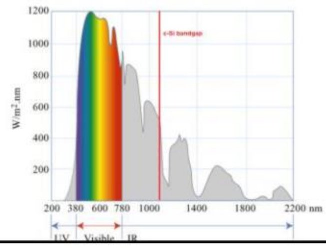
D3: RENEWABLE TECHNOLOGY – PV ON GREENHOUSES



- **Selective foil:**
  - Transmits visible spectrum
  - Reflects solar infrared & Concentrate on PV
- **PV Yield:** 16 kWh/m²/yr (=0.06 GJ/ m²/yr) => η=1.5% (reflection NIR only 40%)



Yield: 0.06 GJ_el/m²/yr (maybe 0.12 GJ_el/m² possible?)

=>Max total PV yield (buildings & greenhouses): 17-23%

[1]Sonneveld et al., 2008, Ontwikkeling van de elektriciteit leverende kas (ElKas)

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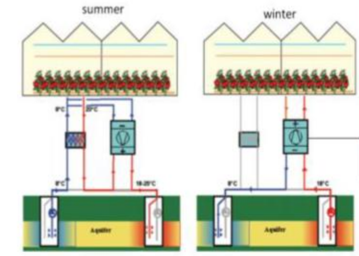
CONCLUSION → WIND TURBINE NECESSARY

Total heat demand:	1.2 GJ/m²/yr
Total heat pump supply	1.2 GJ/m²/yr
Heat pump el demand:	0.25 GJ/m²/yr
Lighting el demand:	0.75 GJ/m²/yr
Total electric demand:	1.00 GJ/m²/yr
PV yield on buildings:	0.11 GJ/m²/yr
PV yield on greenhouse:	~0.09 GJ/m²/yr
Wind turbine:	**0.8 GJ/m²/yr**
Total supplied:	1.00 GJ/m²/yr



Largest turbine NL on land: Enercon E-126
Power 7.6 MW (height tip ~200m).

=>Necessary to add a wind turbine
Electricity demand (greenhouse area 60.000 m² (6 ha) & 0.8 GJ/m²/yr): 13 GWh/yr
Assume 2200 full-load hours => 6 MW turbine
(For full LED lighting (lighting 0.75 → 0.53 GJ_{el}/m²/yr) => required wind turbine reduced to 4,5 MW)

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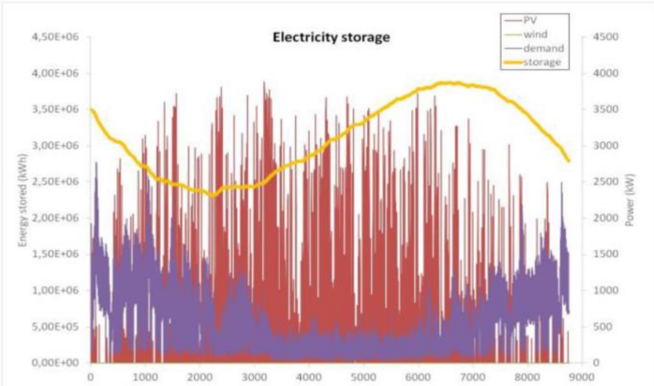
LOW ENERGY CASE: TOMATO WITHOUT LIGHTING

Total heat demand:	1.2 GJ/m²/yr
Total heat pump supply	1.2 GJ/m²/yr
Heat pump el demand:	0.25 GJ/m²/yr
~~Lighting el demand:~~	~~0.75 GJ/m²/yr~~
Total electric demand:	0.25 GJ/m²/yr
PV yield on buildings:	0.11 GJ/m²/yr
PV yield on greenhouse (max):	~0.12 GJ/m²/yr
~~Wind turbine:~~	~~0.80 GJ/m²/yr~~
Total supplied:	0.23 GJ/m²/yr



- No wind turbine needed anymore
- For grid independency ~1.5 GWh battery required
  => presently not feasible (~6x largest NaS battery)

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CONCLUSIONS

- Without lighting => HP aquifer and PV may be sufficient
- With lighting => aditional wind turbine necessary
- Grid independency presently not feasible

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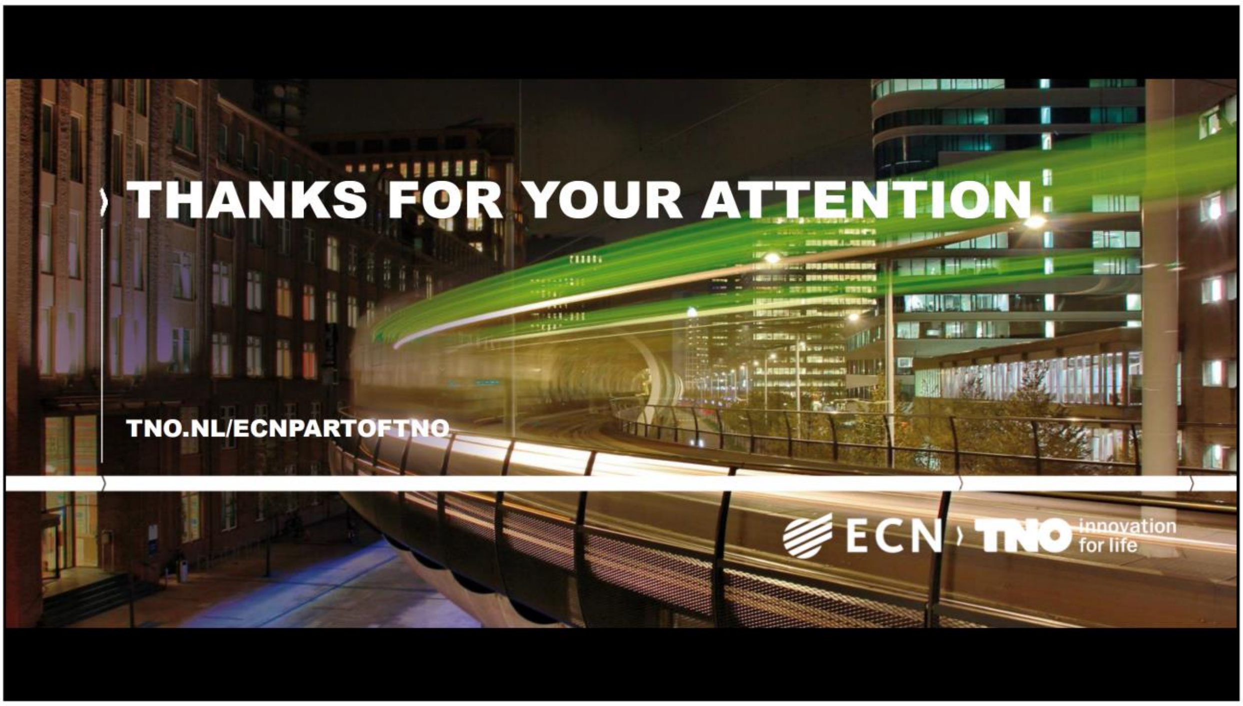

Signature

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