



**One-year field test of a fast acting zinc-bromine  
20kw/60kwh flow battery system to develop a  
business model for distributed small and medium  
sized storage in the Dutch electricity market.**

Jeroen de Veth  
CEO

# Project objectives

- Constructing a business model for distributed storage in The Netherlands linking multiple farms.
- Integrating self consumption of locally produced renewable energy and electricity market opportunities by means of an aggregator.
- Constructing a fast acting, predictive and market aggregator operated battery system.
- Gathering live data from storage system as well as market segments and simulate multiple business case scenario's.

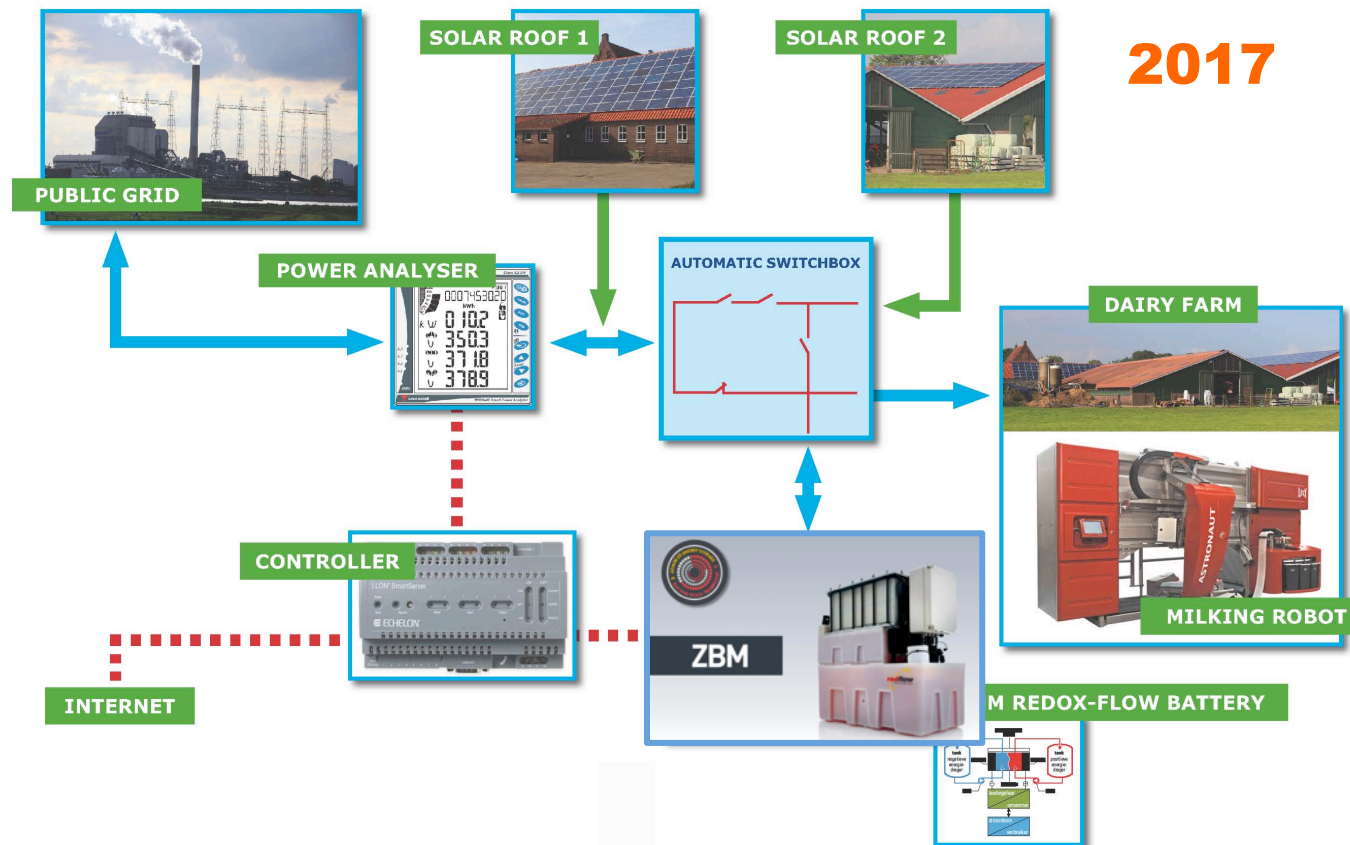
## Facts and figures

- Installed 23 May 2017 in Vierakker (Netherlands)
- Dairy farm, consumes 70.000 kWh/a, 50kWp PV generation
- Storage: 6 Redflow ZBM2 modules, 60kWh in total
- Inverter: Trumpf TruConvert AC 3020, 20kW bidirectional
- Data collection: June to December 2017
- Co-financed by EU and region
- Partners:
  - ICL-IP
  - AgroPower (energy market aggregator)
  - University of Applied Science Arnhem-Nijmegen
  - Dutch Farmers Association

# PHOTON FARMER, VIERAKKER



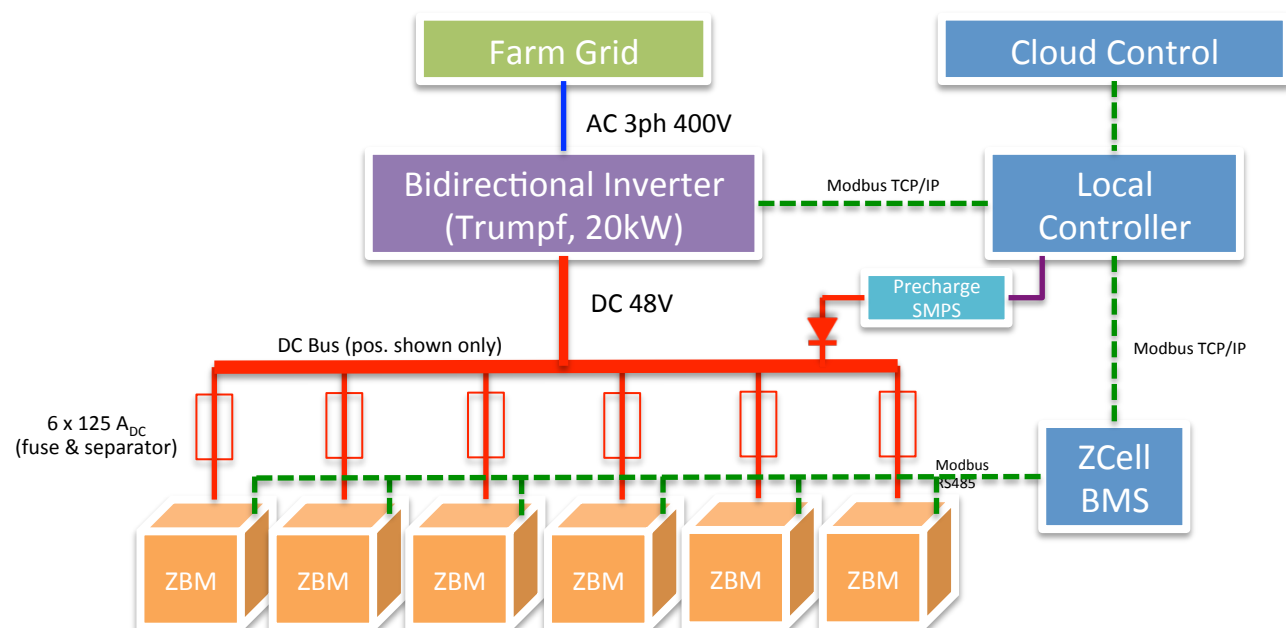
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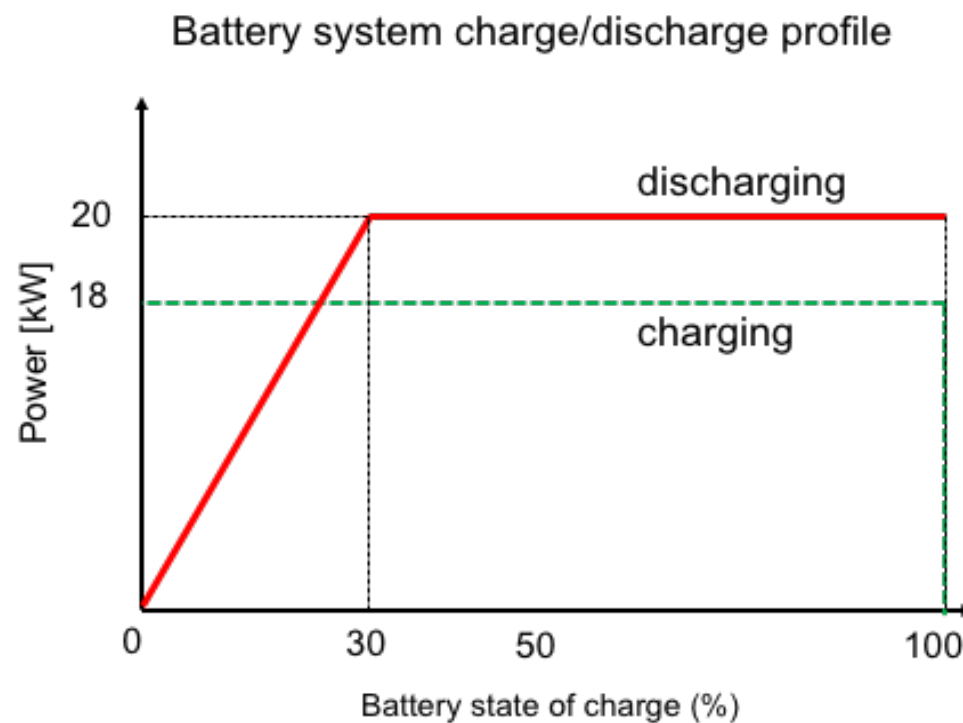
## Storage system: 20kW-60kWh




# Basic system schematic



# Charge-discharge curves



# Full power discharge test


ZCell BMS / Elektronenboer  
v1.3.1


**Status**
Configuration ▾
Tools ▾
Graphs
Logs ▾

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## System Status - Elektronenboer

Unit	Serial ?	Status ?	SoC	Contacts ?	Amp Hours	Volts ?	Amps ?	kW ?	Temp ?	Last Maint ?	Time Limit ?	Firmware ?	Mode ?
System		OK	44.4%	↓ C D S	533.0 AH	46.0 V	426.9 A	19.7 kW	40.5 C				
1	628	OK	64.3%	↓ C D S	128.5 AH	46.2 V	80.8 A	3.7 kW	35.9 C	1d10h	1d14h	32.17.0	Run (702)
2	630	OK	65.5%	↓ C D S	131.0 AH	46.2 V	76.7 A	3.5 kW	36.4 C	1d10h	1d13h	32.17.0	Run (702)
3	631	OK	63.4%	↓ C D S	126.7 AH	46.2 V	80.8 A	3.7 kW	37.3 C	1d10h	1d14h	32.17.0	Run (702)
4	632	Discharge	7.9%	↓ C D S	15.7 AH	46.0 V	49.0 A	2.3 kW	38.3 C	4d2h	-6h7m	32.17.0	Run (702)
5	627	Discharge	6.2%	↓ C D S	12.4 AH	46.0 V	54.5 A	2.5 kW	38.5 C	4d3h	-6h19m	32.17.0	Run (702)
6	633	OK	59.4%	↓ C D S	118.7 AH	46.3 V	85.1 A	3.9 kW	40.5 C	1d10h	1d14h	32.17.0	Run (702)

# High SOC charging behaviour


ZCell BMS / Elektronenboer  
v1.3.1

**Status**
Configuration ▾
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## System Status - Elektronenboer

Unit	Serial	Status	SoC	Contacts	Amp Hours	Volts	Amps	KW	Temp	Last Maint	Time Limit	Firmware	Mode
System		OK	60.9%	↑ C D S	730.2 AH	57.6 V	-121.4 A	-7.0 kW	37.0 C				
1	628	OK	83.5%	↗ C D S	167.0 AH	57.7 V	-39.6 A	-2.3 kW	32.0 C	11h20m	2d17h	32.17.0	Run (702)
2	630	OK	90.9%	↑ C D S	181.8 AH	57.7 V	-40.8 A	-2.4 kW	32.0 C	2d1h	22h45m	32.17.0	Run (702)
3	631	OK	87.3%	↑ C D S	174.6 AH	57.7 V	-41.0 A	-2.4 kW	34.6 C	10h22m	2d17h	32.17.0	Run (702)
4	632	Maintenance	3.5%	— C D S	6.9 AH	44.7 V	1.2 A	0.1 kW	32.8 C	2d16h	22h16m	32.17.0	Run (705)
5	627	Maintenance	0.0%	— C D S	0.0 AH	0.0 V	0.3 A	0.0 kW	33.9 C	2d16h	22h40m	32.17.0	Run (712)
6	633	OK	100.0%	— C D S	199.9 AH	54.5 V	0.0 A	0.0 kW	37.0 C	2d2h	21h54m	32.17.0	Run (702)

# System economy & Business cases

# Economic drivers

- Electricity grid absent or unreliable **NL: not really**
- High electricity tariffs or taxes **NL: not really**
- Maximizing self consumption **NL: balancing scheme - ENDING**
- Subsidies **NL: national on pilots and demonstration + EU**
- Electricity market segments
  - Day Ahead market **NL: low tariffs**
  - Balancing market **NL: interesting, but efficiently organised**
  - Frequency Containment Reserve **NL open market, prices going down**
  - Emergency Power market **NL high power demand, no multitasking**

# Simulation example

## Day-Ahead + Balancing Markets (Battery Only)

- **Charge if**
  - Combination of APX and Balancing markets strategies
- **Discharge if:**
  - Combination of APX and Balancing markets strategies
- **Do nothing if otherwise.**

### Position at the APX (Day Ahead) market

- **Charge from: 01:00 – 06:00 & 12:00 – 16:00**
- **Discharge from: 07:00 – 12:00 & 16:00 – 21:00**

### RESULTS

#### POWER

Max. power (imported from grid) = 18,00 [kW]

Avg. power (imported from grid) = 14,26 [kW]

Max. power (exported to grid) = -20,00 [kW]

Avg. power (exported to grid) = -16,56 [kW]

#### ENERGY

Total Energy - APX Consumption Position = **32,850 [MWh]**

Total Energy Actually Consumed = **15,498 [MWh]**

Total Energy - APX Supply Position = **-36,500 [MWh]**

Total Energy Actually Supplied = **-15,487 [MWh]**

Net energy = **0,011187 [MWh]**

#### COST/EARNINGS

Cost of imported energy = 1.464,56 [EUR]

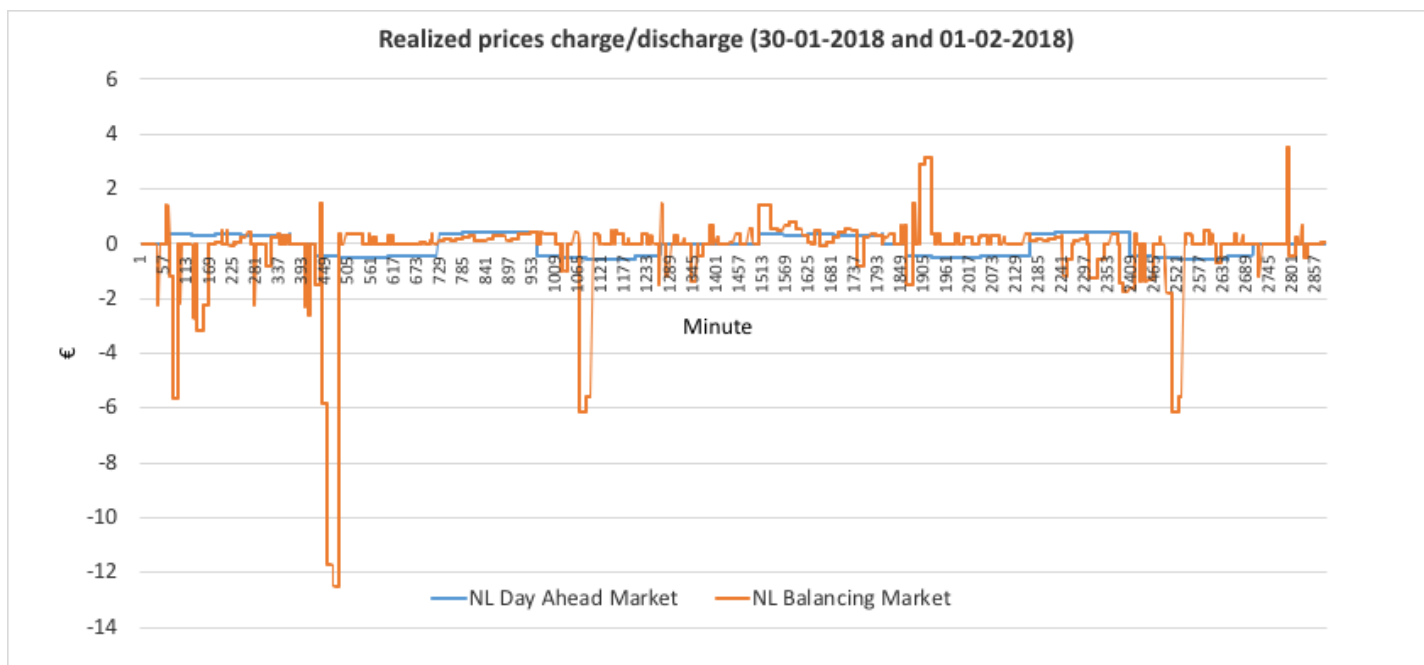
Earnings from exported energy = -3.340,223 [EUR]

Total Earnings (APX + Balancing Markets) = **-1.875,66 [EUR]**

- Total Earnings from APX Market = -509,26 [EUR]

- Total Earnings from Balancing Market = -1.366,40 [EUR]

## 2 day market earning example



# Simulation results

	Self-consumption	Balancing Market (Battery only)	Balancing Market (Battery + Self-consumption)	APX+Balancing (Battery only)	APX+Balancing + SelfConsumption
Max. power (imported from grid) [kW]	47,5	18	56,81	18	56,81
Max. power (exported to grid) [kW]	-54,0	-20	-51,143	-20	-51,143
Total imported energy [MWh]	58,78	11,758	71,20	15,498	72,50
Total exported energy [MWh]	-13,20	-11,746	-28,85	-15,487	-30,143
<b>Net energy [MWh]</b>	<b>45,58</b>	<b>0.012</b>	<b>42,35</b>	<b>0,011187</b>	<b>42,357</b>
Cost of imported energy [€]	+	424,67	2.780,04	1.464,56	2.998,96
Cost of Exported energy [€]	-	-1.761,54	-1.847,13	-3.340,223	-2.597,83
<b>Net Cost of Energy [€]</b>	<b>+</b>	<b>€-1.336,86</b>	<b>€932,91</b>	<b>€-1.875,66</b>	<b>€ 401,13</b>

## Wrap-up

- Market integration can efficiently generate extra earnings for distributed storage, combining multiple sites under one aggregator.
- NL electricity market is highly efficient, so distributed storage must be combined with strong local benefits to reach a positive business case.
- ZnBr redox-flow technology performed very well in this project. Surprisingly flat charge profile.



Thank you for your attention.

Jeroen de Veth MSc  
CEO

*E: [jdeveth@trinergie.nl](mailto:jdeveth@trinergie.nl)  
T: +31623211862*