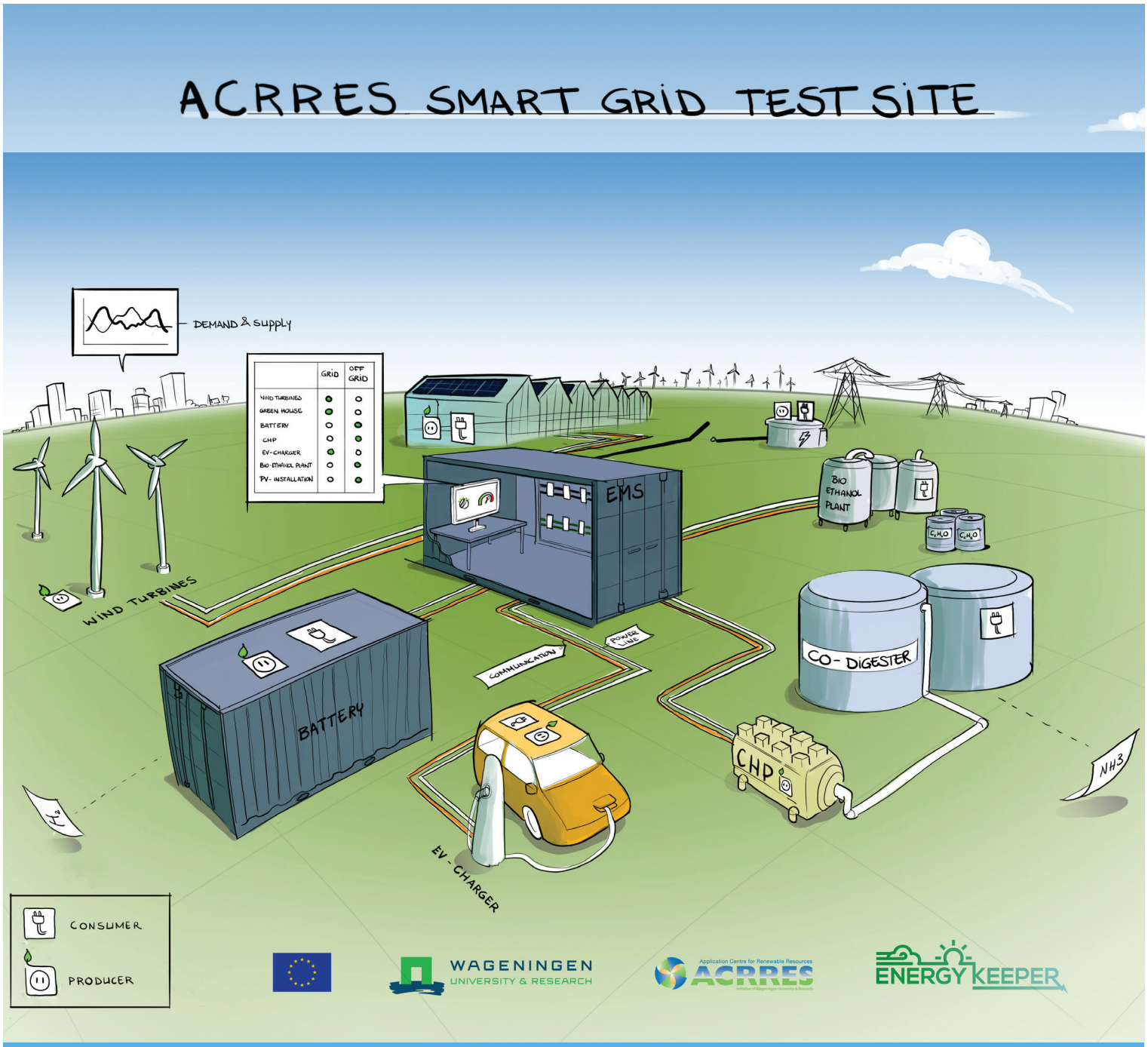

ACRRES Smart-Grid Test Site

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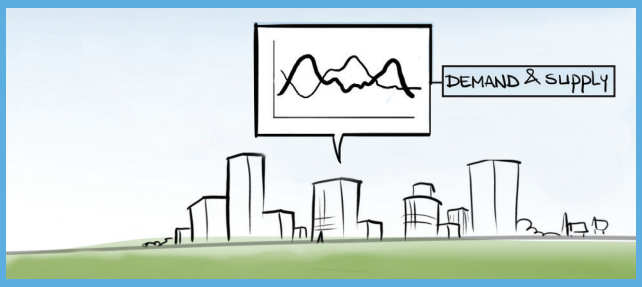
INTRODUCTION

The Dutch government has set the goal to change their energy system to a 100% renewable one by the year 2050 to keep global warming well below 2°C above pre-industrial levels. To be able to handle 100% renewable energy the current energy system needs to become more intelligent. The introduction of smart-grids is needed to be able to manage the production, consumption and storage of energy.



ACRRES SMART-GRID TEST SITE

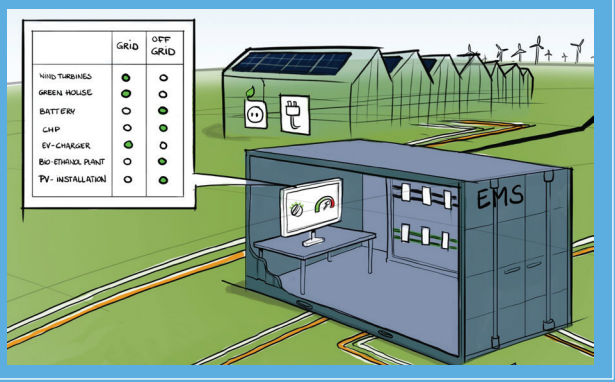
At the Wageningen University and Research wind and solar test site in Lelystad (ACRRES test site) a full functional state-of-the-art smart-grid is available to be able to simulate and test various power distribution scenarios and grid behaviour. The smart grid test site was constructed as a logical evolution of the ACRRES (Application Centre for Renewable RESources) facilities. The addition of the smart grid adds the possibility to integrate renewable energy processes with already in place technology using sophisticated energy management. The battery and energy management system (EMS) play a key role in the test site grid, the EMS has the ability to switch each connected device seamlessly to an on- or off-grid circuit, while both circuits maintain fully functional.

TEST SITE DEVICES

To be able to test and simulate various scenarios, energy producers and consumers are combined within the ACRRES smart-grid. All energy producers are active components that produce renewable energy, their behaviour can be programmed based on various external signals, for example grid frequency or weather forecasts. Some of the energy consumers can be controlled actively, by varying there energy demand grid stability and behaviour can be researched. In addition, some passive energy consumers are connected to the smart-grid, these devices display a more or less continuous energy demand when

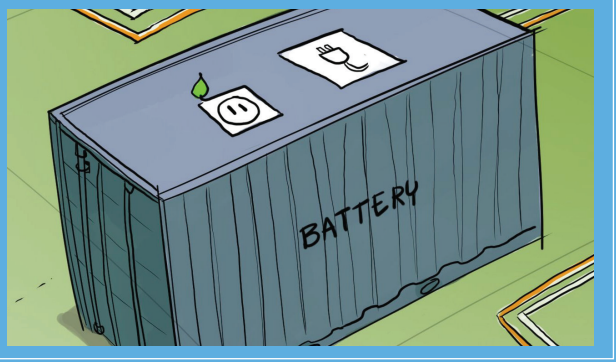
EMS (grid control)

- Controlled by a Programmable Logic Controller (PLC)
- High frequency grid monitoring
- Automatic and programmable test scenarios
- Blackstart testing
- Uninterruptible power supply testing



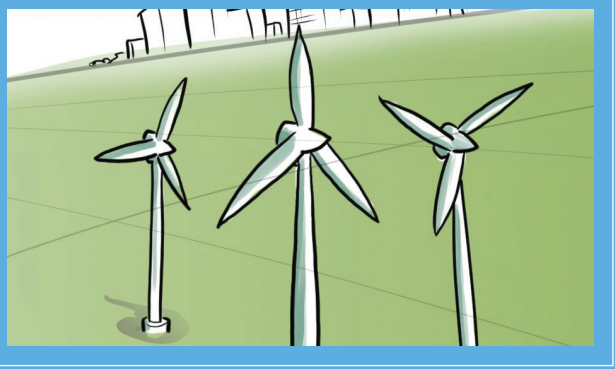
Energy storage (prosumer)

- Long or short term energy storage
- Li-ion and redox flow batteries tested
- State of charge (SOC) based grid regulation
- Energy trading possible
- Kinetic energy storage testing possible



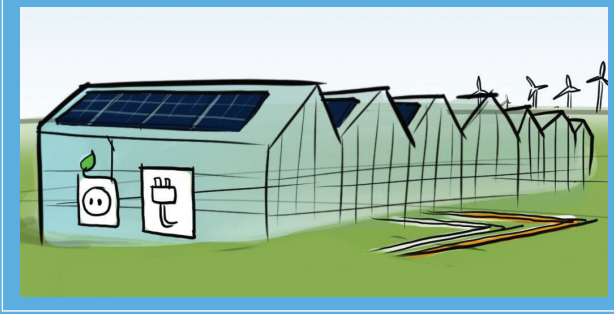
Wind turbines (producer)

- 3 wind turbines generating 30kWp
- Rotor height: 10 meter
- Energy production control via:
  * Grid frequency
  * Modbus (TCP/IP)



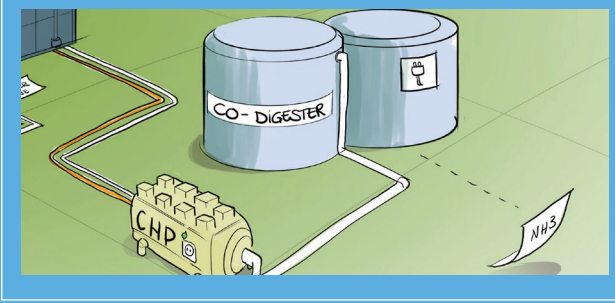
Photovoltaic installation (solar panels) (producer)

- 63 panels generating 15kWp
- Grid frequency based energy production
- Energy production control via:
  * Grid frequency
  * Modbus (TCP/IP)
- Direct DC battery charging possible
- Mounted on top of the greenhouse



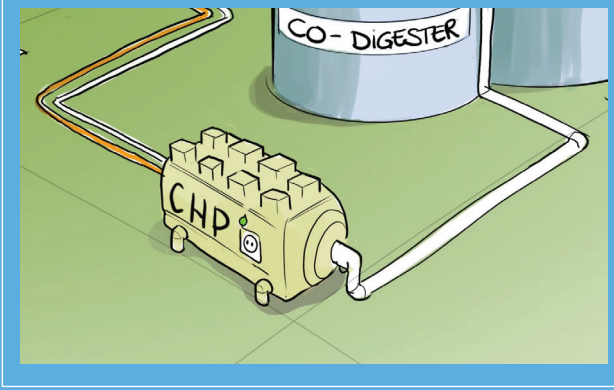
Co-digester (consumer)

- Volume: 2x 500m^3
- Running on manure and grass from nature
- Connected devices:
  * Pre-processing: Molaris hammer mill
  * Methane storage: Bio-CNG and Bio-LNG production
- Passive energy consumer



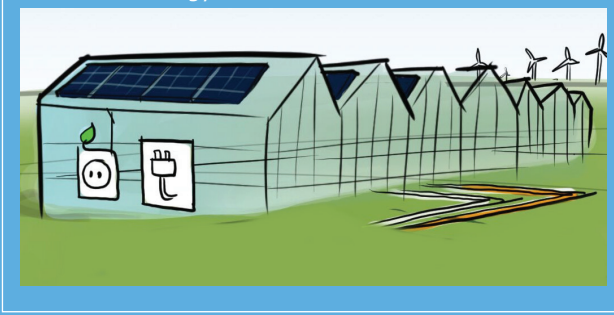
CHP (producer)

- Biogas fed gas motor
- Max output: 125 kWh(e) and 250 kWh(th)
- Energy production control via:
  * Grid frequency
  * Analog signal (4-20mA)
  * set point based, 50-100%



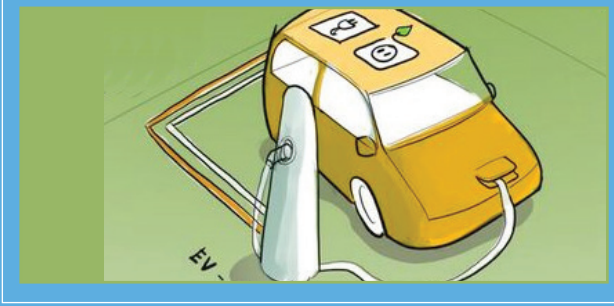
Greenhouse (consumer)

- Surface area: 2000m^2
- Several algae and aquatic biomass cultivation technologies
- Algae and aquatic biomass processing
- Cold and heat storage device
- CHP heat and flu gas used in processes
- Passive energy consumer



EV charger (prosumer)

- Car battery can both store and deliver energy
- Battery behaviour based on, for example:
  * Grid frequency
  * Programmed tests
  * Energy price and availability



Bioethanol pilot plant (consumer)

- Suitable for corn and sugar beet processing
- Processing from feedstock to ethanol
- 2x 1.5m^3 fermentation tanks
- CHP heat used in processing
- Fermentation tank stirrers controllable:
  * Grid frequency
  * Analog signal (0-10 volt)
- Other utilities are passive energy consumers

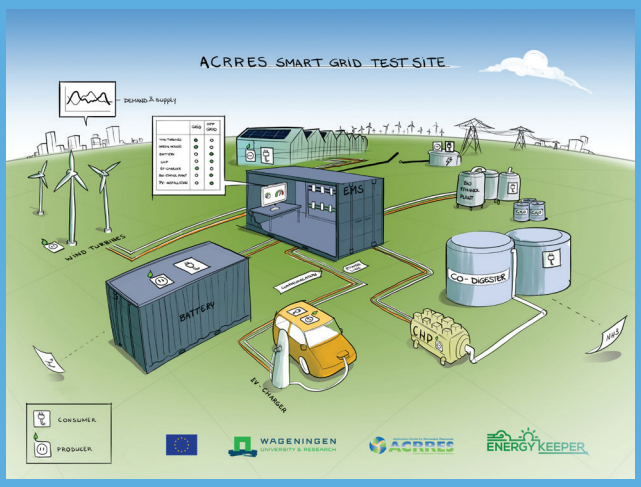
WHAT'S POSSIBLE AT THE ACRRES TEST SITE

The smart grid test facility is large enough to test and simulate real life scenarios but still small enough to have full operational freedom without restrictions. The ability to run the system in full off-grid mode, on-grid mode, or a mix of both, for extended lengths of time when required, creates a fully independent environment with its own specific testing possibilities. Because the smart-grid's energy management system (EMS) can be programmed in virtually limitless possible ways it is possible to test and simulate scenarios that can lead to improved insight in grid balancing and stabilisation. In other words, the ACRRES smart grid test site is an ideal location to test complex energy management algorithms, develop of new grid balancing tools, test device behaviour in smart grids, comparing battery prototypes, test maximized grid utilization and balance and much more.

The devices at the ACRRES smart grid test site can be used not only as energy driven components but also in, non-battery, "energy storage" processes, collectively called "power to X" (PTX). The production of hydrogen by electrolysis of water or steam reforming of bio-methane are examples of PTX. The produced hydrogen can be stored and, later, be used for different applications. Another example of PTX is the production of the nitrogen fertilizer nitric acid from bio-ammonia stripped from co-digesters.

Smart-grid test and simulation possibilities:

- Varying grid frequencies as simulation tool
- Setting device priority based on grid conditions
- Programming device power production in relation to consumption behaviour
- Device switching between on and off grid
- Testing energy storage systems
- Optimizing power line/infrastructure utilization
- Blackstart (after grid blackout)
- Uninterruptible power supply testing
- Energy trading
- Customer specific tests



SMART GRID COMMUNICATION AND CONNECTION

Device name	Max. switched current (A)	Communication options			
		Frequency regulated*	0-10 volt	4-20 mA	Modbus (TCP/IP)
Battery	400	X			
CHP	250	X**		X	
Co-digester	160				
Bioethanol plant	160				
Wind turbines	35	X			X
Mixers	80	X**	X		
EV charger	80	X	X		
Greenhouse	100				
Molaris	63				
PV installation	35	X			X

* devices "listen" to grid frequency and react, in a pre-programmed way, to changes in this frequency.
**devices are controlled by the EMS based on grid frequency

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