



21-23 October 2013

Workshop GreenGrowing

TNO innovation
for life

Energy Efficiency in Greenhouses

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Contents

1. Flexibility in energy demand and supply
2. Flexibility in greenhouse energy management
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Uncertainty of Renewables



- › Weather conditions determine amount of energy
- › Uncertainty in weather pattern
- › Uncertainty in energy supply from RES has to be taken into account in scheduling



From Consumer to Prosumer



- › Increasing amount of “own” RES energy supply of households
- › Surplus of energy supply of households provided to smart grid



Flexible Energy Demand

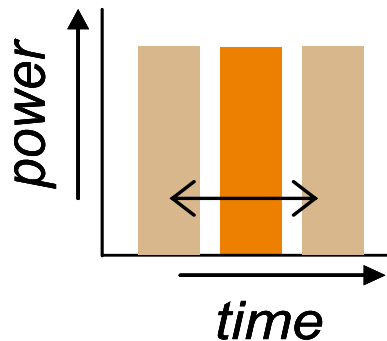


- › Dishwasher and washing machine can flexibly run overnight
- › Electric vehicle can be charged flexibly during parking interval

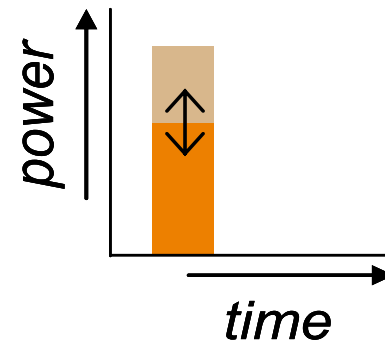


Energy Profile Flexibilities

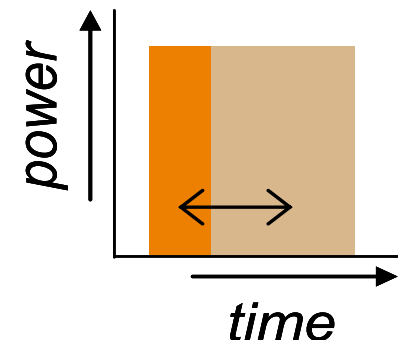
a) start time



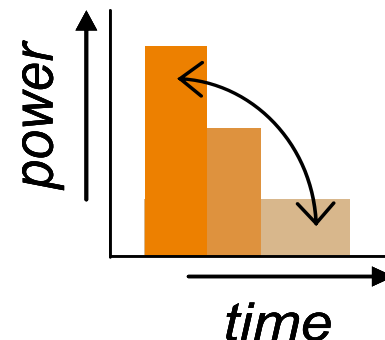
b) power



c) duration



d) energy



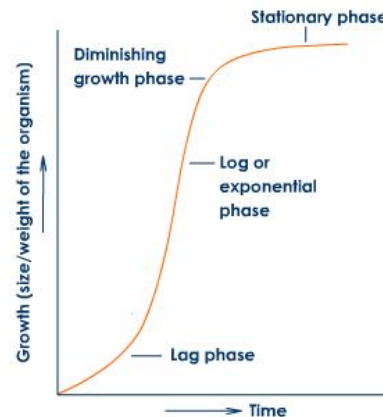
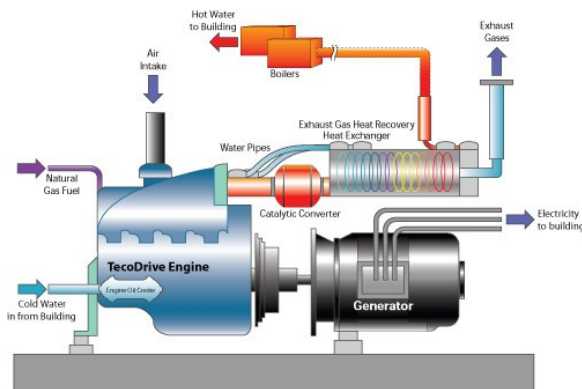
- › Flexibilities are expressed in terms of constraints on an energy profile.
- › Profile elements can have constraints on their power, energy and time.



Greenhouses as Flexible Prosumers



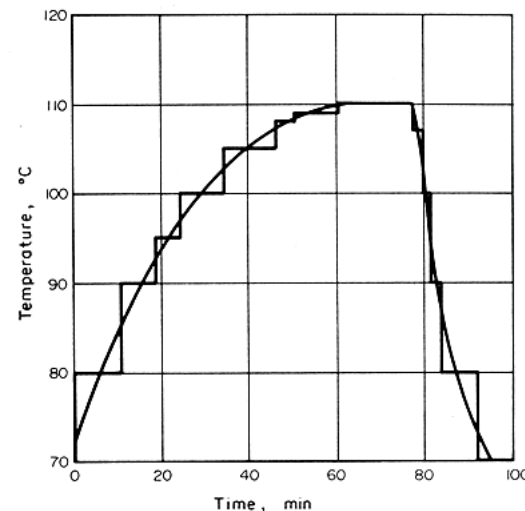
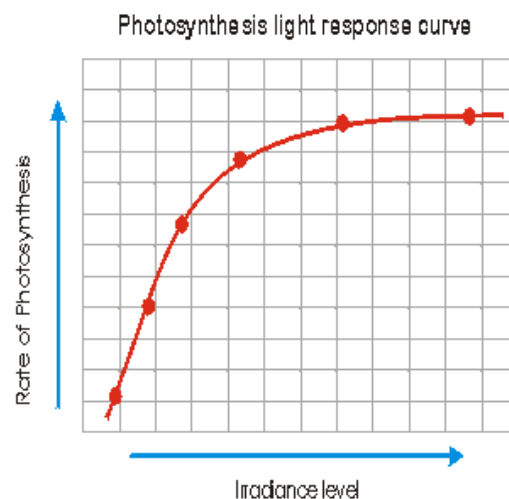
- CHP requires gas and produces heat, CO₂ and electricity
- Depending on greenhouse product climate requirements and wheather CHP can be used flexibly





Flexibility in production/growth curve

- › Flexibility is possible in the production/growth curve.
- › Thus, flexibility in climate parameters (temp, light, CO₂, humidity)
- › Use this flexibility for optimal energy trading





Scope and focus in GreenGrowing

- › **Finetune** flexibility concept for greenhouse energy demand and supply
=> work out the flexibility possibilities in more detail
- › Derive **flexibility profiles** based on existing and (possibly also) new production/growth models
- › **Develop energy management component** that matches flexibilities and supports decision making for energy trading
- › Combined **information provisioning** on greenhouse climate, product flexibility, weather conditions and energy markets.
- › The developed component/system **enables greenhouse controllers** and energy companies to **balance energy demand and supply** in near real-time.

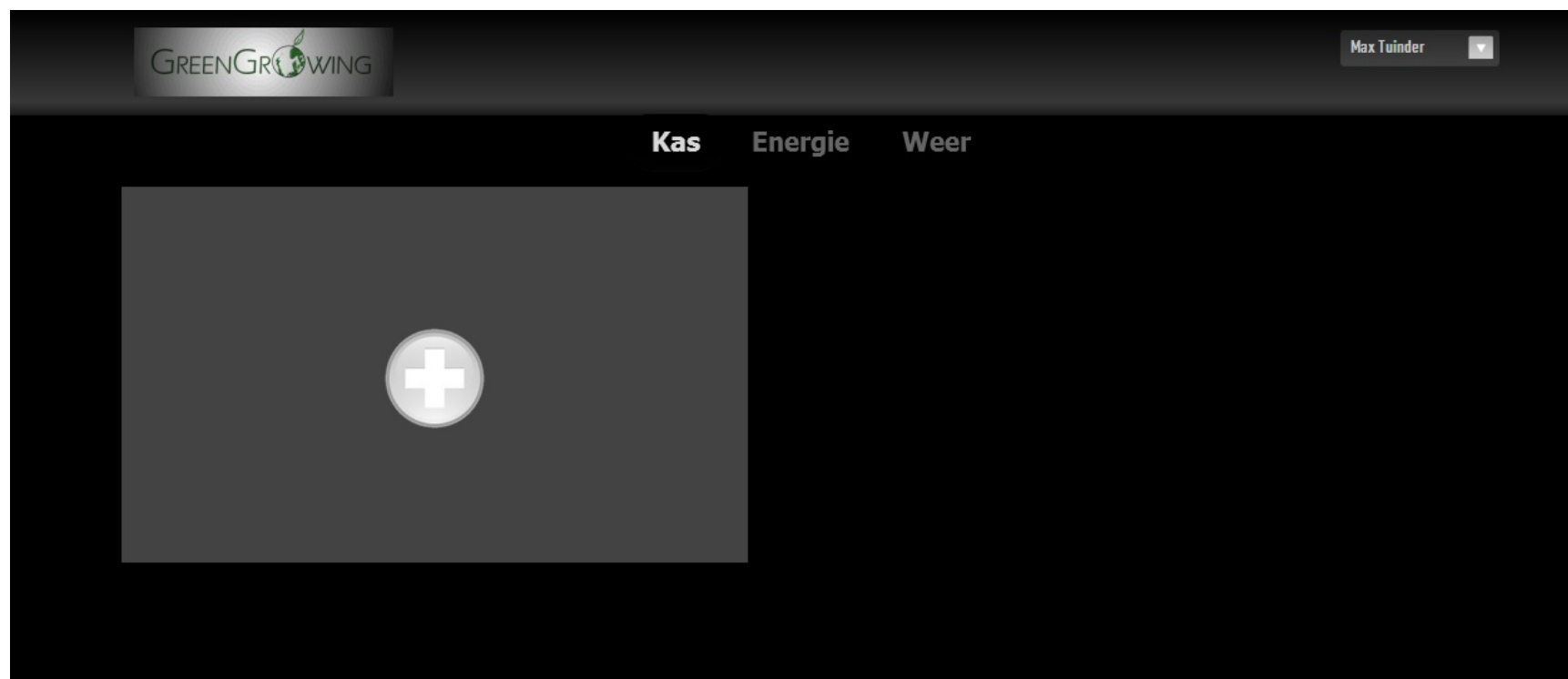


Greenhouse Intelligent Energy Management App – first version

- › App on tablet to combine all possible inputs a grower / greenhouse energy manager needs (Android, Windows, iPad)
- › First focus on information provisioning to grower/energymanager
 - › No decision support yet
- › Combines existing information sources on:
 - › Greenhouse current and near future climate parameters (temp, light, CO₂, humidity)
 - › Energy markets (day-ahead, intra-day, imbalance, OTC)
 - › Weather channels (as local as possible)

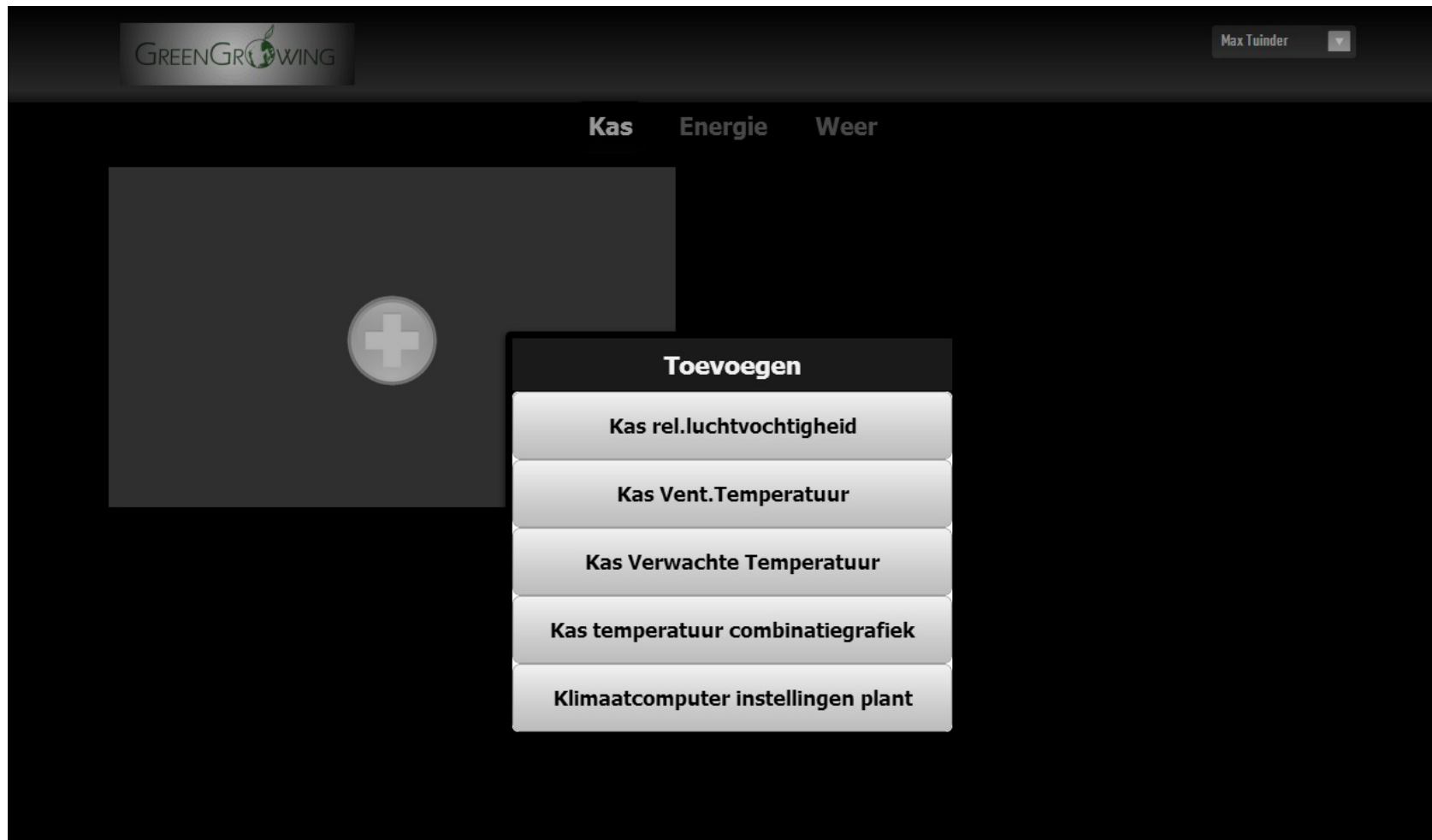


Greenhouse Intelligent Energy Management App – first version



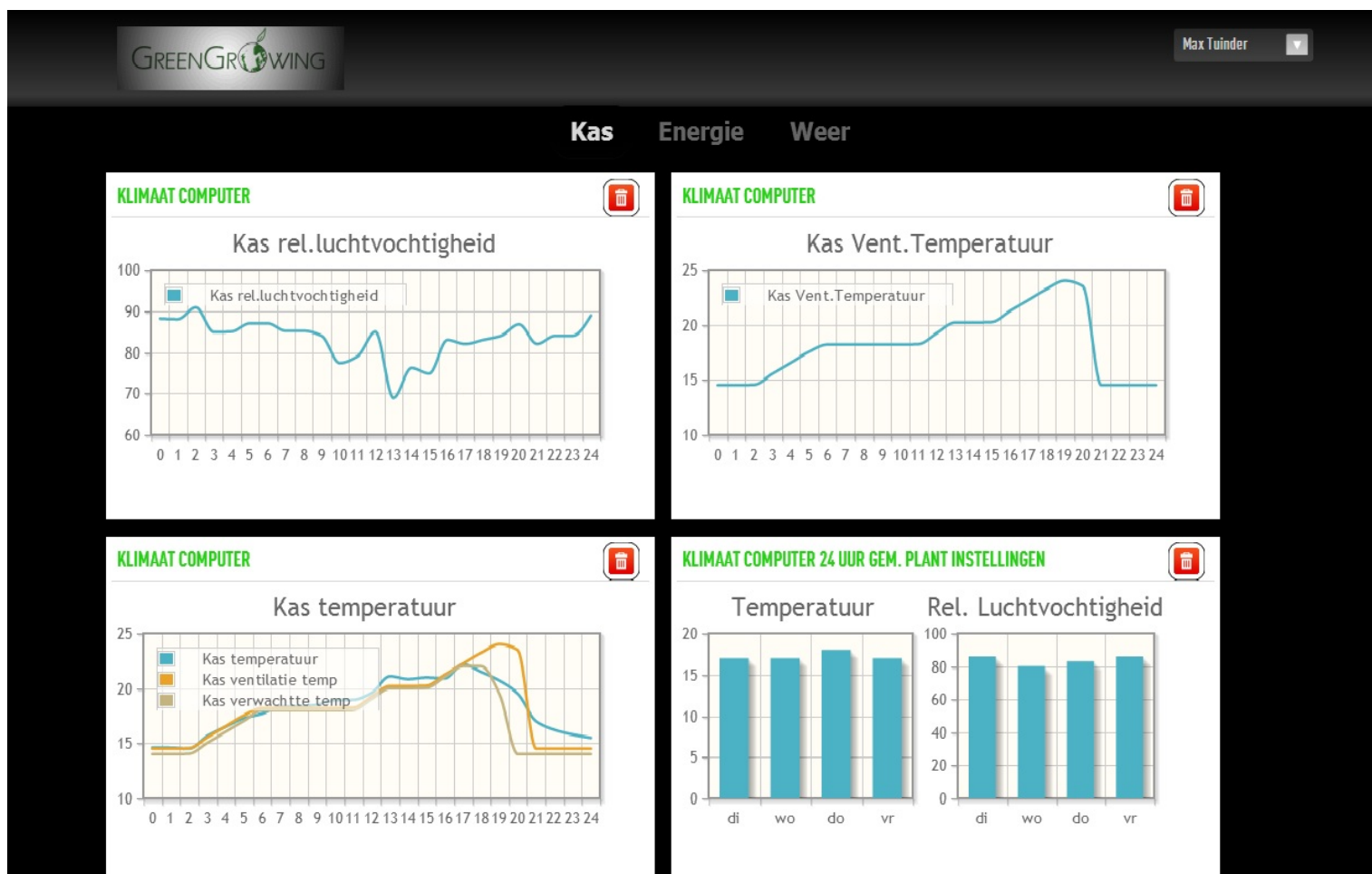


Greenhouse Intelligent Energy Management App – first version





Greenhouse Intelligent Energy Management App – first version



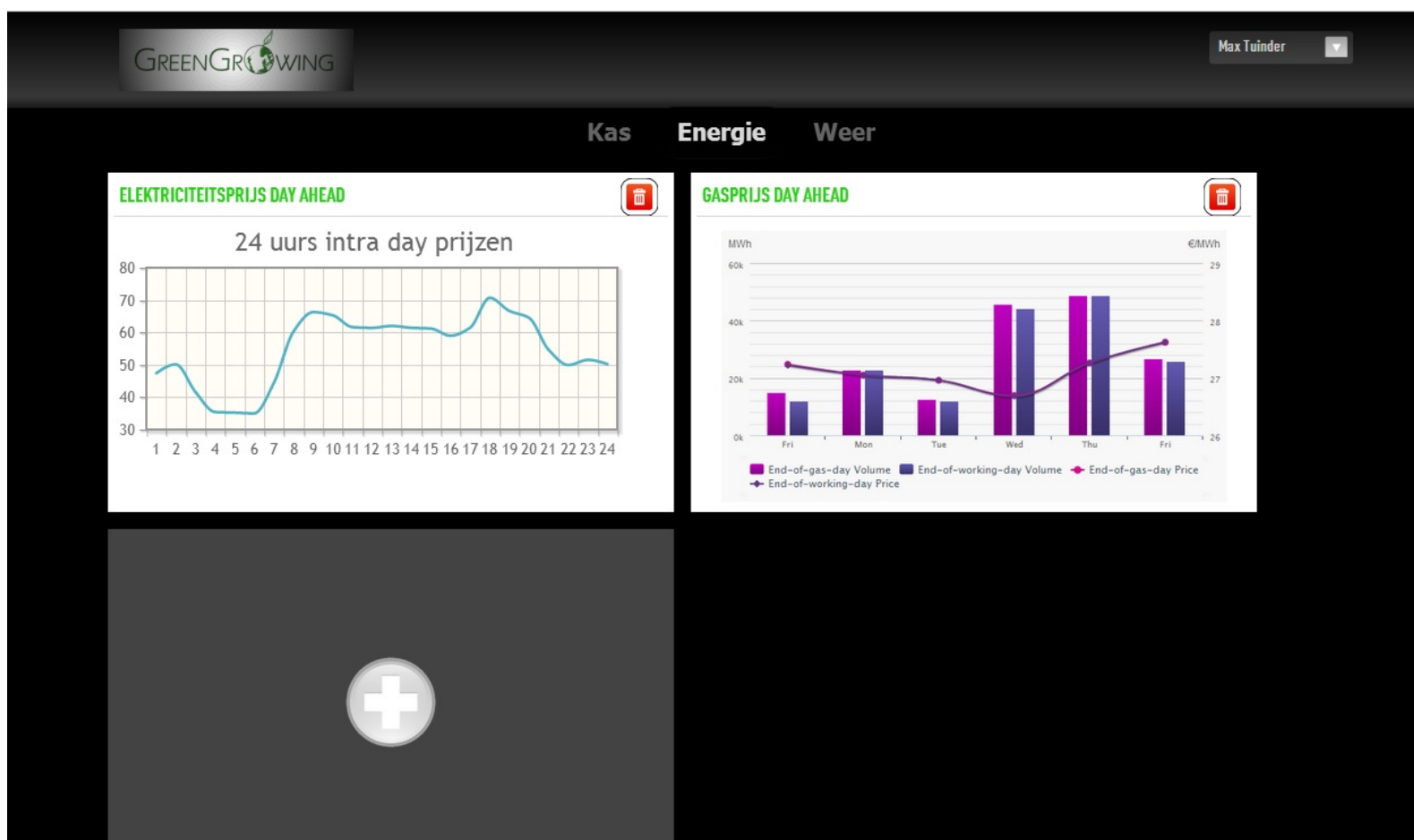


Greenhouse Intelligent Energy Management App – first version





Greenhouse Intelligent Energy Management App – first version



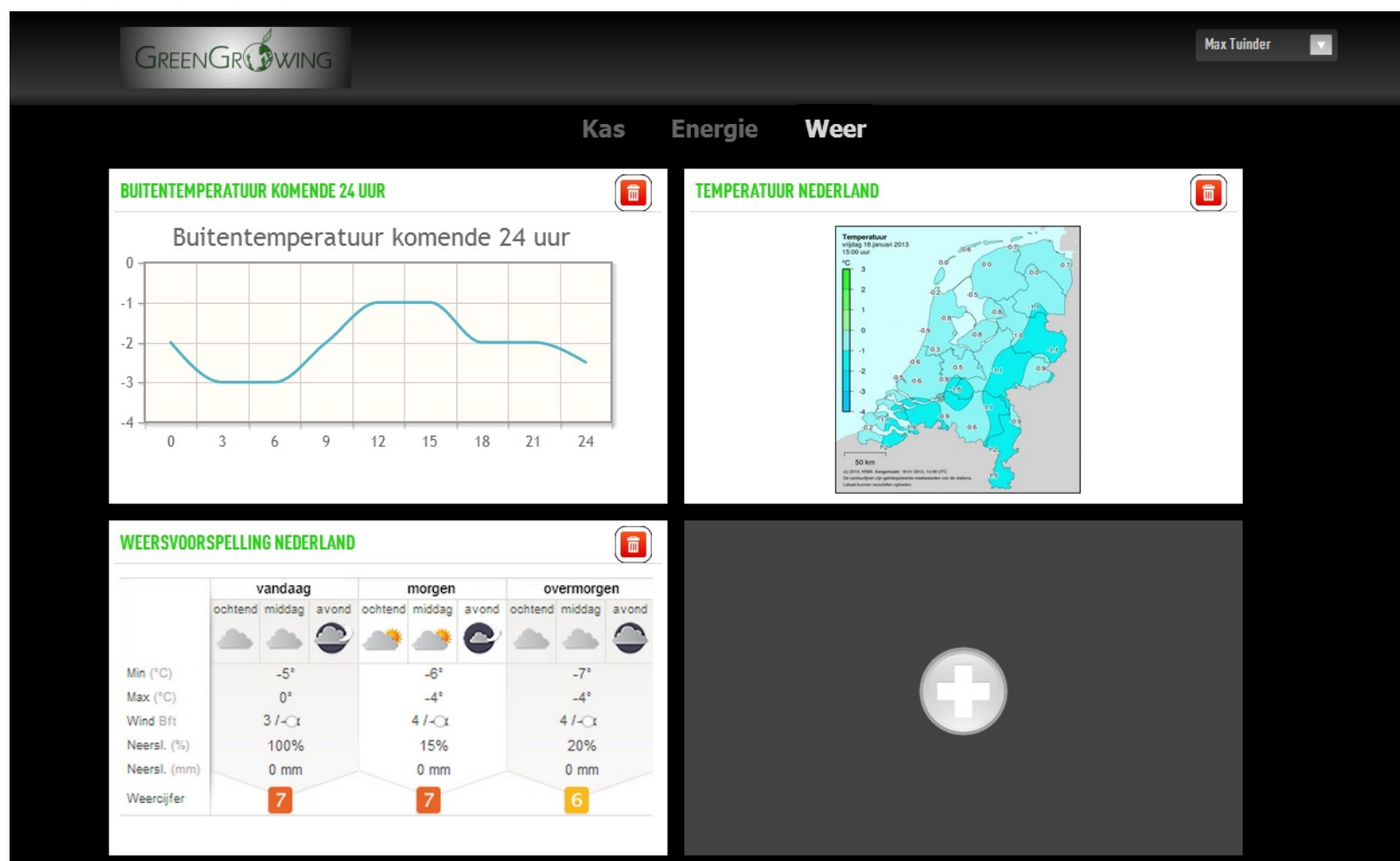


Greenhouse Intelligent Energy Management App – first version





Greenhouse Intelligent Energy Management App – first version





Further developments

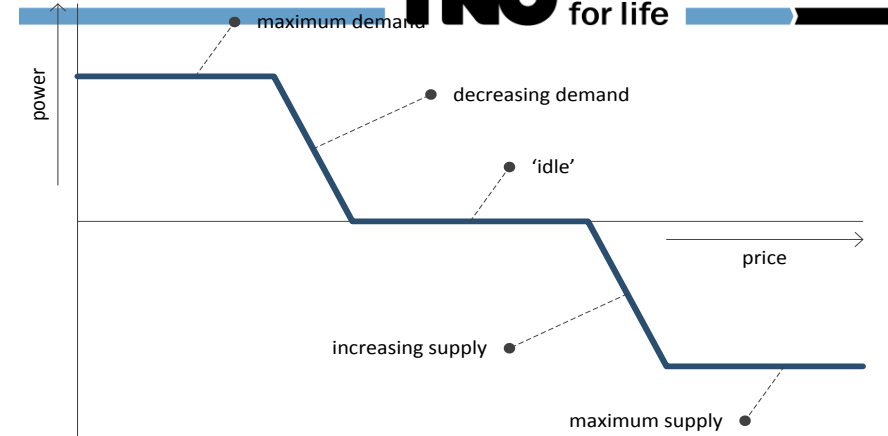
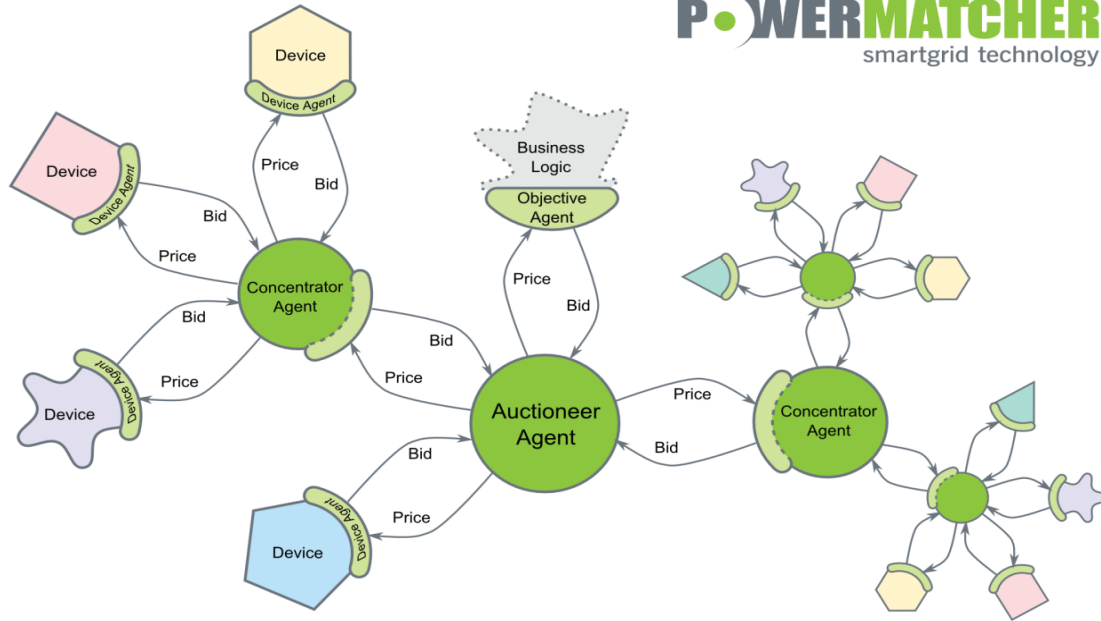
Further development of the app:

- › Connection with data from a Priva climate computer:
 - › Real-time current parameter settings and monitoring
 - › Near-future settings (e.g. next week)
- › Integration or coupling with Dynalight module for flexible lighting
- › Integration or coupling with tools for energy trading (e.g. Powerhouse)

Flexibility profiles based on production/growth models

Pricing strategies of greenhouse “owner”

Trading advice for greenhouse energy manager



PowerMatcher is an approach for **supply / demand management**
which defines a **multi-agent system**
wherein **agents** interact as in a **real-time market**



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**Smart Grid
DSM solutions**

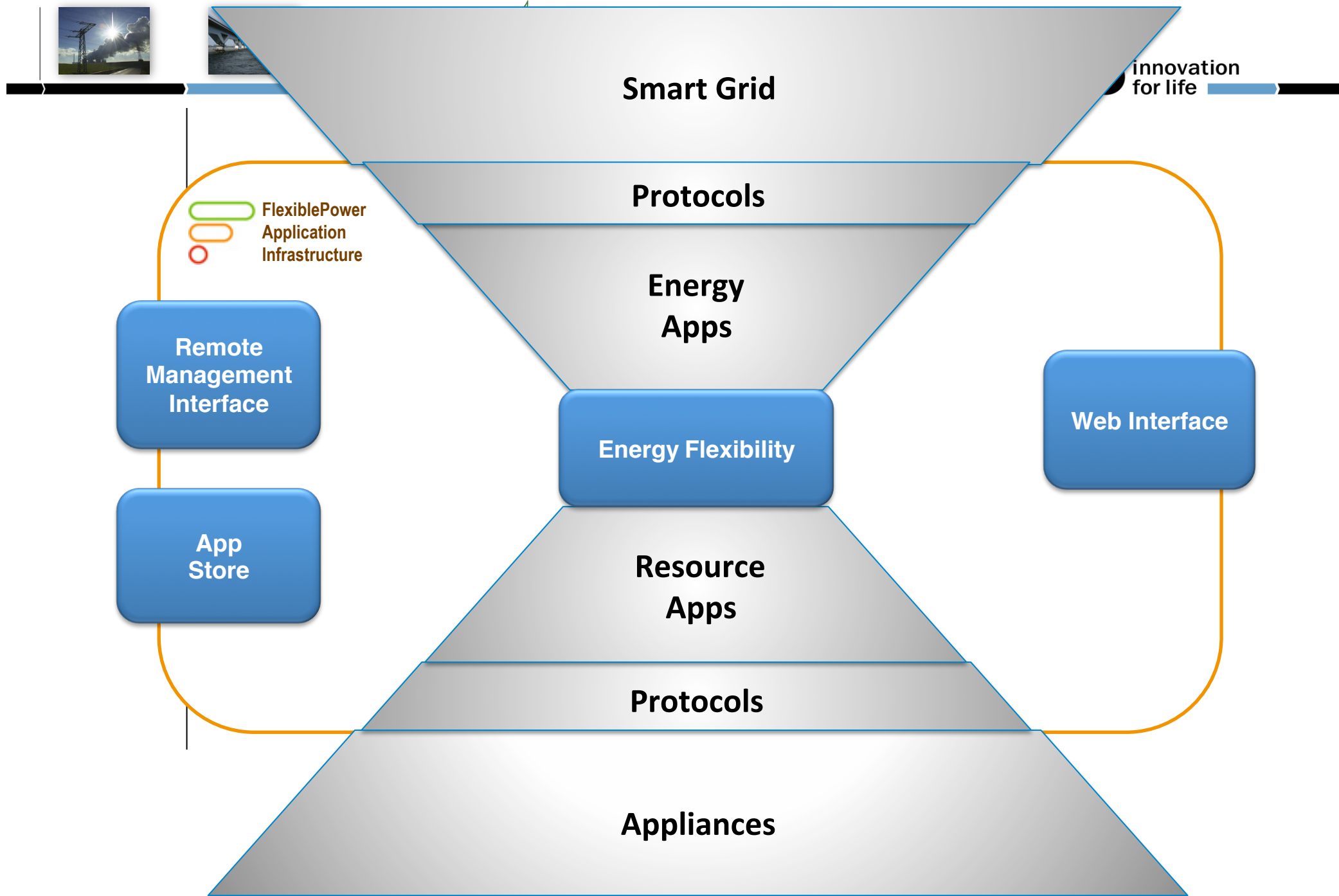
Timeshifter

Buffer

Storage

Un-
controlled

Appliances



POWERMATCHER CONTROLLER

Market Price € 0,00
Last bid 5:47:48 PM CEST
Storage Agent [-1500.0, 0.0, 1500.0] W
Uncontrolled Agent [-1519.0] W



SMARTPV PANEL

Supply at 17:47:50
Power Output 1519 Watt



STORAGE DEVICE MANAGER

State of charge 53%
Total capacity 1,0 kWh
Current mode CHARGE



INRGBOX CONNECTED MICROCHP

Room Temperature 21.8
Target Temperature 4
Kwh Produced 247.13



Dashboard



Appliances



Apps



AppStore



Settings