Hydrogen as seasonal energy storage for Floriade:

The implications of hydrogen in the built environment as part of an energy system

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January 25th 2019

Witteveen Bos
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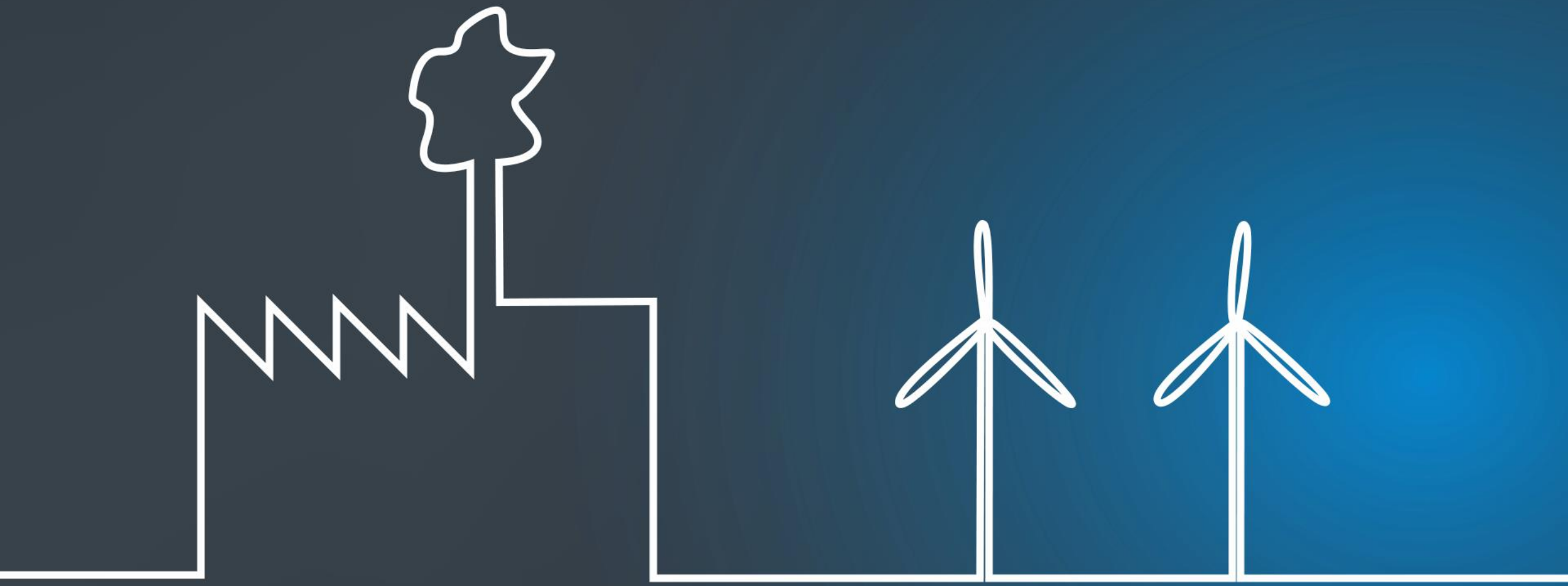


0 Introduction & the energy transition

Hydrogen

- the most abundant element in the universe
- estimated availability as long as the existence of humans
- non-toxic, colorless, odorless, tasteless gas
- Low volumetric weight

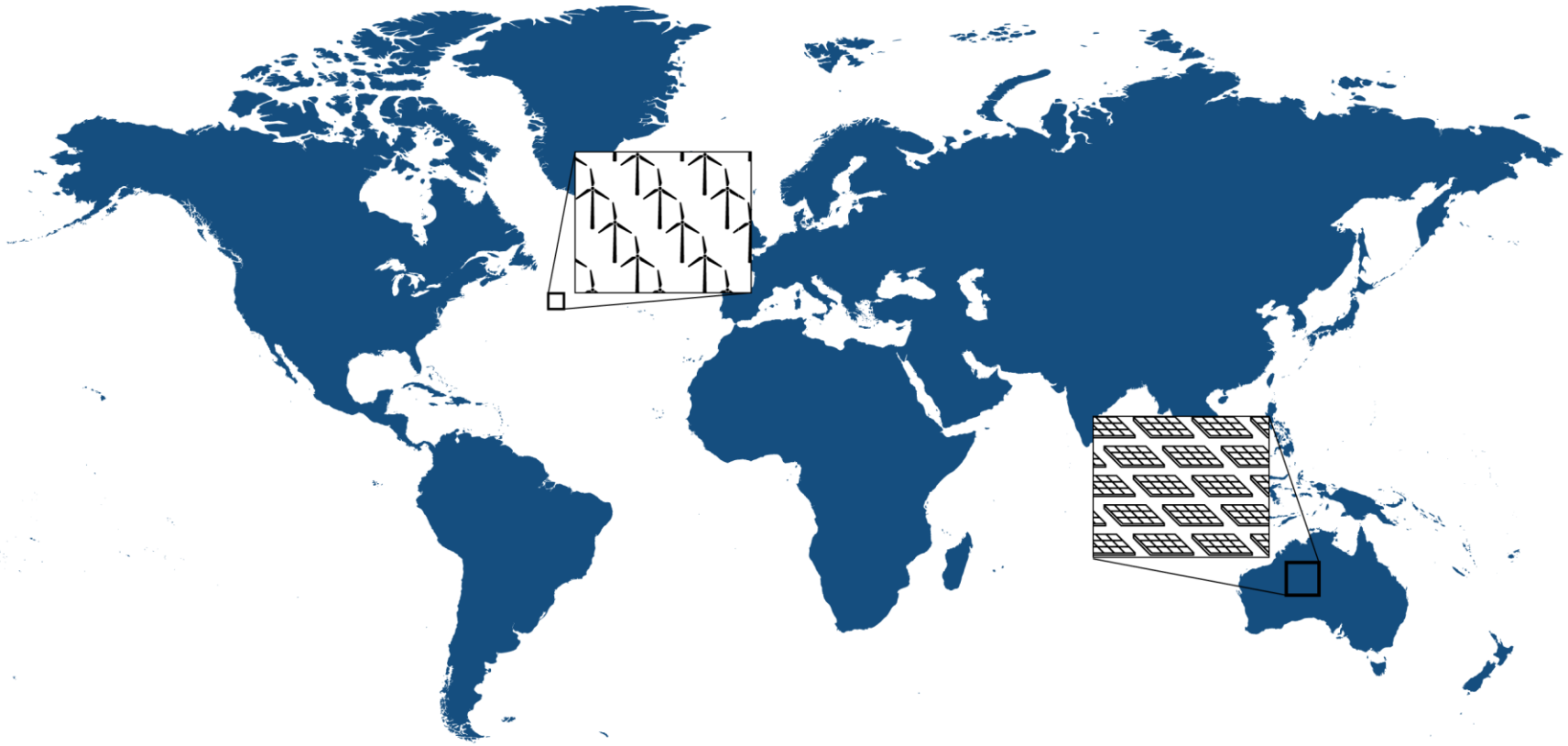
Hydrogen safety

Hydrogen car

Gasoline car

Source: http://evworld.com/article.cfm?storyid=482

All the worlds' energy:
556 EJ = 155.000 TWh

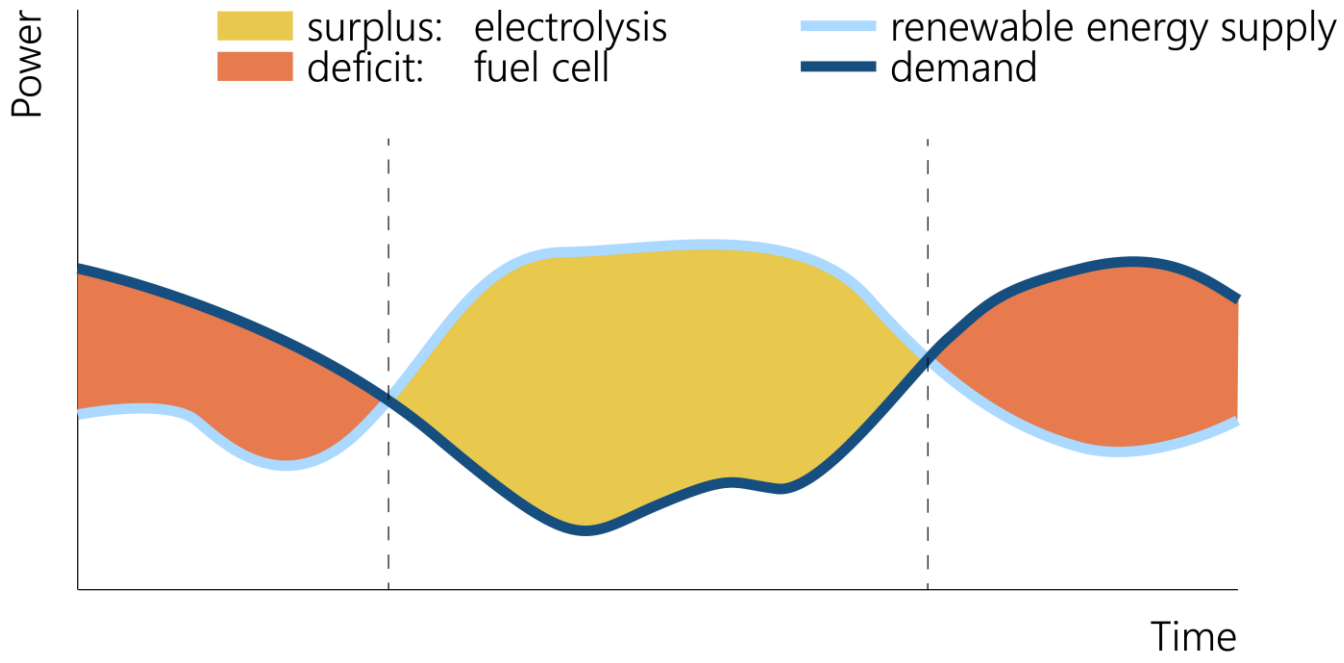


* Based on van Wijk, 2018

Energy mix in the Netherlands in 2016

* CBS, 2017

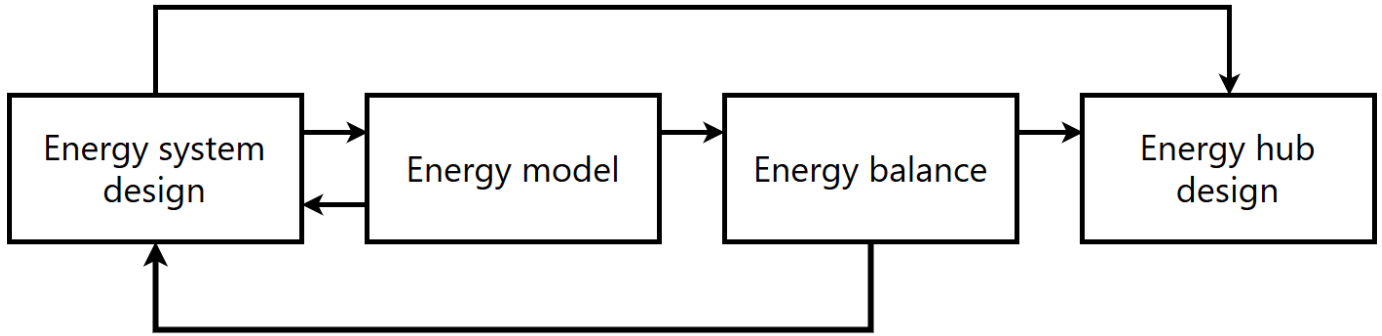
The energy mismatch



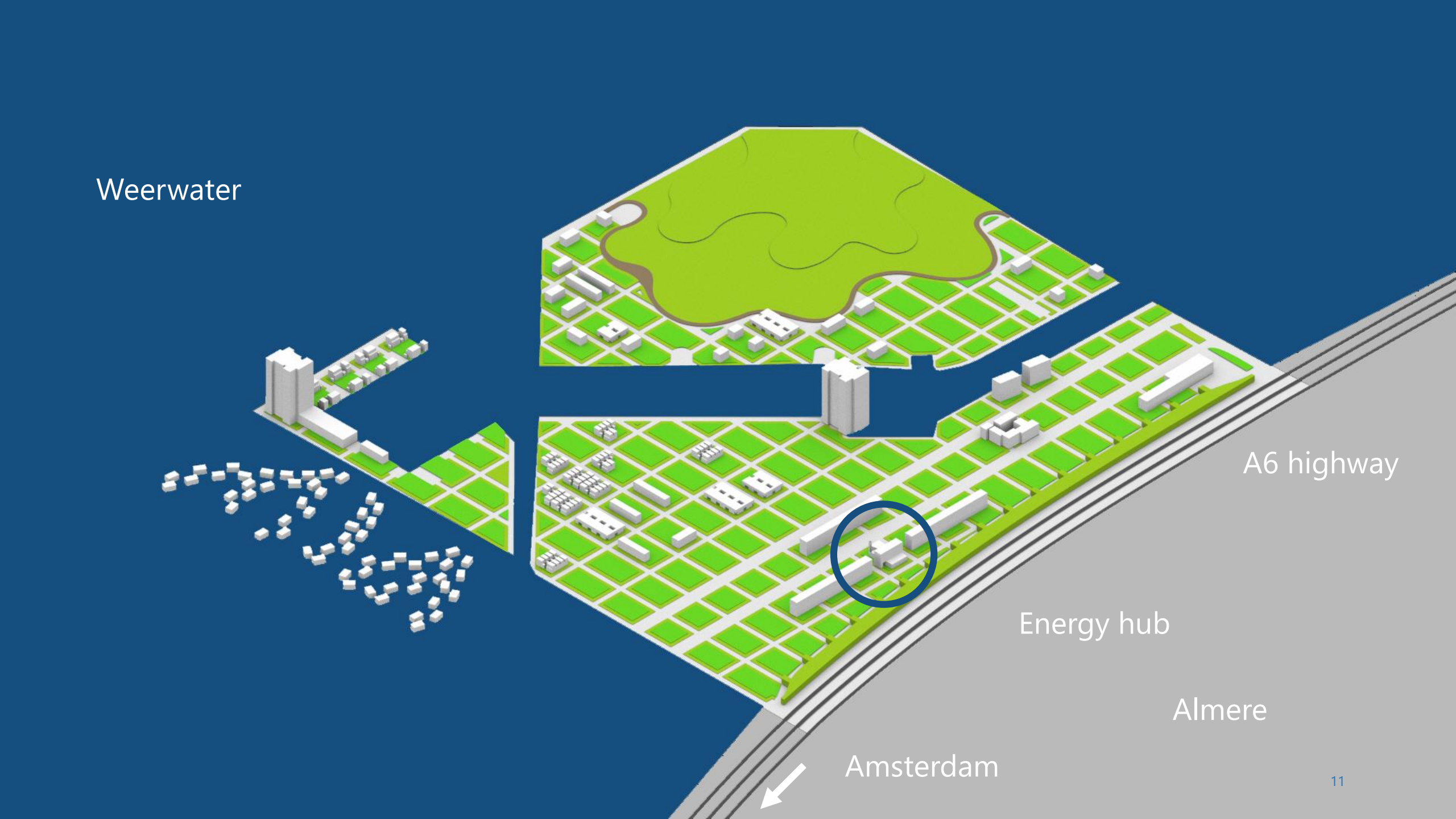
The research

What does an energy system with hydrogen incorporated as seasonal buffer for a newly built residential area look like and what are the implications of the application of hydrogen in the built environment?

Lay out of the research



1 Case study: Floriade


Weerwater
A6 highway
Energy hub
Almere
Amsterdam

Floriade impressions

Copyright Design(ed) by Erick van Egeraat

Floriade impressions

Copyright Design(ed) by Erick van Egeraat

Floriade impressions

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Floriade impressions

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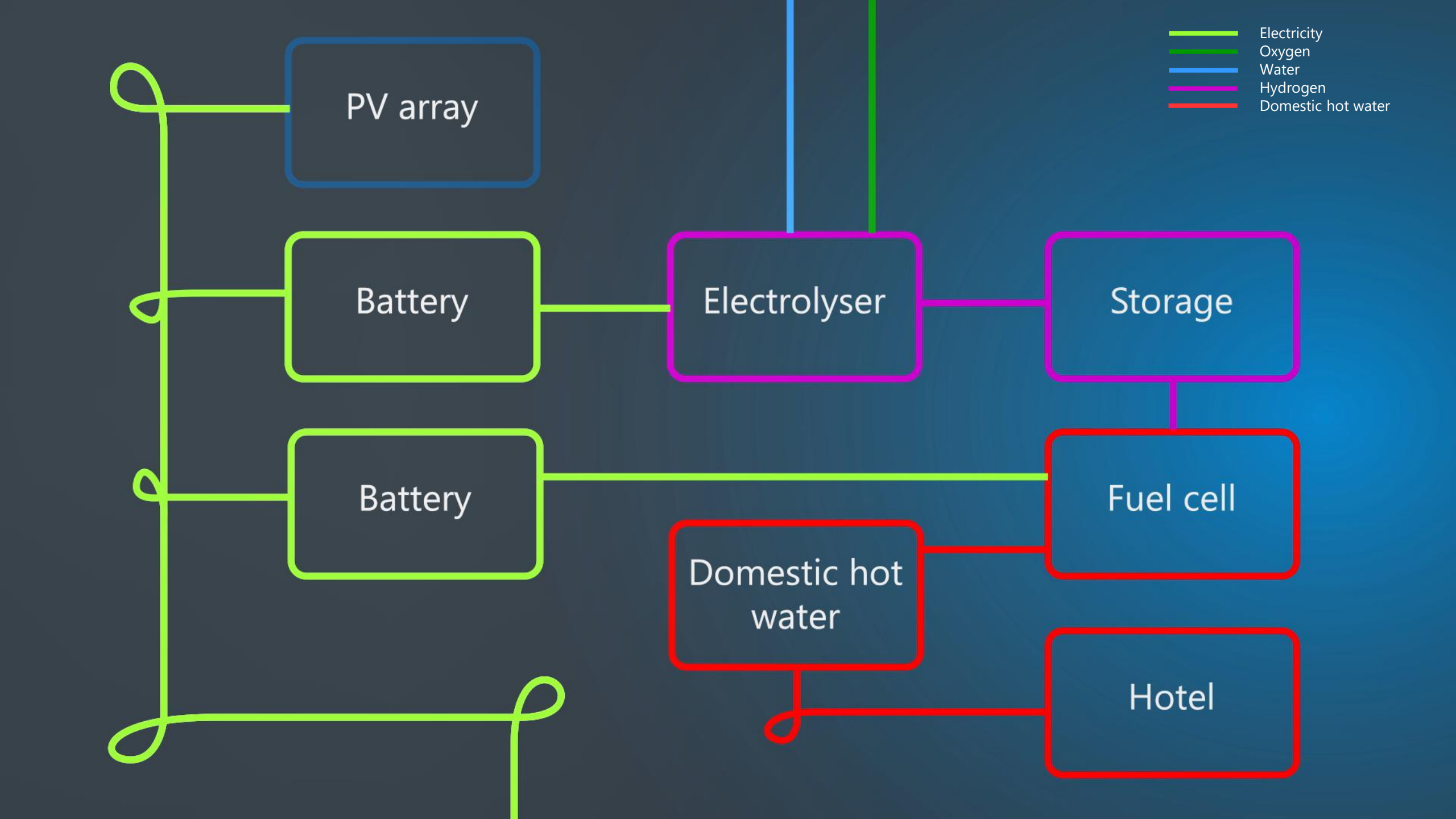
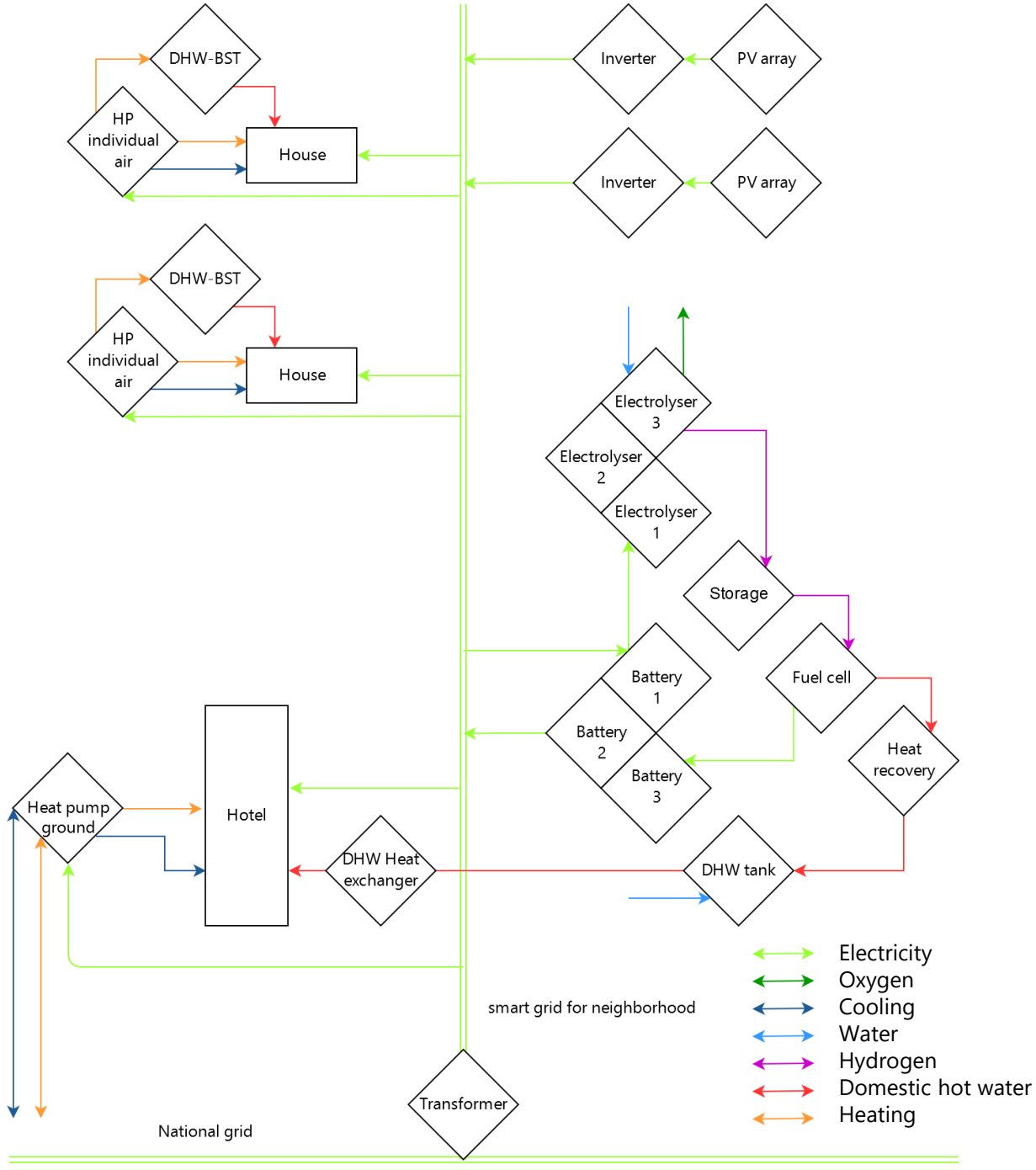
2 Energy system design

Design criteria

- Distribution of locally produced renewable energy
- Reduce load on national grid
- Subterranean infrastructure
- Display hydrogen technology in the context of the built environment

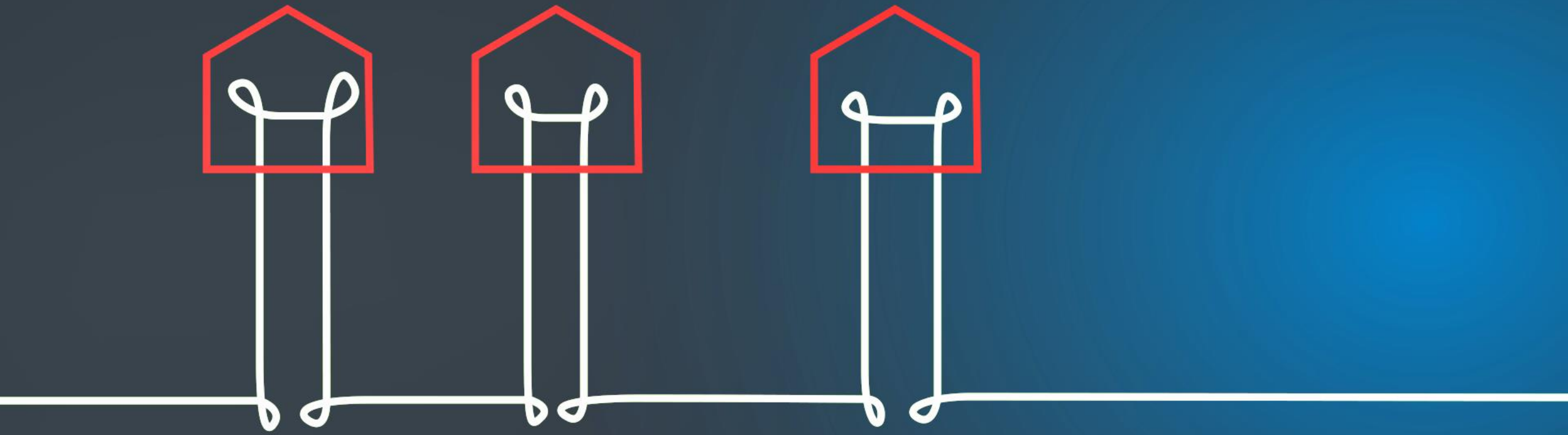

Electricity
Oxygen
Water
Hydrogen
Domestic hot water
PV array
Battery
Battery
Electrolyser
Storage
Fuel cell
Domestic hot water
Hotel


DHW-BST
HP individual air
House
DHW-BST
HP individual air
House
Inverter
PV array
Inverter
PV array
Electrolyser 3
Electrolyser 2
Electrolyser 1
Storage
Battery 1
Battery 2
Battery 3
Fuel cell
Heat recovery
Heat pump ground
Hotel
DHW Heat exchanger
DHW tank
smart grid for neighborhood
Transformer
National grid
Electricity
Oxygen
Cooling
Water
Hydrogen
Domestic hot water
Heating

Energy system conclusions

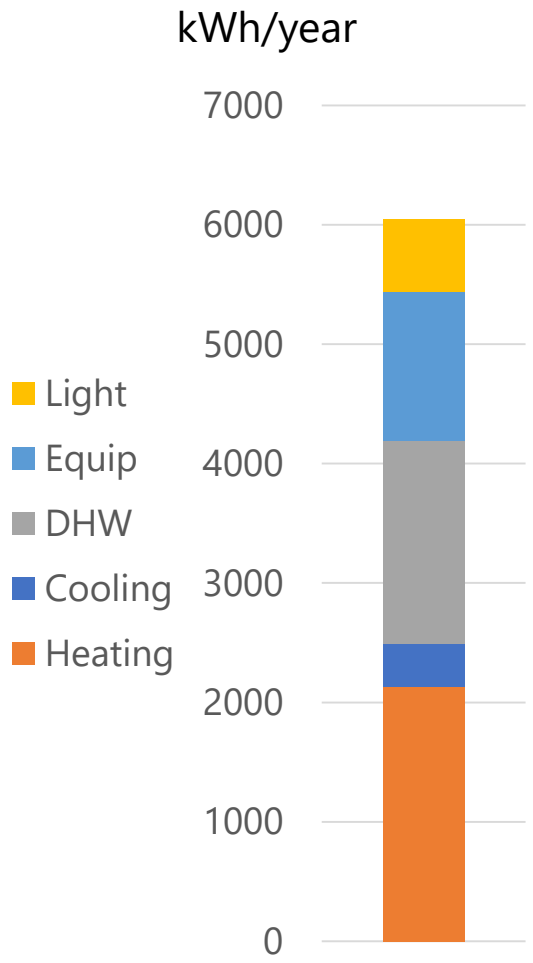
- All-electric solution
- System components are highly dependent on each other

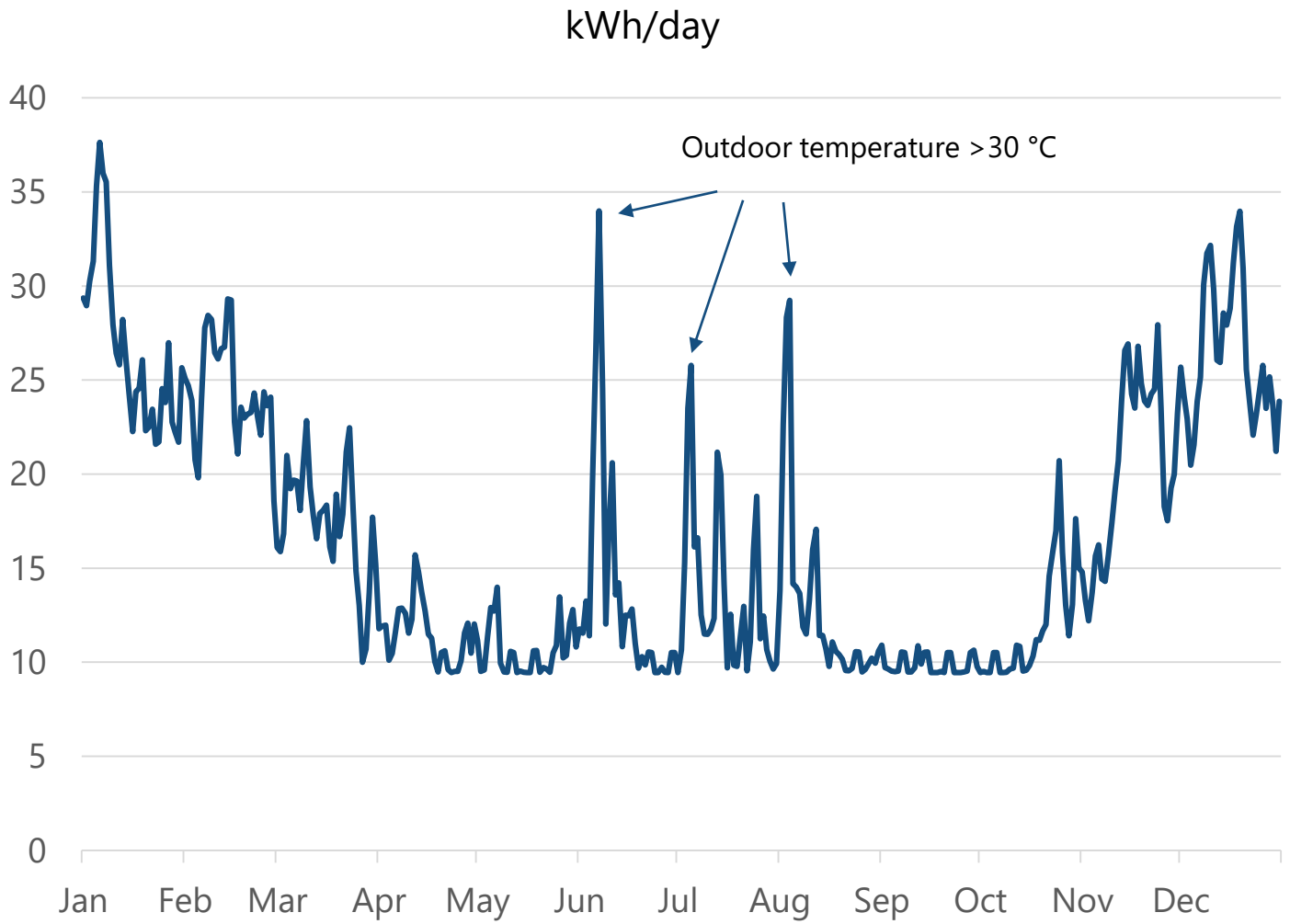
3 Energy modelling



Consumption

Energy consumption of Floriade reference house

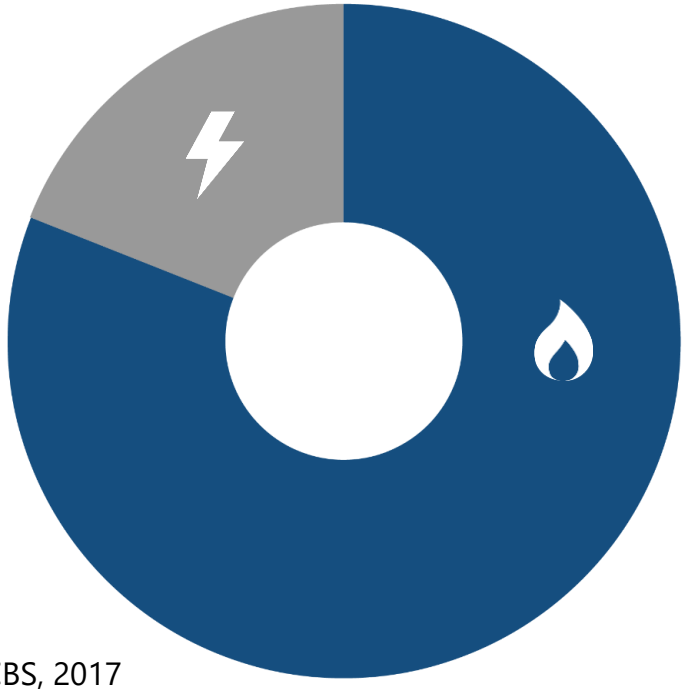




Energy consumption of Floriade house vs Dutch average

Average Dutch house

~17.660 kWh*



* CBS, 2017

Floriade reference house

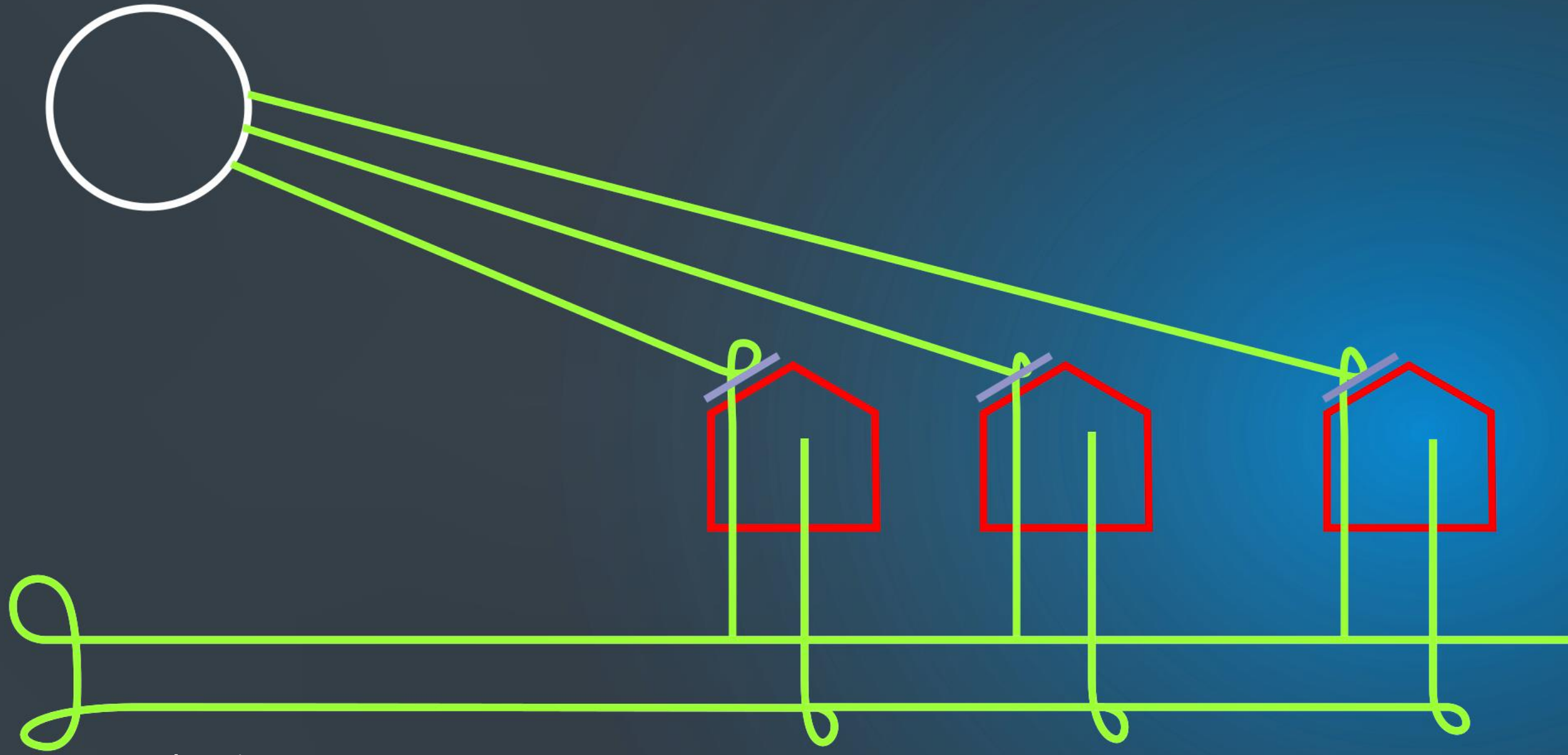
~6.050 kWh

Energy consumption of Floriade

~1.550.000 kWh/year

3 MW wind turbine = 6.500.000 kWh/year

3 hectare solar field = 1.500.000 kWh/year

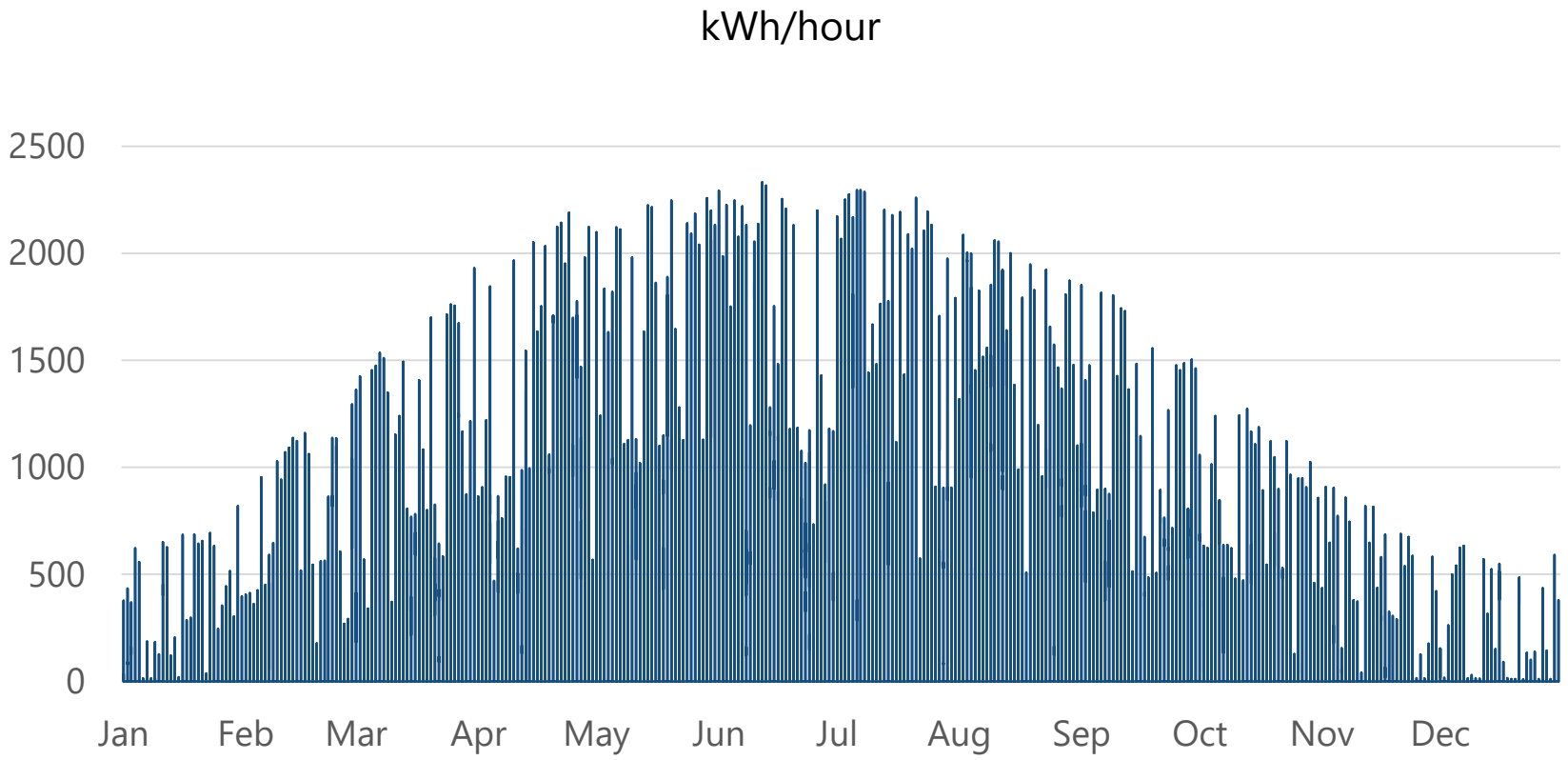


Production

Annual energy production potential

- South oriented PV panels
- 80% of roofs of ground based houses covered
- ~16.000 m^2 of PV panels
- ~3200 kW system size

Annual hourly energy production



Energy production potential of Floriade

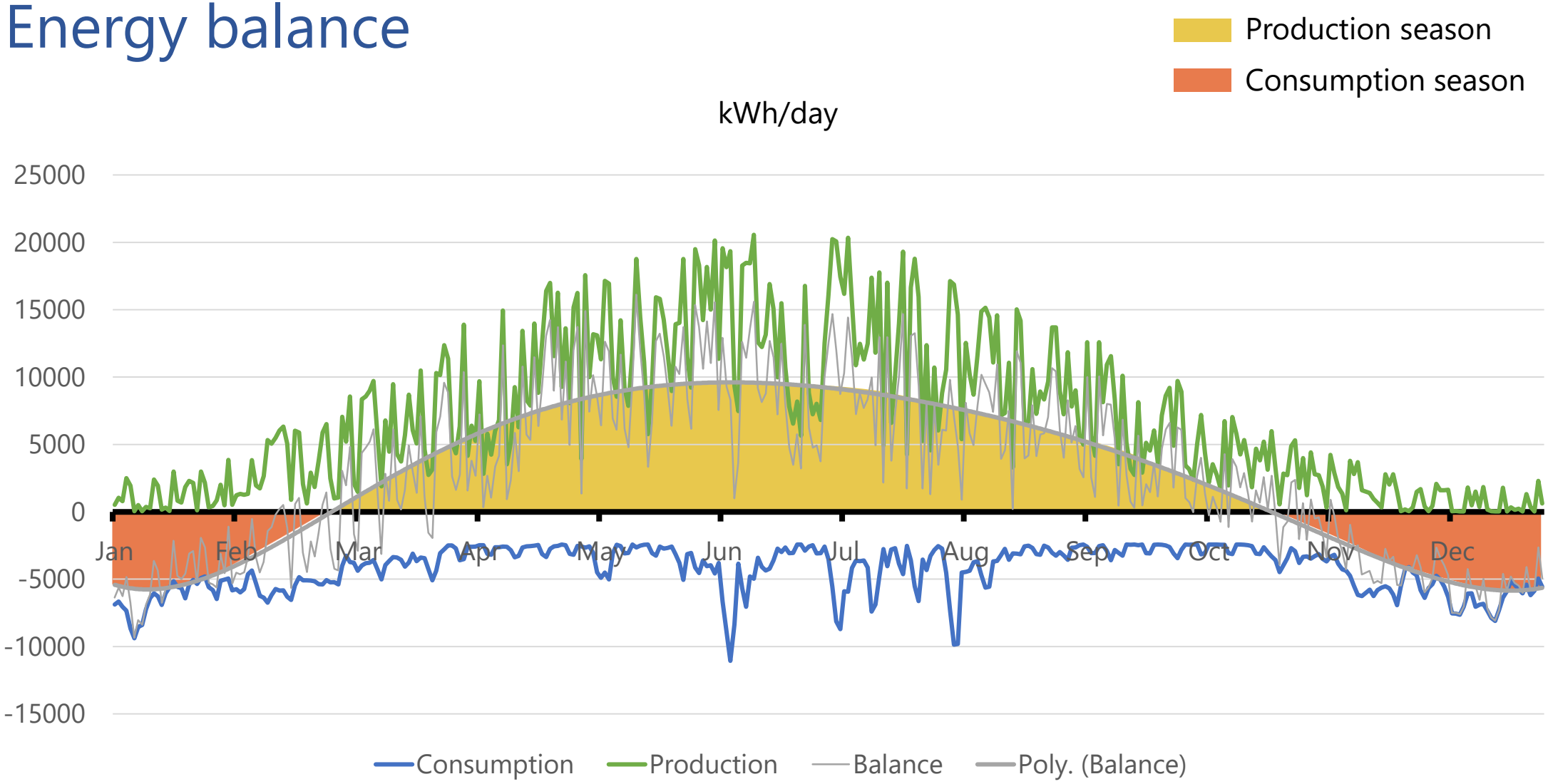
~2.590.000 kWh/year

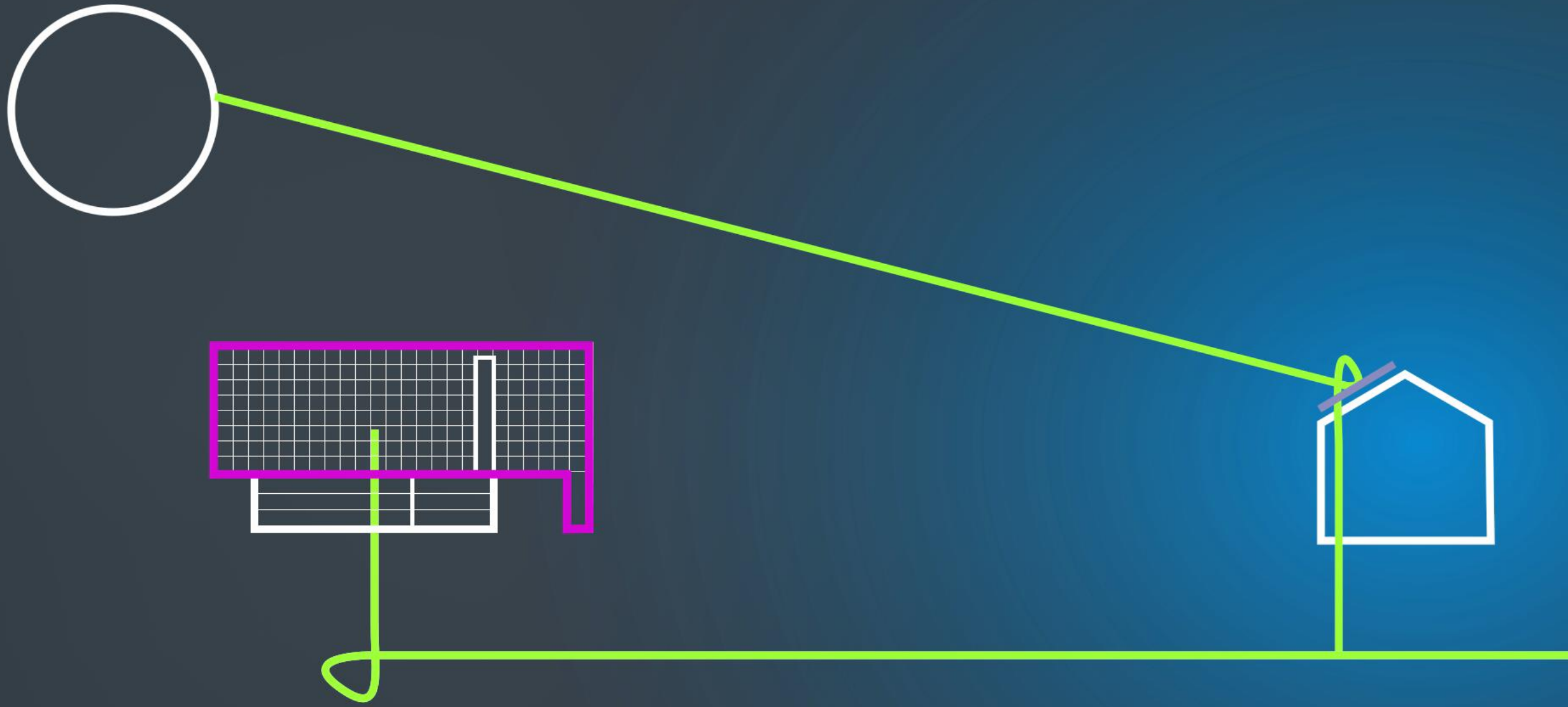
380 Floriade houses

146 Traditional houses

4 Energy balance

Energy balance

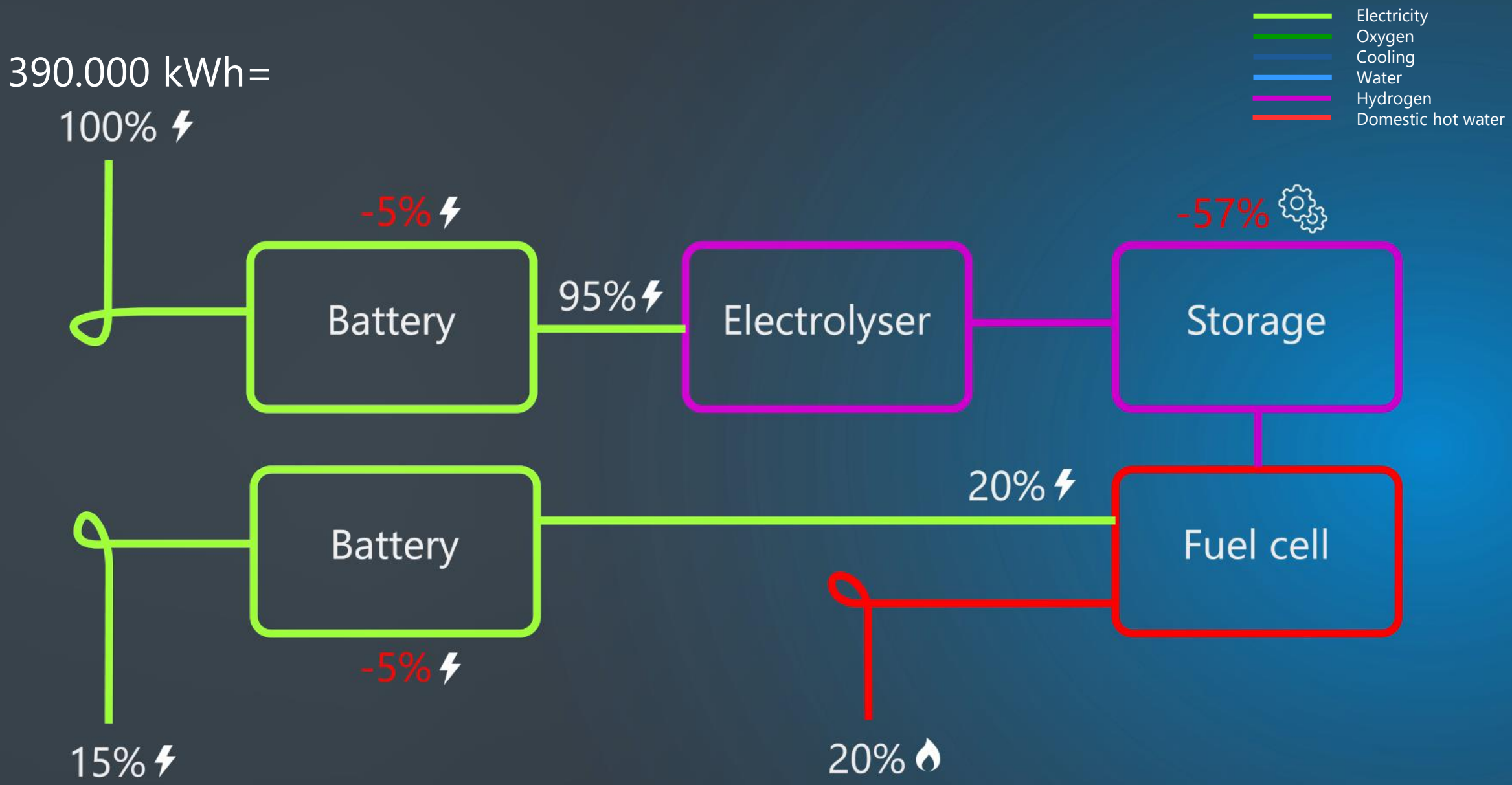




Surplus

Energy surplus

~2.220.000 kWh



System efficiency

System efficiency

- Electric: 15%
- DHW for the hotel: 20%

- Total: 35%

Energy balance conclusions

- Energy consumption: 1.550.000 kWh
- Energy production: 2.580.000 kWh
- Energy surplus: 2.220.000 kWh

- The low energy consumption profiles and system size of the PV array result in the neighborhood being self sufficient for 12.5 days

Energy balance conclusions

- System efficiency: 35%
- High energy losses due to compression & conversions

Improvements

- Increase storage size
- Increase storage pressure
- Intermediate discharge of buffer
- Reduce amount of PV panels in the neighborhood
- Connect more users to the PV array
- Feed surplus energy to the national grid
- Mobility

Mobility

Hydrogen car

Toyota Mirai

1.19 kWh/km

460,000 km

Electric car

Tesla model S

0.19 kWh/km

Hydrogen bus

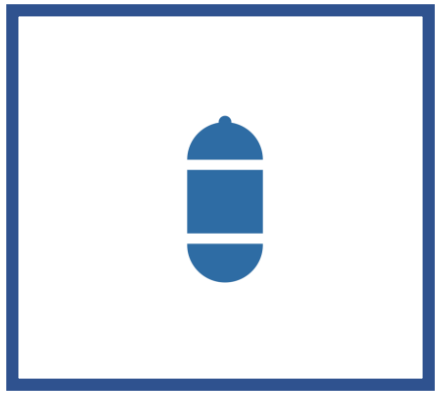
van Hool

9.37 kWh/km

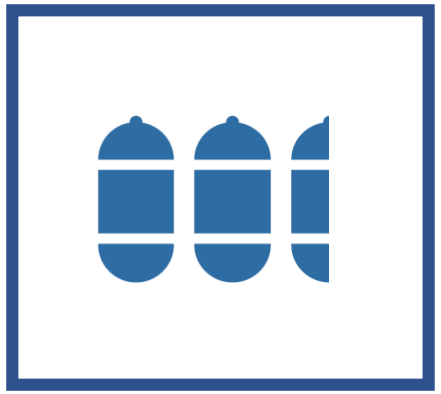
42,000 km

Increase storage pressure

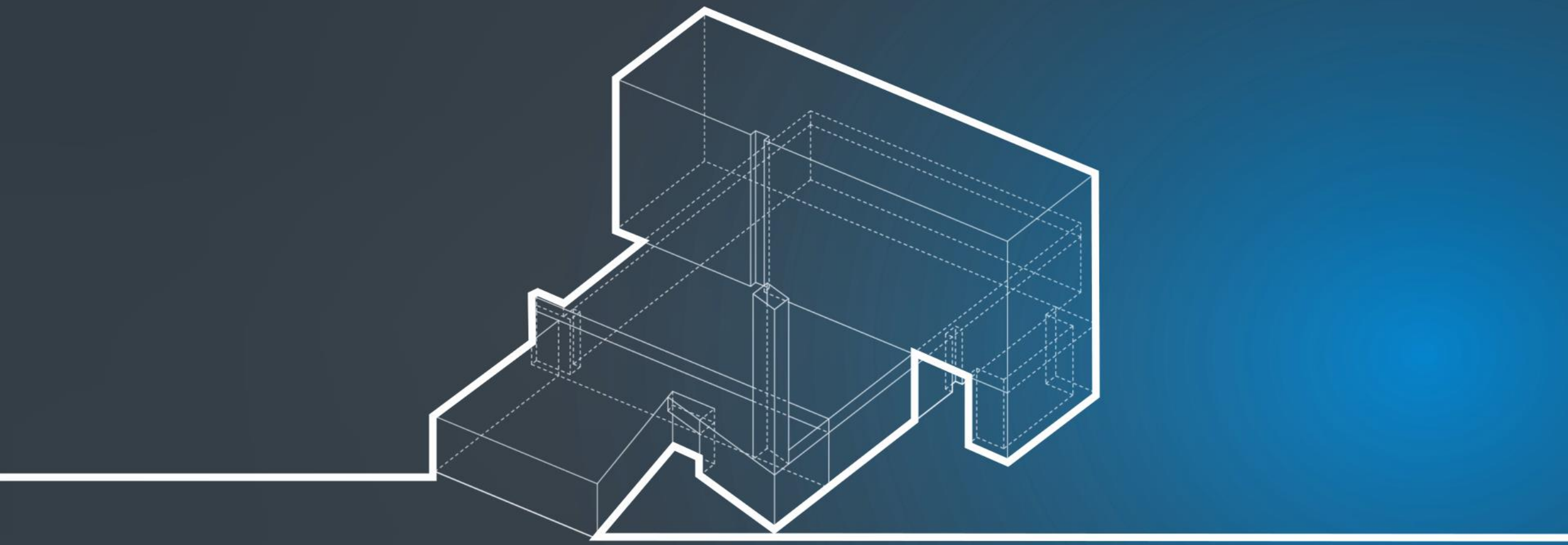
- Higher pressure = smaller volume per kg
- Higher pressure = more energy needed to store hydrogen
- 15% more energy = 2.5x more storage capacity in same volume



200 bar



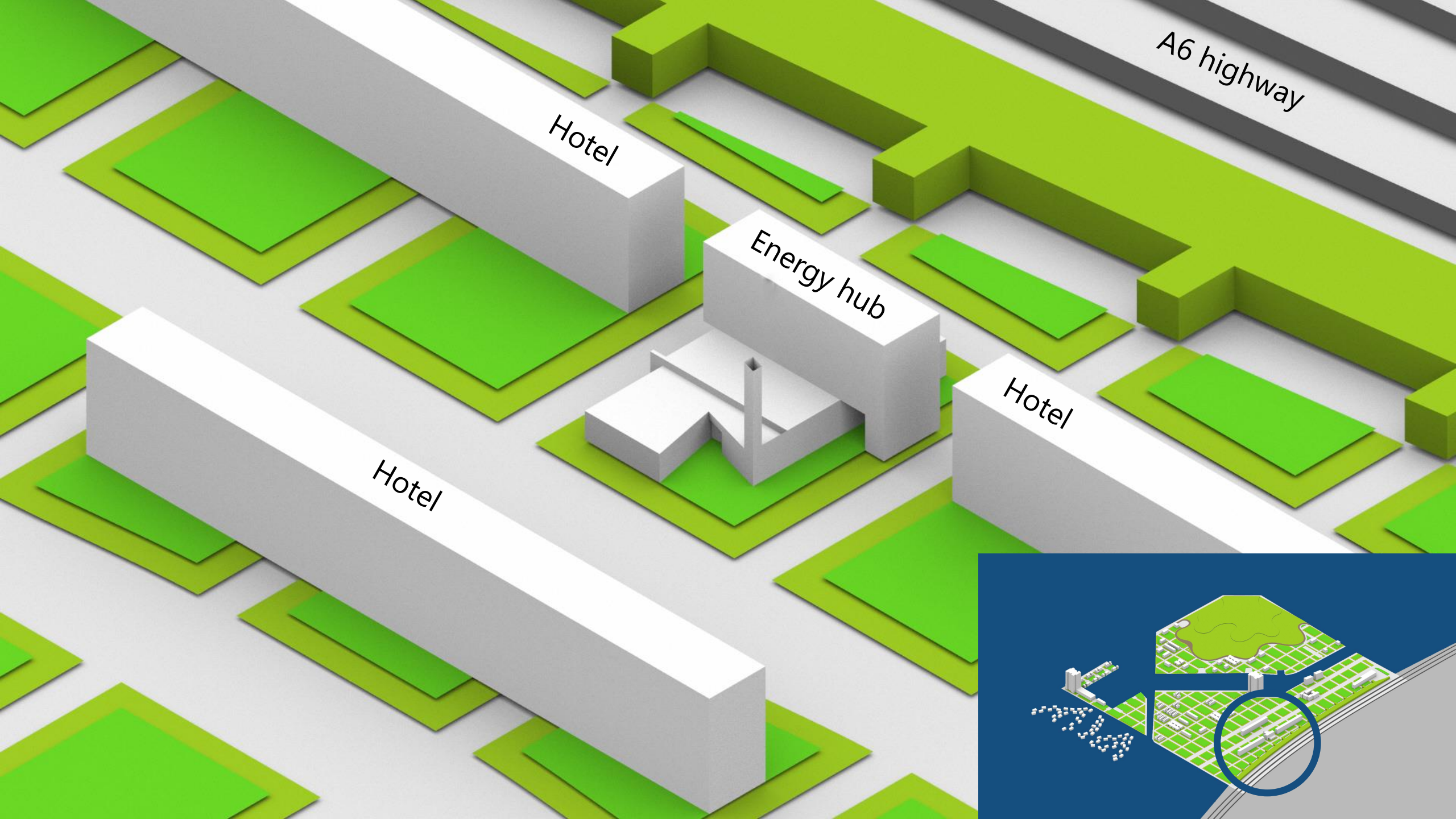
700 bar



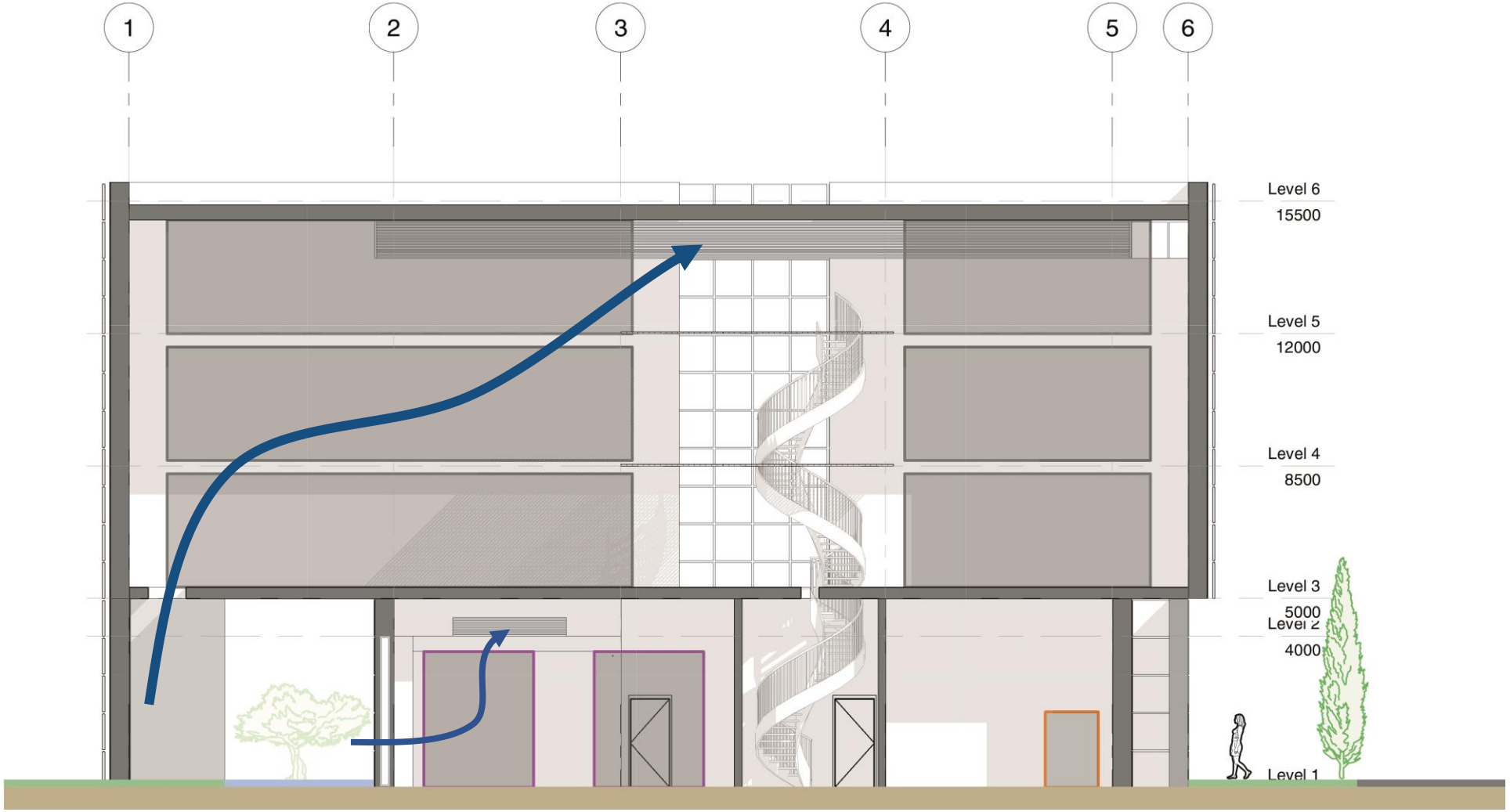
5 Energy hub design

Design boundaries

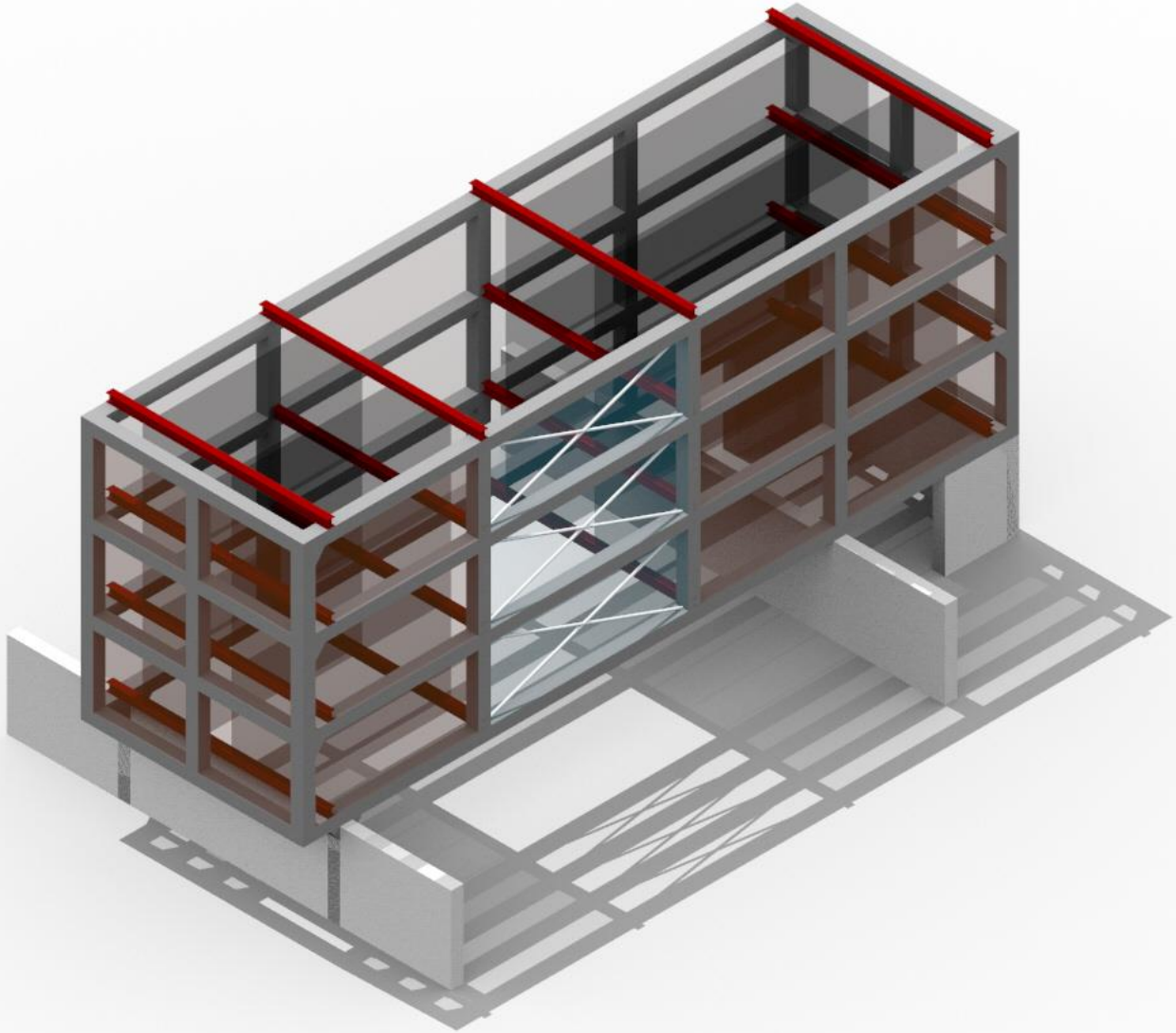
- Components size & connections
- Safety
- Visibility


A6 highway
Hotel
Energy hub
Hotel
Hotel

Ventilation



Construction

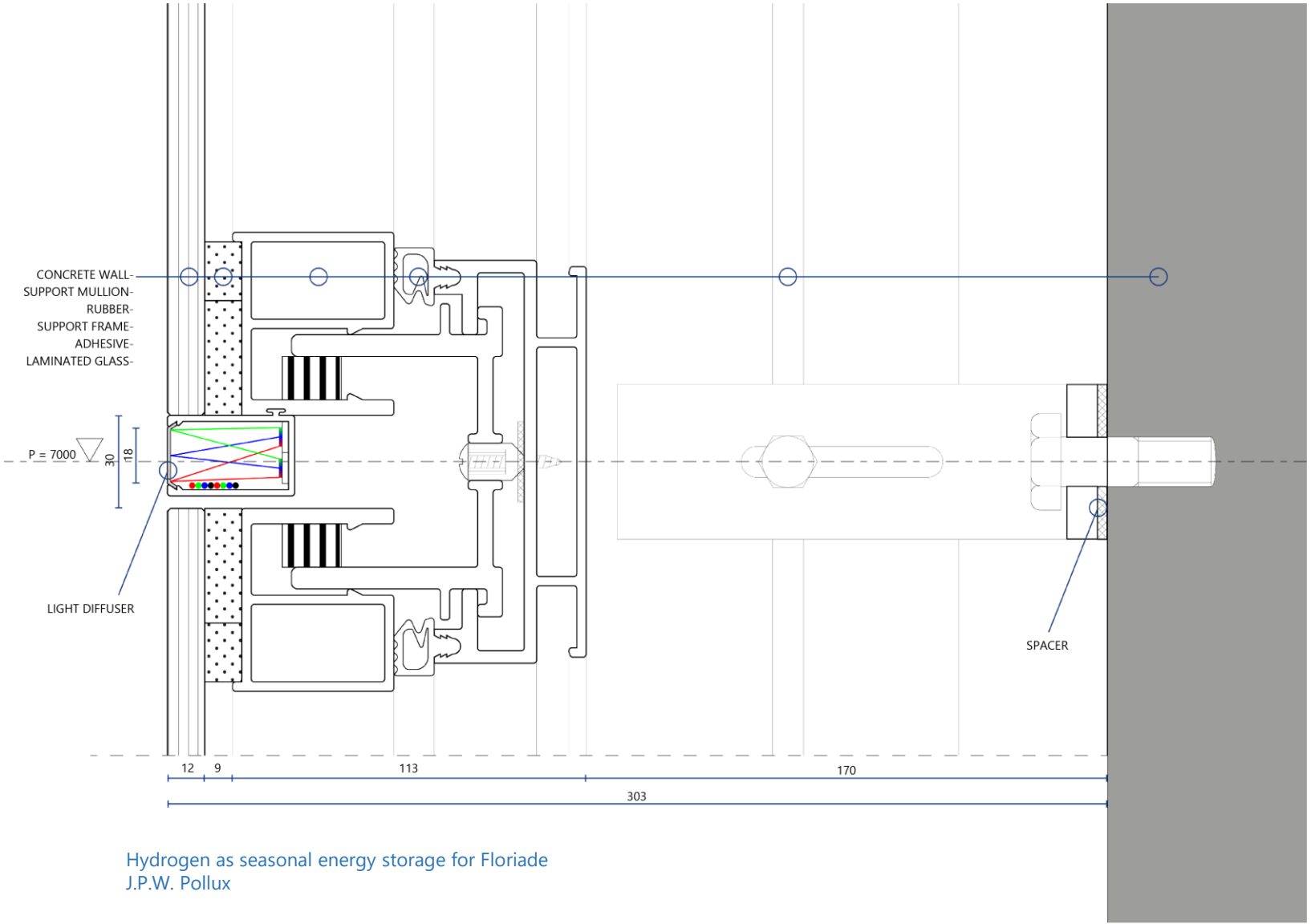


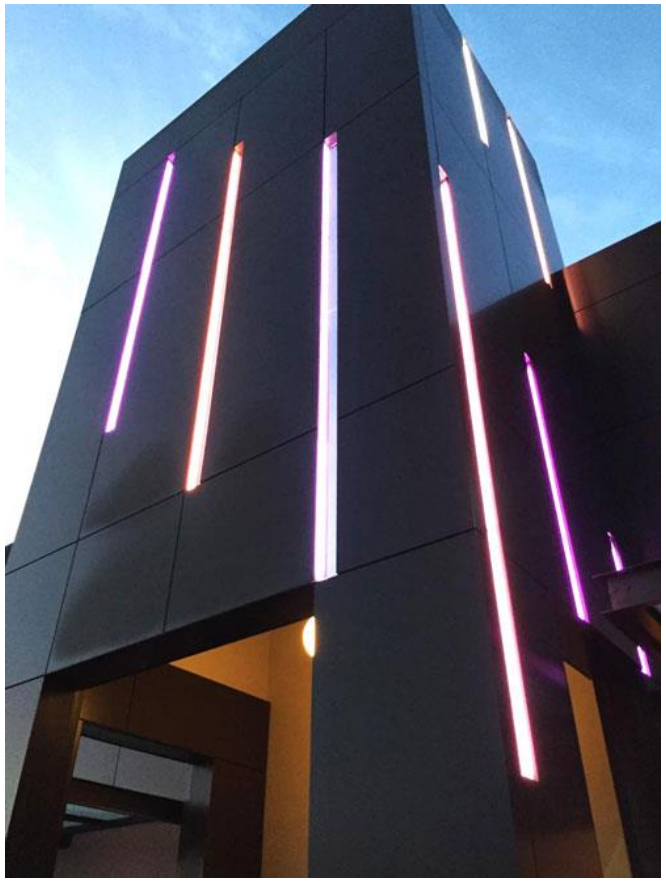
Façade design

Sears headquarters in Alhambra, USA by Albert C. Martin
https://pinupmagazine.org/articles/panorama-a-short-history-of-the-mirrored-glass-facade-buildings-ouida-biddle

Delftse Poort in Rotterdam by Abe Bonnema
https://www.cityguiderotterdam.com/nl/er-op-uit/architectuur/delftse-poort-rotterdam/

Façade design





6 Conclusions and recommendations

Conclusions on the research

- Extensive research with a focus on four parts of an energy system design
- Every part is dependent on other parts
- The low energy consumption profiles and system size of the PV array result in the neighborhood being self sufficient for 12.5 days

Recommendation on the research

- Optimization of system components and configuration necessary with a dynamic model

Recommendation for the Floriade & the energy transition

- Don’t convert hydrogen into electricity
- The efficiency is too low to be feasible with the current state of technology and equipment investments
- Take compression out of the equation

Thank you

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The implications of hydrogen in the built environment as part of an energy system

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