Hydrogen as seasonal energy storage for Floriade:
The implications of hydrogen in the built environment as part of an energy system
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

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

![Graph showing energy surplus, deficit, electrolysis, fuel cell, and renewable energy supply over time.](image)
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
Floriade impressions

Copyright Design(ed) by Erick van Egeraat
Floriade impressions

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Floriade impressions

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Floriade impressions
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
Hydrogen as seasonal energy storage for Floriade

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Energy system conclusions

• All-electric solution
• System components are highly dependent on each other
3 Energy modelling
Consumption
Energy consumption of Floriade reference house

- Light
- Equip
- DHW
- Cooling
- Heating

- kWh/year
- kWh/day

Outdoor temperature >30 °C
Energy consumption of Floriade house vs Dutch average

Average Dutch house
~17.660 kWh*

Floriade reference house
~6.050 kWh

* CBS, 2017
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
Annual energy production potential

• South oriented PV panels
• 80% of roofs of ground based houses covered
• ~16,000 m² of PV panels
• ~3200 kW system size
Annual hourly energy production

kWh/hour

![Graph showing annual hourly energy production with kWh/hour on the y-axis and months of the year on the x-axis.]
Energy production potential of Floriade

~2,590,000 kWh/year

380  Floriade houses
146  Traditional houses
4 Energy balance
Energy balance

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Production season
Consumption season

kWh/day

Consumption
Production
Balance
Poly. (Balance)
Surplus
Energy surplus

~2,220,000 kWh
390,000 kWh = 100%

- Battery: 95%
- Electrolyser: 20%
- Storage: -57%
- Fuel cell: 20%

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
5 Energy hub design
Design boundaries

• Components size & connections
• Safety
• Visibility
Ventilation
Construction
Façade design

Sears headquarters in Alhambra, USA by Albert C. Martin

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

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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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Jerry Pollux
January 25th 2019