The Photovoltaic Potential of a Fleet of Urban Vehicles

Potential and challenges for PV everywhere!

Dora de Jong, Vasiliki Sionti, **Hesan Ziar**

PVMD
Delft University of Technology

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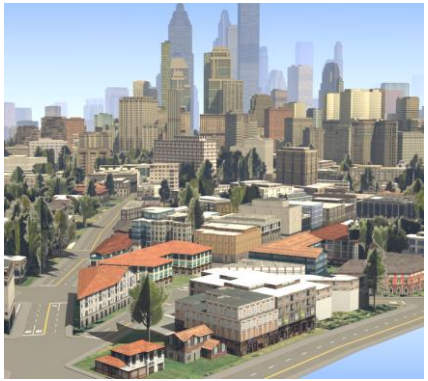
WCPEC-8, Milan, Italy

TU Delft

Research Focus

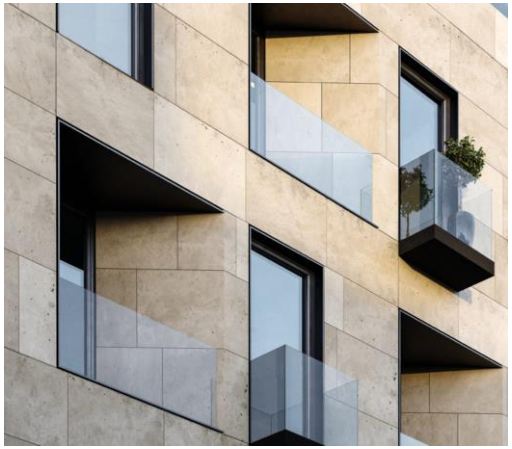
Source × *Converter* × *Time* × ***Area***



H. Ziar, Floating solar stations, Global Energy Associations, 2021.

Research Focus



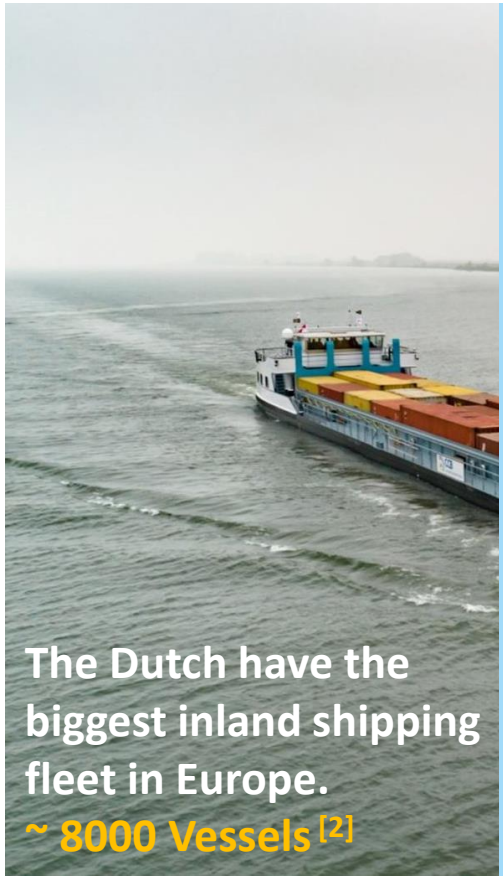
Research Focus

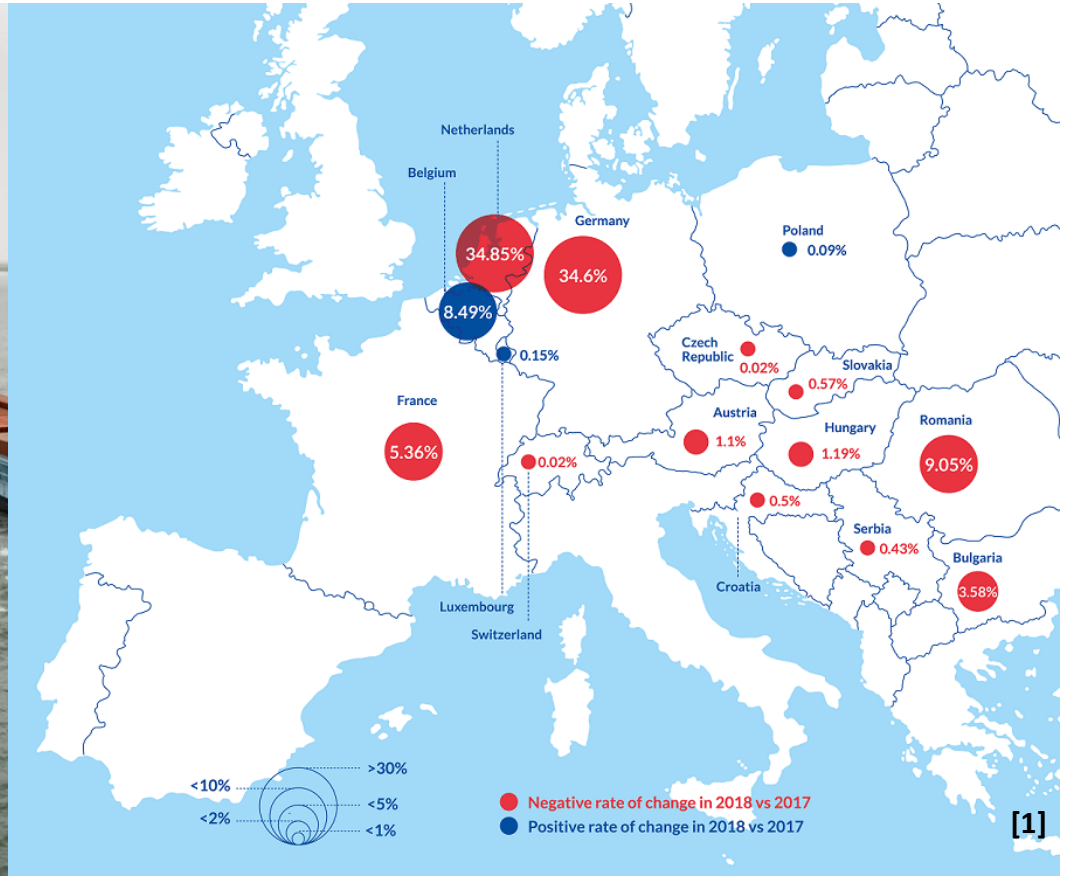
Motivation

Motivation

Concordia Damen, Alphenaar [photo], 2021. https://www.ad.nl/rivierenland/

Motivation



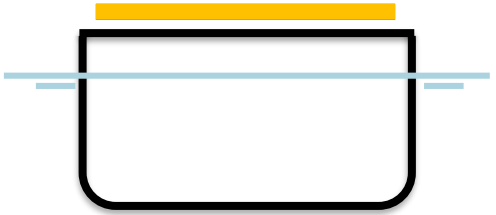


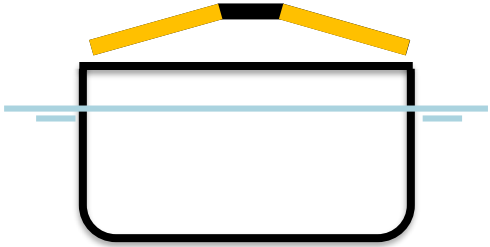
[1] source: Eurostat, OCDE (Switzerland, Serbia), 2019.
[2] Jaarverslag 2019. Netherlands: Centrale Commissie voor de Rijnvaart (CCR 2019).

Motivation

Wattlab, Ms. Oleander [photo]. Solar magazine, 2020. https://solarmagazine.nl/nieuws-zonne-energie/i23093/

Motivation

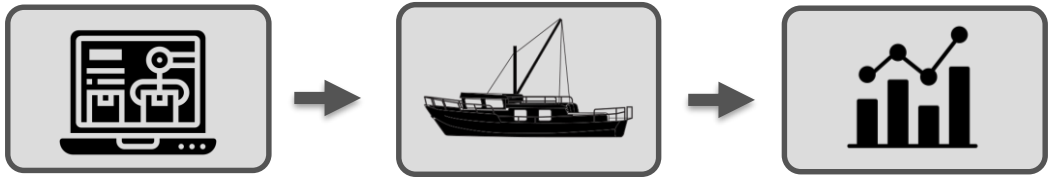




Motivation

Main objectives

Determine the **photovoltaic** potential of
the Dutch **general cargo** inland shipping fleet



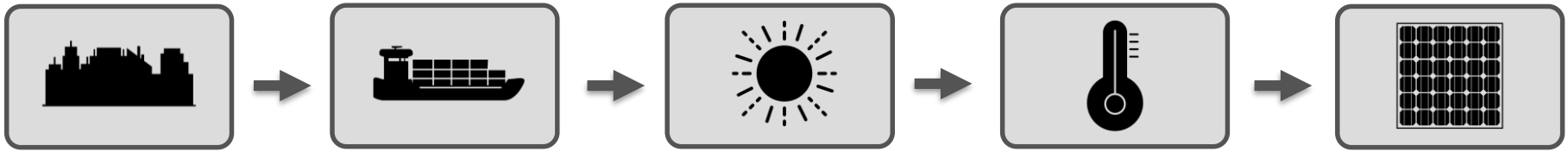
Developing a simulation model

Validating the developed model

Analysing the potential

Simulations and experiments

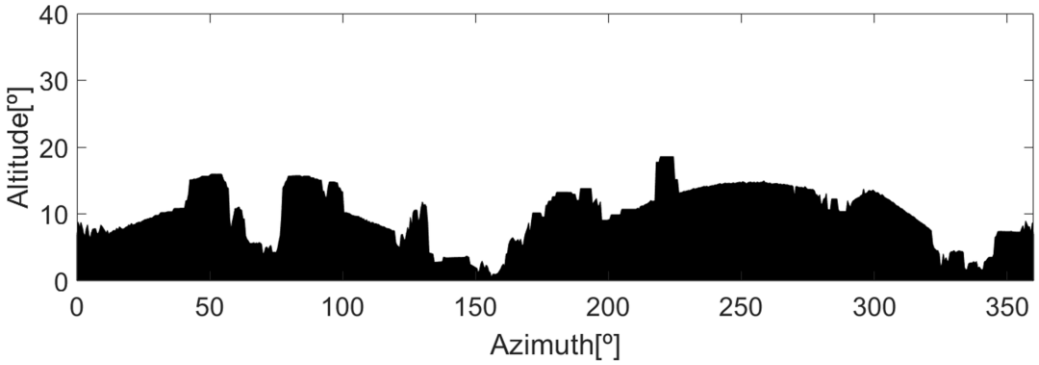
Model overview

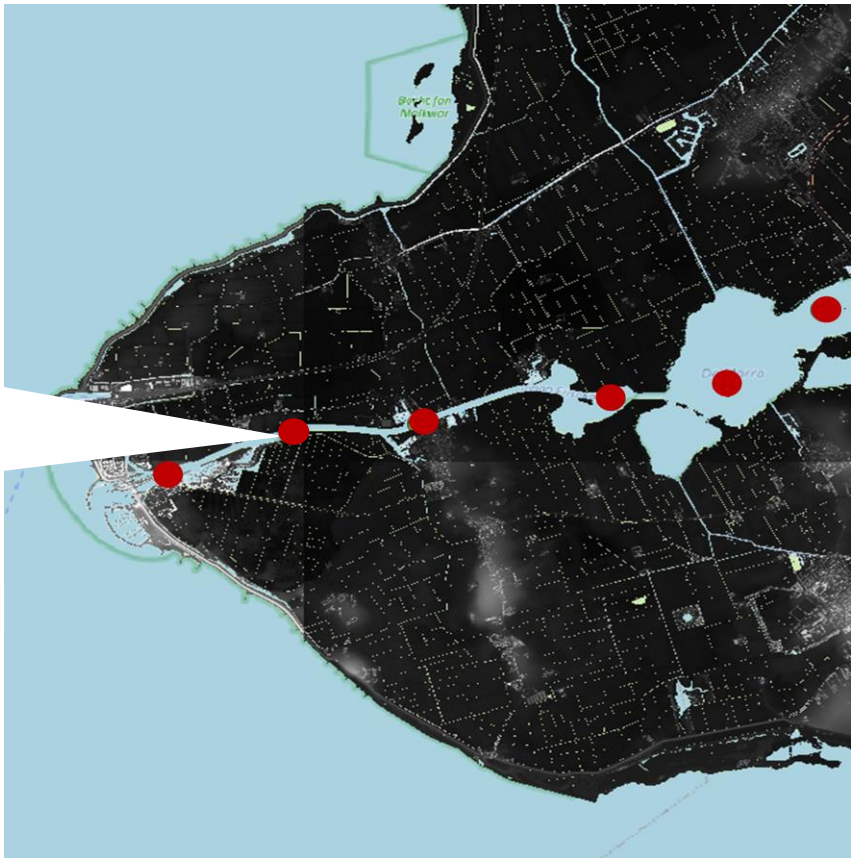


Skyline model → Vessel model → Irradiance model → Module temp model → PV Power model

Model overview

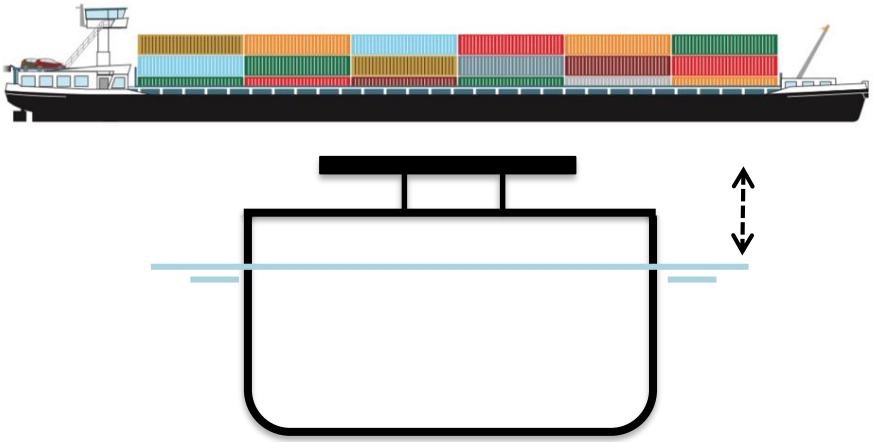
- 1400 LiDAR tiles to generate **~3000 skyline profiles**
- Takes into account the **Sun's solid angle**
- Scans the horizon for **1000 meters**

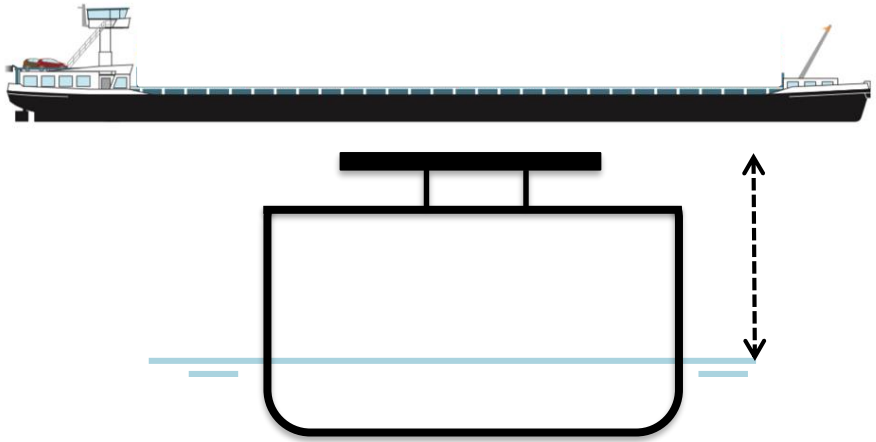




Model overview

- Retrieves type, size, and location data from the AIS*
- Fits PV modules
- Adjusts skylines based on vessel's load

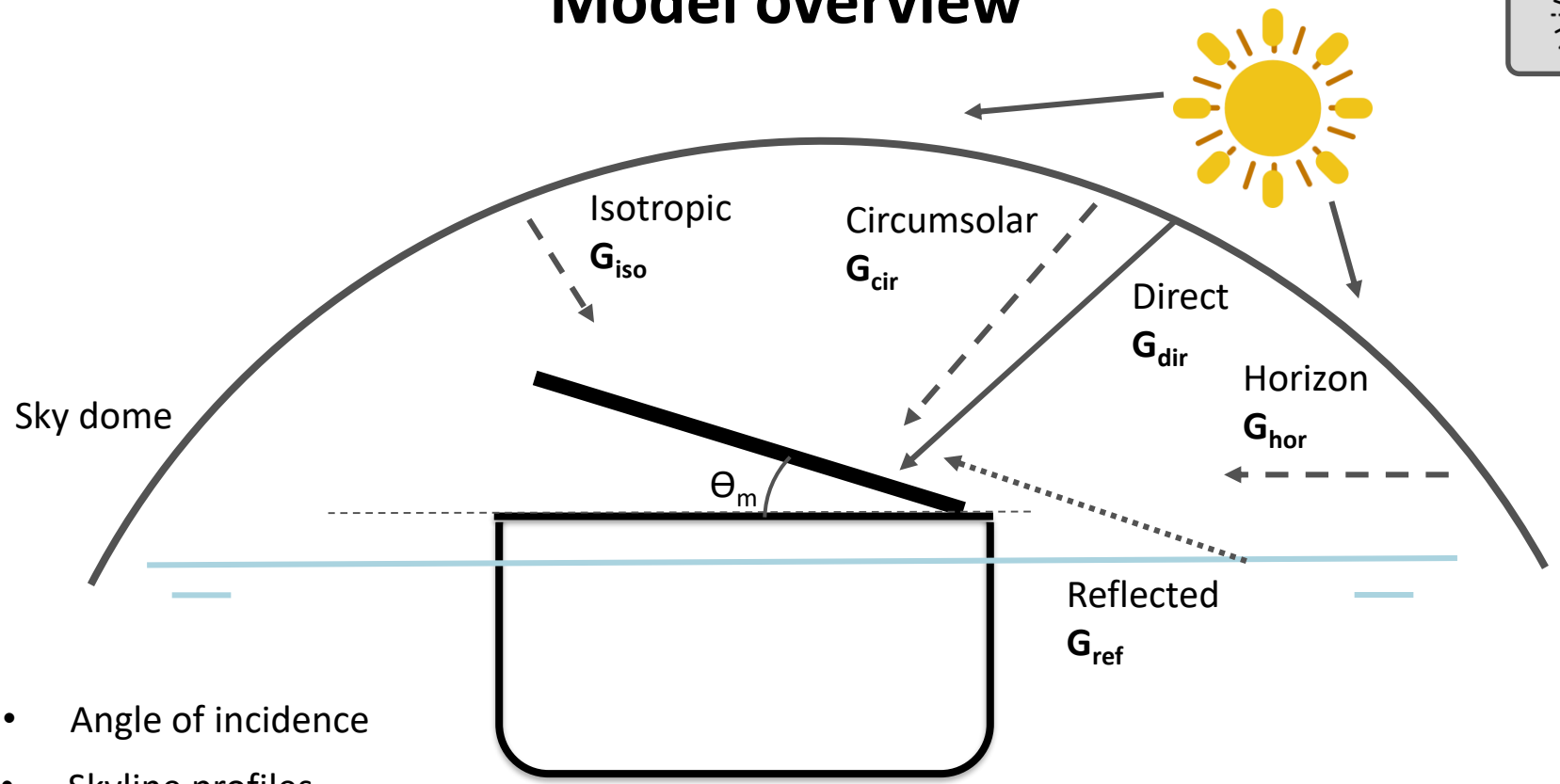




O. C. Koedijk. *Rijkswaterstaat WVL afdeling BNSV, 2020.*

* Automatic Identification System

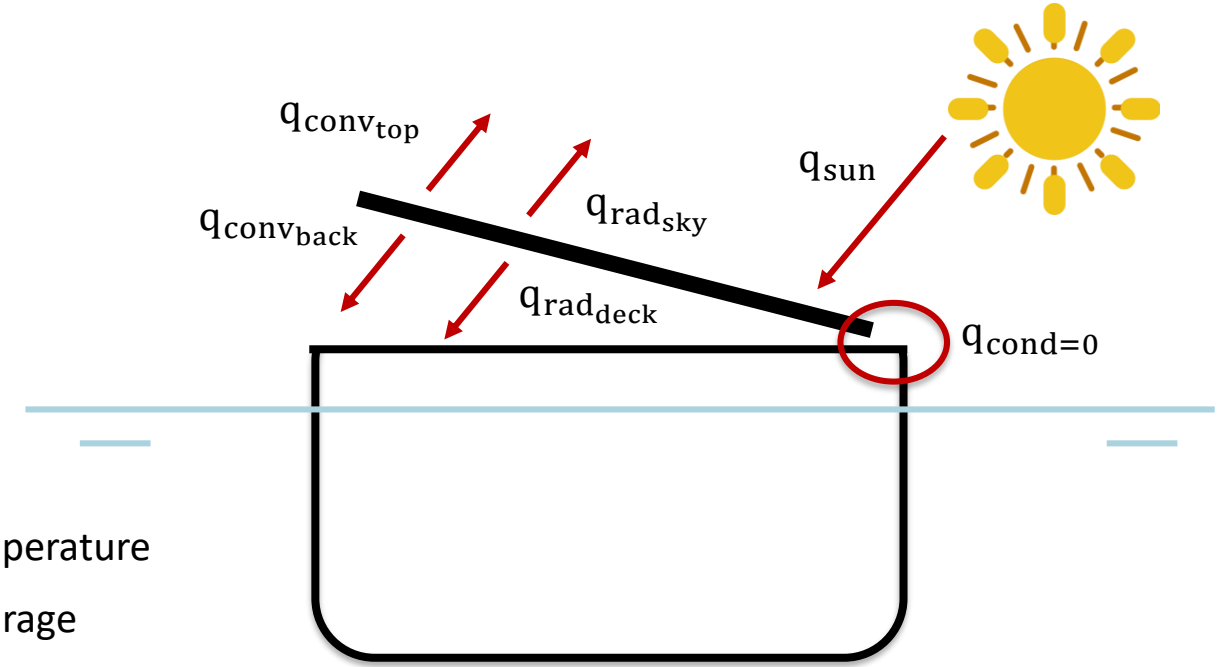
Model overview



- Angle of incidence
- Skyline profiles

Perez, R. et al., *Sandia National Lab*, 1988.

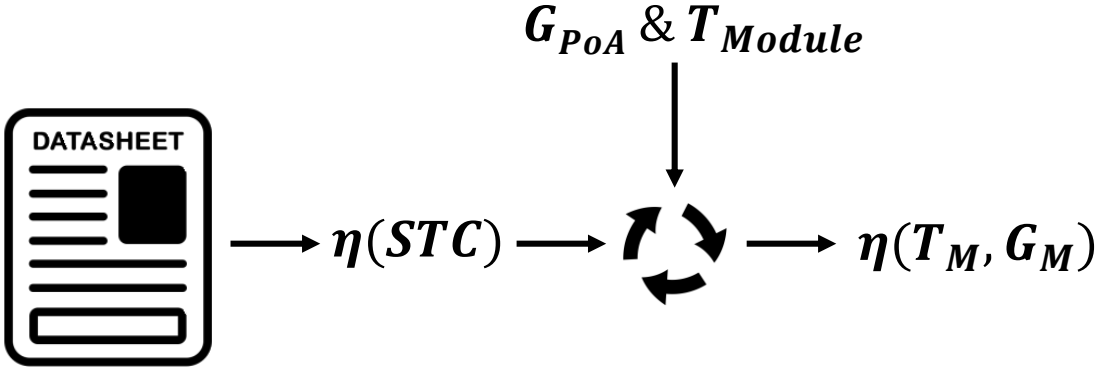
Model overview



- Water temperature
- Cloud coverage
- Ambient temperature
- Corrected wind with vessel's speed vector

M. K. Fuentes, *Tech Rep Scandia National Laboratories*, 1987.

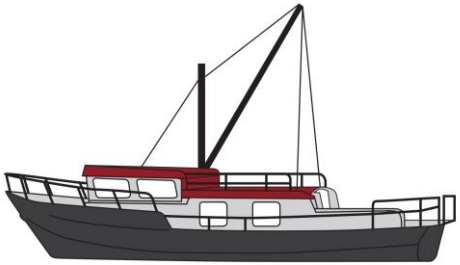
Model overview



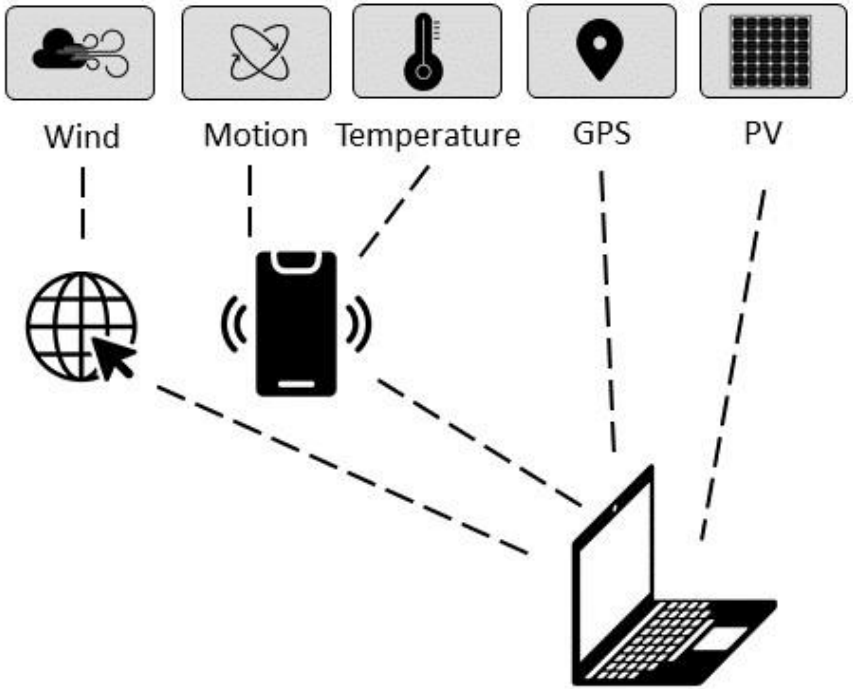
Smets, A. et al., *UIT Cambridge Ltd*, 2016.

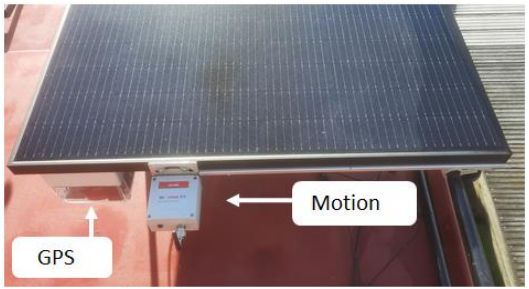
Experiments & validation

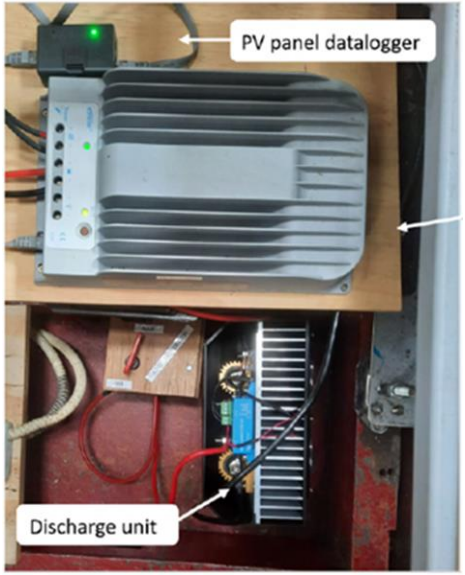
Energy system on board



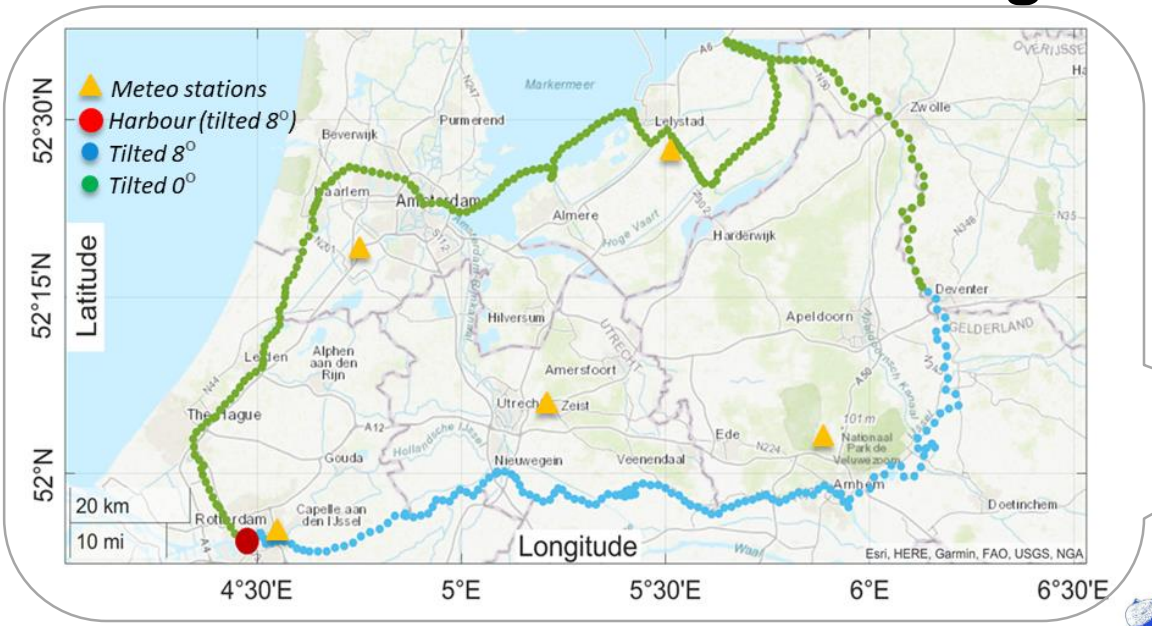
Monitoring system on board







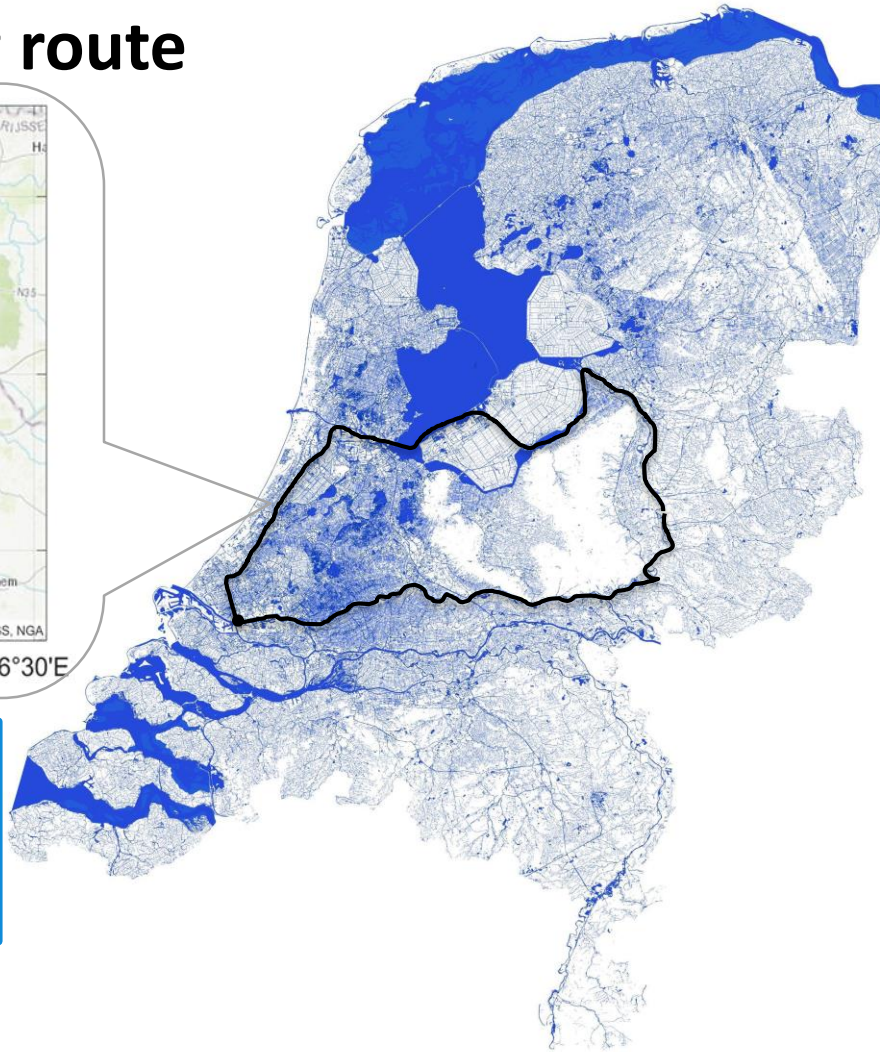
Monitoring route



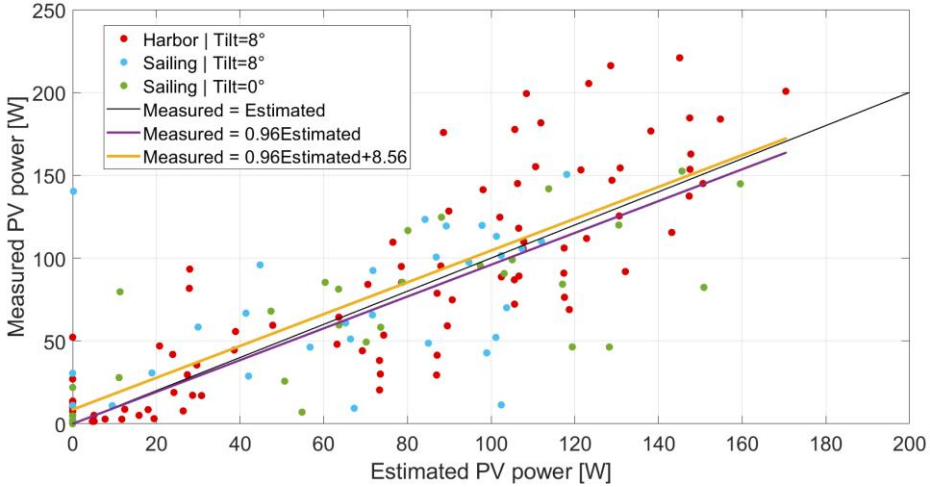
Harbour (tilted 8°)

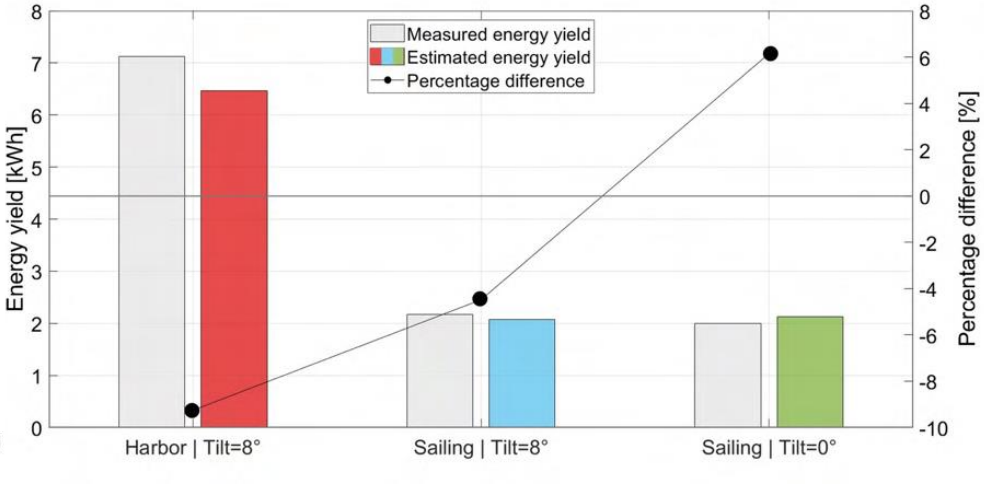
Sailing (tilted 0°)

Sailing (tilted 8°)



Model validation



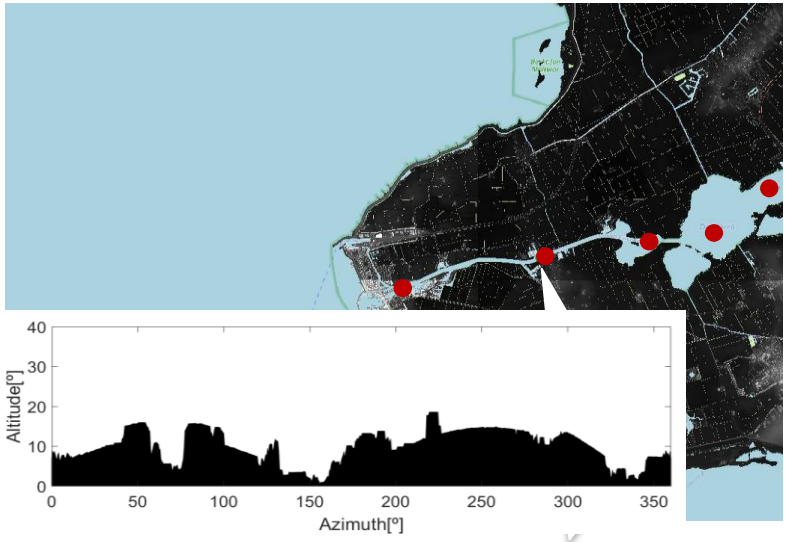


Results

Data-driven findings

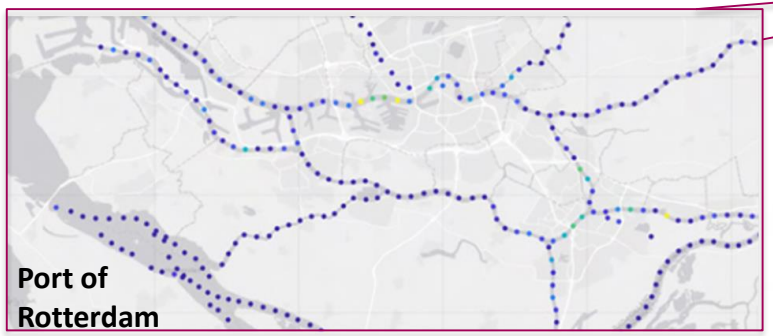
- Probability of sailing during daytime ≈ **50%**

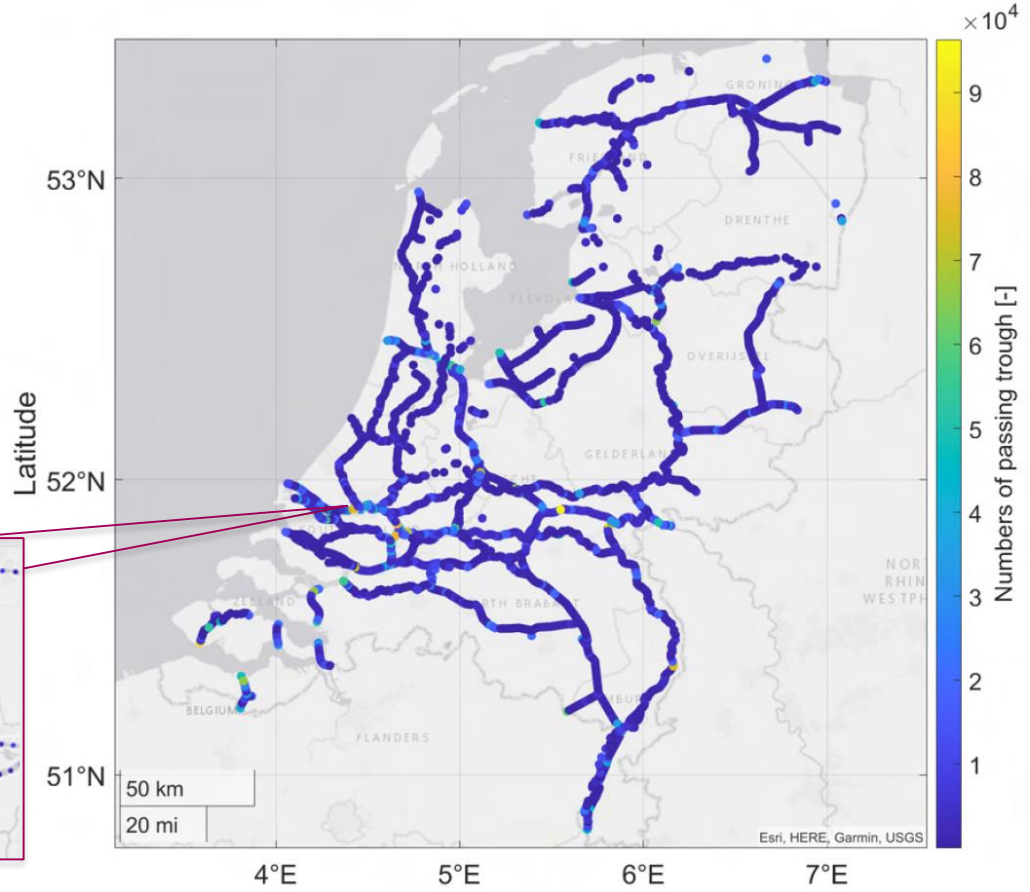
- Average SVF value for vessel ≈ **95%**



Data-driven findings

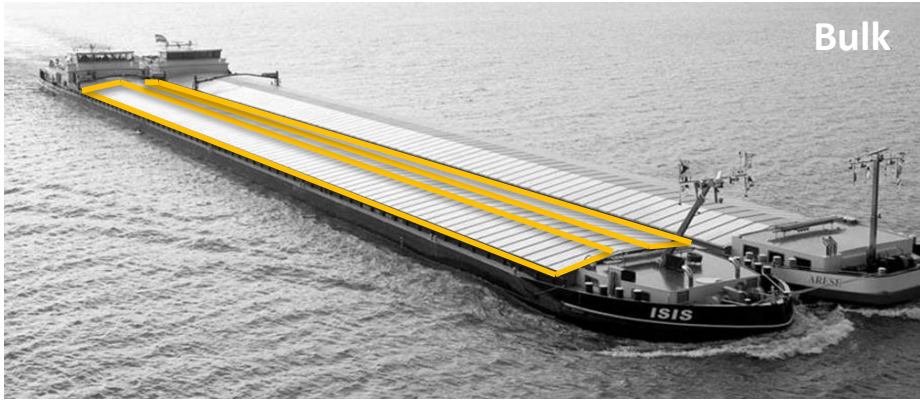
- Uniform distribution in the canals, expect for the ports



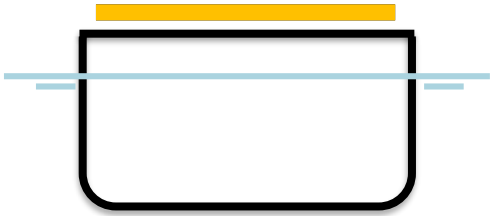


Data-driven findings

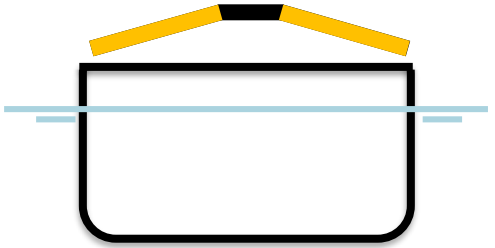
- Container and bulk vessels can utilize respectively 60% and 50% of their surface for PV



60%

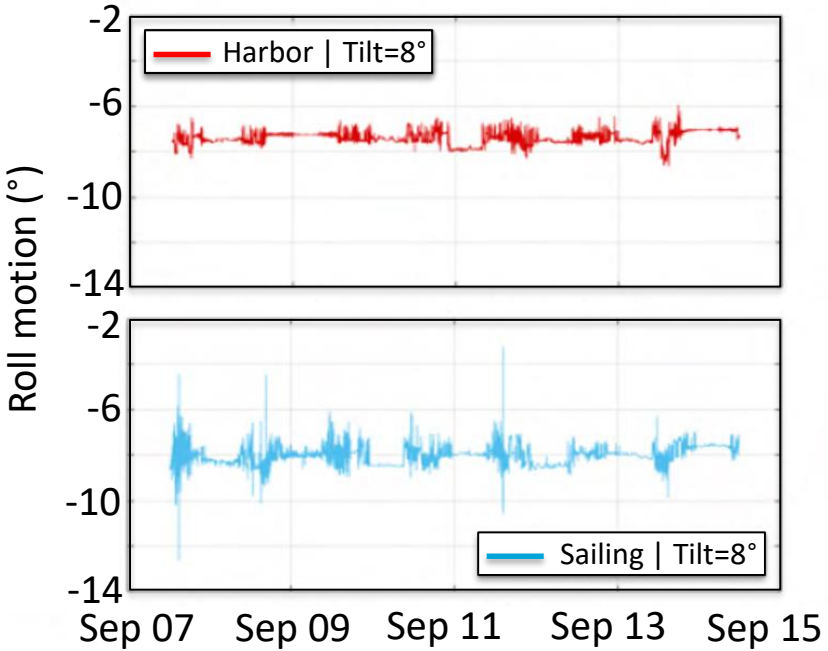


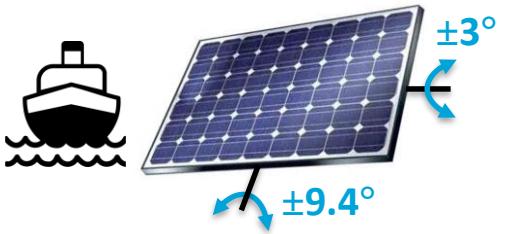
50%



Experimental findings

- More angle variations when cruising

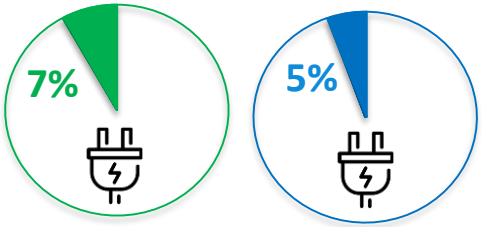


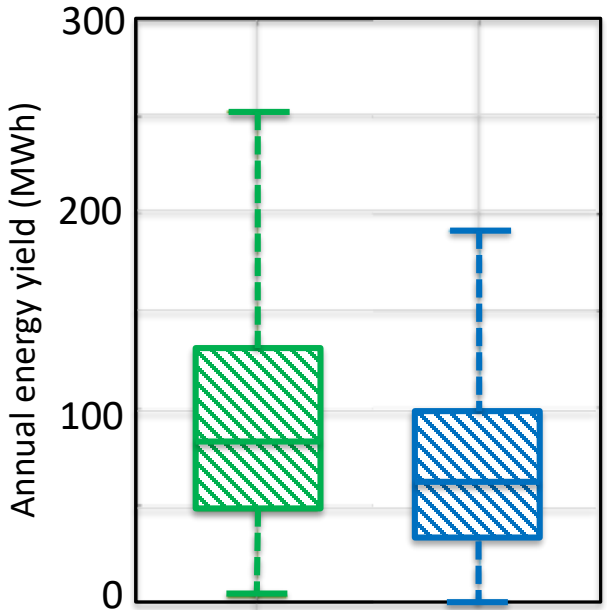


Fleet capacity and yield

- PV Capacity of the whole fleet ≈ **267 MW**

- The average energy yield for **container** and **bulk** vessels is **103 MWh** and **78 MWh**, respectively.





D. de Jong & H. Ziar, *Solar RRL*, 2022.

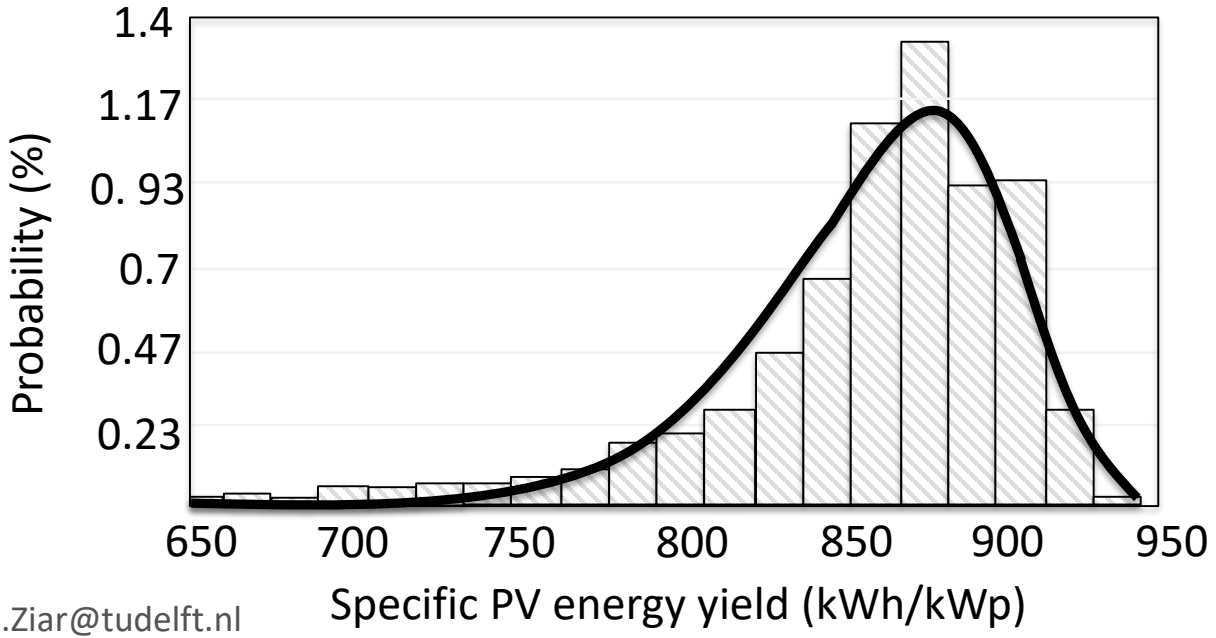
Specific energy distribution

- Specific energy yield of the fleet follows a Weibull distribution

$$f(x,\lambda,\kappa) = \frac{\kappa}{\lambda}\left(\frac{x}{\lambda}\right)^{\kappa-1} e^{-\left(\frac{x}{\lambda}\right)^{\kappa}}$$

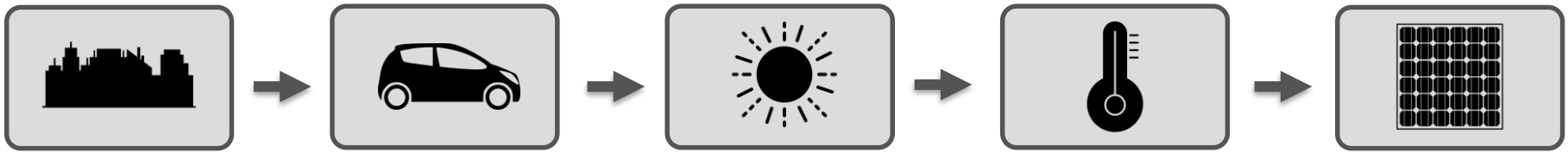
27

880 Wh/Wp



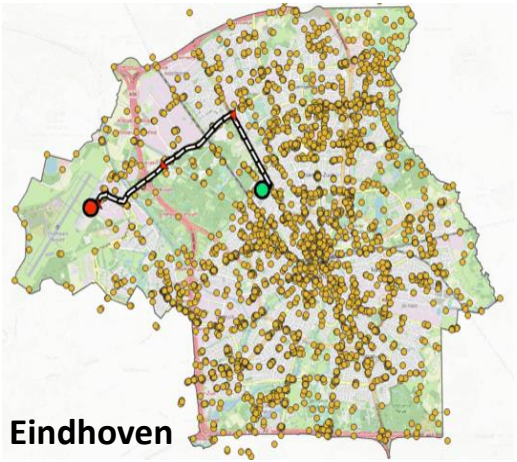
Sensitivity Analysis

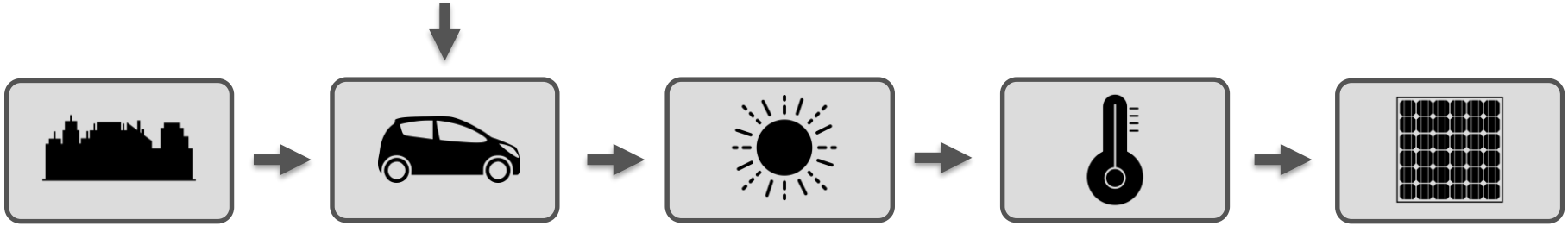
Specific energy distribution (sensitivity analysis)



V. Sionti, MSc thesis, TU Delft, (2021).

Specific energy distribution (sensitivity analysis)

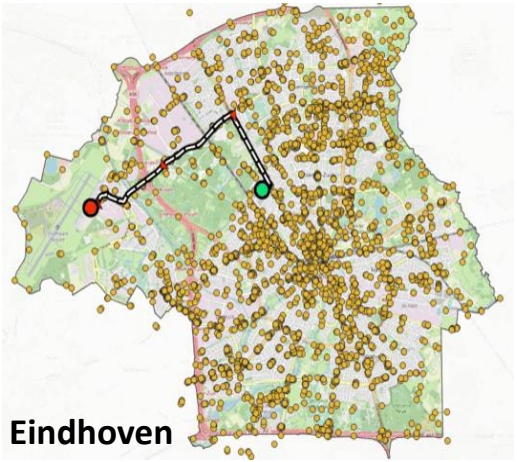


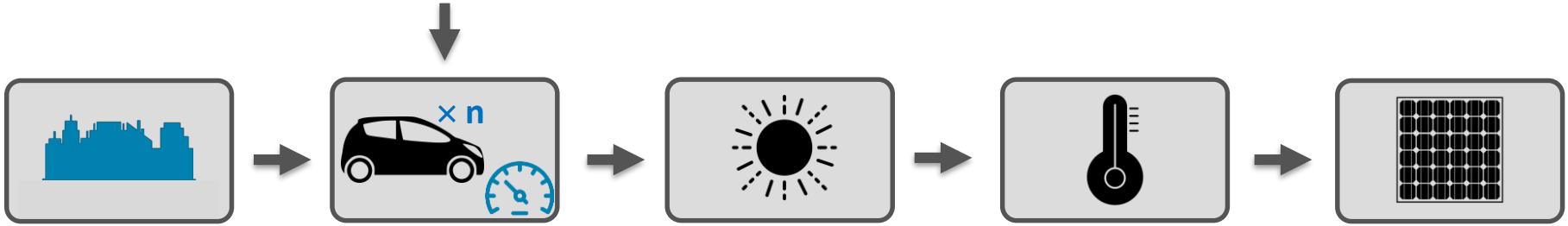


Skyline model → Car model → Irradiance model → Module temp model → PV Power model

V. Sionti, MSc thesis, TU Delft, (2021).

Specific energy distribution (sensitivity analysis)

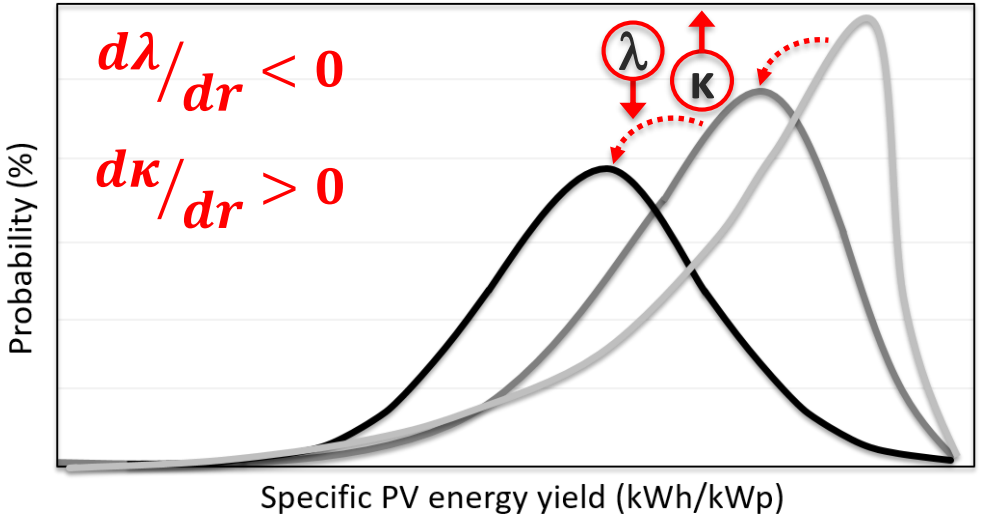


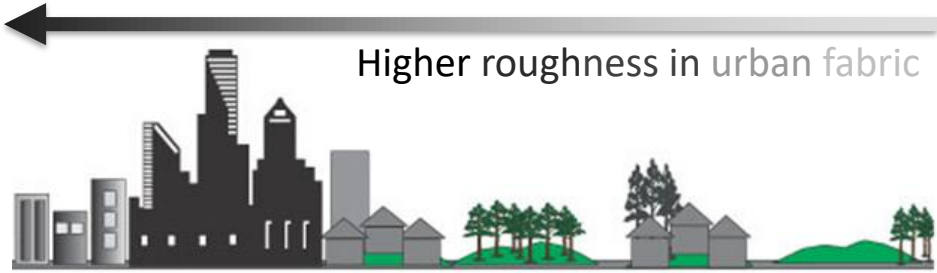


V. Sionti, MSc thesis, TU Delft, (2021).

Specific energy distribution (sensitivity analysis)

- The roughness of urban fabric **(r)** works as a shifter-smoother on the Weibull distribution
- Vehicles' movement speed has a minor effect on the Weibull distribution parameters.
- The bigger the fleet size the better the Weibull fit.

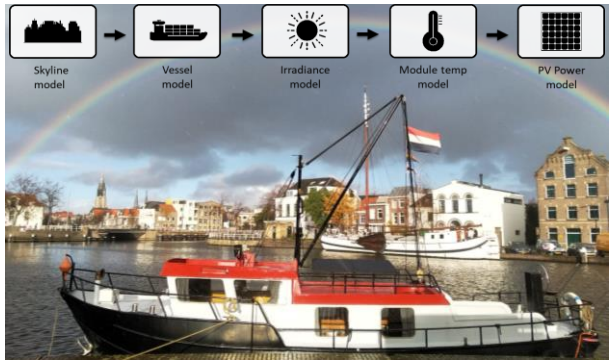




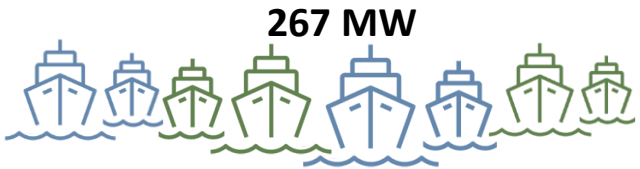
V. Sionti, MSc thesis, TU Delft, (2021).

Conclusions

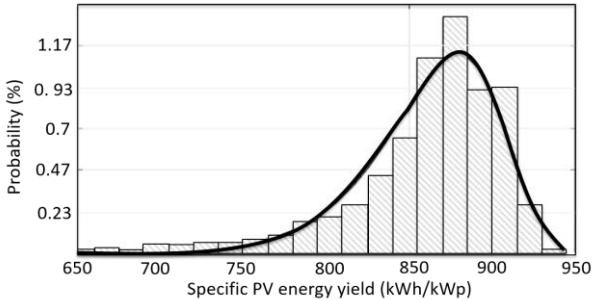
- We developed and experimentally validated a modelling platform for VIPV fleet.



- We tracked the sailing behaviour of ~3000 Dutch inland vessels, they can accommodate 267 MWp of PV and can work as a network of moving DGs.

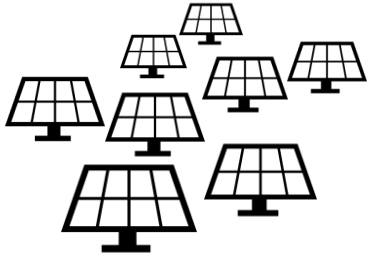


- The specific energy yield of a moving fleet of PV systems in urban areas gives a Weibull distribution.

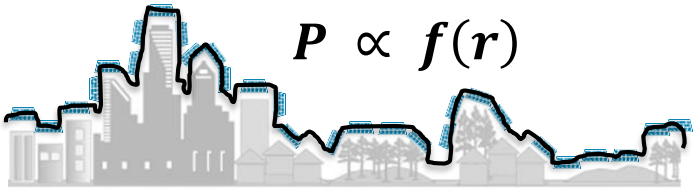


Final remarks

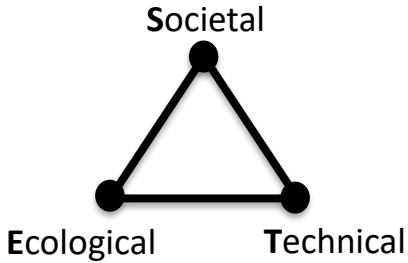
- When putting PV everywhere, study them as a fleet



- The geometry of the urban fabric links to the PV fleet's performance, which can be formulated.



- Putting PV everywhere inherently brings on a **SET** of challenges.



Thank you for your attention!

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