# Generators Efficiency Optimization in a CRAFT Turbine

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WorldWideWind

**EERA DeepWind Conference**
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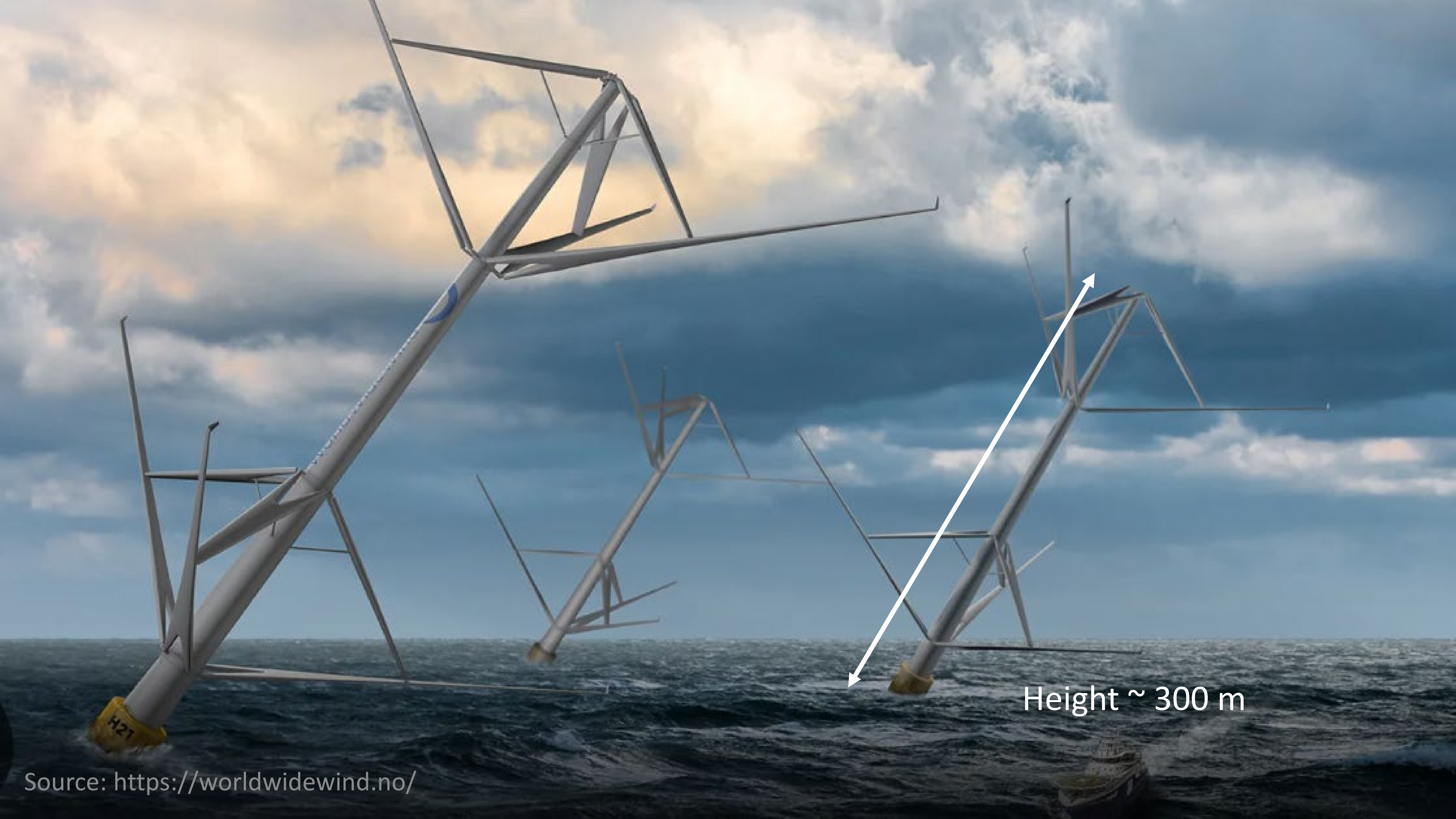
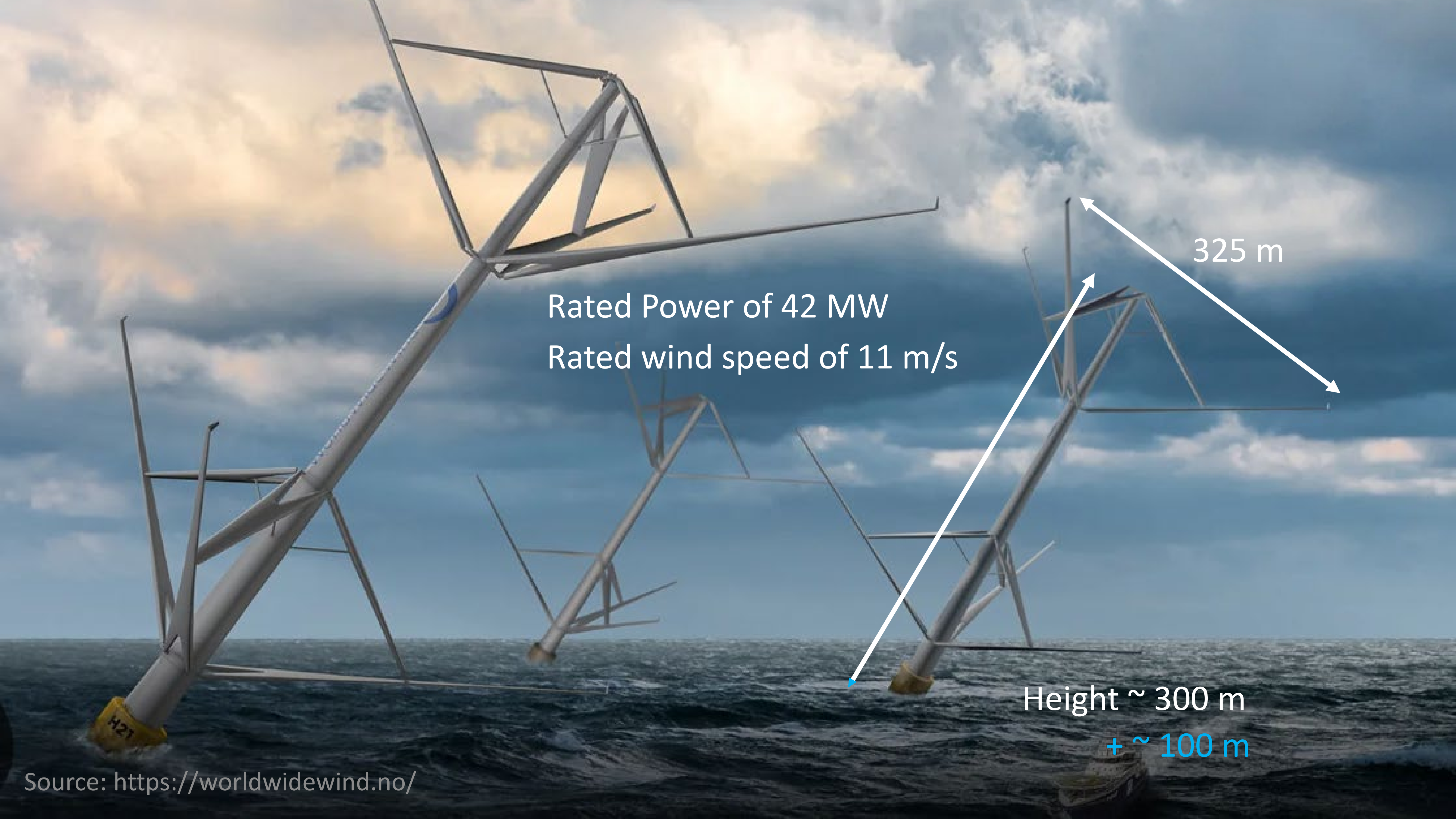

H21
Height ~ 300 m
Source: https://worldwidewind.no/

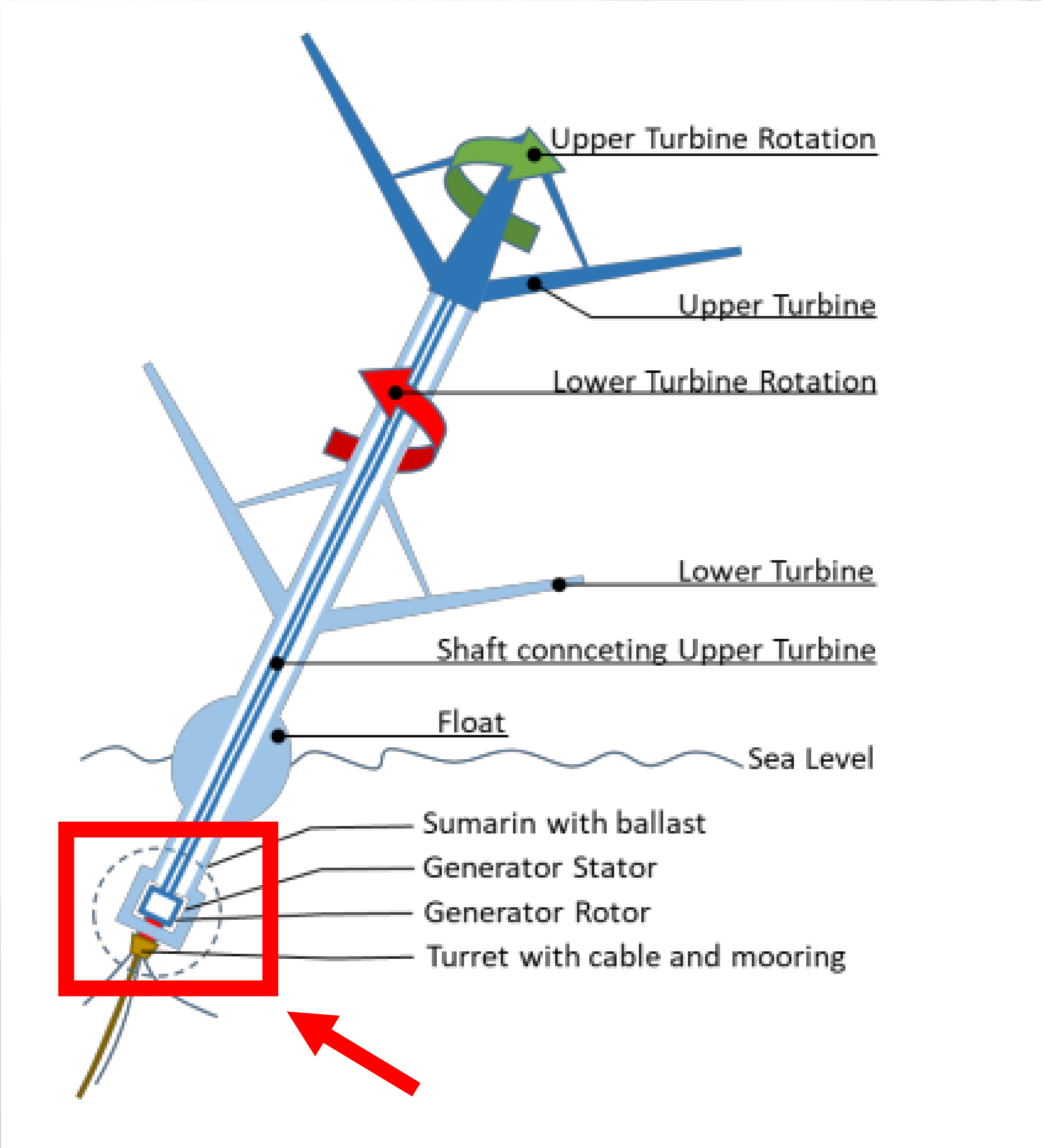

325 m
Rated Power of 42 MW
Rated wind speed of 11 m/s
Height ~ 300 m
+ ~ 100 m
Source: https://worldwidewind.no/

# Counter Rotating Axis Floating Turbine

- Two 3-bladed turbines
- Increased weight under water
  → Improved structural stability


CRAFT
2

# Main generator and Secondary machine




- **Research Objective:**

While maintaining cost-effectivensess and stability, can a synchronous secondary machine be replaced by a less effective asynchronous machine without major loss in produced energy?

- **Secondary machine:**
- Altitude compensation control
- Lower efficiency → Lower cost

- **Main generator:**
- Counter-rotating design

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3

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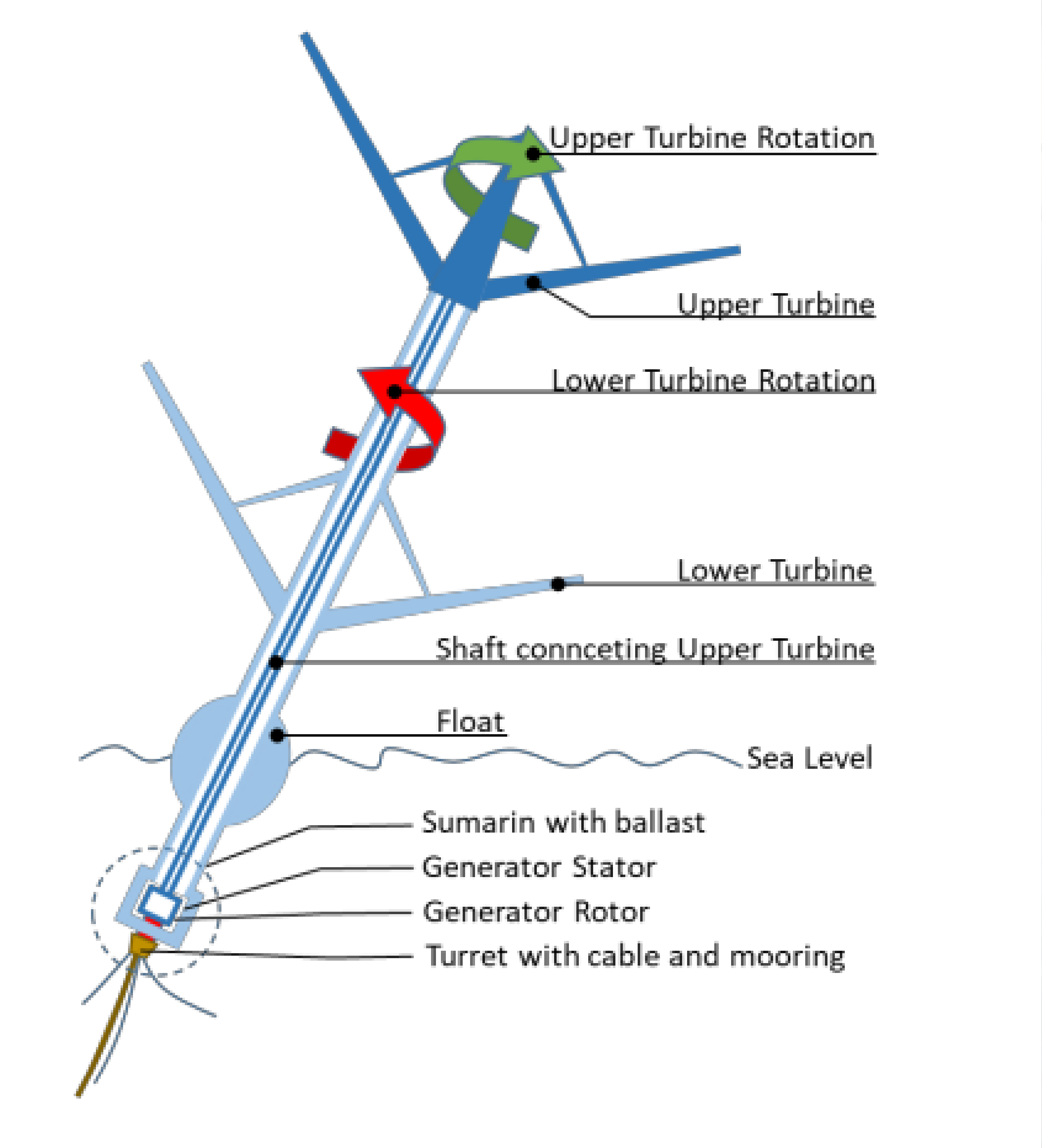
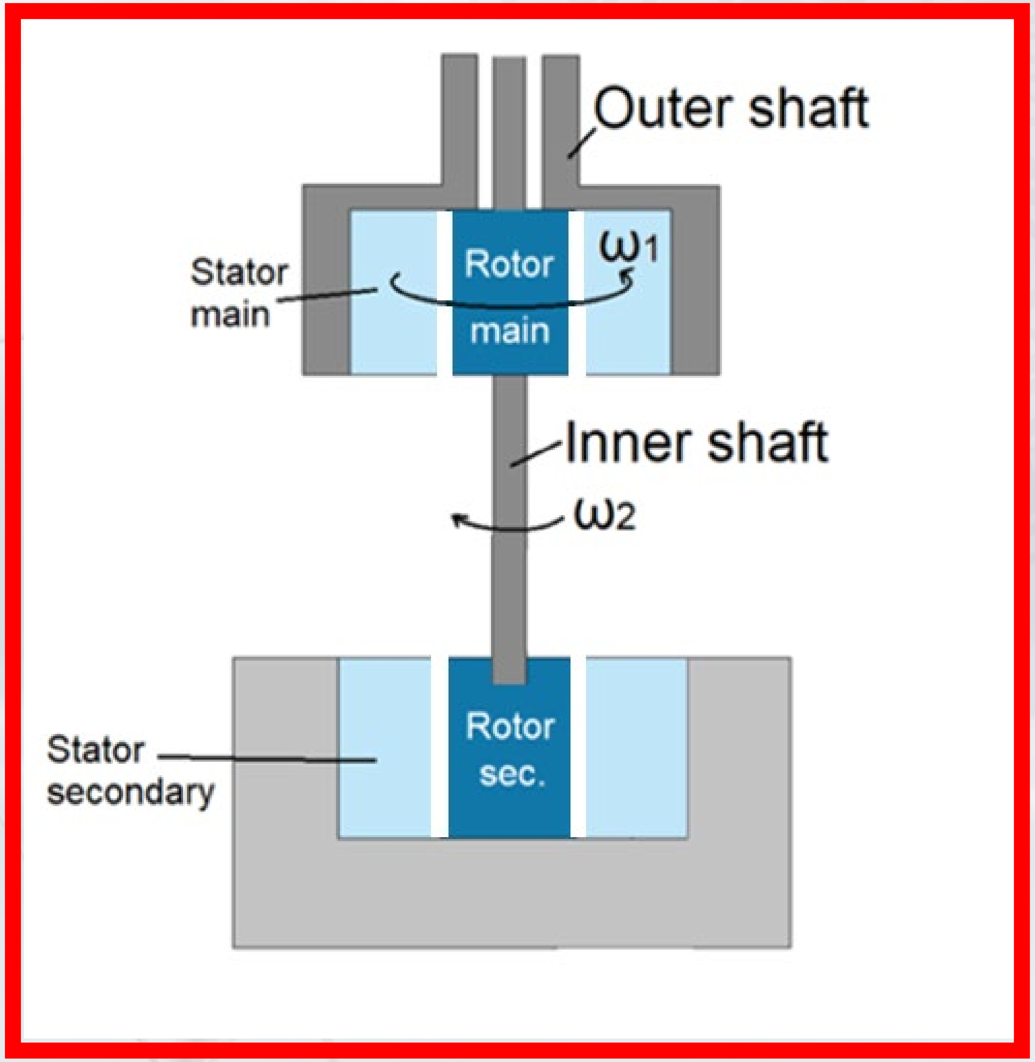
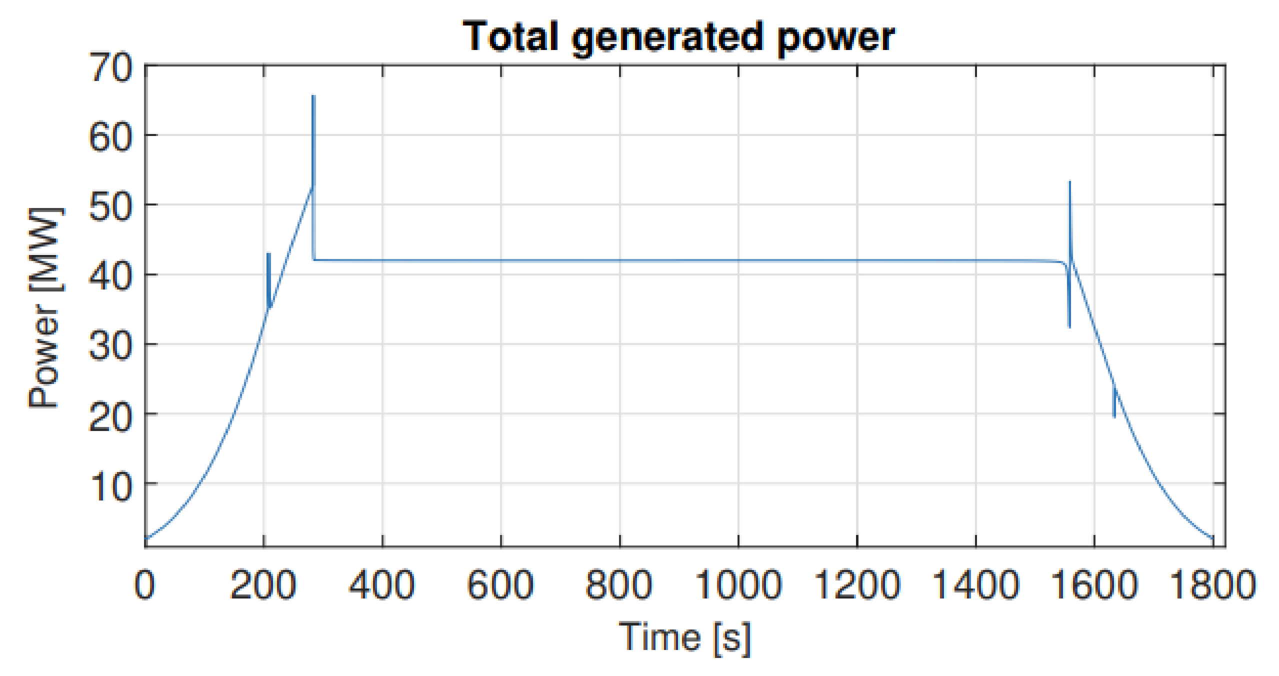
# Main generator and Secondary machine

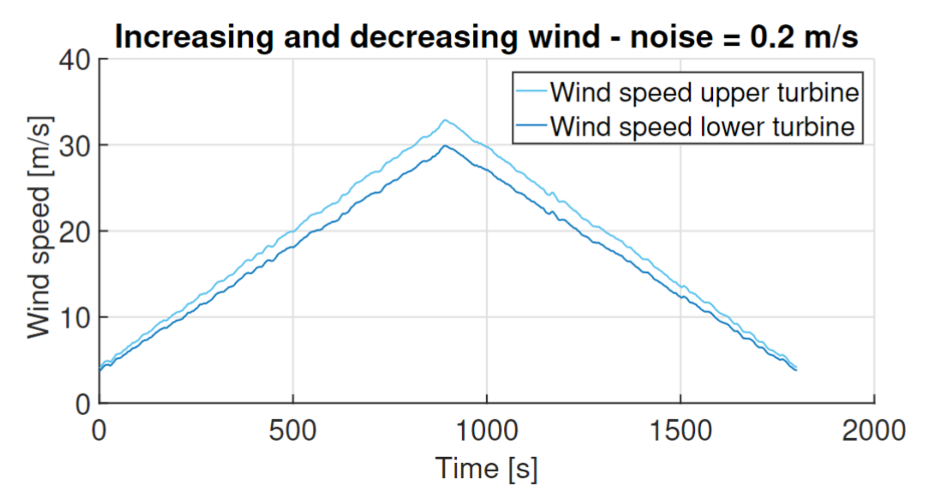


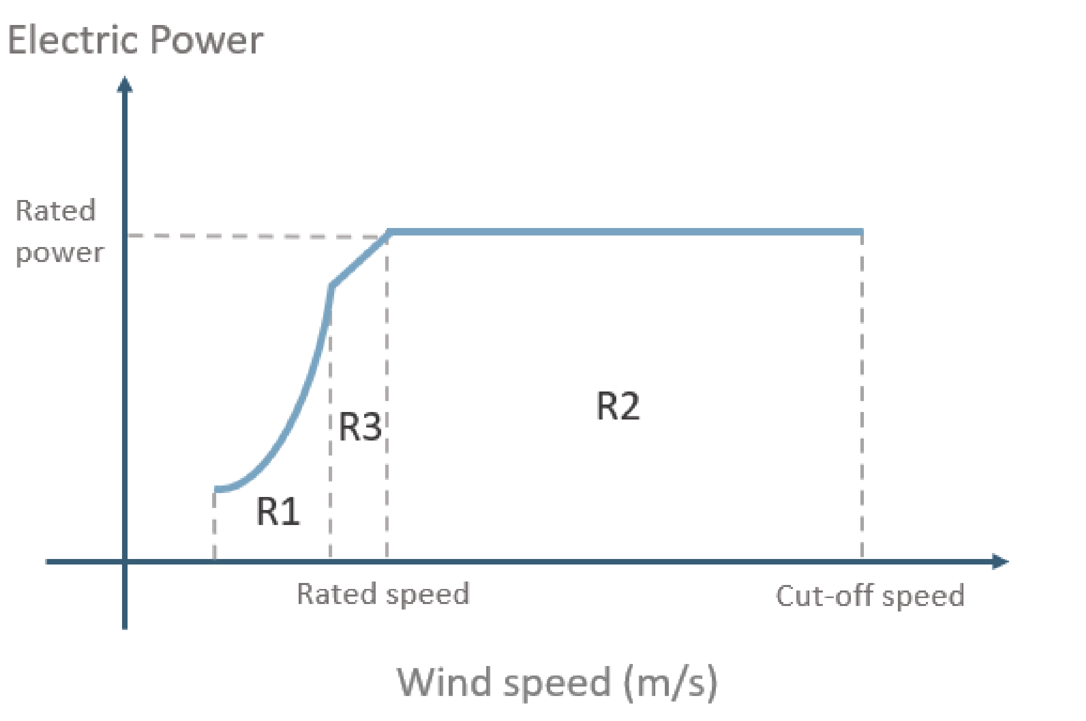



# Control system - Stability test – Strategy 1

**R1:** Maximize energy production
**R2:** Rated Power
**R3:** Constant angular velocity

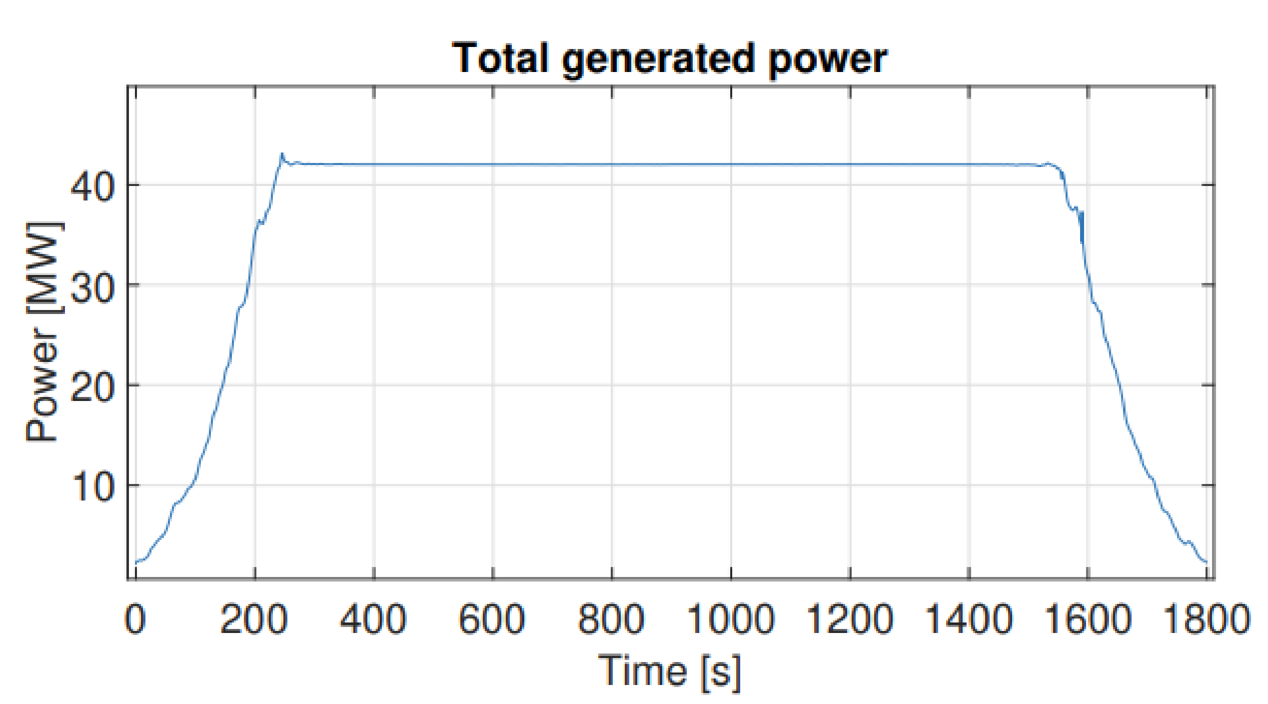


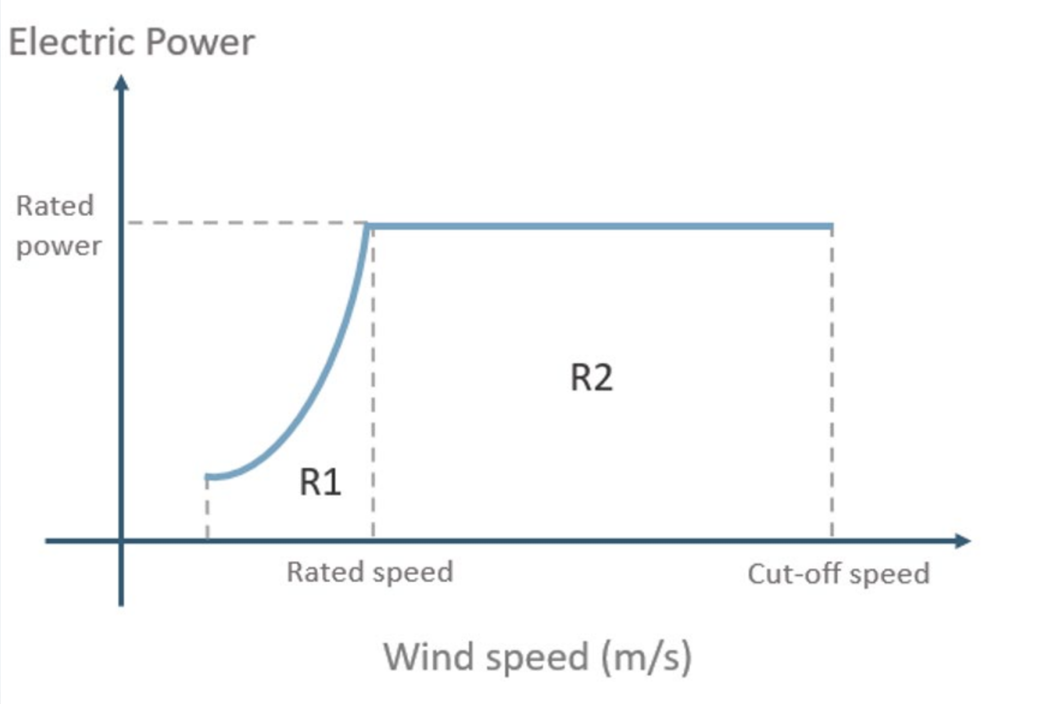



# Control system - Stability test – Strategy 2

**R1:** Maximize energy production.
**R2:** Rated Power.



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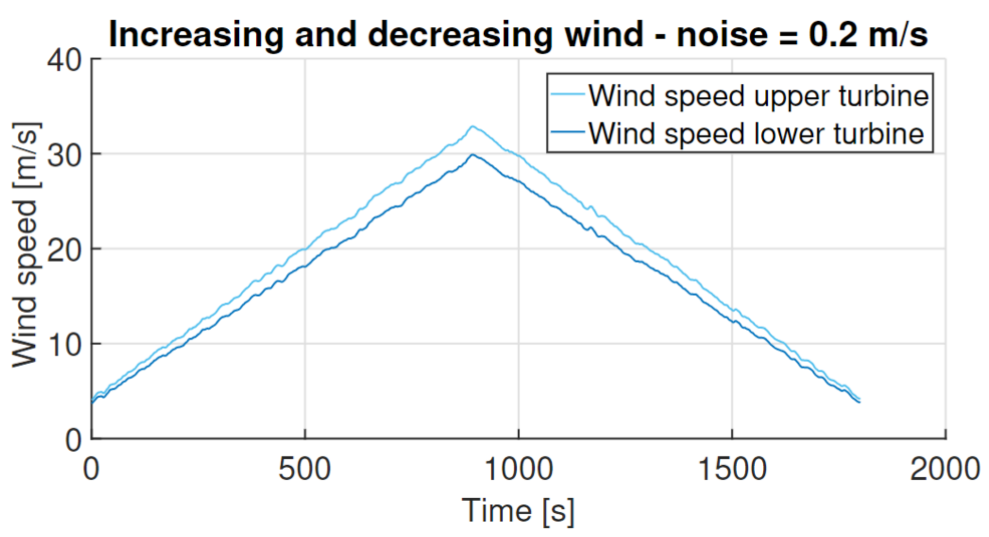
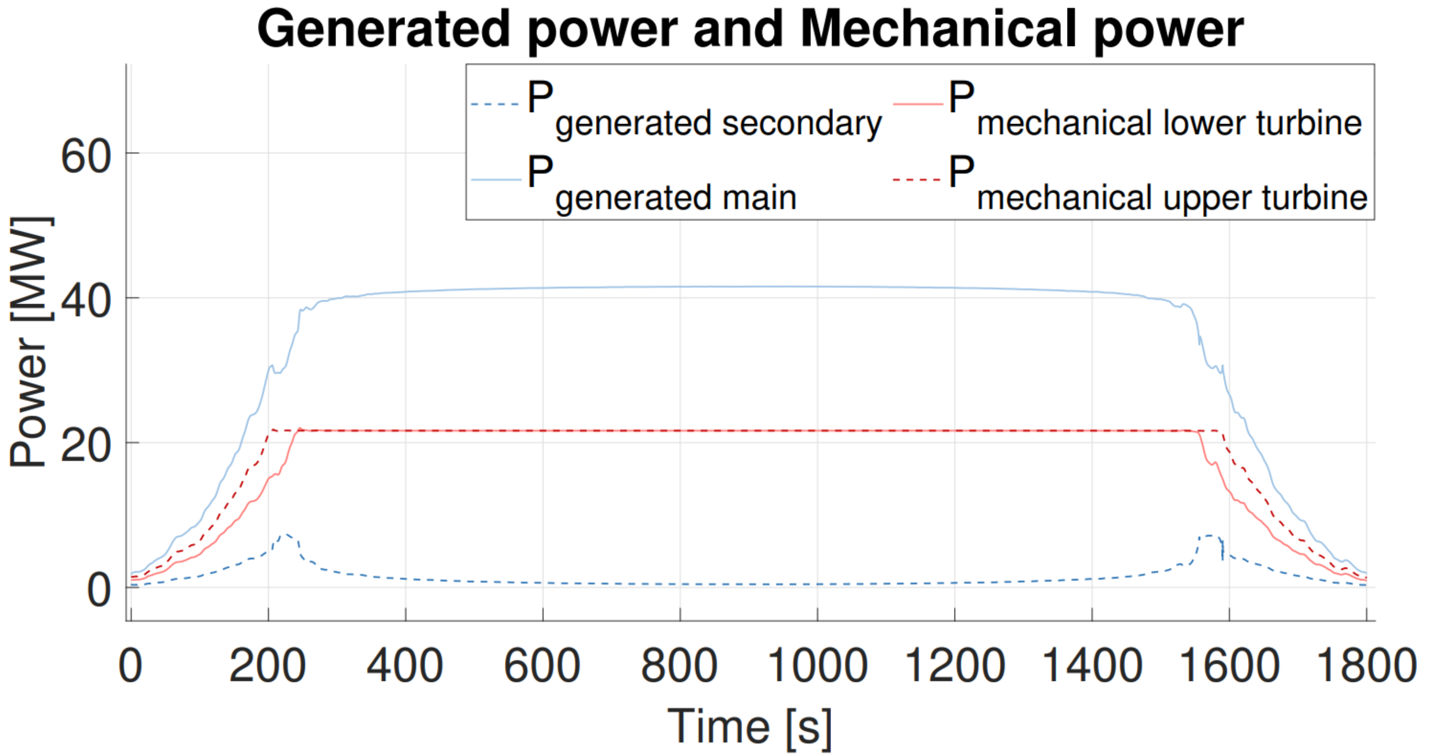
# Simulation 30 min – Power distribution between generators



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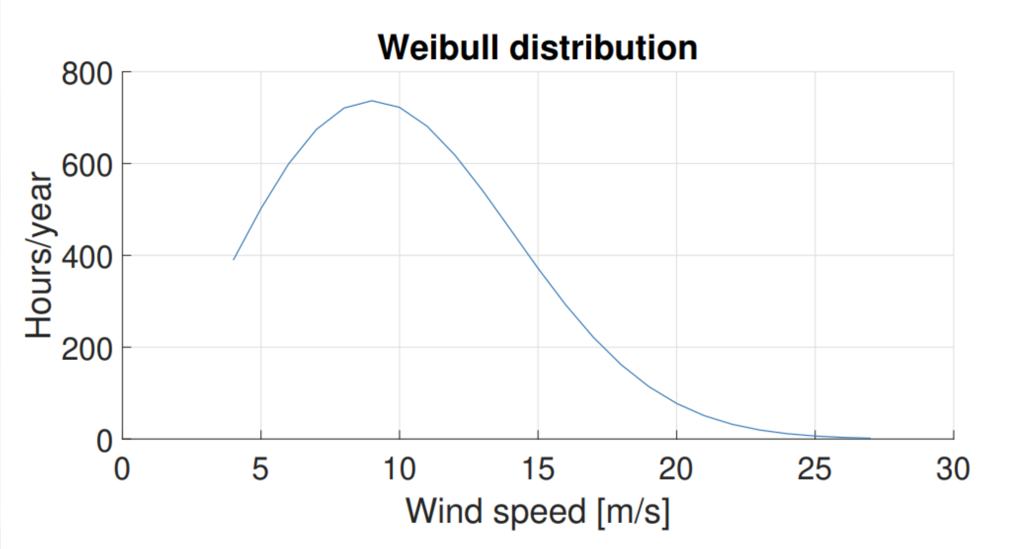
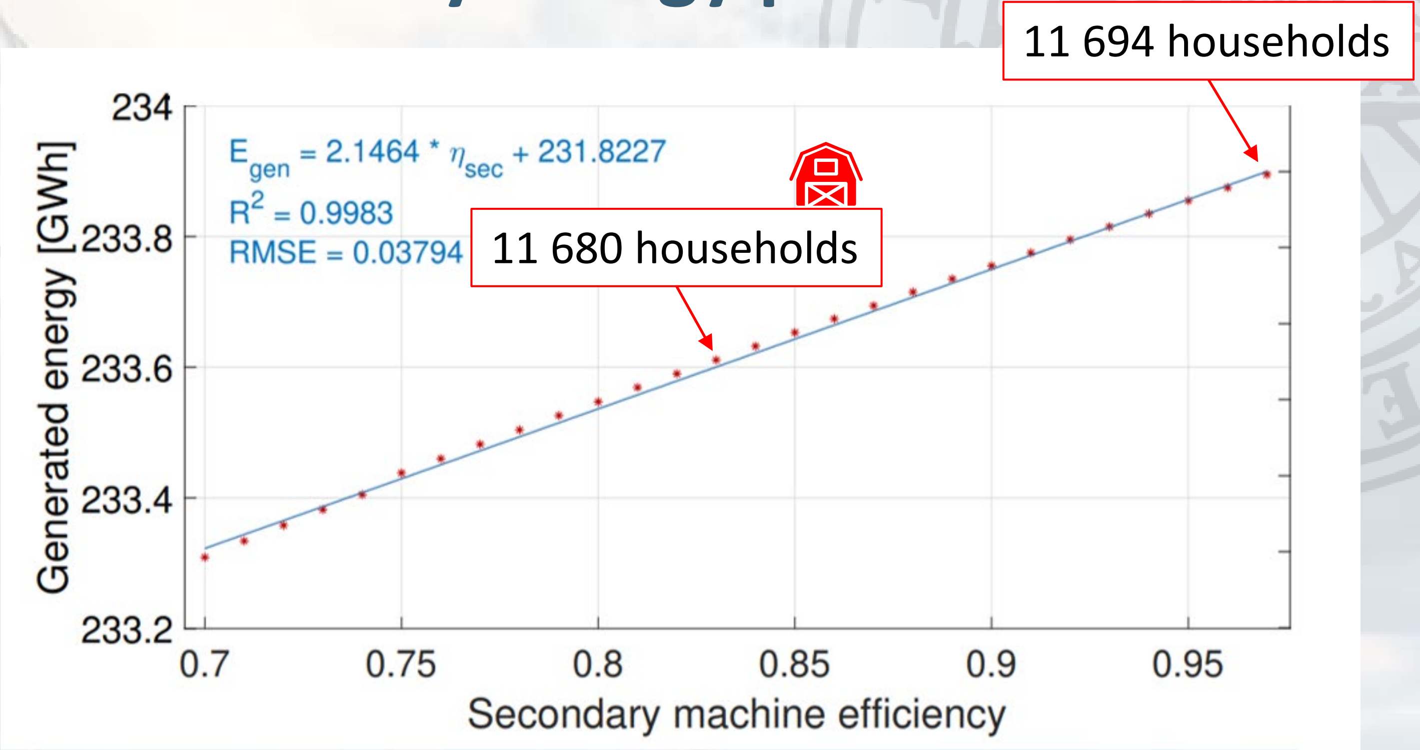
# Various efficiencies in generator – Yearly energy production

- Simulated energy production for 1 year
- Weibull distribution for input winds




| $\eta_{main}$ | $\eta_{sec}$ | $\Delta\eta_{main}$ | $\Delta\eta_{sec}$ | E [GWh] | $(E_{\eta_m\eta_s} - E_{9797})/E_{9797}$ |
|---|---|---|---|---|---|
| 97% | 97% | 0% | 0% | 233.895 | 0% |
| 97% | 93% | 0% | -4% | 233.815 | -0.034 % |
| 97% | 83% | 0% | -14% | 233.611 | -0.121 % |

**14 households**



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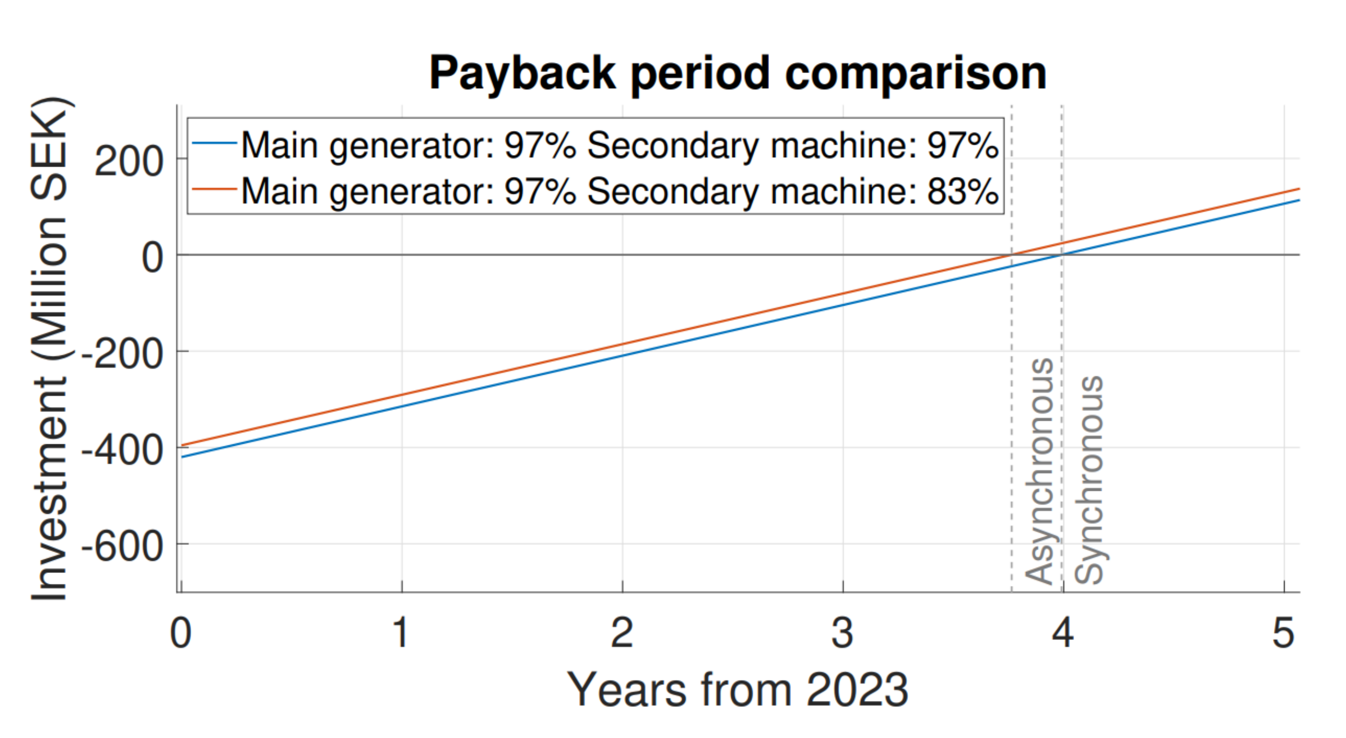
# Economic Analysis

## Initial investment

**Synchronous:** 410 MSEK = **37.3k€**

**Asynchronous:**
**no permanent magnets**
410 MSEK – 24.3 MSEK = 385.7 MSEK = **34.3 k€**

312 tons Ferrite magnets x 40 SEK/kg = 12.5 MSEK
11.8 MSEK saved due to more robust control system




| Generator index | $\eta_{main}$ | $\eta_{secondary}$ | NPV [SEK] | NPVI [%] | T [Years] |
|---|---|---|---|---|---|
| 1 | 97% | 97% | $1.0288 \times 10^9$ | 2.4495 | 3.9904 |
| 2 | 97% | 93% | $1.0283 \times 10^9$ | 2.4483 | 3.9918 |
| 3 | 97% | 83% | $1.0513 \times 10^9$ | 2.6571 | 3.7639 |

5 eurocent/kWh (electricity price)
1 eurocent/kWh (maintentance)

# Conclusion

**Synchronous machine**
**(η secondary = 97%)**

233.895 GWh (11 694 households)

Payback period: 3 years 51,5 weeks

**Asynchronous machine**
**(η secondary = 83%)**

233.611 GWh (11 680 households)

Payback period: 3 years 40 weeks
2.2 % higher Net Present Value

**Economically favourable**

Include maintenance costs, more thoroughly investigate investment differences…

# Thank you!

Q&A



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# Synchronous vs Asynchronous

**- Higher efficiency**
- More complex design
- Needs DC magnetization or permanent magnets
- Constant speed, independent of load.

**- Higher investment cost**
- Suitable for higher power generation

**- Lower efficiency**
- Simpler design
- No DC excitation from an external source needed.
- Allows for more robust control

**- Lower investment cost**
- Not suitable for high power generation

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# Economic Analysis – In depth

$$\mathrm{PV} = \sum_{n=1}^{n} \frac{\text{Total cash flow year } n}{(1+r)^n}$$

$$\mathrm{NPV} = \mathrm{PV} - \mathrm{I}$$

R – discount rate (6%)

$$\mathrm{T} = \frac{\mathrm{I}}{a}$$

I - Initial cost of investment

a – average annual cash flow

$$\mathrm{NPVI} = \frac{\mathrm{NPV}}{\mathrm{I}}$$

# Rotational speed of the turbines – In depth

$$\begin{cases} \dot{\omega}_2 = \frac{P_{\omega_2}}{\omega_2 I_2} + \frac{\tau_{main}}{I_2} + \frac{\tau_{secondary}}{I_2} \\ \dot{\omega}_1 = \frac{P_{\omega_1}}{\omega_1 I_1} - \frac{\tau_{main}}{I_1} \end{cases}$$

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