Exergy analysis of the transient simulation of a renewable-based trigeneration scheme for domestic water and energy supply

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OBJECTIVES OF THIS WORK

- **Exergy analysis** is proposed to assess **efficiency** and to detect potentials for **improvement** in a **renewable-based trigeneration** system.
- The analyzed system includes **PVT** collectors (producing hot water and electricity at the same time), **evacuated tube** collectors, a micro **wind turbine**, energy storage (hot water **tank** and **batteries**) and **two desalination** technologies (reverse osmosis and membrane distillation).
- Due to the transient operation, the use of **two time scales** is proposed.
- The study is based on **TRNSYS** simulation.

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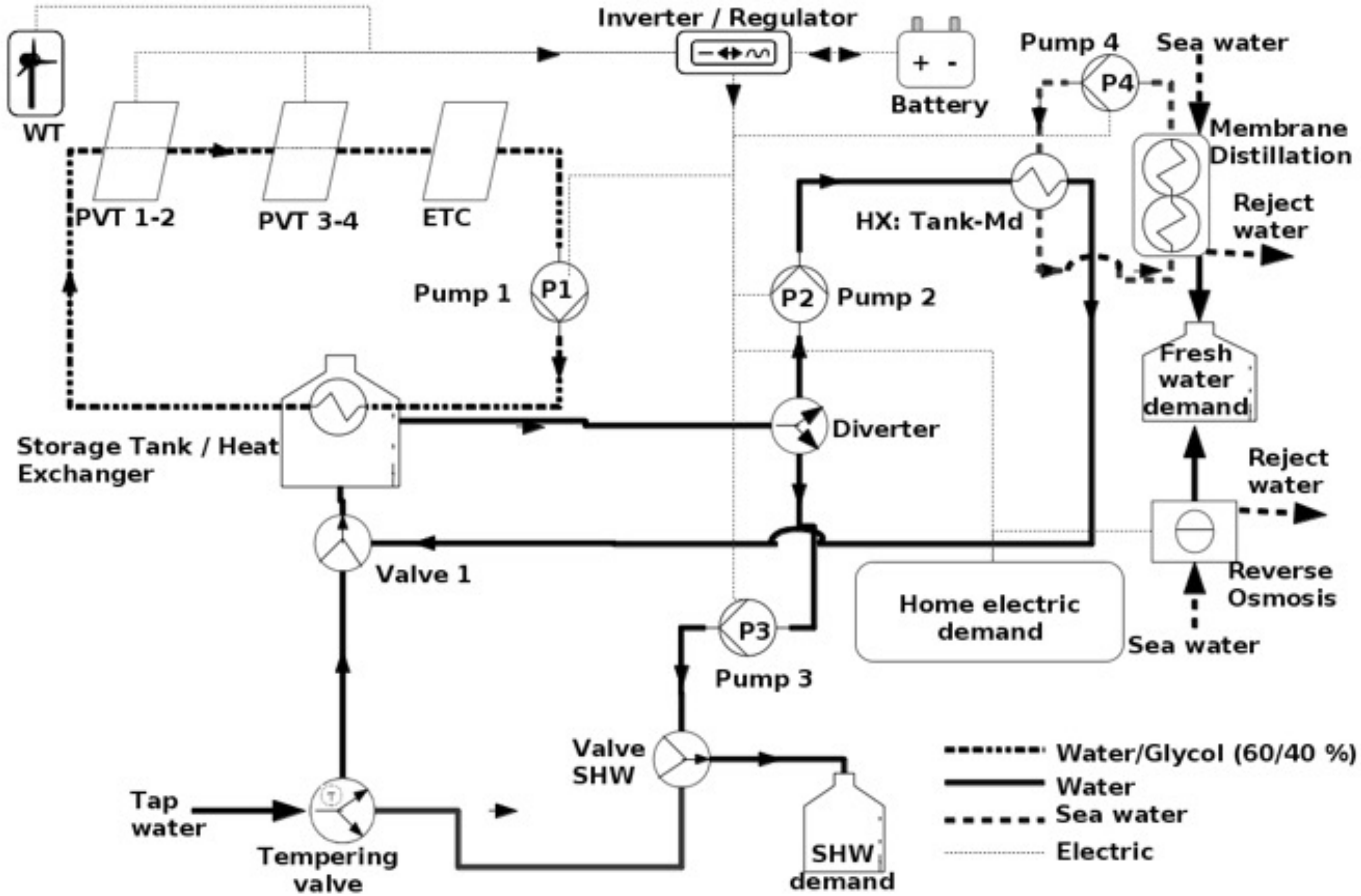
SYSTEM DESCRIPTION



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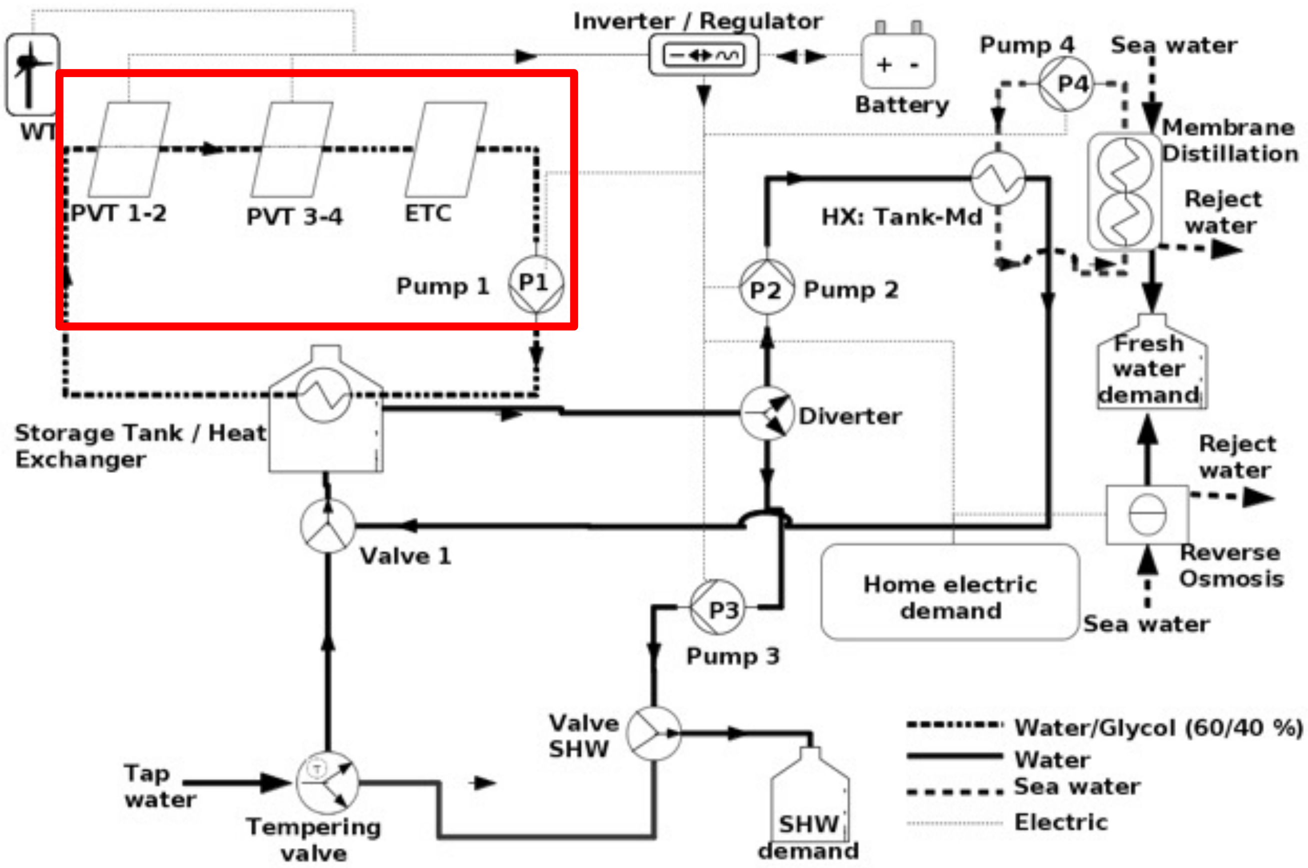
SYSTEM DESCRIPTION



Solar loop

- 4 x 1.63 m2 PVT
- 2 m2 ETC
- Pump

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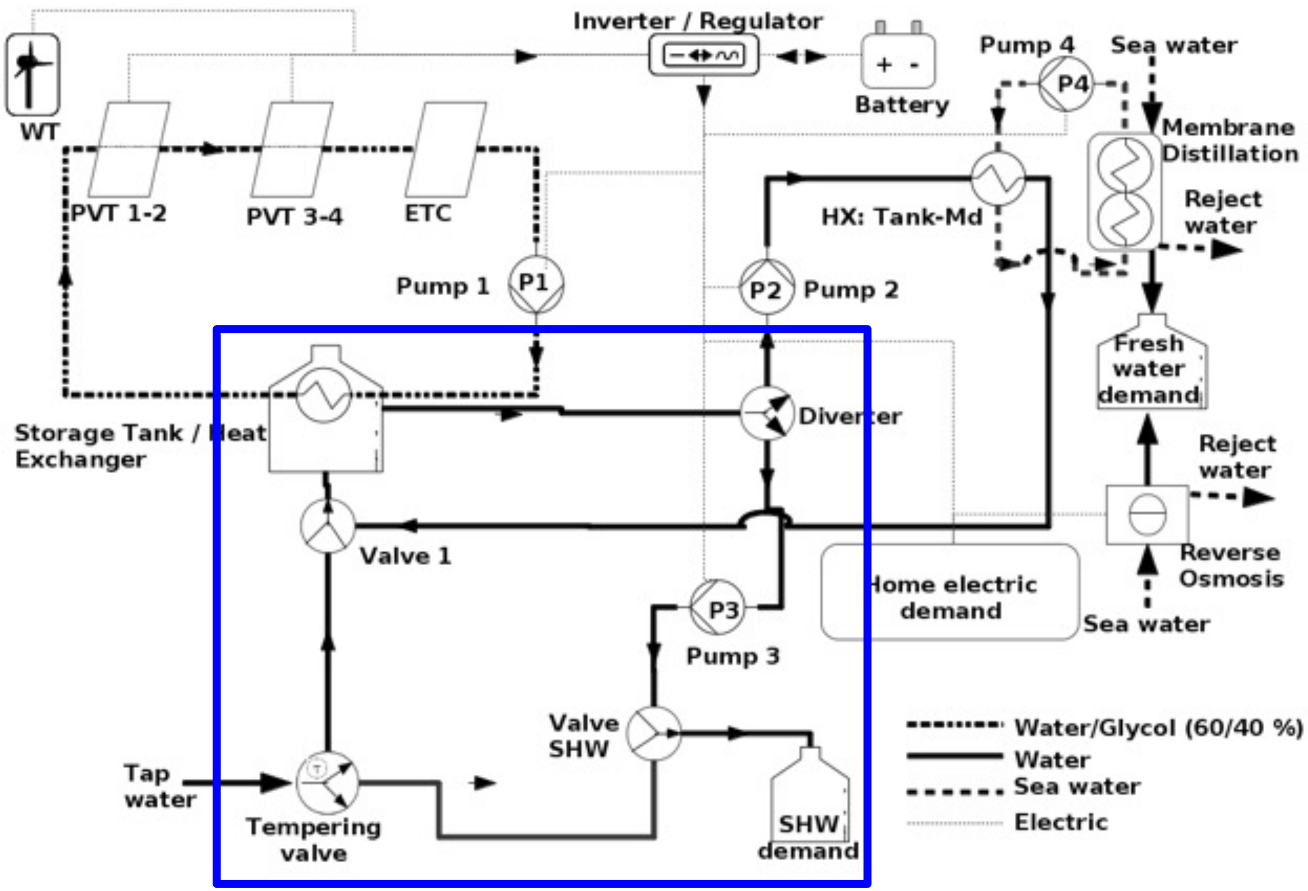
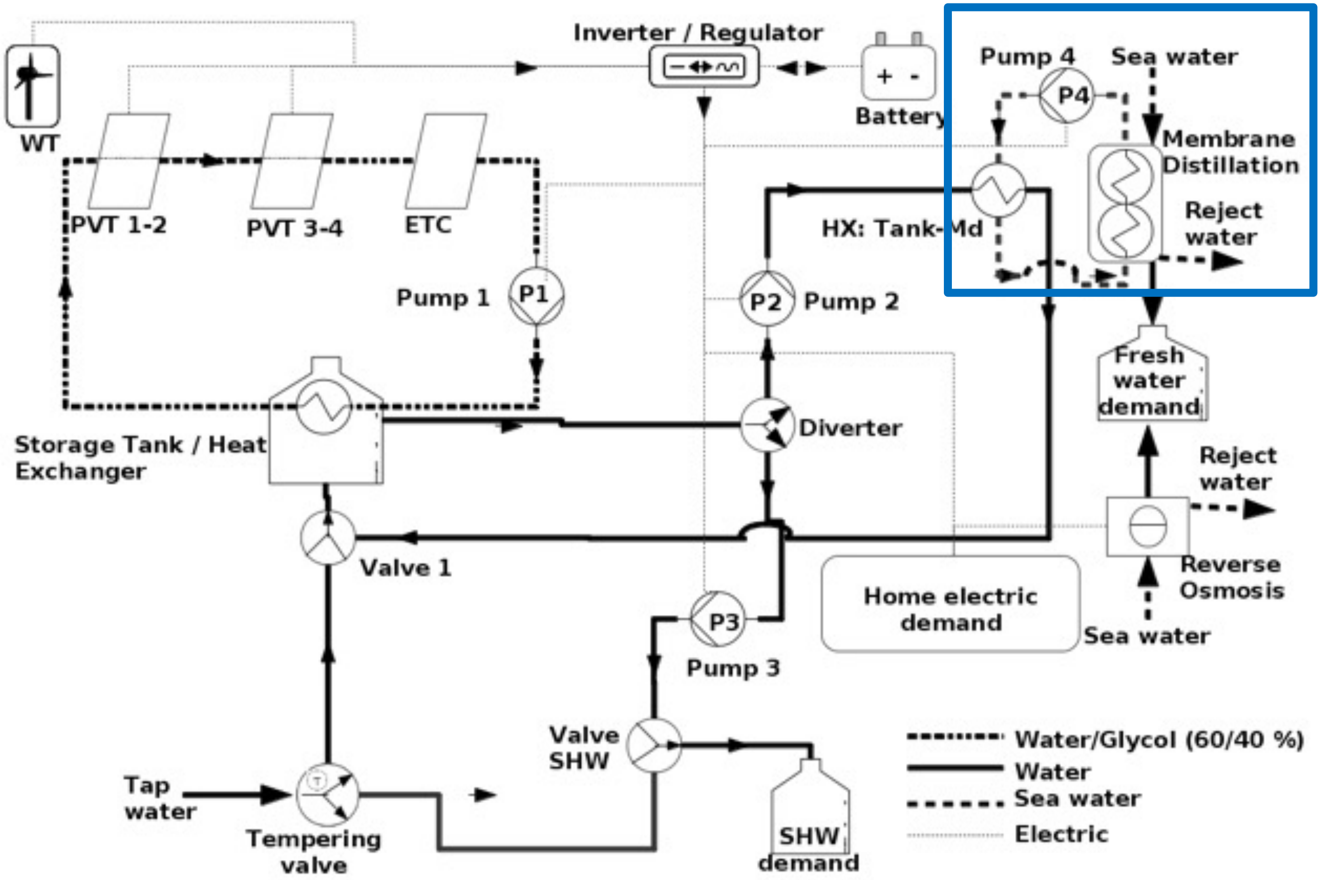


SHW loop

- 325 l tank
- Pumps, valves

SYSTEM DESCRIPTION



MD module

- PGMD
- 20 l/h

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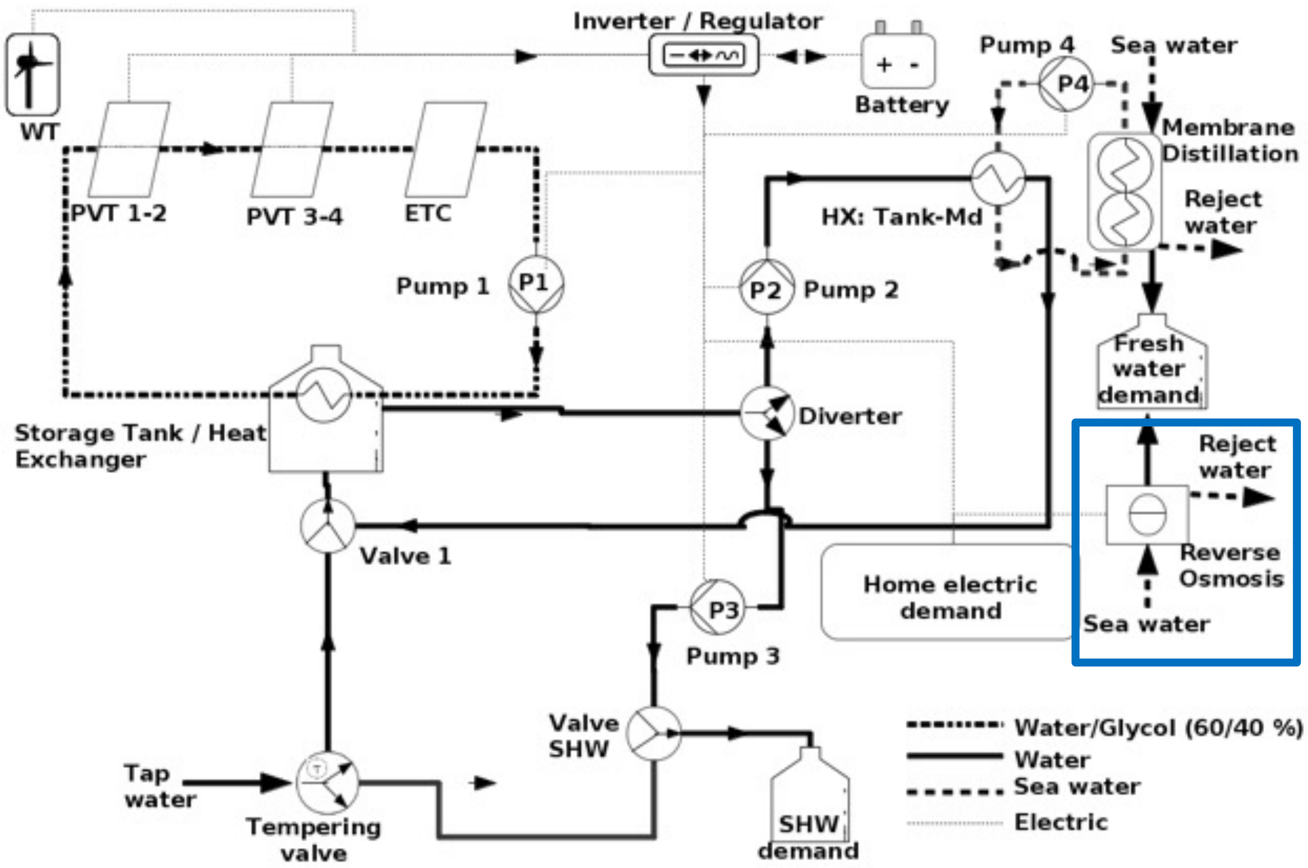

RO module

- 35 l/h
- 110 W

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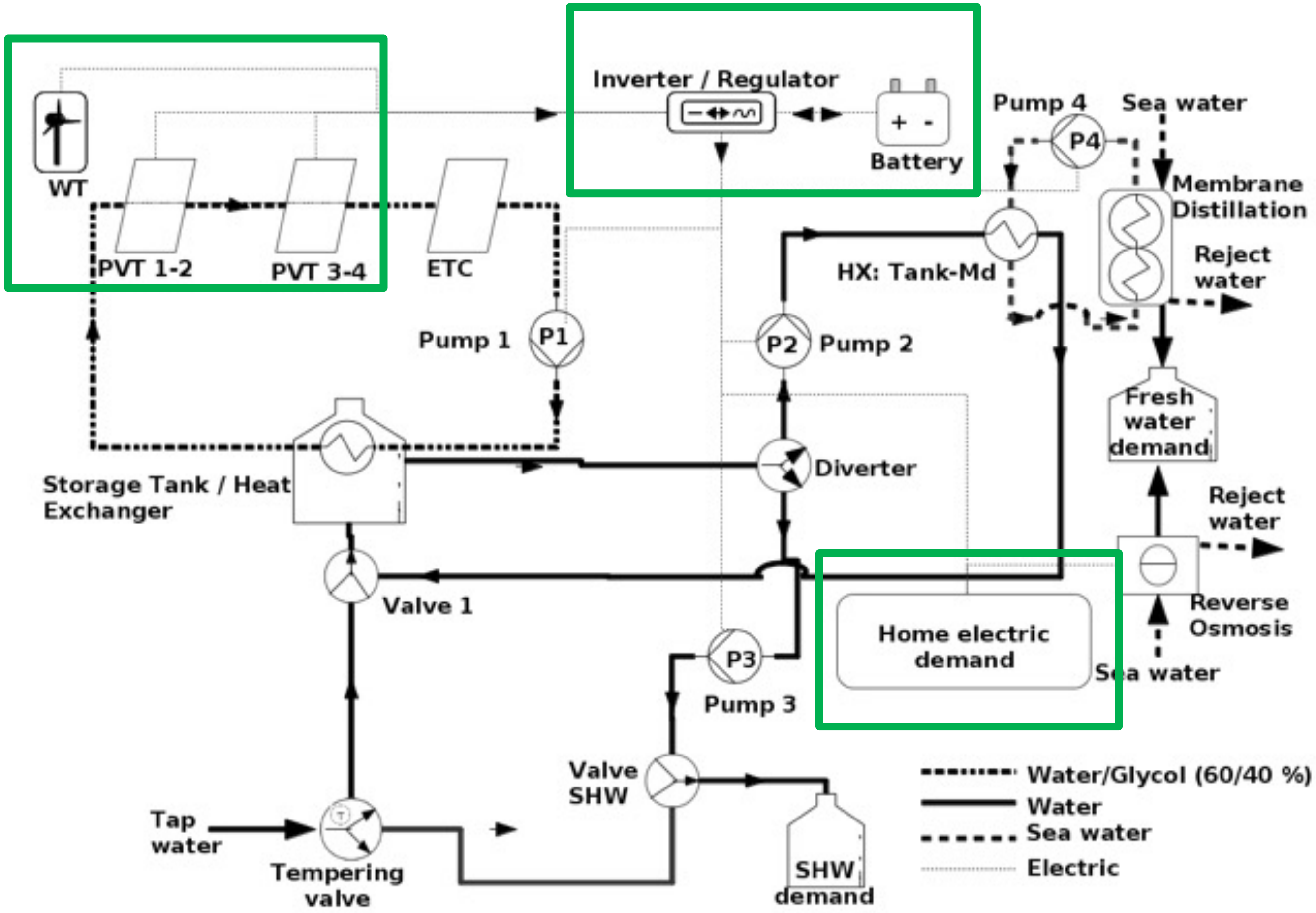


Power module

- 4 x 240 W PVT
- 400 W WT
- 250 Ah Battery
- Power control
- Electric demands

SYSTEM MODELING

- **TRNSYS** model (Acevedo et al., 2016)
- Ad-hoc **model of MD** unit
- Weather conditions at **Zaragoza** (Meteonorm database)
- **Water demand** (Gonzalez et al., 2008)
- **Home power demand** (Villagarcía, 1998)
- One **year, hourly** basis.

EXERGY ANALYSIS

- **Dedicated TRNSYS** types.
- Sun radiation:

$$\dot{B}_{rad} = IA_a\left(1 + \frac{1}{3}\left(\frac{T_0}{T_s}\right)^4 - \frac{4}{3}\left(\frac{T_0}{T_s}\right)\right)$$

- Wind:

$$\dot{B}_{wind} = \frac{1}{2}\dot{m}v^2 = \frac{1}{2}A\rho v^3$$

EXERGY ANALYSIS

- Physical exergy of flow (incompressible with constant p):

$$\dot{B}_{ph} = \dot{m} c_p \left(T - T_0 - T_0 \ln \frac{T}{T_0} \right)$$

- Chemical exergy (salt-water flows):

$$b_{ch} = N_s R T_0 ln \frac{N_s}{N_s + \sum \left(\frac{\beta_i C_i}{\rho M W_i} \right)} \qquad N_s = \frac{1000 - \sum \left(\frac{C_i}{\rho} \right)}{M W_s}$$

EXERGY ANALYSIS

- **Exergy EFFICIENCY.**
- Instant efficiency for detailed analysys (W/W):

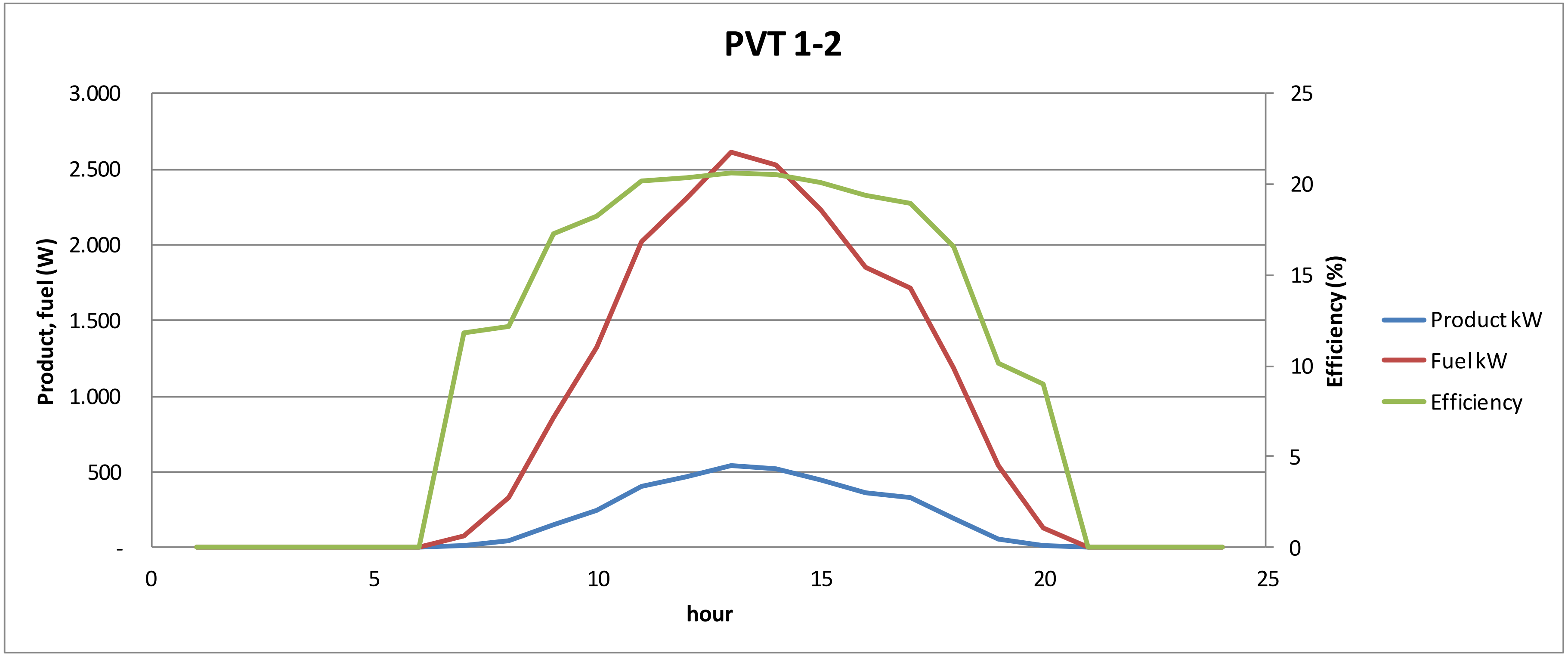
$$\eta_b = \frac{\dot{P}}{\dot{F}}$$

- Average efficiency for aggregated analysis (kJ/kJ):

$$\eta_{b,av} = \frac{P}{F} = \frac{\int_{t_1}^{t_2} \dot{P}(t)dt}{\int_{t_1}^{t_2} \dot{F}(t)dt}$$

RESULTS: DETAILED TIME EVOLUTION

- **PVT 1-2,** example summer day (19th July)



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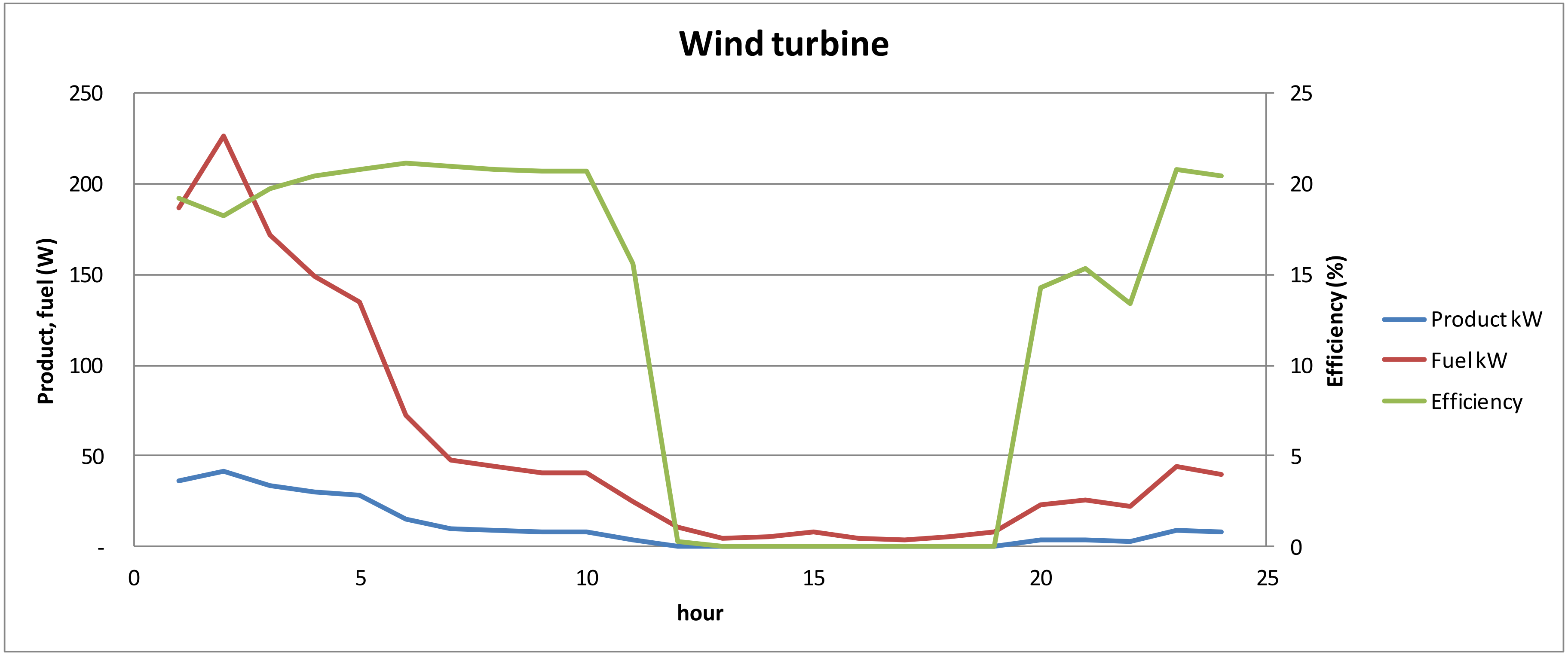
RESULTS: DETAILED TIME EVOLUTION

- **Wind turbine,** example winter day (30th January)



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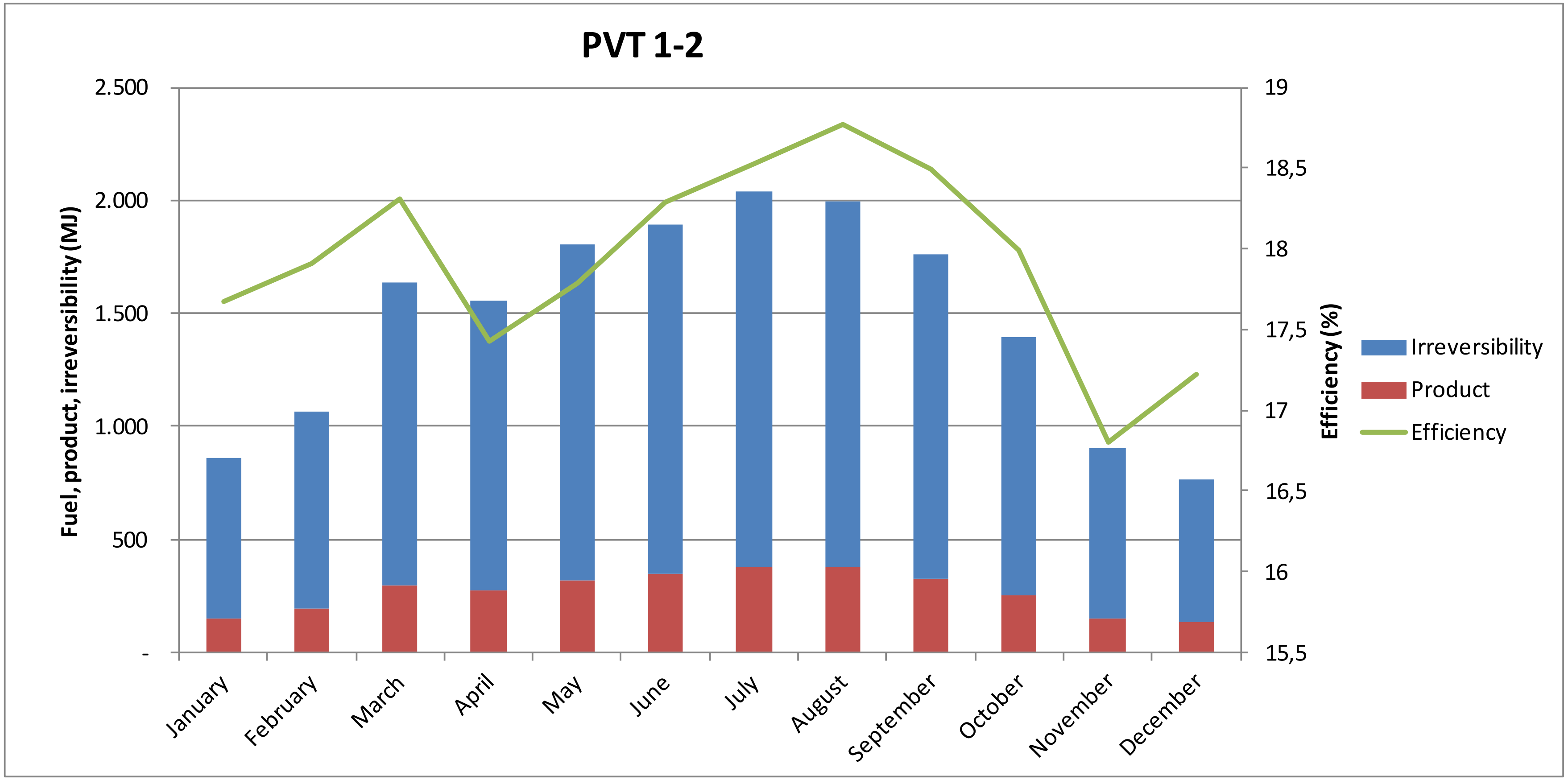
RESULTS: AGGREGATED MONTHLY ANALYSIS

- **PVT 1-2**



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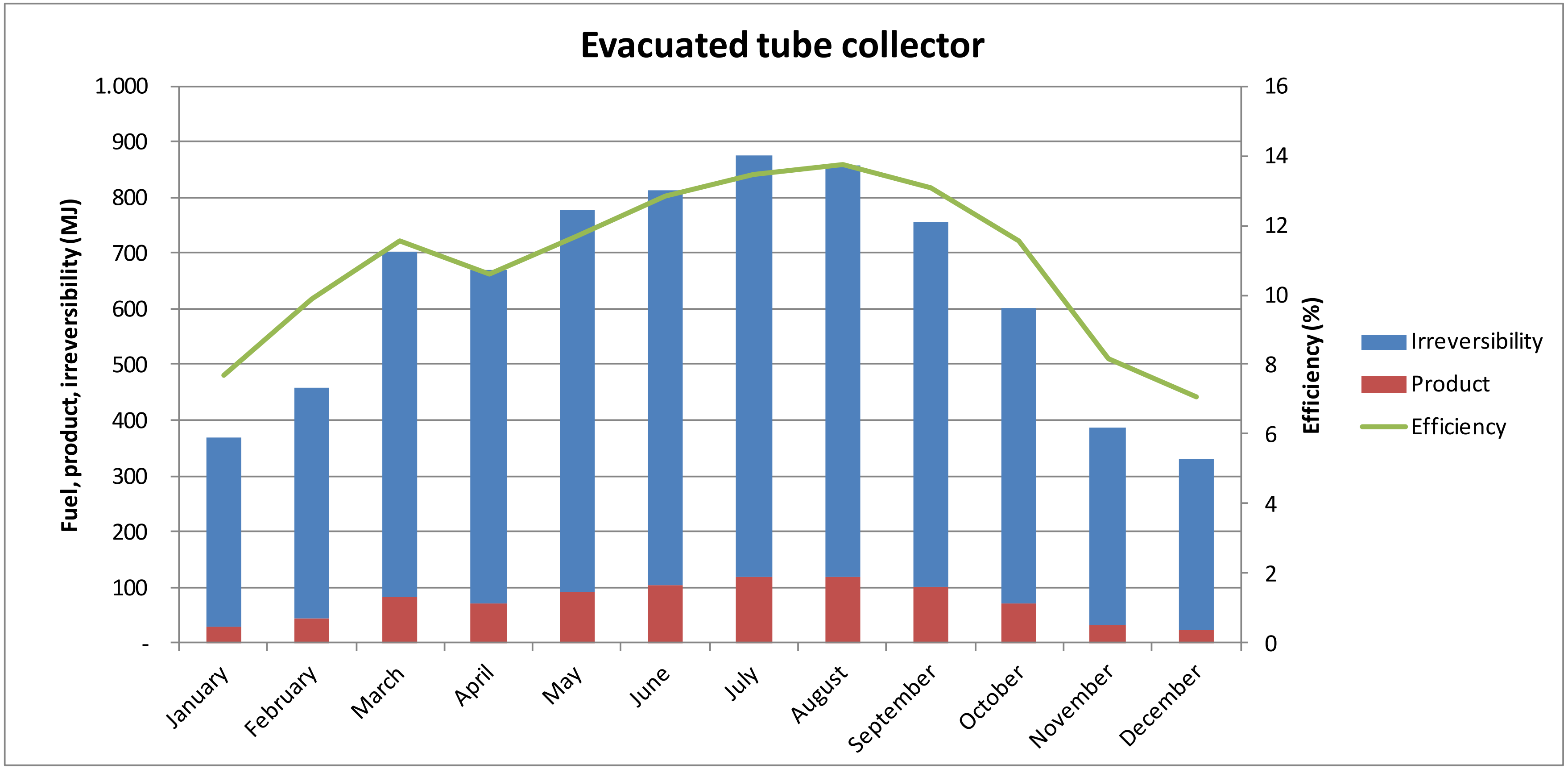
RESULTS: AGGREGATED MONTHLY ANALYSIS

- **Evacuated tube collector (ETC)**



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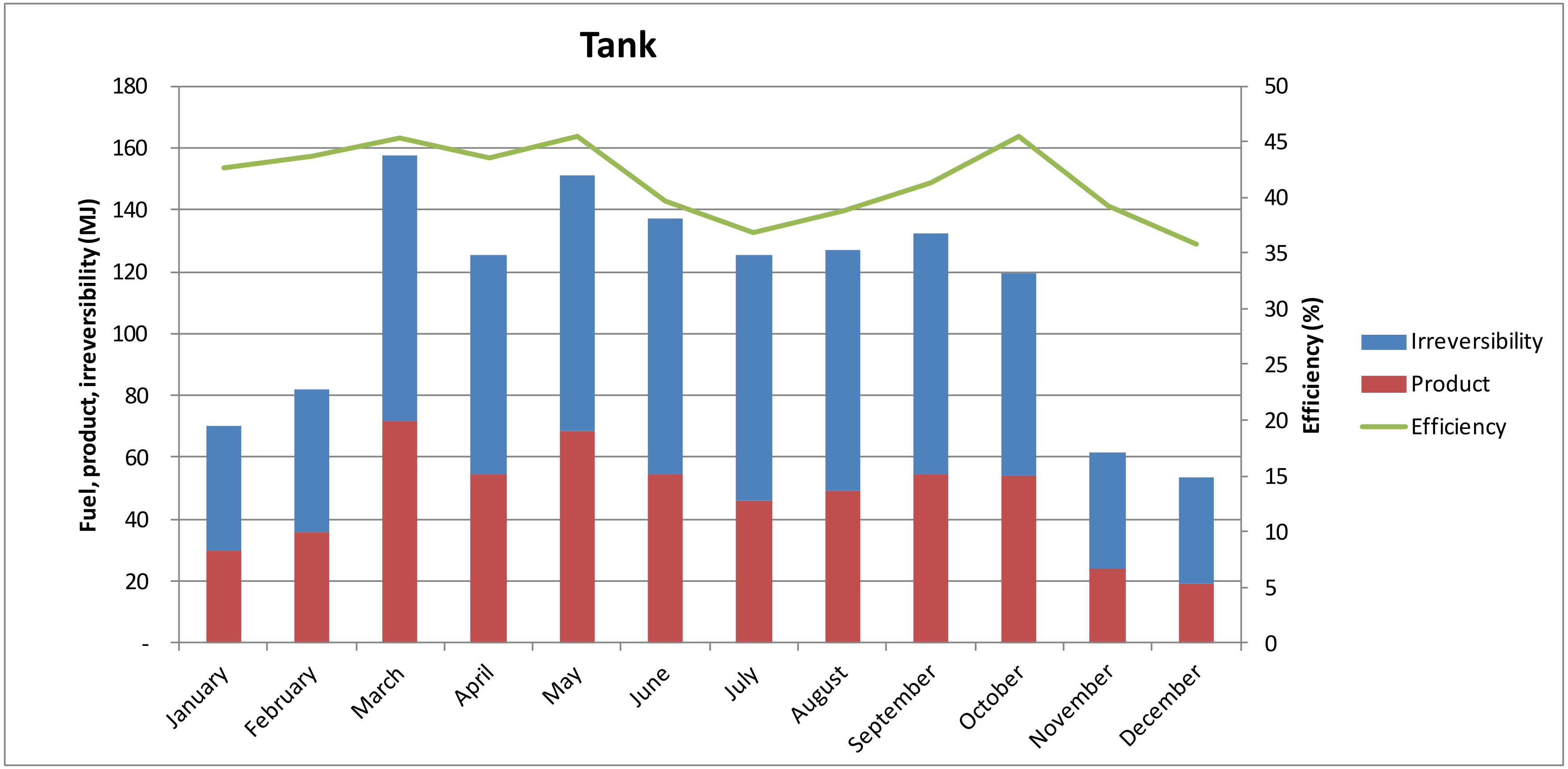
RESULTS: AGGREGATED MONTHLY ANALYSIS

- **Tank**



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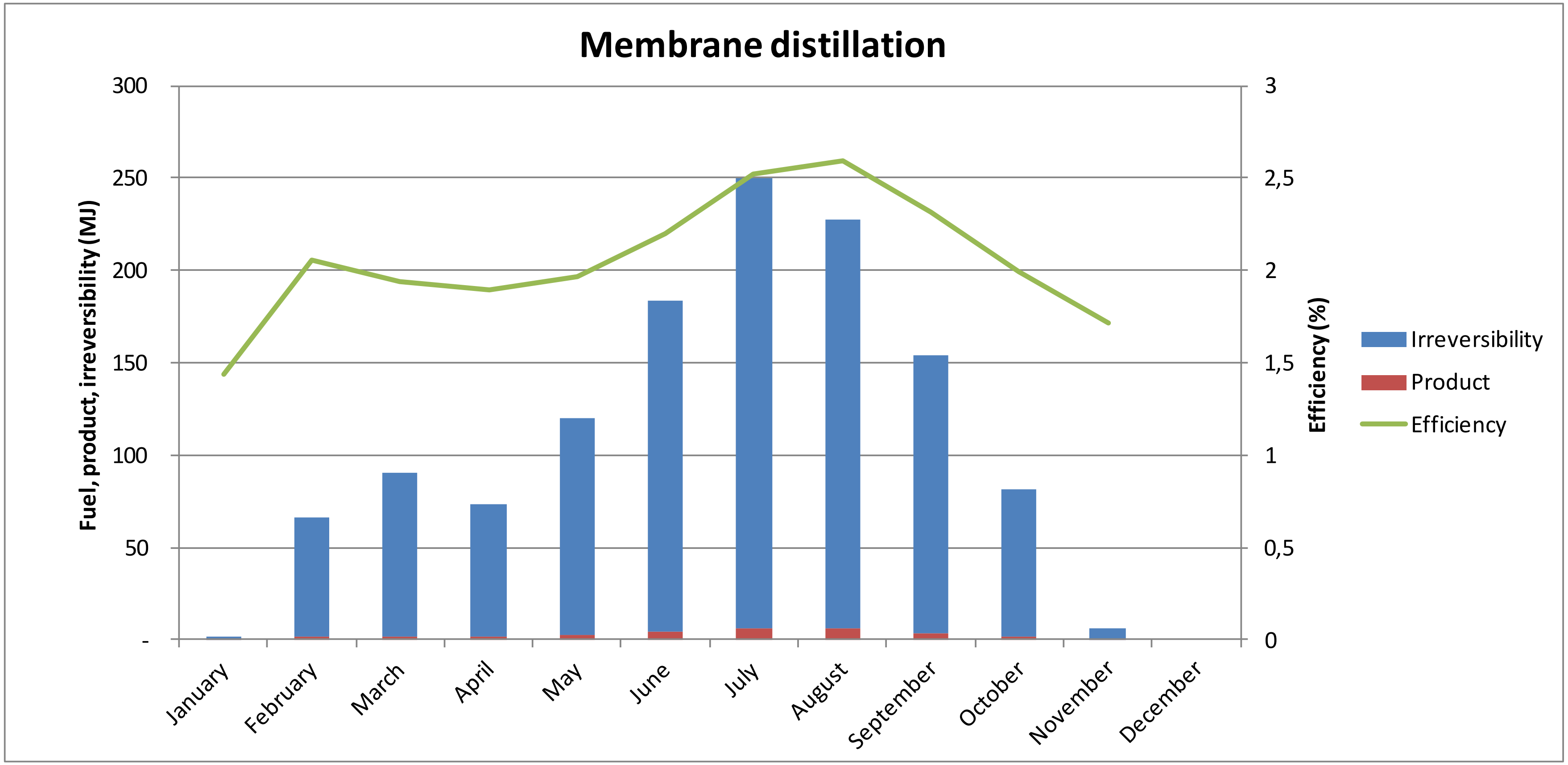
RESULTS: AGGREGATED MONTHLY ANALYSIS

- **Membrane distillation unit (MD)**



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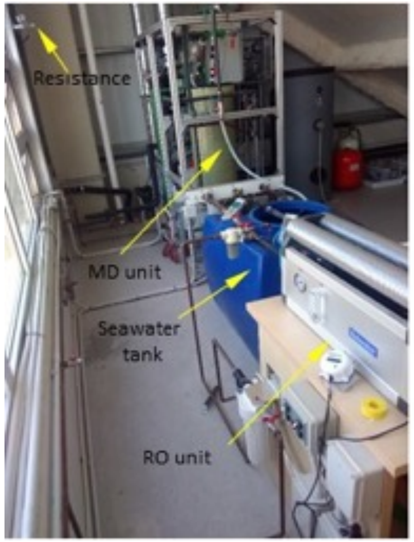
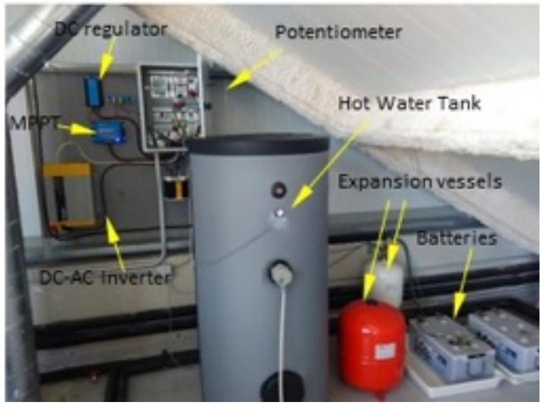
CONCLUSION

- **Exergy** analysis is an useful tool for detecting and quantifying potentials of **improvement** in renewable-based polygeneration systems: **TRNSYS types** can help.
- Because of **transient operation**, two time scales have been applied:
  - **Detailed analysis** (hourly operation).
  - **Aggregated analysis** (monthly basis) for summarizing system behaviour during a year.
- Higher irreversibility appear in **collectors**, but **PVT** have much higher efficiency.
- A relevant source of irreversibility appears because MD **unit** is driven through **several steps** (collector, tank and Hex).

RESULTS: AGGREGATED MONTHLY ANALYSIS

- **Next step:** Exergy analysis of **actual operation data** (the plant has now been erected and results of test are being obtained).





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Thank you for your attention!

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