Predicting the yield of a single slope solar still: A comparison of models

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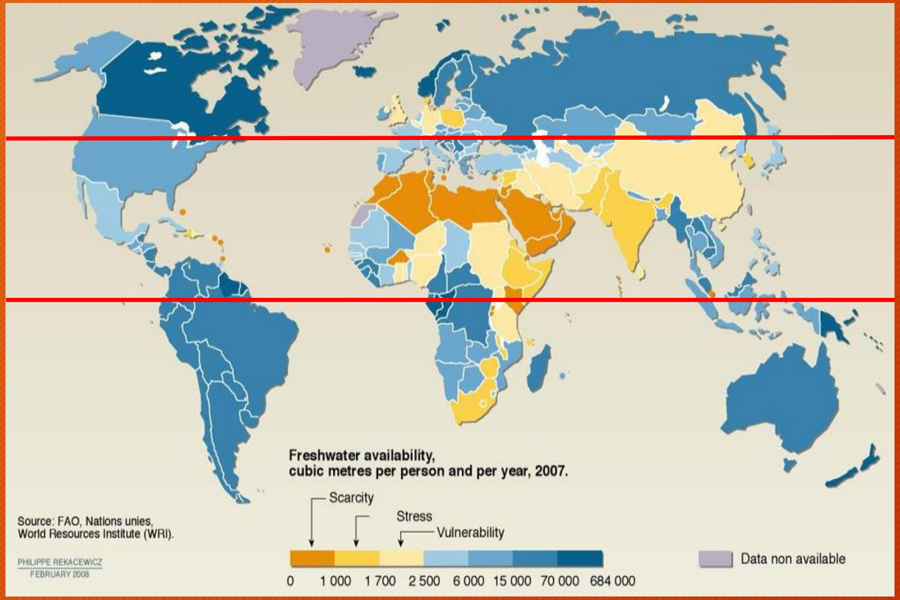
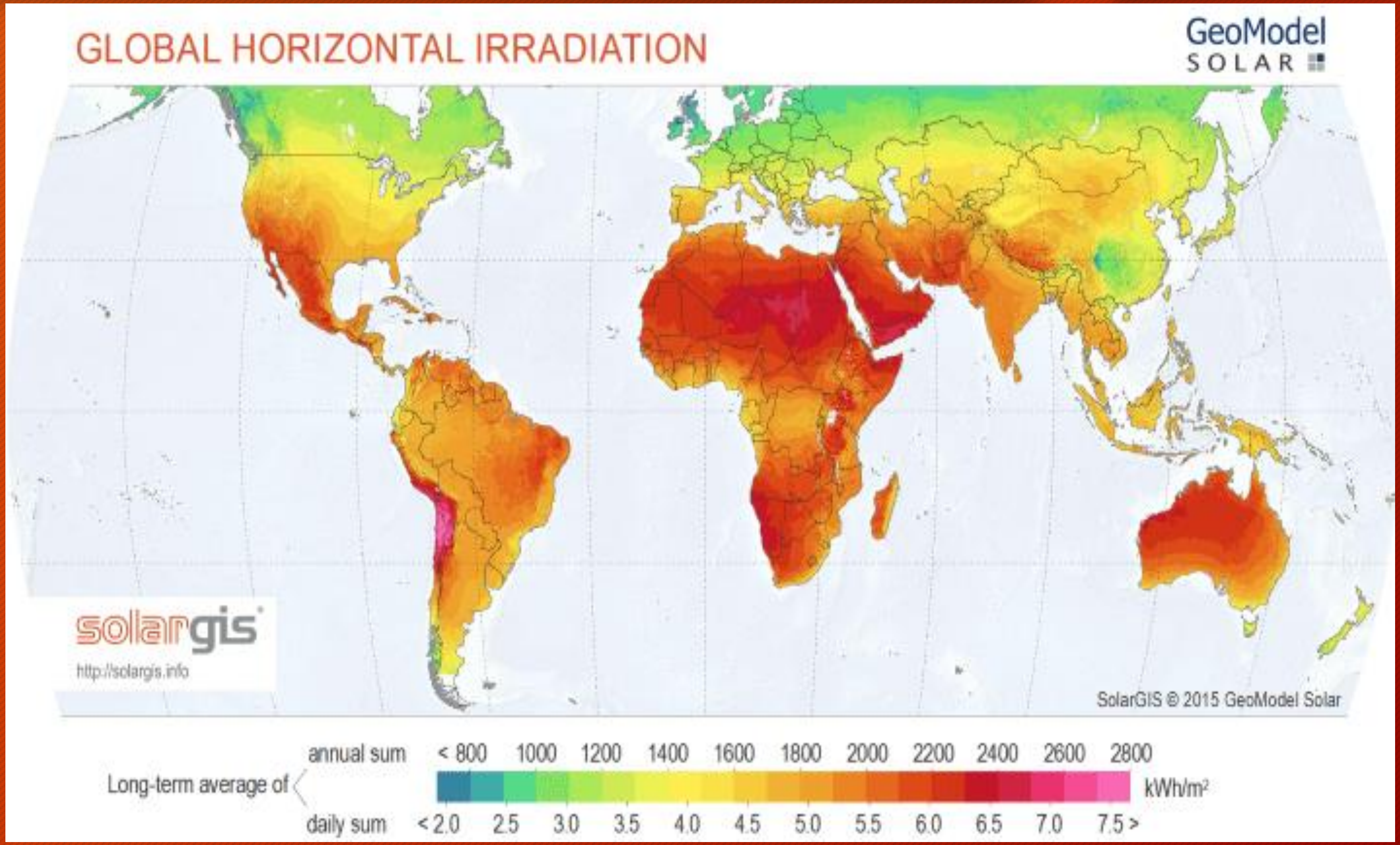
Introduction

- Access to potable water is one of the greatest challenges facing humanity in the 21st century.
- Water resource availability is one of the most important factors for socio-economic development.
- Whether the source of water is from underground or superficial resources, it is always very important to treat water before human consumption.
- Thermal desalination technique can handle high concentration of pollutants and large water demands.

Potential desalination sites

- ❖ With the depletion of conventional energy resources, solar energy appears to be the most viable and sustainable solution to use for water treatment.





World solar energy potential

Thermal models

- Based on the various energy balances of the solar still parts, different thermal models were developed to predict water production from solar stills.

- One of the most critical parameters in the modelling of solar stills is the heat and mass transfer between the absorber plate and glass cover.

- the most often used equation that describes mass and heat transfer in a solar still was developed by Dunkle (1961). However, different researchers pointed out that Dunkle’s model leads to an overestimation of solar still yield.

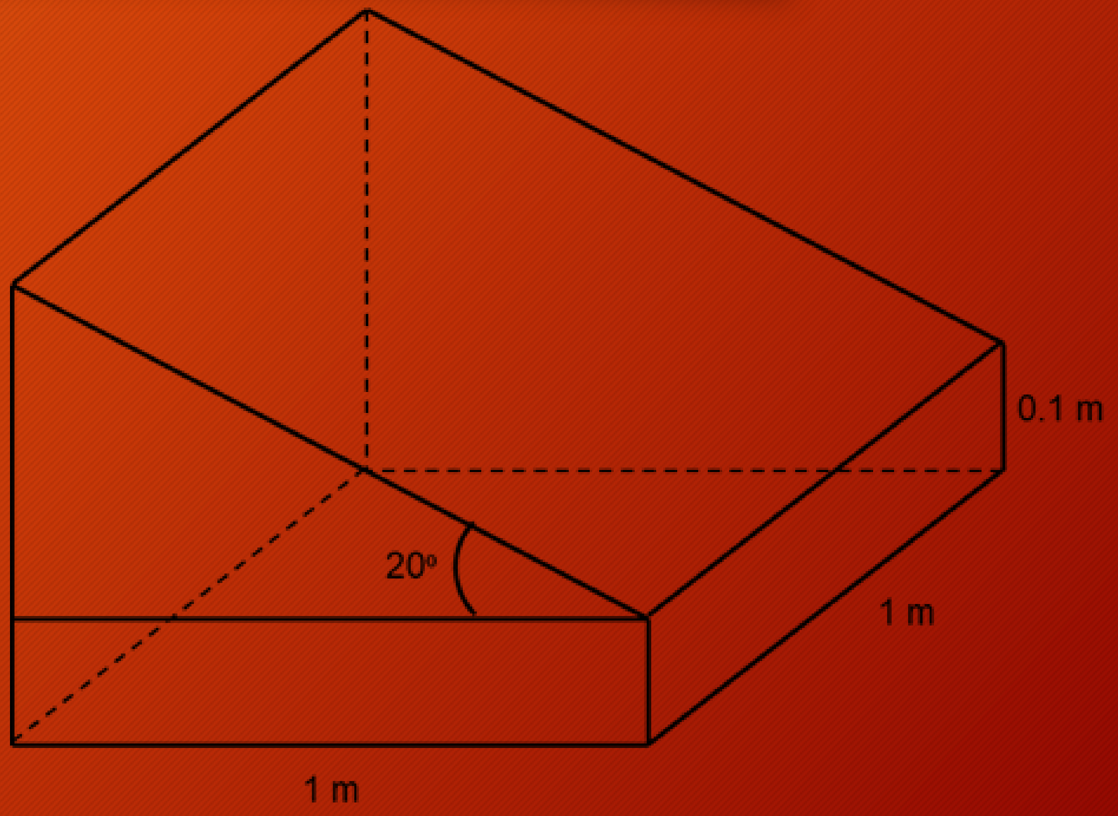
Aim

- In order to overcome the shortcomings of Dunkle model, different models were developed. However, these models appear to have been developed in an ad-hoc manner. Therefore, the aim of this research is to evaluate and compare the performance of single slope solar still models to examine their prediction of annual water production.

Methodology

- Energy balance to determine the temperatures of the absorber, water in the basin, and the cover of the still

- Water produced by a still in Laghout (Algeria), using hourly data for ambient temperature, wind velocity and solar irradiation across a year



Energy balance

- Water

$$M_w Cp_w \frac{dT_w}{dt} = A_{abs} I_T(t) \tau_g \alpha_w + A_{abs} h_{abs-w}(T_{abs} - T_w) - A_{abs}(\boldsymbol{h_{cv\,w-g}} + h_{ew} + h_{r\,w-g})(T_w - T_g)$$

- Absorber

$$M_{abs} Cp_{abs} \frac{dT_{abs}}{dt} = A_{abs} I_T(t) \tau_g \tau_w \alpha_{abs} - A_{abs} h_{abs-w}(T_{abs} - T_w) - A_{abs} h_b (T_{abs} - T_a)$$

- Cover

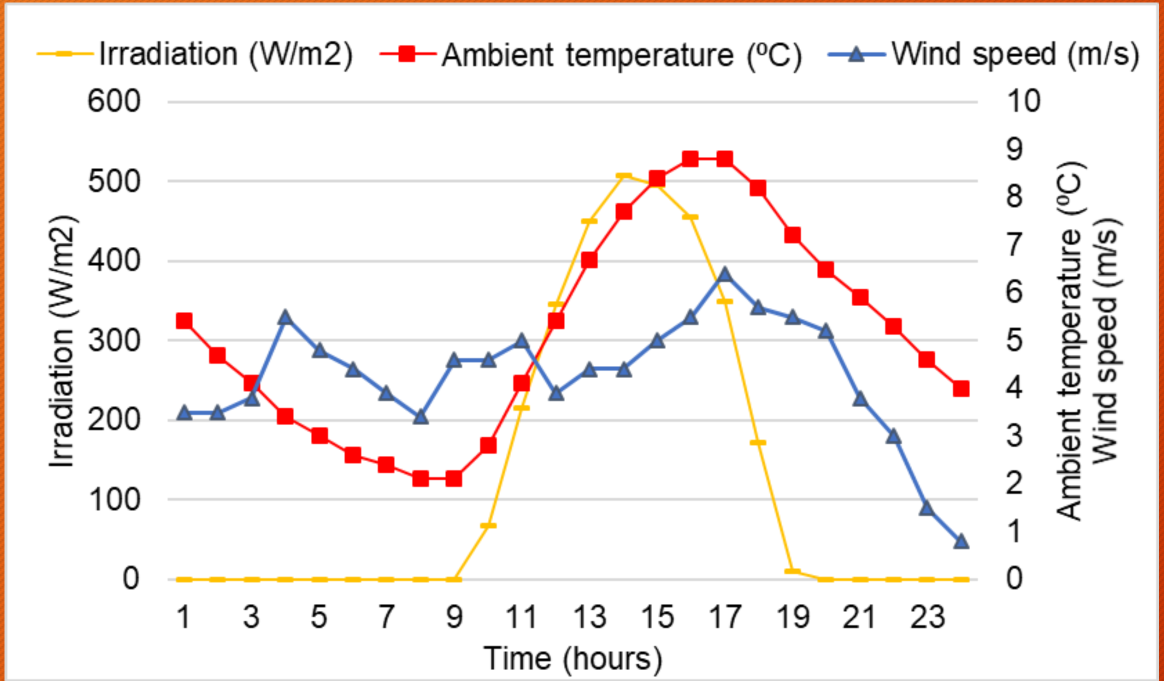
$$M_g Cp_g \frac{dT_g}{dt} = A_g I_T\,(t) \alpha_g + A_g(\boldsymbol{h_{cv\,w-g}} + h_{r\,w-g})(T_w - T_g) - A_g h_{cv\,g-a}(T_g - T_a) - A_g h_{r\,g-a}(T_g - T_a$$

Convective heat transfer

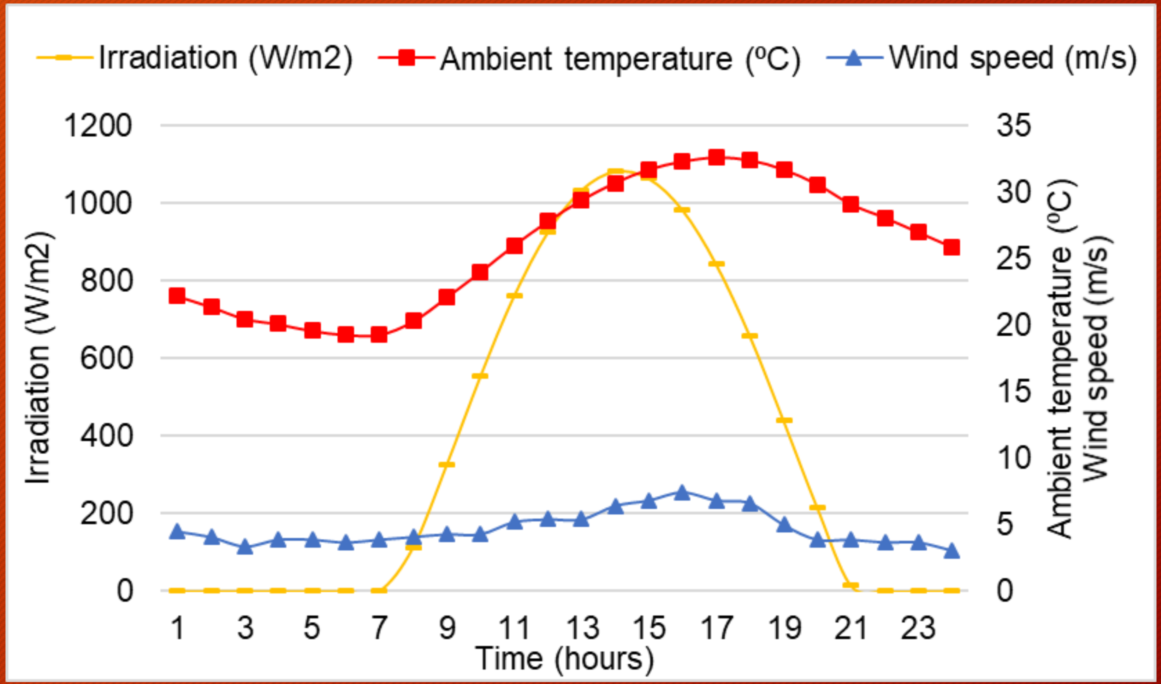
Models used in the study

- Dunkle (1961) $h_{cv} = 0.884\left[(T_w - T_g) + \frac{(P_w - P_g) * (T_w + 273.15)}{268.9 * 10^3 - P_w}\right]^{1/3}$ $h_{ew} = 0.0163 * h_{cv} * \left[\frac{P_w - P_g}{T_w - T_g}\right]$
- Adhikari et al. (1990) $\dot{m} = \alpha * (\Delta T')^n * (P_w - P_g)$
- Shawaqfeh and Farid (1995) $h_{ew} = \frac{\lambda_w * M_w}{2 * C_{p_{mix}} * M_{mix}}\left[\frac{1}{P_{(a)w}} + \frac{1}{P_{(a)g}}\right] h_{cv1}$ $h_{cv1} = 0.057 * Ra'$
- Rahbar and Esfahani (2012) $Nu = 0.28\,(Ra)^{0.25}(A_R)^{-0.16}$
- Jamil and Akhtar (2017) $Nu = 0.0462\,(A_R)^{0.15}(Ra)^{0.34}$

Sample input conditions

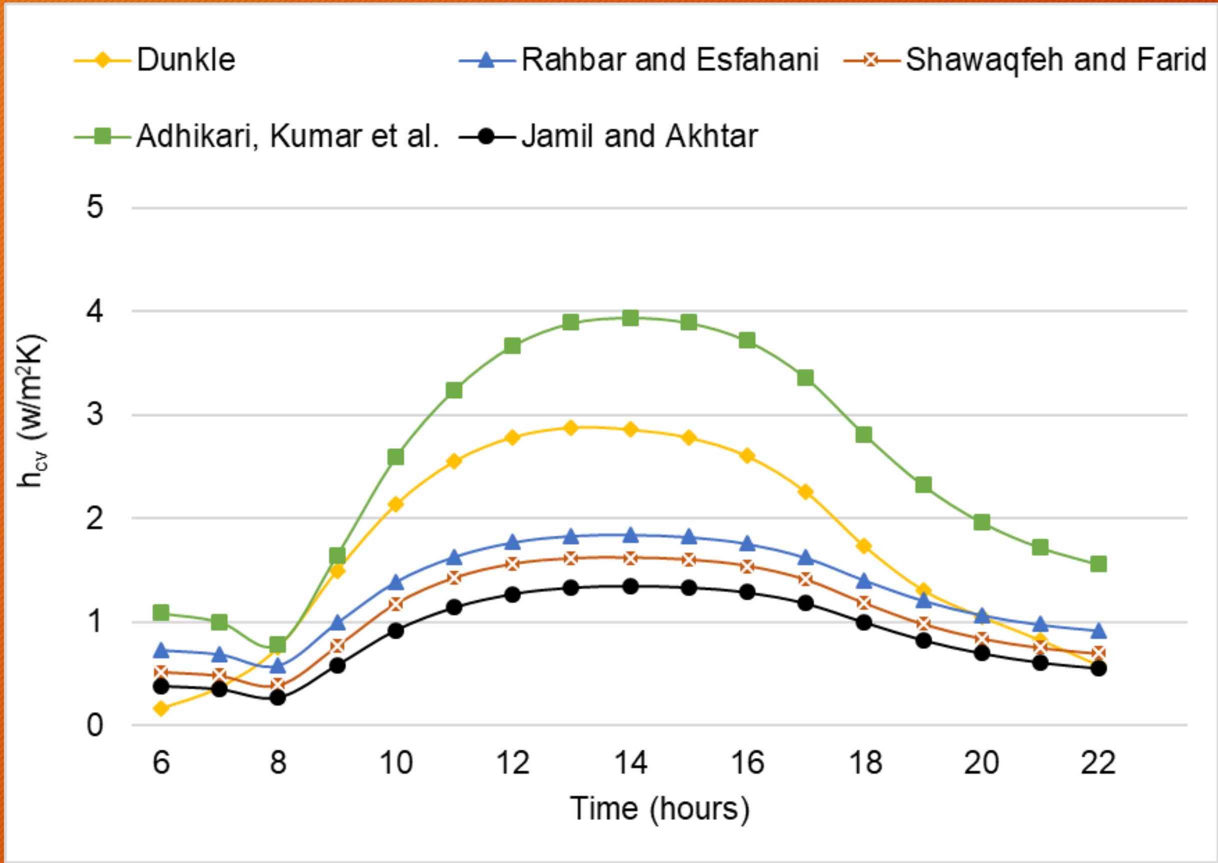


Hourly weather conditions on 31st of December

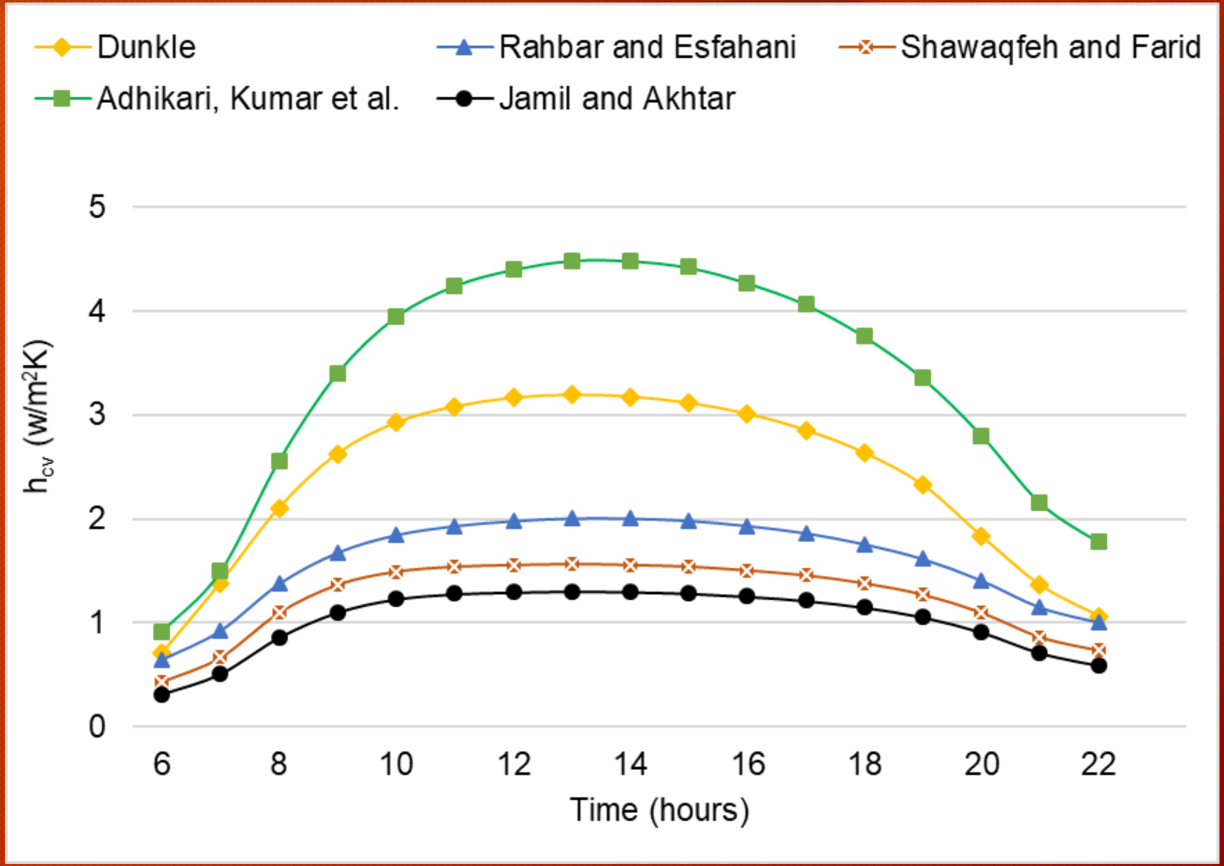


Hourly weather conditions on 27th of May

Results



Convective heat transfer on 31st of December



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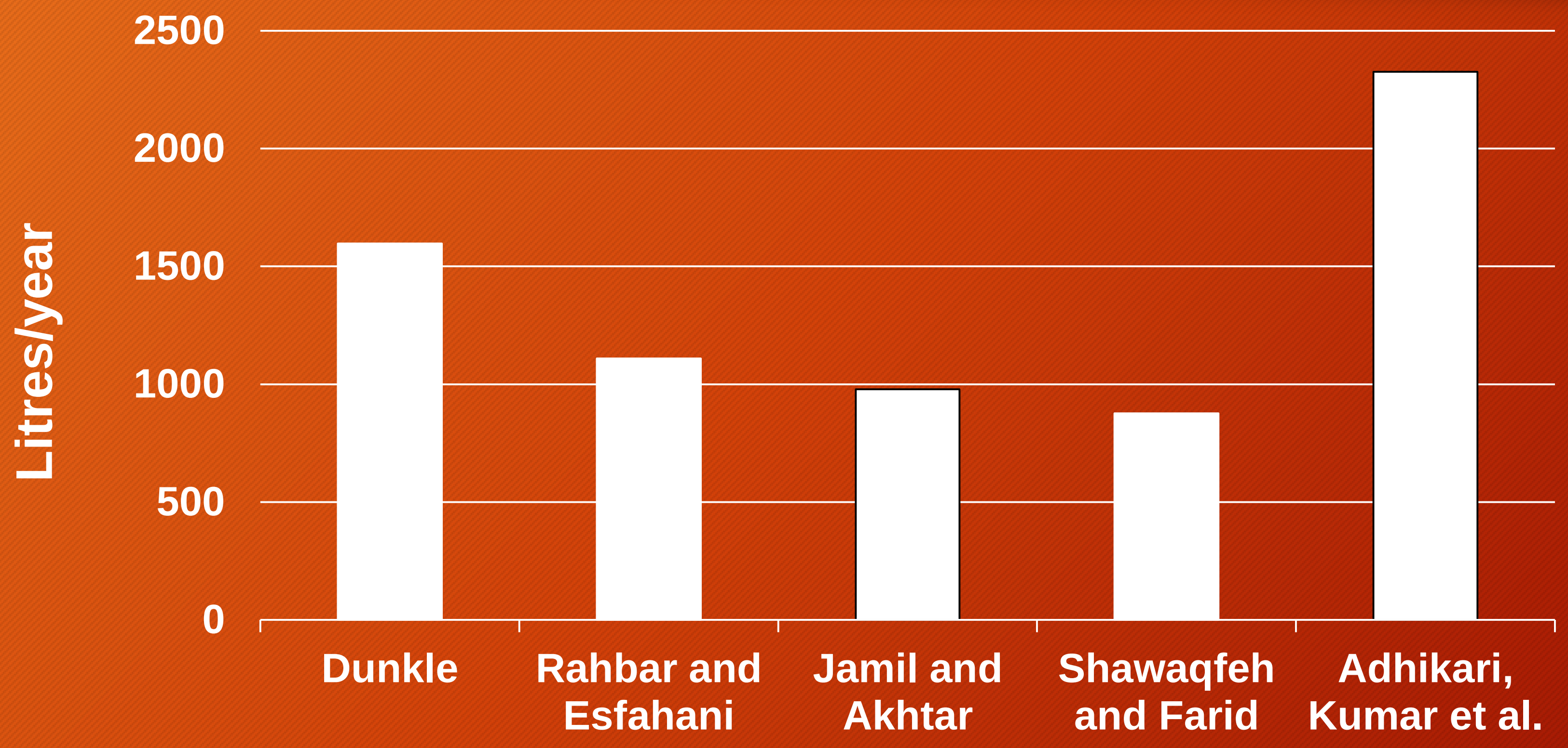
Results



Predicted amount of water for each model per year

Conclusion

- Differences in the daily performance between the models led to significant differences in terms of yearly output.

- There is a need to critically investigate the effect of the different designs and geometrical factors.

- The latter will lead to better predictions of the annual production from these devices and their successful implementation in practical applications.

Questions?

Thank you