Session: **Energy Policy, Programmes and Cross-sectoral Issues**

Reducing the carbon footprint of mini-grids in Africa: the value of solar PV

Théo Chamarande, Benoit Hingray and Sandrine Mathy (paper submitted to *Applied Energy*, Mai 2023)

Rural electrification and carbon neutrality

- Paris Agreement 2015 :

Global pathways reach carbon neutrality of the energy sector by 2050

Some African countries pledge for net-zero emissions by 2050-2060

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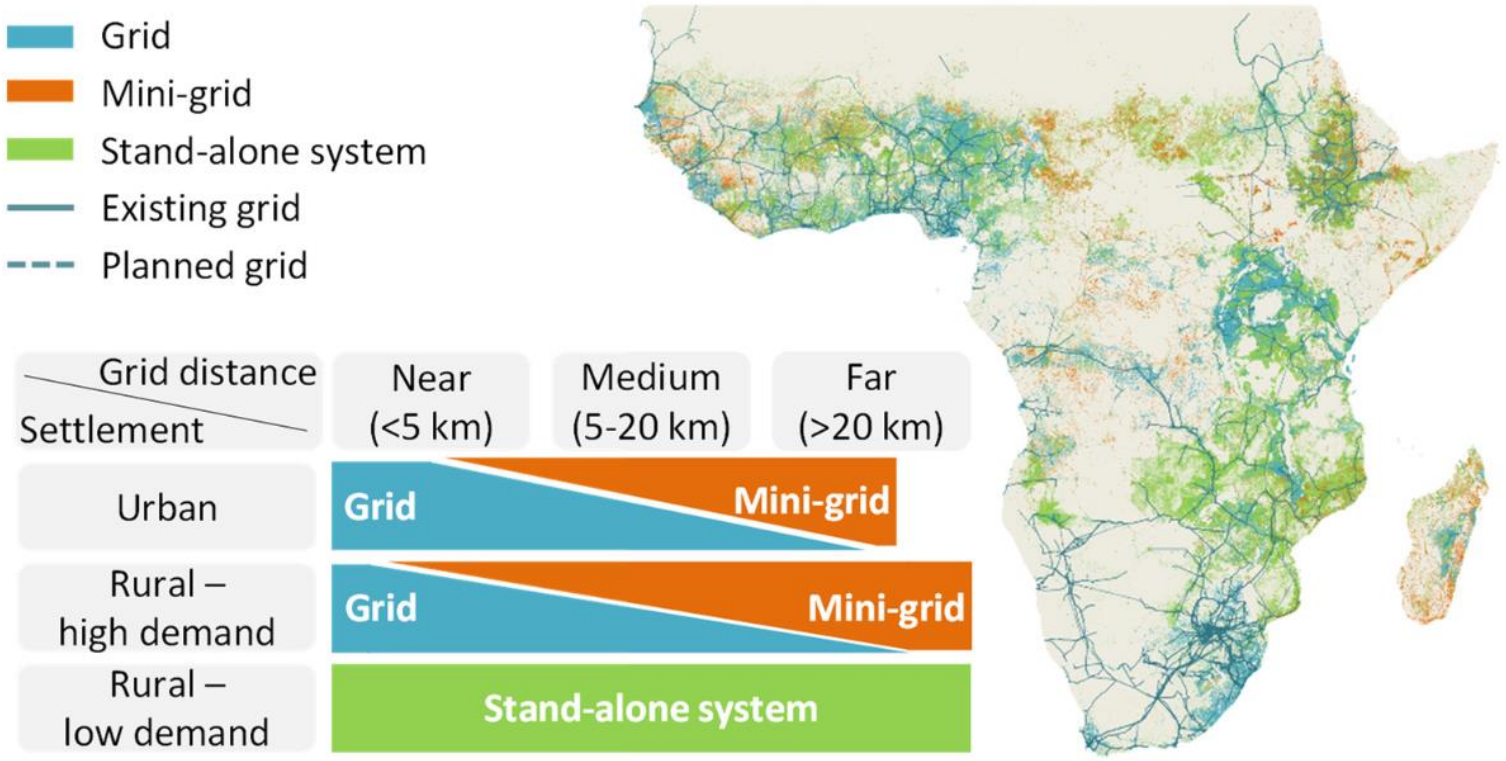


Africa energy outlook 2022 (International Energy Agency)

➢ Solar mini-grids (MG), a promising solution to electrify at low cost and with low emissions ?

Simulating hybrid solar/diesel MG

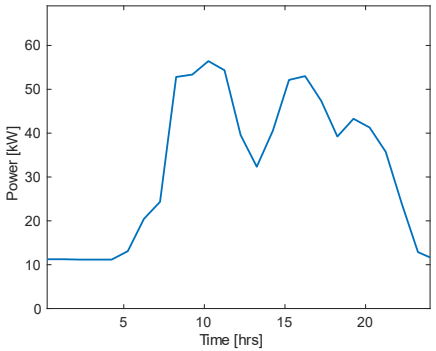
PV production

Irradiance from Heliosat SARAH2

Temperature from ERA5

Batteries

Genset



Typical demand profile from the literature

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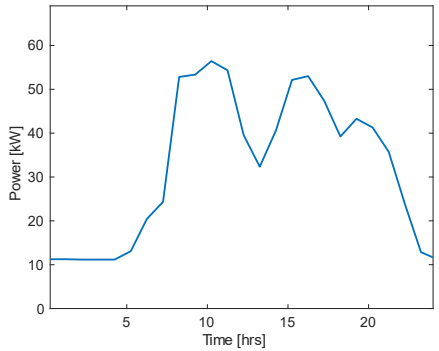

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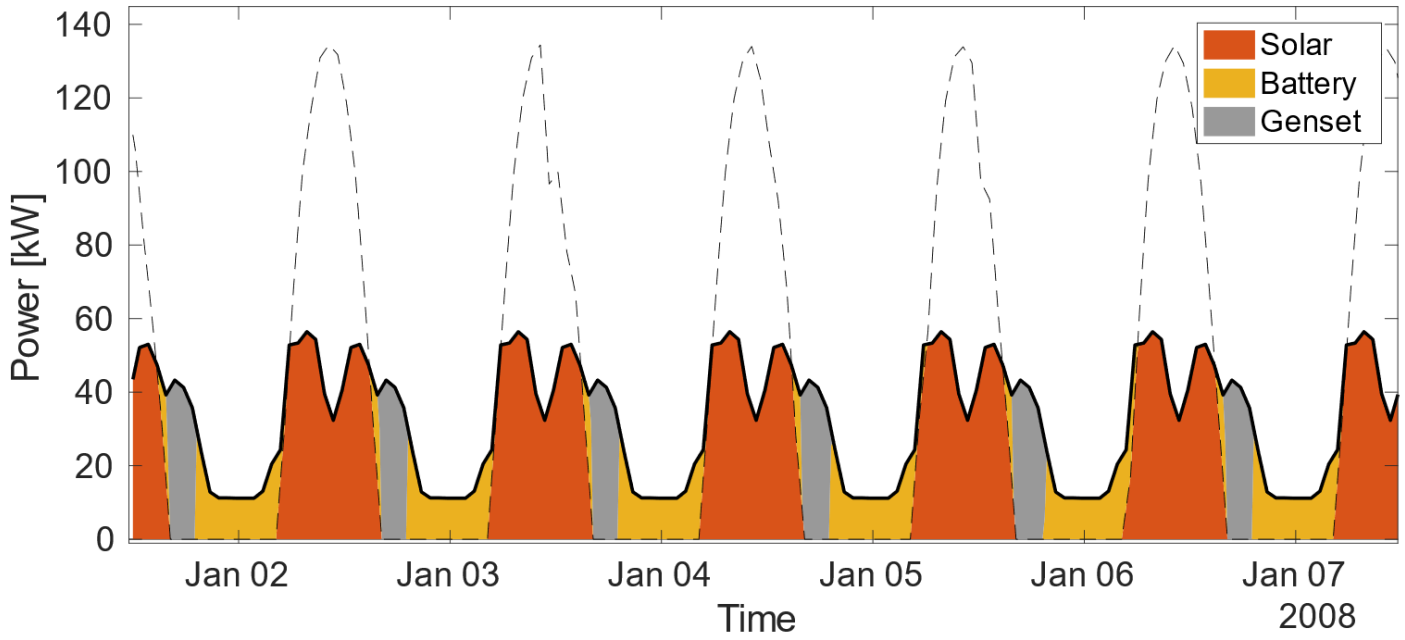

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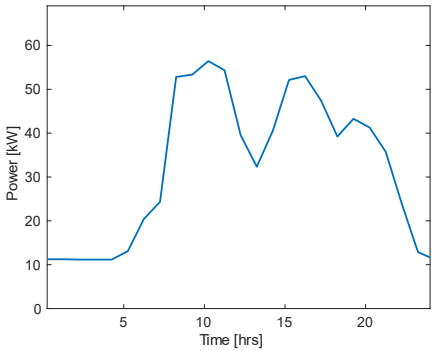

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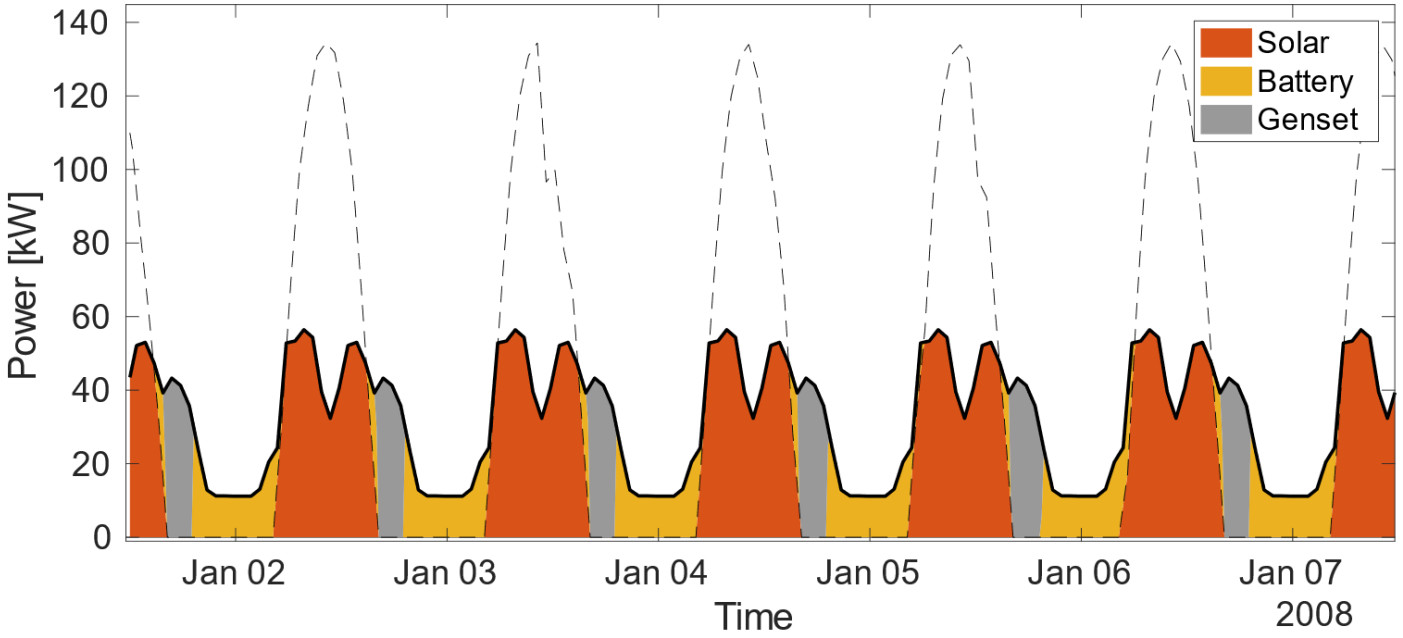


For each configuration :

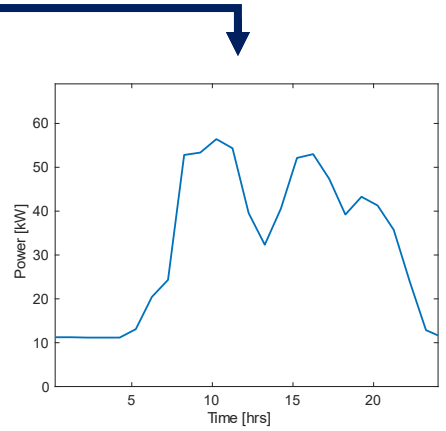
- Levelized Cost of Energy (LCOE)
- Carbon Footprint (CFP)

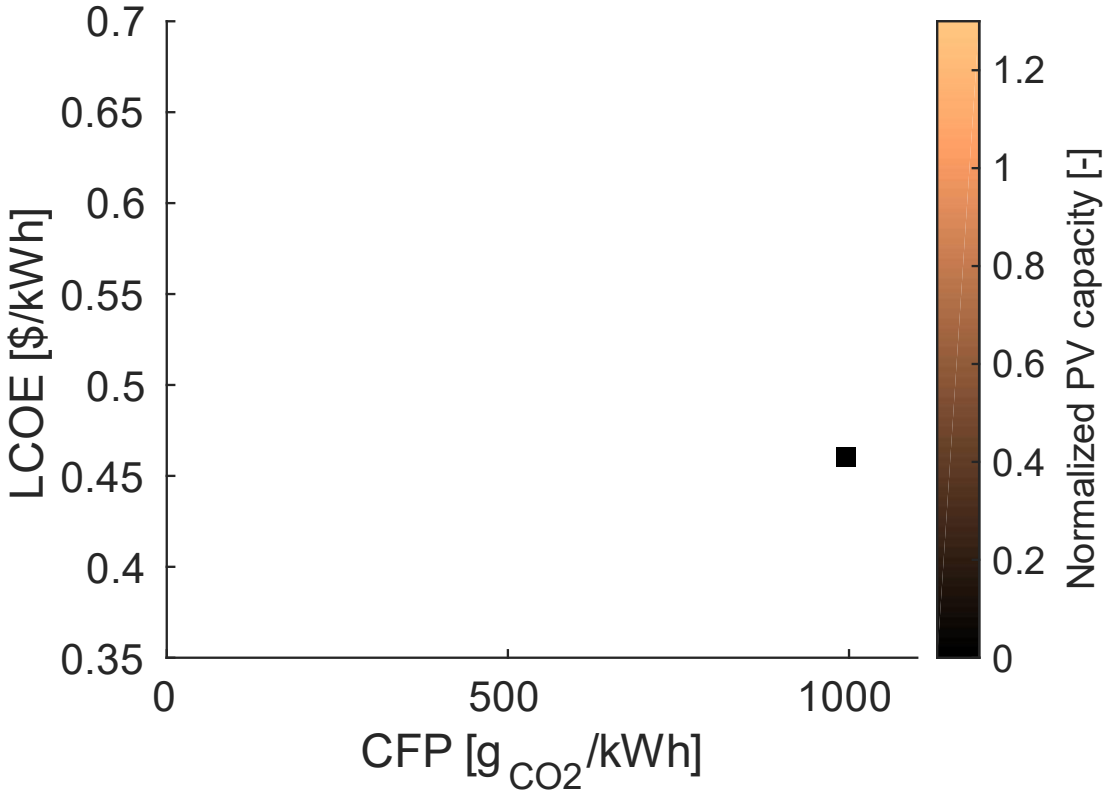
$$CFP = \frac{K_{PV}\alpha_{PV} + K_{bat}\alpha_{bat} + K_{gen}\alpha_{gen} + Fuel_{conso}\alpha_{fuel}}{Supplied\ energy}$$

And similar for the LCOE

Sizing MG with the LCOE and the CFP

Genset





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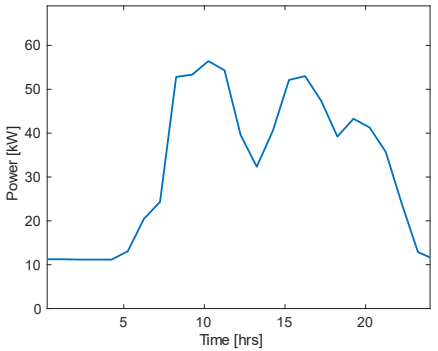

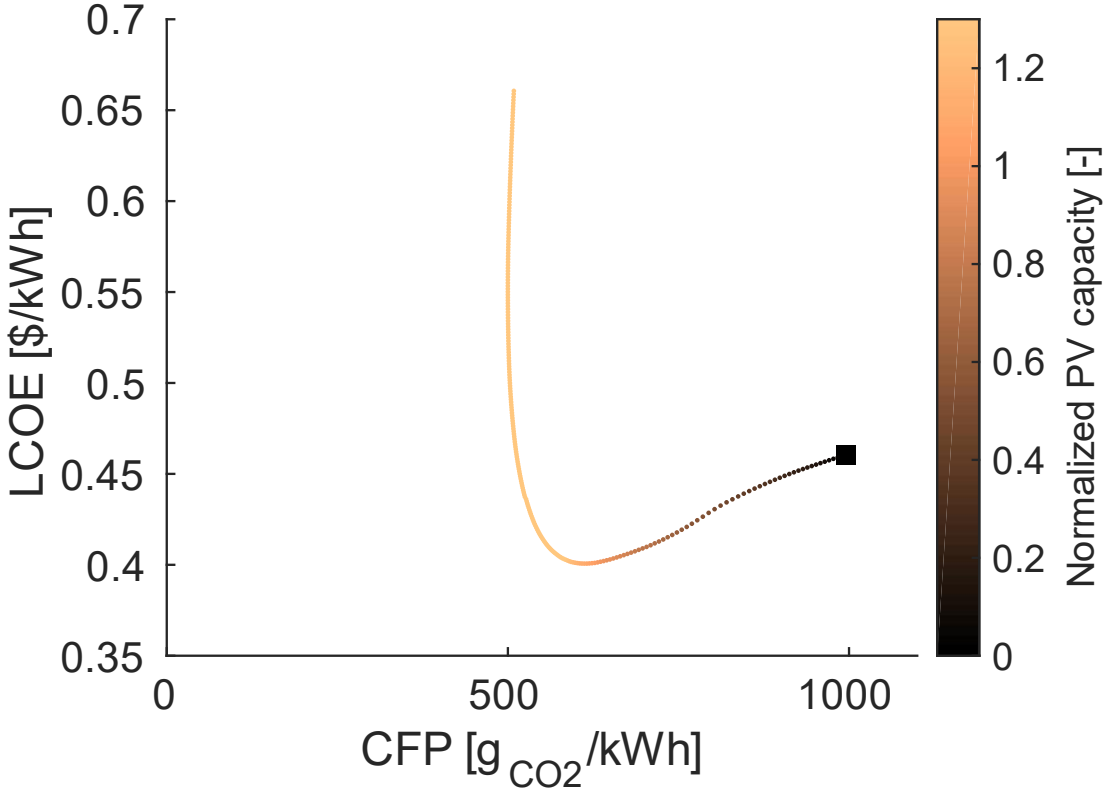

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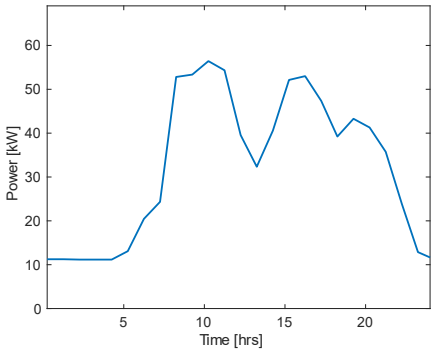
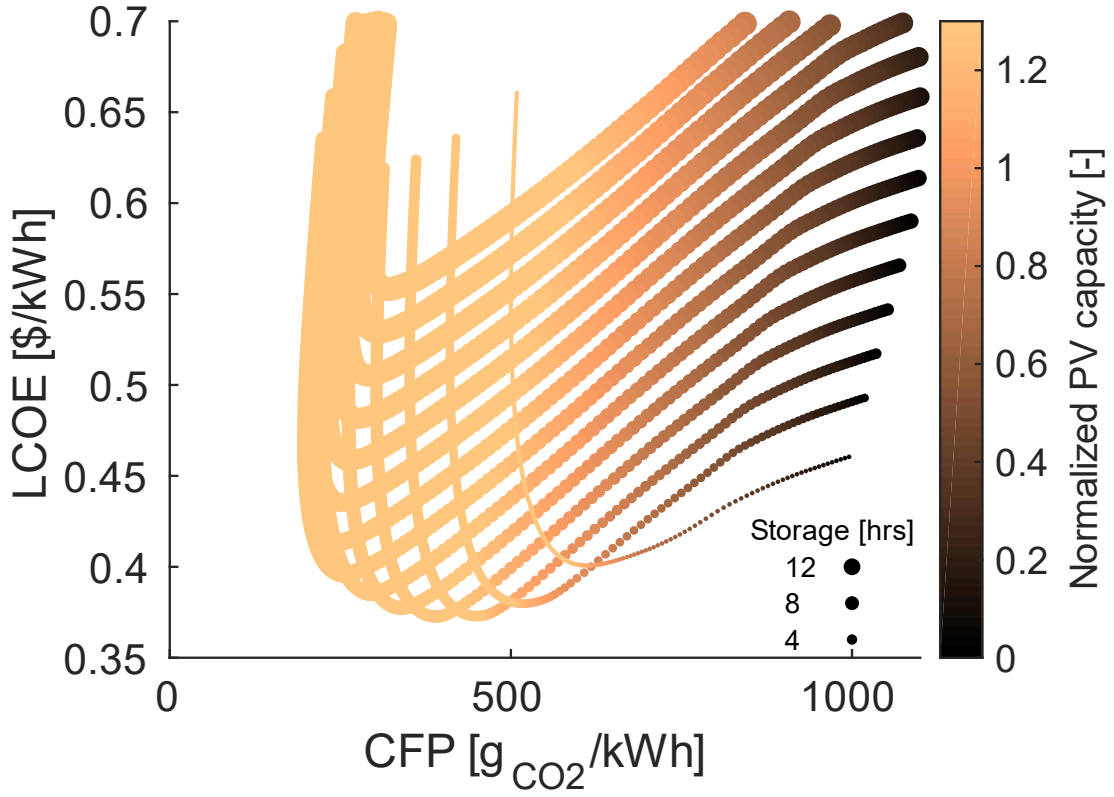
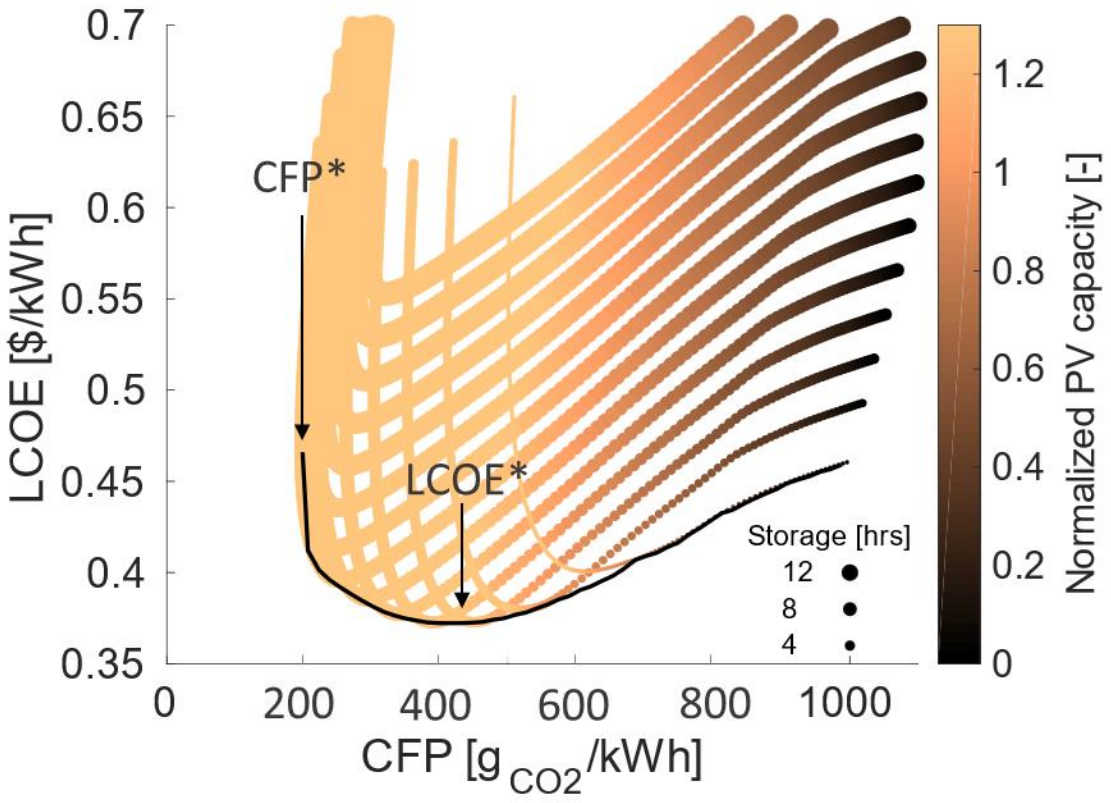




Sizing MG with the LCOE and the CFP

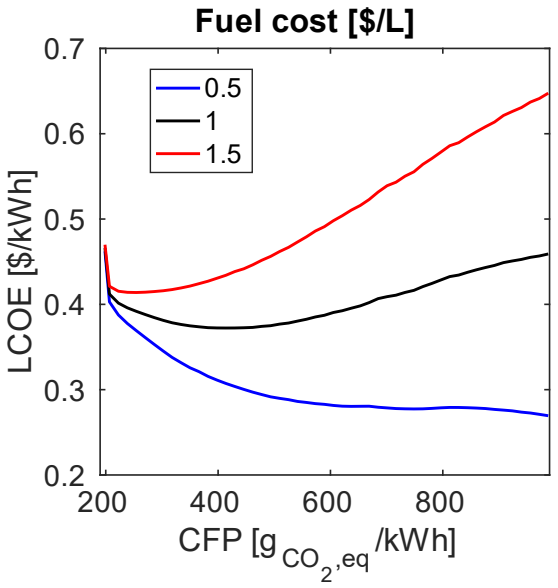
Let's focus on these two optimums (CFP* and LCOE*) and this *envelope* curve !

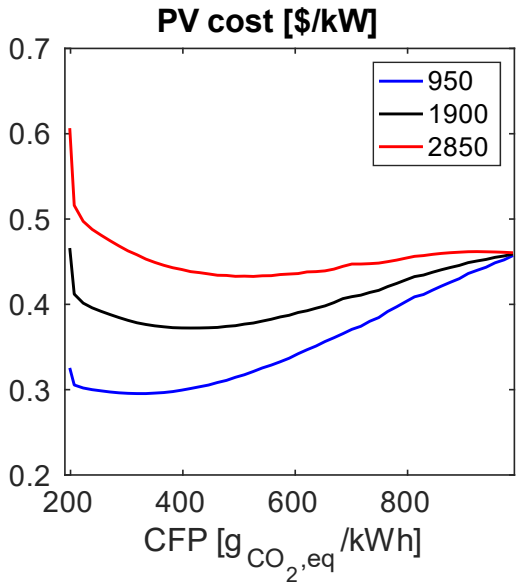


Sensitivity of the results

These curves depends on a lot of factors :

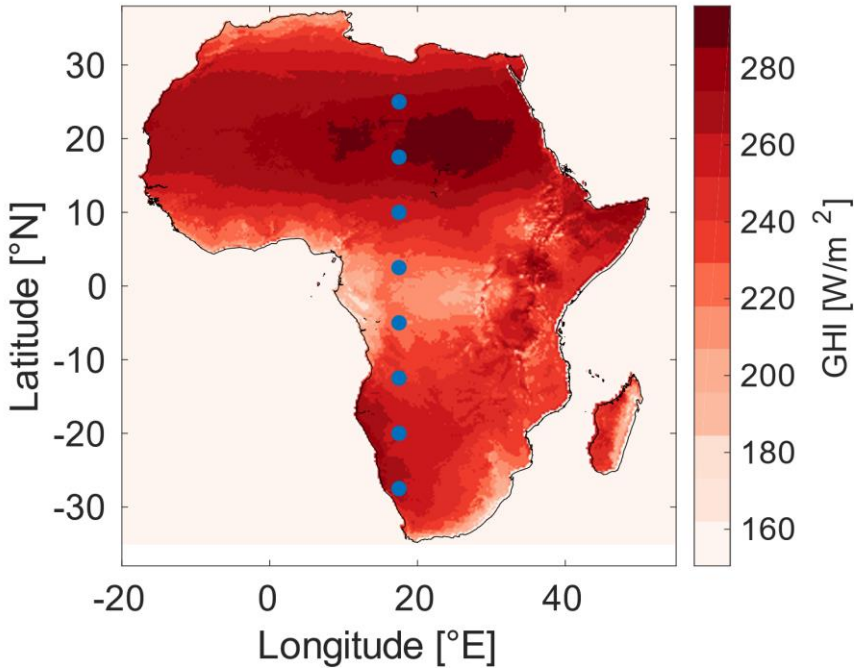
- Costs
- CFP of components
- Lifetimes
- Demand profile
- Solar resource

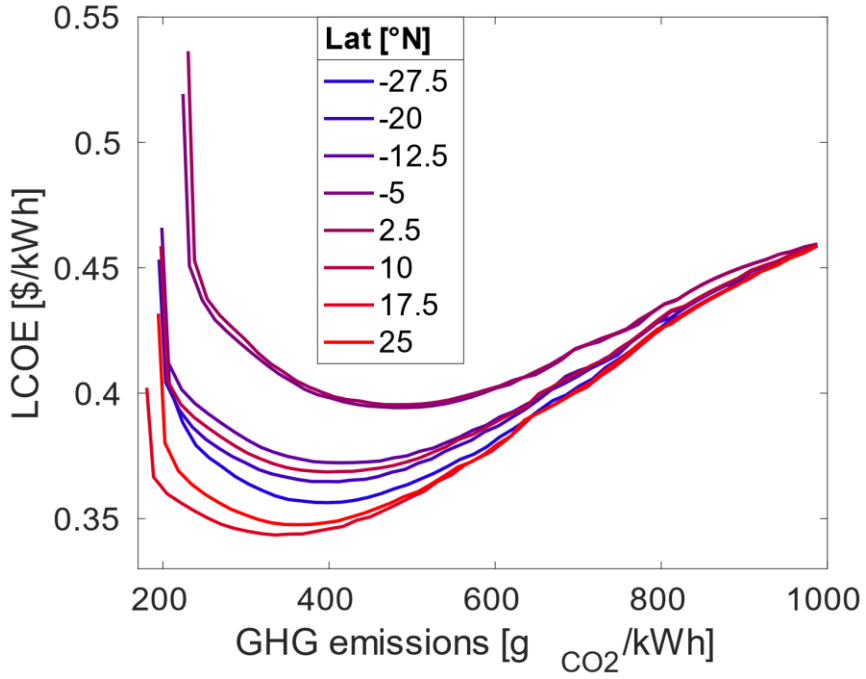




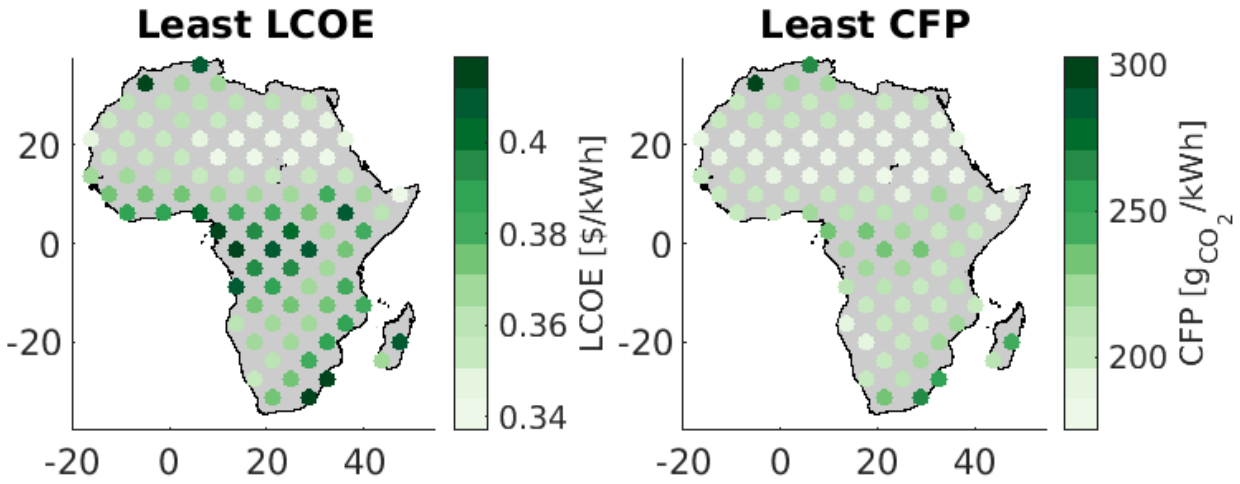
Sensitivity of the results

- For this presentation, focus on the effect of the solar resource





Spatial variability of the optimums



$0{,}34\$/kWh$ < LCOE* < $0{,}45\$/kWh$

$180 g_{CO_2,eq}/kWh$ < CFP* < $300 g_{CO_2,eq}/kWh$

Same geographical pattern for the LCOE* and CFP* values

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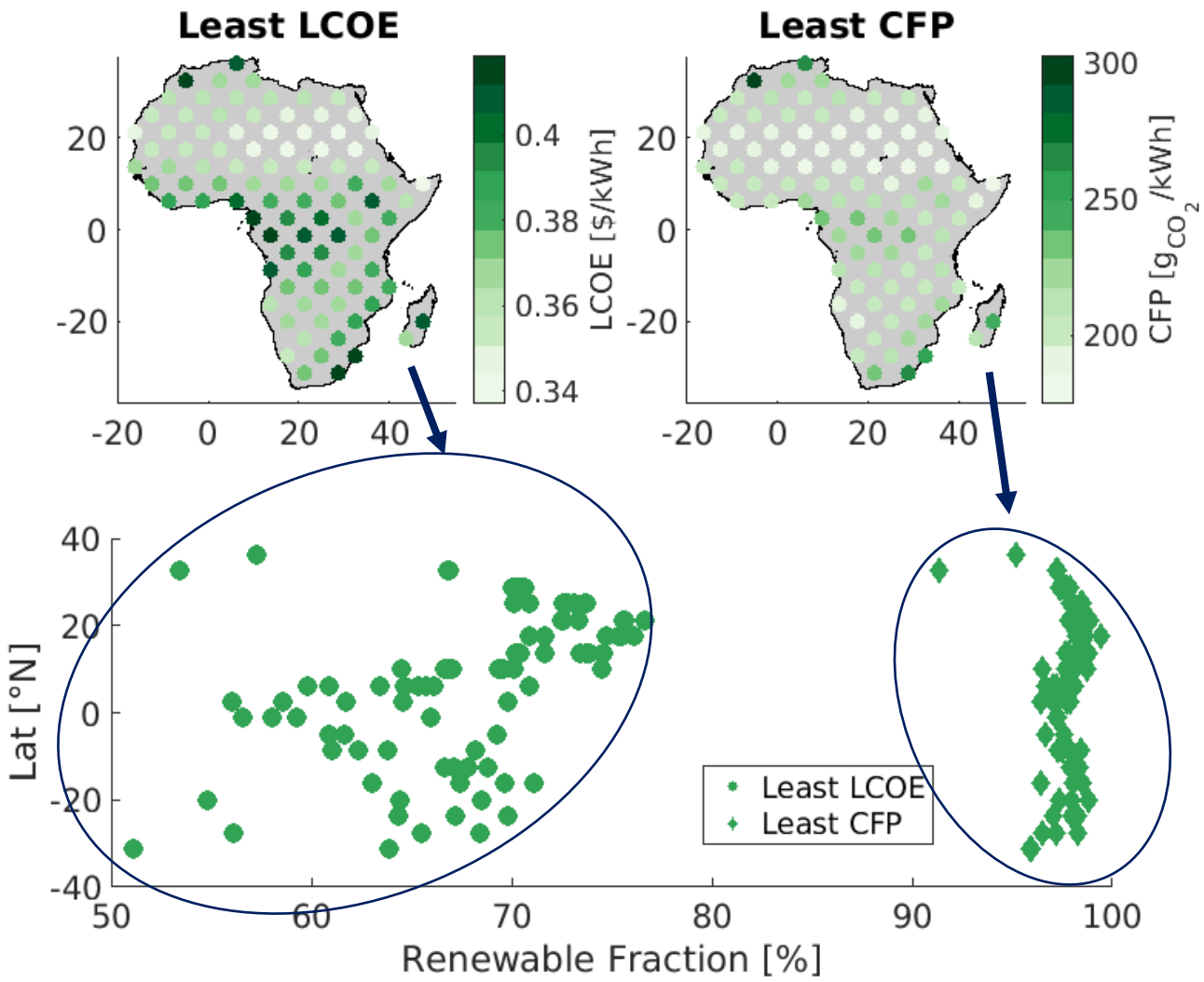

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Same geographical pattern for the LCOE* and CFP* values

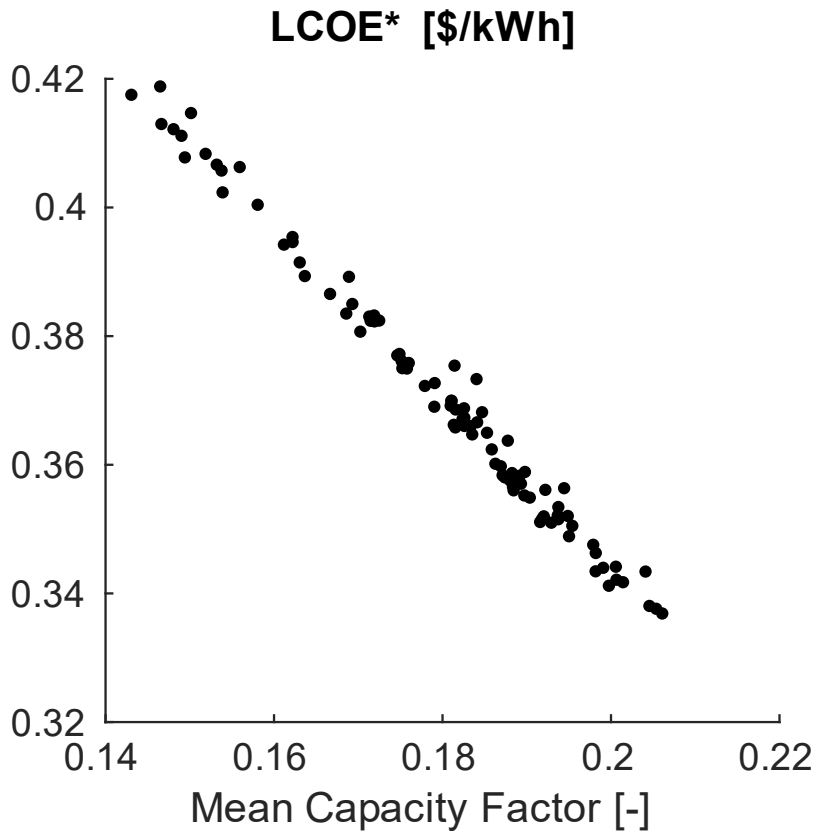
Renewable fraction :

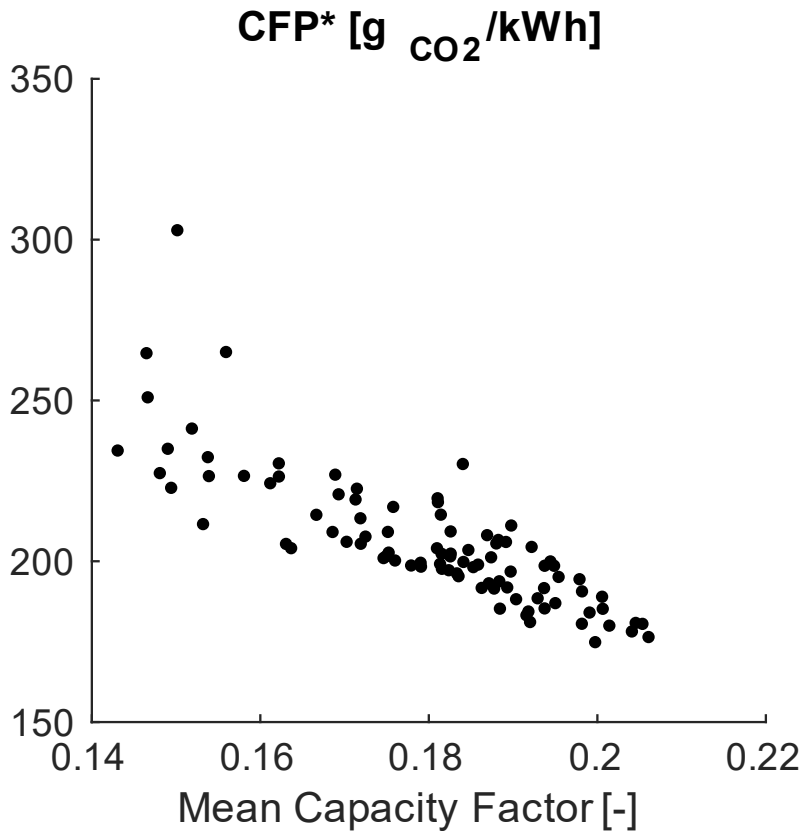
LCOE* between 50% and 80%

CFP* higher than 95%

Depency to the resource characteristics

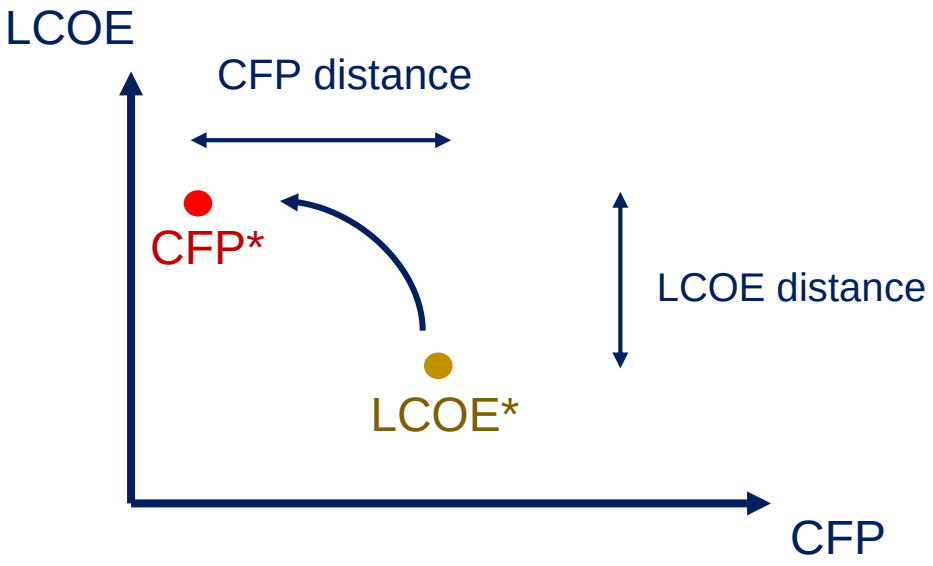
- LCOE* and CFP * values highly depends on the mean capacity factor





The variability of the resource has also an impact, especially on the CFP* values

Distance between the optimums



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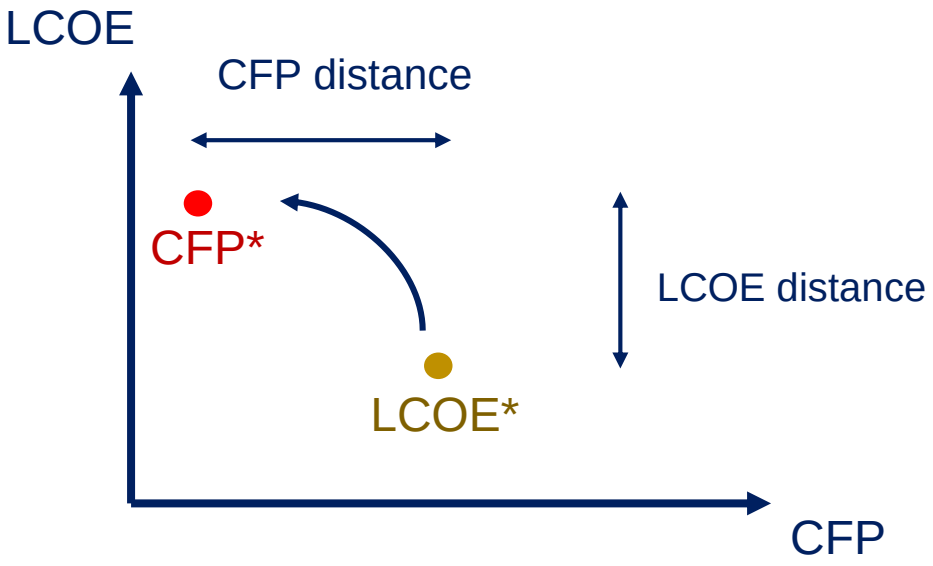
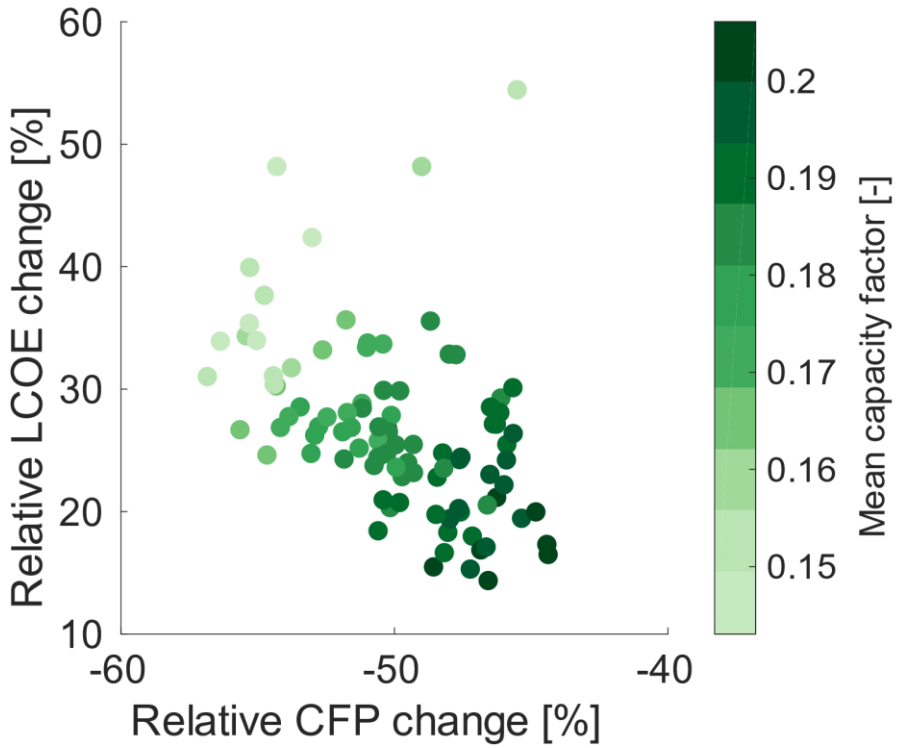
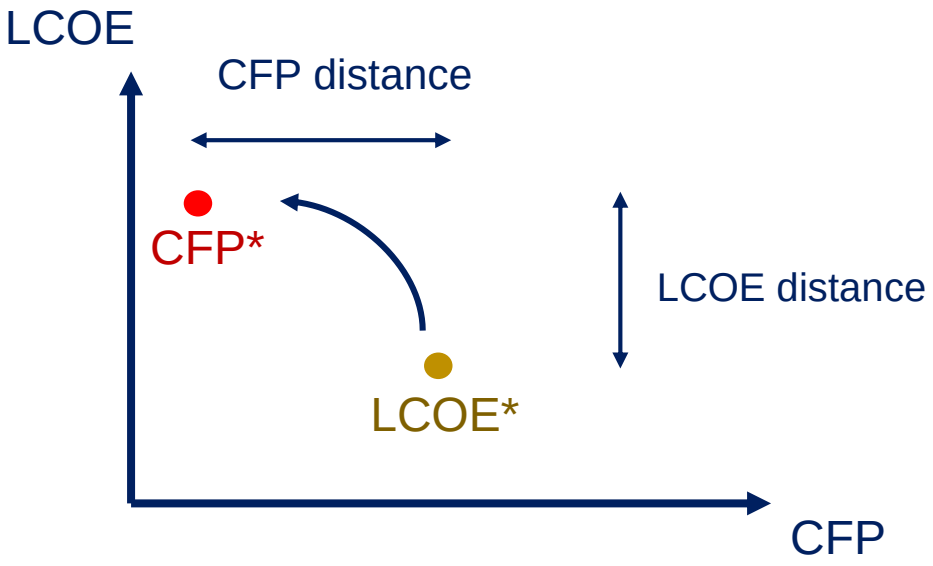
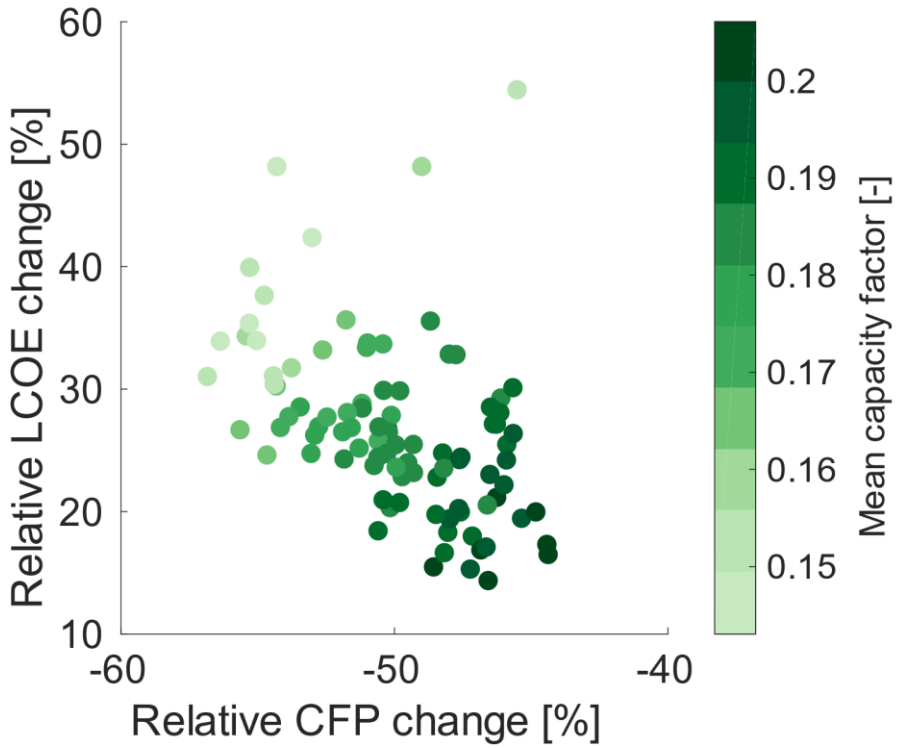




- The characteristics of the solar resource also influence the distance between LCOE* and CFP* values

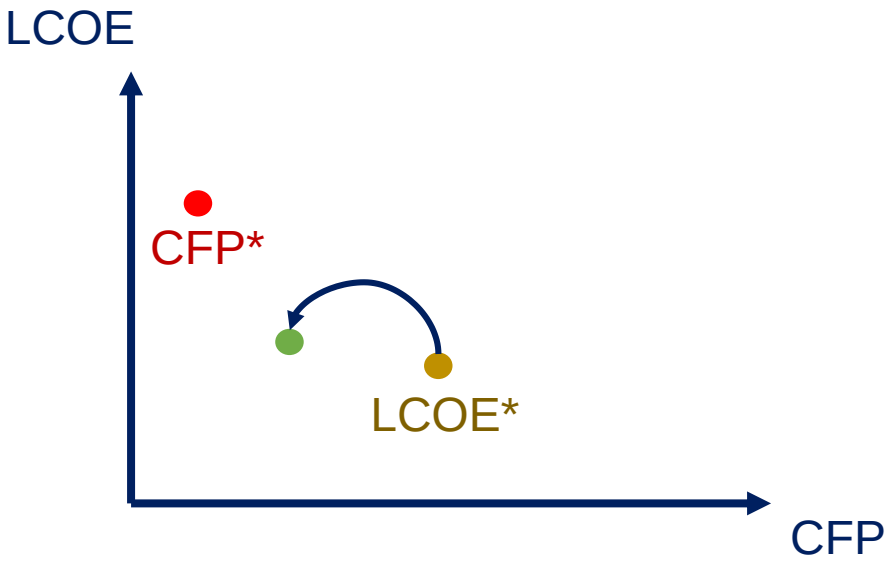
Distance between the optimums





- The characteristics of the solar resource also influence the distance between LCOE* and CFP* values
- Going from the LCOE* to the CFP* configuration requires a relatively high cost increase …

Compromises between LCOE and CFP



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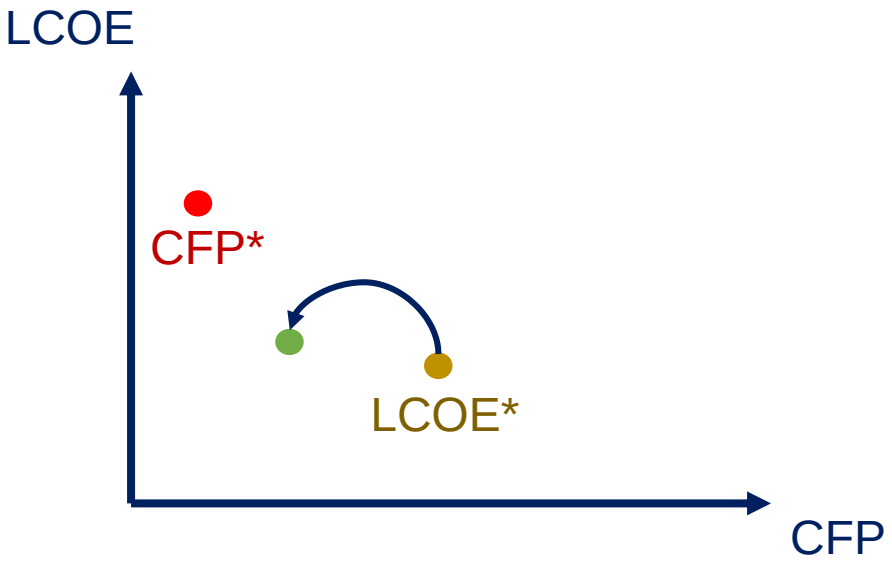

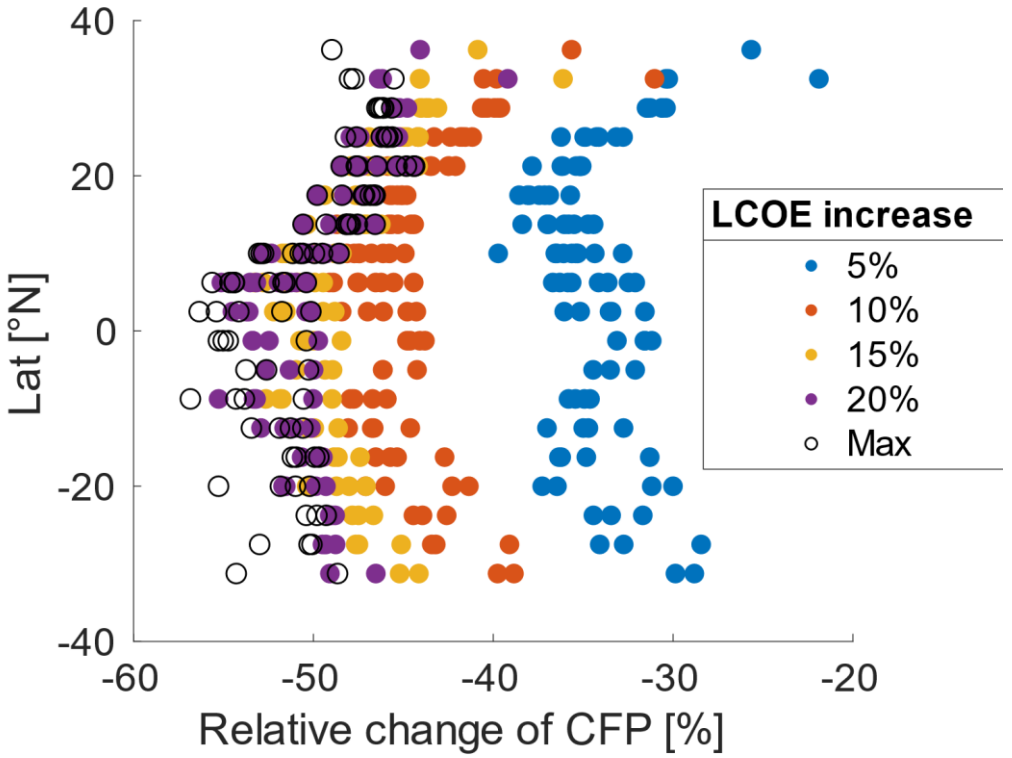

But significant CFP reduction can be obtained with moderate additional costs !

Effect of a shadow carbon pricing

Add a virtual surcharge to the price of carbon emissive projects :

$$Project\ costs_{\ with\ emissions} = Project\ costs_{\ without\ emissions} + Carbon\ emissions * SPC$$

SPC : Shadow price of carbon

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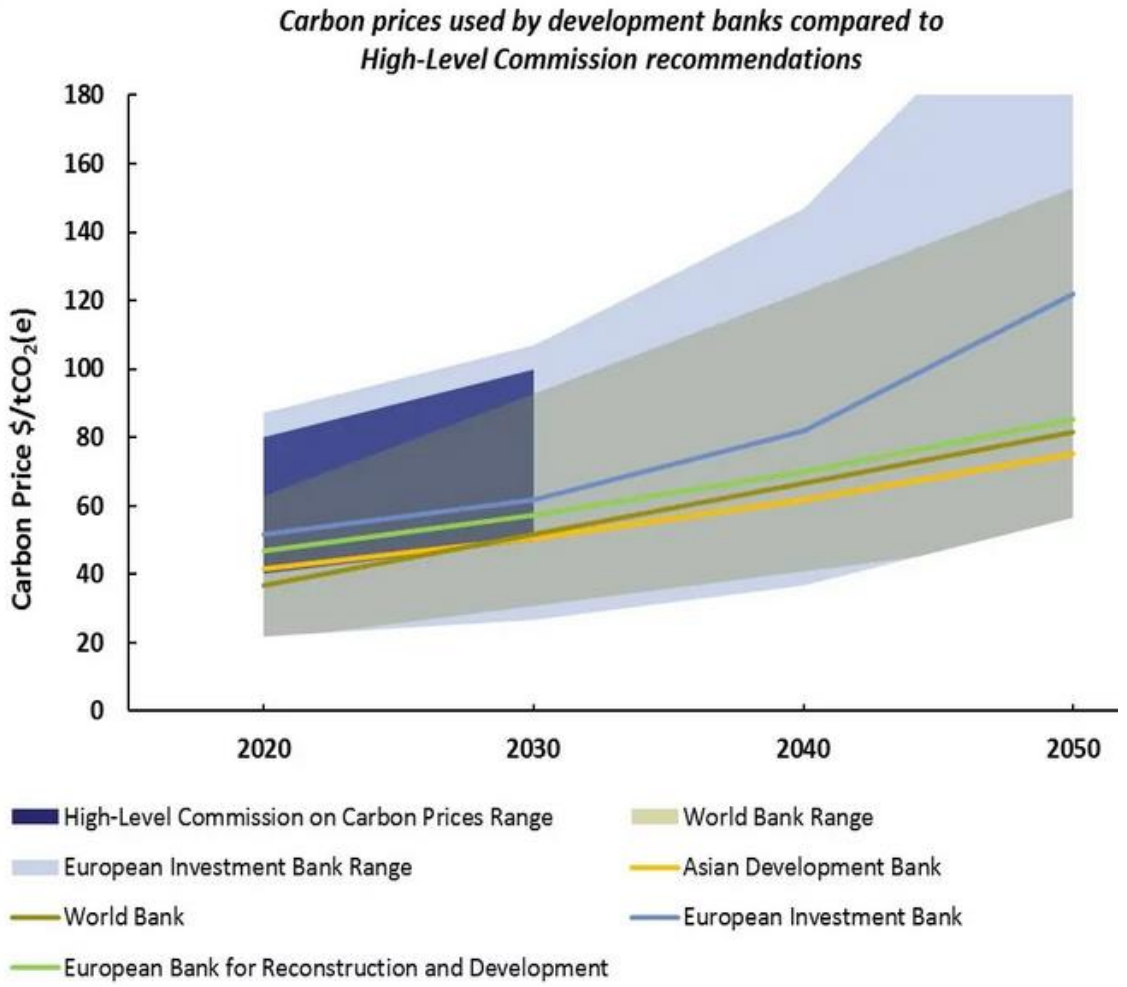

Sources: EBRD (2014), World Bank (2015), HLCCP (2017), EIB (2015), ASDB (2017), All in 2016 prices, adjusted for inflation and EBRD and EIB prices have been converted from EUR to USD using OECD conversion rates.

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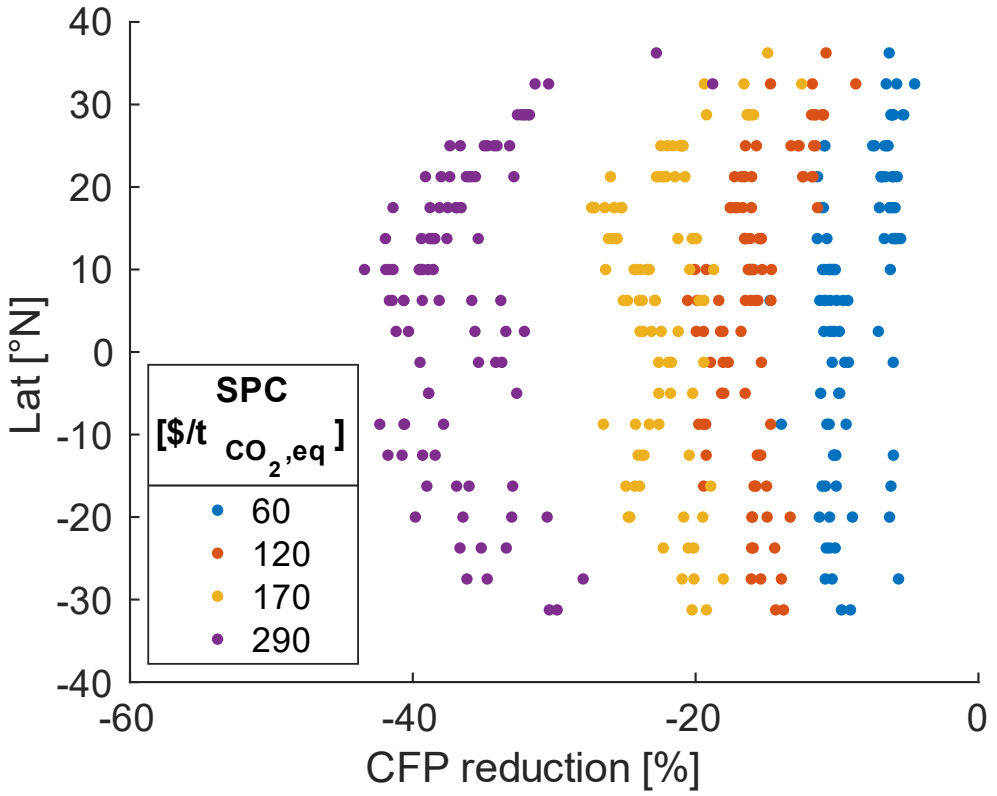
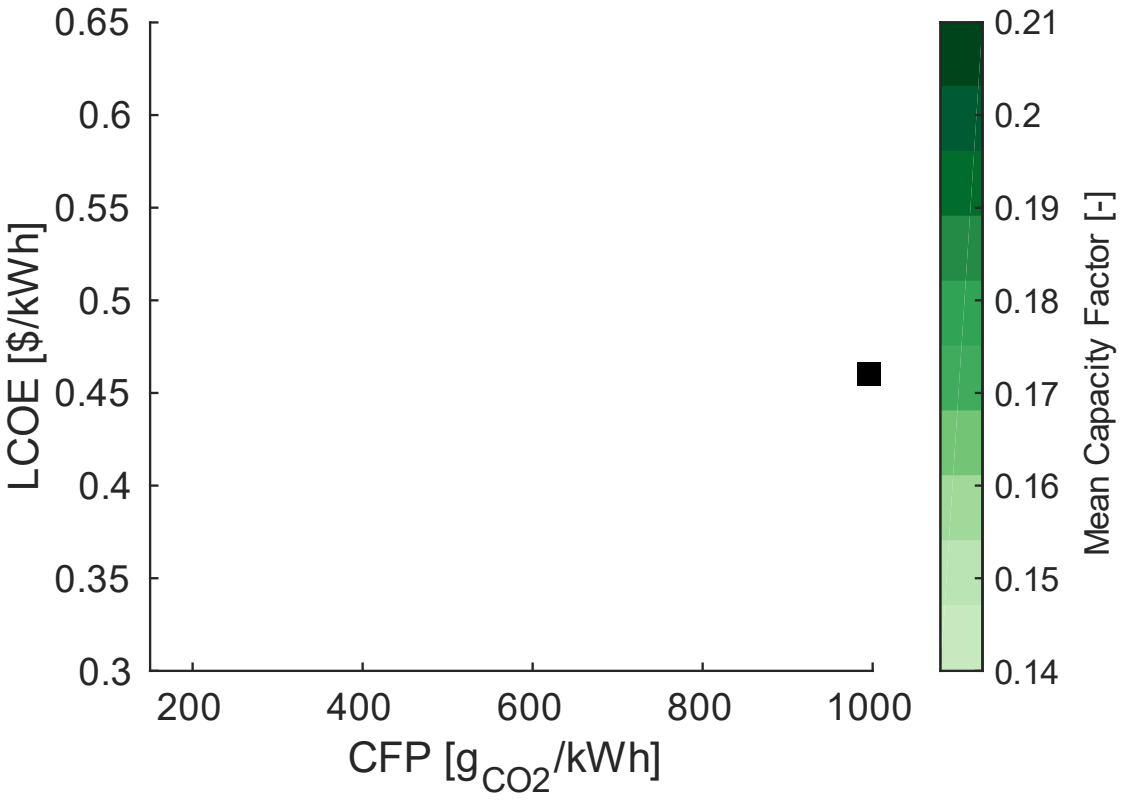
The IPCC (AR6 WG III) estimated the following value for 2030 to limit global warming to :

- 1.5°C between 60 and 120 $\$/t_{CO_2,eq}$
- 2°C between 170 and 290 $\$/t_{CO_2,eq}$



To summarize …



- Many mini-grids currently installed are running on diesel

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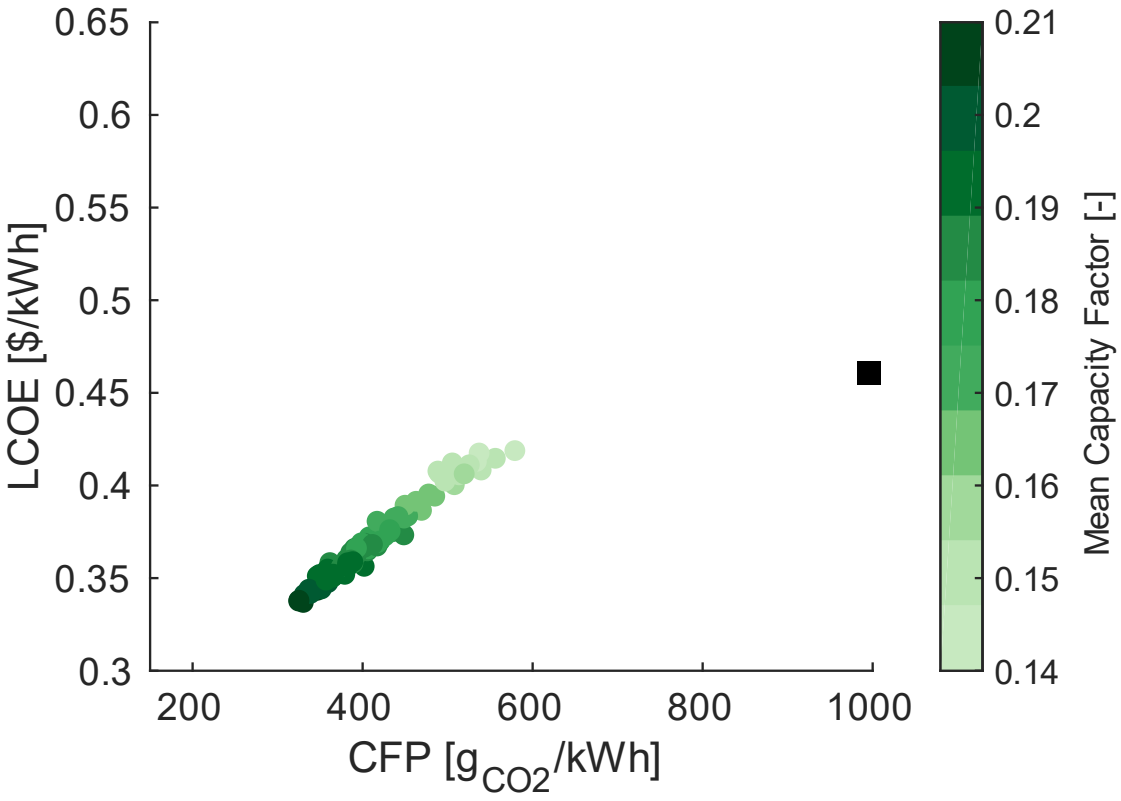

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- Integrating solar energy and batteries would allow to reduce by 45 to 70% the CFP and 5 to 25% the LCOE

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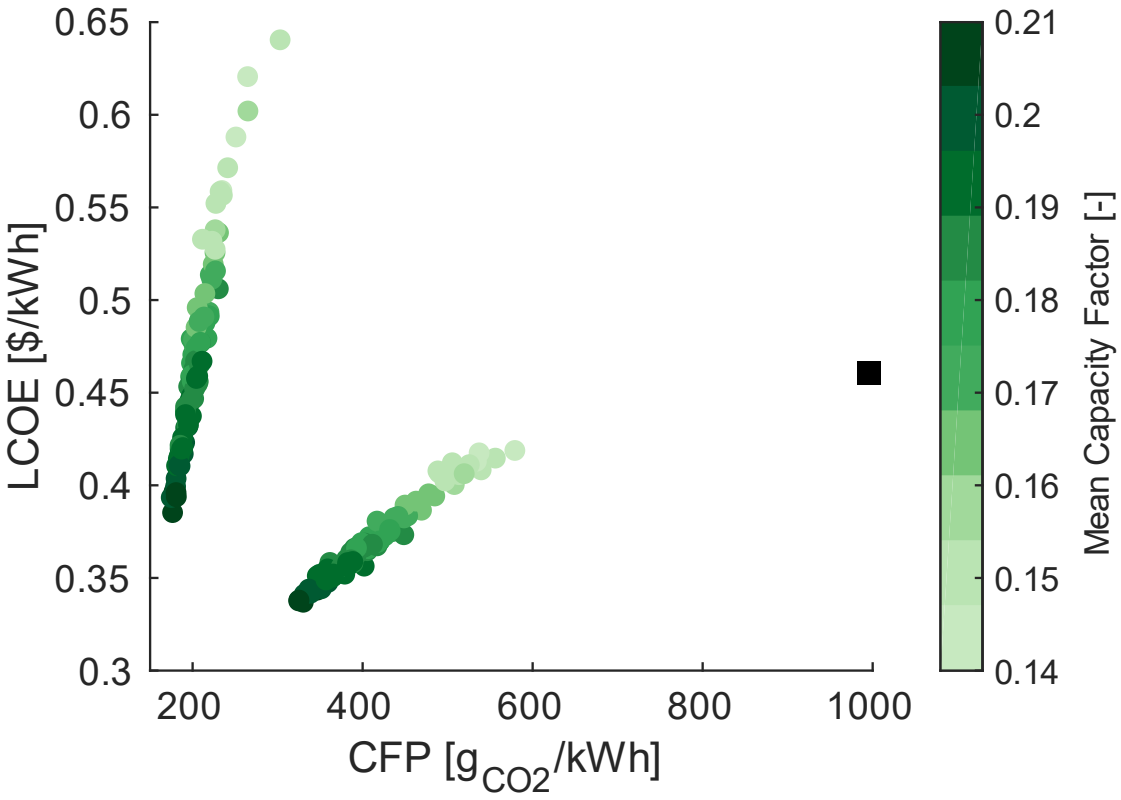

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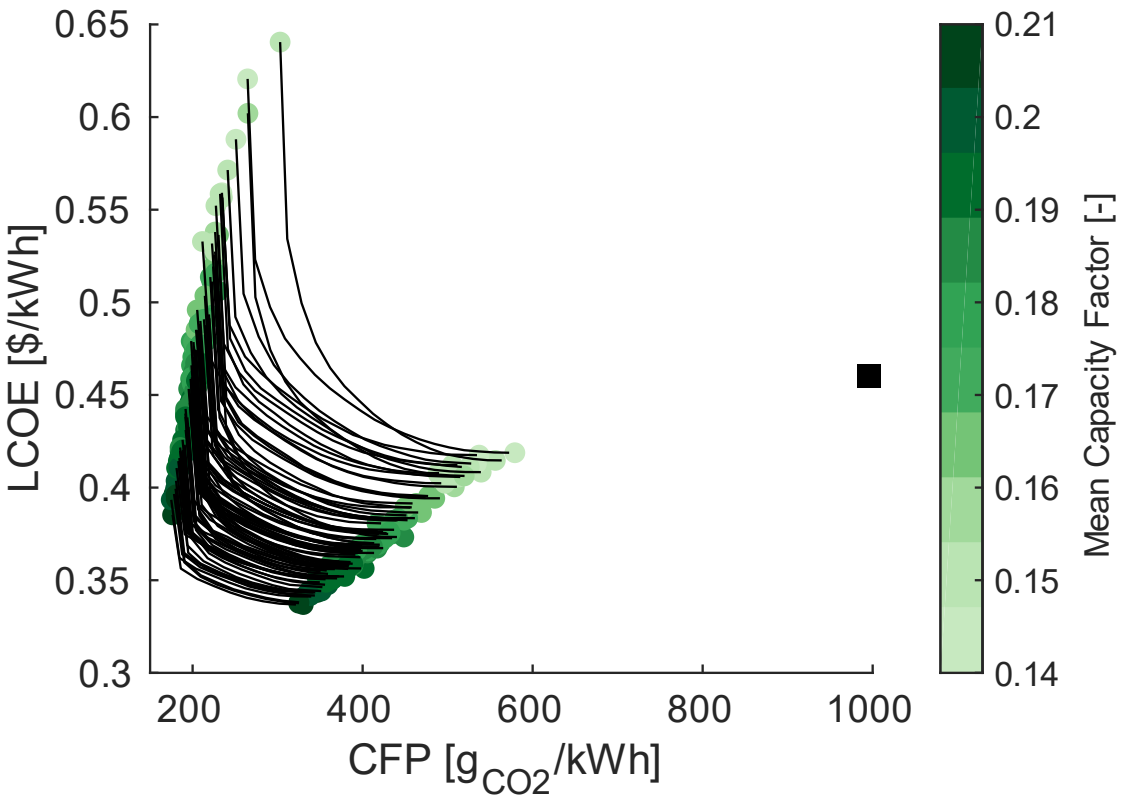

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- Integrating solar energy and batteries would allow to reduce by 45 to 70% the CFP and 5 to 25% the LCOE
- Reduce the CFP of MG to its lowest values (around $200 g_{CO_2,eq}/kWh$) is possible but can strongly increase the LCOE
- But many compromises exist between the optimums and allow to significantly reduce the CFP with moderate additional costs

Thanks for your attention !

Contact : theo.chamarande@univ-grenoble-alpes.fr