This is the first and only homework: H1

It consists of two items (two videos).

Item 1: Solve the attached “Problem on Allocation in a Cogeneration Facility”, hand write the solution on paper with as much detail as you feel necessary. But do not submit it. Instead, make a max-5-min video to illustrate it and comment your results.

Item 2: Make another max-5-min video in which using the following slides (the same I used in class) you explain (like I did in class) the allocation problem and methods that address the need to identify the renewable fraction of the power produced in a hybrid fossil-renewable facility.

If the topic is of some interest to you, the next slide lists some additional references you might find useful. To be clear: none of that is necessary at all for the homework!

G.P. Beretta, P. Iora, and A.F. Ghoniem
Novel approach for fair allocation of primary energy consumption among cogenerated energy-intensive products based on the actual local-area production scenario
Energy: the International Journal, Vol. 44, pp. 1107-1120 (2012).
https://dx.doi.org/10.1016/j.energy.2012.04.047

G.P. Beretta, P. Iora, and A.F. Ghoniem
Allocating electricity production from a hybrid fossil-renewable power plant among its multi primary resources
Energy: the International Journal, Vol. 60, pp. 344-360 (2013).
https://dx.doi.org/10.1016/j.energy.2013.07.047

P. Iora, A.F. Ghoniem, and G.P. Beretta
What fraction of the fuel consumed by a heat-and-power cogeneration facility should be allocated to the heat produced? Old problem, novel approach
Proceedings of the ASME 2013 International Mechanical Engineering Congress and Exposition IMECE2013, November 15-21, 2013, San Diego, California, Proc. ASME 56284, Vol. 6A: Energy, V06AT07A037, ISBN: 978-0-7918-5628-4, paper IMECE2013-66705,
https://dx.doi.org/10.1115/IMECE2013-66705

G.P. Beretta, P. Iora, and A.F. Ghoniem
Allocating resources and products in multi-hybrid multi-cogeneration: What fractions of heat and power are renewable in hybrid fossil-solar CHP?
Energy: the International Journal, Vol. 78, pp. 587-603 (2014).
https://dx.doi.org/10.1016/j.energy.2014.10.046

P. Iora, A.F. Ghoniem, and G.P. Beretta
What fraction of the electrical energy produced in a hybrid fossil-solar power plant should qualify as 'renewable electricity'?
Proceedings of the ASME 2013 International Mechanical Engineering Congress and Exposition IMECE2013, November 15-21, 2013, San Diego, California, Proc. ASME 56284, Vol. 6A: Energy, V06AT07A045, ISBN 978-079185628-4, paper IMECE2013-66706,
https://dx.doi.org/10.1115/IMECE2013-66706

P. Iora, G.P. Beretta, and A.F. Ghoniem
Exergy loss-based allocation method for hybrid renewable-fossil power plants applied to an integrated solar combined cycle
Energy: the International Journal, Vol. 173, 893-901 (2019).
https://dx.doi.org/10.1016/j.energy.2019.02.095

What fraction of the electrical energy produced in a hybrid solar-fossil power plant should qualify as 'renewable electricity'?

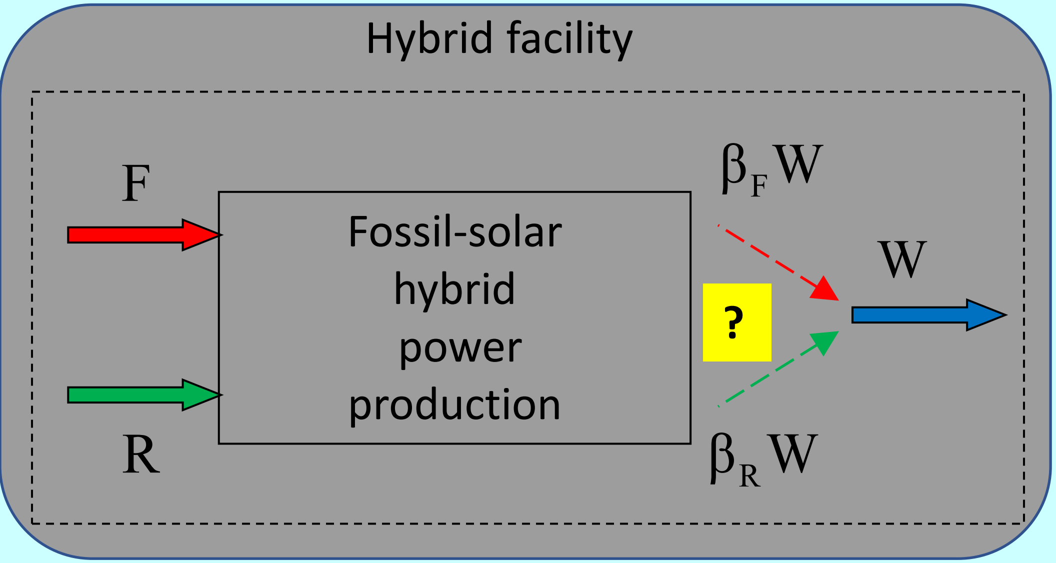
Why is it important?

The question is important because several government programs (in the United States and in most other countries) provide economic incentives* for the production of electricity from solar, wind, and other renewable energy sources. In "hybrid facilities" where these renewable sources are combined/integrated with fossil fuels, the access to these incentives depends on how much of the produced electricity is recognized as renewable.

It is also relevant for multi-fuel power plants or hybrid CHP facilities.

*Examples:
Investment tax credits
Production tax credits
Accelerated depreciation
Cash grants
Loan programs
Grants and loan guarantees to agricultural producers and rural small businesses
Renewable energy tax-credit bonds

Allocation problem in Hybrid Facilities: β_F, β_Q, partial efficiencies, and PES



Partial Efficiencies

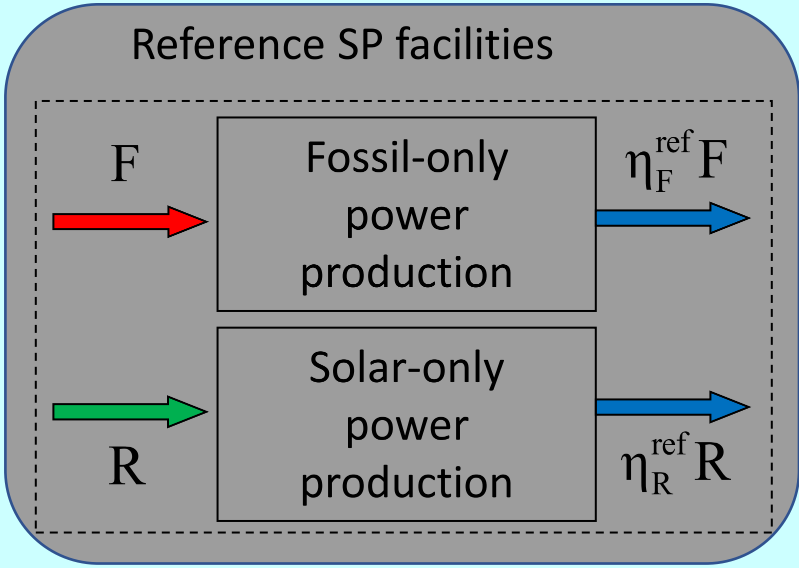
$$\eta_F^{hyb} = \frac{\beta_F W}{F}$$

$$\eta_R^{hyb} = \frac{\beta_R W}{R}$$

Primary Energy Savings vs SP facilities

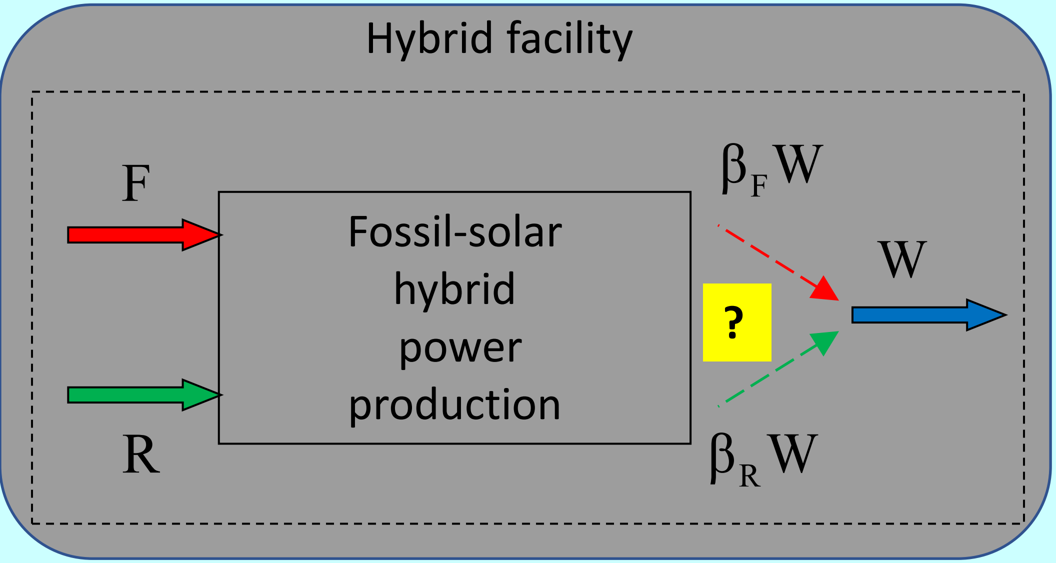
$$PES_F = \frac{\beta_F W - \eta_F^{ref} F}{\beta_F W}$$

$$PES_R = \frac{\beta_R W - \eta_R^{ref} R}{\beta_R W}$$



$$PES = \frac{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref} - F - R}{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref}} = \frac{\beta_F W/\eta_F^{ref}}{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref}} PES_F + \frac{\beta_R W/\eta_R^{ref}}{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref}} PES_R$$

Allocation problem in Hybrid Facilities: β_F, β_Q, partial efficiencies, and PES



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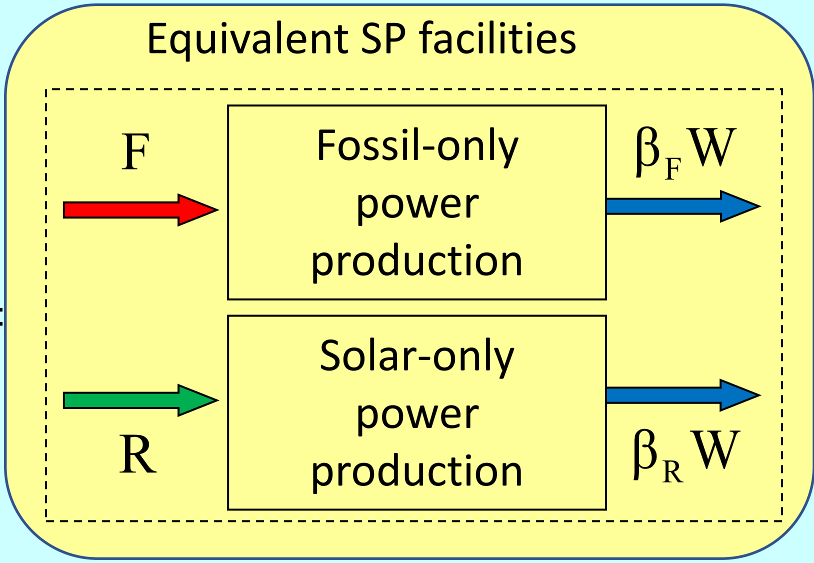
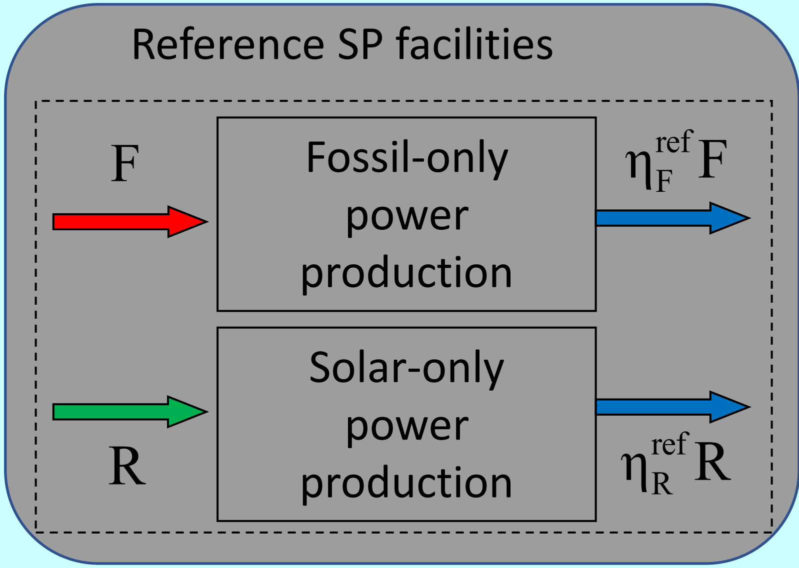




Partial Efficiencies

$$\eta_F^{hyb} = \frac{\beta_F W}{F}$$

$$\eta_R^{hyb} = \frac{\beta_R W}{R}$$

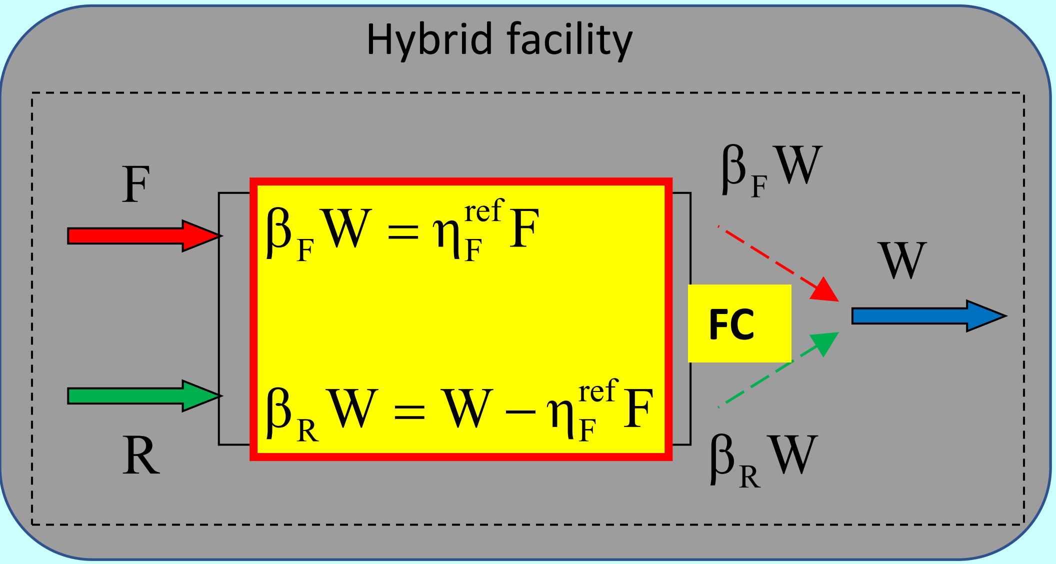
Primary Energy Savings vs SP facilities

$$PES_F = \frac{\beta_F W - \eta_F^{ref} F}{\beta_F W}$$

$$PES_R = \frac{\beta_R W - \eta_R^{ref} R}{\beta_R W}$$

$$PES = \frac{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref} - F - R}{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref}} = \frac{\beta_F W/\eta_F^{ref}}{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref}} PES_F + \frac{\beta_R W/\eta_R^{ref}}{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref}} PES_R$$

Allocation problem in Hybrid Facilities: **Incremental Fossil-Centered Allocation**



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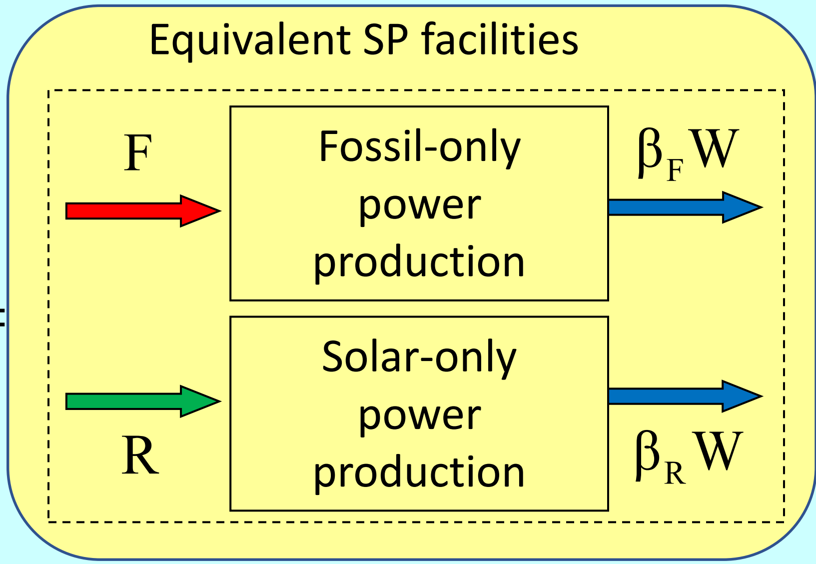


Partial Efficiencies

$$\eta_F^{hyb} = \eta_F^{ref}$$

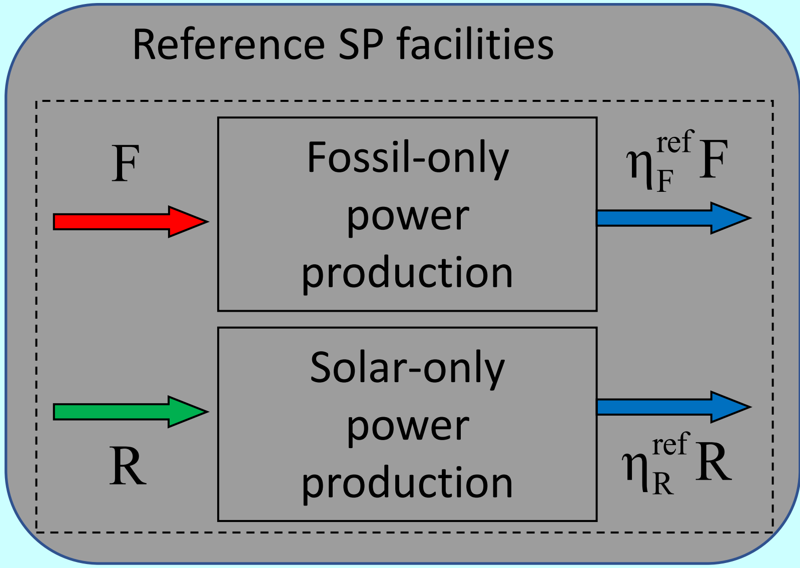
$$\eta_R^{hyb} = \frac{W - \eta_F^{ref} F}{R}$$

Primary Energy Savings vs SP facilities

$$PES_F = 0$$

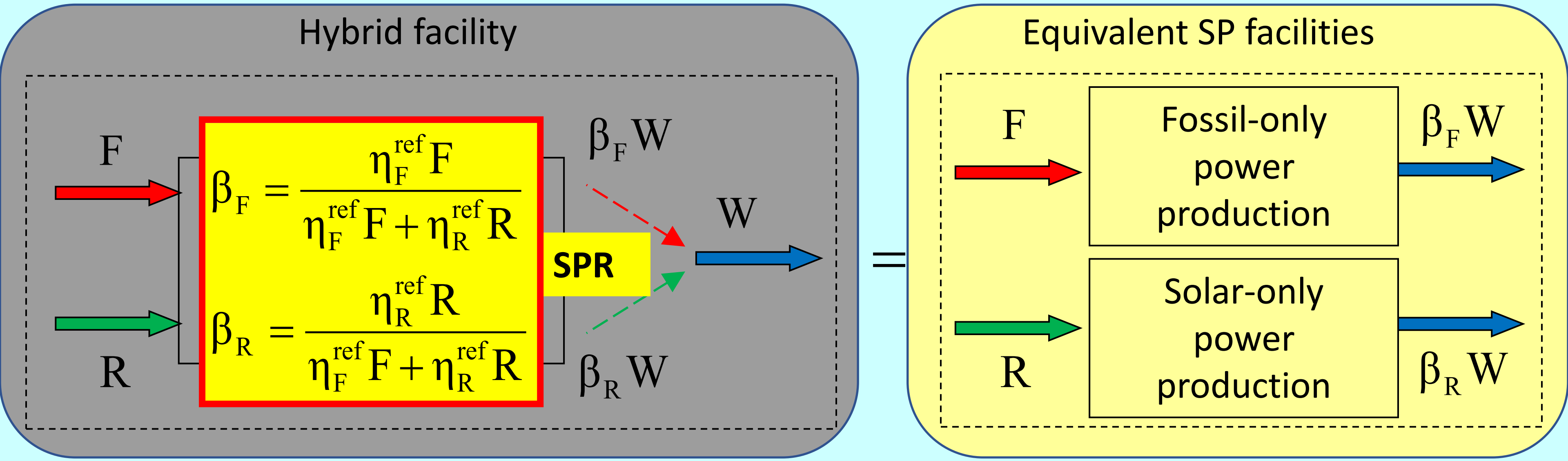
$$PES_R = \frac{W - \eta_F^{ref} F - \eta_R^{ref} R}{W - \eta_F^{ref} F}$$

$$PES_R = \left(1 + \frac{\eta_R^{ref} F}{\beta_R W}\right) PES > PES\,!$$



No allottment of the benefits of hybridization between F and R!

Allocation problem in Hybrid Facilities: Separate Production Reference Allocation



Partial Efficiencies

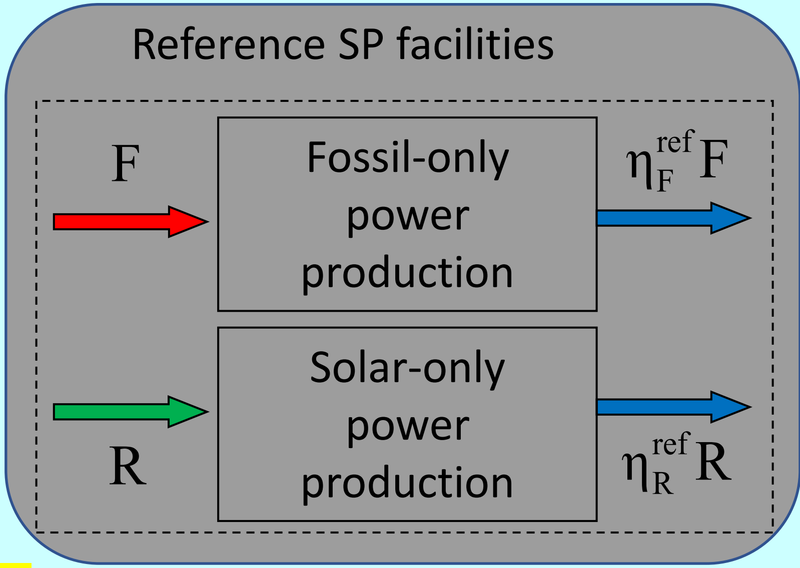
$$\eta_F^{hyb} = \frac{\beta_F W}{F}$$

$$\eta_R^{hyb} = \frac{\beta_R W}{R}$$

Primary Energy Savings vs SP facilities

$$PES_F = \frac{\beta_F W - \eta_F^{ref} F}{\beta_F W}$$

$$PES_R = \frac{\beta_R W - \eta_R^{ref} R}{\beta_R W}$$



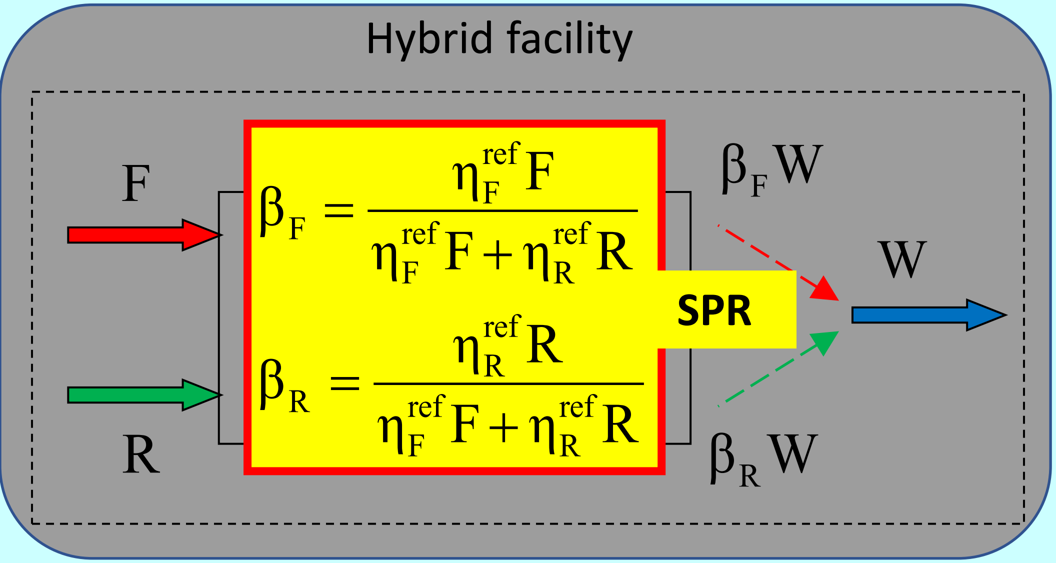
$$PES = \frac{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref} - F - R}{\beta_F W/\eta_F^{ref} + \beta_R W/\eta_R^{ref}} = PES_F = PES_R$$

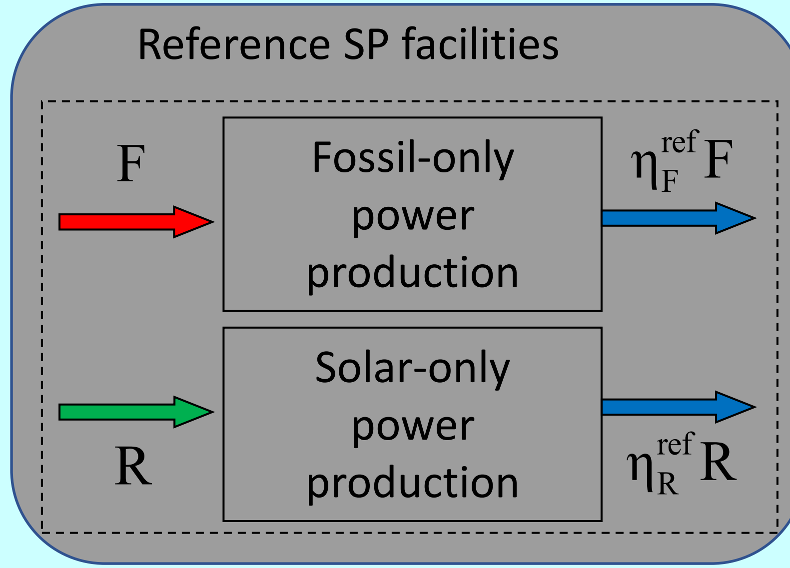
Allottment of the hybridization benefits between F and R is fair only for fair reference values...!!

Choice of reference values η_F^{ref} a η_R^{ref}.

SPR method:

Fixed values set by some <u>local Authority</u>





Exergy method:

Fixed values set by <u>Thermodynamics</u>

Effectively takes as references the REVERSIBLE heat engines!

$$\eta_F^{ref} \approx 1 \qquad \eta_R^{ref} \approx 0.93$$

STALPR Method*: Self-Tuned-Average-Local-Productions-Reference

Adopt reference efficiencies

η_F^{ref} η_R^{ref}

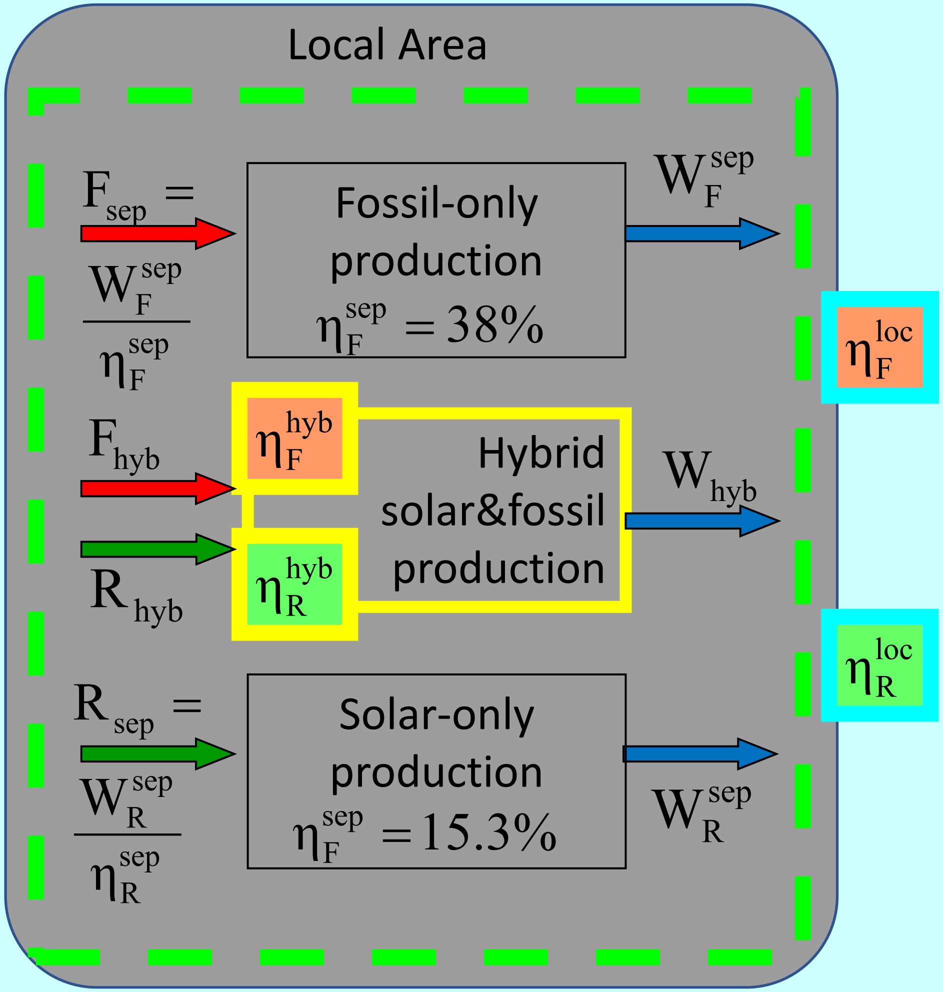
that are representative of the actual average efficiencies

η_F^{loc} η_R^{loc}

of the energy production portfolio (typically the local area where the hybrid plant itself is located) with which the resulting efficiencies of the hybrid plant

η_F^{hyb} η_R^{hyb}

are to be compared.



$$\eta_F^{loc} = \frac{W_F^{sep} + \beta_F W_{hyb}}{F_{sep} + F_{hyb}}$$

$$\eta_R^{loc} = \frac{W_R^{sep} + \beta_R W_{hyb}}{R_{sep} + R_{hyb}}$$

* G.P. Beretta, P. Iora, and A.F. Ghoniem, Energy, Vol. 60, pp. 344-360 (2013)