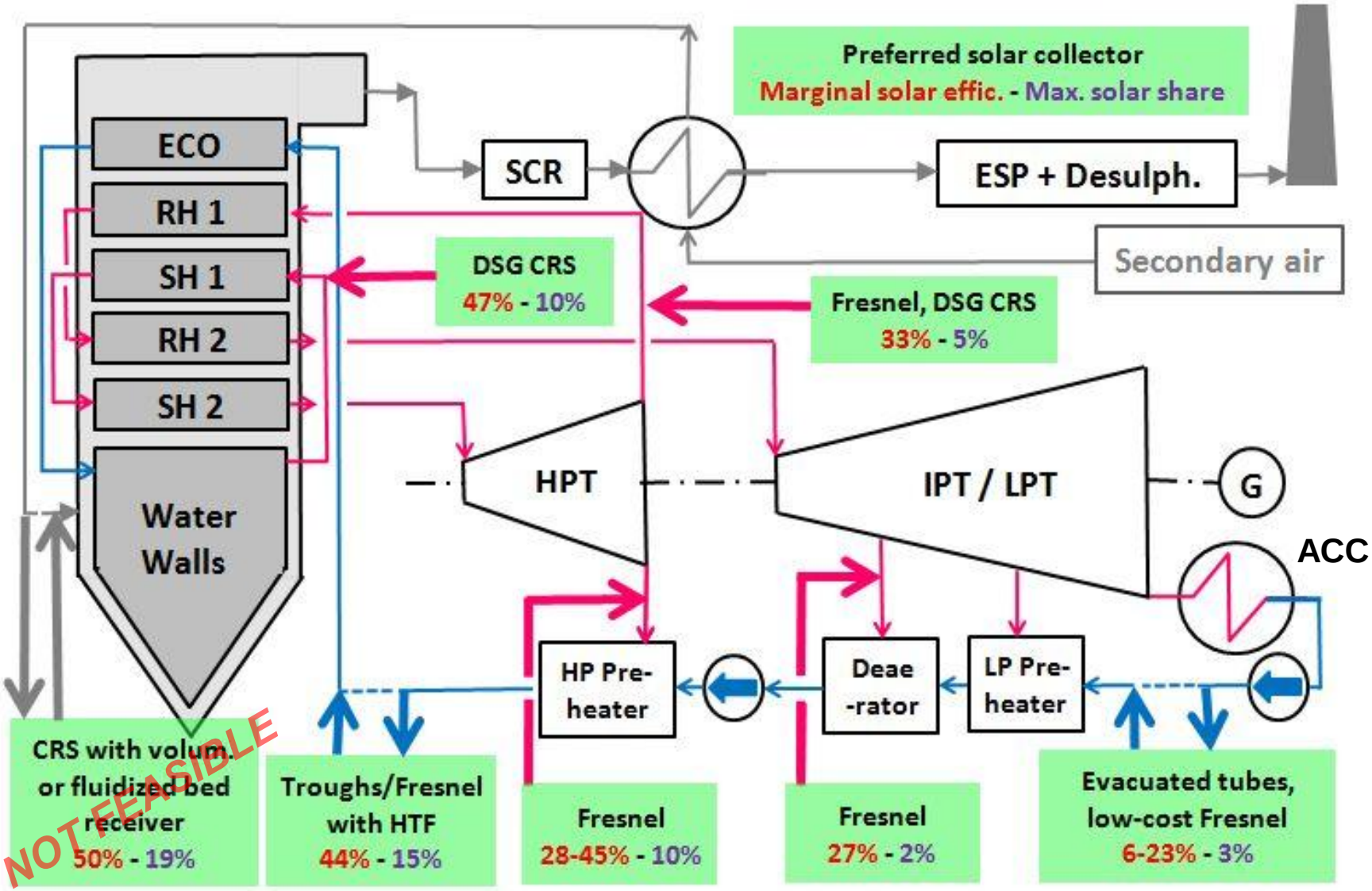
Hybridization of thermal plants is a great driver to increase the CSP share in the global energy mix

- Merits of the concept
  - Lower (~x1.8) LCOE than that of stand-alone CSP plants - Can compete with PV
  - Many developing countries will build CSP and coal plants, or already operate coal plants
  - Solar hybridization of coal plants converted into biomass plants is also possible
- Coal plants in operation or construction: solar boost through FW preheating
  - Liddell (3 MW_e / 500 MW_e unit), Kogan Creek (44 MW_e / 750 MW_e unit - 2013)
- Upcoming projects of hybridized coal plants: other hybridization modes
  - Mejillones (5 MW_{th} / 150 MW_e unit): solar boost with SH steam into cold reheat pipe
  - Bitola (Macedonia): coal saving with additional feedwater preheating after top preheater
- The future: increasing the solar share - How?
  - Combining various modes of solar heat injection into the plant process
  - Designing a Greenfield hybrid solar-coal plant: high efficiency of a modern, supercritical plant and optimal integration of the solar heat input into the process

Options for injecting solar heat into the process

Case study: pulverized coal supercritical plant, 600°C/290 bar – 620°C/55 bar



Economics

Why is the solar electricity from a hybridized coal plant almost twice cheaper than that provided by a stand-alone CSP plant?

Even taking into account a somewhat lower DNI

- Economic synergies
  - Little extra cost apart from the solar field (< half of the total cost of a CSP plant)
- Thermodynamic synergy
  - Some hybridization modes make better use of medium-grade heat (e.g. saturated steam) than a stand-alone CSP plant:
  - Excess of high-grade heat in the boiler → mid-T° heat addition welcomed
  - Some bleedings extract highly superheated steam from the turbine with poor use of the sensible heat – Saturated solar steam is good enough for this purpose

Merit-order of the hybridization modes studied

Project-specific constraints may have an impact on the merit-order

1. Solar preheating of HP feedwater - *Boost* - Top preheater ranks first
2. Additional solar preheating of feedwater – *Coal saving*
3. Solar preheating of LP feedwater - *Boost* - Especially deaerator
4. Solar production of HP/IP steam – *Coal saving*

Challenges – Technical hurdles

- Practical relevance of directly circulating water/steam through the solar field should be checked (water quality is crucial with once-through boilers)
- For solar production of main steam or IP steam, imbalances between the exchangers of the boiler puts a limit on the maximum solar share

  To be checked on a case-by-case basis with the boiler manufacturer
- Solar production of mid-T° main steam: too intrusive to be implemented in an existing plant