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Merging natural gas with solar power generation :

evaluating the potential of Integrated Solar Combined Cycle (ISCC)

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- Introduction to CSP technology
- Introduction to ISCC technology
- Study Objectives & Methods
- Performance & Economic Analysis
- Conclusions

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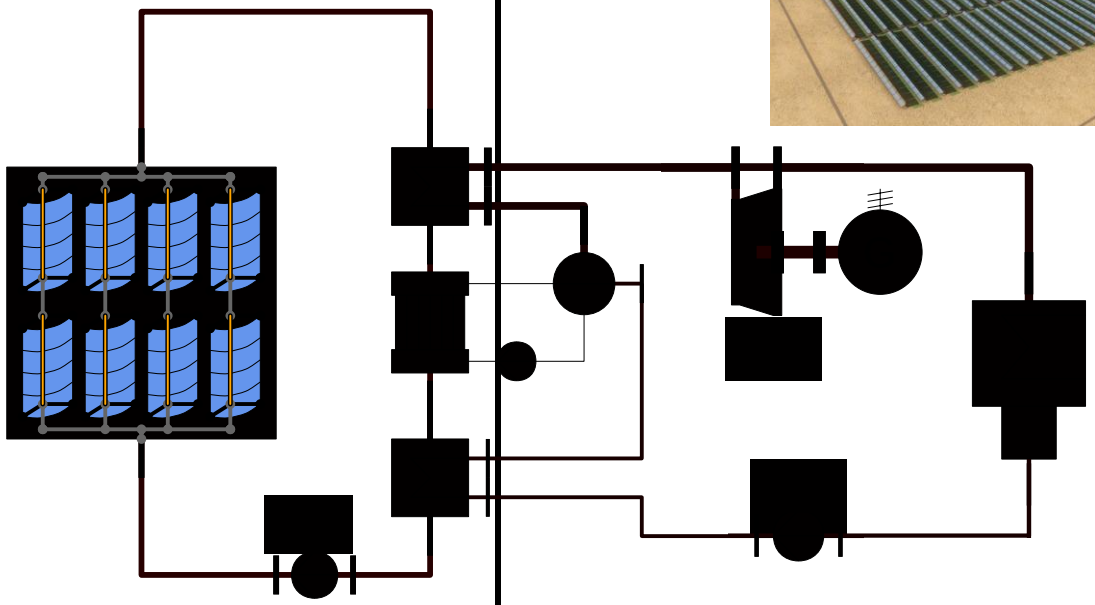
Introduction to CSP technology

CSP Technologies

Reflective Surface
Thermal Receiver

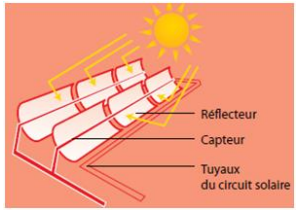
Power Block

Sun → Heat → Power

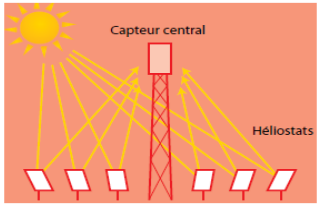


Solar Field ← → Power Block

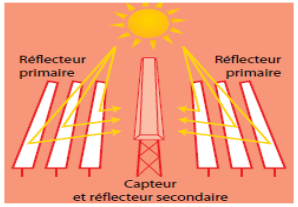
CSP Technologies



Parabolic Trough	
Temperature	390°C – 550°C
Power	1 - 250 MWe
η (yearly net solar to electric)	11%-16%
Heat Transfer Fluid	Diph.Biph.Oxide, Molten Salt



Tower	
Temperature	250°C – 1000°C
Power	1 -150 MWe
η (yearly net solar to electric)	12% -16%
Heat Transfer Fluid	Water, molten salt, air



Fresnel	
Temperature	250°C – 500°C
Power	1- 250 MWe
η (yearly net solar to electric)	8%-12%
Heat Transfer Fluid	Water

- CSP capacity in operation : 1.5 GWe
- CSP capacity planned in 2015 : > 15 GWe

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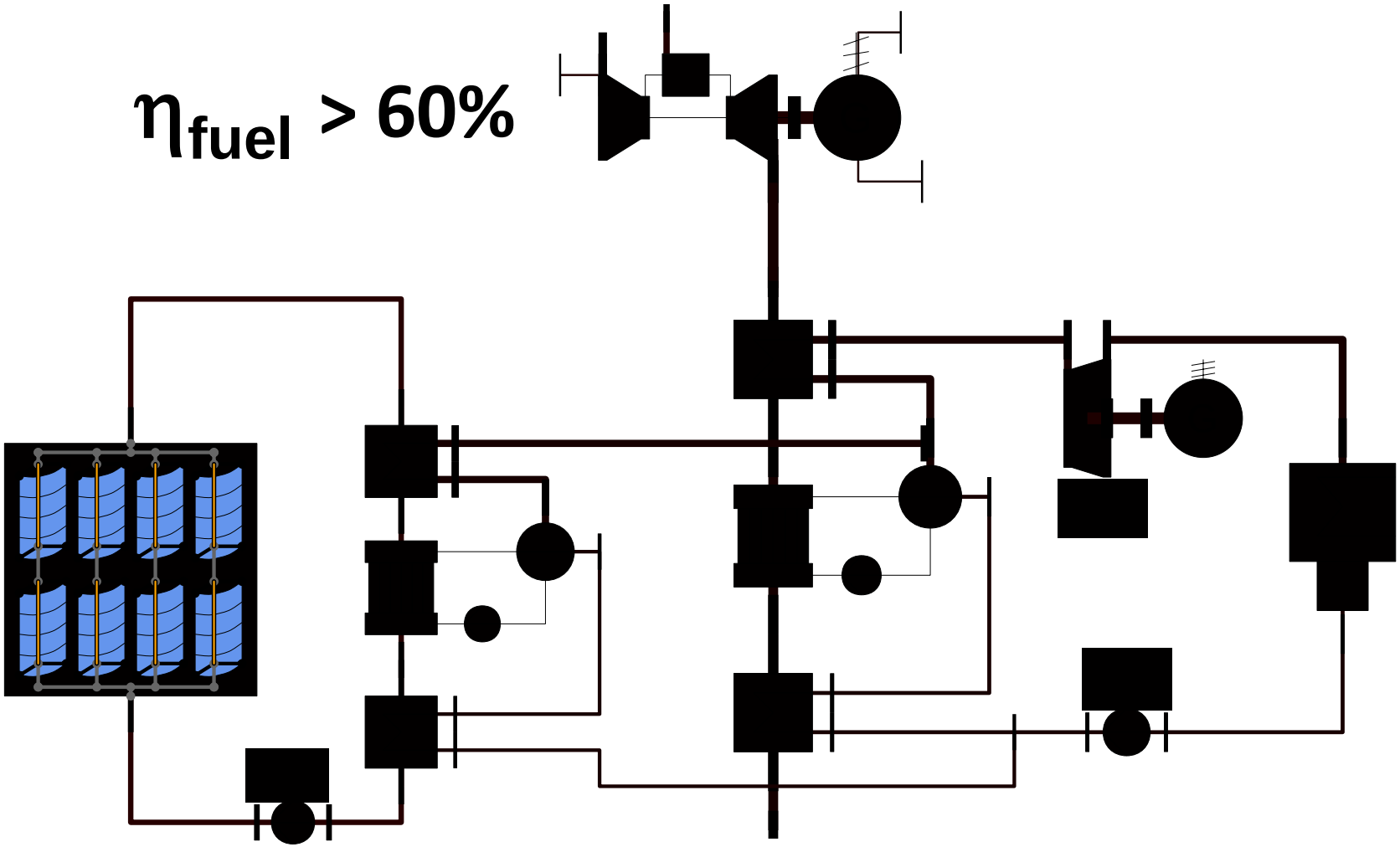
Introduction to ISCC technology

ISCC concept

Integrated Solar Combined Cycle

$\eta_{fuel} > 60\%$



ISCC : main projects

Data	Unit	ISCC Kuraymat	ISCC Ain Beni Mathar	ISCC Hassi R'Mel	ISCC Archimede
Nominal Capacity	MWe	125	470	150	750
GT	-	1 x GE 6FA	2 x Alstom GT13E2	2 x Siemens SGT800	2 x Siemens V94.3A
ST	-	1 x Siemens SST900	1 x 150 MW ST	1 x Siemens SST 900	2 x 125 MW ST
Solar Field Size	m^2	130,800	183,000	180,000	31,586
Solar contribution	MWe	22	20	20	5

And more :
- Martin NextGen (USA)
- Agua Prieta (Mexico)

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Study Objectives and Methods

Study Objectives and Methods

Objective : Identify and Quantify the attractiveness of the ISCC option versus having separate units CSP plant and CCGT plant

Criterion for analysis = levelized Cost Of Electricity **(COE)**

- **Step 1** : Evaluation of the COE of a **400-MWe class CCGT** and a **100 MWe CSP plant**
- **Step 2** : Selection of a ISCC technical architecture
- **Step 3** : Evaluation of the COE of an ISCC with 4 different given solar field sizes
- **Step 4**: Comparison between ISCC COE and the COE of a CCGT + a CSP plants **weighted by the solar share** of ISCC production

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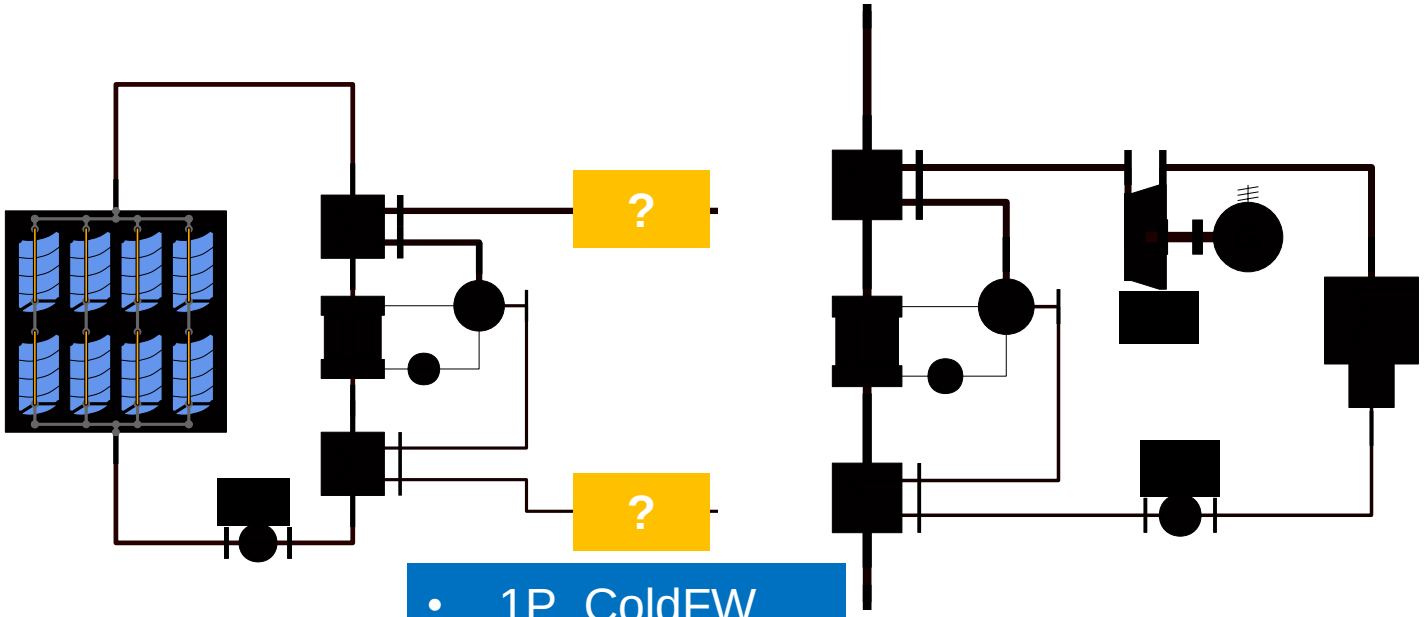
Performance and Economic Analysis

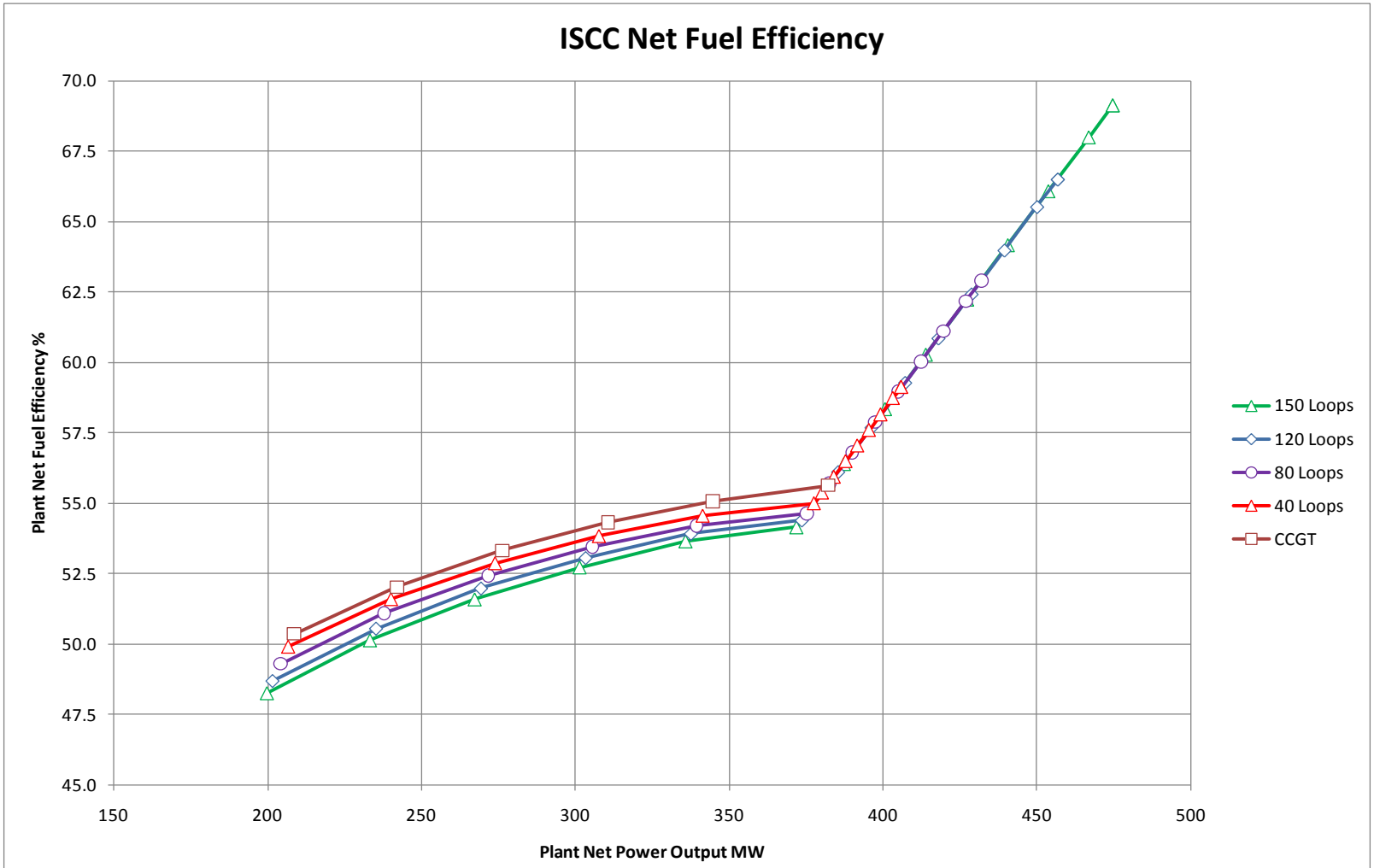
Solar Steam Integration : different options, optimal solution ?



- 1P_ColdFW
- 1P_MidFW
- 1P_HotFW
- 1P_Reheat

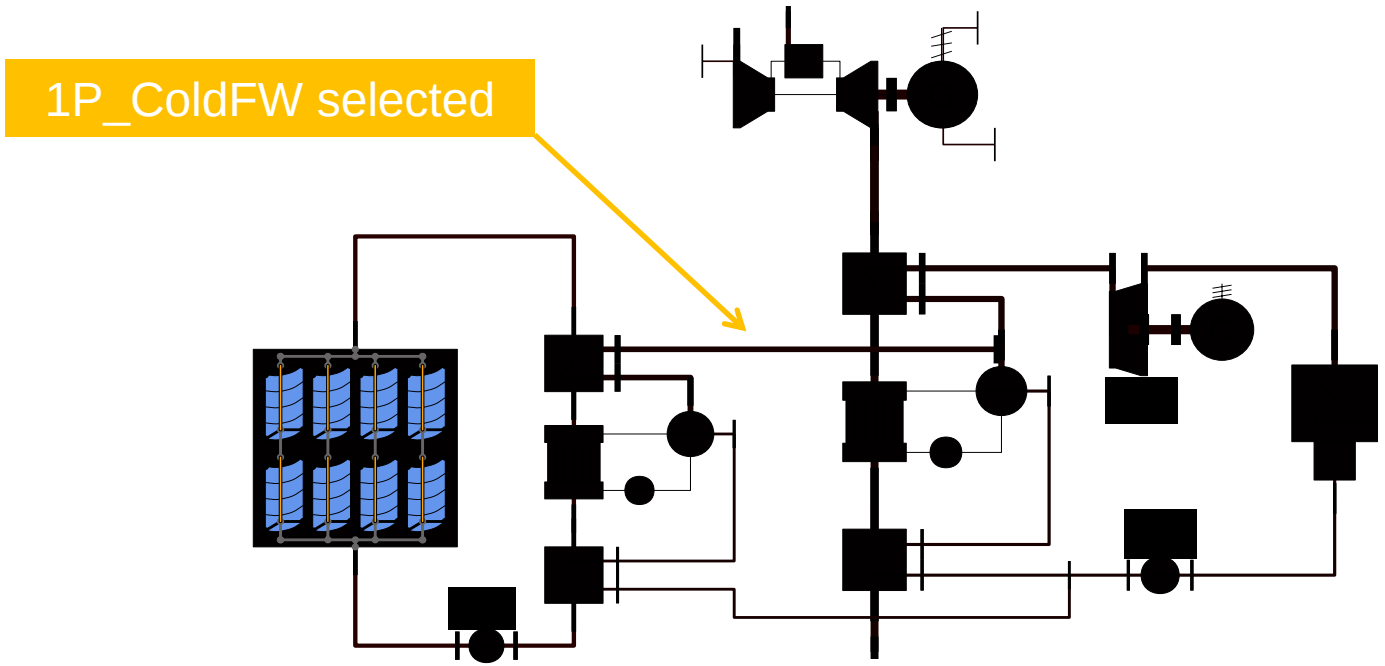
Selection on :
- Technical feasibility
- ISCC « solar mode » net efficiency
- ISCC « CCGT mode » net efficiency,

ISCC Net Fuel Efficiency



Operation of an ISCC plant in times without solar irradiation is less efficient than with CCGT

Solar Steam Integration : different options



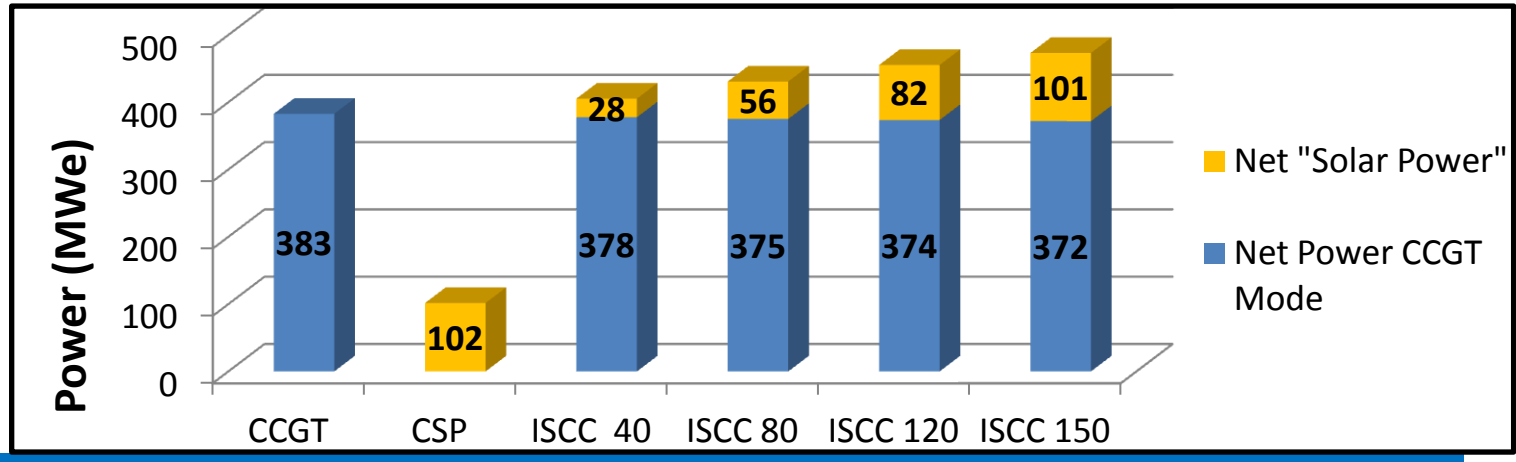
- **ISCC plant requires special design and adaptations** to mitigate the negative effects of the ‘over sizing’ during non-solar operation.

- The **maximum size of the solar field is limited** by the heat available in the GT exhaust gas to superheat the solar steam to desired temperature

ISCC : Design and Annual Performance Data

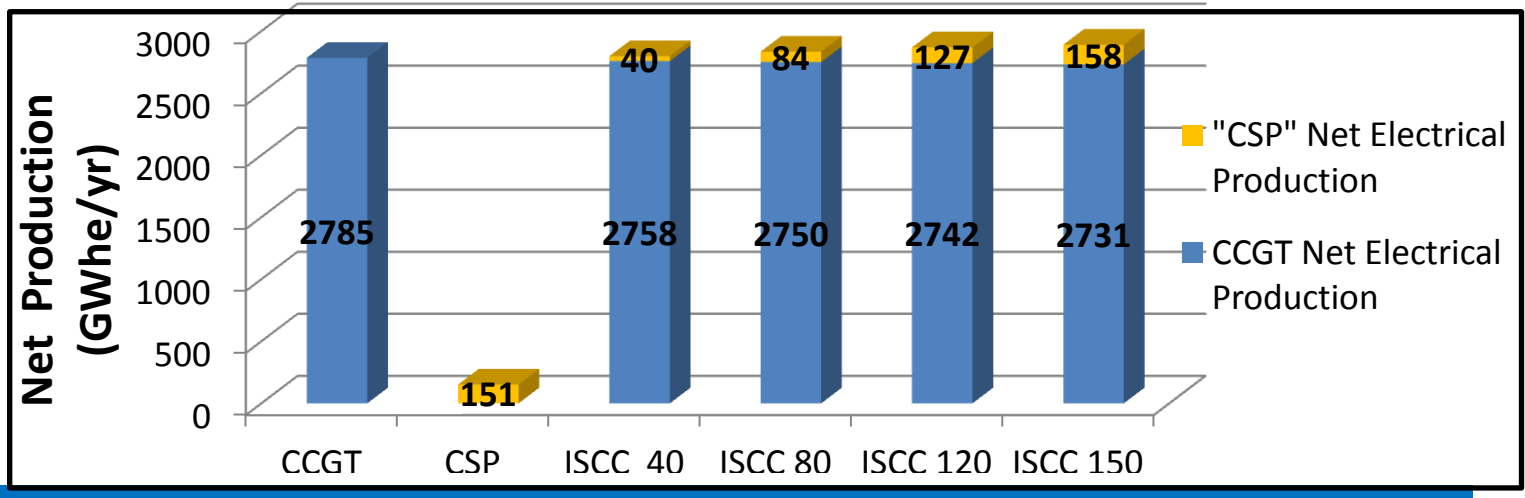
Design

DNI : 840 0 W/m²
Ta = 31.1 °C
p = 1.032 bar
Rh = 35%



- Design Solar Share from 7 to 21%
- Net Fuel efficiency : « solar » from 59% to 69% / «CCGT» from 56% to 54%

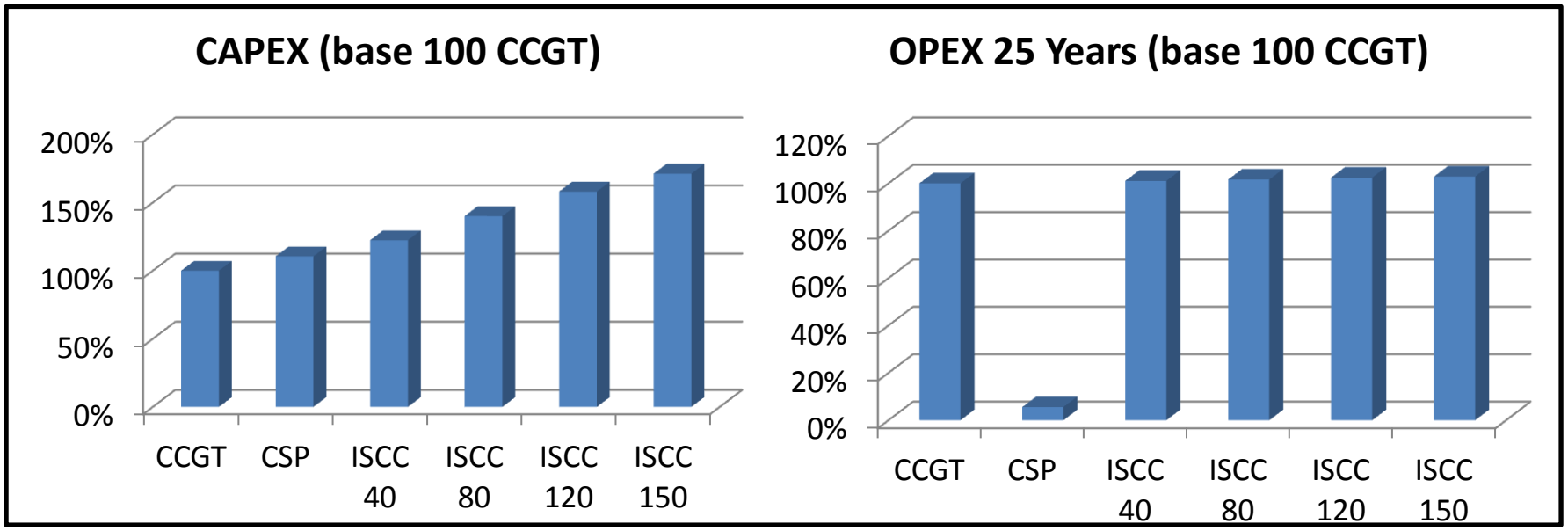
Annual Performance



- Yearly Solar Share from 1.5% to 5.5%

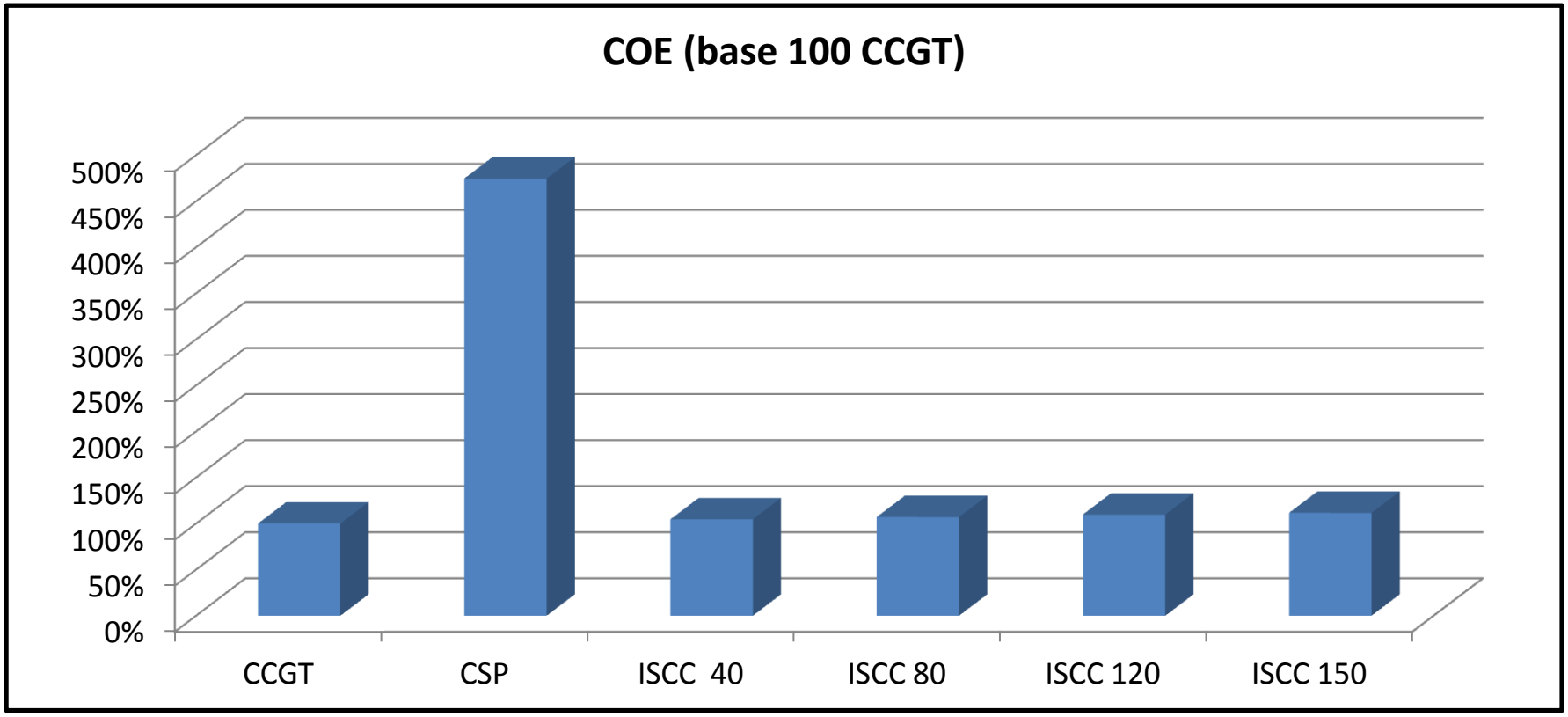
CAPEX and OPEX evaluation

- CAPEX evaluation
- OPEX evaluation : 3 gas price scenario, CO2 costs
- Plant Lifetime : 25 years



- The **incremental CAPEX for ISCC** is **less than 2/3** of the **CAPEX for a stand-alone CSP plant** of equivalent capacity.
- Shared O&M costs

CCGT, CSP, ISCC COE comparison

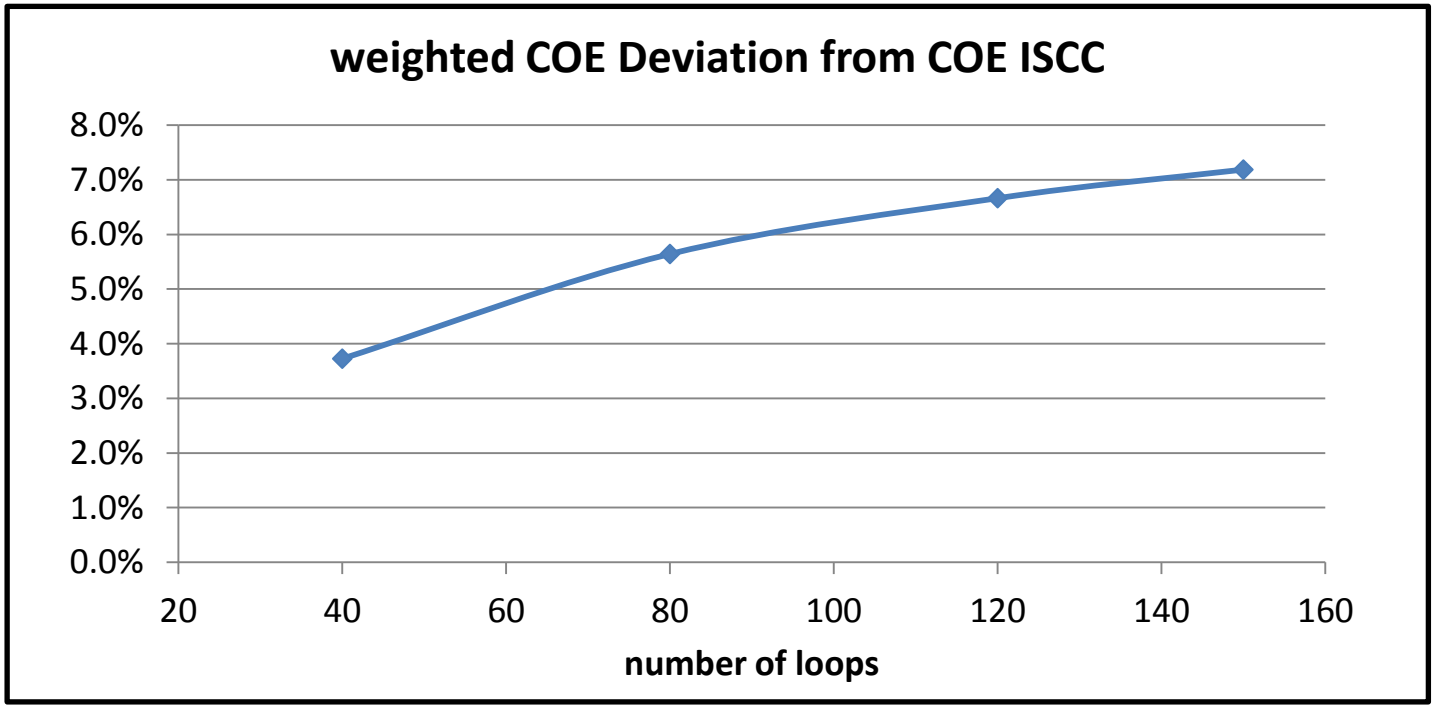


COE of ISCC is in the **order of magnitude of current CCGT technology** (+5% to 12%)

…what about the weighted comparison ?

ISCC / CCGT + CSP weighted COE Comparison

Weighted COE = Solar Share * COE CSP + (100%-Solar Share) * COE CCGT



COE of ISCC is 7% less than weighted COE of CCGT+CSP for the largest size investigated

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Conclusions

Conclusions

- ISCC is an **economically attractive option to produce electricity from renewable ressources**
- Higher fuel efficiency, **lower CO2 emissions/kWh.**
- The **efficiency of solar energy conversion in ISCC is higher than in stand-alone CSP plants**
- Continuous operation of CCGT plant minimizes start-up and shut-down losses of CSP.

Benefits of ISCC compared to separate CCGT and CSP Plants

Other options to combine Natural Gas and Solar Power generation :
Gas booster, Fresnel or Tower CSP technologies with DSG…

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Questions ?