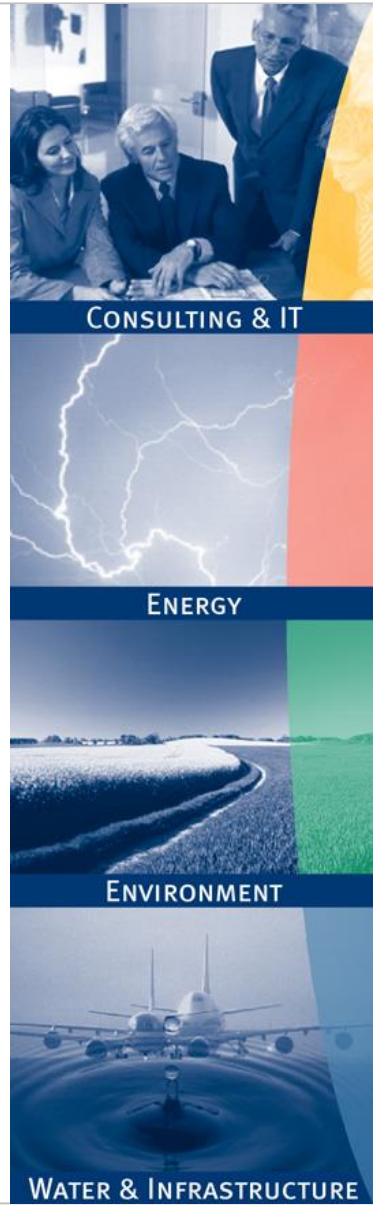
# Trends in Energy Markets and the Importance of Energy Storage for CSP

## Workshop Presentation

**Freiburg, 27 October 2016**



# CSP Markets and Risks

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# Presentation Topics

- **Basics**
- **Trends in CSP Target Markets**
- **Importance of Energy Storage**
- **Situation for CSP in an Unbundled Energy Market**
- **Conditions for Medium Scale CSP with Storage**

20 minutes

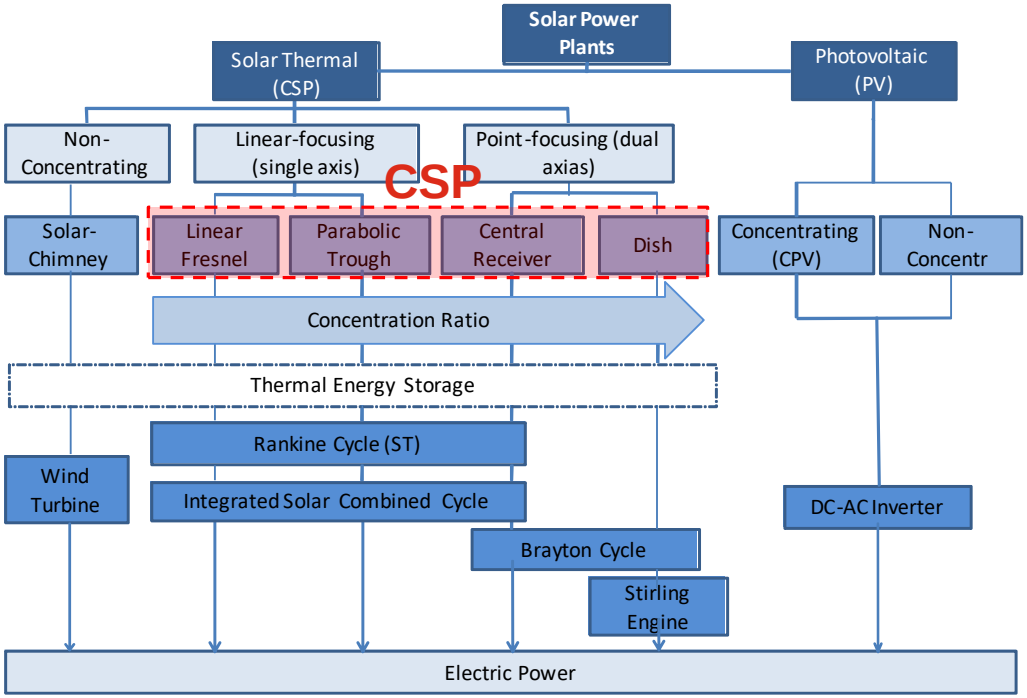
- **Discussion**

10 minutes

# The Fichtner Group

- Established in 1922 and family-owned ever since
- Germany's biggest independent engineering and consultancy enterprise for infrastructure projects
- More than 1,500 employees worldwide – 500 in our Home Office (Stuttgart, Germany)
- Project experience in 170 countries
- Represented in more than 50 countries (24 subsidiaries, 100 branch and project offices, presence in 60 countries, several of which in Asia)
- Over 1,800 ongoing projects – 600 of these in our Home Office
- Total turnover of €285 million in 2015
- Capital investment volume under planning in the home office: €180 billion – of which some €53 billion is in renewable energies

# Concentrated Solar Power Plants




## Key facts:

- Main CSP technologies: Parabolic Trough and Central Receiver (Solar Tower)
- Initial conversion of solar into thermal energy
- Possibility to include a thermal energy storage or to hybridize
  - → High capacity factors possible
  - → Dispatchable solar power
- Incorporation in conventional power plants
- Increased grid stability
- Mainly conventional components used
- Economy of scale leads to larger plants (up to 300 MW)
- High local shares possible

# CSP Power Plant Configurations

## Solar Only:

- Not-dispatchable and only suited for summer peaks (PV cheaper option)
- Capacity factors of only 25 – 30%

## Thermal energy storage:

- Key feature of CSP, incorporation in combination with an oversized solar field
- Capacity factors >80% possible; dispatchable power generation

## Solar-hybrid (fossil):

- Different options for hybridisation: back-up boiler, gas fired superheater, etc.
- Due to low Rankine cycle efficiency, only moderate hybridisation feasible

## Integration on conventional power plants:

- Solar steam used as fuel saver in CCGTs (➔ ISCC) and STPPs;
- Potential for solar add-ons in existing power plants or as greenfield plant

## Hybridization with other REs or WtE plants:

- Integration of solar steam in biomass, geothermal or in WtE ensure 100% renewable power generation.
- (indirect) hybridization of CSP power plant with TES and PV power plant






Source: Sener, SMAG, Fichtner, Masdar

# Project Finance Fundamentals

## Projects need to be financed

- Payback of the construction costs by revenues during the operation period (25 years commercial life)

## Finance Structure

- Balance sheet of a generation company (classic power industry) → mostly still partly bank finance
- Independent power producer → often: 80% bank finance, 20% equity

## Revenue Possibilities

- Feed in tariff
- Energy market
- CO2 certificate

## Security of Revenues

- Banks require security that their loan will be repaid (4 to 8 % interest rate)
- Equity investors require profit (10 to 15 %)

# CSP Target Markets – Situation Today

- **Spain** → consolidated plant portfolio & decreased consumption, no new plants, existing CSP plants paid a topping onto market sales which is calculated on basis of actual market price and income required by a reference plant → outdated model
- **US** → Transmission companies buy RE generation to fulfill a minimum portfolio, open IPP bidding process, CSP struggles to compete against PV since capacity value is currently not considered → to be revised to provide new incentives
- **North Africa**→ mainly Morocco, large scale plants are tendered as IPP projects, project requirements are derived from network studies and macro-economic considerations
- **Middle East**→ Large new capacity planned at UAE and Saudi, tendered as IPP based on network studies and macro-economic considerations
- **China** → Feed in tariff, projects are approved by government, mainly driven by macro-economic considerations
- **Chile** → Open energy market with day ahead market and bilateral PPA's, CSP, PV, wind and conventional plants are in competition
- **South Africa** → projects with predefined capacity and minimum storage range tendered as IPP's → CSP projects are struggling to get financial close due to change in tariff regime

# CSP Target Markets - Main Trends

- Whenever **network studies and macroeconomic considerations** are made, CSP with a certain minimum storage range was tendered as IPP, Examples: UAE, Morocco, (China)
- Solar plants are tendered as **hybrid plants** (PV, CSP) to produce low price PV electricity during daytime and have high capacity value generation during evening peak, Examples: Morocco
- In **open energy markets**, CSP competes with conventional plants during evening and night slots, during day PV is dominating and challenges the entire market, Examples: Chile
- In **energy based markets** with larger conventional capacity, mainly PV is selected to cover a certain green energy target, Examples: US, South Africa
- Especially at **small grids** strong regulatory actions are required to facilitate a healthy development as a fast und unregulated PV market penetration challenges historic structures of financing the power sector and ensuring security of supply

# Expected Future Competitive Situation

- **Competition PV vs. CSP vs. Conventional**: the main competitor of CSP are conventional plants, PV has come to extremely low cost which makes competition by other technologies on energy production basis almost impossible

- **Fuel Cost Insecurity vs. Energy based Revenues**: In energy based markets, conventional plants become more and more difficult to be financed since PV takes a large part of the turnover during daytime and all projections show rising fuel cost.

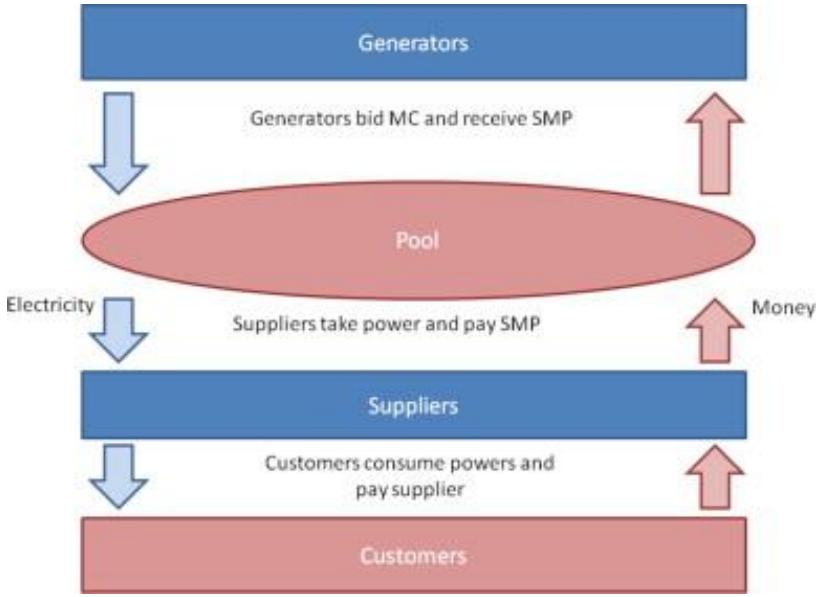
- **Electric battery storage** will become a stand-alone network feature which is not linked to any technology → recent tender in Jordan or Tesla project in Australia

- **Cost and lifetime performance of battery storage** will become decisive for the competition in energy markets, recycling costs may be added in developed countries

- **Transformation of generation portfolio** from conventional to renewable requires market arrangements which provide **secured revenues** to all kinds of technology in dependency to their value for the system. At smaller grids, medium scale CSP can play an important role until battery solutions may become dominating

# Situation for CSP in an Unbundled Market

- **Future income of project depends on market development**
  - Electricity demand
  - Deployment of renewable energy sources
  - Fuel types, fuel prices and CO2 prices
  - Development of conventional power generation fleet
  - Change in policies e.g. fuel switch due to stricter industrial regulations concerning emissions (coal and heavy fuel oil to light fuel oil and natural gas)
  - Change of energy market rules




- **Depth finance of projects requires a solid market forecast and security of minimum income to pay back the loan**
  - Market study
  - Worst case scenarios
  - Securing of minimum income by regulator?!

- **Project needs to be competitive under all market scenarios**
- **Competitive situation in market slots (e.g. 17:00 to 23:00)**
- **Being able to flexibly react on future changes in competition**

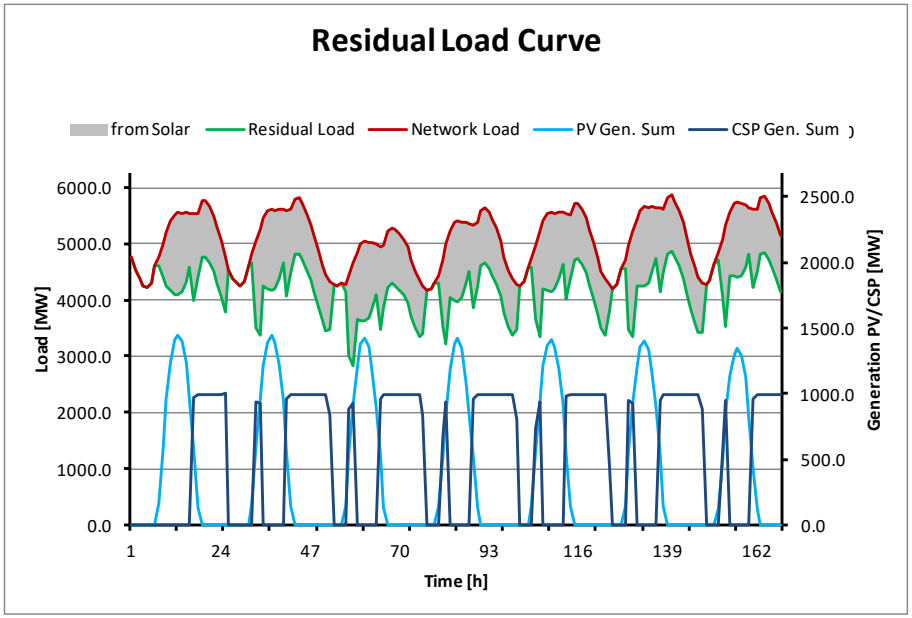
# Importance of Energy Storage

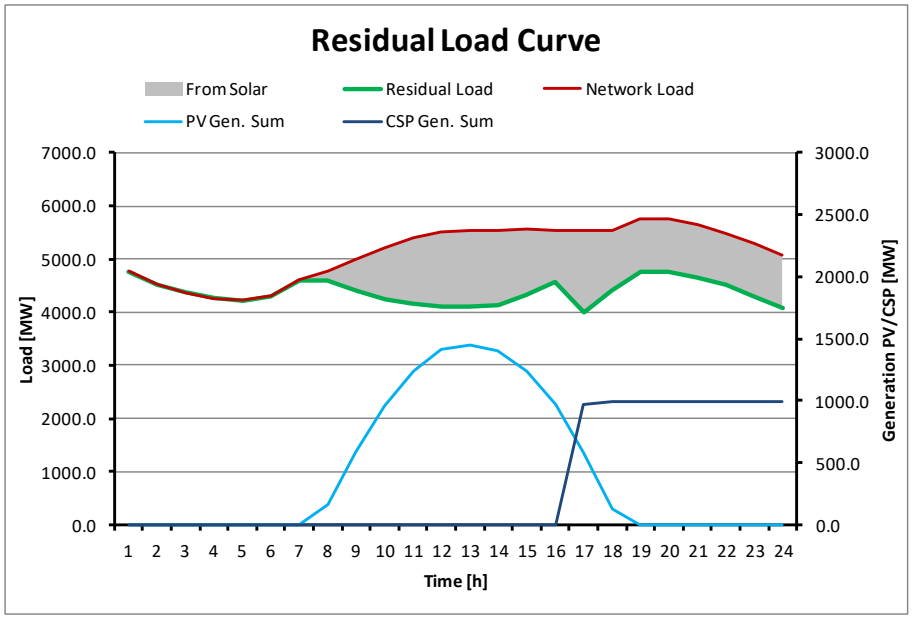
## Network Demand vs. PV and CSP Generation Profile

- Only with Storage CSP can compete in future markets
- Battery storage will become a stand-alone network feature

## Generation Cost

- PV < 5 ct/ kWh already today (without finance concessions)
- CSP trend: < 10 ct / kWh, Combined Cycle at 50 € / MWh > 10 € ct /kWh
- Large scale CSP / PV hybrid IPP plants < 8 ct / kWh



# Conditions for Medium Scale CSP with Storage

- **Network size or topography limit plant size** : at grids with below ~ 1 GW peak capacity and low transmission capacity, implementation of large RE generation units is not reasonable; at some networks topography is unsuitable for large units (e.g. Greek islands)

- **High conventional generation cost:** Fuel cost are forecasted > 50 € / MWh (LHV), coal and nuclear are not an option (which is typical from small networks)

- **Market arrangements:** Mechanisms generally allow competition against costly and potentially inefficient conventional units rather than against PV

- **Policy**: Government ensures an open competition without undue advantages to established generators (e.g. former public generation companies)

- **Network requirements**: Capacity value and security of supply are assessed in network studies, market policy gives the incentives to implement the types of plants which fulfill basic network requirements

- **A good implementation basis** is considered IPP tendering of generation slots with a certain capacity range and certain minimum operating capabilities to be fulfilled, winning the IPP tender provides the market security required for financing the project

# Questions and Discussion

- **Questions by the Audience**
- **Other Opinions**
- **Comments**

# Backup Slides

# Fuel Costs

Source: IEA, World Energy Outlook 2016

- Main sources are World Bank and IEA
- Fuel oil prices are directly linked to crude oil prices
- Natural gas prices where detached from oil prices during the financial crisis, but are expected to reconnect
- Fuel demand is rising from population growth (100% sure) and expected global economic recovery (99%)
- All sources predict that fuel costs are going back to pre-crisis levels and beyond

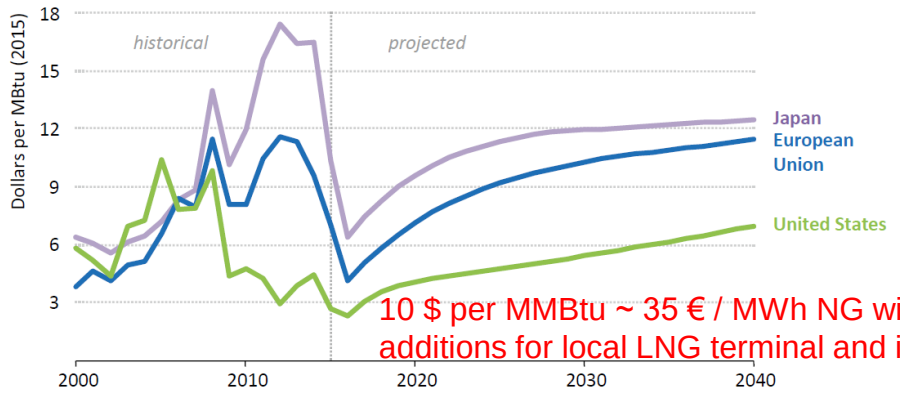
**Table 1.4** ▷ Fossil-fuel import prices by scenario

| | | New Policies Scenario | | | Current Policies Scenario | | | 450 Scenario | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Real terms ($2015)** | **2015** | **2020** | **2030** | **2040** | **2020** | **2030** | **2040** | **2020** | **2030** | **2040** |
| **IEA crude oil** ($/barrel) | 51 | 79 | 111 | 124 | 82 | 127 | 146 | 73 | 85 | 78 |
| **Natural gas** ($/MBtu) | | | | | | | | | | |
| United States | 2.6 | 4.1 | 5.4 | 6.9 | 4.3 | 5.9 | 7.9 | 3.9 | 4.8 | 5.4 |
| European Union | 7.0 | 7.1 | 10.3 | 11.5 | 7.3 | 11.1 | 13.0 | 6.9 | 9.4 | 9.9 |
| China | 9.7 | 9.2 | 11.6 | 12.1 | 9.5 | 12.5 | 13.9 | 8.6 | 10.4 | 10.5 |
| Japan | 10.3 | 9.6 | 11.9 | 12.4 | 9.9 | 13.0 | 14.4 | 9.0 | 10.8 | 10.9 |

Notes: MBtu = million British thermal units. Gas prices are weighted averages expressed on a gross calorific-value basis. All prices are for bulk supplies exclusive of tax. The US price reflects the wholesale price prevailing on the domestic market. The China and European Union gas import prices reflect a balance of LNG and pipeline imports, while the Japan import price is solely LNG.

80 $ per barrel ~ 60 € / MWh for heating oil

**Figure 1.5** ▷ Natural gas prices by region in the New Policies Scenario



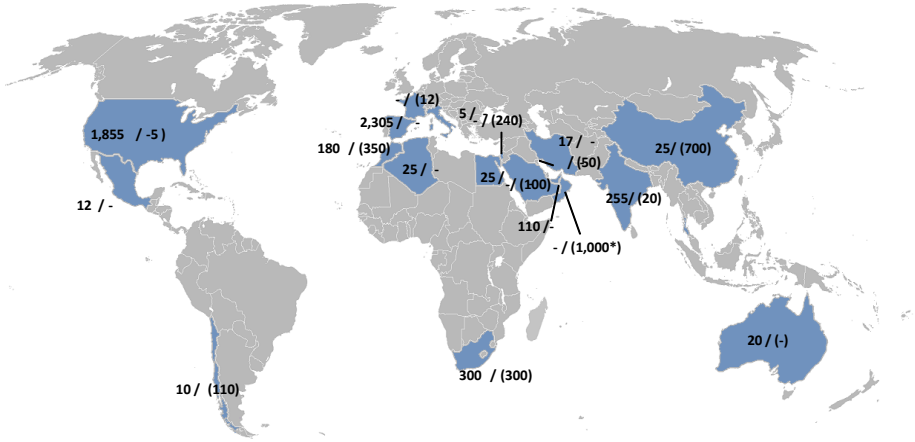

*Natural gas prices in the main regions are connected by an increasingly flexible global trade in LNG*

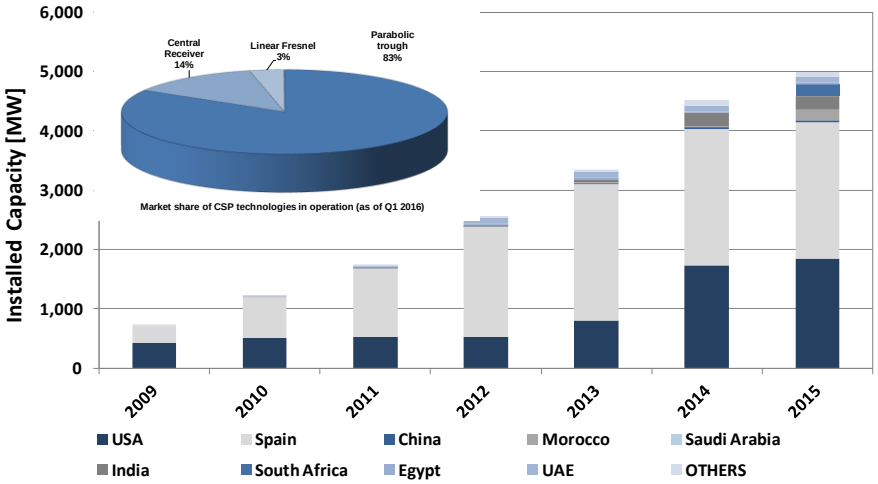
10 $ per MMBtu ~ 35 € / MWh NG without additions for local LNG terminal and infrastructure

Notes: US price is a wholesale price; other prices are average import prices.

# Current Global CSP Market

## WORLD WIDE CSP DEPLOYMENT Q2 2017



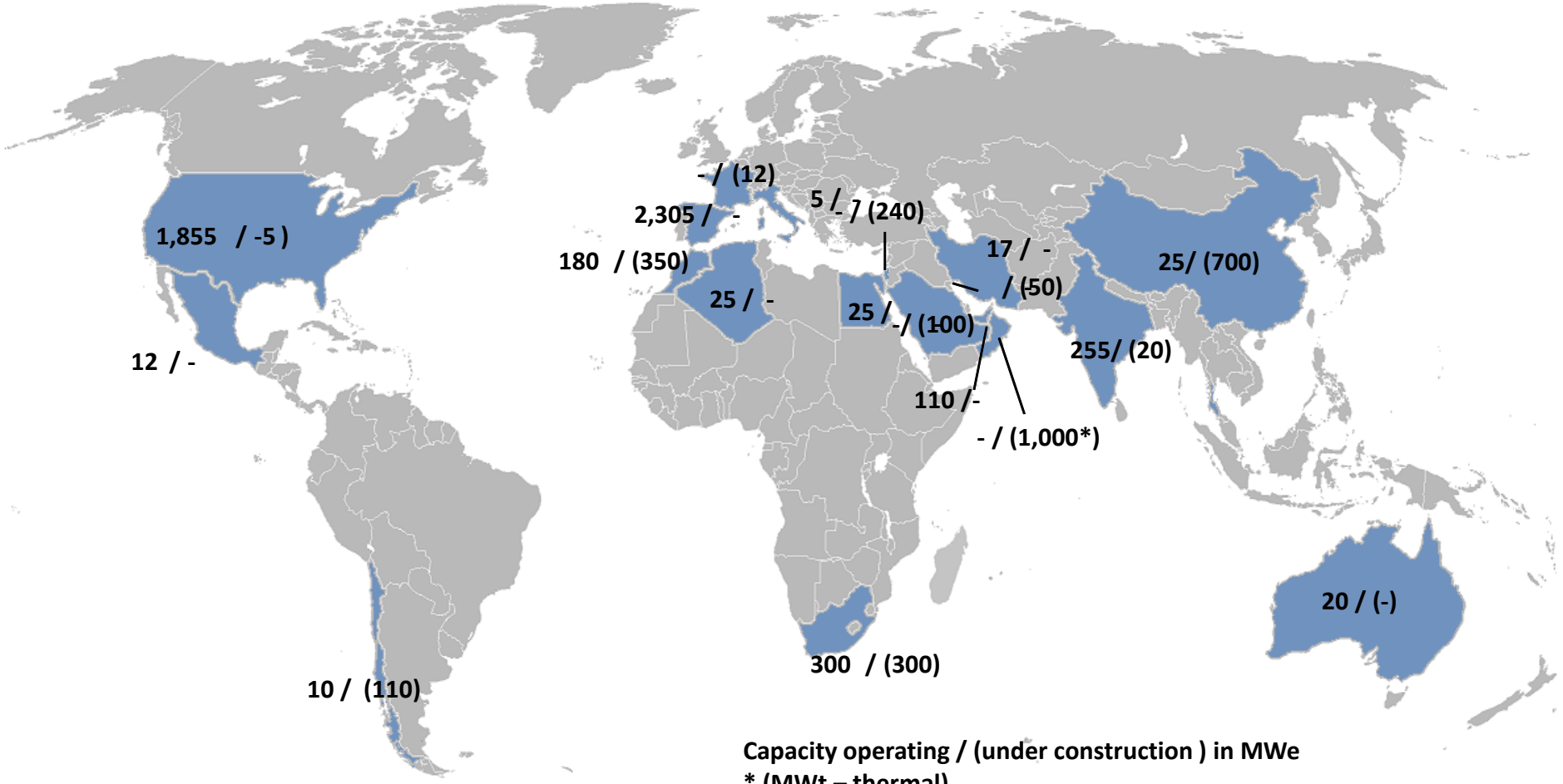

## STATUS OVERVIEW

- ~ 5,100 MW in operation as of Q2 2017
- ~1,800 MW under construction
- Recent tenders in Chile, UAE and Australia showed considerable tariff reductions (US$ 7 – 9 cents/kWh), increasing the interest in CSP technology;
- Dispatchability feature, i.e. thermal energy storage is the key driver;
- More than 80% of operating capacity based on parabolic trough technology
- Solar tower (molten salt) main emerging CSP technology;
- Further direct molten salt technologies (parabolic trough and linear Fresnel) under development and demonstration;
- In the last years, CSP market dominated by Spain and USA, followed by RSA and India.
- China now main emerging market; followed by MENA region;
- Continuing market consolidation;

Source: Fichtner in-house CSP data base

# Current Global CSP Market (II)

## WORLD WIDE CSP DEPLOYMENT Q2 2017




Capacity operating / (under construction ) in MWe
* (MWt – thermal)

Source: Fichtner in-house CSP data base