CONCENTRATING SOLAR SYSTEMS: SOLAR THERMAL



EMPEREAL's offerings

SOLAR PV

1

- Bankable Utility scale PV power plants
- World Class EPC team with experience over 500MW
- Large Roof top solutions
- O&M of Solar PV plants

SOLAR THERMAL (CSP)

2

- Continuous production of power using Solar Thermal & Thermal storage
- Suitable for any steam based application

Solar DESALINATION

3

- Generate fresh water using solar energy
- Water at <$1.3 p/$m^3$ from PV desalination using MED, RO or FO
- Facilitates community scale, decentralized power and water generation

SPECIALTY SURFACE COATING

4

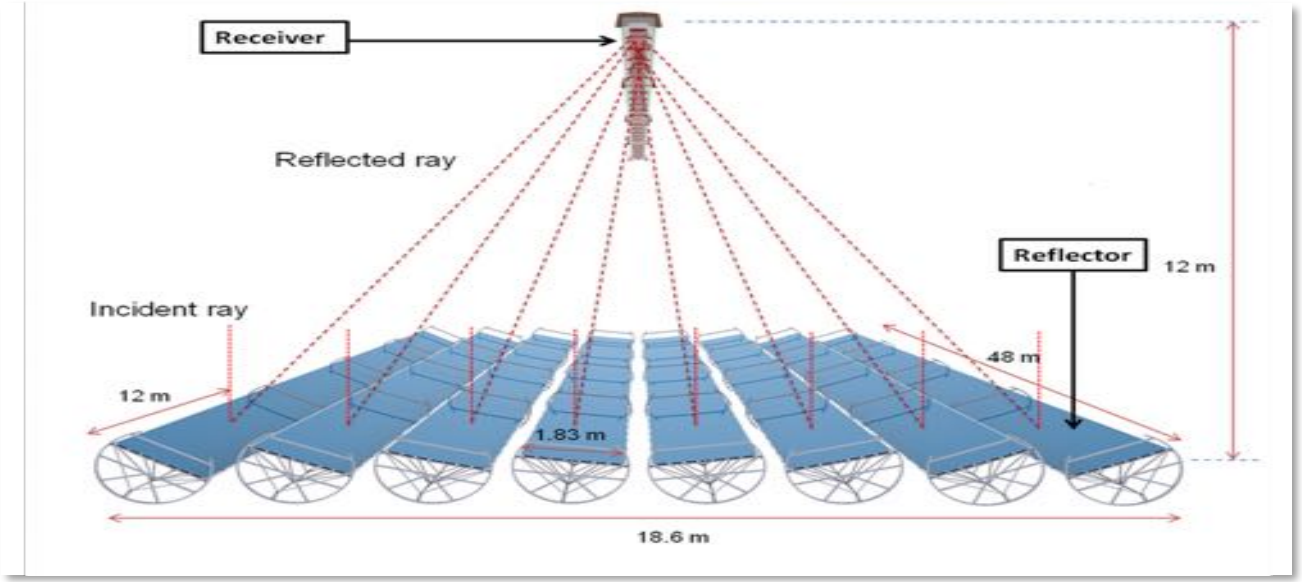
- Innovative polymer coatings for enhanced
  - anti-corrosion
  - heat protection
  - fire protection of surfaces

Many parts of the world with their high solar radiation are ideally suited for various applications of CSP and PV

PHOTOVOLTAIC & SOLAR THERMAL (CSP) TECHNOLOGIES

- Empereal Solar energy solutions produces reliable power and water at prices CHEAPER than conventional methods
- Empereal Solar thermal solutions convert the sun's heat into HIGH TEMPERATURE STEAM
- Photovoltaic (PV) Solutions convert LIGHT ENERGY into electricity

CONCENTRATING SOLAR THERMAL POWER
LFR



- Simple and Robust
- Single Axis Tracking
- Land Efficient
- Wind Resistance
- Direct Steam Generation
- Solar to steam conversion efficiencies > 60%

- At Empereal we are committed to continuous research and development – A view of our Solar Thermal R&D Centre in TamilNadu, India

EMPEREAL's LFR: custom made configurations

MEDIUM TEMPERATURE APPLICATIONS

- Upto 260 degrees C saturated steam
- Useful for power generation or combined power and water desalination solutions
- Can suit a wide range of operating parameters

HIGH TEMPERATURE WITH THERMAL STORAGE

- 400 to 500 degrees C super heated steam
- Useful for power generation with efficient thermal storage
- Provides high efficiency and cost effective energy storage

SOLAR THERMAL

- Molten salt in PCM mode and accumulator based storage
- Used in power generation solutions for 24X7 operation
- Customizable for different operating temps and pressure

LOW COST HIGH EFFICIENCY SYSTEM

- For hot water applications – 80 to 98 degrees C
- For water desalination and air conditioning
- Can work with thermal storage for continuous operation

EMPEREAL'S RESEARCH CENTRE

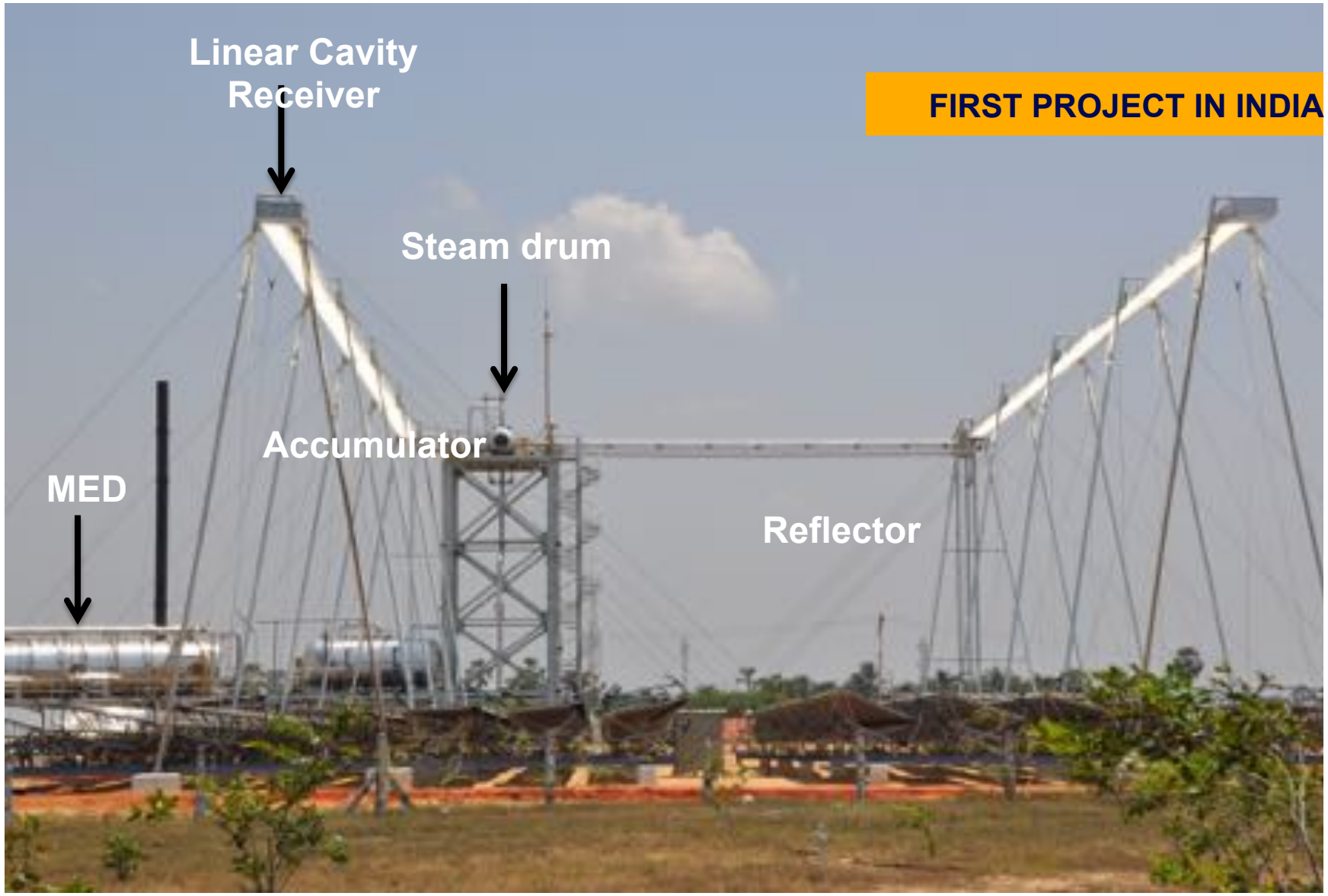
- Ex President of India, Dr. A. P. J. Abdul Kalam inaugurated our research centre in 2009

PARABOLIC TROUGH COMBINED SYSTEM

- Development of a 2MWth Solar Thermal Power Facility – Commissioned in 2011
- Role: Complete design, procurement, installation and hot commissioning.
- Steam output: 3200 kg/ hr, 45 bar, 257 deg C dry saturated steam
- Storage: 45 min accumulator storage

SOLAR-BIOMASS THERMAL DESAL.SYSTEM

- Commissioned in 2013
- Role: Design, Engineering, Implementation and O&M
- Capacity: 150,000 liters per day potable water



SOLAR DESALINATION: AWARDS

Key features

- Produces ultra-pure industrial grade water (< 5ppm)
- Direct saturated steam generating LFR technology
- Thermal energy storage for uninterrupted and reliable operation
- Integration of solar and biomass for round-the-clock production
- Durable and safe technology
- Unique, Innovative, Scalable, Replicable, Eco-friendly, Decentralized

This project was identified as one of the Top 8 Technology Innovations of 2011 by Massachusetts Institute of Technology, USA

The project won the prestigious National Innovation Award for 2014 from Indian Chamber of Commerce (FICCI) and HSBC

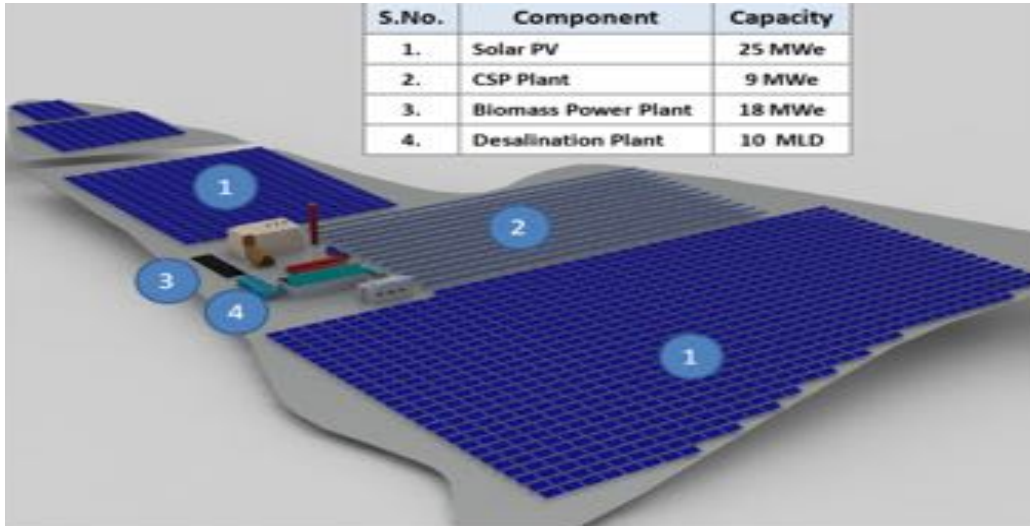
SUPER HEATED STEAM WITH THERMAL STORAGE

- Role: Design, Engineering, Installation and Commissioning in 2014
- Capacity: 50kW, Steam at 420 – 500 Deg C

MOLTEN SALT & ACCUMULATOR THERMAL STORAGE

- 4 Hour, 1.25 GJ of thermal energy storage – commissioned in 2014
- Thermal storage based on Molten Salt in PCM mode and accumulators
- Reliable and cost effective thermal energy storage at a fraction of the cost of battery storage for electricity

CONSULTING: SOLAR THERMAL & DESAL PLANT



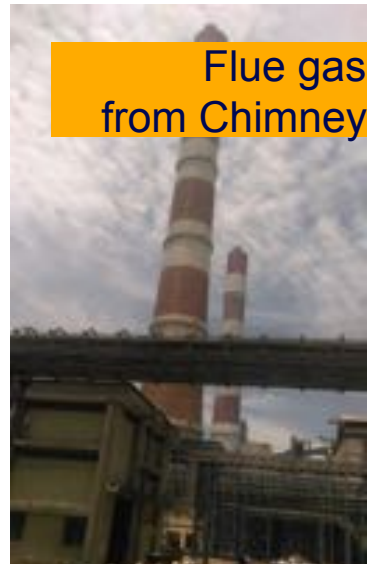
S.No.	Component	Capacity
1.	Solar PV	25 MWe
2.	CSP Plant	9 MWe
3.	Biomass Power Plant	18 MWe
4.	Desalination Plant	10 MLD

- 50 MW Solar Thermal Hybrid Power Plant with 15 MLD desalination plant in Valinokkam Salt complex in Tamil Nadu, India
- In collaboration with ILF Consulting Engineers, Abu Dhabi
- Bankable techno-commercial configuration
- Final configuration – 32MW PV, 6MW CSP, 12 MW Biomass, 10 MLD Thermal desal (MED)

FLUE GAS DESALINATION:
2000 MW NTPC SIMHADRI COAL POWER PLANT

- Waste heat from the 2000MW coal plant flue gas captured for MED based thermal desalination to produce precious boiler replenishment DM water
- Role : Design, Detailed engineering, System Integration, Implementation and Commissioning
- Capacity: 120,000 Liters per day of 0.5 ppm DM water

UNUTILIZED RESOURCES TO IMPROVE SUSTAINABILITY



The flue-gas based desalination plant in Simhadri was inaugurated on 11 February 2017

LFR PLANT: FINE TUNING

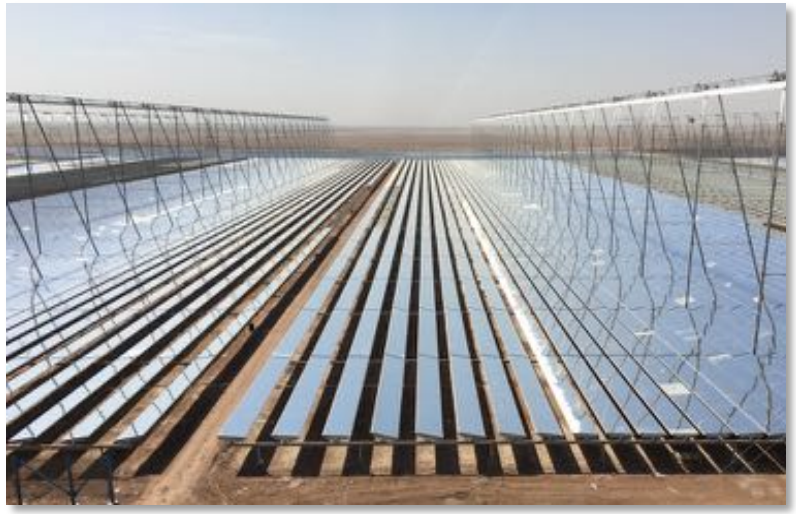
Empereal is fine tuning the engineering and operations of the entire plant to meet its operations and production targets (Dec 2015 – ongoing)

WORLD'S LARGEST LFR PLANT: PERFORMANCE ENHANCEMENT

- Revamped control logic and process flow of the plant
- Implemented innovative thermal monitoring
- Optical and Thermal plant modeling and optimizations
- Designed and implemented fixtures to overcome material defects

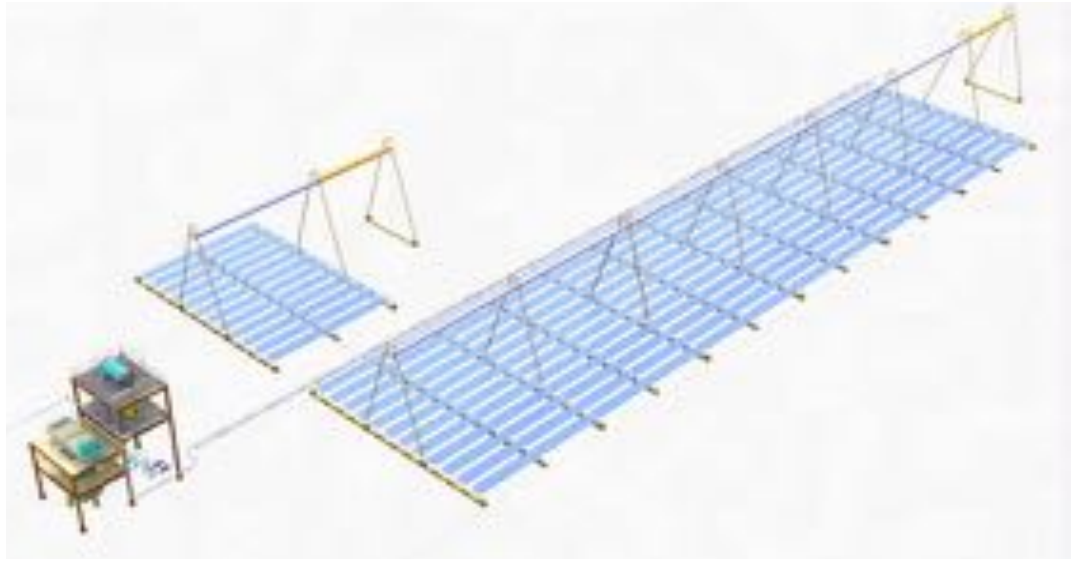
Achievements

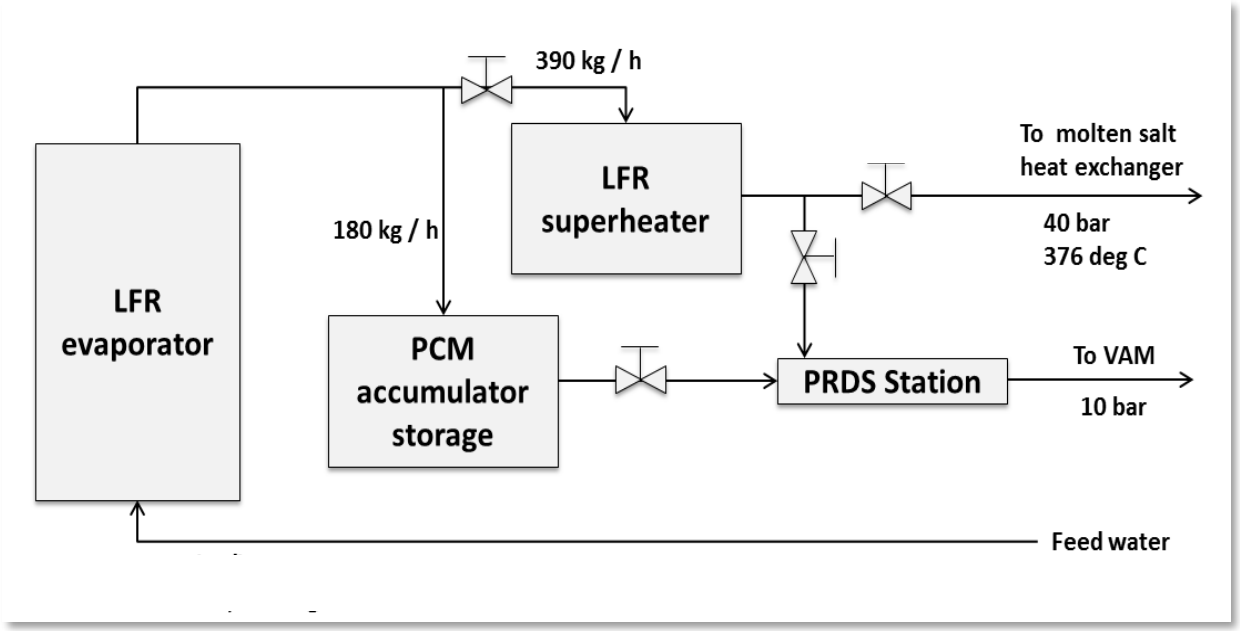
- Stabilized operations
- Improved LFR outlet steam temperature from 340 Deg C to 390 Deg C
- 15% increase in steam production
- Improved utilization of solar collector area
- Stable control systems and enhanced revenue and profits



24x7 3.5MWe SOLAR THERMAL PLANT FOR NTPC: FIRST PHASE

- Detailed Engineering and project execution of a Linear Fresnel reflector (LFR) with Phase
- Change Material (PCM) thermal storage
- Installation, Commissioning and Operations of the LFR plant and Storage
- Integration of the plant with Vapor Absorption Module (VAM) driven Space Cooling solution
- Expected completion date: 30 Sep 2018





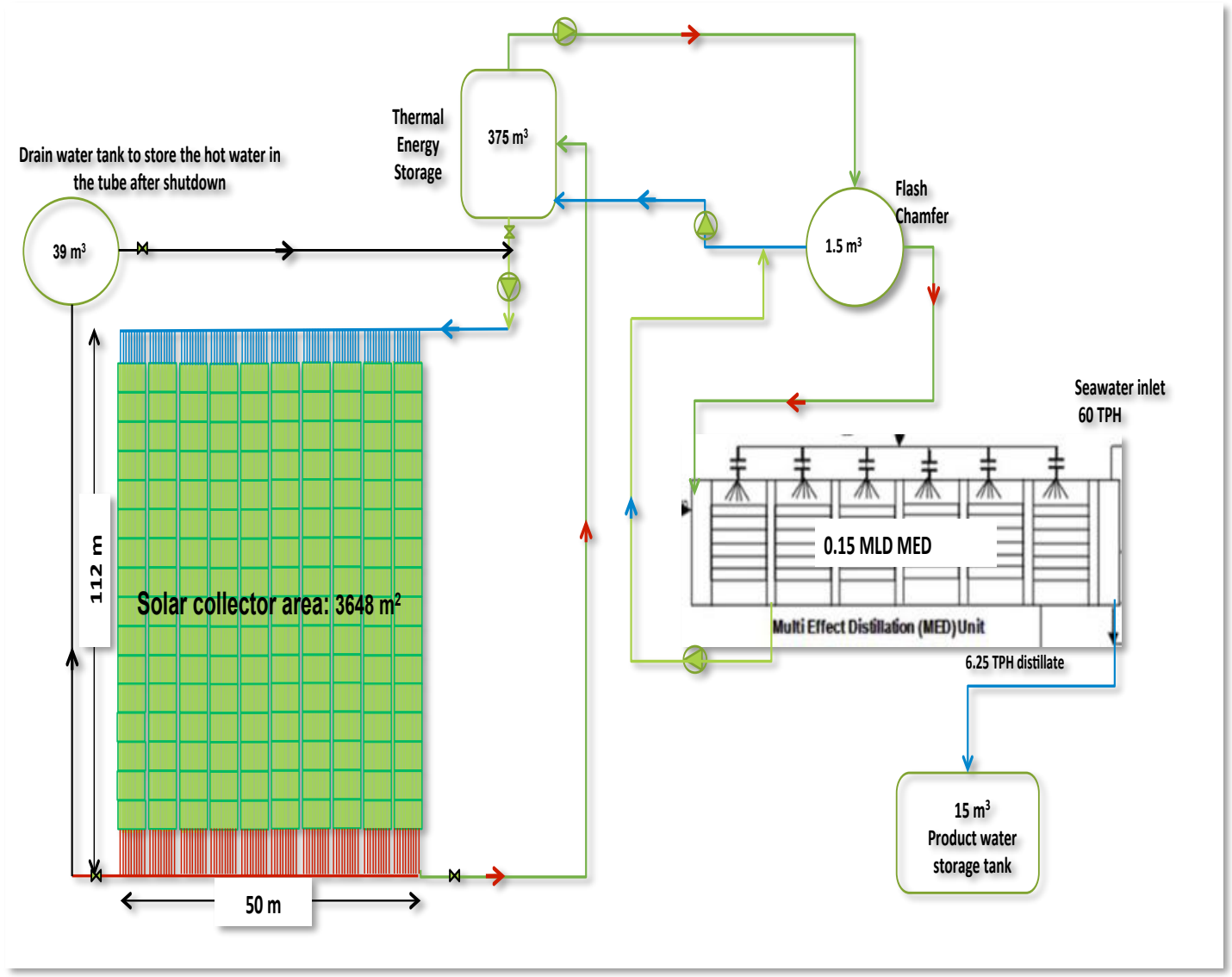
LOW COST LFR & ALGAE CULTURE FOR BRINE DISPOSAL

- Research project conducted under a research grant by government of India
- Innovative project to utilize reject brine from desalination for algae culture
- Provides ability to improve environmental footprint of desalination plants
- Algae Dunaliella is under testing currently

SOLAR THERMAL DESALINATION SYSTEM

- Empereal LFR based Solar Thermal system
- Under setup for Masdar, UAE
- To be commissioned by April 2017

COST EFFECTIVE & INNOVATIVE 24x7 SOLAR DESALINATION



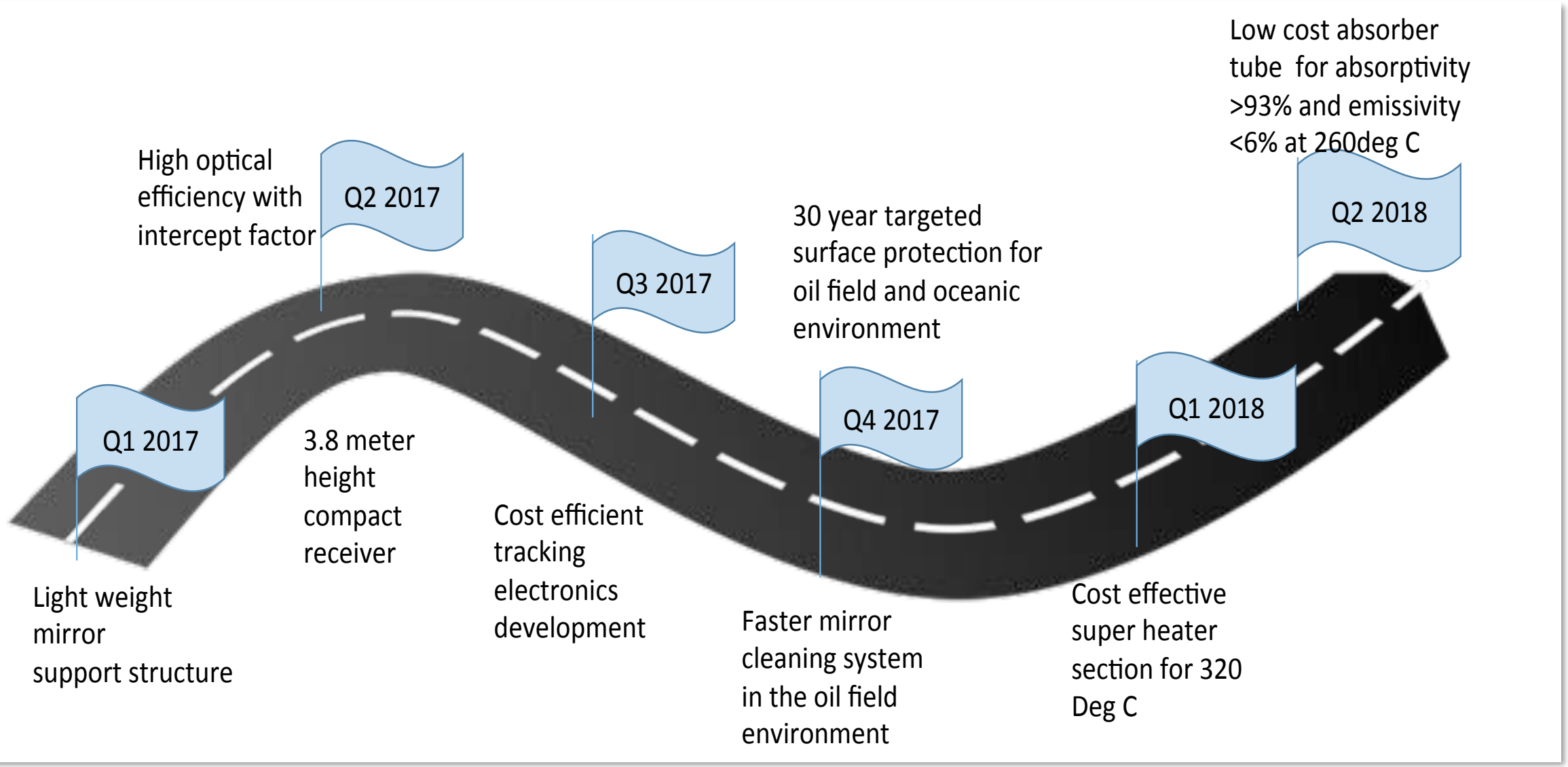
LFR PLANTS: CLEANING AND O&M

- Semi automatic cleaning systems to minimize water use and faster cleaning
- Current consumption: 0.35 Liter per Sq. Mtr and 1450 Sq. Mtr per hr
- After extensive research we find that this type of a large scale cleaning system is cost effective
- We are working with partners to develop a cost-effective, water-effective system suitable for cleaning an LFR system even under oilfield or oceanic conditions

EMPEREAL'S PATENTS

N	Products/Process	Country	Year	Patent
1	Dr. C. Suresh Kumar, M. Pratap, N. Prabhakar, V. Thiru Ganasampath Kr, J. Semeon, and B. S. Vishnu Kumar "Linear Cavity Receiver for Solar Direct Saturated Steam Generating System" Indian patent Application No. 1645/DEL/2010, and date of filing: 14/07/2010	India	2010-2011	Patent Pending
2	Dr. C. Suresh Kumar, M. Pratap, N. Prabhakar, V. Thiru Ganasampath Kr, J. Semeon, B. S. Vishnu Kumar, S. Natrajan and G. Backialakshmi ""Reflector Unit for a Linear Fresnel Reflector Solar Energy Collector System Field of Invention" Indian patent Application No. 636/DEL/2011, and date of filing: 08/03/2011	India	2010-2011	Patent Pending
3	Dr. C. Suresh Kumar, M. Pratap, N. Prabhakar, V. Thiru Ganasampath Kr, J. Semeon, B. S. Vishnu Kumar, S. Natrajan and G. Backialakshmi "Single Axis Tracking Assembly for a Linear Fresnel Reflector Solar Energy Collector System: Indian patent Application No. 637/DEL/2011, date of filing: 08/03/2011	India	2010-2011	Patent Pending
4	Dr. C. Suresh Kumar, M. Pratap, N. Prabhakar, V. Thiru Ganasampath Kr, J. Semeon, and B. S. Vishnu Kumar "Direct Saturated Steam Generating Linear Fresnel Reflector Solar Energy Boiler" Indian patent Application No. 3594/DEL/2011, date of filing: 12/12/2011	India	2010-2011	Patent Pending
5	Dr. C. Suresh Kumar, Shinu M. Varghese, M. Pratap, N. Prabhakar, J. Semeon, B. S. Vishnu Kumar "Direct saturated and superheated steam generating Linear Fresnel Reflector solar energy boiler with secondary reflector and single absorber tube" Indian patent Application No: 3388/ DEL/2013, date of filing: 20/11/2013	India	2013-2014	Patent Pending
6	Dr. C. Suresh Kumar, M. Pratap, N. Prabhakar, B. S. Vishnu Kumar "Reflector unit for a Linear Fresnel Reflector solar energy collector system" Indian patent Application No:, date of filing: 06/03/2014	India	2013-2014	Patent Pending
7	Dr. C. Suresh Kumar, M. Pratap, B. S. Vishnu Kumar and S. Harish Kumar "Closed loop single axis ganged tracking assembly with feedback for a Linear Fresnel Reflector solar energy collector system" Indian patent Application No:661/DEL/2014, date of filing: 10/03/2014	India	2013-2014	Patent Pending
8	Dr. C. Suresh Kumar, M. Pratap, B. S. Vishnu Kumar and S. Harish Kumar "Linear Cavity Receiver for generating direct high temperature super heated steam using secondary reflector (SR) and evacuated tube collector (ETC) for Linear Fresnel Reflector solar energy collector system" Indian patent Application No:662/DEL/2014, date of filing: 10/03/2014	India	2013-2014	Patent Pending
9	Dr. C. Suresh Kumar and Shinu M. Varghese "Method of sea water desalination using solar and biomass energy" Indian patent Application No: 60/DEL/2014, date of filing: 08/01/2014	India	2015	Patent Pending
10	Dr. C. Suresh Kumar and Shinu M. Varghese "Solar biomass power and desalination plant" " Indian patent Application No:61/DEL/2014, date of filing: 08/01/2014	India	2015	Patent Pending

LFR: IMPROVING PERFORMANCE & COST



Empereal
Energizing communities

SOLAR PHOTOVOLTAIC SOLUTIONS for RAPIDLY GROWING ECONOMIES



REFERENCES: MW-scale completed projects

- Empereal Harsha LLP is our Solar PV EPC arm which has commissioned over 390 MW of solar PV projects

- Over 165MW projects are currently under implementation including a single 110MW solar PV power plant

REFERENCES: rooftop and ground mounted

- Many projects completed in India and new projects started in UAE, Kazakhstan and Maldives
- 393 MW of Free Field and Roof top projects completed in 8 countries
- Empereal Harsha is one of the leading and most cost efficient solar PV EPC companies

REFERENCES: carport, tracker

REFERENCES: Delhi IGI airport

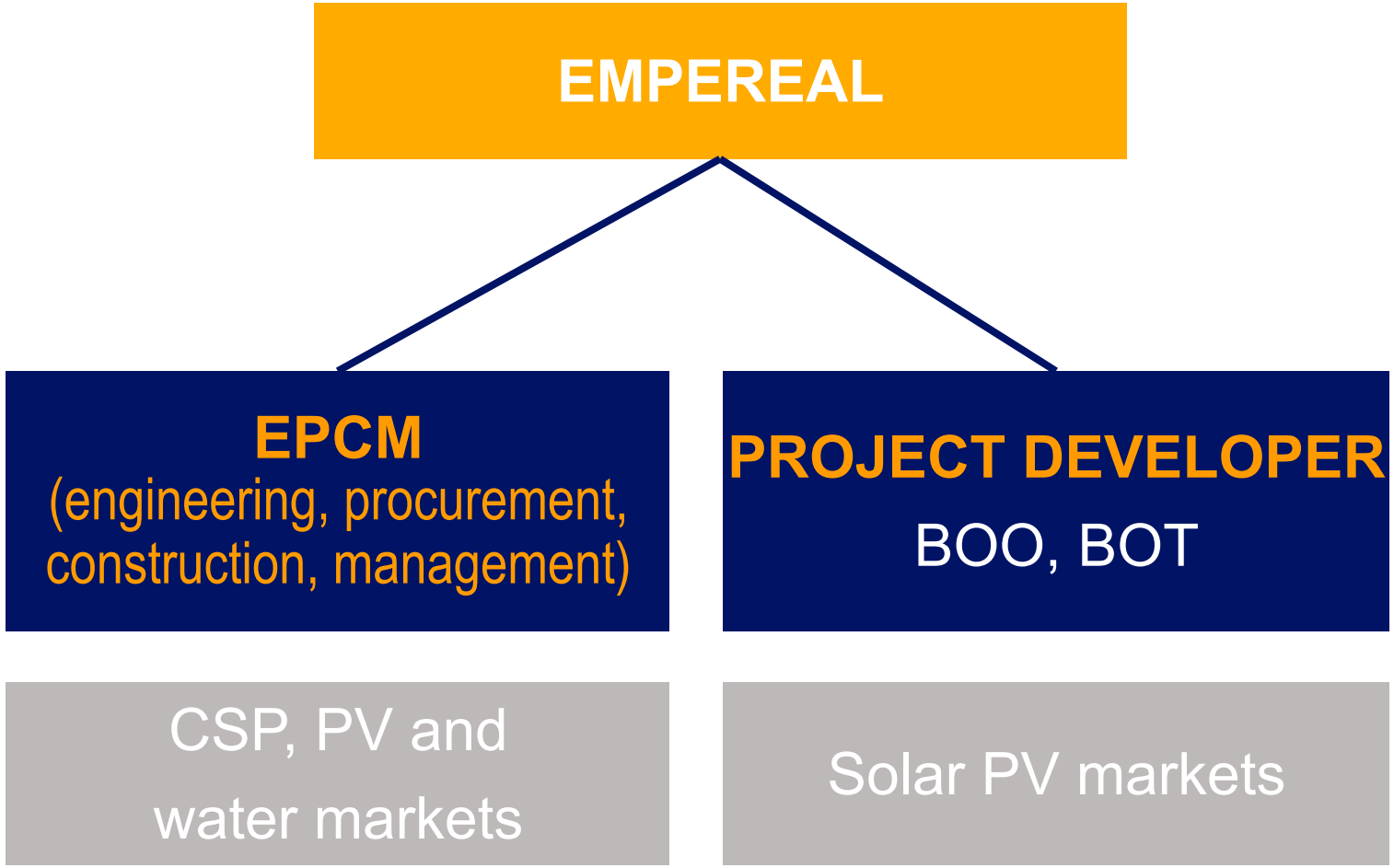
- 2 MW installation
- Rooftop system
- Complex project implementation environment
- Commissioned in 2017

REFERENCES: TATA Automotive factory

- 2 MW installation
- Rooftop system
- Commissioned in 2017

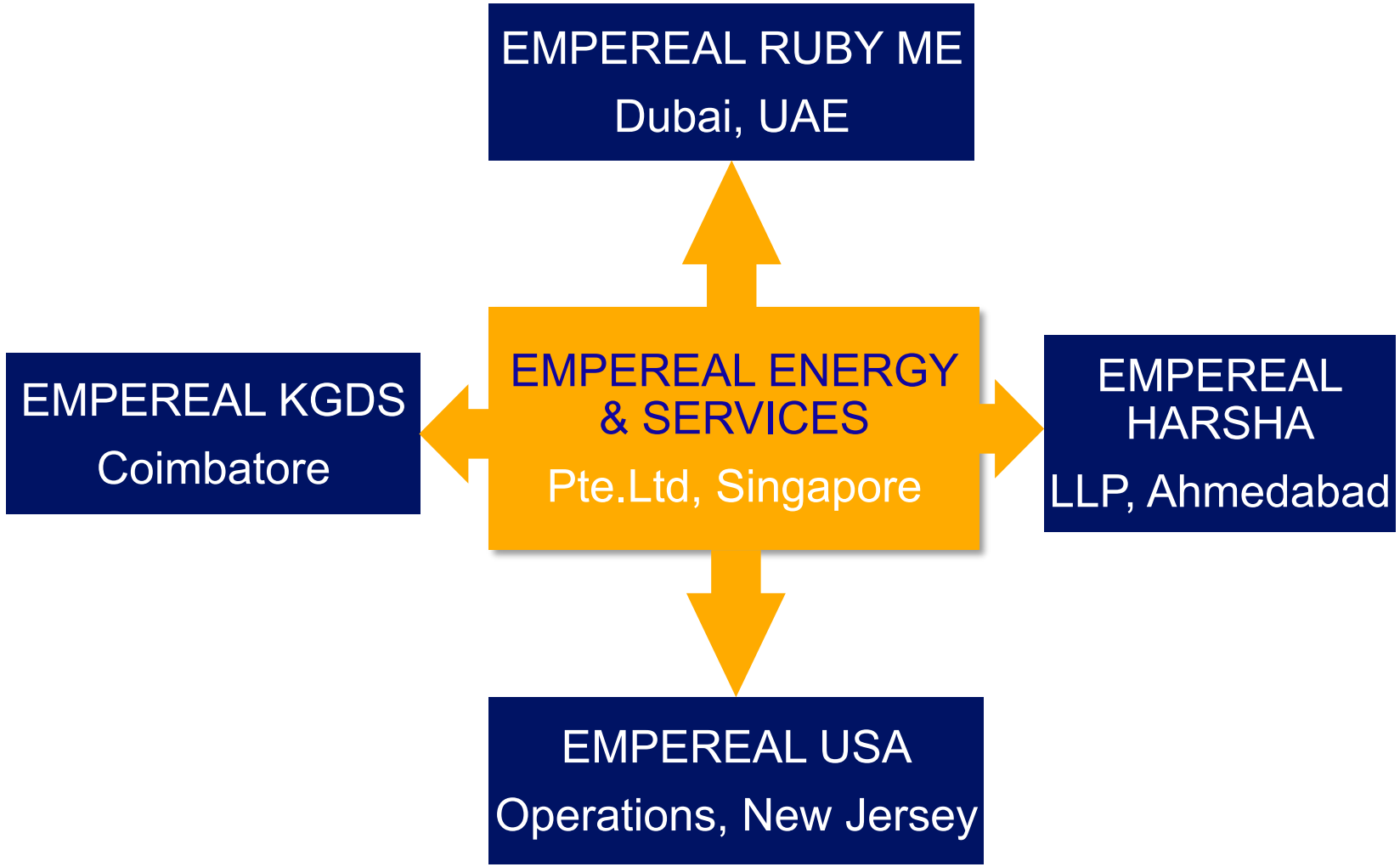
EMPEREAL BUSINESS MODELS

- Empereal operates in multiple business models
- Consulting
- Feasibility studies
- Design
- Engineering
- Financing
- Implementation
- Operating & Maintenance



EMPEREAL CORPORATE STRUCTURE

- Headquarters in Singapore
- Research and development centres in India
- Business and Project offices in Singapore, India and UAE



THE EMPEREAL ADVANTAGE

- Customizable products
- Innovative, proven and reliable solutions
- World class systems and projects at very cost effective prices
- Patented and award winning solutions
- Experienced team of professionals
- Continuous focus on research, development and excellence

Empereal
Energizing communities

THANK YOU FOR YOUR ATTENTION