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U.S. Department of Energy Gen 3 CSP Roadmap

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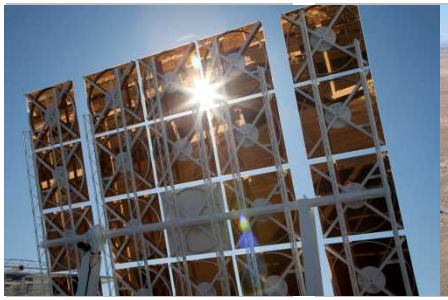

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Gen 3 CSP Roadmap

Concentrating Solar Power Gen3 Demonstration Roadmap

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Technical Report
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January 2017

Contract No. DE-AC36-08GO28308

- Goal is to develop 10 MW_e demonstration of solarized supercritical CO_2 Brayton cycle
- Identifies 3 technology pathways
  - High-Temperature Molten Salt
  - Particle Receiver
  - Gas Receiver
- Identifies and prioritizes gaps and research needs

High-Temperature Molten Salt

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Collector Field

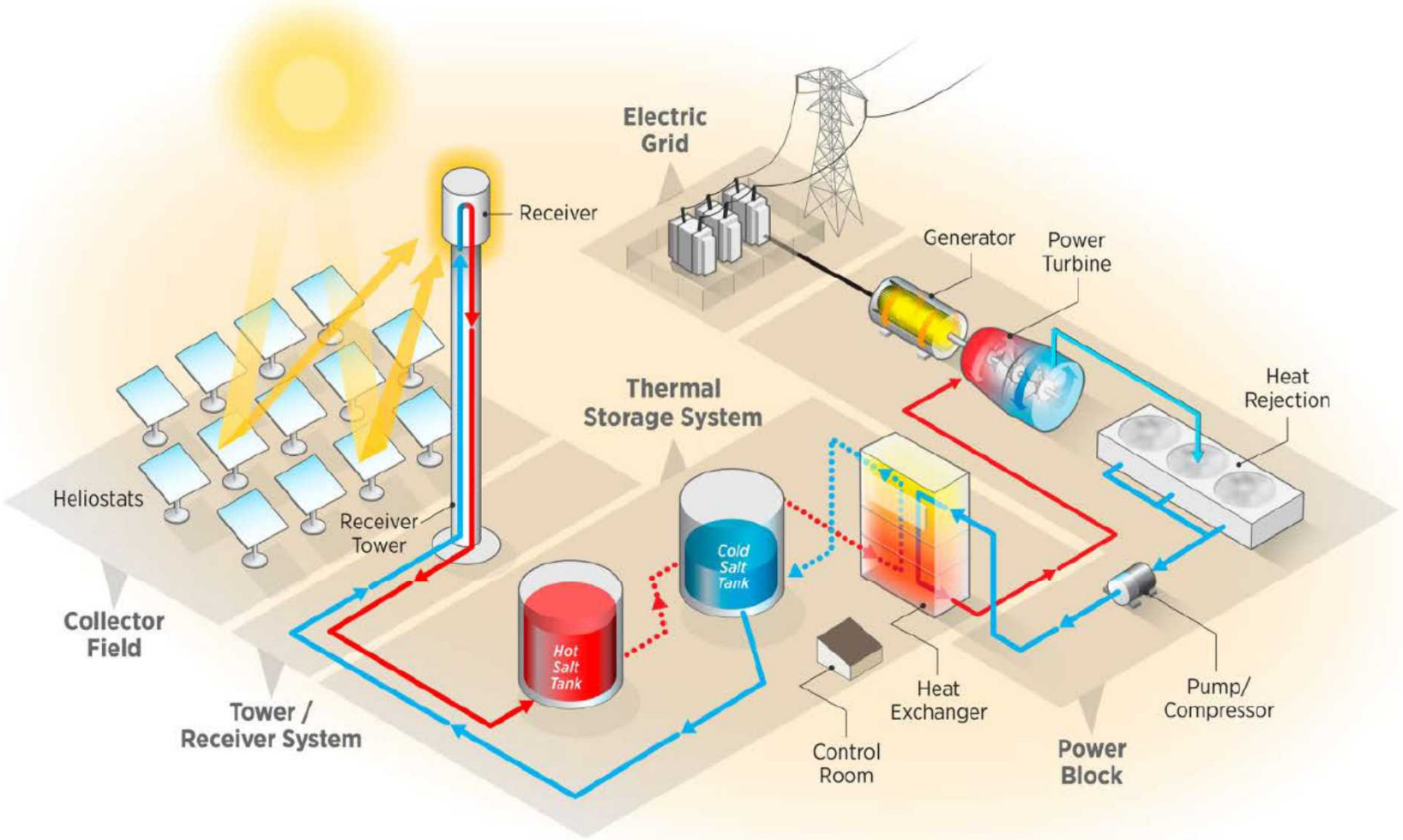
- Cost <$75/m^2
- Concentration ratio >50
- Operable in 35-mph winds
- Optical error <3.0 mrad
- 30-year lifetime

	Molten Salt	Falling Particle	Gas Phase
Receiver *Cost < $150/kWth* *Thermal Efficiency > 90%* *Exit Temperature > 720°C* *10,000 cycle lifetime*	• Similarities to prior demonstrations • Allowance for corrosive attack required	• Most challenging to achieve high thermal efficiency	• High-pressure fatigue challenges • Absorptivity control and thermal loss management
Material & Support *Cost < $1/kg* *Operable range from 250°C to 800°C*	• Potentially chloride or carbonate salt blends; ideal material not determined • Corrosion concerns dominate	• Suitable materials readily exist	• Minimize pressure drop • Corrosion risk retirement
Thermal Storage *Cost < $15/kW$_{th}$* *99% energetic efficiency* *95% exergetic efficiency*	• Direct or indirect storage may be superior	• Particles likely double as efficient sensible thermal storage	• Indirect storage required • Cost includes fluid to storage thermal exchange
HTF to sCO_2 Heat Exchanger	• Challenging to simultaneously handle corrosive attack and high-pressure working fluid	• Possibly greatest challenge • Cost and efficiency concerns dominate	• Not applicable

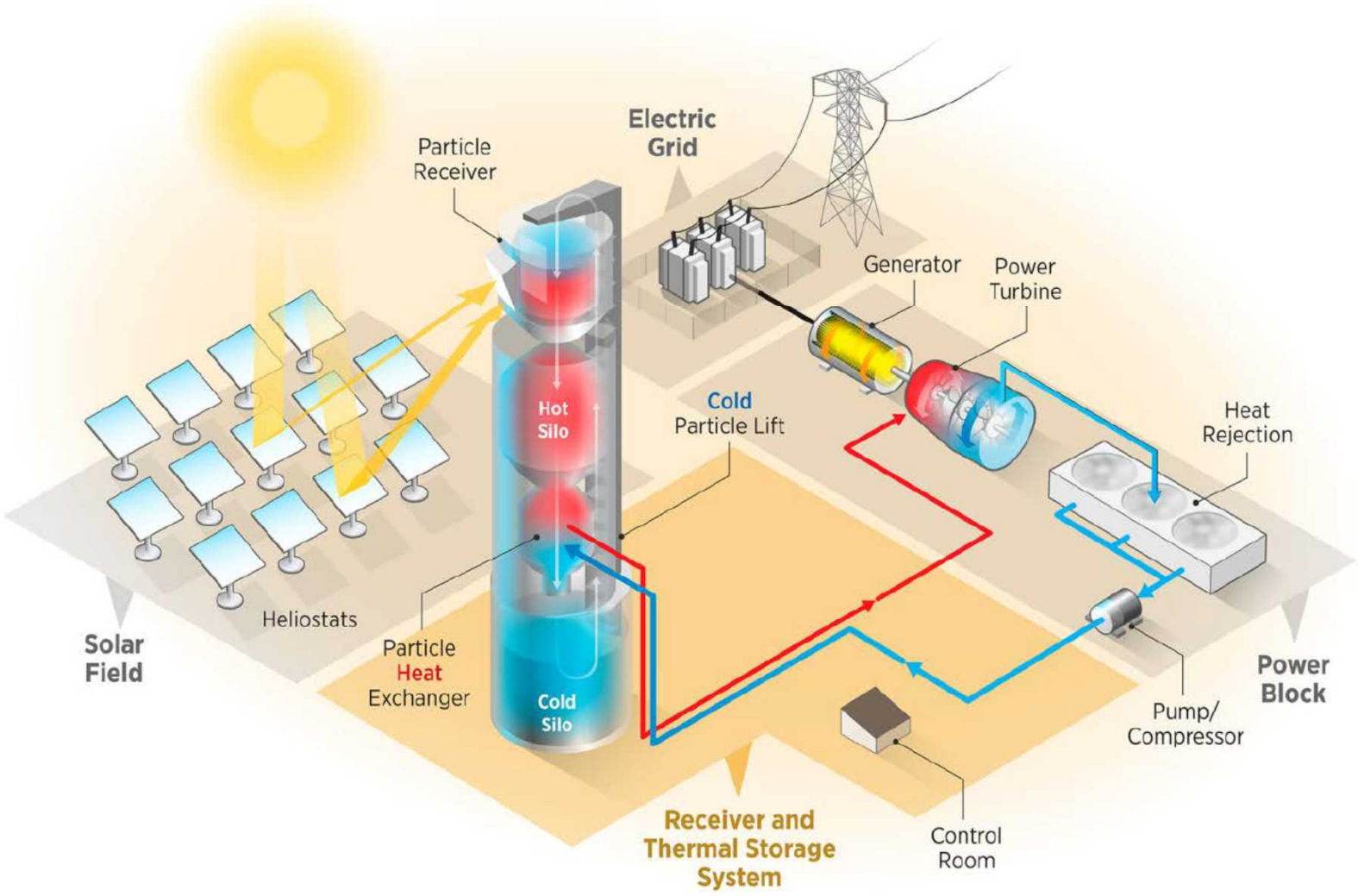
Supercritical CO_2 Brayton Cycle

- Net thermal-to-electric efficiency > 50%
- Power-cycle system cost < $900/kW$_e$
- Dry-cooled heat sink at 40° C ambient
- Turbine inlet temperature ≥ 700°C

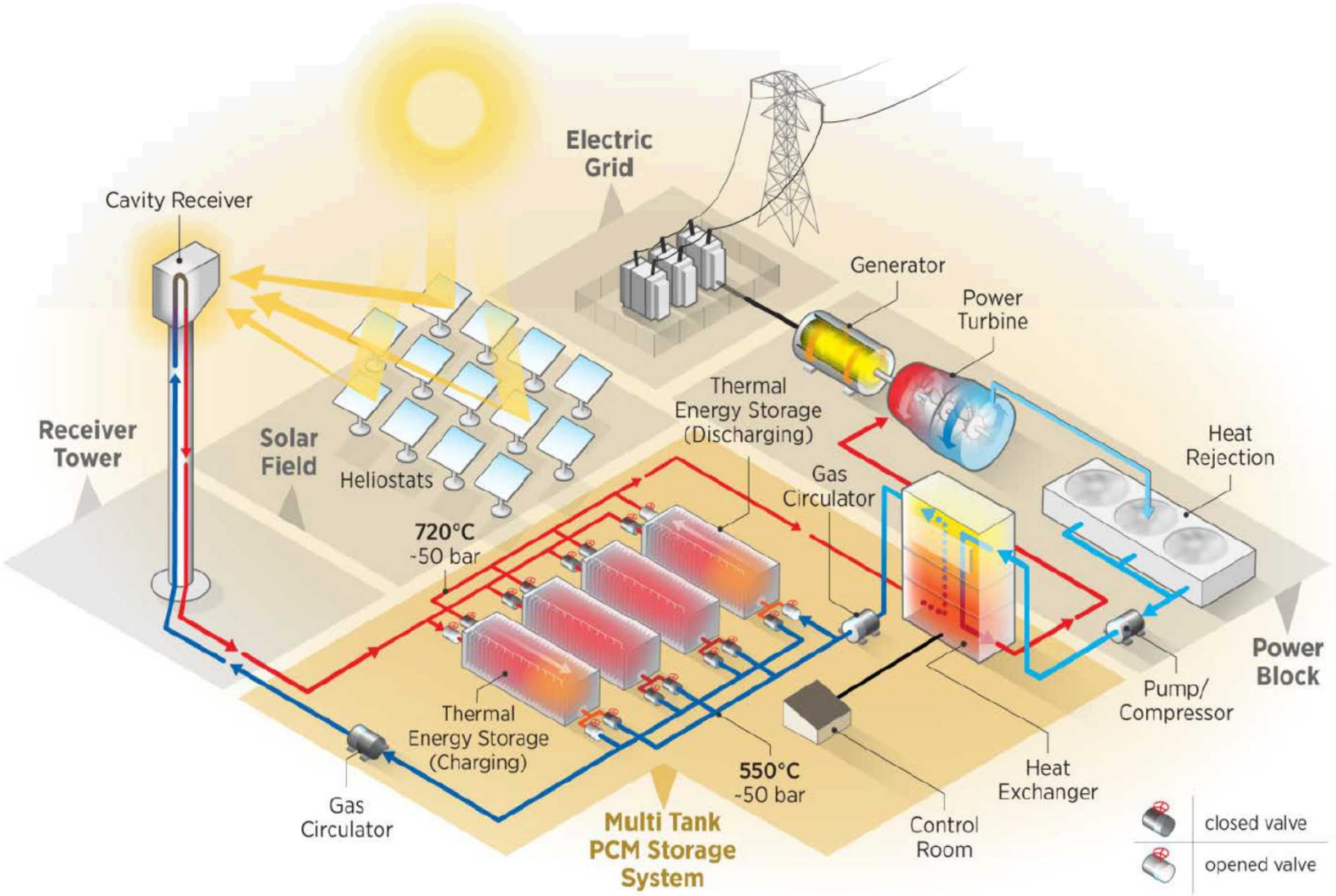
Molten-Salt System



Particle-Based System



Gas-Based System



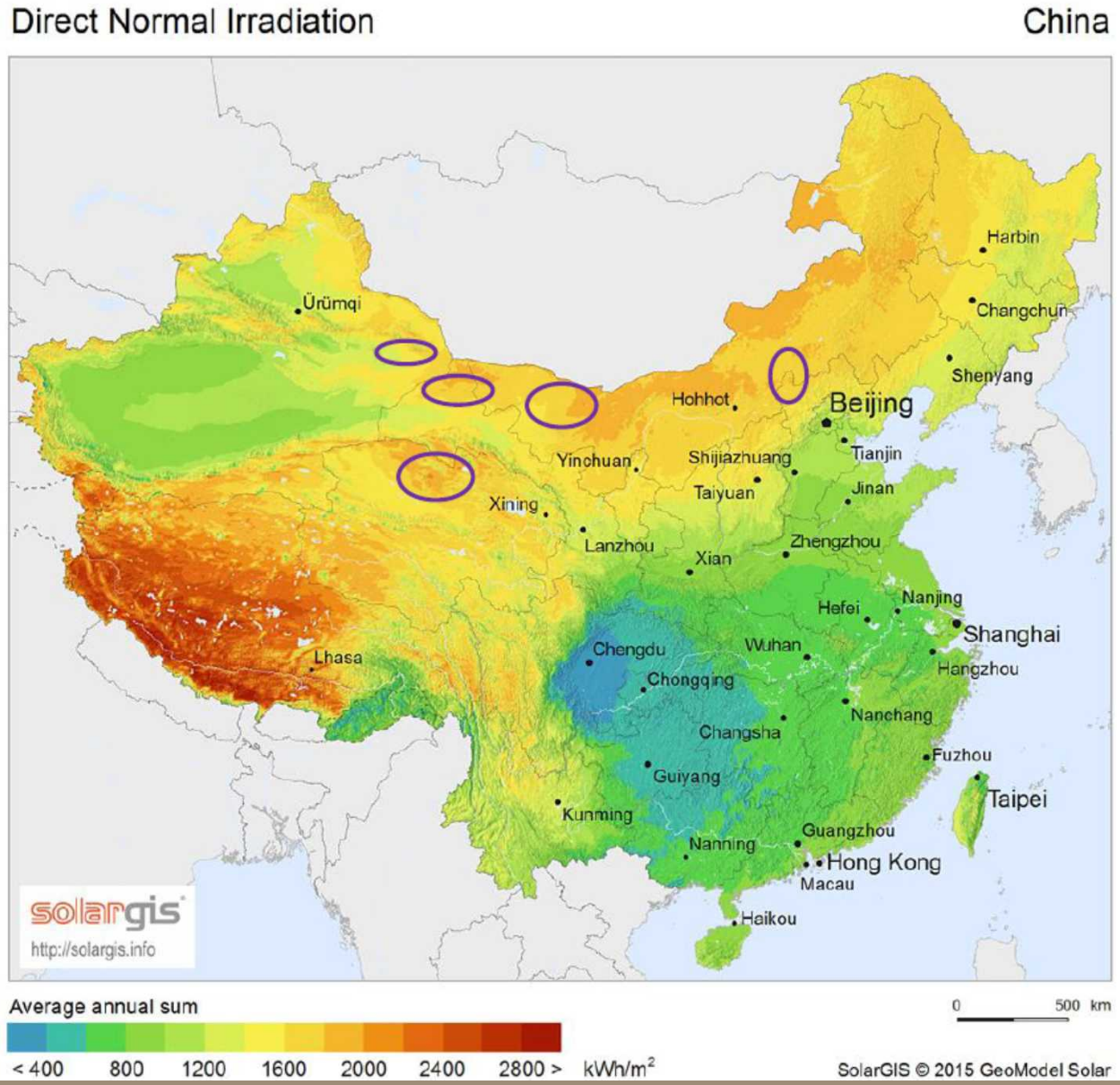
Gen 3 Funding Opportunity

- Ge 3 Funding Opportunity Announcement likely to be announced in a few months
- DOE recently announced 6-year $80M Award
  - 10 MW_e sCO_2 Brayton pilot plant
  - Supercritical Transformational Electric Power (STEP) program
  - Managed by the Gas Technology Institute, Southwest Research Institute (SwRI), and GE Global Research

CSP in China

- In September 2016, China announced 20 new CSP power plants to be deployed by end of 2018
  - 1.35 GW total
  - Feed-in tariff of 1.15 RMB kW/h (~$0.17/kWh)
  - Minimum of 4 hours of thermal storage for each plant
- Multiple CSP technologies employed
  - 9 central receivers (685 MW)
  - 7 parabolic troughs (464 Mw)
  - 4 linear Fresnel systems (200 MW)

Location of proposed CSP plants in China



Existing CSP Plants in China

SunCan Dunhuang 10 MW molten-salt central receiver plant with 15 hours of storage