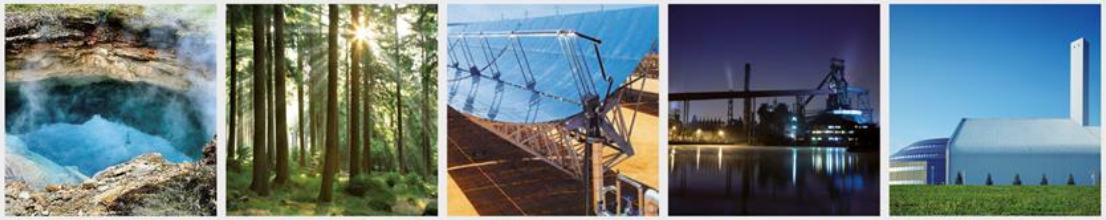


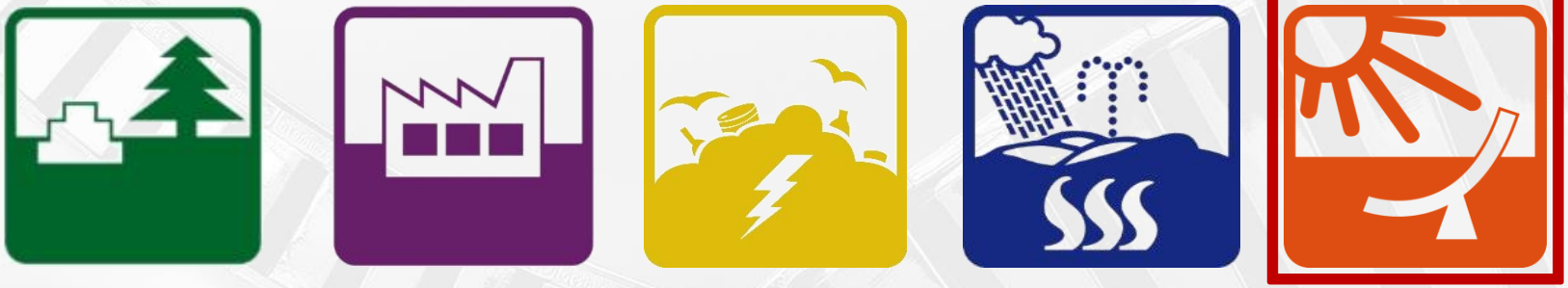
clean energy ahead
TURBODEN®
a group company of MITSUBISHI HEAVY INDUSTRIES, LTD.

Turboden Solar Thermal Power Applications

LLOYD'S REGISTER · LRQA
ISO 9001

Doc.: 12-COM.P-23-rev.13
Update: 29/05/2015

ORC Applications - Solar Thermodynamic



Biomass | Heat Recovery | Waste to energy | Geothermal | Solar Thermal Power

Solar Thermal Power

Turboden units allow to convert the heat collected by solar collectors into electricity through an efficient thermodynamic cycle. Concentrating Solar Power systems with ORC Turboden can be cost-effective in the range between 200 kW and 15 MW electric.

Copyright © – Turboden S.r.l. All rights reserved

Solar Energy Market

Solar energy can be harnessed by different technologies. Each of the technologies covers the part of the market where it can bring the highest cost-effectivness rate.

Turboden ORC mostly finds its place in industrial scale sector from 1 to 10 MWel.

Copyright © – Turboden S.r.l. All rights reserved

Italian Decree July 6th, 2012

Feed in tariff is paid for 25 years from date of commercial operation of the plant.

Plants will also be paid the market price for electricity sold

Feed in tariff in table are referred to plants that will be started up by 31st December 2015.

Feed in tariff [€/kWh el]			
Integration rate	**Up to 0.15**	**Between 0.15 and 0.50**	**Above 0.50**
Tariff added to the price of sale for plants with collecting surface up to 2500 m²	0.36	0.32	0.30
Tariff added to the price of sale for plants with collecting surface above 2500 m²	0.32	0.30	0.27

Feed in tariff will be reduced by 5% in 2016 and a further 5% in 2017.

A minimum thermal storage capacity is required:

- 1.5 kWh_{th}/m^2 of collecting surface (for plants with a collecting surface bigger than 50,000 m^2)
- 0.4 kWh_{th}/m^2 of collecting surface (for plants with a collecting surface between 10,000 and 50,000 m^2)

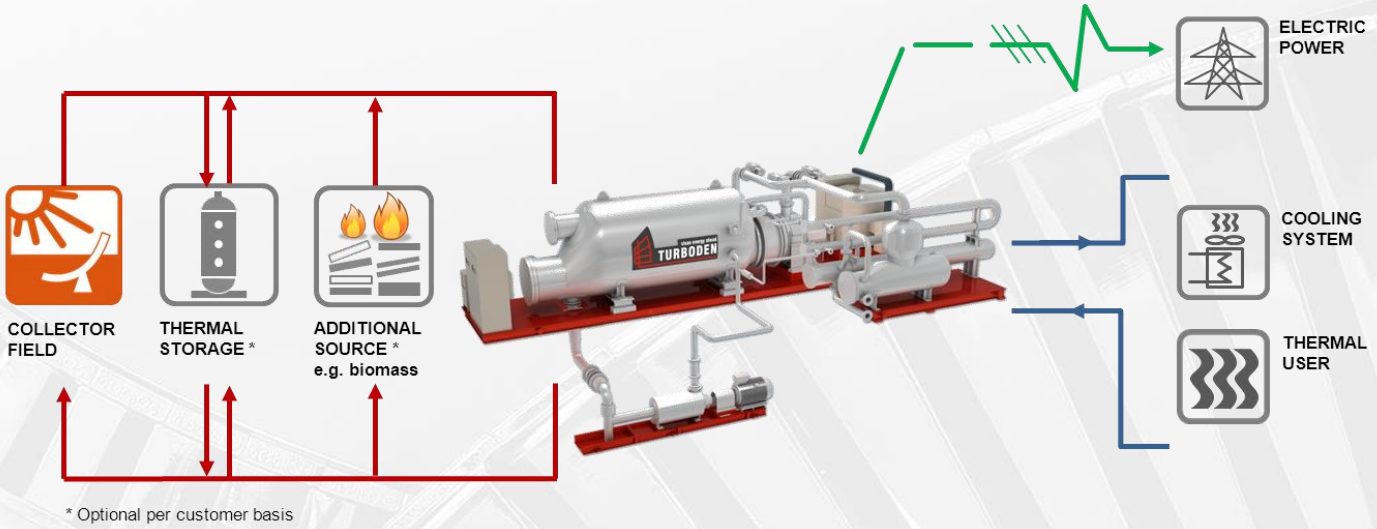
In those plants where hibridization source is renewable, integration rate is conventionally zero.

Copyright © – Turboden S.r.l. All rights reserved

Solar Thermal Power Plant with ORC unit

The ORC power block uses **organic fluid to drive the turbine** instead of a traditional high pressure steam.

This results in a **reliable**, **efficient** and **user friendly** solar thermal power plant



Turboden ORC strenghts in CSP plants

Electrical efficiency up to 26%

Capability to adapt to load variation easily and quickly

Partial load operation down to 10% of the nominal load

Direct air condenser. No water consumption

Synchronous or asynchronous generation

Remote Control operation
No operator needed on site

Low O&M requirements

Ease of hybridization with biomass or heat recovery plants

Possibility to couple to low cost/medium scale solar collectors

Possibility to use mineral/synthetic oils or saturated steam as heat transfer fluid

Copyright © – Turboden S.r.l. All rights reserved

clean energy ahead
TURBODEN®
a group company of MITSUBISHI HEAVY INDUSTRIES, LTD.

Different Heat Transfer Fluids

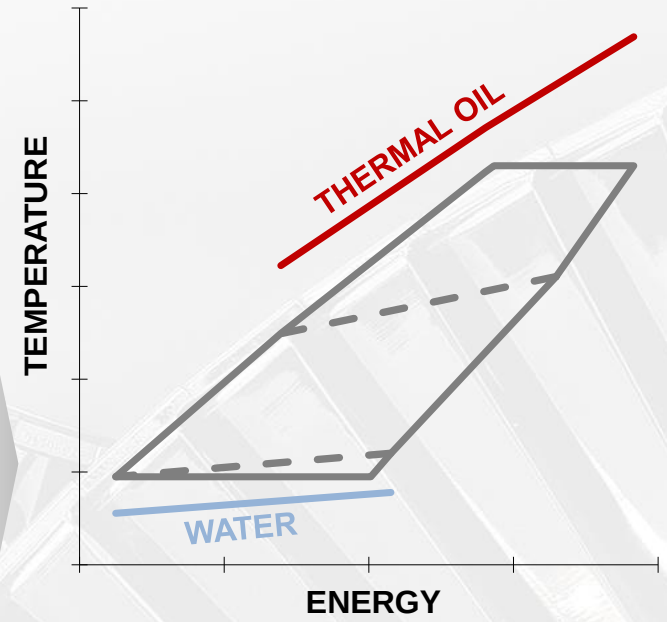
Th. oil parabolic trough system

***Figure 1**: Eurotrough solar collectors*

Th. oil linear Fresnel reflectors

***Figure 2**: FERA Fresnel solar collectors*

Turboden solution



Thermal oil (mineral or synthetic) between **250-300°C** feeds **Turboden HR** (20% electrical efficiency) or **Turboden HRS** units (24% electrical efficiency).

Partial load down to 10% of thermal power input

→ Non-harmful mineral or synthetic oil

→Thermal oil also as storage medium

→ Higher equivalent working hours considering storage

→ Heat transfer fluid working at ambient pressure

→ High ORC efficiency

Copyright © – Turboden S.r.l. All rights reserved

Different Heat Transfer Fluids

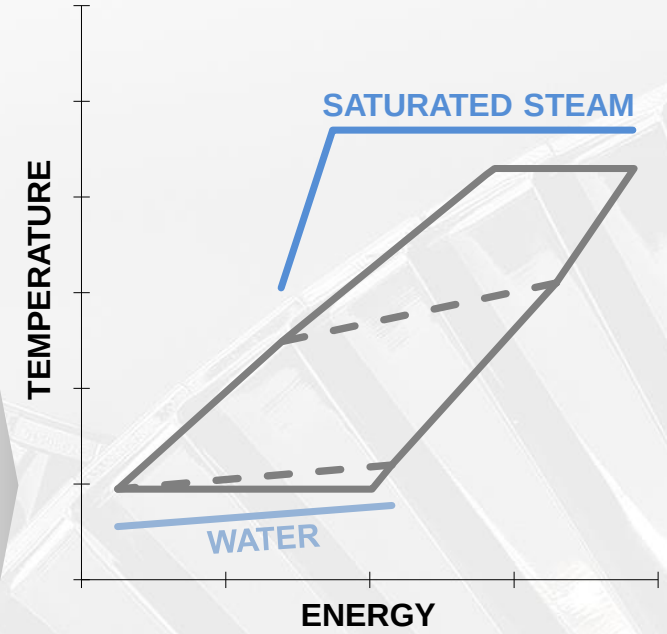
DSG linear Fresnel reflectors

***Figure 3**: AUSRA Fresnel collectors*

DSG parabolic trough system

***Figure 4**: Solarlite solar collectors*

Turboden solution



Saturated steam at **~20 barA** can feed **Turboden HR** units (20% electrical efficiency)

Saturated steam at **~60-70 barA** can feed **Turboden HRS** units (25% electrical efficiency)

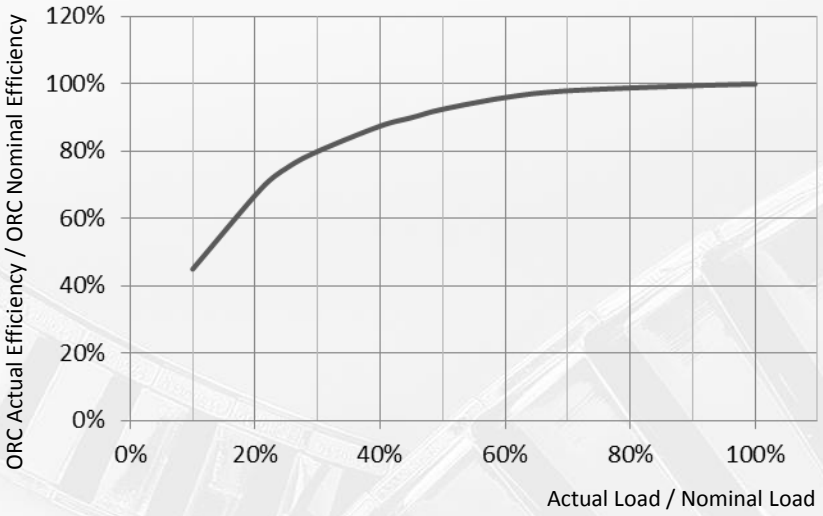
- → **Lean configuration**
- → **Lower CAPEX**
- → **Environment friendly**
- → **Partial load with saturated steam inlet even below 5 barA**

Copyright © – Turboden S.r.l. All rights reserved

Flexible and Automatic

"One of the key points in the the success of ORC technology is the capability to adapt to load variation easily and quickly"

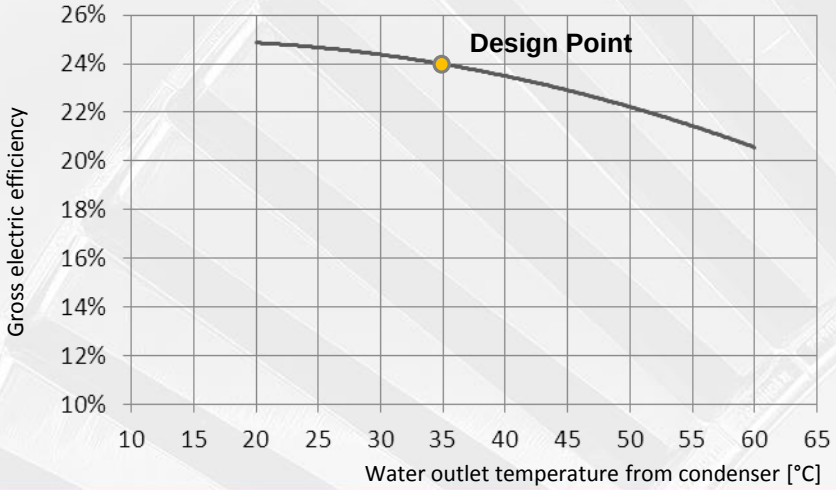
ORC Partial Load Efficiency



Part load operation down to 10% of nominal load.

Mantains 90% of cycle efficiency down to 50% of loading

Cooling water temperature effect on cycle efficiency (HRS Units)



Turboden ORC units automatically adapt the cycle at the ambient temperature variations

Copyright © – Turboden S.r.l. All rights reserved

clean energy ahead
TURBODEN
a group company of MITSUBISHI HEAVY INDUSTRIES, LTD.

Reference Plants

Customer:
Italcementi Group

Site:
Ait Baha, Morocco

DNI:
2,400 kWh/m^2_year

Turboden unit:
Turboden 18 HR (2 MW_{el})

Figure 5

Figure 6

Figure 7

Plant type:
hybrid – heat recovery from waste heat of cement factory plus solar collectors with pebble stone thermal storage

Solar field area:
Aperture area: 6,159 m^2
Nr. of string: 3
String length: 215 m
Thermal power: 4 MW_{th}
Storage capacity: 12 h
HTF: hot air

***Figure 5**: Turboden 18 HR in Ait Baha plant*

***Figure 6**: Airlight conctrete solar collector structure*

***Figure 7**: view of Italcementi cement factory in Ait Baha with solar field*

Copyright © – Turboden S.r.l. All rights reserved

clean energy ahead
TURBODEN®
a group company of MITSUBISHI HEAVY INDUSTRIES, LTD.

ENAS project

***Figure**: FERA Fresnel solar collectors.*

- **Final Customer**: ENAS (Ente acque della Sardegna)
- **EPC**: CEIF Soc. Coop. (Cooperativa Elettricisti Installatori Forlivesi)
- **Site:** Ottana (Nuoro, Sardegna)
- **Size:** 650 kW_{el}
- **Turboden unit:** Turboden 6 HR (Nominal working conditions: thermal oil 260/150°C, cooling water 25/35°C, gross efficiency 21%)
- **Plant type**: pure solar plant with 6 loops FERA Fresnel solar collectors (about 10.000 m^2) and a direct two-tanks thermal oil storage with thermal capacity of almost 5 equivalent working hours

Copyright © – Turboden S.r.l. All rights reserved

Archimede project

Figure: *Turboden 12 HRS*

- **Final Customer**: Archimede S.r.l. Società di Ingegneria
- **EPC**: Archimede S.r.l. Società di Ingegneria
- **Site:** Melilli (Siracusa, Sicilia)
- **Size:** 1180 kW_{el}
- **Turboden unit:** Turboden 12 HRS (Nominal working conditions: thermal oil 305/204°C, cooling water 25/35°C, gross efficiency 25%)
- **Plant type**: hybrid solar plant with about 8.000 m^2 solar collectors coupled to a 3 MW_{th} natural gas boiler.

Copyright © – Turboden S.r.l. All rights reserved

R&D solar projects

SOLAR project

Public-Private laboratory for the development of innovative technologies for distributed power production from Solar energy. DM 593/00 art.12 DM 19447

Description:

- Study and development of new-designed concentrated solar collectors
- Study of innovative thermal fluids with nanoparticles
- Realization of a prototype scale ORC connected to solar collectors
- Master studies for qualified energy technicians

Budget: 12,3 Meuro - Grant: 9,1 MEuro

Beneficiaries:

- Università del Salento (Coordinator)
- Università degli Studi di Catania
- CNR-IMM
- Costruzioni solari Srl
- Politecnico di Bari
- STC Srl
- TCT Srl
- Turboden Srl

EUROSUNMED project

Euro-Mediterranean cooperation on research & training in sun based renewable energies. FP7-ENERGY-2013-1

Description:

- Developing new technologies in 3 energy areas: PV, CSP and grid integration,
- Establishing strong networking between EU and MPC
- Disseminating the results of the projects

Beneficiaries:

- France: CNRS, EMRS
- Norway: Sintef, Sintef Energy
- Spain: Cener, IK4 Tekniker
- Belgium: EUREC
- Italy: Turboden
- Morocco: CNESTEN, CNRST, MASCIR, Agdal University, Al Akhawayn University, MASEN
- Egypt: Helwan University, Alexandria University, Nile Valley Engineering

Copyright © – Turboden S.r.l. All rights reserved

Turboden at a Glance

Copyright © – Turboden S.r.l. All rights reserved

Turboden strong points

R&D

- Participation in national & EU research programs
- Cooperation with EU Universities and Research Centres
- Thermodynamic cycle optimization
- Working fluid selection & testing
- Thermo-fluid-dynamic design and validation
- Implementation & testing of control/supervision software
- Many patents obtained

Sales/marketing

- Pre-feasibility studies: evaluation of technical & economical feasibility of ORC power plants
- Customized proposals to maximize economic & environmental targets

Design

- Complete in-house mechanical design
- Proprietary design and own manufacturing of ORC optimized turbine
- Tools
  - Thermo-fluid-dynamic programs
  - FEA
  - 3D CAD-CAM
  - Vibration analysis

Operations & manufacturing

- Outsourced components from highly qualified suppliers
- Quality assurance & project management
- In-house skid mounting to minimize site activities

Aftermarket service

- Start-up and commissioning
- Maintenance, technical assistance to operation and spare parts service
- Remote monitoring & optimization of plant operation

Copyright © – Turboden S.r.l. All rights reserved

Turboden – a Group Company of MHI

clean energy ahead
TURBODEN
a group company of MITSUBISHI HEAVY INDUSTRIES, LTD.

Energy & Environment

the largest segment of MHI

over $12 billion (in fiscal 2013)

Energy & Environment

Providing optimal solutions in the energy-related fields of thermal power, nuclear energy and renewable energy in different environmental areas and for Chemical plants & other industrial infrastructures elements.

Machinery, Equipment & Infrastructure

Providing a wide range of products that form the foundation of industrial development, such as machine tools, material handling, construction machinery, air-conditioning and refrigeration systems.

MITSUBISHI HEAVY INDUSTRIES, LTD.

Mitsubishi Heavy Industries is one of the world's leading heavy machinery manufacturers, with consolidated sales of over $32 billion (in fiscal 2013).

Foundation July 7, 1884

Commercial Aviation & Transport Systems

Delivering advanced land, sea and air transportation systems, including civilian aircraft, commercial ships and transit networks.

Integrated Defense & Space Systems

Providing advanced land, sea and air defense systems, including naval ships, defense aircraft, launch vehicles and special vehicles, as well as space-related services.

Copyright © – Turboden S.r.l. All rights reserved

Notes

Copyright © – Turboden S.r.l. All rights reserved