



POLITECNICO  
DI MILANO



# Field Performance Evaluation of ORC Geothermal Power Plants Using Radial Outflow Turbines

**FEDERICO MINOLI**  
Proposal Engineer

*AUTHORS*

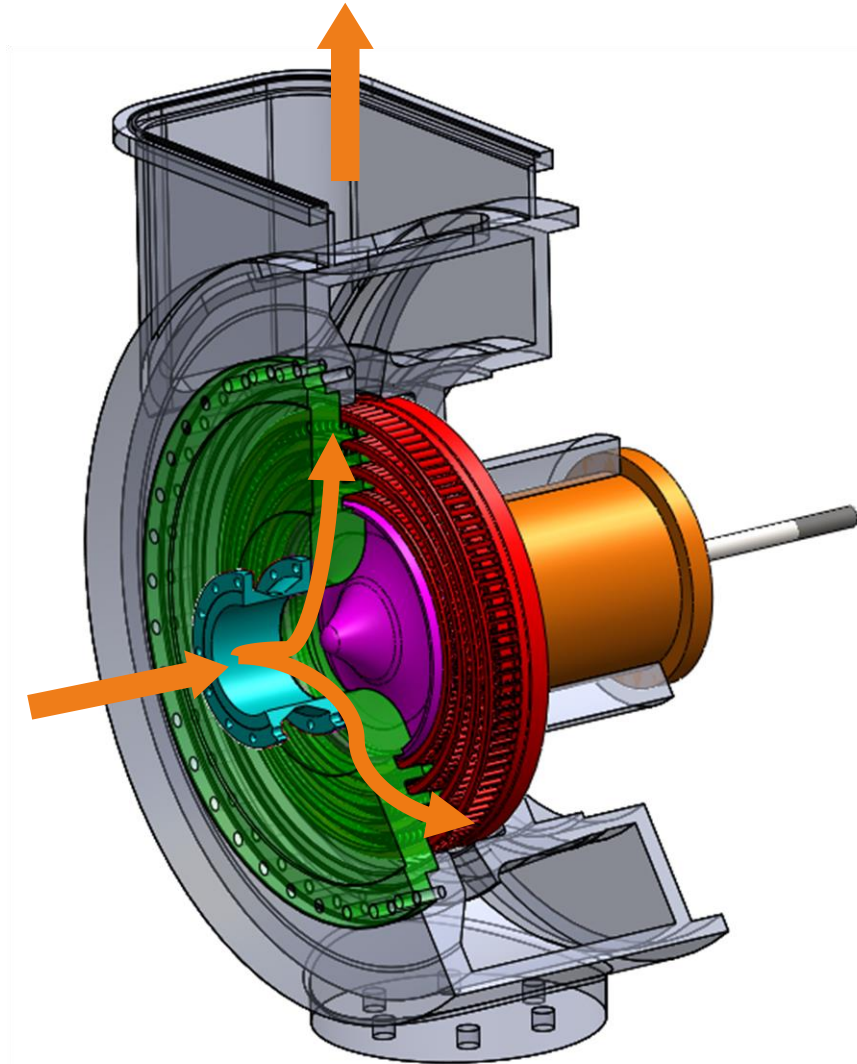
L. Zanellato,  
M. Astolfi,

E. Macchi,  
D. Rizzi

# SUMMARY

- › EXERGY's Radial Outflow Turbine technology
- › Greeneco power plant description
- › Akca power plant description
- › Experimental measurement campaign
- › Methodology: error minimization process
- › Results: Greeneco and Akca turbine efficiency
- › Conclusions

# THE RADIAL OUTFLOW TURBINE

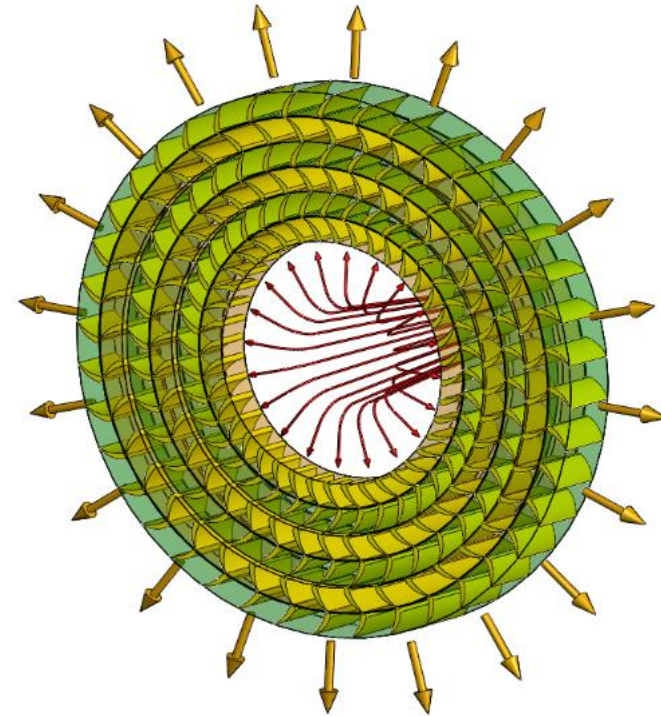


3D cross section of the radial outflow turbine

# THE RADIAL OUTFLOW TURBINE

Why choose a centrifugal (outflow) turbine to expand a fluid?

- › **Excellent Match** between volumetric flow and the cross section
- › **Straight blades**
- › **Easy maintenance:** mechanical group fast substitution
- › **Lower vibration**



Only the Radial Outflow Turbine allows multiple pressure admissions on a single disk.

GREENECO  
ENERJI,  
SARAYKÖY 1,  
TURKEY

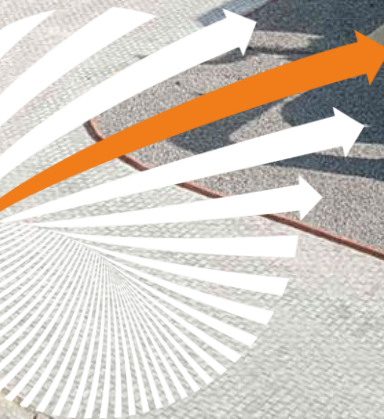
YEAR: 2015  
APPLICATION: GEO  
POWER: 12 MW



**EXERGY**

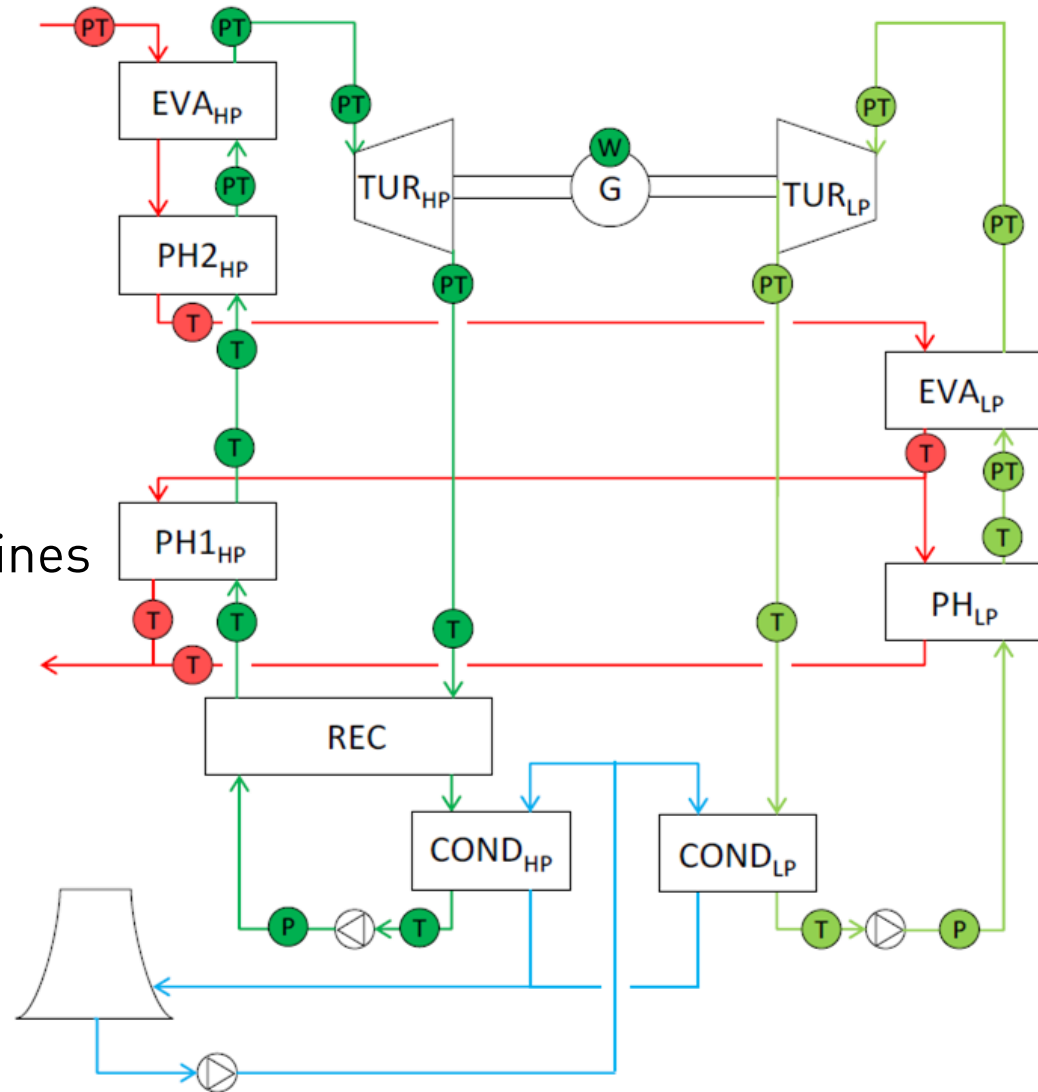


Gruppo  
Industriale  
Maccaferri



# GREENECO

- > Steam = 20 tons/hr
- > Brine = 1350 tons/hr
- > T source = 135°C
- > 2 pressure levels, 2 turbines
- > Water cooled (20°C)
- > Isopentane
- > 12 MW gross



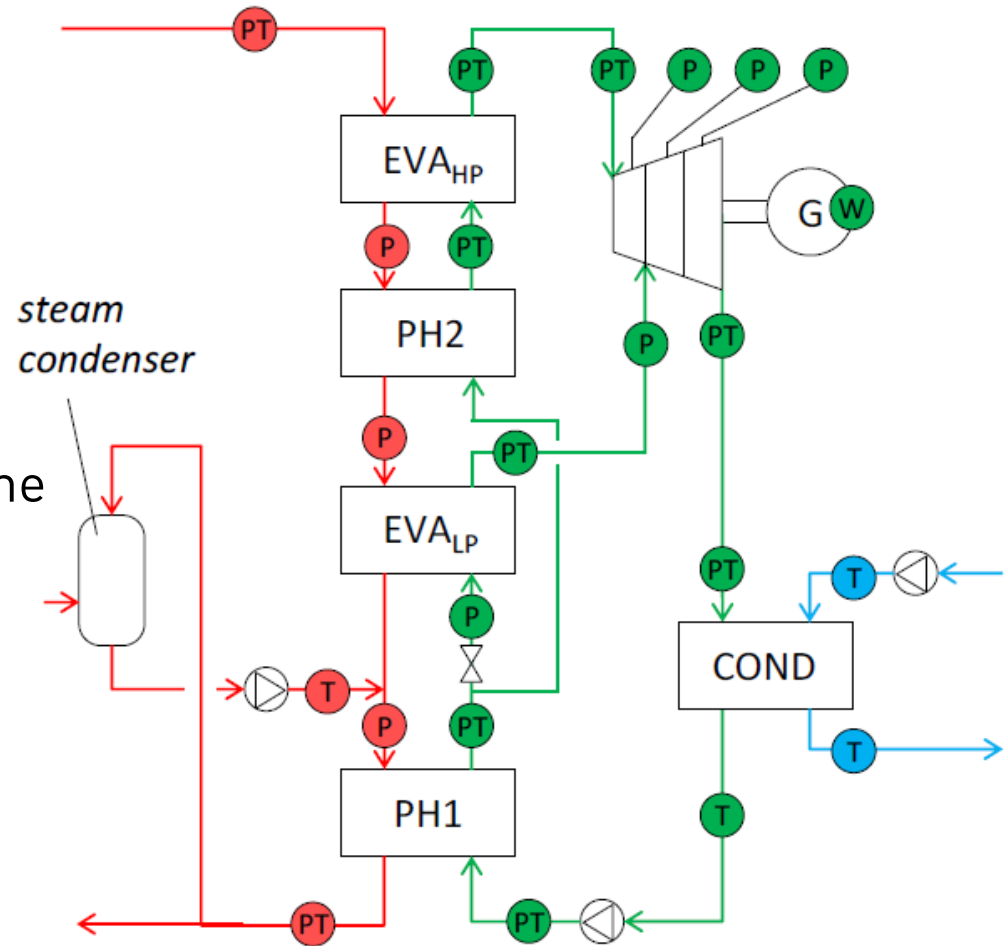


# AKÇA ENERJİ DENİZLİ, TURKEY

YEAR: 2014  
APPLICATION: GEO  
POWER: 4 MW

# AKCA

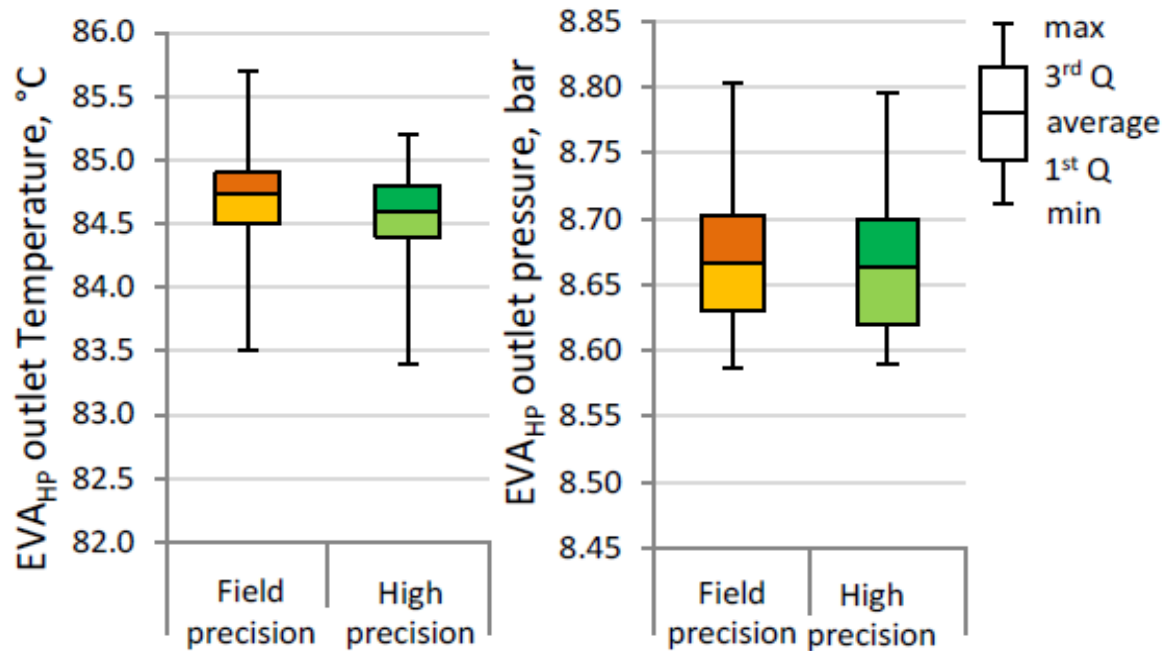
- > Steam = 8.8 tons/hr
- > Brine = 691 tons/hr
- > T source = 105°C
- > 2 pressure levels, 1 turbine
- > Water cooled (18°C)
- > Refrigerant
- > 3.9 MW gross





# EXPERIMENTAL MEASUREMENTS

- › Integration of higher precision instrumentation
- › Analysis on 20 minutes of instruments data every 5 seconds



# METHODOLOGY

$$\eta = \frac{(h_{in} - h_{out})}{(h_{in} - h_{out,is})}$$

BUT....Turbine efficiency is very sensitive to outlet temperature

(2°C means 8%)



Increase the consistency of the analysis

- › Turbine inlet conditions verified with RefProp
- › Turbine flow rate is verified with factory measurement on turbine geometry
- › Heat and mass balances at each component
- › Gross power output check

ITERATIVE ERROR MINIMIZATION PROCESS

# RESULTS

- > GREENECO: brine mass flow rates converge with turbine outlet temperature inside instrument accuracy (+/- 0.25°C)
- > AKCA: turbine efficiency and LP evaporator pinch point converge with turbine outlet temperature between the 2 measured values



- >  $\eta$  Greeneco HP = **85.5 %**
- >  $\eta$  Greeneco LP = **88.4 %**
- >  $\eta$  Akca = **92.0 %**

# CONCLUSION

- › Direct calculation of turbine efficiency from measurements is affected by uncertainty even for high precision instrumentation



- › Consistency of measured data checked with heat and mass equations and energy output ✓
- › Exergy turbines result in a very high efficiency
- ›  $\eta$  Greeneco HP = **85.5 %**
- ›  $\eta$  Greeneco LP = **88.4 %**
- ›  $\eta$  Akca (patented 2 pressure levels on a single disk) = **92.0 %**



operating  
hq

## HEAD OFFICE

Via degli Agresti, 6  
40123 Bologna (BO) ITALY

## OPERATING HEADQUARTERS

Via Santa Rita, 14  
21057 Olgiate Olona (VA) ITALY  
Tel +39 0331 18 17 711  
Fax +39 0331 18 17 731

[EXERGY-ORC.COM](http://EXERGY-ORC.COM)

[INFO@EXERGY.IT](mailto:INFO@EXERGY.IT)