




**E-RATIONAL**  
VALUE FOR HEAT


E-RATIONAL is a BEP Europe division  
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Electricity from  
Low Temperature waste heat  
with  
Organic Rankine Cycle  
Guy De Graeve- BEP Europe

1-2-2012 2/31





**BEP Europe** 

- BEP Europe is part of an international group with HQ in US, global sales network and production facilities in US, China and Belgium.
- BEP Europe in Brugge, Belgium :
  - >100 people
  - 7500 m<sup>2</sup> production facilities, including machining, welding, assembly, testing
  - Automotive, Clean Energy
  - Approx. 20 M€ turnover/year


since 2008 

ORC


since 1996 

since 1986 

history






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BEP Europe's long Track record as Equipment manufacturer

- Automation projects
- End of line testing equipment for automotive industry
- "Wheel and tyre" assembly
- Equipment for energy recovery

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VALUE FOR HEAT

Projectgroep Biomassa & WKK  
**BIO WKK**

**E-Rational's mission** is to provide sustainable energy solutions based on common sense: No Heat To Waste!

With our E-rational machines, low grade waste heat is transformed to virtually free green electricity

**E-rational stands for a rational, logical approach of sustainable energy production.** With a subtle hint of irrationality in our brand name, we want people to start thinking about current irrational energy approaches and use again their common sense.

Consistent reasoning combined with proven facts has led to our E-rational product range

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The multiple "E" of E-Rational

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**Worldwide Energy consumption**

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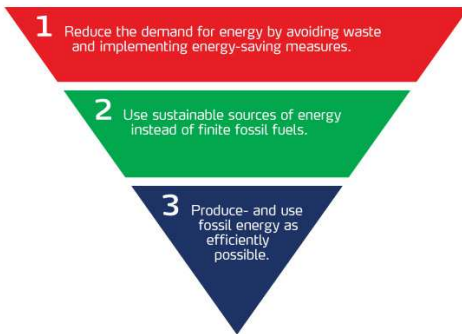
**Energy concern**

Renewable energy Consumption by Source  
(US DOE-EIA Energy Survey 2006)

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**E-RATIONAL** VALUE FOR HEAT **Energy efficiency** Projectgroep Biomassa & WKK **BIO WKK**

**The Trias Energetica concept:**  
the most sustainable energy is saved energy.



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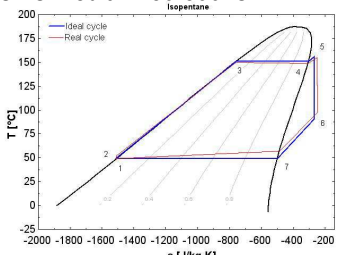
**E-RATIONAL** VALUE FOR HEAT **Energy efficiency** Projectgroep Biomassa & WKK **BIO WKK**

- Avoid fuel consumption
- Use best technology to reduce energy consumption
- Avoid energy losses
- Heat recovery:
  - Re-use as heat source: 100% efficiency ⇒ Do it!!
  - Distribute (sell) heat: 100% efficiency ⇒ Do it !!
  - No other use of heat ⇒ ORC is possible solution

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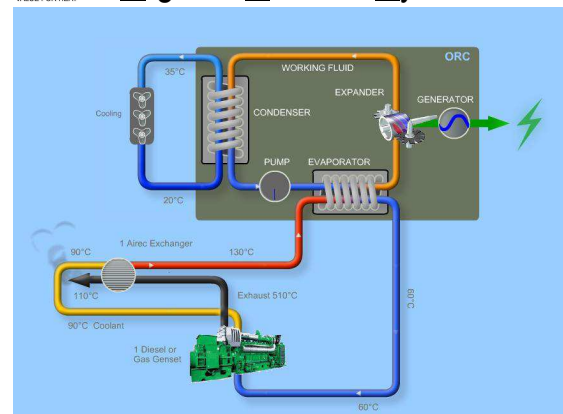
**E-RATIONAL** VALUE FOR HEAT **Organic Rankine Cycle** Projectgroep Biomassa & WKK **BIO WKK**

- Rankine cycle: Steam cycle: high temperature and pressure
- Organic: use of cooling fluid → Low temperature
- Waste heat transformed into electricity
- Working range ORC medium: 50-300°C



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**E-RATIONAL** VALUE FOR HEAT **Organic Rankine Cycle** Projectgroep Biomassa & WKK **BIO WKK**



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**E-RATIONAL** VALUE FOR HEAT **Projectgroep Biomassa & WKK BIOWKK**

## "Fuel" for ORC?

- Waste heat which is lost anyway:
  - Engines, CHP (gas, bio gas, diesel, ...): jacket cooling + exhaust gas
  - Low pressure (waste) steam
- Industrial processes:
  - Steel, glass industry
  - Combustion processes (bio fuel, waste incineration )
  - Exothermic processes in chemical industry
  - Petrochemical industry: cool down distillates
  - Power plants
- Geothermal applications, District heating; CSP
- Fluids and gases

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## Efficiency of ORC

Parameters for efficiency

- "Carnot" Efficiency : only theory
- Hot side
- Cold side: the colder the better
- Efficiency of ORC components: fluid, expander, generator, ...
- Real ORC efficiency: fraction of Carnot : 30-50%
- Optimise external users: cooling circuit, pumps

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## Efficiency of ORC

Carnot Efficiency :  $\eta = 1 - \frac{T2}{T1}$

Whereas  
 T1 is Hot Side (K)  
 T2 is Cold Side (K)

Carnot for cold side: 25°C = 298 K

400°C:	55,7%
200°C:	36,9%
120°C:	24,3% => ORC: 8,5 – 11%
90°C:	17,9% => ORC: 6-8%

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## Efficiency of ORC

### Influence of cold side on efficiency

Hot Side Temp (°C)	10°C Cold Side	20°C Cold Side	30°C Cold Side	40°C Cold Side	50°C Cold Side
70	6.5	5.5	4.5	3.5	2.5
80	7.5	6.5	5.5	4.5	3.5
90	8.5	7.5	6.5	5.5	4.5
100	9.5	8.5	7.5	6.5	5.5
110	10.5	9.5	8.5	7.5	6.5
120	11.5	10.5	9.5	8.5	7.5
130	12.5	11.5	10.5	9.5	8.5
140	13.5	12.5	11.5	10.5	9.5
150	14.5	13.5	12.5	11.5	10.5

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## How to define potential

Parameters:  
 Medium: water, oil, steam, exhaust gas  
 Density and heat capacity of the medium  
 Flow  
 $\Delta T$ : temperature in and out  
 Cooling of the ORC

$$Q = m \cdot c_p \cdot \Delta T$$

$m$  : mass flow in kg/s  
 $c_p$  : heat capacity of hot side in kJ/kgK  
 $\Delta T$ : Temperature interval between in and out in K  
 $Q$  = Thermal power in kW

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## Some examples

Hot water:  
 Flow: 27,78 kg/s (100 m<sup>3</sup>/h)  
 Specific heat capacity water: 4,19 kJ/kgK  
 $\Delta T$ : cool down from 130°C to 90°C  
 Thermal Power: 4 656 kWth

Thermal oil:  
 Flow: 2,27 kg/s (11m<sup>3</sup>/h)  
 Specific heat capacity 2,5 kJ/kgK,  
 Density: 742 kg/m<sup>3</sup>  
 $\Delta T$ : Cool down from 200°C to 100°C  
 Thermal Power: 567 kWth

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## Some examples (2)

Low Pressure Steam:  
 Flow: 0,8 kg/s (2,8 T/h)  
 Evaporation heat at 150°C: 2 107 kJ/kg  
 $\Delta T$ : Cool down from 150°C till 100°C and condense  
 Thermal Power: 1 391 kWth

Flue gases:  
 Flow: 20,72 kg/s (100 000 Nm<sup>3</sup>/h)  
 Specific heat capacity air at 200°C: 1,026 kJ/kgK,  
 Density at 200°C: 0,746 kg/m<sup>3</sup>  
 $\Delta T$ : Cool down from 260°C till 160°C  
 Thermal Power: 2 126 kWth

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## ORC project

- ORC-unit
- Hot side: heat recovery
- Cooling
- Piping
- Electrical connection
- Installation
- Permits

Use the produced power or sell to the grid?  
 Incentives?

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## Example of project

### Bio gas Engine

COOLING DEVICE  
Rated Cooling capacity = 1000 kWth

BEP ORC  
Total heat input = 1808 kWth  
Total electrical power = 220 kW

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## E-Rational ORC Units

- Range scalable from 50 kW<sub>e</sub> – 250 kW<sub>e</sub>
- Modular design
- Expander using Z-screw technology
- Use of standard components:
  - Optimised cost
  - Reliable and durable concept
  - Low maintenance

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## E-Rational 50

- Bruto 50 kW<sub>e</sub>- 400V AC 50Hz
- ORC medium: Honeywell r245fa or Solkatherm
- Input Temperature: 80-150°C
- Thermal Power > 650 kW<sub>th</sub>
- Extended software control
- Automatic connection to the grid
- Size: 2300 x 1830 x 1525 mm
- Weight: 3 tonnes

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## E-Rational ORC Unit

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## E-Rational 250


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- Bruto 250 kW<sub>e</sub>- 400V AC 50Hz
- ORC medium: Honeywell r245fa or Solkatherm
- Input Temperature: 80-150°C
- Thermal Power 3 MW<sub>th</sub>
- Extended Software control
- Automatic connection to the grid
- Size: 20 ft container (6m x 2,5m x 2,6m)
- Weight 25 Tonnes

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**E-RATIONAL** VALUE FOR HEAT **E-Rational production** Projectgroep Biomassa & WKK **BIO WKK**

Example (values per year)

50 kWe \* 8 000 h = 400 000 kWh = 400 MWh  
 250 kWe \* 8 000 h = 2 000 000 kWh = 2 000 MWh

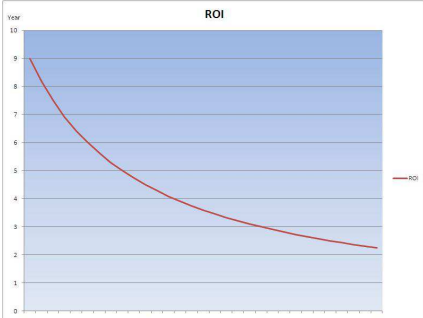
Compare:

4 000 m<sup>2</sup> PV → 320 MWh → 224 Tonnes CO<sub>2</sub> → 91 households  
 2 MW Wind turbine 4 400 MWh → 3 080 Tonnes CO<sub>2</sub> → 1257 households  
 50 kW ORC → 400 MWh → 280 Tonnes CO<sub>2</sub> → 114 households  
 250 kW ORC → 2 000 MWh → 1 400 Tonnes CO<sub>2</sub> → 570 households

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**E-RATIONAL** VALUE FOR HEAT **E-Rational Applications** Projectgroep Biomassa & WKK **BIO WKK**

- Generated power can be used or sold
- Green energy certificates
- Short ROI
- High IRR



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