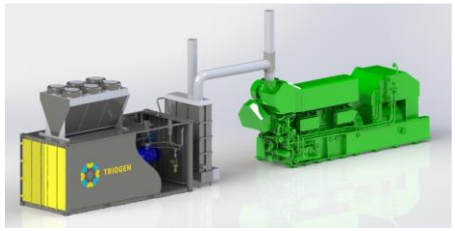
Triogen

Power From Heat

ORC 2017, Milano, 14-09-2017



Triogen Group B.V.
Nieuwenkampsmaten 6-01
7472 DE Goor
The Netherlands

15 years of innovation and product development results in a market ready product Triogen ready to tackle international markets (outside EU)

Milestones in the history of Triogen

2001

Founded by Prof. Jos van Buijtenen

Development work with Lappeenranta University (Finland).

2002

First experimental unit developed.

The founders of Aan de Stegge Mechanical become shareholder.

2005

Installation of a **demonstration unit** at a landfill site in the Netherlands.

Duration tests for 1.5 years.

2008

5 beta-units installed and running.

Development of standardized unit WB-1.

2010

Yellow & Blue becomes shareholder.

TU Delft starts turbine development.

2012

First units installed in biomass applications.

Wadinko becomes shareholder.

2013

First sales in Czech Republic, Italy, and Belgium.

Introduction of WB-1 Vario.

Development of new turbine nozzle, increasing output.

2015

2016

Launch of the “e-box”, Triogen’s next standard, containerized ORC with significantly lower cost.

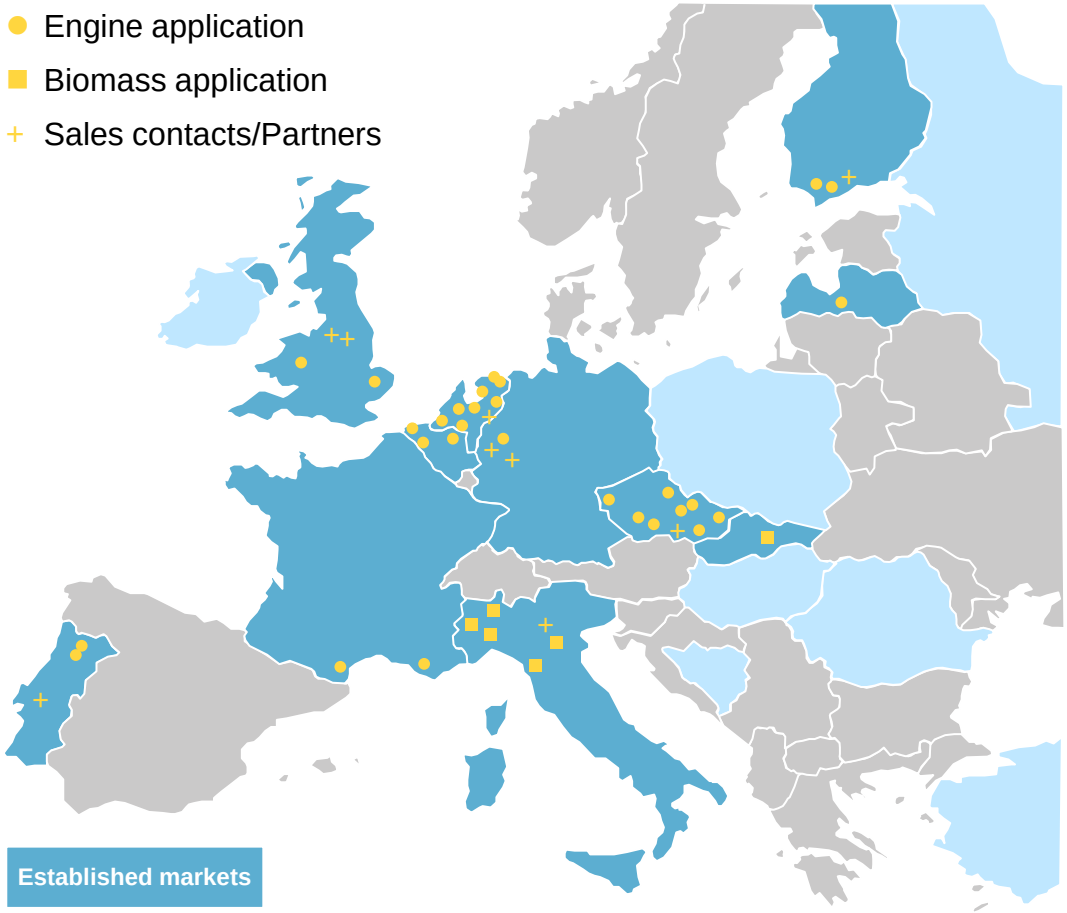
2017

ORC Development → First Generation ORC: WB 1 → **New Generation ORC: e-box**

Triogen's joint sales efforts with its network of distributors have lead to more than 40 units installed all over Europe

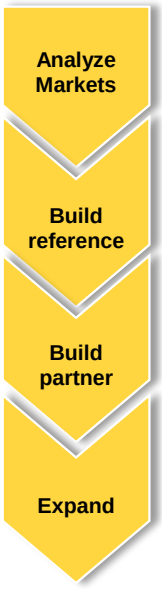
Triogen ORC installations map across Europe

- Engine application
- Biomass application
- \+ Sales contacts/Partners



Market Development Stages

- **Triogen operates a two-tier sales organization:**
  - Direct sales for: new, NL + neighboring markets and fleet owners
  - Distributors cover operational regional markets
- **Observations:**
  - Consistent pricing to avoid channel conflict
  - Sales partners with ORC experience are welcome, no need for exclusivity



1. Identify markets/applications with attractive business cases
2. Find potential projects direct and mature the opportunity
3. Attract potential distributors based on 1. and 2.
4. Create references by aggressively pursuing first projects
5. Ensure quality projects by substantial technical support / turnkey install by Triogen
6. Train distributors to handle follow up projects more independently
7. Add and expand distributor network
8. Expand application base in the market

The Triogen ORC uses heat that can originate from may sources

Residual or waste heat can be found in

- **Exhaust gases from**
  - gas engines
  - diesel engines
  - gas turbines

Fuelled by fossil fuels or:
landfill gas, biogas, bio-diesel, mine gas, sewage gas

- **Various industrial processes**
  - petro-chemical
  - food & dairy
  - base-metal
  - glass, cement, brick manufacturing
- **Combustion of fuels not suitable for use in internal combustion engines and turbines (off-spec fuels)**
  - residuals and waste
  - biomass, wood
  - Flare gas (landfill gas, industrial flares)

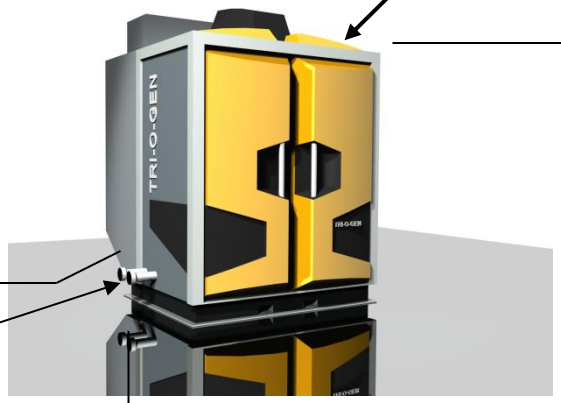
Example of the application of the Triogen ORC

Engine application

Engine Exhaust Gas
600 – 1200 kW_{heat}
350 – 550 °C

Gas / Diesel Engines
1 – 2 MW_e

ORC Exhaust Gas
180 - 220 °C



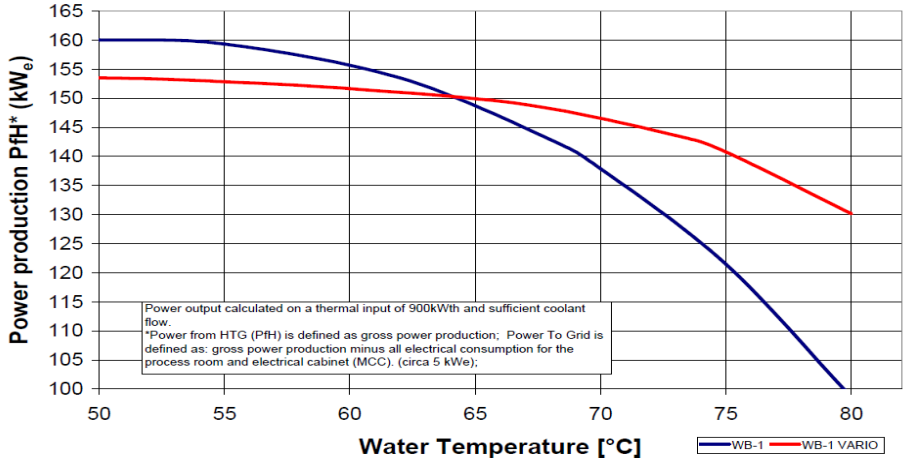
ORC Power
80 – 175 kW_e

Tin: 35 - 70 °C

T_{out}: 55 - 80 °C

Condenser Cooling Water
400 – 700 kW_{heat}

The Triogen ORC CHP @ varying condensation (coolant) temperatures



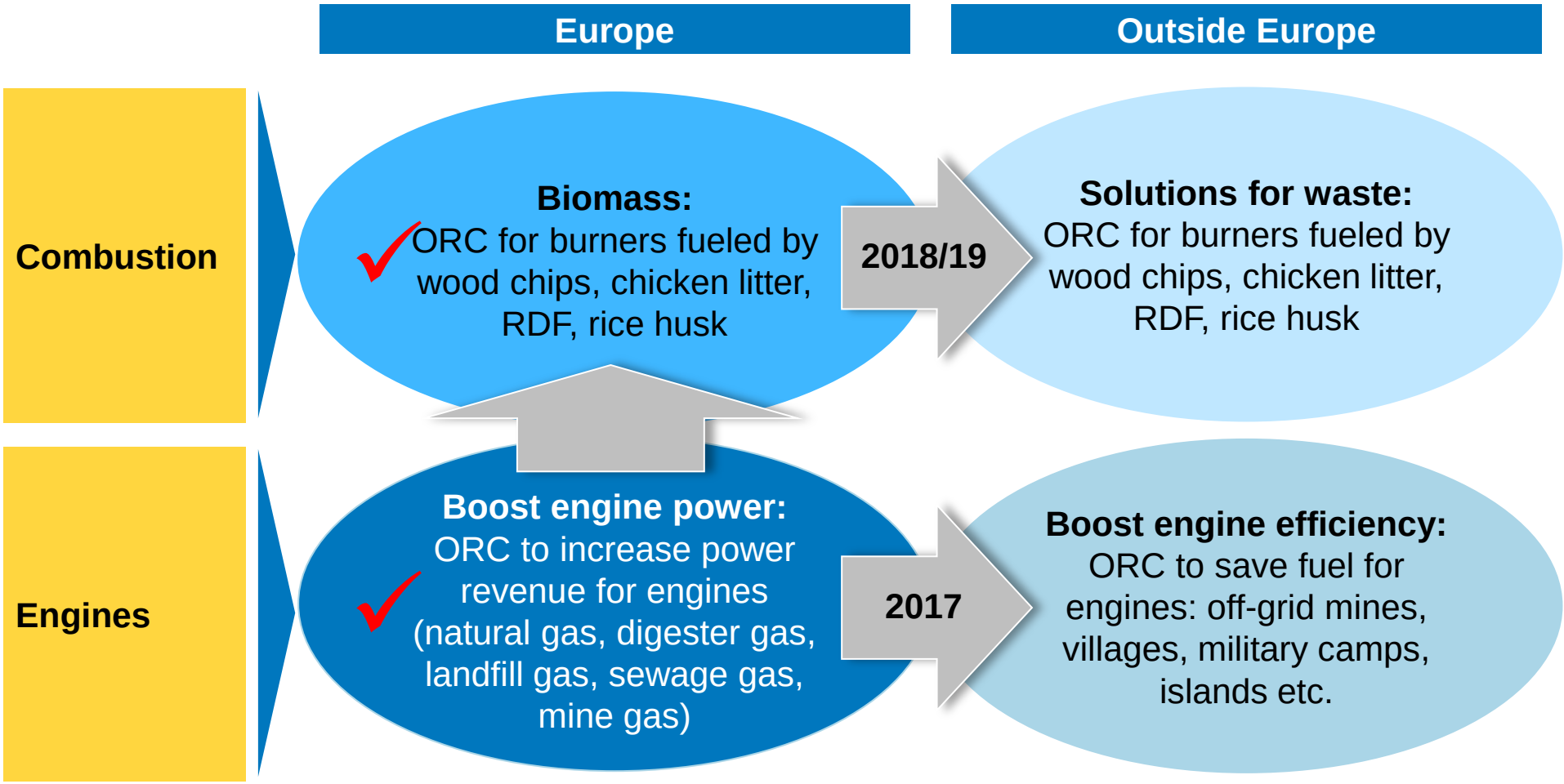
Example of the application of the Triogen ORC

Biomass

- Solid biomass can not be used directly for generation of electricity
- Biomass can be combusted in furnaces and boilers
- Flue gases from furnaces can be fed to an ORC evaporator
- Triogen system can absorb high temperature (< 600 °C) flue gas
- High temperature flue gas heat suitable for conversion into electricity
- Low temperature residual heat is still available for heating and drying purposes
- Five plants in operation/commissioning in Southern and Eastern Europe
- Evaporator with special cleaning device to remove flue gas dust

From the basis of engines in Europe, Triogen is growing into new applications and regions

Market segmentation



Triogen has developed its next standard, the e-box a Highly standardized ORC

e-box, based on over 900.000 hours of operational experience

- **Standard 20 ft shipping container**
  - Holds all process equipment except for the heat supply and heat rejection systems
- **Designed to minimize total cost**
  - Parts
  - Production
  - Transport
  - Installation
  - Commissioning
  - Maintenance
- **Furthermore to meet customer requests:**
  - Better pricing
  - Increased robustness
  - Easier installation
  - Simpler user interface
- **The core** (turbo generator, process values, controls etc.) **remain unchanged initially**

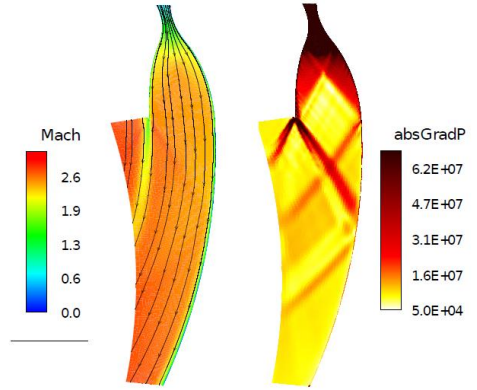
Approach

- Divide the system into groups
- Determine for each component in each group its function
- Determine if this function is necessary, if it can be combined or if it can be achieved in a more cost effective way

Next steps in development for the e-box

Future, component development, First results to be tested Q2 2018

- (increased power up to 200+ kW_e)
  - New turbine blade shapes under development @ TU Delft based on fundamental knowledge developed from government sponsored project
  - Improve electrical generator and inverter @TU Eindhovenon fundamental knowledge developed from government sponsored project
  - New HTG bearing system to further increase robustness and reduce losses
- Next step in containerization
  - Heat supply and heat rejection systems in a second 20 ft shipping container



(a) Mach Number contour (b) Pressure Gradient Contour

Questions?

www.triogen.nl