October 5th, 2017 Dubrovnik, Croatia

CE-HEAT: Comprehensive model of waste heat utilization in CE regions

Saša Erlih, E-zavod, Ptuj, Slovenia
CONTEXT OF THE PROGRAMME

146 MILLION CITIZENS
246 MILLION EUROS ERDF
9 PROGRAMME COUNTRIES
4 THEMATIC PRIORITIES
76 REGIONS AND CITIES
10 SPECIFIC OBJECTIVES

TAKING COOPERATION FORWARD
35 projects approved in first call

**Priority Axis 1**
Cooperating on innovation to make CENTRAL EUROPE more competitive
- Technology/Innovation Transfer
- FabLabNet
- NUCLEI
- 3DCentral

**Priority Axis 2**
Cooperating on low carbon strategies in CENTRAL EUROPE
- Public buildings
  - TOGETHER
  - ENERGY@SCHOOL
- Public infrastructure
  - Dynamic Light
- Energy planning
  - CitiEnGov
  - CE-HEAT
  - GeoPLASMA-CE

**Priority Axis 3**
Cooperating on natural and cultural resources for sustainable growth in CENTRAL EUROPE
- Natural heritage and biodiversity
  - UGB
  - Sustree
- Water management
  - AMIIGA
  - PROLINE-CE
- Waste and resource efficiency
  - STREFOWA

**Priority Axis 4**
Cooperating on transport to better connect CENTRAL EUROPE
- Heritage sites and historic buildings
  - RESTAURA
  - COME-IN!
- Intangible cultural heritage
  - ECRR
  - YouInHerit
  - InduCult2.0
- Freight transport
  - ChemMultimodal

**Social Innovation**
Focus IN CD

**Entrepreneurship**
CERiecon

**Innovation Financing**
PPi2Innovate
CROWD-FUND PORT

**Innovation Ecosystems**
URBAN INNO
Trans3Net

**Innovation Management**
I-CON

**TAKING COOPERATION FORWARD**
Background

- The challenge was identified as one of the pressing issues at the global and local scale - with little success in the past.
- In order to improve governance in waste heat utilization, better and comprehensive planning, but also monitoring tools are needed.
- Additionally to these, strategic solutions has to be integrated into policies on regional/local level.
Main objective

Improving governance of energy efficiency in Central Europe by increased exploitation of waste heat - endogenous Renewable energy source.
APPROACH

TWP1 - Creating digital waste heat cadastres in regions
Providing planning and monitoring tool

TWP2 - Waste heat utilization toolbox
Providing tools for waste heat utilization investment development

TWP3 - Pilot projects
Implementing Testing Evaluating

TWP4 - Upgrading local, regional and national waste heat management
Waste heat utilization action plans Trainings Transnational platform

Increased waste heat utilization in Central Europe
MAIN OUTPUTS

7 DIGITAL GIS CADASTRES
developed and integrated into existing cadastres

1 WH UTILIZATION TOOLBOX & PLATFORM

for planning and management of WH utilization investments (guidelines and manuals for planning and management)

7 PILOT PROJECTS

3 strategic low-carbon planning, 4 thematic projects

7 REGIONAL WH UTILIZATION ACTION PLANS
developed and integrated into low-carbon strategies

TAKING COOPERATION FORWARD
RELATED INITIATIVES

European Union

- Heat Atlas Flanders (BE)
- RES Atlas Bavaria (DE)
- Heat Roadmap Europe (Horizon 2020)
RELATED INITIATIVES

Slovenia

• EnGIS - web-portal visualization of renewable energy sources in Slovenia (presentation of RES / overview of RES potentials)
• New platform in development (BORZEN)
Integration of stakeholders into project activities

• Establishment and involvement of Regional steering groups
• Putting the Waste heat into discussion

Facilitate investments

• Creation of platform for investors
• Stressing importance of WH utilization on CE level and beyond
Identification of WH sources and creation of GIS cadastres

- Developed WH cadastre for Thuringia (Germany)
- Establishment of preliminary cadastre for Friuli Venezia Giulia
- Others to follow
E-zavod (SLO), CE-HEAT coordinator

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+386 02 749 32 26

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twitter.com/ce-heat
Waste heat recovery using ORC for bottoming IC engine

Aleš Hribernik, University of Maribor
Content

- Introduction
- ORC model
- Economic model
- Results and discussion
- Conclusions
WASTE HEAT RECOVERY TECHNOLOGIES

Waste heat recovery technologies

Active
- Waste heat to heat (WHTH)
  - Mechanical vapour compressor (MVC)
  - Sorption heat pump
- Waste heat to cold (WHTC)
  - Sorption chiller
- Waste heat to power (WHTP)
  - Steam Rankine Cycle
  - Organic Rankine Cycle
  - Kalina Cycle

Passive
- Heat exchangers
- Thermal Energy Storage (TES)
Exhaust gases leaving the IC engine flow through the super-heater, evaporator and preheater, and reject their heat to the working fluid before being released to the atmosphere. High pressure working fluid vapour expands in the turbine and then enters the condenser, where the exhausted vapour first rejects heat to the vapour cooler and finally condenses to the liquid phase. The condensate is then pumped to the working pressure and fed to the system of heat exchangers to produce fresh high pressure superheated vapour.
A simple model written in Excel was developed to determine the main system operational parameters. ORC operational points 1 through 7 are calculated, when the fresh vapour thermodynamic state \((p_1, T_1)\) and condensation temperature \(T_3\) are set as input data. Using the REFPROP database as an Excel Add-in, it was possible to find all other thermodynamic states, turbine and pump specific work and thermodynamic efficiency of the system.
R134a was used as ORC working fluid with critical temperature and pressure at 101.06 °C and 4.059 MPa, respectively. Condensation temperature was set constant at 35 °C while evaporator pressure and fresh vapour temperature $T_1$ were changing. When the evaporator pressure was set constant, a simple trial and error procedure was used to find the optimal fresh vapour temperature $T_1$ at which the thermal efficiency is the highest.
Electricity Production Cost \((EPC)\) can be estimated as:

\[
EPC = \frac{C \cdot R + M}{E}
\]

where:
- \(C\) - capital cost of the ORC system,
- \(R = \frac{i(1+i)^{time}}{(1+i)^{time}-1}\) - capital recovery factor,
- \(E\) - ORC system annual electricity output,
- \(M\) - operating and maintaining annual cost.
Capital cost is the sum of the capital cost of each system component, including the cost of assembling:

\[ C = C_T + C_P + C_{PH} + C_E + C_{SH} + C_{VC} + C_C \]

Any component capital cost was adopted from the literature.

- Turbine capital cost:  \( C_T = f_T(P_T) \)
- Pump capital cost:  \( C_P = f_P(P_P, \Delta p_P) \)
- Heat Exchanger cost:  \( C_{HE} = f_{HE}(A_{HE}) \)
HEAT TRANSFER AREA OF HEAT EXCHANGER

The plate type heat exchangers were applied due to their compactness and high heat transfer coefficients. The heat transfer area is calculated as:

\[ A_{HE} = \frac{\dot{Q}}{U \Delta T_m} \]

where:

\( \dot{Q} \) - heat flow rate,
\( U \) - overall heat transfer coefficient,
\( \Delta T_m \) - logarithmic mean temperature difference.
Overall heat transfer coefficient is calculated from:

\[
\frac{1}{U} = \frac{1}{\alpha_h} + \frac{l}{k} + \frac{1}{\alpha_c} + R_f
\]

where: 
- \(\alpha_h\) - heat transfer coefficient at the hot side,
- \(\alpha_c\) - heat transfer coefficient at the cold,
- \(l\) - plate thickness,
- \(k\) - plate conductivity,
- \(R_f\) - fouling resistance for both surfaces of the plate.
RESULTS

Both ORC and the economic model were applied in a parametric study to investigate the parameters that influence thermodynamic and economic effectiveness of the bottoming ORC system.

A commercial diesel generator set is considered as a topping system. The engine is an inline 6 cylinder 4 stroke supercharged diesel engine.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical power output (kW)</td>
<td>235.8</td>
<td>Engine speed (rpm)</td>
<td>1501</td>
</tr>
<tr>
<td>Torque (Nm)</td>
<td>1500</td>
<td>Fuel consumption (kg/h)</td>
<td>47.79</td>
</tr>
<tr>
<td>Exhaust temperature (°C)</td>
<td>519</td>
<td>Exhaust mass flow (kg/h)</td>
<td>990.79</td>
</tr>
</tbody>
</table>
RESULTS

Electricity production cost

- EPC reduces with $p_{ev}$;
- EPC to high.
RESULTS

ORC investment cost structure at $p_{ev} = 3$ MPa

Vapour cooler + Superheater

- CT: 14.14%
- CP: 9.76%
- CPH: 2.14%
- CE: 15.83%
- CSH: 7.45%
- CVC: 6.94%
- CC: 20.09%

TAKING COOPERATION FORWARD
ORC operating with saturated vapour

- EPC and $\eta_t$ have extreme values;
- Maximal thermal efficiency reduces;
- Minimal EPC reduces by 0.05 EUR/kWh.
** RESULTS **

** ORC influence on topping IC engine **

- Back pressure increases with $p_{ev}$;
- Maximal corrected thermal efficiency reduces;
- $\eta_{t,corr}$ extreme moves to lower $p_{ev}$.

$$y = 3.036E-06x^2 + 1.454E-03x$$

$R^2 = 1.000E+00$

![Graph showing the relationship between back pressure increase (kPa) and IC engine power reduction. The graph includes a curve with points indicating the behavior of different parameters such as $\eta_t$, $\eta_{t,corr}$, and $\Delta p_{bp,i}$ as a function of evaporator pressure (MPa). The y-axis represents the IC engine power reduction in percentages, while the x-axis shows the back pressure increase in kPa.](image_url)
Exhaust gas temperature influence on $EPC$, power and cost of ORC system
Exhaust gas flow rate influence on $EPC$, power and cost of ORC system
CONCLUSIONS

- Electricity Production Cost does not correlate proportionally with the thermal efficiency. A thermodynamically more efficient ORC working with superheated vapour does not attain higher economic efficiency than a simple ORC working with saturated vapour; moreover, the estimated Electricity Production Cost was more than 15% higher.

- Pressure drop at the exhaust gas side of heat exchanger can reduce the topping IC engine output power substantially, therefore, special attention has to be paid to hold pressure drop low even at the cost of increased investment cost of the heat exchanger.

- High exhaust gas temperature and mass flow rate improve the economic viability of an ORC system the most. Both increase ORC power faster than system cost. Therefore, the Electricity Production Cost reduces with exhaust gas temperature and mass flow rate.
THANK YOU FOR YOUR ATTENTION!
Czech Institutional Setting of Waste Heat Utilization and Construction of a Local Central Heating System in the Context of People’s Preferences

CE HEAT / National energy savings center / Ondrej Vojacek
WASTE HEAT UTILIZATION IN CR: INSTITUTIONAL SETTINGS

• Broader context:
  • 38.1% of the Czech households is supplied with the district heating systems (1.5 mil households)
  • 1800 central heating sources over 5 MW
  • 31% of all fuels used in energy sector in CR goes into heat generation (out of which is 68% domestic fuels - mainly coal and wood)
  • 57% => the share of heat supply over 300 MWth input
  • 75% => share of heat produced in co-generation
  • 400 entities in EU ETS
WASTE HEAT UTILIZATION IN CR: INSTITUTIONAL SETTINGS

- Supporting schemes in the Czech Republic: Enterprise and Innovations for Competitiveness
  - PA 3.2.: Increase of energy efficiency of the commercial sector (*main criteria are CO₂ emissions reduction and final energy consumption reduction*)
  - PA 3.4.: Use of low-carbon technologies in the fields of energy treatment and secondary raw materials usage
  - PA 3.5.: Increase of the efficiency of the district heating systems

- Operational program Environment
  - Improving the quality of air in towns and cities
  - Waste and material flows, environmental burdens and risks
  - Energy savings
WASTE HEAT UTILIZATION IN CR: INSTITUTIONAL SETTINGS

- Other important general barriers:

- Third side access to the networks => stability of waste heat supplies

- Huge amount of regulations in energy sector
  - 2 energy acts
  - 30 public notices
  - Several hundred technical norms
  - Not well working Energy regulatory office (LR discussion)
  - etc.

- Building law act (very long approval procedures with not given deadlines)
CASE STUDY OF SKRIPOV VILLAGE
CURRENT SITUATION

- Skřípov village/city: 350 inhabitants

- Office furniture manufacturer
  (Big amount of wood waste from production)

- Currently: 2 boilers (aprox. 2MW)

- Existing small district heating (within the town of Skripov) aprox. 100 metres from the company distance (18 households + municipal buildings)

- Current price of the heat EURO 13/GJ (tax included)
COMPANY DRIVERS TO CHANGE

• New emission limits: needed installation retrofit

• Additional wood waste since 2019 (moving 2nd part of the factory from Opava to Skripov)

• Burning biomass at zero cost vs. storage costs (EUR 76 000/year)

• Possibility of covering own electricity consumption

• Extension of the current district heating

• Planned: solar power plant on the roof of the new building
In order to find out the demand for joining the Skripov district heating the research in the Skripov city was done
THE RESEARCH AMONG HOUSEHOLDS

• Methodology: the questionnaire distributed together with the local newspaper

• Return rate only 38% (133 households responded)

• Current heating:
  □ Coal (35%)
  □ Wood (41%)

Spending on heating:
  □ EUR 380 - 680 /year (28%)
  □ EUR 680 - 1060 /year (37%)
  □ EUR 1060 - 1450 /year (21%)
WILLINGNESS TO CHANGE HEATING

• Over 50% (answer „Yes“)
• Potential of 83% (answer „maybe“)

• Main reasons initiating the change:
  □ Lower price
  □ Easier operation
  □ No maintenance
WILLINGNESS TO CHANGE HEATING

- lower price
- easier operation
- more ecological
- no maintenance
- no revisions (boiler/chimney)
- higher safety
- subvention
- higher reliance
- connection to a private network
- connection to a public network
REASONS WHY NOT TO CHANGE HEATING

- Initial investment
- Heat price increase after the investment is done

= legitimate reasons

![Pie chart showing reasons why not to change heating]

- Initial investment: 45.3%
- Increase in price after the investment: 36.0%
- Inconvenience of implementation: 7.0%
- Dependence on someone else: 3.5%
- Other reasons: 8.1%
HOUSEHOLD´S TRADE OFF

• Switching to the central heating system has both: benefits and risks
• The central heating system is:
  □ Easier to operate
  □ Requires little maintenance and effort
  □ Requires investment
  □ Is more expensive

Households need to consider these factors before making the decision

It is difficult to design system without the knowledge of the concrete heat demand
CONCLUSIONS

• Long tradition of the central heating in the Czech Republic

• Currently several programs for energy efficiency running => not any of them focused directly to the waste heat utilization

• Generally energy investments in the Czech Republic complicated: many pointless administrative burdens

• Potential of heating in the village not utilized
  □ Burning the wooden chips is economically viable

• Households are hesitant
  □ The new technology is costly
  □ User-friendliness may not outweigh the monetary costs
Ondrej Vojacek / Jan Brabec / Lenka Zemkova
National centre for Energy Savings / Jan Evangelista Purkyně
University in Ústí nad Labem
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12th SDEWES Conference, CE Heat Special session
5th October 2017, Dubrovnik

Recycling Management in Biogas Plant

CE 622 CE-HEAT, Forschung Burgenland GmbH, Johann Binder
BIOGAS PLANT - CE HEAT

Situation in Austria

Example 1
Biogas Plant
WOLF

Example 2
Biogas Plant
STREM

Challenges
Recommendation
Recycling Management in Biogas Plant

Situation in Austria

- 300 Biogas plants
- 80 MW Capacity
- feed in tariff for electric power
- obligation to use parts of “waste heat”
Recycling Management in Biogas Plant

Upcoming problems for biogas plants in Austria

- Biogas plants are operating with (expensive) agricultural products (e.g. maize, sunflower)
- Market price for el. power is decreasing the last 10 years
- Follow up funding seems to be insufficient, because only short term support is guaranteed
- Searching for alternatives is just at the beginning
BIOGAS PLANT - CE HEAT

Situation in Austria

Example 1
Biogas Plant WOLF

Example 2
Biogas Plant STREM

Challenges Recommendation
Recycling Management in Biogas Plant

Example 1: Biogas Plant WOLF (Burgenland, Austria)

Different input material including “waste”

- Dung from hen and cattle: 6 tons/day
- Waste from soy oil production: 3 tons/day
- Maize or panic grass: 6 tons/day
- Grass from green fields: 6 tons/day
- Waste from corn: 3 tons/day
Recycling Management in Biogas Plant

Example 1: Biogas Plant WOLF (Burgenland, Austria)

realising circle economy by using synergies
Recycling Management in Biogas Plant

Example 1: Biogas Plant WOLF (Burgenland, Austria)

Main goals

- reaching a full recycling process
- using only regional available products including waste
- sustainable operation of the plant
- at least economic balance of the plant
BIOGAS PLANT - CE HEAT

Situation in Austria

Example 1
Biogas Plant
WOLF

Example 2
Biogas Plant
STREM

Challenges
Recommendation
Recycling Management in Biogas Plant

Example 2: Biogas Plant Strem (Burgenland, Austria)
Recycling Management in Biogas Plant

Example 2: Biogas Plant Strem (Burgenland, Austria)

Input material in the beginning (2005)

- Maize silage: 25 tons/day
- Grass silage: 6 tons/day

Goal: to replace maize with “waste input” like grass
Recycling Management in Biogas Plant

Example 2: Biogas Plant Strem Cogeneration
Recycling Management in Biogas Plant

Example 2: Biogas Plant Strem (Burgenland, Austria)

Circle economy is aspired

- 500 kW electric power with feed in tariff
- 550 kW thermal power (waste heat) for the local district heating system
- residues from biogas plant are used as dung for the local fields which produce Maize
Recycling Management in Biogas Plant

Example 2: Biogas Plant Strem (Burgenland, Austria)

Conception of the plant

- thermophil fermentation (2 fermentation units)
- separation of digestates (remains from fermentation)
- storing of input materials in flexible silo
- storing of liquid residues in lagune
Recycling Management in Biogas Plant

Example 2: Biogas Plant Strem (Burgenland, Austria)
Recycling Management in Biogas Plant

Example 2: Biogas Plant Strem (Burgenland, Austria)

acting as research and demonstration plant

- using local agricultural resources
- using local “waste” resources
- using residues from local wastewater treatment plants
Recycling Management in Biogas Plant

Example 2: Biogas Plant Strem (Burgenland, Austria)

Topics for research and development

- optimization of start up process
- handling of “dry” fermentation process
- optimization of process engineering and reactor loading
- development of expert system for the process
BIOGAS PLANT - CE HEAT

Situation in Austria

Example 1 Biogas Plant WOLF

Example 2 Biogas Plant STREM

Challenges Recommendation
Recycling Management in Biogas Plant

Challenges, Recommendations

- “traditional” production will end; 
  new strategies have to be developed
- agricultural materials become too expensive; 
  new input materials have to be used
- el. power production is not sufficient 
  further products have to be market 
  (heat, gas, CO\textsuperscript{2}, residues)
- stand alone solutions are risky 
  co-operation with synergies should be searched
12th SDEWES Conference, CE Heat Special session
5th October 2017, Dubrovnik

Recycling Management in Biogas Plant

CE 622 CE-HEAT, Forschung Burgenland GmbH, Johann Binder
October 4th – 8th, 2017 Dubrovnik, Croatia

**UTILIZATION OF WASTE HEAT FROM HYDRO-POWER PLANTS**

Saša Erlih, E-zavod, Ptuj, Slovenia

Boštjan Gregorc, Dravske elektrarne Maribor, Slovenia
GLOBAL TRENDS

- Global growth of human population to 10 billion up to year 2050 (50% of the population will be located in metropolitan areas)
- Issues of Climate changes and economic migrations
- Increase of energy demand
Increased consumption of natural gas and petroleum products
Stagnation of coal use
Growth of energy produced from renewable sources
FUEL SHARES IN ENERGY PRODUCTION

2014 fuel shares in world total primary energy supply

Fuel shares in world electricity production in 2014
• Hydro capacity in operation ≈ 1123 GW (in 2016)
• The largest share of electricity generation from hydroelectric power plants is generated in the Asian region
• The potential for waste heat?
WASTE HEAT IN INDUSTRIAL AND ENERGY PROCESSES

- Temperature regime of waste heat source - °C
- Transfer medium - gas, liquid ...
- Waste Heat source power - MW
- Annual potential of waste heat source - MWh
WASTE HEAT IN HYDROPOWER PLANTS

- Exploitation of waste heat of cooling systems of generators and bearings
- Low temperature heat source (20 - 40 °C)
- Dynamic operation of hydroelectric power plants (covering peak energy)
- Location of hydroelectric power plants - distance to potential heat consumers
Technical data HPP

- Annual generation - 270 GWh
- Net capacity - 60 MW
- Installed flow - 550 m³/s

Potential of a waste heat source at a HPP Mariborski otok approx. 500 kW

Waste heat is utilized for the heating of DEM premises (the center of management of all DEM plants)

Optimization with heat storage system and heat pumps
TECHNOLOGICAL SCHEME OF WASTE HEAT RECOVERY SYSTEM
WASTE HEAT RECOVERY SYSTEM - HPP

- The use of a dual cooling systems (generators) at the HPP (open / closed)
- Use of storage tanks (reservoirs) 2 x 50 m³
- Working temperature of the heat sink 25 - 35 °C
- Utilization of heat pumps to raise the temperature level of water
CONCLUSION

- By developing novel technologies for exploiting low-temperature heat sources, the use of waste heat is becoming more and more attractive for investors.
- Utilization of waste heat improves the energy efficiency of existing systems.
- The utilization of waste heat at the hydroelectric power plant increases the total energy efficiency by approx. 1.5%.
- Estimation of the specific costs of the investment of the waste heat recovery system at the hydroelectric power plant is approx. 500 € / kW.
Thank you for your attention
Exploiting waste heat in Croatia, potential and challenges

CE-HEAT, Energy Institute Hrvoje Požar, Ilja Drmač
WASTE HEAT IN CROATIA

Introduction
Project CE-HEAT

Introduction
El Hrvoje Požar

Focus-
preferential
electricity
producers
(biomass, biogas,
cogeneration)

Waste heat utilization

Conclusion
PROJECT PARTNERS

TAKING COOPERATION FORWARD
CE HEAT

TWP1 - Creating digital waste heat cadastres in regions

Providing planning and monitoring tool

TWP2 - Waste heat utilization toolbox

Providing tools for waste heat utilization investment development

TWP3 - Pilot projects

Implementing Testing Evaluating

TWP4 - Upgrading local, regional and national waste heat management

Waste heat utilization action plans

Trainings

Transnational platform

Increased waste heat utilization in Central Europe
CE HEAT

How much?

What can we do with it?

Is it feasible?

Is it economically justified?

Where?

WASTED (LOST) ENERGY

TAKING COOPERATION FORWARD
Energy Institute Hrvoje Požar
Address: Savska cesta 163, 10001 Zagreb, Hrvatska; PP 141

Phone: 01/6040-588
01/6326-100

Fax: 01/6040-599

E-mail: eihp@eihp.hr

http://www.eihp.hr/
EIHP IN THE REGION

TAKING COOPERATION FORWARD
EIHP AROUND THE WORLD

- electricity
- oil & gas
- renewables
- energy efficiency
- regulatory

national strategies
- project feasibility and bankability
- energy balances and statistics
- corporate restructuring
- mergers and acquisitions
PREFERENTIAL ELECTRICITY PRODUCERS (BIOMASS, BIOGAS, COGENERATION)

Production process

A Primary fuel energy [ MWh ]
B Electricity production [ MWh ]
C Produced useful heat [ MWh ]
D Produced heat [ MWh ]
E Waste heat [ MWh ]
**PREFERENTIAL ELECTRICITY PRODUCERS (BIOMASS, BIOGAS, COGENERATION)**

<table>
<thead>
<tr>
<th>Type of plant / primary energy source</th>
<th>Number of plants</th>
<th>Power [ MW ]</th>
<th>Electricity production [ MWh ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass power plants</td>
<td>12</td>
<td>25,955</td>
<td>177.911</td>
</tr>
<tr>
<td>Biogas power plants</td>
<td>26</td>
<td>30,435</td>
<td>210.162</td>
</tr>
<tr>
<td>Cogeneration plants</td>
<td>6</td>
<td>113,293</td>
<td>234.053</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>169,683</td>
<td>622.126</td>
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</tbody>
</table>

*Annual report on the work of the Croatian Energy Regulatory Agency for 2016

**Annual efficiency of the production plant**

<table>
<thead>
<tr>
<th>Type of plant / primary energy source</th>
<th>Report of annual efficiency of the production plant</th>
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</thead>
<tbody>
<tr>
<td>Biomass power plants</td>
<td>4/12</td>
</tr>
<tr>
<td>Biogas power plants</td>
<td>7/26</td>
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<tr>
<td>Cogeneration plants</td>
<td>1/6</td>
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</tbody>
</table>
## PREFERENTIAL ELECTRICITY PRODUCERS
**(BIOMASS, BIOGAS, COGENERATION)**

### Average values

<table>
<thead>
<tr>
<th></th>
<th>Biomass</th>
<th>Biogas power</th>
<th>Cogeneration¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio between produced heat energy and electricity</td>
<td>4,68</td>
<td>1,58</td>
<td>2,45</td>
</tr>
<tr>
<td>Ratio between utilized heat energy and produced</td>
<td>0,37</td>
<td>0,35</td>
<td>0,11</td>
</tr>
<tr>
<td>Degree of energy utilization</td>
<td>55%</td>
<td>60%</td>
<td>11%</td>
</tr>
</tbody>
</table>

### Type of plant / primary energy source

<table>
<thead>
<tr>
<th>Type of plant / primary energy source</th>
<th>*Power [ MW ]</th>
<th>**Power [ MW ]</th>
<th>Power ratio * and ** [% ]</th>
<th>*Electricity production [ MWh ]</th>
<th>**Electricity production [ MWh ]</th>
<th>Production ratio * and ** [% ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass power plants</td>
<td>25,955</td>
<td>13,50</td>
<td>52%</td>
<td>177,911</td>
<td>112,665,72</td>
<td>63%</td>
</tr>
<tr>
<td>Biogas power plants</td>
<td>30,435</td>
<td>29,44</td>
<td>97%</td>
<td>210,162</td>
<td>233,376,19</td>
<td>111%</td>
</tr>
</tbody>
</table>

### Available data:
- Nominal electric power - 40/44;
- Nominal heat power - 30/44;
- Primary fuel energy, Electricity production, Produced useful heat - 13/44

¹Ratio between utilized heat energy and produced = 0,5; Degree of energy utilization=50%.

*Annual report on the work of the Croatian Energy Regulatory Agency for 2016
**Calculated from available data (we had access to information for 10/12 biomass plants).
### Production of heat energy - calculation

<table>
<thead>
<tr>
<th>Type of plant / primary energy source</th>
<th>Produced heat [ MWh ]</th>
<th>Produced useful heat [ MWh ]</th>
<th>Heat losses [ MWh ]</th>
<th>Produced useful heat with 50% utilization [ MWh ]</th>
<th>Potential [ MWh ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass power plants</td>
<td>832.320</td>
<td>310.502</td>
<td>521.817</td>
<td>416.160</td>
<td>105.658</td>
</tr>
<tr>
<td>Biogas power plants</td>
<td>78.402</td>
<td>27.176</td>
<td>51.226</td>
<td>39.201</td>
<td>12.025</td>
</tr>
<tr>
<td>Total</td>
<td>910.722</td>
<td>337.679</td>
<td>573.044</td>
<td>455.361</td>
<td>117.683</td>
</tr>
</tbody>
</table>

### Heat energy, potential for utilization

<table>
<thead>
<tr>
<th>Type of plant / primary energy source</th>
<th>Potential with 60% utilization [ MWh ]</th>
<th>Potential with 70% utilization [ MWh ]</th>
<th>Potential with 80% utilization [ MWh ]</th>
<th>Potential with 90% utilization [ MWh ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass power plants</td>
<td>188.890</td>
<td>272.122</td>
<td>355.354</td>
<td>438.585</td>
</tr>
<tr>
<td>Biogas power plants</td>
<td>19.865</td>
<td>27.705</td>
<td>35.546</td>
<td>43.386</td>
</tr>
<tr>
<td>Total</td>
<td>208.755</td>
<td>299.827</td>
<td>390.899</td>
<td>481.971</td>
</tr>
</tbody>
</table>
PREFERENTIAL ELECTRICITY PRODUCERS (BIOMASS, BIOGAS PLANTS)
PREFERENTIAL ELECTRICITY PRODUCERS (BIOMASS, BIOGAS, COGENERATION)
Increase efficiency of the plant:
- Pre(heating) of fermenter
- Sterilization of equipment
- Greenhouse heating
- Dryers
- Pre(heating) of domestic hot water...
BIOGAS PLANT

The chart illustrates the energy output of a biogas plant over 12 months. The x-axis represents the months, and the y-axis shows the energy output in kWh. The data includes:

- Heat production
- Electricity production
- Produced useful heat
- Heat loss
- DHW
- Heating energy

The bar graph shows the raw output, while the line graph highlights the efficiency and energy distribution throughout the year.

Interreg Central Europe
CE-HEAT
European Union
European Regional Development Fund

Taking Cooperation Forward
Incorporate development of energy facilities with physical planning.
CONCLUSION

Steps for moving forward in waste heat utilization:

Identification of the waste heat
Feasibility study
Legal and financing issues

Development and promotion of waste heat utilization handbook
Promotion of sustainable physical planning
Technology transfer
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El Hrvoje Požar
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12th SDEWES Conference
Dubrovnik, 05.10.2017

Utilization of Waste Heat in Thuringia - Current State and Outlook

Thüringer Energie- und GreenTech-Agentur GmbH - Anton Wetzel
INTRODUCTION

Thuringian Energy and GreenTechAgency

- Founded in 2010, currently 18 employees
- Mainly financed by the Free State of Thuringia
- Tasks:
  - neutral, independent, pre-competitive consulting
  - cross-linking of public authorities, companies, R&D and educational institutes as well as with local citizens
  - Initiating, moderating and coordinating of projects
- Project examples: wind energy service point, energy management for municipalities, e-mobility etc.
INTRODUCTION

Opportunities for Waste Heat Utilization

1. Internal Heat Utilization:
   - Decreasing the occurrence of waste heat
   - Reintegration of waste heat into the production process or in the heat supply in buildings
   - Internal transformation for other useful energy forms (electric energy, air conditioning)

2. Heat that cannot be utilized internally can be used by third parties (i.e. neighboring establishments, for residential or commercial heating)
### WASTE HEAT POTENTIAL IN THURINGIA

<table>
<thead>
<tr>
<th>Branch of Industry</th>
<th>Energy consumption in TJ in 2014</th>
<th>WH-share % (60-140°C)</th>
<th>Source</th>
<th>WH potential 60-140°C in TJ</th>
<th>WH potential &lt;60°C in TJ</th>
<th>Total WH potential in TJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining and quarrying</td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacture of food products, beverages, tobacco</td>
<td>3960</td>
<td>15% (total)</td>
<td>Hita et al., 2011</td>
<td>594,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacture of textiles, wearing apparel, leather ect.</td>
<td>444</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacture of wood and of products of wood and cork</td>
<td>2563</td>
<td>3%</td>
<td>estimation ThEGA</td>
<td>76,9</td>
<td>38,4</td>
<td>115,3</td>
</tr>
<tr>
<td>Manufacture of paper and paper products</td>
<td>9726</td>
<td>20% (total)</td>
<td>Schnitzer, 2012</td>
<td>1945,2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Printing and reproduction of recorded media</td>
<td>530</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacture of chemicals and chemical products</td>
<td>3781</td>
<td>8%</td>
<td>ifeu, 2010</td>
<td>302,5</td>
<td>151,2</td>
<td>453,7</td>
</tr>
<tr>
<td>Manufacture of basic pharmaceutical products</td>
<td>190</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacture of rubber and plastic products</td>
<td>3739</td>
<td>3%</td>
<td>ifeu, 2010</td>
<td>112,2</td>
<td>56,1</td>
<td>168,3</td>
</tr>
<tr>
<td>Manufacture of other non-metallic mineral products</td>
<td>14434</td>
<td>40% (total)</td>
<td>estimation ThEGA</td>
<td>5773,6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacture of basic metals</td>
<td>4904</td>
<td>30%</td>
<td>ifeu, 2010</td>
<td>1471,2</td>
<td>735,6</td>
<td>2206,8</td>
</tr>
<tr>
<td>Manufacture of fabricated metal products</td>
<td>3820</td>
<td>3%</td>
<td>ifeu, 2010</td>
<td>114,6</td>
<td>57,3</td>
<td>171,9</td>
</tr>
<tr>
<td>Manufacture of computer, electronic and optical products</td>
<td>1119</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacture of electrical equipment</td>
<td>721</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacture of machinery and equipment</td>
<td>1439</td>
<td>3%</td>
<td>ifeu, 2010</td>
<td>43,2</td>
<td>21,6</td>
<td>64,8</td>
</tr>
<tr>
<td>Manufacture of motor vehicles and transport equipment</td>
<td>3275</td>
<td>3%</td>
<td>ifeu, 2010</td>
<td>98,3</td>
<td>49,1</td>
<td>147,4</td>
</tr>
<tr>
<td>Manufacture of furniture</td>
<td>271</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>294</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair and installation of machinery and equipment</td>
<td>237</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biogas plants</td>
<td></td>
<td></td>
<td>TLL, ThEGA 2017</td>
<td>1501,20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Server</td>
<td></td>
<td></td>
<td>estimation ThEGA</td>
<td>1323,56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>55601</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14465,70</td>
</tr>
</tbody>
</table>
Progression of installed cooling

Source: Umweltbundesamt 2014
Waste heat potential to meet demand for cooling in Germany's operations

Source: Umweltbundesamt 2014
Schuler Pressen GmbH, Factory in Erfurt

- Heat recovery in a forge via heat exchange (700 kW)
- Utilization of exhaust gas temperature (up to 600 °C)
- Yearly savings: ca. 1,000 MWh Heat
- Pay back period: 1,58 years
Fraunhofer-Institute for Digital Media Technology in Ilmenau

- New building constructed utilizing waste heat from servers
- Server cooling through heat exchange and air recirculation cooling (14°C/18°C)
- Summer: Cooling (Building & Server) with further heat transfer and 36 bore hole heat exchangers; meeting the peak load through additional cooling units
- Winter: Temperatur increased from 18 to 28°C (concrete core activation) or 45°C (Heating) via heat pumps (peak heat load)
Venner Energie eG (citicen energy cooperative)

- Waste heat from a wafer manufacturer: ca. 8 GWh
- Installation of finned tube heat exchangers (50 to 200 kW) on 15 baking lines
- 154 connected housing units
- 6.5 Mio. kWh/year heat demand
- ca. 90% met through waste heat
- 10 km of pipeline
- 1,000 m³-heat storage + gas boiler for peak load
- 4 Mio. € Investition
- 1.100 t CO2-Savings
Goals

- Create awareness for „Waste Heat Resources“
- Depict industrial and agricultural waste heat potential
- Increase the transparency for producers and consumers of waste heat
- Gain input for heat concepts from communities and energy providers
- Initiate capital investment
Waste heat sources in Thuringia from BImSchV

- 366 Data records for 2012
- In total 753 GWh waste heat
- 77 Biogas plants
- 134 Data records > 1 GWh
- TOP 5
  - Zellstoff- und Papierfabrik Rosenthal GmbH: 62 GWh
  - Glaswerk Ernstthal GmbH: 59 GWh
  - Erdgasverdichterstation Rükersdorf: 57 GWh
  - Stahlwerk Thüringen GmbH: 32 GWh
  - ulopor Thüringer Schiefer GmbH: 23 GWh
WASTE HEAT CADASTER

Bildnachweis: © GDI-Th; Datenlizenz Deutschland Namensnennung2.0 (https://www.govdata.de/dl-de/by-2-0); Datenquelle: www.geoportal-th.de; ThEGA GmbH
Examples of proposed projects:

- HFP Bandstahl GmbH & Co. KG
- Thüringer Porzellan GmbH

Bildnachweis: Google Maps; ThEGA GmbH
Call for Project Idea Submissions

- Financing of at least two feasibility studies a 15,000 €
- Requirement: Registration of waste heat source in Cadaster
- Selection criteria: CO2-savings and reproducibility, but flexibility with respect to the object of investigation
- Submission deadline: 31.10.2017
- Expert support from ThEGA

- Current status: 5 interested companies
FUNDING OPPORTUNITIES

- **GREEN** invest (maximum amount up to 80%)
  - Energy Efficiency (consultation & Investment)
  - Demonstration projects (Studies & Investment)
- KfW-Energy Efficiency Program - Waste Heat (loans + repayment subsidies or subsidies: 30-40%; 10 % Bonus for KMU)
- BAfA Support program for main technologies (subsidies: 20-30%)
- NKI - Support program for cooling and air condition systems (subsidies for thermal cooling plants, heat storage, heat pumps for waste heat utilization)
- MAP Premium (60 €/m + 1.800 € per building connection) + KWKG (district heating + heat storage)
- In preparation: Support program for rural heating networks
CONCLUSION

- A diverse potential for waste heat in Thuringia exists
- Identification of sources of waste heat in the cadaster:
  www.thege.de/abwaerme
- Continuously enhancement and update of the cadastre
- Identification of 5 promising waste heat sources for pilot projects
- Waste heat utilization can be very economically (support programs in Germany)
- External use of waste heat: new business models for energy supply companies, ESCOs and citizen energy cooperatives
THANK YOU FOR YOUR ATTENTION

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(ThEGA) anton.wetzel@thega.de

CE-HEAT
www.interreg-central.eu/ce-heat

www.thega.de/abwaerme