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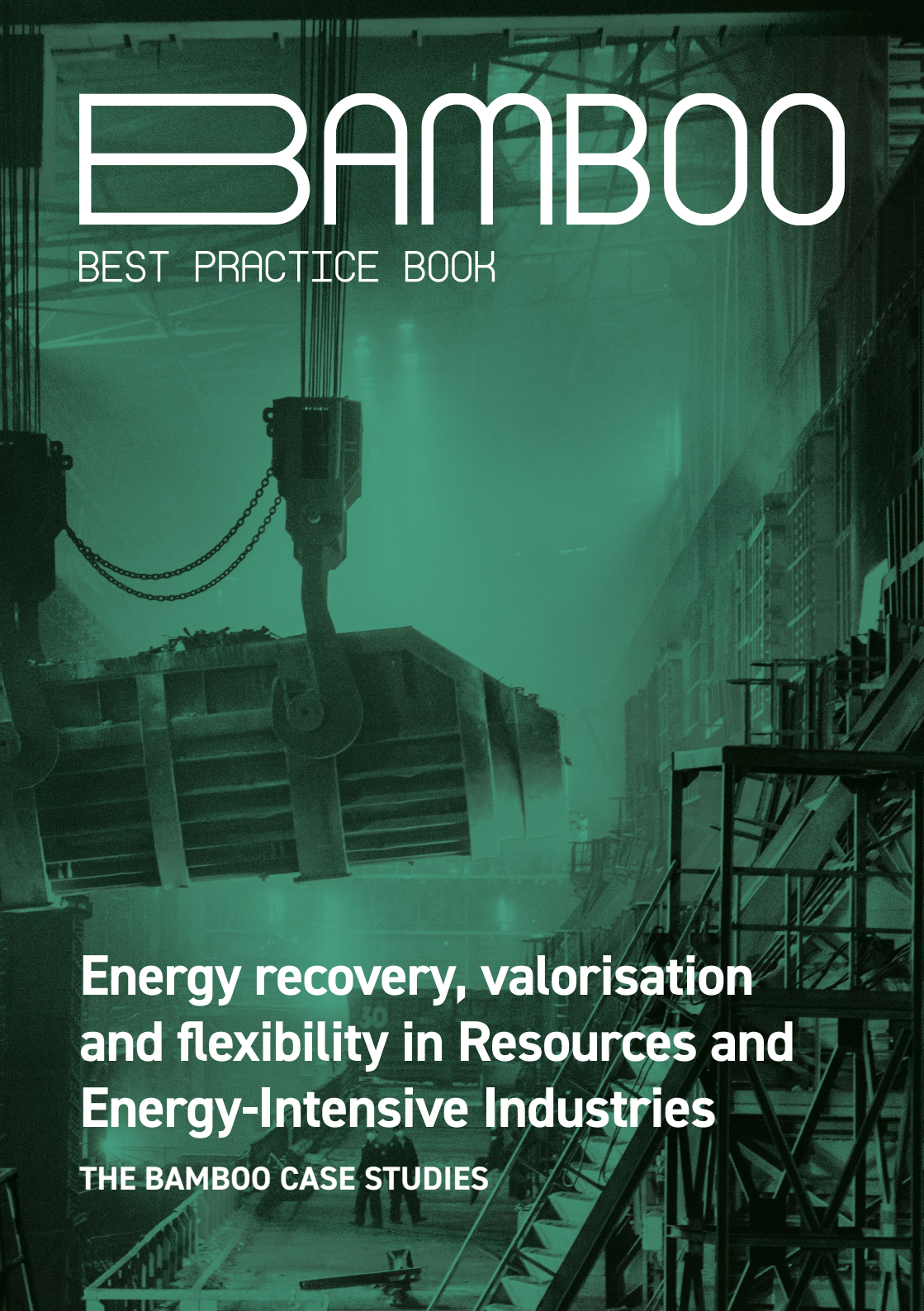
BEST PRACTICE BOOK



Energy recovery, valorisation and flexibility in Resources and Energy-Intensive Industries

THE BAMBOO CASE STUDIES



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INTRODUCTION

BAMBOO has developed pioneering technologies to improve the efficiency and flexibility of heavy industrial processes. To this end, every technology focuses on one of the project innovation pillars: waste heat recovery, electrical flexibility and waste stream valorisation.

THE PILLARS

Waste heat recovery technologies valorise the energy from waste streams exhaust temperature, which is wasted in most cases. Thanks to these technologies, the energy recovered can be reintroduced within the process. BAMBOO has studied the relevant flows in terms of waste heat recovery potential and their different uses, for example to generate steam or electricity. This increases the flexibility options of the plant.

The adoption of **electrical flexibility** in consumption makes it possible for industries to benefit from lower electricity prices and to provide grid services. It may also enable renewable energy to be integrated. BAMBOO has developed an innovative virtual battery that allows a whole industrial plant to consume electricity according to the grid conditions, by addressing grid services and facilitating the integration of renewable energy cited above.

Through **waste stream valorisation** the calorific value of many waste streams has been enhanced as fuels for other processes, thus being a potential revenue flux for the industries. Specifically, thanks to combustion monitoring systems that enable the replacement of fossil fuels by off-gases, BAMBOO has deployed technologies and processes that valorise these streams.

WASTE HEAT RECOVERY



Organic Rankine Cycle

Industry: Petrochemical
Demo site: Tupras refinery, Turkey
Partners: Turboden SpA, Tupras

Organic Rankine Cycle (ORC) technology is a system based on a closed-loop thermodynamic cycle for the generation of electricity and, in CHP applications, thermal power. This technology has proven to be valid in different sectors other than O&G, like glass, cement and steel industries, and it can enable the recovery of the excess waste heat produced by industrial processes. Based on this experience, the BAMBOO project thoroughly explored how to valorise several heat sources at a different range of temperatures. This led to the innovative idea of replacing traditional coolers with newly developed heat exchangers that cool down the refining product to the target temperature, while heating and vaporising the ORC working fluid directly.

General **pros** of the ORC are:

- Huge **CO_2 reduction** at a reasonable cost, comparable with a carbon tax (25-40 EUR/tonCO_2).
- Energy production at a competitive LCOE (0.03 to 0.05 EUR/kWh) compared to other renewables.
- Improvement of the **sustainability** process, and reduction of its energy consumption.
- **Sustainable solutions** for customers reducing the CO_2 emissions at their end.
- **Simplicity and cost-effectiveness** are guaranteed while reliability and safety are maintained.

SWOT analysis based on the potential application of the ORC technology in the Tupras refinery:

STRENGTHS

- Approximative production of 31,000 MWh of **clean electricity** over two years.
- **8,300** tons of CO_2/y avoided in Turkey.

WEAKNESSES

- **6,750** tons of CO_2/y avoided in Europe.
- Demo part has not been developed due to the Covid situation and limited project timeline.
- **High extra costs** that undermine the project itself.

OPPORTUNITIES

- Several **market** opportunities in the Turkish market.
- Room to improve the **environmental quality** and meet the EU goals.

THREATS

- O&G companies are used to very **high-profile specifications** and top-of-the-class components.
- **Change in the approach** needed from both sides for a solution that meets the minimum requirements of an O&G company and the need to be economically feasible.



Industrial Heat Pumps and Steam-Generation

Industry: Steel
Demo site: ArcelorMittal plant, Spain
Partners: AIT, EDF, EI-JKU, AMII

In the BAMBOO project, heat pumping technologies suitable for producing saturated steam with output pressures of up to 5 bar (152°C) were demonstrated. This relatively novel market segment increases the potential applicability across energy-intensive industries, due to the number of relevant processes that work at higher temperatures. The applications for steam in these processes are wide-ranging. It is used for heat transfer, especially in the food & beverage, chemical, pulp and paper sectors and in low-temperature processes in the steel industry. It is also relevant as a process reactant in the chemical and pharmaceutical industry.

General **pros** of heat pumping technologies are:

- Reduced costs if implemented correctly
- Valorisation of waste heat.
- Increased energy efficiency.
- Reduction of CO_2 emissions.

SWOT analysis of the potential application of this technology (i.e. heat pump with flash tank) in the Spanish plant of ArcelorMittal compared to a gas-fired steam boiler:

STRENGTHS

- Making use of **waste heat**, i.e. increase energy efficiency.
- **Possibility for CO_2-neutral electrification**, i.e. decarbonized process heat.
- **Possible independency from fossil fuels.**
- The goal of **producing steam with a pressure of 5 bar** (152°C) was reached within the BAMBOO project.

WEAKNESSES

- A new installation of a heat pump requires **careful planning.**
- **Dynamic** operation **limited.**
- **Higher CAPEX.**
- More complex equipment and more individual parts, therefore **more vulnerable supply chains.**

OPPORTUNITIES

- **Applicable in other industry sectors** (e.g. food & beverage, chemical, pulp and paper).
- **Possibly cutting OPEX,** esp. regarding emission certificates and energy efficiency.
- **Enables integration of renewables** through electrification (Power-to-heat).
- **Possible use of various heat sources** (geothermal, solar, ambient).
- **Simultaneously heating and cooling possible** (benefit increases).

THREATS

- Possible **high electricity-to-gas** price ratios (including emission certificates) extend the payback period.
- Use of renewable gases **may prevent use of more efficient heat pumping technologies** (cmp. strengths).

WASTE STREAMS VALORISATION



Multifuel Low NOx Burner

Industry: Mineral
Demo site: Yerakini plant, Greece
Partners: Fundación Circe, CERTH, Grecian Magnesite

The possibility to change the combustion process and reduce emissions by using a different fuel mix is at the core of this pillar in BAMBOO. The project tested the use of both **biomass** and **pet coke** in the mineral industry, with encouraging results. Indeed, replacing the pet coke with biomass in the process of co-firing resulted in a reduction of SOx emissions due to the displacement of sulphur in the fuel blend. In addition, the use of biomass showed a reduction of NOx emissions and flame temperatures, leading to lower levels of thermal NOx. The reduction of NOx could be higher by replacing the burner with a new low NOx burner.

General **pros** of the low-NOx burner technology are:

- **Less dependence** on fossil fuel by using biomass.
- **Lower CO_2 emissions** by using carbon-neutral biomass.
- **Lower NOx emissions** by using a low-NOx burner and biomass.
- Lower SOx emissions by using biomass.
- Possible **flexible energy consumption** according to market prices.
- Possible **waste heat recovery.**
- **Lower production cost** by paying less for CO_2 tariffs.

SWOT analysis based on the application of the multifuel low NOx burner in the Grecian plant of Grecian Magnesite:

STRENGTHS

- **NOx emissions cut by over 40%,** with no biomass.
- **Using biomass** allows a 47% decrease in SO_2 emissions and a further reduction of NOx by 21%.
- Ability to work in **different operation modes** according to the temperature of the kiln.

WEAKNESSES

- **High temperatures** are required to produce dead-burned magnesite, which cannot be accomplished without **conventional fuel in the mix.**
- **Lower impact** is shown for chemical and petrochemical, food, and machinery.

OPPORTUNITIES

- **Replication** of the system to further processes and industries.
- Reduction **value chain costs** depending on the availability of biomass within the area.

THREATS

- **Biomass types** are restricted by their availability in required quantities.
- Extensive use of biomass will require the **provision of relevant infrastructure.**
- **Damage risk** to the kiln lining due to the high temperature necessary



Flame Monitoring System

Industry: Steel
Demo site: ArcelorMittal plant, Spain
Partners: Fundación Circe, ArcelorMittal

Manufacturing processes in the steel industry produce some **off-gases** which can be **used as fuels** at different points in the plant. Alternatively, these gases can be sold to external companies for steam and electricity generation. This is the case of the **Blast Furnace Gas (BFG)**, generated in the blast furnaces process. BFG is burnt in steelmaking processes to reduce the consumption of natural gas. BAMBOO contributed to increasing the share of BFG in the Spanish plant of ArcelorMittal. The project created some combustion CFD models and developed a flame monitoring system to evaluate BFG combustion conditions. The monitoring of the combustion is of interest for the steel industry as a way to optimise the operation and maintenance of processes with BFG.

General **pros** for the flame monitoring system:

- **Energy savings**, for example, due to the reduction of fuel consumption.
- **Reduction of emissions**, and thus lower environmental taxes.

SWOT analysis based on the potential application of this technology in the Spanish plant of ArcelorMittal:

STRENGTHS

- **Additional and automated insights** about combustion conditions (detection of slight variations undetected by the human eye...).
- **Robustness** to different scenarios (conventional and low NOx burners, system placement...).
- **High-detail monitoring** (image-based sensors).

WEAKNESSES

- **Further work to adapt the system** to novel and/or significantly different operation conditions.
- **Higher hardware cost** than traditional and simpler combustion sensors.

OPPORTUNITIES

- **Diagnosis of individual burners** for furnaces with multiple burners.
- **Replicability** of the system for other plants with the same process.
- **Adaptation** to already installed vision systems.
- **Adaptation to other industries** (cement, ceramic, power plants...).

THREATS

- Increase of **hardware** cost in the market (image-based sensors, control system...).
- Dubious **benefits of these tools** versus traditional supervised monitoring.

ELECTRICAL FLEXIBILITY



Virtual Battery Model

Industry: Pulp and paper
Demo site: UPM, Germany
Partners: AIT, TU Braunschweig

The virtual battery concept helps analyse how electricity and heat can be flexibly produced and used, considering regional renewable electricity generation and regulatory frameworks. The partial replacement of fossil fuels with renewables was made possible by using the flexibility potential of industrial consumers and their power plants.
Furthermore, the virtual battery encourages optimal consumption the electricity from the national grid versus on-site power generation by a **combined heat and power plant (CHP)** and generation from renewables like **photovoltaic (PV).** It does this in line with regulatory frameworks, production requirements and the technical characteristics of energy provision. This optimisation concerns the operation of energy supply assets and also the scheduling of the production process.

General **pros** of virtual battery:

- Reduction of the carbon emissions for the production of 1 ton of paper.
- Integration of (on-site) renewable energy sources like PV.
- Balance of daily/seasonal fluctuations would be available.

SWOT analysis based on the potential application of this technology in the German plant of UPM:

STRENGTHS

- Different scenarios can be evaluated simultaneously.
- Better **integration** of on-site PV.

WEAKNESSES

- **Results** are currently under evaluation
- Data set-up of systems depends on exchange with an **industrial partner.**

OPPORTUNITIES

- A mathematical optimisation model has been set up to analyse the **impact** of the frame conditions.
- Promising **technology combinations** in the energy supply systems.
- Potential **investments** in energy storage systems or power-to-heat assets have been considered in the analysis.

THREATS

- Combination of design and operation can lead to **long calculation times.**
- Dubious **interpretation** of the results if not support by expertise.



Energy Forecasting Platform

Industry: All
Demo site: All
Partners: N-SIDE

The Energy Forecasting Platform provides forecasts to support industrial sites in optimizing production planning and valorising their energy flexibility, in line with fluctuating short-term price signals. They are used as inputs for this purpose.
This platform **allows industries to plan their production based on the day-ahead and intraday markets by minimising their energy cost.** The consumption of electricity will shift to low-price hours so that industrial sites can directly valorise their flexibility on the relevant markets, without the need to rely on an external partner such as an aggregator.

General **pros** of Energy Forecasting Platform:

- Combination of advanced energy knowledge with machine learning expertise.
- Leveraging hundreds of (live) data inputs.
- High reactivity, with up to one update per minute.
- Compatible with most used communication protocols (HTTP(S), FTP ...).
- User-friendly visualization of your forecast results and their performance.
- API connection for easy integration.
- Robust monitoring and alerting system.

SWOT analysis based on the potential application of this technology:

STRENGTHS

- For a CWE country (i.e. Germany, France, Benelux and Austria), **the performance of the day-ahead price forecast** (published in D-1 at 9.00 AM) ranges between 40 EUR/MWh and 100 EUR/MWh in MAE in 2022.

WEAKNESSES

- **Accuracy** of the energy forecasts **depends on the geography and/or market.** Some markets are more difficult to tackle by the Energy Forecasting Platform.

OPPORTUNITIES

- Activation of **fuel flexibility**, waste heat, and production flexibility when it is the most suited

THREATS

- Changing regulations **don't allow** users to benefit from **flexibility in some areas.**
- **Lack of liquidity** in some markets.

CONCLUSION

"The success of the BAMBOO project wouldn't have been possible without the commitment of Europe's intensive industries to energy efficiency and decarbonisation. With EU support, the project's wide-ranging consortium came together for 54 months to pioneer waste heat recovery, waste streams valorization and electricwal flexibility. These partners identified and overcame several barriers to the industrial implementation of the new technologies presented here. I am sure these will spread in the coming years, helping towards the EU's goal of climate neutrality by 2050."

Jorge Arroyo
BAMBOO Project Coordinator





BAMBOO

BOOSTING NEW APPROACHES FOR FLEXIBILITY MANAGEMENT BY OPTIMIZING PROCESS OFF-GAS AND WASTE USE

bambooproject.eu

info@bambooproject.eu

@bambooH2020

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