UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

GEIPP
GLOBAL ECO-INDUSTRIAL PARKS PROGRAMME

2023

RECOVERY AND REUSE OF WASTE HEAT IN ECO-INDUSTRIAL PARKS

BEST PRACTICE SERIES

GEIPP
GLOBAL ECO-INDUSTRIAL PARKS PROGRAMME

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Table of Contents

INTRODUCTION AND STATE OF PLAY

Industry as the final user for energy has grown significantly in recent decades, particularly in developing and emerging economies, and now makes up more than a third of global energy demand (IEA 2022). Within industry, fossil fuels remain the dominant source of energy at 68% in 2021, with the sector's energy mix remaining relatively unchanged since 2010 (IEA 2022).

In typical industrial plants, energy use can be divided into the following three categories

- **Onsite generation of power and other utilities** (steam, water and air) to be used directly in the plant.
- **Process energy use** distributed through process heating, cooling, refrigeration, machine operations etc.
- **Non-process energy use** such as space heating, cooling, ventilation, support services etc.

Of the three categories, a study commissioned by the US Department of Energy found that more than 80% of total plant energy usage tends to come from onsite generation and process energy applications and almost all losses from these two categories are in various forms of heat (Thekdi and Nimbalkar 2014). Indeed, depending on the industry, it is estimated that between 20 to 50% of industrial energy input is lost as waste heat (US DoE 2017). Consequently, recovering this waste heat and reusing it as an energy source for further industrial applications is a crucial pathway for improving energy efficiency of industry.

When it comes to the reuse of waste heat, a number of options exist at different scales and different levels of complexity.

- The waste heat can be reintegrated into the same process;
- It can be reused within the same plant in another process or to heat the water and/or factory premises;
- It can be extracted and supplied to another plant or fed into a local heating or cooling network

All of these pathways are explored during UNIDO's technical assistance to companies through resource efficient and cleaner production assessments, while eco-industrial park approaches also aim to foster greater adoption of reuse between plants where feasible. Ultimately, the selection of suitable waste heat recovery approaches requires the identification of waste heat sources and assessment of the quantity and quality of waste heat as well as the economic viability of recovering the heat. At the same time, the identification of potential consumers for the reuse of the waste heat must also be undertaken. Such assessments are key to being able to recover waste heat, reduce costs and environmental impacts.

Waste heat recovery is a key component of the Eco-Industrial Park approach enshrined in the International Framework for Eco-Industrial Parks developed by UNIDO, World Bank Group and GIZ. In particular, it represents a key performance requirement under the Energy topic of the Framework including the requirement for industrial parks to have an industrial heat recovery strategy, and initiatives seeking to solidify networks for waste heat and energy exchange at park level.

The case studies presented in this Best Practice Issue therefore aim to explore how waste heat recovery systems were identified, planned and implemented within Industrial Parks in their efforts to become Eco-Industrial Parks with support from UNIDO through its various interventions, including the Global Eco-Industrial Parks Programme (GEIPP). The various examples demonstrate the different levels at which waste heat can be recovered and reused, including lessons learnt and success factors.

CASE STUDY 1: STEAM GENERATION THROUGH BIOGAS RECOVERY IN HOA KHANH INDUSTRIAL ZONE, VIET NAM

Within the context of an intervention on Eco-Industrial Parks in Viet Nam, UNIDO provided technical assistance to tenant companies based in the Hoa Khanh Industrial Zone to explore resource efficient and cleaner production (RECP) opportunities, with a particular focus on those opportunities that could foster industrial symbiosis. One of these opportunities involved the recovery of biogas produced by the wastewater treatment plant of Heineken—one of the largest anchor tenant companies in the park—in order to generate steam that would then be used by Heineken in its production processes.

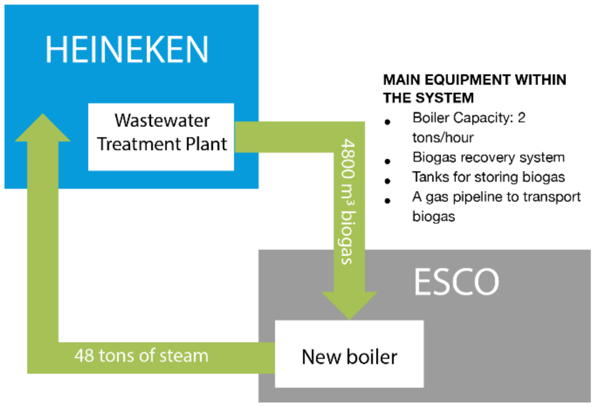
More specifically, during the RECP assessments, it was found that Heineken's wastewater treatment plant was generating an estimated 4,800 m^3 of biogas composed of 20-30% carbon dioxide, 60-70% methane and trace amounts of nitrogen, oxygen etc. At the time of scoping, this biogas was being disposed into the atmosphere without any treatment or collection. However, given the significant calorific value of the biogas, particularly its methane content, its potential use as a fuel presented a significant opportunity for improved environmental performance for the company.

Further exploration of the opportunity involved the identification of possible energy sinks, either within the same company or elsewhere in the industrial park. In this case, Heineken itself had a large energy requirement for specific production processes that were being fulfilled by an Energy Service Company (ESCO) which supplied it steam using a large boiler located a mere 350 meters away from the Heineken plant. The proximity and existing business relationship between Heineken and the ESCO were key factors in the decision to further explore the opportunity.

Given the amount of biogas produced per day, the intervention proposed was for the ESCO to invest in a biogas fired boiler with a capacity of 2 tons/hour in order to generate heat energy and produce stream which would then be supplied back to Heineken, fulfilling a third of Heineken's steam demand.

In practice, this required the construction of a gas pipeline that would connect the wastewater treatment plant to the new boiler on the premises of the ESCO. This scheme is captured in Figure 1.

Figure 1. *Biogas recovery and steam production scheme*



The business model proposed for the scheme was for the biogas to be transferred from Heineken to the ESCO at zero cost to the ESCO, which would install the system and maintain and operate it. The ESCO would continue to sell the same amount of steam to Heineken at the same price. There was thus no additional cost to Heineken while generating environmental benefits from the averted direct release of methane and consequent reduction of emissions of about 17,000 tons CO2 eq/year (assuming maximum production capacity).

The business case and estimated environmental benefits are summarized in Table 1.

Table 1: *Business case and estimated environmental benefits*

Total Investment (CAPEX)	USD 112,300
Operation Cost (OPEX)	USD 26,500 per year
Revenue	USD 231,400 per year
Simple Payback	± 3 months
Carbon Dioxide Reduction	±17,000 tons CO2eq/year

	(assuming maximum production capacity)
Reduction in consumption of biomass	±33%

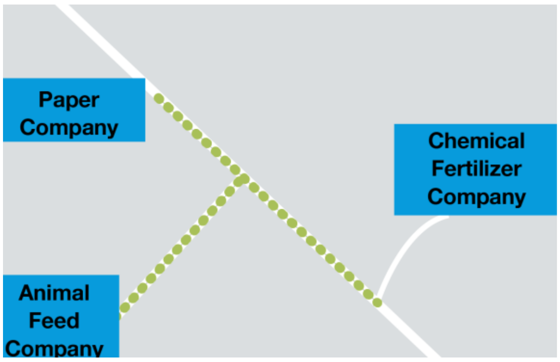
During implementation of the opportunity in 2019, the two parties decided to install a smaller capacity boiler (1.5 tons instead of 2 tons per hour) based on more in-depth calculations of biogas generation and collection capacity. A de-aerator was also installed to remove the hydrogen sulfide (H_2S) from the biogas due to its corrosive effects on machinery. The COVID pandemic and resulting economic slowdown meant a reduction in Heineken's production, and so the average emissions reductions directly linked to biogas collection are currently closer to 10,000 tons/year but are expected to increase as production ramps up again.

CASE STUDY 2: UTILITY SYNERGY THROUGH COMMON BOILER FOR STEAM GENERATION IN TRA NOC INDUSTRIAL PARK, VIET NAM

Scoping studies conducted with tenant firms in Tra Noc Industrial Park revealed that several tenant companies owned and operated small boilers housed within their premises to produce steam for their regular production activities. A subsequent RECP analysis of these companies further found that many of these boilers were running inefficiently, either due to the relative size of the boiler or the lack of capacity within each company to operate and properly maintain the boilers.

In an effort to contribute to the more efficient use of boilers across the companies, several options were explored. Among these options were further training of operators and exploring the potential for a utility synergy through the use of a larger boiler that could provide services to more than one company. To pilot the second option, UNIDO technical experts selected 3 companies located close together (within 300 meters for any two companies). These companies included a paper and packaging firm, a firm producing animal feed and a chemical fertilizer company. All had small or medium-sized boilers producing between 2.5 and 6 tons of steam per hour. The schematic of the relative placement of each company is available in Figure 2.

***Figure 2**: Length of steam from Paper Company to connect to steam system of the other companies is 600 meters*



Following further consultations and interest from the three companies, it was determined that to bring in the required expertise and experience to maintain and operate the boiler as well as provide the initial investment, an energy service company (ESCO) should become involved. The model proposed was for the paper and packaging company to lease out space on its premises to the ESCO to set up a boiler with a capacity of 21 tons of steam per hour in order to meet the requirements of the three companies. The investment, operation andmaintenance would be provided by the ESCO, thus eliminating operation and maintenance costs at the level of each company which could also liquidate their existing boilers to the open market.

One of the key benefits of the initiative in addition to greater efficiency was the consolidation of fuel types. All three companies had previously used different types of fuel, including coal which would now be replaced with biomass. The investment cost for implementing the initiative amounted to just under 1 million USD with operation costs of 762,400 USD per year. However, the revenues generated from selling the steam (1.08 million per year) meant the payback period would be just 3 years and the ESCO was interesting in investing in and operating the technology. Further details of the business case and environmental benefits are available in Table 2.

***Table 2:** Business case and environmental benefits of common boiler utility synergy*

Total Investment (CAPEX)	USD 996,000
Operation Cost (OPEX)	USD 762,400 per year
Revenue from selling steam	USD 231,400 per year
Simple Payback	3 years
Carbon Dioxide Reduction	±26,000 tons CO_2eq/year

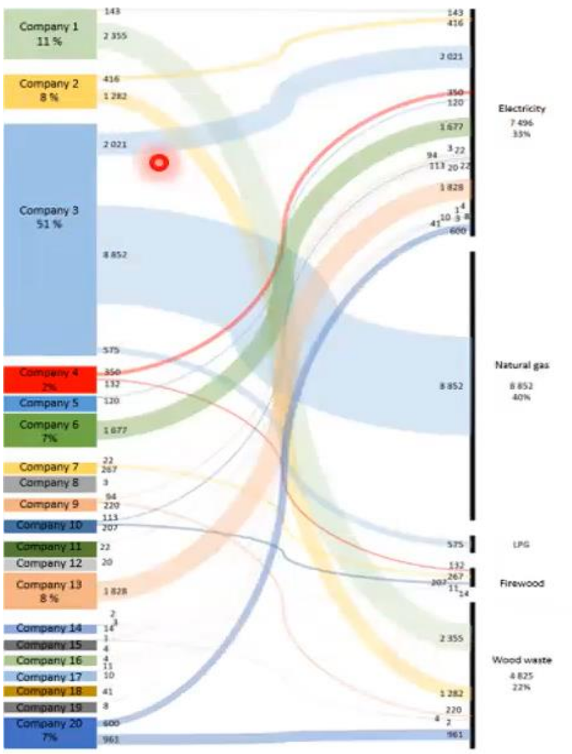
Reduction in coal consumption displaced by biomass	10,000 tons per year
Savings for each company (based on zero operational costs and purchase of steam)	*Company 1*: 82,200 USD/year *Company 2*: 15,400 USD/year *Company 3*: 188,900 USD/year

For the companies, the fact that they did not need to invest was a key selling point. While they now purchased steam instead of producing it, the cost was less than if they had to maintain and operate their own boiler system. The expected environmental benefits from the introduction of the common boiler includes 26,000 tons CO2e/year.

CASE STUDY 3: HEAT RECOVERY FROM COMPRESSORS FOR WATER HEATING AND HOT WATER SUPPLY IN BILA TSERKVA VANTAZHNYI AVIATSIYNYI KOMPLEKS (IP BVAK), UKRAINE

Despite the difficult circumstances faced by businesses in Ukraine, GEIPP has continued to work closely with parks and their tenant companies to mainstream EIP approaches. Indeed, energy conservation and energy recovery have become of paramount importance for businesses to continue their operation.

Figure 3. Annual energy consumption in IP BVAK



In BVAK Industrial Park, GEIPP-Ukraine has consequently been performing RECP assessments for the various tenant companies in order to capture material and energy flows in the park. Among the companies assessed was the largest anchor tenant in the park—a large manufacturer of metal packaging. Further examination of energy flows from all twenty companies within the park revealed that the anchor tenant was by far the largest consumer of energy (see Figure 3).

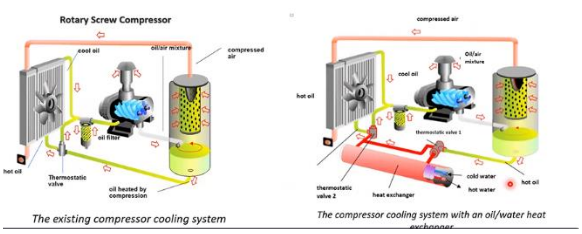
Indeed, the company operates four air-cooled compressors to support its production processes and in typical cases, 95% of the energy consumed by compressors is converted to heat, with only 5% being converted to compressed air. Consequently, the Programme has been working on two separate initiatives to recover this waste heat both to be reused within the company but also for other tenants.

INITIATIVE 1: Installation of additional heat exchangers

Currently, the anchor tenant has already installed a Rotary Screw Compressor to recover some waste heat which it uses for space heating for the factory in winter. However, the RECP assessments revealed that within this existing setup, an additional water heat exchanger could be installed to allow the company to heat water for sanitation purposes (see Figure 4 for details about the setup).

It is expected that the additional heat exchanger installed in September 2021 can save up to 8000 m^3 of gas and produce 2600 m^3 of heated water at a temperature sufficient to meet the needs of the company with regard to sanitation. At the time of installation, the payback period for the technology was expected to be 1 year.

Figure 4. Installation of additional heat exchanger



INITIATIVE 2: Waste heat synergies between the anchor and tenant companies

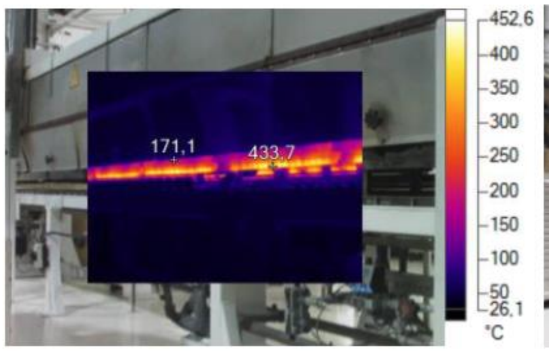
An additional opportunity emerged to reuse waste heat produced by the anchor tenant company. The proposed intervention involved the recovery of heat from flue gases to provide space heating for premises in winter. However, during the summer, this waste heat would remain unused. Consequently, the RECP experts of the programme sought additional opportunities for reuse elsewhere in the park.

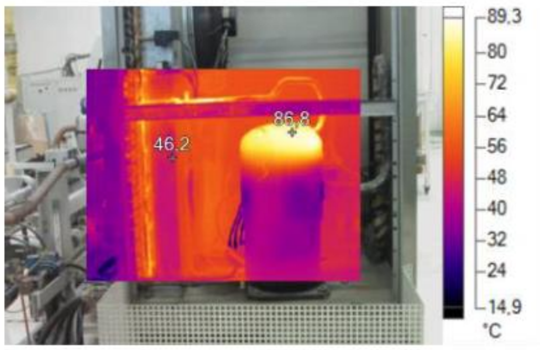
IP BVAK has a high proportion of small and medium companies producing furniture and each company dries the wood in their respective factories. This characteristic of the park emerged as a key point of synergy for the use of waste heat from the anchor tenant. The programme is now whether the waste heat can be used to build a common facility for all the furniture producing companies to dry their wood and thus further reduce emissions resulting from heating.

Figure 5. Using waste heat for wood drying during off-season and warm seasons

The assessment of feasibility of this initiative is currently ongoing but it has already raised an important challenge linked to incentives provided to businesses to share waste heat and energy flows in industrial parks. Currently, in order to sell its waste heat to neighboring tenants, the anchor tenant would need to obtain a license which would allow it to create a micro-market for energy. The administrative burden of applying for the license is a significant enough one that in many cases, the companies will choose not to explore the option further.

GEIPP-Ukraine is therefore working closely with the Ukraine Ministry of Economy to create a more enabling legal environment for the sharing of waste streams and identifying other policy barriers impacting the adoption of eco-industrial park approaches in Ukraine.



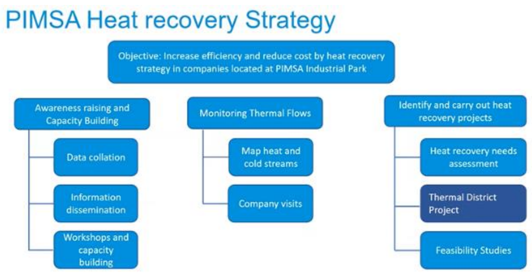


CASE STUDY 4: PILOTING A THERMAL DISTRICT IN MALAMBO INDUSTRIAL PARK IN COLOMBIA

As part of the GEIPP interventions in partner countries, priority parks are regularly assessed for their progress against the International Eco-Industrial Parks Framework. These assessments over time help the parks generate a plan for how they intend to improve their score against set EIP performance benchmarks.

As one of the priority parks in Colombia, the Malambo Industrial Park (PIMSA) developed a plan for how it would improve its EIP performance across the range of thematic pillars including heat recovery. One of the key action areas for PIMSA included the development of a heat recovery strategy whose objective is to increase efficiency and reduce costs by recovering heat in companies located in PIMSA. The strategy is built on three key pillars which are illustrated in Figure 6.

Figure 6. *PIMSA Heat Recovery Strategy*

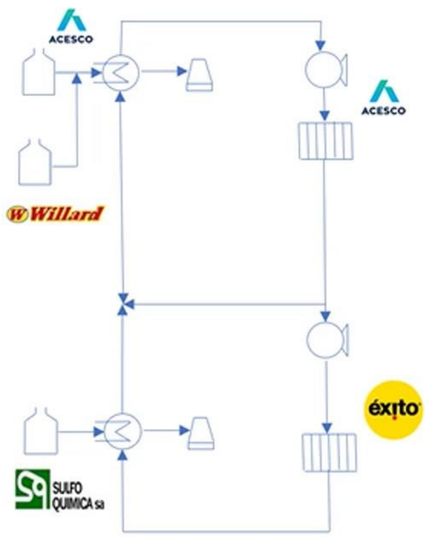


As a result of the implementation of various activities under the strategy, a thermal district project emerged as a proven solution for delivering heating or cooling services between firms generating waste heat with potential end users in other tenant companies.

In order to implement such a system, a comprehensive assessment of the demand for energy was required for PIMSA. As a result, it was estimated that the demand for refrigeration amounted to 1000 tons of refrigeration (TR) between two large tenant companies in the park. Further assessments of various sources of residual heat in different tenant companies generated the finding that the different sources had the potential to supply up to 85% of the total cooling demand of the industrial park.

However, a key challenge in the implementation of such a system was the identification of a suitable business model that would enable matching the cold water demand curve of industries with the sources of production of cold water. Among the main sources of waste heat streams were three tenant companies specializing in the production of batteries and electric accumulators, steel products, and aluminum sulfate respectively. The main consumers/sinks for cold water included a distribution center for various food products, and a steel products manufacturer (see Figure7).

Figure 7: *Schematic of heat sources and sinks in PIMSA*



Consequently, to implement the thermal district concept, the heat would need to be collected from the waste heat generating companies, brought to absorption chillers and pumped through insulated piping systems to the cold water end-users. The cost of investment associated with the establishment of the system proved to be a significant constraint, requiring USD 3.3 million to cover all the companies and meet the demand for 1000 TR. As such, the park decided to initiate the project at a smaller scale through a pilot that would supply 300 TR by connecting just two of the tenant companies. The business case and environmental benefits of the pilot are captured in Table 3.

Table 3: PIMSA pilot thermal district: business case and expected environmental benefits

Total Investment (CAPEX)	USD 960,000
Operation Cost (OPEX)	USD 26,000 per year
Revenue	USD 173,000 per year
Payback period	6 years
Expected Emissions Reduction	380 tCO2e/year
Electricity savings	2 MWh/year

The implementation of such a thermal district, while still at the planning stage, touches on all pillars of the EIP approach. For park management, it represents the development of a new service providing hot and cold water to tenant companies and can both generate an additional revenue stream and be a key component of the branding and positioning of the park as it tries to attract new tenants. The thermal district also offers substantial environmental benefits in terms of emission reductions and energy efficiency gains. Moreover, innovative projects such as the thermal district can yield substantial social dividends, from immediate job creation to community recognition and employee empowerment. Finally, for the companies involved in the scheme, the thermal district can represent important reductions in costs.

However, the successful implementation of a thermal district requires that a number of preconditions must be met. First, there must be enough sources of residual heat and the heat must be available in the right amount. Second, the heat sources and sinks must be located in reasonably close proximity to one another. Third, the presence of a large anchor tenant company means that a larger quantity of energy can be delivered and is crucial for the success of a pilot phase of the project and can serve as launchpad for a larger scale project.

CONCLUSION

Recovery and reuse of waste heat is a part of the mainstreaming of eco-industrial park approaches. First, it can improve energy efficiency, reducing the amount of energy wasted during industrial processes, which in turn can result in cost savings and improved competitiveness for businesses. Second, by capturing and reusing waste heat, businesses are harnessing an important lever for the reduction in their greenhouse gas emissions while often reducing their reliance on fossil fuels. Successful waste heat recovery initiatives, such as the case studies illustrated in this Best Practice Issue, can serve as models for replication in other contexts

The recovery of waste heat in industrial parks is a multifaceted process that requires collaboration between all stakeholders involved. Replicating successful waste heat recovery initiatives in other contexts can be challenging, but there are some common strategies that can be applied. Anchor tenants in particular can help create critical mass and support the adoption of waste heat recovery technologies and should be engaged early in the process through a dedicated stakeholder engagement strategy that clearly articulates the benefits of the proposed solution to the companies involved. This process requires trust and may be facilitated by the presence of a park management entity.

The legal and regulatory environment also plays a critical role in the success of waste heat recovery initiatives. Strict waste regulations can impact the transfer of biomass, biogas, or heat, making it essential to have regulations that support and facilitate the exchange of energy resources. An enabling legal environment, such as the one being created in Ukraine through amendments to electric energy market regulations, heat supply regulations, and environmental impact assessment requirements, can facilitate the exchange of energy resources between companies.

Furthermore, companies often have limited space to install the technologies required for waste heat recovery, so common infrastructure and business models that use Energy Service Companies (ESCOs) to manage the investment, deployment, and operation of waste heat recovery and use technologies can be effective solutions. However, this must be coupled with a sound business model that articulates the distribution of roles and responsibilities, investment among others. Therefore, contracting is also required to ensure that all stakeholders are aware of their responsibilities. Each project will require a unique solution, and in many cases, park management can act as an intermediary.

Finally, setting up heat reuse networks often involves significant infrastructure development planning and financing. Proximity between the businesses participating in the initiative may be one of the deciding factors in determining the viability of the project from a financial point of view and this proximity relies on sound concept planning by industrial park management entities.

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