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Renewable energies and energy efficiency in the Indonesian textile sector – opportunities and challenges

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Abstract: The Indonesian textile industry faces fundamental challenges regarding legal international and national requirements on sustainable production, as it has to deliver significant decarbonisation of their production. Energy consumption is one part, which is tackled exemplary by the EnaTex project (2021 – 2024), funded by German Ministry of Research and Development. This paper gives an overview of possible approaches for energy savings and implementation of renewable energies to replace fossil energies in power and heat by research activities in cooperation with fully integrated textile factories in Indonesia. The factories use mainly hard coal as fuel to generate steam and thermo-oil as process heat and are 100% supplied by electricity grid which is powered by 85% with fossil fuels. The novel approach, adapted for the textile industry, focus on recycling of waste heat with the method of process integration, using the Pinch analysis method to determine possibilities to save fuel. This approach is the base to substitute coal by implementation Renewable Heat and Power in a subsequently step. Within this analysis co-firing of local solid biomasses and production of biomethane from organic residues and sewage are being investigated as solutions. Further aspects are provision of green energy by means of PV and green hydrogen.

Keywords: textile industry; waste heat utilisation, renewable energies; energy efficiency.

1. Introduction

Data from the Copernicus Climate Change Service show that 2020 [1] was as a warning example also the warmest year on record for Europe. The average global temperature is today 0.95 to 1.20 °C higher than at the end of the 19th century. Scientists consider an increase of 2 °C, compared to pre-industrialized levels, as a threshold with dangerous and catastrophic global consequences for climate and environment. Indonesia participated at the COP26 [2] and agreed to push for higher ambitions in the nearer future.

Textile brands and production industries worldwide enhance the sustainability of their products. One of the main concerns is diminishing the fossil energy consumption by Energy Efficiency (EE) and Renewable Energy (RE) measures. Especially in Indonesia, the dependency from coal as fuel for process heat is omnipresent.

In the "Master Plan for National Industrial Development", the Indonesian government acknowledges the national textile industry as one of the ten most important industrial sectors, with over 1.13 million employees. It is also a target industry of Indonesia's Industry 4.0 strategy, which is established in the "Making Indonesia 4.0" master plan. Furthermore, the textile industry ranks fifth in Indonesia's gross domestic product and Indonesia is the fifteenth most important exporter of textile products in the world. To ensure competitiveness, the textile sector's share of Indonesian exports is to be increased from 2% to 5% by 2030. At the same time, the government has called for cost reduction by increasing production efficiency and by serving the globally growing market segment of sustainable textile production [3]. A study commissioned by the Indonesian government confirms that energy efficiency measures which can be undertaken in the short term can result in a 30% reduction in energy consumption. At 80%, the greatest potential for savings resides in the most energy-intensive processes of "textile finishing" (wet and dry finishing, the process of dyeing and equipment with functionalities) and in the use of more efficient machinery equipment along the entire textile production line [4]. Political guidelines to increase energy efficiency in the industry (annual energy increase of 1% until 2025) along with government programmes for implementation of energy management systems in the textile industry are intended to relieve the emission burden of the Indonesian textile sector, with currently 14 Mt CO_2eq of direct and 22 Mt CO_2eq of indirect emissions in 2028 [4]. To comply with international climate agreements, Indonesia aims to reduce its greenhouse gas emissions from 1990 levels by 29% by

2030 (UNFCCC) and to nearly double the share of electricity generated from renewable sources to 23% by 2025 (2017: 12.5%). [5] In 2016, 90% of the primary energy consumption of approximately 8.8 EJ was covered by fossil fuels, primarily domestic hard coal. Primary energy consumption is expected to increase to 54 EJ by 2050 due to demographic and economic developments. The forecast of electricity consumption states that hard coal is currently and will continue to be the dominant energy source, according to the Indonesian Ministry of Energy's 2018-2027 National Energy Plan. [3]

2. The EnaTex Project

In order to strengthen a sustainable form of energy use and supply, energy policy guidelines such as the "Green Energy Strategy" and legal norms regarding energy efficiency and the promotion of renewable energies have been established and announced within the national "Master Plan for Energy" (RUEN) and for achieving "Energy Savings" (RIKEN) have been introduced in Indonesia. [6]

Within this political framework, the EnaTex project exemplary focus on the finishing process of textile production process to evaluate the possibilities to safe energy and GHG-emissions by EE and RE within generation, distribution and utilisation of power and heat. The main focus for the IZES gGmbH is the heat supply, which currently is based on hard coal combustion to generate steam and to heat up thermo oil for provision of process heat.

This paper focus on the identification and systemic optimisation of heat distribution and utilisation. While classical approaches to energy optimisation often focus on improving the efficiency of the individual equipment delivered by a special supplier which is in the own interest of suppliers and manufacturers. But experience shows, however, that the optimal linking of energy flows in the overall "company" system (production-site) usually brings a much greater increase in efficiency than the often very costly improvement in the efficiency of individual components and equipment.

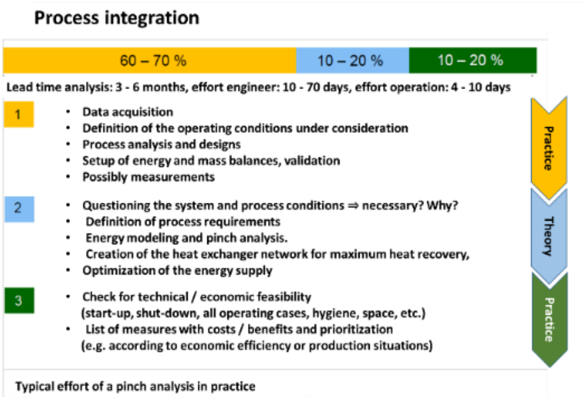
It’s assumed, that in fully integrated textile companies each machinery is solely optimist internally and connected to an energy supply network but not integrated in this supply process to optimize energy usage but to fulfil production requirements. Kim et. al. 2022 [7] identified for the textile industry, that for example reactive dyeing consumes enormous amounts of energy owing to the absence of a proper heat recovery system. The recovery of waste-heat means reuse of certain energy level as input for other machines can generate less primary energy consumption in-situ without fuel switch. The main principle is the reuse of remaining exergy (temperature level) and enthalpy (energy content) by establishment of an Heat Exchanger Network (HEN) where Linnford et. al. [8] defines typically 20-30% energy saving potentials by implementation of such a network.

A HEN is a solution to a comprehensive integrated production process, ranging from individual machinery to a total site and can be applied for combination of different heat containing media (steam, condensate, thermos-oil, air, etc. This “process integration” approach is designed to establish trade-offs between operational costs (minimal energy and resource requirements and minimal emission) and investment costs by debottlenecking current processes without interruption of production process and quality.

3. Materials and Methods

Within EnaTex, as first step the factory energy supply and distribution as well as the production process chain will be mapped and analysed. For the optimisation by this „process integration“, the Pinch Analysis (PA) method, first published by Linnford and Flower in 1978 [9] will be applied. The PA is an important and advanced tool in energy process integration. It is applicable to the optimisation of virtually all thermal energy systems and has been used successfully in a wide range of industries.

The focus of the PA is always on a holistic optimisation of the thermal energy supply at process and plant level. It is named after the Pinch Point which identifies the theoretically minimum of a possible energy requirement for the provision of cooling and heating for processes. This is primarily achieved by ideally interconnecting existing energy flows by means of a heat exchanger network (HEN) for internal heat recovery of different flows within thermal energy content (water, thermos-oil, steam). The basic prerequisite for the application of the PA is the simultaneous presence of cooling and heating demand, which require one or more process steps. The areas of application range from individual production steps, to a sub-area of production (e.g. a production line), to a holistic consideration of one or more production plants with a local connection. The following figure 1 shows the time schedule for identification and implementation of the PA which is being applied in EnaTex.



Process integration

Lead time analysis: 3 - 6 months, effort engineer: 10 - 70 days, effort operation: 4 - 10 days

1
- Data acquisition
- Definition of the operating conditions under consideration
- Process analysis and designs
- Setup of energy and mass balances, validation
- Possibly measurements

2
- Questioning the system and process conditions ⇒ necessary? Why?
- Definition of process requirements
- Energy modeling and pinch analysis.
- Creation of the heat exchanger network for maximum heat recovery,
- Optimization of the energy supply

3
- Check for technical / economic feasibility
  (start-up, shut-down, all operating cases, hygiene, space, etc.)
- List of measures with costs / benefits and prioritization
  (e.g. according to economic efficiency or production situations)

Typical effort of a pinch analysis in practice

Figure 1. Applied Methodology of Pinch Analysis – practical issue [10]

The main task of process analysis is the identification of the “Pinch point”. Two so-called compound curves (hot-red, cold-blue) in the enthalpy-temperature diagram (see figure 2), which are each formed from the sum of the enthalpies in the considered temperature intervals of all heat-emitting (hot) and heat-absorbing (cold) material flows. As shown, the PA divides the process in to thermodynamically separate regions: left of the pinch point the heat surplus, which can be reused to a certain energy level and right of pinch point the thermal deficit which can be balanced by connecting the heat surplus

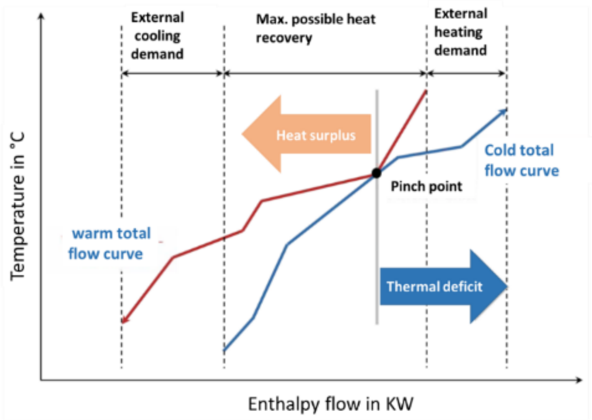


Figure 2. Pinch Diagram [10]

This minimum temperature difference at the pinch occurs at a certain enthalpy. The area of curve overlap parallel to the enthalpy axis gives the maximum possible heat recovery. With this method, the quality of different heat exchanger networks can be determined globally. By determining the minimum temperature difference, the maximum heat gain can be calculated and the network size and costs can be estimated.

4. Results and Discussion

The EnaTex projects intends to maximize the energy efficiency and minimize the total cost of the textile finishing process by the optimum design of the HEN system as best practices approach exemplary.

As constraint to be investigated, the potentials level of reusing waste heat depends on the availability of temperature levels of the processes and the intended reuse. Certain heat levels are displayed in figure 3, showing typical pairings for connection within a HEN.

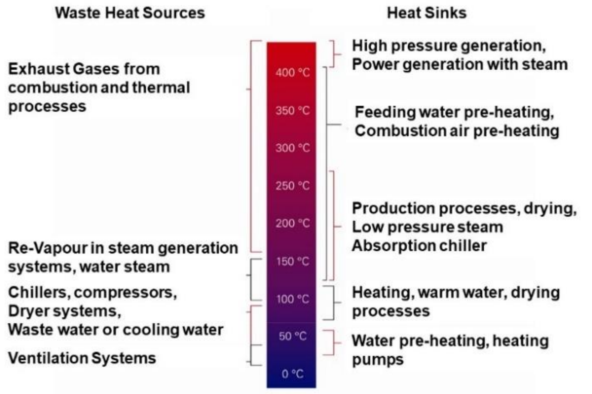


Figure 3. Possible heat potentials and sinks in Industries [11]

As stated, a HEN is limited to certain temperature levels and common pairings (compare figure 2 and 3) as well as by operational constraints, which has to be considered.

According to Kemp (2006) [12] it can be highlighted that a successful implementation of a HEN, waste heat of a single machinery can be reused as input for other machineries on site. This can be done even cross-media such as air/water, water/water, steam/water and thermo-oil/water. Important are the result of the PA along the "heat" and the "cold" curve, to combine the appropriate flow. At the pinch point, where the hot and cold streams are the most constrained, large heat exchangers are required to transfer heat between the hot and cold streams, generating high investment costs. In order to reduce capital cost, in practice a minimum temperature difference (Δ T) at the PA is demanded, e.g., 10 °K. At this point it's possible to estimate the heat exchanger area and capital cost, and hence the optimal Δ T minimum value. However, the cost curve is quite flat and the optimum may be affected by "topology traps". The pinch method is not always appropriate for simple networks or where severe operating constraints exist. Kemp and Lim (2019) [13] discusses these aspects in detail for complex systems.

The application of energy efficiency approaches therefore has technical limits and regarding the intendent decarbonisation of the production process Renewable Energy sources (RES) are suitable to compensate the remaining thermal deficit as well as to supply heat to processes which are proved as not suitable for a HEN.

The PA therefore should always consider costs factors by establishment of HEN to enable a comparison to RE-systems alone or in combination to achieve the optimal cost-benefits factor. This evaluation on RE systems in EnaTex comprises photovoltaics, solid biomass, biogas/biomethane, windpower, geothermal and solar thermal energy to substitute the current hard coal as energy fuel for heat. Novel approach of sector coupling are the conversion of RE power generation into Green H_2 and the provision of heat-from-power with High-Temperature Heating Pumps (HT-HP). Those HPs converting the waste heat using the organic Rankine cycle to generate 4 – 5 times heat out of the electrical power input. Such HP can be used either to increase the HEN efficiency as well as standalone systems for singe machines. Important is the supply with power from RES such as photovoltaic or wind energy to generate an added value for climate protection. Kim et. al. 2022 [7] states exemplary states for a HEN, applied on waste water of dyeing process, a reduced energy consumption of max. 73.65% by application of HT in the process.

5. Conclusions

Despite the various contributions of conventional waste-heat recovery systems to increase energy efficiency, several challenges still need to be solved. The optimal layout of the HEN as well as possible re-arrangement of piping and machinery on the production site as well as installation of small scale, decentral optimized HEN. However, since textile production is using different textiles and therefore distinguished dyeing, additives etc. the production process on site is very heterogeneous, that the average temperature of waste heat sources continuously changes and may present an average in collection pipes. Thus, the PA must consider fluctuation and therefore include buffers or other technical means for optimal configuration of the HEN to assure that the maximum amount of waste heat generated in the processes cannot be recovered.

As challenge, the integration of heat between hot and cold streams, and finding the optimal HEN in terms of costs, needs numerical algorithms which computation efforts extends exponentials in complex systems. For simple networks of a few streams and heat exchangers, hand design methods with simple targeting software are often adequate, and aid the engineer in understanding the process. As the textile industry is very dynamic and production can alter daily with certain machines are in maintenance or modification for new products, the HEN must be robust and fail-safe designed. Back-ups such as buffer systems are inevitable. The optimal configuration will be determined finally by a techno-economic analysis with focus on reduction of the cost and energy of the whole system, to contribute the economic and environmental improvements in the textile industry.

As example for 100% decarbonisation potentials, the project partner Brückner GmbH from Germany analysed for Stenter systems, that 50% of CO_2eq-emissions can be avoided by improvment of the operation control systems, and integration of a HEN. The remaining 50% of the remaining CO_2eq-emissions by application of RE systems.

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