BACKGROUND

Industrialization is vital for economic development and has helped bring millions out of poverty in recent decades. But as more countries industrialize, growing consumption, rapid urbanization and unsustainable use of natural resources is exacerbating climate change and polluting the ecosystems on which we depend (UNIDO 2017). The pattern of current production and consumption, scale and speed of resource use has almost reached the limit of what planet can offer and sustain. While it is essential that industry continues to grow and prosper, it is also worth considering changing the mindset of the way industrial sector does business and becoming more efficient and responsive to resource consumption and waste generation.

INTRODUCTION

Pagottan Sugar Mill is located at Pagottan Village, Jl. Raya Madiun-Ponorogo KM 9, Madiun, East Java. It is one of the sixteen factories of state-owned sugar plantation company, PT. Perkebunan Nusantara XI (PTPN XI). The company volunteered to join the resources efficient and cleaner production (RECP) - Indonesia demonstration programme in the food sector category. Before implementation of the techno-economically viable RECP options, RECP assessment and baseline data was collected and compiled by National expert and company’s RECP team. The objective of the assessment was to assist Pagottan Sugar Mill in reducing the use of resources and minimizing waste generation. Focus of RECP was on energy, water, and materials efficiency, and waste management. Water being a scare commodity was prioritized along with energy consumption. After the identification of feasible RECP options, the next step was to convert option to viable solutions and prepare implementation plan to embark implementation of techno-economically viable and environmentally desirable RECP solutions.

PROCESS DESCRIPTION

Pagottan Sugar Mill produces white sugar by processing sugar cane using sulphitation process for bleaching. The main raw material, sugar cane, was mostly outsourced from farmers (>80%) and the rest was from captive plantation (<20%). Sugar recovery before RECP assessment and implementation after RECP was 7.52% which is below global benchmark but this study has not focused on sugar recovery in this phase. The process flow chart of sugar production in Pagottan Sugar Mill is depicted as Figure 1. Specific resource consumption of important resources before the RECP (as baseline consumption data before RECP) and potential of RECP for similar mills is presented in Table 1.

### Table 1: Baseline data and potential of RECP in Pagottan Sugar Mill

<table>
<thead>
<tr>
<th>No.</th>
<th>Components</th>
<th>Unit</th>
<th>Baseline before RECP</th>
<th>RECP potential</th>
<th>Saving potential USD/year</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific energy consumption (SEC)</td>
<td>kWh/ton cane</td>
<td>32.9</td>
<td>30</td>
<td>92,800</td>
<td>Milling using electrical energy</td>
</tr>
<tr>
<td>2</td>
<td>Electricity generation from bagasse</td>
<td>kWh/ton bagasse</td>
<td>122.7</td>
<td>150</td>
<td>218,400</td>
<td>Based on benchmarks</td>
</tr>
<tr>
<td>3</td>
<td>Specific water consumption</td>
<td>m³/ton cane</td>
<td>7.7</td>
<td>7.0</td>
<td>7,840</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Specific WW generation</td>
<td>m³/ton cane</td>
<td>6.2</td>
<td>5.6</td>
<td>38,400</td>
<td>WWTPC 0.25/m³</td>
</tr>
<tr>
<td>5</td>
<td>GHG emission</td>
<td>ton CO₂/y</td>
<td>675 T</td>
<td>0</td>
<td>675 T</td>
<td>Surplus energy</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>319,040</td>
<td></td>
</tr>
</tbody>
</table>

- Assumed TCD 320,000 ton/year
- Electricity price USD 0.1/kWh
- Sugar price USD 0.7/kg
- Bagasse is 25% of cane with 50% moisture content
- Water price USD 0.035/m³
- Wastewater treatment cost USD 0.20/m³
RECP POTENTIAL
UNIDO employs its long standing expertise in improving agricultural processes and light manufacturing to help raise both productivity and incomes, in particular through support for small and medium-sized enterprises (SMEs), and by increasing the participation of women and young people in productive activities. The most significant RECP potential in sugar mill is the yield (sugar recovery) improvement and energy-related area. Sugar mill produces bagasse as by-product which is generally utilised for generating electricity for captive power consumption of factory and sale of surplus energy. This will save electricity consumption which means saving for electrical energy and reduction of GHG emissions.

RESOURCE EFFICIENCY & EMISSION REDUCTION MEASURES
Number of RECP options were identified during the RECP assessment and feasibility analysis by RECP team of Pagottan Sugar Mill. Some of the options are listed below:
- Strict monitoring of incoming sugar cane quality (inert %age and cane maturity) to achieve higher efficiency of the process and less sugar loss.
- Control of timing between juice crushing and pH adjustment to reduce sugar inversion.
- Optimize water management particularly in cooling water for condenser. Minimizing the water consumption could be done by recirculating the cooling water using spray pond or cooling tower.
- Adjust adequate retention time for cooling and crystallizing sugar before centrifugation process.
- Avoid spillage or leakage on all equipments.
- The maintenance of pump especially for massecuite must be improved and checked regularly.
- Optimize boiler efficiency to generate maximum steam and power

RECP OPTIONS IMPLEMENTED
By the time this case study is written, limited RECP options agreed by management were implemented and their results is compiled in this case study. Some of the reported RECP measures implemented until compilation of this case study are briefed in Table 2 and the achieved results, such as saving in electricity and water consumption, are compiled and presented in Table 3.
The major concern of Pagottan Sugar Mill reported was insufficient amount of water availability during the milling season. The water is used for several unit operation however critical usage area is condenser injection. Inadequate amount of water available for the cooling system for injection was major concern and in scarcity of water condenser was not working properly. During RECP programme assessment, it was noted that the existing cooling tower was broken, therefore, it was not able to cool down the condenser water temperature as required. This resulted in a higher cost and water usage due to usage of significant amount of fresh water taken from the ground and river. During RECP implementation, a new cooling system was installed which resulted in reduced fresh water consumption due to recycling of cooled water from cooling tower.

Installation of Vapour Line Juice Heater (VLJH) results in the reduction of steam consumption up to 3 ton/hour. VLJH is a heat exchanger between vapour and juice where the steam from the end of the evaporator is being utilized to heat up the raw sugar juice. Therefore, the sugar juice’s temperature which enters the juice heater increases and resulted in decreasing steam demand. In addition, with VLJH, the amount of condenser water is reduced since the amount of steam which enters the condenser is reduced as well.

As presented in Table 3, the specific energy consumption (SEC) was reduced to nearly 30 kWh/ton cane which is close to the benchmark for a sugar mill using electric motor for cane crushing/milling. As a result, consumption of purchased electricity from PLN (state-owned electricity company) decreased from 3.53 kWh/ton cane to 2.12 kWh/ton cane despite of reduce energy generation from bagasse. Reduced SEC/ton cane resulted in the reduction of GHG emissions. However, there was reported decline in electricity generation per ton bagasse: from 122.7 kWh/ton bagasse before RECP to 113.2 kWh/ton bagasse after RECP. This may be attributed to the low crushing days 103 days in 2017 while the previous year was 145 days. Low crushing days also indicate the mill was not operating continuously and low crushing due to non-availability of cane. The reason for reduced energy despite of steam savings need to be studied and will be reported in next phase case study.

<table>
<thead>
<tr>
<th>No.</th>
<th>Implemented RECP options</th>
<th>Investment (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Implementation of a cooling tower</td>
<td>17,500</td>
</tr>
<tr>
<td>2</td>
<td>Installed Vapour Line Juice Heater (VLJH)</td>
<td>98,000</td>
</tr>
<tr>
<td></td>
<td>TOTAL INVESTMENT</td>
<td>115,500</td>
</tr>
</tbody>
</table>

Table 2: Resource efficiency measures implemented by Pagottan Sugar Mill

The implementation of moderate number the RECP options in Pagottan Sugar Mill has contributed to the reduction in GHG emissions, energy consumption, and water consumption. The implementation investment and savings reported indicate a payback period of 1.2 year on investment. Though there has been moderate reduction in electrical energy and related GHG but this can be improved further by improving power generation efficiency.

**RESOURCE EFFICIENT AND CLEANER PRODUCTION**

The Resource Efficient and Cleaner Production (RECP) programme has long been a central element in the work of UNIDO on the environment. This flagship initiative, run jointly with the United Nations Environment Programme (UNEP) and funded principally by Switzerland, delivers services to improve resource productivity and environmental performance in 63 developing countries and economies in transition, targeting governments, civil society and businesses, with a particular focus on SMEs.

Resource Efficient Cleaner Production (RECP) is a new and creative way of thinking about products and the processes that make them. It is achieved by the continuous application of strategies to minimize the generation of wastes and emissions. RECP strategy which comprises of following eight techniques were applied in this case study:

1. **Good House Keeping (GKH):** appropriate provisions to prevent leaks and spills (such as preventative maintenance schedules and frequent equipment inspections) and to enforce the existing working instructions through proper supervision, training etc.
2. **Input Material Change (IMC):** replacement of non-renewable inputs by low carbon renewable feed stock.
3. **Better Process Control (BPC):** modification of the working procedures, machine instructions and process record keeping in order operating the processes at higher efficiency and lower rates of waste and emission generation.
4. **Equipment Modification (EM):** modification of the production equipment and utilities (for instance through addition of measuring and controlling devices) in order to run the processes at higher efficiency and lower rates of waste and emission generation.
5. **Technology Change (TC):** replacement of the technology, processing sequence and/or synthesis pathway in order to minimize the rates of waste and emission generation during production.

<table>
<thead>
<tr>
<th>No.</th>
<th>Components</th>
<th>Unit</th>
<th>Before RECP</th>
<th>After RECP</th>
<th>Savings (US$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SEC</td>
<td>kWh/ton cane</td>
<td>32.9</td>
<td>30.4</td>
<td>80,000</td>
</tr>
<tr>
<td>2</td>
<td>Electricity generation from bagasse</td>
<td>kWh/ton bagasse</td>
<td>122.7</td>
<td>113.2</td>
<td>NQ</td>
</tr>
<tr>
<td>3</td>
<td>Specific water consumption</td>
<td>m³/ton cane</td>
<td>7.7</td>
<td>7.4</td>
<td>3,360</td>
</tr>
<tr>
<td>4</td>
<td>Specific WW generation</td>
<td>m³/year</td>
<td>6.2</td>
<td>5.9</td>
<td>19,200</td>
</tr>
<tr>
<td>5</td>
<td>GHG emissions</td>
<td>kg CO2/ton</td>
<td>32.3</td>
<td>29.8</td>
<td>800 ton CO2/year*</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>102,560</td>
</tr>
</tbody>
</table>

Table 3: Results of RECP measures implemented to date

**CASE STUDY**

**Indonesia**

**Resource Efficient Cleaner Production**

*SEC Savings is considered from PLN purchased electricity*
6. **On Site Recovery/Reuse (RR):** reuse & recycle of the wasted materials and energy (thermal energy) in the same process or for another useful application within the company.

7. **Production of Useful By-Product (BP):** transformation of the wasted material into a material that can be reused or recycled for another application outside the company.

8. **Product Modification (PM):** modification of product characteristics in order to minimize the resource usage and associated environmental impacts of the product during or after its use (disposal) or to minimize the environmental impacts of its production.

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