Food and Drink – PI Specifics

How can process integration help me?

Process integration (PI) is a very efficient approach to improving the energy efficiency of large and complex industrial facilities. PI refers to the application of systematic methodologies that facilitate the selection and/or modification of processing steps, and of interconnections and interactions within the process, with the goal of minimizing resource use. PI can be used in new designs, or in existing installations, in order *to* ***ensure that energy, water, and raw materials are used optimally.*** Among PI techniques, pinch analysis is the most often used.

Pinch analysis is a systematic procedure for investigating the energy flows in a given process, and for quantifying the minimum practical utility demands for process heating and cooling. The latter information is very useful, as it allows us to compare the actual energy consumption with a minimum, and to identify the real potential for improvement. It allows us to benchmark the plant's energy consumption against its minimum achievable energy consumption. Maximum potential for cogeneration, and the viability of heat pump applications can also be analyzed with PI tools.

Once the targets for minimum energy consumption are identified, pinch analysis can be used to identify energy-saving projects that allow us to approach these targets in practice (taking into consideration plant constraints, such as current piping location). These projects may be located in the various processes/units, or in utility systems (steam production and distribution systems, cooling systems, etc.), and can be the basis of long-term investment planning.

Aspects of conventional energy audits (boiler efficiency, compressed air systems, insulation, steam traps, etc.) can be included with the PI approach, in order to complete a global and systematic analysis of the entire process. It is essential to use specialist software to assist in processing the large amount of data involved in a PI analysis. There is suitable software available that allows the rapid calculation of energy-saving potential, and provides an environment to rapidly design or redesign optimal heat exchanger networks.

The most important requirements for performing a PI study are practical process knowledge in the relevant industry, and significant experience in applying PI techniques. The ideal time to apply pinch analysis is during the planning of major investments, and before the finalization of process design. Maximum improvements in energy efficiency, together with reduced investment, can be obtained for new plant design because many of the plant layout constraints can be overcome through redesign. Additional benefits include reduced capital cost in the utility systems, as well as improved utility performance.

In retrofit projects, by comparison, improvements in energy efficiency usually require some capital expenditure. In this case, PI can be specifically directed towards ***maximizing the return on investment***. PI techniques ensure that combinations of project ideas are evaluated simultaneously, to avoid both "double-counting" savings, and conflict between projects. Indeed, the final investment strategy for the available opportunities will ensure that site development is consistent and synergistic.

Whether for an existing plant retrofit or a new plant design, pinch analysis generally begins with carrying out a heat and material balance that is representative of each process. A model is then built from this balance, in order to represent the heat load for heating or cooling each relevant process stream. This model allows us to:

- Define the minimum utility consumption targets for process heating and cooling (steam, cooling water, chilled water, etc.);
- Identify the possibilities for process-to-process and utility-to-process heat transfer improvements;
- Identify how to change the existing process operation to further reduce energy consumption.

A model of the site utility system may be produced in parallel with the PI study. Through this model, all savings identified within the processes can be directly related to savings in purchased utilities. This avoids the common error of recommending utility-saving projects in one part of the site, while shifting the problem to another point on the site. A common example of this error is where apparent savings of low-pressure steam in one process leads to steam venting elsewhere.

The following table summarizes typical percentage savings in total purchased fuel, for a range of simple payback periods, as identified through PI techniques—mainly pinch analysis. (For Pulp & Paper, the percentages are expressed in terms of total steam production from boilers and recovery boiler).

Energy-Saving Potential through Process Integration (%)

Industrial Sector	Quick Win	Payback 1-3 years	Payback 3-6 years	Total Potential *
Oil Refining	up to 5	10-15	up to 15	10-25
Petrochemicals	up to 5	5-10	up to 20	10-25
Iron & Steel	up to 5	5-15	10-20	10-30
Chemicals	up to 5	10-15	up to 25	15-35
Food & Drink	5	15-25	up to 25	15-40
Pulp & Paper	5	10-25	25	10-35

* Total potential is not simply the summation of all columns because some long-payback projects may be an alternative to some of the quick-win and medium-payback options.

Additional energy savings, typically between 5% and 15%, can be obtained through good housekeeping (steam traps and leaks, furnace tuning, cleaning of fouled heat exchangers, etc.), as well as through monitoring and targeting, process modifications, etc. The numbers vary, depending on the amount of attention that energy receives at the facility before these methods are applied, as well as on other factors such as complexity, and the fouling potential of the materials being handled.

The following specifics on PI for the food and drink sector are based on the worldwide experience of applying PI in this sector. The results are generic and not adjusted for local conditions of geography and climate.

Application of PI to the food and drink industry

Product quality is paramount in all industry sectors and especially so for food and drink. Generally, there is a natural resistance to making changes to process operations that might conceivably affect product quality. Fortunately, the PI data can be constrained to prevent project proposals that can upset product quality.

A common feature in food and drink manufacturing is the use of batch and continuous processes. The PI procedure can simultaneously address batch, semi-continuous, and continuous unit operations, and deliver practical and feasible results. In these cases, energy savings may involve heat storage if, for example, heat sources and heat sinks are not synchronized. Further savings may be achieved by rescheduling batch operations, with spin-off improvements in yield. For continuous operations, energy savings typically involve direct heat recovery between process streams, and may encompass indirect heat recovery via existing or new utilities, such as a hot water loop.

The PI track record shows that, for revamping projects, energy savings and expansion objectives are met at lower capital costs than when using conventional energy assessment techniques. In new plant design, the emphasis is on selection of the optimum process configuration, and cost savings can be even higher than for revamping projects. Significant energy and capital will be saved because plant layout can be configured to minimize the energy consumption at greatly reduced infrastructure costs. PI techniques may be applied alongside of the engineering company's design process, with no adverse effect on the engineering schedule. Indeed, time can be saved through the early elimination of suboptimal alternatives, and the concentration of effort on the best solutions.

The application of PI is complementary to the know-how and expertise of a good process engineering company. Common unit operations that must be given careful consideration include:

- Evaporation, concentration, distillation;
- Drying;
- Pasteurization;
- Coking, mashing, etc.;
- Refrigeration;
- CIP (clean-in-place) systems.

PI can be used to achieve:

- Energy savings, and GHG emissions reduction;
- Water rationalization and reuse;
- Integration of new processes (new machine, new line, etc.);
- Debottlenecking, expansion;
- Optimizing evaporator integration with the background process heating loads;
- Optimization of any process operation that requires heat;
- Review of any process development plans in the context of the best available technology and their impact on utility demands;
- Production rate optimization to maximize the output for existing equipment.

PI studies can include aspects of conventional energy audits, such as steam traps replacement, and control of oxygen excess in boilers. However, for the purposes of the remainder of this document, only the benefits attributable directly to PI activities are enumerated and quantified.

Typical Sub-Sectors and Size Considerations for worthwhile PI Study

PI is appropriate for application within Breweries, Distilleries, Sugar Plants, Dairies and dairy products, Corn Processing, Starch, Edible Oils and also has a track record in the general food industry.

A PI study can be tailored to be worthwhile for plants that have relatively small energy usage of around 10 t/h of steam (22,000 lbs/h - about 1.5M$/year at a natural gas cost of 0.23$/m3 and 70% efficiency for steam production and distribution) but this will depend on how the steam is used. Plants that use less steam or that use the bulk of the steam in specialist equipment, such as jacketed vessels, evaporators, ejectors, turbine drives, tank coils, etc. are unlikely to produce good savings results. This is because it is not usually practical to replace the steam consumed in these types of equipment with any form of heat recovery.

Benefits of PI

Traditionally, capital spending on outright energy conservation projects has not been a priority in North American industries. In Canada, the recent ratification of the Kyoto Protocol should change this focus. The PI approach, combined with conventional energy efficiency audit, and with monitoring & targeting techniques, is probably the best approach that can be used to obtain significant energy savings and GHG emissions reductions. PI can lead to the following benefits:

- Quick-win and short-payback projects save up to 5% of energy costs with a one-year payback;
- Medium-payback projects produce a further 15%–25% energy saving within a one-to-three-year payback;

- Long-payback projects can produce additional savings of up to 25% of the site energy bill with overall payback times of four to six years.

Overall, the savings opportunities identified by PI studies in food and drink plants typically amount to between 15% and 40% of the purchased fuel.

The track record for this sector indicates that between 50% and 75% of recommendations for improvement are taken to the implementation stage. These usually include the quick-win projects and the most attractive medium-payback projects. Long-payback projects (typically, utility infrastructure projects, such as a gas turbine with heat recovery steam generation system) are more often implemented when they provide additional economic incentives to their stand-alone energy payback (e.g., production increases, avoidance of capital spending, security of electricity procurement, etc.), making them attractive compared to existing investment plans. In retrofit situations, plant layout, construction materials, and maintenance of product/operating integrity are key influencing factors in the economic viability of implementing heat recovery improvement projects.

The implementation record for projects identified by pinch analysis has been a function, primarily, of economic factors, particularly, the lack of availability of capital, and the low cost of energy in the past few decades. The competitive capital market and organizational focus on product quality, product enhancement, and environmental compliance-driven investments have been important influencing factors. The implementation rate of longer-payback projects could, however, progressively increase within the new context of the Kyoto Protocol.

General Approach used to carry out a PI Study

A PI study is usually carried out in two main phases: a phase where minimum energy consumption targets for process heating and cooling are determined, and a design phase. Whether on an individual unit, or on a broader, site-wide basis, the first phase of work is to quickly, but accurately, identify the scope for energy savings, prior to undertaking detailed design activities in the second phase. This phase is traditionally based on a heat and mass balance, produced from test run data, typical operating data, process simulations, or a mixture of these data sources. The data required include process flow rates and temperatures, as well as heat loads across all major exchangers for a representative operating case. Where available, heat transfer coefficients are important for effective capital cost targeting, i.e., for determining the required investment costs to achieve in practice the identified energy-saving potential. (Small heat transfer coefficients will imply larger heat exchangers, and thus, larger investments, and vice-versa.) Economic data for steam and fuel costs, and acceptable investment criteria are also important. Where possible, meter readings may be used for cross-checking, and for reconciling conflicting data.

In the second phase of work, systematic design techniques are used to develop the individual projects that will achieve the savings-potential identified in the targeting phase. More detailed equipment design considerations, plant operating and layout issues, and economic cost estimates are developed in order to more accurately define the achievable potential energy-savings and their related costs within each unit.

The water balance can have a profound effect on PI results in water-based processes where energy and water may be intimately related. Analyzing the water network in advance of the PI study often identifies quick-win energy saving ideas that may involve the rationalization of water users, and supplies to and from various hot and cold water tanks.

Typical deliverables of a PI study

The deliverables of a PI study are a function of the size, complexity, and particular issues of the plant, as well as the specific requirements of plant management. The typical deliverables may include the following:

- Assessment of current energy consumption efficiency;
- Heat and mass balance of the process, including a process simulation, when appropriate;
- Identification of the minimum energy consumption targets for process heating and cooling;
- Identification of cost-effective projects that reduce energy consumption within and between the processes, and that swap high cost utility use for lower cost utility;
- Specification of a utility scheme tailored to the site's specific requirements;
- Evaluation of marginal cost for steam and electricity production;
- Calculation of the potential for on-site power generation to reduce dependence on external supply;
- A simulation of the site's steam and condensate systems for "what if" project-evaluation, and, ultimately, for day-to-day optimization;
- Preliminary engineering- and cost-evaluation of recommended projects; and
- A consistent strategy for energy-related investment.

Generally, the deliverables will take the form of a report, with details and schematics for each recommended project. Heat and mass balance and simulation can be provided in computer files.

Typical Projects

Economic projects identified during a PI study are plant-specific and depend on the following: size and arrangement of the plant, required pipe distances and routes, space constraints, operating limitations, and level of engineering needed to overcome local hazards or influencing conditions. The paybacks presented below may differ from plant to plant. A non-exhaustive list of typical projects includes the following:

- Quick Wins:
  - Operational improvements to refrigeration systems, e.g. adjusting compressor pressure to ambient temperature;
  - Hot water management improvements, e.g. balancing hot water supplies with demands;
  - Enhanced evaporator performance, e.g. improved non-condensible venting.
- Short- to medium-payback projects, typically with a one- to three-year payback:
  - Instrumentation modifications, e.g. improved control loops;
  - Optimization of refrigeration systems, e.g. increasing refrigerant pressures within operational constraints;
  - Evaporator feed preheat by improving heat recovery;
  - Rearranging existing heat exchangers to make better use of them, and addition of new heat exchangers;
  - Increased use of low-grade vapours from a multi-effect evaporator;
  - Pasteurizer heat recovery, e.g. use of heat storage;
  - Recovering steam condensate to boiler house;
  - CIP water preheat by heat recovery;
  - Dryer air preheat using heat recovery.
- Long-term payback projects, typically with a three- to six-year payback:
  - Indirect heat recovery via a hot water loop;
  - Kettle vapour heat recovery;
  - Heat integration of hot dryer exhaust;
  - Cogeneration (CHP) via steam turbine, gas turbine, or gas/diesel engine;
  - Boiler economizer (payback will be lower for large steam boilers);
  - Mechanical vapour recompression (heat pumps);
  - Increased number of evaporator effects.

Errors in PI application

The most common errors made during a PI study (in no particular order) are:

- "Let's get the low-hanging fruit first." This generally leads to much lower savings because some projects are conflicting and segmented, which makes the cost of remaining heat-recovery projects prohibitive;
- Ignoring possible changes in the upcoming 2–5 years (regulation, equipment replacement, expansions). This may result in projects that are obsolete by the time plant personnel is ready to implement them, or that don't achieve the forecasted payback;

- Ignoring possible process changes, such as modifications to set points (e.g., temperature of hot water). This generally results in many low-payback projects being overlooked;
- Not working with plant personnel. This often results in projects not being implemented, or not being understood;
- Carrying out only a steam balance, and using that as a starting point. Such an approach generally does not fully reveal potential, and may lead to significant errors;
- Errors in analyzing marginal economics (e.g., boiler minimum turndown, drives vs. turbo generators and fuel used in boilers for header pressure control), or in analyzing changes in economics (e.g., better boiler control, better steam and power management, and changes in production to take advantage of night-time energy costs).

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