APPLICATION NOTE
WIND POWERED INDUSTRIAL PROCESSES

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SUMMARY

This Application Note outlines two methods to assess the viability of industrial processes, powered by an onsite wind turbine. Onsite wind power offers cost savings and other competitive advantages to companies capable of benefitting from it.

Both of the methods outlined focus on whether an organization has the flexibility needed to gain maximum benefit from self-consumption of onsite wind power.

The first method – the 'Flexibility Checklist' – sets out ten criteria that measure an industrial processes' capacity to operate flexibly: energy efficiency; efficient energy storage; time behavior; partload-ability; overload-ability; synchrony; adaptation over short timescales; adaptation over long timescales; the activation rate; and whether the potential flexibility is conceptual or proven.

Companies can score themselves against each criterion. The Flexibility Checklist provides a quick and easy assessment of potential problems from powering industrial processes with on-site wind turbines, although it is not sufficiently thorough to enable final decision-making.

The second method – the 'Flexibility Audit' – starts with a comprehensive assessment of an industrial sites' potential flexibility. The audit will search for potential flexibilities right down to the individual device level. The auditors take an open-minded approach in order to uncover flexibility where it is not expected. Data from the audit are combined with data on the company's power consumption and business processes to model optimum solutions. The Flexibility Audit requires greater commitment from the company, but delivers results that are built on tested data.

The concept of value in flexibility is relatively new to most company managers. The identification of flexibility is not part of most energy reviews. Grid regulation across Europe has been blind to the benefits of onsite wind power with local consumption. Transmission, distribution and generation companies have little reason to champion the concept because it would result in a loss of generation, transmission and service revenues.

Given the newness of the concept and the institutional unpreparedness, there may be some reluctance on the part of companies to invest in on-site wind generation for self-consumption. However, researchers modeling with both the Flexibility Checklist and the Flexibility Audit have identified strong business cases

From a technological point of view, there are no insurmountable barriers to the concept and, if circumstances are favorable, wind-powered processes could be a real benefit to industrial companies daring to take the step.

Introduction

This Application Note outlines two methods that company decision makers can use to test whether their industrial processes are suitable to be powered by onsite wind power. Both methods focus on a company's ability to operate flexibly in response to fluctuations in power supply because of the intermittent nature of wind.

Cost predictability

The relative predictability of the costs of onsite wind power contrasts with the unpredictability of future wholesale electricity market prices and future fossil fuel costs. The gap between the cost of onsite wind power and the cost of power purchased from the grid in Europe's regions has been mapped in the report '*Flexible Industrial Processes: a valuable tool to accommodate big scale variable renewables*' published by the Copper Alliance. In some areas, the cost savings from onsite power generation is likely to be 20 Euro cents per kWh by 2020.

As renewable energy penetrates deeper into Europe's electricity networks, fluctuations in supply without corresponding dips and rises in demand will increase energy cost volatility for companies purchasing from wholesale electricity markets. Network imbalances will cause frequency variations across the grid. If the imbalances are not corrected quickly, they could result in brown-outs or black-outs. There is growing international pressure to eliminate fossil fuel subsidies and to limit or tax fossil fuel emissions. The supply of imported fossil fuels is vulnerable to international crises and fossil fuel exploitation is becoming increasingly expensive.

Most of the lifecycle costs of a wind turbine are incurred at the time of its installation. Therefore, a wind turbine owner can predict with relative certainty the cost of the power that will be generated over the lifetime of the turbine. By generating power from wind onsite, companies can meet some or all of their own power needs. They can avoid charges for grid services as well as the costs and taxes associated with the purchase of electricity. Approximately 68 GW of potential onsite wind power that could serve some of Europe's largest energy-intensive industries has been identified in the Copper Alliance report. This figure of 68 GW is only a start. A researcher for the Confederation of European Paper Industries (CEPI) has identified considerable scope for energy demand flexibility in Europe's pulp and paper industries. That industry alone consumes 111 TWh of electricity per year.

The use of non-polluting fuels can also bring reputational benefits to the company, improving relations with local communities, as well as with the company's own workforce.

Self-generation with self-consumption

As the cost of wind power generation has dropped, European governments have reduced the levels of feed-in tariff they are prepared to pay. That will encourage increased self-consumption. When feed-in tariffs are higher than the cost of grid power, companies are incentivized to sell all their wind power to the grid and to purchase all their consumption needs from the grid. As Feed-in tariffs move closer to wholesale market prices, some self-consumption combined with load management will be the best economic choice. When the cost of grid power is greater than the feed-in tariff, maximum consumption of onsite wind power is the most rational option.

Consumption of wind energy close to the point of generation reduces both the energy demands on the grid and the levels of potentially destabilizing intermittent supply entering the grid. Up to now, there has been little incentive for transmission and distribution companies to encourage self-generation and consumption, because they gain no revenue from it. That situation may change. Some parties are considering charging renewable energy generators for the right to feed electricity into the grid when supply levels are high and demand low.

Flexible industrial energy consumption can also create revenue-generating opportunities. As renewable penetration in the electricity generation mix increases, companies that can provide or consume power in response to Balancing Responsible Parties' requests may be able to charge for that service.

The tools to manage wind-integrated industrial processes already exist. Demand Side Management has become increasingly familiar to companies with energy-intensive processes. The DSM software tools that enable companies to manage their power demand in response to market price signals can also be used to manage demand in response to weather signals.

The first question for any company contemplating a move to wind-integrated industrial processes is, whether they have the process-flexibility to exploit the opportunities. This Application Note sets out two methods that will help them answer that question.

FLEXIBILITY CHECKLIST

GENERAL ASPECTS

The first flexibility-testing method to be outlined in this Application Note is the Flexibility Checklist. It can identify issues very quickly, but it is not a final decision-making tool. It does not investigate the company's processes in depth.

Prior to using the Flexibility Checklist, 2 questions should be addressed:

1. What is the cost of onsite wind energy generation compared to the cost of power purchase from the local grid? That establishes whether onsite wind power generation would provide an adequate return to justify investment.
2. Should the power generated by the wind turbine be consumed onsite or sold to the grid? To assess that question a comparison is needed between the feed-in tariff paid for electricity sales to the grid and the cost of power purchases from the grid.

If the outcome of that investigation is a finding that it would be best to consume the electricity onsite, the next question is whether the processes are flexible enough to cope with variability of power supply. This can be addressed using the Flexibility Checklist, which consists of 10 characteristics[1] that are placed in a checklist matrix and given a 'traffic light' score. Green, if it adds high flexibility, Orange if it provides medium flexibility or if the assumed flexibility is untested, and Red if it is a barrier to process flexibility.

The Flexibility Checklist was originally designed to assess the suitability of large-scale energy-intensive industrial processes for onsite wind power. The 8-point checklist omitted two key issues: how efficiently companies used energy and how efficiently they stored energy. The original checklist assumed that the industrial processes consumed as little power as possible, and that all thermal storage units, such as cold stores, are well-insulated to minimize energy loss. However, for smaller-scale processes or for businesses where energy is not such a crucial element in total costs, the energy efficiency and efficient thermal storage of processes cannot be assumed, because they may not be as closely scrutinized. Therefore, two extra points have been added to the Flexibility Checklist.

The 10 characteristics are placed in a checklist matrix and given a 'traffic light' score. Green, if it adds high flexibility, Orange if it provides medium flexibility or if the assumed flexibility is untested, and Red if it is a barrier to process flexibility.

The matrix below shows the scoring for some of Europe's largescale industrial sectors. Below the matrix, the 10 characteristics are explained in greater depth:

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[1] The Flexibility Checklist was originally designed for large-scale energy-intensive industrial processes and consisted of 8 points. It assumed that the industrial processes consumed as little power as possible, and that all thermal storage units, such as cold stores, are well-insulated to minimize energy loss. However, for smaller-scale processes or for businesses where energy is not such a crucial element in total costs, the energy efficiency and efficient thermal storage of processes cannot be assumed, because they may not be as closely scrutinized. Therefore, two extra points have been added to the Flexibility Checklist.

	Energy efficiency	Energy storage	Time behaviour	Overload-ability	Partload-ability	Synchrony	Power gradient - Short timescale	Power gradient - Long timescale	Activation effort	Development state	Overall score
Chlorine-Alkali production	High	High	Continuous	High	High	Yes	Low	High	Low	Proven	**High**
Aluminium production	High	High	Continuous	Medium	Medium	Yes	High	Medium	Low	Conceptual	**Medium**
E-steel making	High	High	Batch	Low	High	No (material)	Medium	High	Medium	Conceptual	**Low**
Cold storage	High	High	Continuous / Batch	Medium	Medium	Yes	High	Medium	Low	Conceptual	**Medium**
Desalination	High	High	Continuous	High	High	Yes	Medium	High	Low	Demo	**High**

Energy efficiency

The starting point for any flexibility investigation should be to analyze whether the process operates with as little energy consumption as possible. Minimum energy consumption will prevent installation of an over-capacity of renewable energy alternatives. It will also help minimize energy costs.

Efficient energy storage

To operate flexibly, many industrial processes will need stores or buffers to enable processing to continue at times when little power is available. Those buffers could take a range of forms. It might be a requirement to store heat, to keep areas cold, or to store gases or liquid under pressure, for example. Losses of heat, cold or pressure by those stores will need to be replaced and the supply of replacement energy is a cost that needs to be taken into account when assessing the value of a move to flexible operation. For example, a well-insulated (and therefore energy-efficient) cold storage unit can be operated flexibly at lower cost than poorly insulated units, because it can be kept within its temperature limits more easily during power supply variations.

If improvements in energy storage will be needed for viable flexible operation, the capital costs of storage improvements will need to be added as a cost, when calculating whether flexible operation would offer the required return on investment.

Time behaviour

Some industrial processes can be slowed or speeded up easily, while others do not offer the same flexibility.

Continuous processes tend to be more appropriate for power by wind than batch processes, because the energy demand of a continuous process is more uniform and could be matched more easily to the fluctuating power supply. However, the line separating continuous from batch processes is not always clear.

Partload-ability

A process is partload-able if it is technically possible to run the core process below nominal operation levels in response to dips in energy supply.

If a process is not partload-able, it may be possible to get around the difficulty by splitting it into two or more smaller-scale processes that can be run in parallel when there is sufficient power available to operate at full load.

Overload-ability

The ability to operate an industrial process temporarily at higher rates when excess power is available provides considerable scope for flexible operation with onsite wind power.

Many industrial processes offer overload-ability at a price. Nominal operating conditions are decided by balancing operational costs against the value of the output. Therefore, increases in output would be acceptable where operational costs can be lowered. Onsite wind power can often provide those lower operational costs, because it provides electricity that is effectively free.

According to the Confederation of European Paper Industries, investment in additional electrically powered boilers and drying processes would enable the European pulp & paper industries to provide considerable overload-ability. Where capital investment would be needed to provide overload-ability, any reductions in energy costs that result from the investment also need to be taken into account.

Overload-ability in upstream or downstream processes can provide an opportunity to create buffers around an inflexible central process during periods of high power availability. Those buffers may enable the central process to continue to operate at a constant rate during periods of low power availability.

Synchrony

If upstream and downstream processes can smoothly and automatically adapt to variations in the rate of the core process, the process provides synchrony. High levels of synchrony make a process well-suited to wind-power.

Adaptation in short timescales

A process's ability to adapt in minutes or seconds to fluctuations in available power makes it highly suitable to be supplied by onsite wind power. In practice, the ability to adapt rapidly implies overload- or partload-ability.

Adaptation over longer timescales

To gain maximum benefit from the available wind power, it is necessary to bring the time-series of power generation and power consumption into line. A process that can adapt continuously to long-term and larger-scale changes through overload- or partload-ability is more advantageous than processes where flexibility is only possible in discrete adaptations.

The power output function of a wind turbine is *a priori* a continuous one, therefore the optimal power consumption function will be continuous as well. In other words, a process that can only adapt in steps will normally not adapt as closely as a continuous one.

Activation effort

The activation effort required to start up a process or to shut it down will affect the adaptability of the process to wind power supply.

Is the concept proven?

If a process has been proven to operate flexibly, it should be given greater weight by the decision-maker than a process that has merely a theoretical potential to adapt to intermittent power. There is no substitute for proven experience.

Points for consideration

The Flexibility Checklist has been used to identify previously unconsidered opportunities to install 68 GW of new wind power serving five major energy-intensive industrial sectors in Europe (see '*Flexible Industrial Processes: a valuable tool to accommodate big scale variable renewables'*).

The checklist, as set out here, is not sufficiently thorough to support a final decision to invest in onsite wind power. However, it can act as a ready guide when a project is being scoped. It will highlight some potential barriers to process flexibility.

The Flexibility Checklist should be used carefully. It appears to rank and assess its ten characteristics equally. In fact, some are more important than others.

Energy storage is a primary concern

If flexible operation at reasonable cost requires major investment in improvements to energy storage, flexible operation may not be possible. Therefore it is vital to consider at an early stage what energy storage a flexible process will require, whether that energy storage will need capital investment, and whether that capital investment is so high that it nullifies the gains from flexible operation.

Partload-ability

Partload-ability should also be a priority consideration. It is extremely difficult to build in flexibility to a process that cannot be operated at partload. However, there may be ways around an apparent lack of partload-ability. For example, some processes can be broken down into smaller scale processes running in parallel. When available power reduces, one or more of the smaller-scale processes can be shut down.

The Flexibility Checklist criteria were applied in an assessment of some of the largest energy-intensive industries in Europe. The method identified the highest potential in chlorine-alkali-electrolysis by membrane cells. This continuous process is already variably operated because the process capacity depends on the demand and market prices of chlorine, caustic soda and hydrogen, as well as the grid electricity tariff. The process can be operated in partload and to some extent in overload. Other processes identified that showed potential were desalination, primary aluminium production, and cold storage.

Electro-steelmaking provided the lowest potential of the processes studied. It is mostly operated as a batch process with no potential for overload-ability. Electro-steelmaking requires significant effort for activation (adjusting the supply and preparation of the raw materials and of the post-processing of the variable flow of molten metal). In order to achieve a high yield from the expensive electric arc furnaces, the process is usually operated at maximum capacity (therefore, no overload-ability). Assuming appropriate measures for control of the arc voltage and arc resistance (length), the alteration of power consumption is possible but it would require significant modifications to the furnace and electrode actuation in order to allow highly automatic and energy-efficient processing.

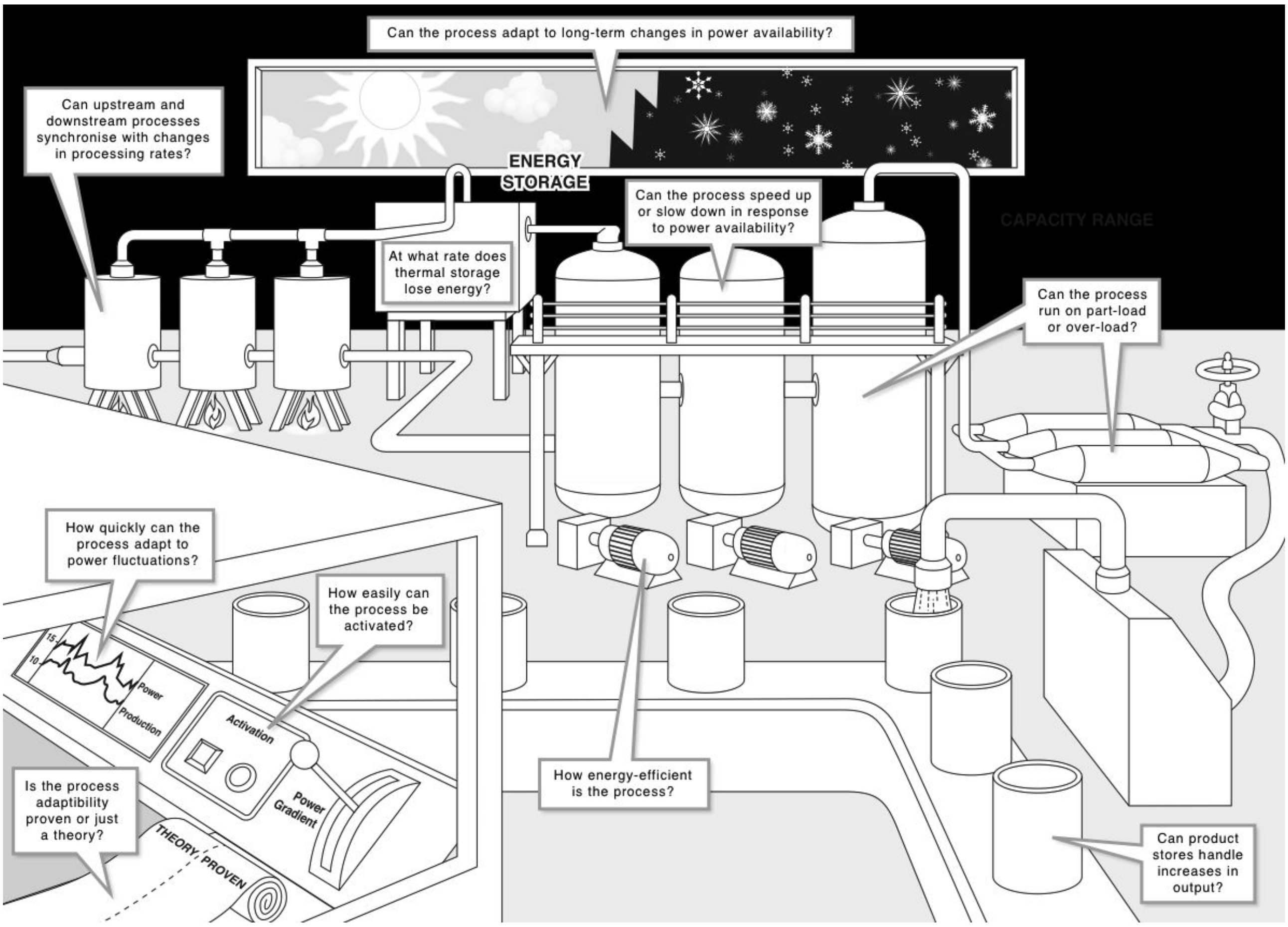

Figure 1 – Applying the Flexibility Checklist to a business site.

Flexibility Audit

The Flexibility Audit is a very different tool to the Flexibility Checklist. The Flexibility Checklist provides a quick, top-down overview of an organization's suitability to the demand side flexibility that is needed for Wind-Integrated processes. The Flexibility Audit, on the other hand, is a detailed investigation of the energy flexibility of a particular industrial site (or sites). The Flexibility Audit starts with the individual machine, individual processes, energy account centers… building a picture from the ground up.

Flexibility is not normally included or identified in standard energy audits. The following four-step Flexibility Audit to identify a company's ability to manage its power flexibly is unique. The method was developed as part of a project to investigate the potential for a switch to onsite wind power in some of the largest ports of Northern Europe.

The four steps in the flexibility audit are: (a) Identification; (b) Quantification, (c) Valorization; and (d) Implementation.

Identification

The audit begins with a detailed technical investigation of energy consumption and energy needs across the organization. The investigation measures energy need and energy consumption, right down to the device level, across the organization. Active and close involvement of local staff is encouraged – their insights and knowledge of the device or installation under investigation will add value to the auditing process.

The flexibility auditors look at issues such as energy efficiency, energy storage and overload-ability. But they must also remain open to the unexpected. For example, the auditors will remain attentive for over-powered processes or under-used sources of power generation as well as the cost-management of energy resources.

Quantification

The aim of the Quantification process is to translate the technical properties identified during the onsite investigations into values that are independent of the type of installation: Time; Energy; Power; and Frequency,

Time

The key 'time' question is for how long, and how easily, could a facility be switched off or operated at reduced power without exiting its 'comfort zone'. The definition of 'comfort zone' is the point where the reduction in power consumption places a major constraint on normal operations.

During Flexibility Audits at the Port of Antwerp, comfort zones were found to vary widely. Some devices could operate on reduced power for only a few minutes, others could be switched off for days before normal operations were constrained.

The level of business activity needs to be considered when calculating the boundaries of a comfort zone. Therefore, it may not be possible to identify a single 'Time' figure. For example, a well-insulated cold store might be able to operate without power for 24 hours during a quiet weekend, but the same cold store might only be able to switch off the power for short periods during a busy work day when the doors are being opened very often and product at a range of temperatures is being moved in and out.

Power

The definition of Power in a flexibility audit is the answer to the question: "How much power can you really switch off over a given time period?" The answer to that question should be a kW figure. The complication, of course, is that the kW figure will vary depending on the definitions of 'comfort zone' and 'time'.

Energy

The energy saved is a multiple of the power saved over a given time (-kW x time = -kWh).

However, because of the wide range of variables that have some effect on power usage in a busy industrial setting, the effects of power reductions have to be examined carefully. For example a facility could reduce its power consumption by 2MW for half-an-hour. However, if power was reduced by just 1MW, the same plant might continue within its 'comfort zone' for between 4 and 7 hours.

Frequency

How frequently can an energy-saving event – such as switching off energy-consuming devices or moving to partial load – take place? The more frequently such an event can occur, the more valuable it will be. If events can only be repeated at low frequency, it may not justify the time and resources needed to enable the flexiblity.

Ideally, the Quantification process would deliver 'flexibility factors' in hours, kW, kWh and frequency per year. But, as stated above, such a definitive outcome is not possible, because the quantification is dependent on variables such as the boundaries of the business's energy "comfort zone". That is a matter of business judgment, not scientific measurement.

Valorization

The outcomes from the Quantification process are fed into a series of business models. The aim is to see whether the implementation of each flexibility factor delivers value to the business. The research team that developed and undertook the first flexibility audit used a complex Preference Ranking Evaluation methodology to benchmark competing energy strategies (including self-consumption of onsite wind power). The business model delivering the highest value was identified for implementation.

Implementation

The original flexibility audit in the Port of Antwerp identified some major opportunities to deliver energy savings and flexible operation in support of onsite wind power.

A facility processing sludge dredged from the Port of Antwerp's channels offered a combination of large scale storage and pumping overcapacity that created opportunities for energy shutdowns that could last days at a time. Without load management, 60% of the produced wind energy from an onsite turbine could be used onsite in this energy-intensive process. With load management, almost 80% of the wind energy could be used locally, resulting in an overall energy cost reduction of almost 20%.

Points for consideration

The Flexibility Audit has a number of strengths. Its conclusions are built on actual measurements at the site. That provides solid data for analysis. It can also result in the discovery of unexpected opportunities for flexibility. And it allows assumptions about potential flexibility to be tested.

For example, chemical processing companies often consume energy at a steady rate, 24 hours per day, 7 days per week. However, investigations at one of the largescale chemicals plants in the Port of Antwerp discovered that there was considerable opportunity for demand management, due to both partload- and overload-ability. Power consumption could vary across a 10% range (+4% to -6%) for long periods without risking exiting the chemical plant's 'comfort zone'.

On the other hand, assumed flexibility can disappear on investigation. It was discovered that forklift trucks at a fruit logistics company were being charged during the late afternoon. Delaying charging to take advantage of the cheaper night tariffs promised considerable cost savings. However, on further investigation, it was discovered that delayed charging risked interference with the company's core business. The forklift trucks needed to be available in cases where cargoes of fruit arrived ahead of schedule. Night charging was ruled out.

Quantification

Quantification of the economic benefits from flexibility is not easy. The kW, kWh and time savings cannot be combined to deliver a single 'flexibility factor'. Quantification relies on simplified versions of often complex processes for its business models.

For example, cold store flexibility depends on a wide range of factors including the insulation levels of the building, the total thermal capacity of the stored goods, activity within the building, the temperature of the goods on arrival and the length of time they are stored. When there are so many variables, accurate models can be difficult to generate.

Yet, modelling exercises can identify considerable potential gains. Simulations using data from a cold store in the Port of Antwerp suggested an onsite wind turbine and flexible power management could reduce energy purchases at the expensive day tariff by up to 70%. Overall, energy costs could be reduced by 15%.

Energy-efficient storage

The efficiency of energy storage – particularly thermal energy storage - is an important consideration in the Flexibility Audit process (just as it is an important consideration in the Flexibility Checklist). It is virtually impossible to store heat, or to store material under pressure, without some loss over time. If batteries are used, there will always be loss of energy there too. In fact, it is usually simpler and cheaper to store product as flexibility buffers, rather than to use stores that lose energy in one form or another over time. Storage of raw materials, semi-finished goods or final product usually results in no, or very little, energy loss.

Frequency

The more frequently a process can vary its power consumption without exiting its comfort zone, the easier it can be integrated with onsite wind power. Frequency is an important factor when considering the value that can be extracted from process flexibility.

Unexpected discoveries

If the investigators remain open to all possibilities during the planning of an audit, completely unexpected flexibility opportunities can emerge. For instance, diesel-electric cranes at the Port of Antwerp were discovered as a potential power source. The cranes were in use only 25% of the time. Their generators could be used to reduce the need for power from the grid during periods of peak – and expensive - demand.

In planning an audit, it is important that the investigations go 'outside the box'. For instance, the Port of Antwerp also contains thousands of refrigerated containers (known as 'reefers'). Typically, the refrigeration unit on a reefer will consume 10 to 15kW of electricity per hour during its time in port. That level of power consumption may be needed when the containers are loaded with fruit in tropical countries, but it is not necessary to preserve the fruit in a North European port. The audit team established that the reefers could meet refrigeration needs while consuming just 3-4 kW/hr. That would deliver an energy saving of up to 11 kWh per reefer.

Cost of adaptation

The Flexibility Audit should form part of an ongoing process. It is common for the process to identify opportunities for flexibility that would require considerable investment in retrofitting. The best time to maximize process flexibility at least cost is often at the process design stage.

Revenue-generating opportunities

Flexible industrial processes may enable on-site wind generation with self-consumption; alternatively it could be used to provide balancing services to the local Transmission System Operator. The potential to deliver three types of balancing service were investigated during the *e-harbours* project:

- Primary reserve capacity: the provision of reserves on request used to rule out imbalances in return for an availability fee.
- Secondary reserve capacity: where the industrial site can be asked to consume more or consume less, depending on the TSO's balancing need, in return for a service fee.
- Tertiary reserve capacity: where the company can be asked to consume more, generate more, or consume less, depending on the TSO's balancing need, in return for an availability fee, a fee for balancing provision, plus compensation for use of the reserve.

On analysis, the provision of secondary reserve capacity offered greatest value to the companies.

This could be an alternative use of flexible industrial processes if the circumstances for on-site wind generation are not favorable.

The value of process flexibility (the 80:20 rule of thumb)

Previous applications of the Flexibility Audit estimated that they could extract approximately 80% of the theoretical value from flexibility initiatives with relative ease. Extracting the final 20% could be complex, difficult, and at times expensive. For example, identifying the theoretical value that could be extracted based on given past weather conditions has proven to be relatively easy. However, extracting the maximum value through the accurate prediction of future wind conditions and market prices, is far more difficult.

The more complex the industrial operation, the more difficult the researchers have found it to estimate and extract full theoretical value of the process flexibility. But even when extracting full value was difficult, it was often well-worth doing. For example, it might only be possible to extract 50% of the full theoretical value from the provision of balancing services. It is still worth doing if 50% of the theoretical revenues is a considerable amount.

Flexibility in business clusters

Could a number of businesses combine their energy management in order to maximize their flexibility and the consumption of local wind power, while minimizing their need for external power?

During the *e-harbours* project, an attempt was made to model a "Virtual Power Plant" joining the flexibility of various industrial sites together.

The idea proved extremely complex to implement. It required the close collaboration of a cluster of companies with transmission and distribution system operators. The companies in the cluster varied greatly in size and in their patterns of activity. Three of the companies were connected to the distribution grid; a fourth – consuming power on a much larger scale – was connected to the transmission grid. The regulatory and contractual systems needed to support the idea were not in place. There is insufficient information available for organizations to generate and test business cases for the provision of energy balancing services.

In short, the complications and information gaps make the concept of combined energy demand management impractical – a step too far for the moment.

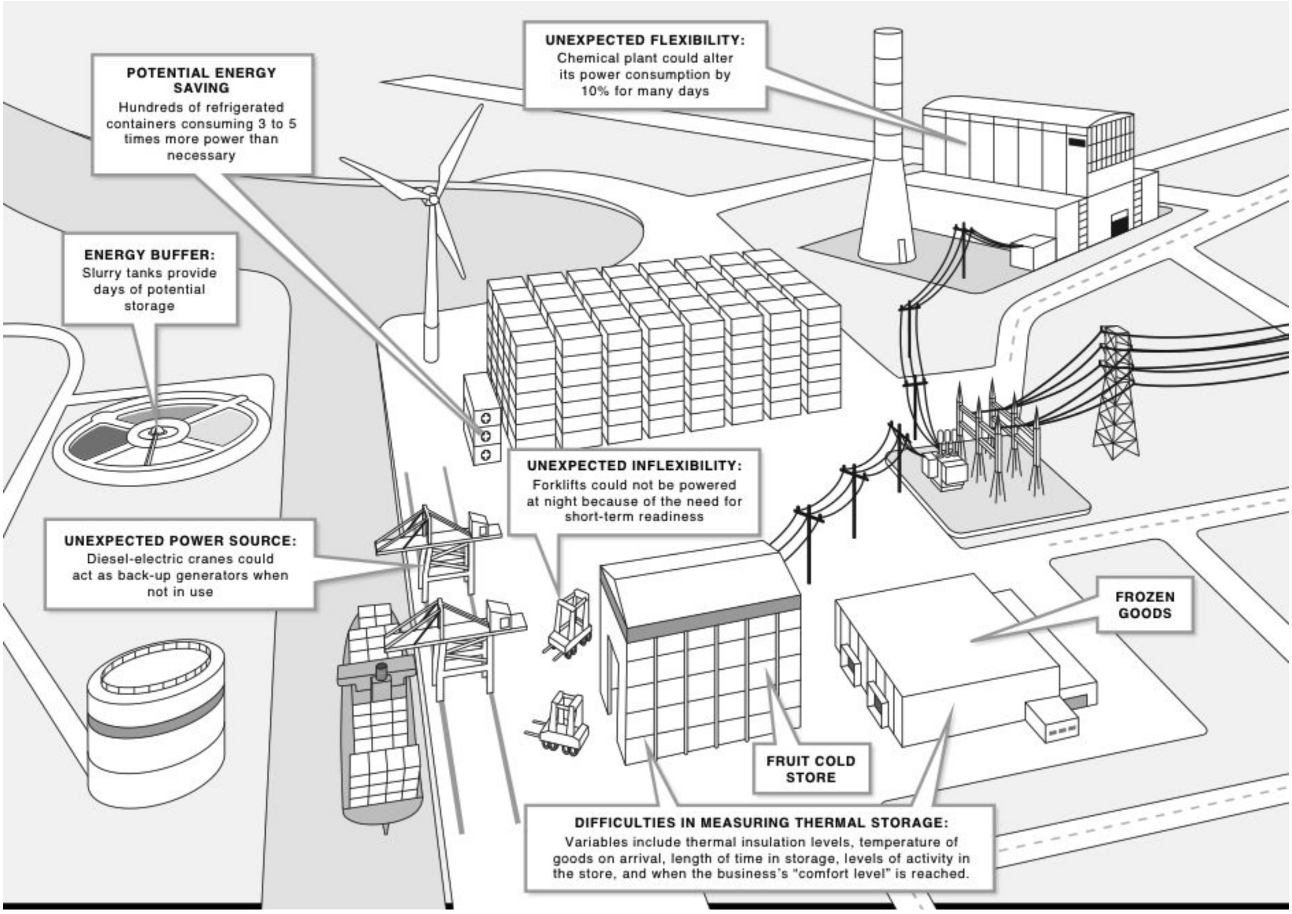

Figure 2 – Possible outcomes from an Energy Flexibility Audit of port businesses.

Conclusion

Flexibility is not measured in standard energy audits and its potential value is often missed. But that potential value can be substantial. Researchers on the *e-harbours* project found strong business cases for investment in wind-integrated industrial processes where the wind conditions are suitable. Self-consumption of onsite wind power can provide cheap power with relative cost certainty and it offers protection against potentially adverse future market conditions.

From a management and technological point of view, the software tools that allow companies to respond flexibly to weather signals are tested and proven. They were developed to allow companies to react to price signals as part of smart grid and demand side management solutions. Whether companies react to weather signals or market price signals, there is little difference. In theory, weather signals should be more predictable. The weather is just one of many variables that influence market prices for energy on a grid where the penetration of renewables is high.

Small changes can improve flexibility significantly. But practical barriers can make the application of those small changes difficult. For instance, split budgets between the team that could benefit from onsite wind generation, and the team that will have to carry the burden of the investments. The cost of retrofitting or re-organizing processes to maximize flexibility can be a disincentive. The best moment to consider flexibility is – obviously – at the process design stage.

Other potential barriers include the need for construction permits, issues with accessibility to the grid, the difficulty of creating commercial agreements with Distribution or Transmission System Operators, and the cost of grid connection.

There is a lot to gain if more electricity was consumed on the site where it was generated. It would ease pressure on grids as the penetration of intermittent renewable energy increases. However, even though Distribution and Transmission System Operators could technically benefit from on-site generation and self-consumption by electricity users, they will rarely support such a concept since it is a double-edged sword for them. It could also result in a reduction in their revenues.

If self-generation and consumption of wind power is to reach its potential, regulations need to change. At the moment, many Transmission System Operators reward industrial companies that place constant and predictable loads on the network. That approach would penalize companies with wind-integrated processes. Norway is the exception. For many years, companies in Norway have been given price incentives to consume the excess of hydropower available at night and over weekends. Norway's regulations should be seen as best practice by regulators in other European countries, according to CEPI.

A change of mindset is needed. When companies consider Demand Side Management, the option of onsite wind power is rarely included. Companies may be reluctant to exploit process flexibility opportunities if they fear that it would interfere with their core business.

That change in mindset is underway. There is anecdotal evidence that industrial power consumers are increasingly adopting 'soft load management' – where software suggests alterations in load management in response to price signals from the wholesale electricity markets. 'Hard load management' – where industrial power consumption automatically responds to price signals - will follow.

In a supply-driven energy market, onsite wind power can offer lower generation costs and relative cost certainty, while eliminating many third party transmission and service charges.

Once companies are practiced in altering demand in response to market price signals, onsite wind-integrated processes are the next logical step.

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