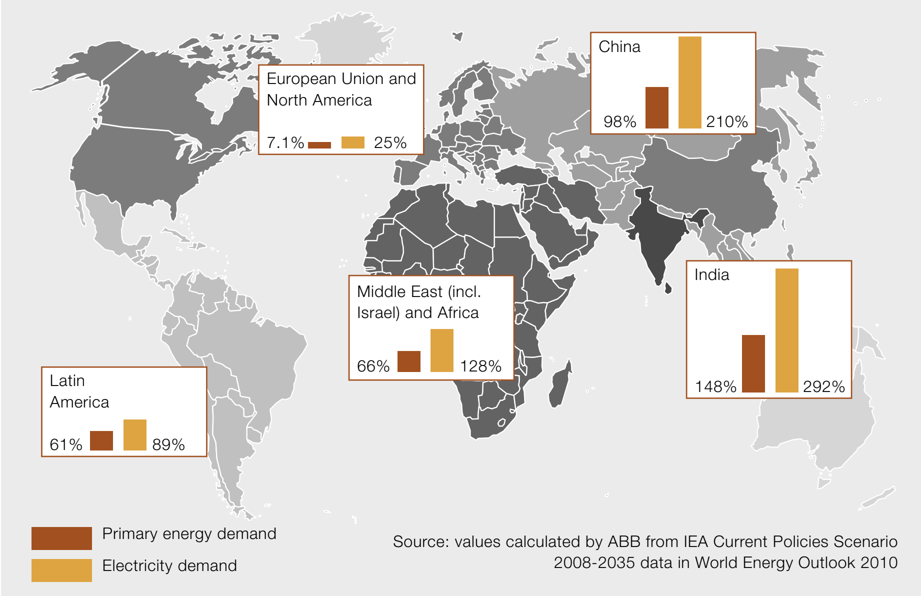
The other alternative fuel

Energy efficiency is a critical part of a sustainable energy policy for many power plants

WERNER JANIK, JOSEPH LAUER – As the global population continues to grow, so too does its hunger for energy. The long-term consequence of this will be a diminished supply of fossil fuels, currently the world's primary energy source. However, fossil fuels are also responsible for much of the CO_2 emissions produced today which severely impact the world's climate. Therefore as long as there is a continued reliance on fossil-based energy production this "catch 22" situation will remain. Of course it has long been known that renewable energy sources are the solution to this predicament. However, although rapid progress is being made to substitute thermal power plants with renewable energy sources, many issues still need to be resolved before renewable sources can effectively contribute to the overall energy mix. Unfortunately time is running out for planet Earth as it waits for further developments in renewable energy sources or the long expected break-through in nuclear fusion. In parallel to this work, action needs to be taken to protect the planet and to preserve its assets and biosphere for future generations; this can be achieved by the application of already developed energy efficiency methods and technologies.

1 A demand growth comparison of primary and electrical energy



The majority of the electrical energy produced today is based on the combustion of fossil fuels. In fact coal fuels more than 40 percent of the world's electricity supply, making electricity generation the single largest and fastest growing contributor to CO_2 emissions. The growth rate of renewable energy generation is high, and the correlation between energy use and emissions could effectively be reduced by the application of renewable energy sources. Unfortunately the contribution of renewable energy in the overall energy mix is still quite small and research is ongoing to efficiently integrate greater amounts of renewable energy.

Planet earth does not have the luxury of time on its side and therefore other improvements need to be made in parallel if the pattern of global energy use and the correlated carbon footprint is to be improved.

Projections by the International Energy Agency (IEA) show that using energy more efficiently has a greater potential to curb CO_2 emissions over the next 20 years than all the other options put together. The application of energy efficiency technology, methods and behaviors can immediately affect (ie, lower) the correlation between economic growth and energy use. In the field of power generation, in thermal power plants in particular, technology and methods required to achieve this are already available from ABB.

Today's energy challenges

In all regions of the world the demand for electrical energy is rising twice as fast as the demand for primary energy → 1. This trend is particularly noticeable in the expanding economies of the Middle East, India and China where demand is expected to be between 140 and 261 percent compared with between 89 and 116 percent for primary energy.

However, satisfying demand is really about striking the correct balance between the production and consumption of electrical energy. Hence the global target for energy efficiency will be to generate as much electrical energy as is possible out of the available fossil fuels, and at the same time consume as little of this energy as possible. By doing this every barrel-equivalent of saved electrical energy can be considered as "additional alternative fuel" which is available for other purposes.

In the chain of electrical energy production and consumption, up to 80 percent of energy can be lost, the majority of which occurs during generation.

Energy efficiency – the other alternative fuel

The chain of electrical energy production and energy consumption usually contains losses, the biggest of which are illustrated in → 2. It shows that from primary energy sources, such as gas or oil right down to the industrial user or private households, about 80 percent of energy is being lost. The majority of these losses occur during the generation process in power plants mainly because of the thermodynamic fundamentals of the process itself. For example, a conventional coal-fired power plant that can produce 500 MW of gross electrical energy is considered. The plant is around 25 years old with a typical thermal plant efficiency of 34 percent at a net heat rate of 10.2 BTU/kWh [1]. Even though the plant was originally designed for base load operation, this philosophy has changed to ensure the plant is capable of meeting the more fluctuating demands of today's grids, ie, the annual capacity factor has been reduced to about 70 percent with lots of part-load operation between 50 and 90 percent. This practice has become more or less standard in many of today's power generation facilities, and it inherently has the potential to generate an "alternative fuel," ie, energy efficiency.

But before any power plant invests in energy efficiency improvements, three fundamental questions must be considered:
- Who has the know-how and technology to implement cost-effective energy efficient methods?
- What kind of savings can be generated?
- How can it be achieved?

The first two questions can be answered in one sentence: Methods and technologies developed by ABB enable an improvement in energy efficiency of between 8 and 10 percent. Looking at it another way, the amount of additional fuel available and savings possible (per annum) from the reference coal-fired 500 MW power plant example presented above are:
- Original fuel consumption: 1.4 billion kg (3 billion pounds)
- Additional energy to grid: 21.25 MWh
- Energy saved: 22.5 million kWh
- Reduction in CO_2 emissions: 260,000 tons
- Equivalent additional alternative fuel: 340 million pounds (enough to run approximately 850 cars for one year!)

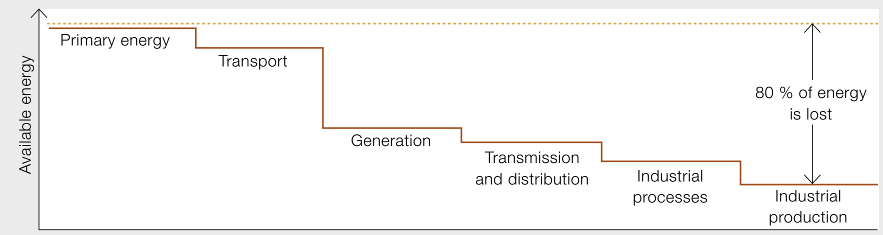
In terms of the economic feasibility of implementing energy efficiency methods and technologies, ABB's experience has shown that an average payback period of between two and three years is all that is required to achieve these targets.

ABB's energy efficiency improvement methodology

ABB's approach to energy efficiency improvement consists of a three-phase methodology:
- Phase 1: Opportunity identification
- Phase 2: Master plan
- Phase 3: Implementation

The accompanying tools and techniques used in this methodology have been developed through the experiences gained from working on a wide and varying range of energy generating and consuming processes at many customer sites over several years. Each step of the energy efficiency improvement methodology aims to deliver precisely the information needed to enable power plant operators to move forward with confidence and eventually complete a program of improvements that will deliver real and sustainable energy savings.

2 Losses of up to 80 percent can occur along the entire energy value chain



3 ABB's opportunity identification study provides a comprehensive assessment of a wide range of energy management aspects

Technology and control
Identification of improvements through process control, equipment modification or alternative energy efficient technologies, typically covering the following energy systems:
- Fired equipment (gas turbines, furnaces, heaters, etc.)
- Steam boilers, turbines and systems
- Electricity generation and equipment
- Major pump, fan and motor systems
- Electrical systems – high-voltage and site medium-voltage/low-voltage users
- Compressed air and industrial gases
- Heating, ventilation and air conditioning (HVAC)
- Industrial refrigeration and chilling systems

Behaviors and practices
Assessment of behaviors and practices relating to energy efficiency across site processes and utility operations through a comprehensive review versus best practice including:
- Energy strategy and policy
- Energy management methods
- Capital investment
- Information technology
- Operational management
- Operational planning and performance
- Training and development
- Maintenance practices and strategies
- Staff motivations

Opportunity identification

The first phase is concerned with an energy efficiency assessment, which aims to: identify specific opportunities to deliver improvements by confirming how, where and why energy is used; identify areas of inefficiency; and compare current performance with established industry best practices. A wide range of energy management aspects are outlined in → 3.

Within a typical coal-fired power plant similar to the 25-year old one described previously (ie, 500 MW gross electrical energy, production, plant efficiency of 34 percent, net heat rate of 10.2 BTU/kWh, annual capacity factor of about 70 percent) the aspects that would form components of the opportunity identification study are given in → 4.

Projections by the IEA show that using energy more efficiently has a greater potential to curb CO_2 emissions over the next 20 years than all the other options put together.

Footnote

1 The British thermal unit (BTU) is a traditional unit of energy equal to about 1.055 kilojoules. It is approximately the amount of energy needed to heat 0.454 kg of water 0.556°C.

4 Components of an opportunity identification study for a 25-year old 500 MW gross electrical energy coal fired power plant with an efficiency of 34 percent

Steam turbine performance and control
- Thermodynamic performance
- Condenser performance (where applicable)
- Optimization of extraction/back-pressure steam control
- Turbine control – as individual units and global control of fleet for optimum heat rates

Gas turbine (GT) performance and control
- Thermodynamic performance
- GT predictive maintenance
- Performance degradation
- GT control – as individual units and global control of fleet for optimum heat rates

Boiler performance and control
- Thermodynamic performance
- Feed-water conditions
- Boiler control – as individual units and global control of boilers for optimum heat rates
- Steam distribution systems

Electrical balance of plant
- Motors and drives (pumps and fans)
- Transformers
- Switchgear
- Field devices
- Compressed air system

Energy management system(s)
- Energy metering, monitoring and recording
- Extent of KPI analysis and ongoing performance assessment
- Integration within energy management policy

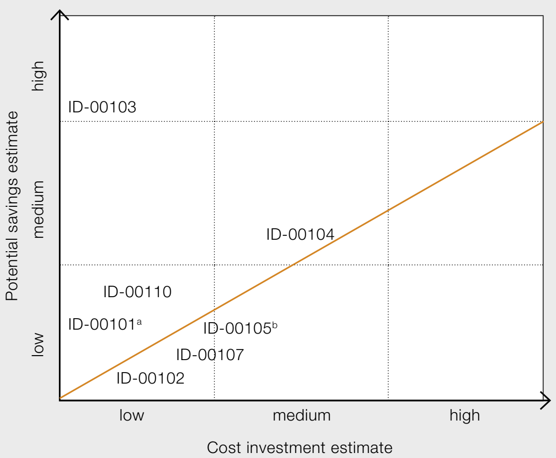
Panel board equipment
- Data acquisition system
- Alarm systems
- Auxiliaries

Overall plant heat rate
- Opportunities to further optimize

6 Measures identified for energy efficiency improvements in a coal-fired power plant

- Optimization of coal handling
- Improvement of ID and FD fan flow control
- Improvement of boiler feed water pump control
- Implementation of high efficiency motors and drives
- Optimized turbine controls
- Advanced steam temperature control
- Stabilization of firing rate and combustion optimization
- Excess oxygen reduction for boiler combustion
- Improved feed water pressure and level control
- Electric power system improvement (gsu's and auxiliary transformers)
- Reduction of leakages
- Reduction of thermal losses
- Thermal optimization of chiller operations

5 An opportunity identification payback chart



Plant Area A1
Project Considered

ID101 PXXQ (Dys Chassess)
3.2.1 VSD Installation on 1 x pump

ID102 PXXW (Dys Agitation)
3.2.1 VSD Installation on 1 x pump

ID103 PXX Pressure control
3.2.1 Pumping system pressure

ID104 PXX Pumping system
3.2.1 VSD Installation on 1 x pump

ID105 PXX, PXY, PXZ pumps
ID106 VSD Installation on 1 x pump
ID108 VSD in each above pumping system
3.2.1

ID107 PXX Pumping system
3.2.1 VSD Installation on 1 x pump

ID109 SX Cooling tower
3.2.1 Reduce 'overcooling' – elevate CW temperature

ID110 SX Cooling tower
3.2.1 VSD Installation on fans

By assessing each of these aspects, ABB would be able to describe the nature and scale of the energy saving opportunities and make clear recommendations about what further steps to take to realize additional potential benefits. After finalization of the energy efficiency assessment out of a comprehensive portfolio of identified project opportunities, the most promising ones are executed.

Another way of determining which individual measures should be realized is by using a generated payback chart which presents a qualitative overview of the identified energy saving opportunities with respect to the expected energy savings and likely investment costs ➔ 5. Or to put it another way, the payback chart visually presents a basic interpretation of opportunity payback. This graphical evaluation helps to quickly identify which measures (normally those above the orange line) have the potential to give a good return on investment.

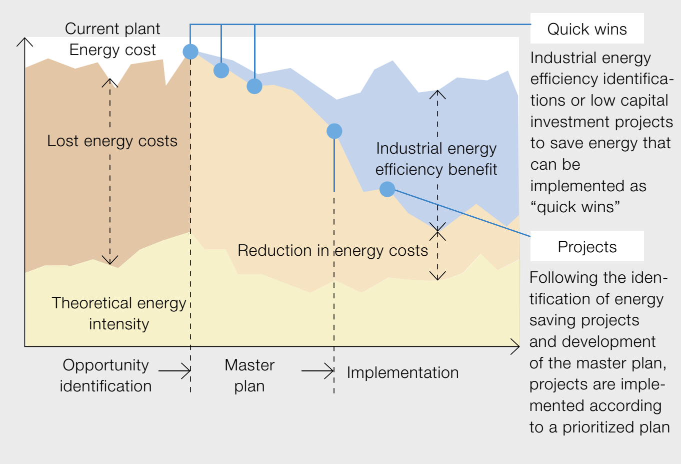
For the coal-fired power plant example, the measures finally identified as worth the investment for energy efficiency improvements and which are very typical for such examples are given in ➔ 6.

It is not only technical measures that will improve the energy efficiency of power plants; improving operational practices both on the plant management and operator levels also has a significant impact. Examples for improvement potential can be found in lots of power plant operations:
- The manual shutdown of devices that are not needed
- The increased isolation of walk downs frequency
- The development of an effective lighting-replacement policy
- The establishment of a device-replacement policy based on a life-cycle cost assessment (LCA)
- The development of a policy for predictive maintenance
- The establishment of an energy efficiency targeting program

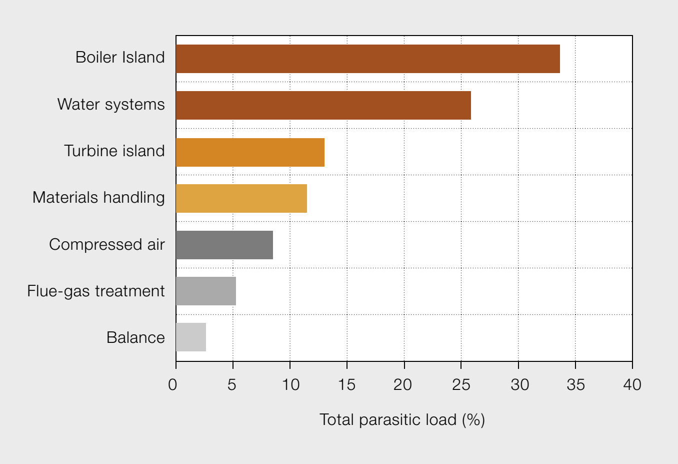
Master plan

In this phase the opportunities identified in the assessment phase are developed into a detailed implementation plan. The master plan takes the form of a suite of improvement projects, each with well understood and calculable benefits. The master plan is generally developed by ABB together with the client, and at the end of the phase a clear roadmap, including detailed project specifications, are developed to allow the most economic implementation of the energy saving opportunities. Some of the quick and easy measures can already be imple-

7 Energy cost assessment using ABB's three-phase methodology



8 Certain areas of a power plant contribute more to the overall plant energy consumption



mented by the client during this phase without the assistance of ABB. While many opportunities can be implemented with ABB's core technologies, those that are not based on these technologies may be implemented by third parties.

Implementation

The implementation phase covers the execution of the implementation projects and is generally carried out by ABB and the client together, or depending on what is needed to achieve the defined targets, by ABB with the appropriate technology partners or other original equipment manufacturers.

Measuring success

All implemented methods for energy efficiency improvement are effectively useless if the benefits cannot be seen on a daily basis. Therefore it is essential to implement proper tools to record and show the achieved improvement in all relevant areas of the plant. This information is needed for all implemented measures either in plant technology and control, monitoring and targeting or in behaviors and practices.

Success, especially for coal-fired power plants strongly depends on the operational mode of the plant; plants operated in steady-state mode have little potential for optimization while those with significant part-load operational modes are ideally suited to energy efficiency improvement identification exercises → 7.

In the 500 MW example mentioned in this article, a heat-rate improvement of about 8 percent can be achieved. Greenhouse gas emissions can also be reduced by 8 percent relative to the increased plant power output. This value is more or less distributed between the different plant areas, depending on the influence of each area to the plant parasitic load → 8.

These results can be achieved thanks to ABB's strength and flexibility in finding the best possible solution to improve energy efficiency in power plants.

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Title picture
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