V. ENERGY SAVINGS IN INDUSTRY

A. Energy Use in Industry

Industry is the major user of energy in modern society, accounting for roughly 40% of final energy use. Coal or oil are heavily used, especially by primary industry and manufacturing and refining. Gas is being used increasingly to replace coal because it is a cleaner fuel producing less impact on the environment. Electricity is only a minor component of industrial energy use although its use in driving electric motors is very important.

The major sectors within industry can be categorised as follows:
Manufacturing – this includes the processing of primary resources into consumer products. Mineral refining, oil refining and chemical manufacturing are some areas of energy use where considerable savings could be made. Such activities often occur in the industrial zones of major cities.

Power Generation - the power generation industry is a massive user of fossil fuels and accounts for more than 50% of international greenhouse gas emissions. Many power stations are very inefficient and there are strong economic and environmental incentives to save energy in the power supply industry. Most cities have major power stations and these are often a cause of air pollution as well.

Mining – this is a primary industry which generally occurs outside cities, often in remote parts of the country. Energy intensity is high in most mining operations but there is an incentive to save energy because energy wastage is reflected in the cost of the minerals.

Agriculture – another major user of primary energy which takes place in rural areas and is largely beyond the scope of city governments to influence it.

Construction – is a modest user of energy, particularly liquid fuels because this activity often takes place at sites where electric power is not readily available. Considerable savings are available in this sector because there is often a large amount of wastage in construction activities

The main focus will therefore be on energy savings in manufacturing and power generation as these are the major users of industrial energy in cities.

B. Energy Auditing in Industry

Energy auditing in industry takes a similar approach to audits undertaken in the commercial sector (Chapter 4, Section C. and will generally involve:

- An analysis of existing energy consumption records to determine where, how and how much energy is being used in the plant. It will also seek to identify trends in consumption data

- A walk through audit that documents where the main areas of energy consumption exist within the plant. This phase will identify any obvious areas of wastage together with the most promising areas for potential savings

- A detailed analysis phase which will take the data obtained in the previous two phases and prepare detailed plans for energy savings options. These plans will include details on the energy use and cost of each stage of the production process as well as costings and expected payback periods of the various energy saving options proposed.

In the case of the industrial sector, the main focus should be level three auditing, where the individual processes are analysed, for example, the production of steam for use in commercial laundries. Although level one auditing, which focuses on the analysis of energy use through and investigation of the tariff structure of existing energy purchases, should be undertaken, the greatest potential for savings in the industrial sector will usually revolve around the selection, operation and maintenance of efficient equipment in the process.

1. Planning for Energy Efficiency in Industrial Processes

Once an initial energy audit has been undertaken, it will provide an important first step in monitoring and achieving the progress towards energy efficiency goals. This information is the baseline energy consumption, or the energy usage associated with current practices in the factory as well as existing equipment. Known as T_0, this is the energy consumption prior to any systematic energy efficiency measures being undertaken.

In conjunction with the result from the screening survey, the establishment of this baseline information allows energy managers to set targets for reduced energy consumption which can be achieved through changes in the management and operation of the industrial process as well as targets which would be possible through the implementation of energy efficient technologies.

Short Term Energy Efficiency Targets

Energy efficiency targets, which can be achieved in the short term, as a result of streamlined operation of the plant, are known as T_1, or housekeeping targets. These energy savings will usually be the result of the efficient use of energy consuming equipment, a reduction in the amount of waste energy, timely maintenance of equipment and continual monitoring of the energy consumption of the industrial process. Specific examples of housekeeping targets for electric motors, compressed air systems, process heating, steam and heat recovery are covered later in this chapter, and are symbolised by (T_1).

Figure 5.1: Energy efficiency targets in industry can help to focus resources to acheive the best results.

Long Term Energy Efficiency Targets

Further reductions in energy consumption which can only be achieved through purchase with a high capital cost, are known as T_2, or investment targets, and should ideally be based on the lowest energy consumption of best practice examples of similar industrial processes. As the purchase of expensive capital equipment is required to achieve these targets, careful modelling should be undertaken to ensure that the investment is sound, ie that the payback period of the equipment is not greater than the working life of the equipment.

The establishment of investment targets is a complex process, requiring a large amount of technical knowledge of similar industries, the options available for energy savings through the investment in new capital, as well as knowledge and skills in economic modelling. However, a large number of international best practice examples and case studies from industrialised nations, particularly in Europe and the United States, has increased the amount of information and data available on international best practice. Much of this information is available through CADDET – Energy Efficiency, the US Office of Industrial Technologies and the World Energy Efficiency Association, whose details are at the end of this chapter. Some examples are provided in Section D - Case Studies at the end of this chapter.

Innovation Energy Efficiency Targets
Energy efficiency is an area of increasing technological innovation and some consideration should also be given to setting T_3, or innovation targets. These targets are based on the energy consumption of state of the art technologies, which are still economically viable. Innovation targets, whilst not immediately achievable, may become achievable in the medium to long term as a result of changes in the economic environment (i.e. greatly increased profitability of the industry), the production environment (i.e. the need for a higher quality or specialised product for niche markets) or regulatory changes (i.e. the introduction of legislation governing pollution control, energy consumption or the Kyoto protocol).

C. Strategies for Energy Savings in Industry

The strategies for achieving energy savings in industry are quite different to those for most other sectors. Industry is very diverse and is often controlled by very large multi-national corporations. In this context the appropriate approach needs to be carefully considered. Industry is generally receptive to efforts to cut its energy costs but it is less likely to be attracted to regulatory measures that increase its operating costs.

Technical Options
The technical options available for energy savings in the industrial sector are as diverse as the industries themselves. However, they principally revolve around the saving of energy in areas such as:

- Electric Motors
- Compressed Air
- Steam
- Furnaces
- Heat Recovery

The production of onsite power and heat (or steam) through Cogeneration systems, or Combined Heat and Power (CHP) systems can also result in energy savings, through the utilisation of waste energy associated with the production of power.

Opportunities for energy savings in relation to the operation and maintenance of industrial buildings also exist, although these are often similar to the commercial sector and are discussed in Chapter 4 of this publication.

1. Energy Savings and Electric Motors
Electric motors usually account for almost half of total industry energy consumption, and represent a significant opportunity for financial savings from energy consumption.

Four areas offer potential savings with regard to the selection and operation of electric motors:

- energy efficient motors (T_2)
- variable speed drives (T_2)
- correctly size motors (T_2)
- regular maintenance (T_1)

Energy Efficient Motors
By definition, one motor will be more efficient than another motor if it uses less energy to produce the same rated output. Most energy efficient motors are usually constructed with higher quality materials and advanced manufacturing techniques and result in less waste energy being produced through reduced vibration, noise and heat. Some countries have adopted minimum energy performance standards for new electric motors, many others have developed standards, which motors must meet in order to be

sold as energy efficient motors. These regulatory measures offer the potential for long-term savings, although are unlikely to result in wide scale energy reductions in the short term as they are rarely retroactive, relating only to future purchases, which may be made five to ten years in the future. Case Study 35 examines the minimum energy performance standards developed for electric motors sold in Australia.

Variable Speed Drives

Electric motors, which are able to operate at different speeds according to the amount of power supplied to the drive unit, are known by a variety of terms including, Variable or Adjustable Speed Drives and Adjustable or Variable Frequency Drives, as well as inverters (although not all inverters are variable speed drives). Variable speed drives are ideal for situations where a motor, or the device the motor drives, does not operate at full capacity during its entire operation, for example fans and pumps in HVAC systems and distribution systems in processes. In these situations, the variable flow rate of the fluid (i.e. air, water, acid etc.), is often obtained by physically restricting the system to achieve the lower flow rate, or installing vanes and throttles.

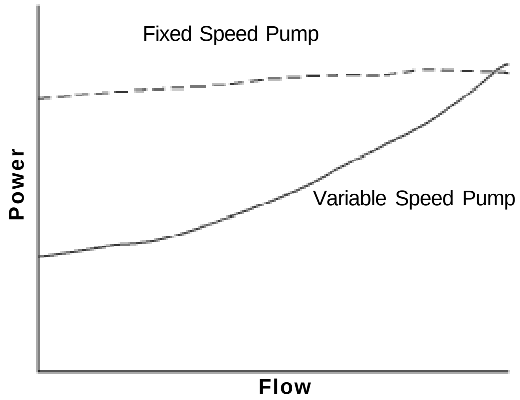

Figure 5.2: Pump flow rate comparison between fixed and variable speed drives.

Variable speed drives allow the speed of the drive, and hence the flow rate of the fluid, to be reduced by decreasing the amount of power supplied through the use of power control units. The main advantage of these drives is when the speed of the fluid fluctuates between low and high flow rates. For example the flow rate of conditioned air in a temperature controlled building, a smaller amount of power can be used to drive the unit, as compared to single speed drives (Figure 5.1).

Case Study 36 examines the effect of variable speed drives on HVAC applications in the textile industry.

Correctly Sized Motors

In many applications, the speed of a device powered by an electric motor is relatively constant. In these situations, high efficiency single speed motors are ideal as they are usually more efficient near the rated load of a motor than variable speed drives. However, careful attention should be paid to ensuring that the motor is not significantly oversized given the usual load. As with applications where the load fluctuates, motors, which are operated at less than full load, are operating far less efficiently than those at or near the rated load.

See Case Study 37 for an example of how downsizing an electric motor can reduce energy costs.

Maintenance of Electric Motors

As with other pieces of capital, electric motors and the devices they drive should be regularly serviced and maintained to:

- ensure components are clean and free from dust and oil.
- operating at peak performance as compared to the manufacturers specifications
- identify areas of wear or damage before the performance of the motor is degraded
- increase the operating life of the motor

Frequently, when electric motors fail, it is due to a fault in the stator wire. In this situation, rewinding the wire usually repairs the motors. Whilst motors can be rewound to have about the same level of efficiency, some reduction in efficiency will usually occur. It is usually not practical, or cost effective, to have an electric motor of a lower efficiency rewound to a higher efficiency as the material used in the stator core and rotor will also influence the overall efficiency of the motor. However, a motor failure does represent an opportunity to upgrade to a higher efficiency motor.

2. Energy Savings and Compressed Air Systems

In many industrial processes, compressed air systems can consume a large component of energy use, and hence offer the potential for large financial savings from reduced energy consumption. The largest component of a compressed air system is the compressor unit. Compressors can utilise a variety of fuel sources, including diesel, petrol and electricity. Whilst this discussion will focus on electric compressors, the principles apply across all fuels, although predicting financial savings may be difficult where the fuel price, especially for oil based fuels, fluctuates rapidly.

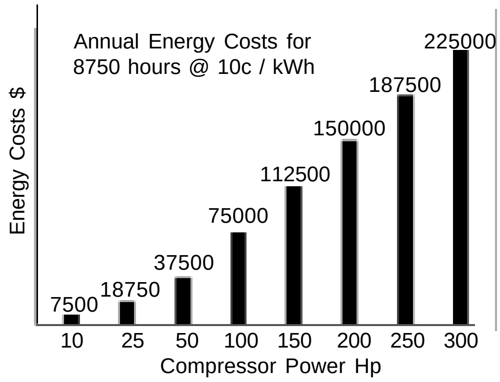

Figure 5. 3: Compressor Annual Energy Costs (Kaeser Compressors

Energy savings from compressed air systems will usually result from savings in two areas:

- compressor unit (T_2)
- distribution system (T_1/T_2)

Compressor Units

At the heart of all compressors, irrespective of fuel type, there are three areas that are essential for energy efficiency:

- Compressor Motor
- Compressor Element (also known as the Airend)
- Compressor Control System.

Compressor Motor

Energy savings for motors in general are discussed at length in the previous section. In addition to these, consideration should be given where feasible to replace electric motors with diesel fuels and vice versa, if energy, and hence financial savings are possible.

Compressor Element

The airend of the compressor is the component that is responsible for compressing the air in the compressor unit. The performance of compressor elements will depend largely on the type of element in the unit (rotary screw, rotary vane, reciprocating or centrifugal) and may vary by as much as 20% between the styles. The size of the element is also an important factor as larger, under utilised or poorly functioning compressors will use more energy than smaller units operating at full capacity. Reducing the operating pressure of the larger compressor may also result in energy savings.

Control Systems

The development of microprocessors has had an important effect on the efficiency of air compressors. Modern controls are able to match the air supply to the demand much more efficiently than is possible manually, and savings of up to 45% may be possible, through the installation of a number of smaller compressors which can be brought online automatically to match the demand for air.

Aside from savings associated with energy consumption from the compressor components, financial savings will result from compressor units, which are appropriately located, correctly installed, maintained and serviced regularly as indicated in Table 5.1 (Kaeser Compressors, .

Component	Potential Saving through Maintenance
Oil Filter	1%
Inlet Filter	1%
Separator	2%
Cool running, synthetic oil	4%

Table 5.1: Energy savings through compressor maintenance (Kaeser Compressors)

Typically, compressors are located out of sight in the factory and consideration should be given to ensure that they are not subjected to extremes of temperature and are appropriately ventilated, to prevent overheating. Reducing the compressor inlet air temperature by shading the location, or through increasing ventilation of this inlet can also offer significant savings. The correct installation and commissioning of new equipment as well as regular recommissioning of existing equipment after major services and repairs, should ensure that the system is operating efficiently.

Heat Recovery

One of the results of the process of compressing air is the generation of considerable amounts of heat. The use of a heat recovery system can increase the overall efficiency and cost-effectiveness of the operation. In many applications, the waste heat from compressed air systems, particularly from oil cooled rotary screw compressors, can be used in process and space heating applications. Water-cooled oil coolers can supply water for process heating applications at between 50°C to 70°C. Space heating is available from systems where cooling air is reticulated through pipes for distribution through buildings.

The Distribution System

After the compressor unit has compressed the air, it will need to be transported either through reticulated pipes or bottles to the location of the end use. Whilst some air leakage is almost unavoidable, care should be taken to eliminate audible air leaks, especially in reticulated compressed air systems. Audible leaks result in large amounts of energy being wasted, (between 25 and 35%), maintaining pressure to the compressed air tool or device. Thereby increasing the amount of air that must be compressed to complete the task.

Condensation in the distribution system should be minimised by eliminating its presence in the inlet air or providing systems for removing it from the distribution network. In reticulated systems, condensate traps, which collect and remove moisture from the distribution system, also pose as potential areas of energy loss. Traps which are not functioning correctly, or are manually controlled are especially prone to wasting energy. Filters should be regularly checked and cleaned as blocked or partially blocked filters will increase the pressure, and hence the energy, required to operate the system.

Case Study 38 examines how an evaluation of compressed air systems can result in financial savings through energy management.

3. Energy Savings and Steam Generation

Steam is used for a multitude of purposes in industrial plant. It can provide heat for chemical processing, hot water for cleaning purposes, steam for input to turbines for producing power and so on. Steam is generally produced by boilers. Boilers typically operate well below their optimum efficiency and savings of approximately 15% should be readily achievable.

As with all examples of industrial energy efficiency, it is important to consider the whole steam system from generation to recovery. Heat (and thus energy) losses in the steam generation and distribution systems will result in poor heating at the location of the end use.

4. Boilers

Energy savings in the generation side of steam use are usually the result of efficiency improvements in the operation of the boiler. In maximising the efficiency of boilers two key principles need to be addressed: first, the level of excess air (the extra air needed to ensure good combustion of the fuel in the boiler) and secondly the temperature of the flue gases needs to be kept as low as possible (otherwise a large part of the heat that was produced in the boiler will go up the chimney).

Good monitoring can be used to assist in achieving these outcomes. In addition, to these, the utilisation of high quality water, free from contaminants, ensures that the minimum amount of heat is required to produce steam.

In boiler plants, there are typically four areas of potential savings:

- Monitoring equipment (T_1/ T_2)
- Load management (T_1)
- Condensate return (T_1/T_2)
- Fuel selection (T_1)

Monitoring Equipment

Boilers are a potential source of energy savings since they are frequently inadequately monitored, even at the simplest level, resulting in efficiency losses, and hence. Simple, but regular analysis of the flue gases, including chemical analysis of the gases and its temperature, will help determine if the boiler is operating efficiently. Care should be taken to ensure that the tests are conducted with load levels of at least 65 – 70% and that the load and gas (steam) pressures are constant. Once this level of analysis is well established, additional monitoring equipment which can determine the gross thermal efficiency of the boiler, may be required.

Case Study 39 and Chapter 8 demonstrate the potential for energy savings in boilers in a hospital environment, as well as options for financing energy efficiency projects.

Load Management

As with electric motors and air compressors, boilers do not run efficiently when they are operating at less than their recommended operating pressures. Significant cost savings can result where load management strategies, such as only operating the number of boilers to produce the required amount of gas/steam and advance warning of changes in the gas/steam load are given to boiler plant staff, are implemented.

Condensate Return

Unfortunately, there will always be some efficiency losses in process heating due to boilers as a result of condensate. Boilers and reticulation systems which are fitted with condensate return systems are far more efficient than those where the condensate enters a waste stream. The efficiency gains are largely the result of chemical profile of the steam condensate, which is typically hot and free of oxygen. This liquid requires less energy to convert the already heated and deoxygenated liquid to gas (especially steam).

Fuel Selection

There are seven common types of fuels available for boilers:

- Coal
- Natural gas
- Liquefied petroleum gas (LPG)
- Furnace Oil
- Diesel
- Electricity
- Wood, or wood wastes (Biomass)

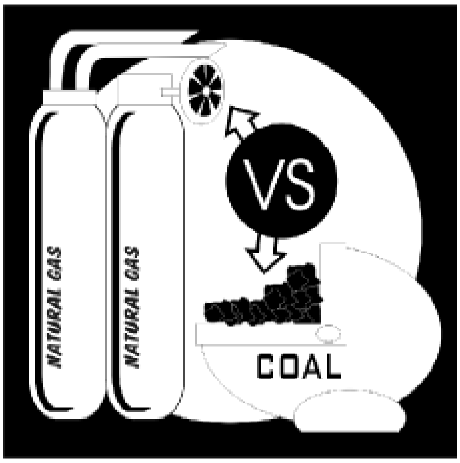

Figure 5.4: The selection of alternate fuel sources may result in financial savings

In many parts of the world, coal is used as a boiler fuel as it is usually the cheapest industrial fuel source. However, many countries are looking towards natural gas and biomass as alternatives due to the increasing cost of the traditional fossil fuels, diesel, coal and electricity as well as regulatory changes.

When selecting or reviewing the fuel selection for boilers, careful consideration should be given to ensure that the full cost of the fuel, including transportation cost, is considered. For example, a boiler in a pulp and paper mill may be more cost effective if it utilised the wood waste from the pulp process than coal or natural gas, despite a supply of both nearby.

Cogeneration, the simultaneous production of heat and power is also a potential area of energy savings, through the on site generation of heat / steam and electricity.

5. Energy Savings in Steam Distribution Systems

As with compressed air systems, the distribution of steam throughout an industrial facility is a potential area of energy loss, and hence increased operating costs. Steam traps are used in steam distribution systems to remove condensate as it forms. They often have the dual function of removing any entrapped air in the system. The presence of air and condensate in steam systems reduces the effectiveness of heat transfer in these systems as they tend to form insulating layers on heat transfer surfaces.

This means that temperatures have to be higher in order to achieve the same rate of heat transfer. Also the presence of air reduces the overall temperature of the system which is governed by the pressure of the steam. If part of the pressure of the system is caused by entrapped air, the net pressure of the steam is less than that read on the steam gauges and so the temperature will be lower than expected. Regular checking of steam traps and air vents is essential for the efficient operation of steam plant.

Energy is also wasted in steam distribution systems where heat is lost to the environment through inadequate insulation of the reticulation system. Care needs to be taken with valves and fittings that, if not properly insulated, lead to significant heat loss. Any heat lost in the distribution system means that additional fuel has to be consumed in the boiler to make up for this loss.

Condensate is an inevitable product of any steam system either as a result of heat loss or simply as a result of using the steam to transfer heat to a process. This condensate represents a source of hot, very pure water and so is an ideal feedstock for the boiler input. Assuming that the condensate has not been contaminated by the process, the use of condensate is a very effective example of using waste heat (or heat recovery).

6. Energy Savings and Furnaces

Furnaces are widely used in the manufacturing and mining industries. Although similar to boilers, they are usually used to melt metals for casting. Many of the potential areas for energy savings are the result of high capital cost, or require detailed changes in the current operation of the factory or smelter. These include rescheduling to reduce the occurrence of a furnace being heated with less than an optimum load, automatic control of furnaces, insulation of the furnace as well as modifications to the furnace. Although these items require large amounts of capital, consideration should be given to these issues, especially where the furnace is due to be replaced, or where a new furnace is to be purchased.

Cost effective, simple strategies for reducing the energy consumption of furnaces are very similar to those discussed in the section on boilers, and includes fuel selection, monitoring equipment (to ensure there is not excessive air in the melt) and load management.

Furnace systems often offer good potential for heat recovery systems where the very high temperatures in the exhaust air can be used to preheat the combustion air entering the system.

Case Studies 40 and 41 demonstrate the potential for energy savings from energy efficient furnaces in two common industries.

7. Energy Savings Through Heat Recovery

In many processes considerable amounts of waste heat are produced. Examples include the exhaust stacks of engines, boilers or furnaces, condensate in steam systems, and waste streams from washing, heating applications as well as compressed air systems.

Heat recovery involves the use of these waste heat streams to provide useful heat for another part of the plant. Heat exchangers are used to extract heat from the waste stream and transfer it to a second fluid flow. In many instances the waste heat from one part of the process can be used to preheat a fluid for use in that same process. For example the hot air in the exhaust of a furnace can be used to preheat the combustion air used in the same furnace.

Waste heat is usually best identified as part of an overall energy audit of the industrial process or facility. The audit should identify the fluid type (liquid or gas), the amount of fluid generated, either as a volume or flow rate, temperature of the fluid, the time of production (i.e. only between 10am and 2pm), its location as well as the location of heat using processes. From this information, the monetary value of the waste heat should also be determined.

Once the size and location of the waste heat product is known, a detailed analysis of the energy saving potential as well as the process of selecting an appropriate heat exchanger can be undertaken. Heat exchangers are devices which recover the waste heat from one process for use in another process.

There are a variety of heat exchangers available on the market, suitable for both batch and continuous feed operations. Recuperator type heat exchangers are able to work in continuous feed processes as the heat recovery from the fluid is steady. In regenerator type heat exchangers, heat recovery is delayed due to the storage period required for the release of heat from the fluid, and thus are best suited to batch processes. Careful consideration must also be given to the physical and mechanical performance of the proposed heat exchanger prior to purchase.

8. Energy Savings Through Cogeneration

Cogeneration is best explained by its alternate name of Combined Heat and Power (CHP). As it suggests useful process heat is generated simultaneously with power. Usually, electrical energy is produced through the combustion of fuel, generating heat as a by-product. Excess heat is recovered and used for process heat applications, including steam. Aside from increases in energy efficiency, CHP has the added advantage of increased reliability of supply for industry, especially where electricity supply is irregular or unreliable. Fuel substitution prov ides greater flexibility for CHP, where cheaper or renewable fuels are available to replace conventional fuels.

Cogeneration has been extensively used throughout the world in industry and non-industrial applications, such as district heating. However, regulated electricity industries pose significant institutional barriers for cogeneration projects. Case Study 42 examines cogeneration in a typical industrial process, whilst Case Studies 43 and 44 look at regulatory issues associated with the development of cogeneration projects.

9. Awareness Raising and Education

Awareness raising and education of the need and potential for energy savings is as important to the industrial sector as it is to the domestic and commercial sectors. Potential activities for encouraging energy savings are discussed at length in Chapter 4.

Operator behaviour can have a significant effect on the effectiveness of energy efficiency measures in industrial plant. Simply turning off equipment when it is not being used can provide an easy way of saving both energy and money. Education programs can provide considerable potential for energy savings.

10. Regulatory Measures

There are several regulatory measures that can produce energy savings in the industrial sector. These include:

- minimum energy performance standards. Some countries have introduced regulations requiring office equipment to meet minimum standards of energy efficiency
- deregulation of the electricity industry to encourage the development of cogeneration
- building codes can be used to ensure that new buildings meet minimum standards for passive solar design in order to reduce energy use
- changes in the regulatory environment as a result of the control of emissions, such as carbon dioxide and international obligations, such as United Nations protocols

11. Economic Measures

The economic measures available to encourage energy efficiency in the industrial sector are similar to those offered to the commercial and domestic sectors and include:

- time of use tariffs
- subsidies for substitute fuels (including biofuels)
- subsidies for the use of renewable energy
- tax relief for investment in energy efficient equipment
- levies and penalties on energy use

E. References and Resources

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Energy Efficiency: A Guide to Current and Emerging Technologies
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