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D 4.1: Current process description Wineries (English)

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Transfering
Energy Save
Laid on Agroindustry

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About this report

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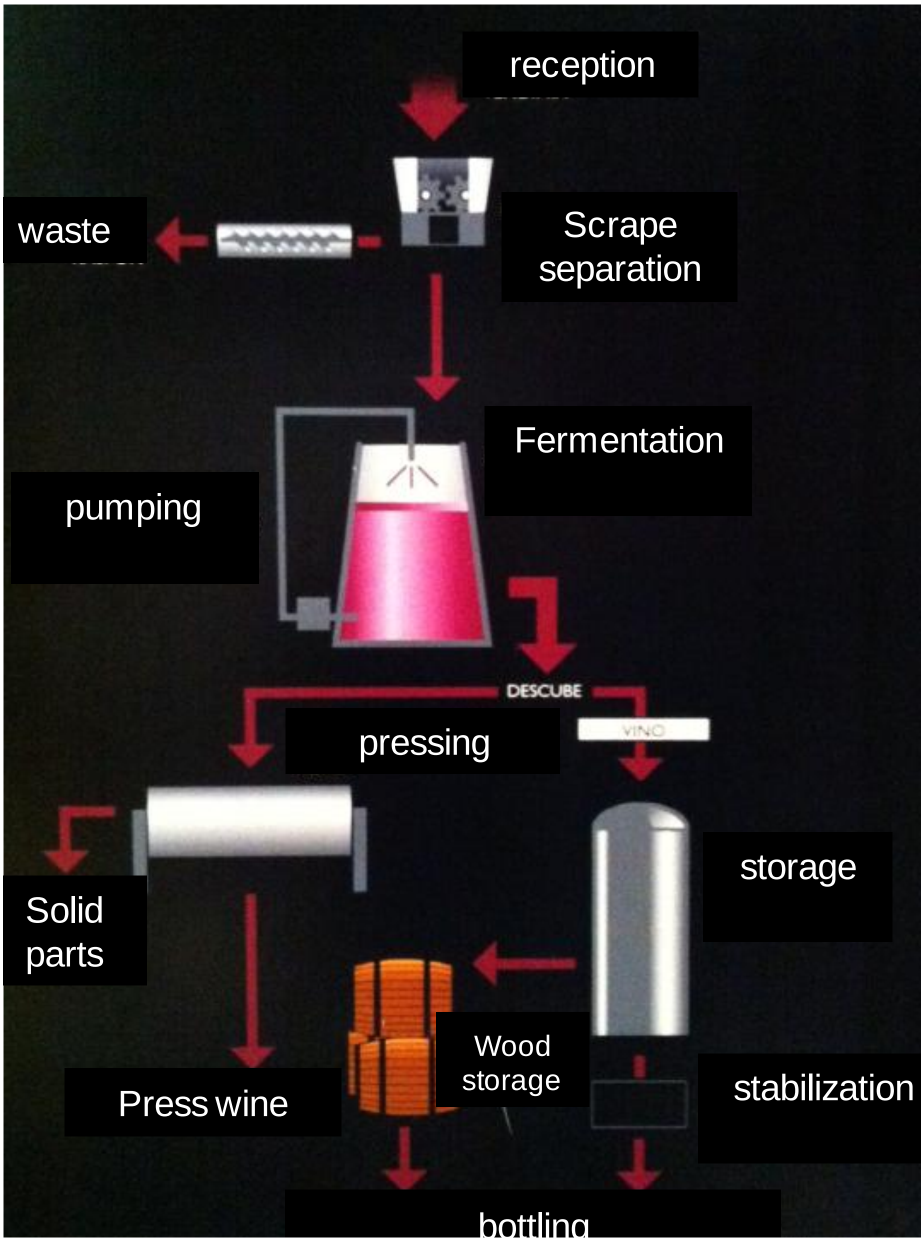
1. Introduction

The European Union is the leader in the global wine market. With an annual production of 175 million hectoliters, EU represents 45% of the wine-growing areas, 65% of production, 57% of consumption and 70% of exports.



The wine market has evolved considerably in the last decades. It is necessary to distinguish an initial period of equilibrium, followed by a phase of sharp increase in production even with stable demand and, finally, from the eighties, a steady decline in consumption and a marked tendency towards quality differentiation.

From 1980, interventionism in the wine sector became quite intense, with the ban on planting and the obligation to distil the surplus. Removal of wine surpluses represented a considerable expense for the sector. In the late eighties financial incentives were increased for uprooting vineyards (European Commission, 2008).

The goal of achieving a better balance between supply and demand is clear in the last years. Producers are trying to adjust their production to a market that demands more quality in order to achieve sustainable competitiveness in the context of increasing international competition as a consequence of the GATT agreements. It is necessary to strengthen the reputation of European wineries and to regain market share in the EU and in the rest of the world. At the same time, both keeping the traditions of EU wine production and enhancing their social and ecological function in rural areas are also prioritary goals (European Commission, 2008).

It is remarkably that a very important part of the wine sector is succeeding in the adaptation to the growing demand from emerging economies. A key point is presently the production of wine of acceptable quality at very competitive prices and the bulk wine export at affordable prices to markets that have limited ability to acquire high-cost wines: exports are increasing to countries like China and Russia. This leadership in production costs is closely related to the improvement of energy efficiency.

2. Sector characteristics

Overview of wineries: processes

The production processes considered in this document go from the reception of the grapes in the winery to the dispatching of wine, which can be distributed bottled or in bulk. Red and white wine production is included.

2.1. Grapes reception, destemming and crushing

When grapes arrive to the winery to be introduced into the facilities, they are weighed in the scales to determine the exact amount of product and the quality. A sample is taken to measure the sugar content and other properties of the grapes.

Figure 1. Grape discharge.

Then the grapes are discharged into the receiving hopper, in general, an inverted truncated pyramid made on stainless steel and fitted with screw conveyors transporting the grapes towards the crusher. In the crushing process, the skin is broken for releasing the pulp and juice (grape must) without removing the sticks. This process implies a strong aeration of the must.

Mechanical work comprises two operations:

- Destemming is the process of separating stems from the grapes.

Figure 2. Destemming.

- Crushing is the process of breaking the skin for liberating the pulp and the juice. In this process the woody part is removed for waste, because during the maceration it can transmit unpleasant or herbaceous flavors in the red wine production process. It is carried by an endless belt and collected on the outside of the winery into a hopper.

2.2. Alcoholic fermentation

The product obtained from the crusher (pulp and must) is transported using pumps to the tanks of fermentation where alcoholic fermentation takes place. The sugars contained in the paste are converted to ethyl alcohol. This process requires the presence of yeast, microscopic fungi, with natural presence in the skins (selected yeast can be added to the process). Oxygen is the initial trigger of fermentation because yeasts need it in their phase of growth. However, at the end of this process of fermentation, the oxygen content should be small to prevent loss of ethanol and appearance of acetic instead.

Figure 3. Fermentation tank.

The alcoholic fermentation is an exothermic process. It means that releases energy as heat. This make necessary to control the temperature since, if it increases too much (25-30ºC), yeast begins to die stopping the fermentation process, so tanks incorporate cooling jackets for temperature control. In the process, a cap of pulp is formed in the surface of the tank pushed by the carbon dioxide produced. Besides, the must is pumped from the lower part of the tanks to the upper part and it is released in form of shower, promoting the fermentation and activating the color extraction from the pulp in red wines.

2.3. Pressing to storage

With red wines, pressing is carried out after the alcoholic fermentation (not in the case of white wines in which pressing is done just after destemming). The liquid product of the alcoholic fermentation passes to presses where controlled pressure is applied separating liquid from the solid phase. Usually there are two pressing processes with different quality between first and second pressed wine. The liquid from the presses is conducted to tanks. Solids (pomace) are usually used in distillation.

Once the tanks are filled with the must to be transformed in wine, malolactic fermentation is carried out in few days. This process consists in transforming the malic acid to lactic acid, lowering the pH, while polyphenol and glycerol concentration increase. In this process the wine loses acidity and gains in smoothness and aroma.

The malolactic fermentation process must be controlled to prevent problems in the wine, since the lactic bacteria that degrade the malic acid may attack other substances causing undesirable effects (acetic acid). The optimum temperature for growth of the lactic bacteria is 20-23°C. Above 30°C the bacteria begin to die and below 15°C it is difficult to end the process. So temperature control is needed again in this process.

In white wine production, pressing usually takes immediately after extraction and before alcoholic fermentation. There are not important differences concerning energy consumption with respect to red wine production.

Figure 4. Presses.

2.4. Stabilization and fining

After the malolactic fermentation, the wine is pumped from one tank to other removing in the process the solid elements, which can transfer undesirable sensorial qualities. SO2 is added for better conservation. The resulting wine or "cupage" is obtained. In this process, wine becomes pretty clean. This process is followed by the filling of tanks with similar wines, obtaining a homogeneous batch.

After about two months of resting, wine is clarified with bentonite and gelatin by using the suitable doses. The fining process has three phases. First clarifying agents react producing turbidity; then solid particles appear; finally particles flocculate, as a result it facilitates their elimination.

Afterwards, wine is stabilized at a temperature lower than zero degrees and it rests with this level of temperature about two weeks. Wine cooling produces physical transformations: insolubilization of tartrate crystals and of ferric complexes, proteins, and other components in colloidal form. Then, filtering is carried out for eliminating microorganisms and colloids and for obtaining a clean product, In the filtration process, the visual quality of the wine is improved. Filtration can be performed either through diatomaceous earth of different sizes or through cellulose or by centrifugation.

Figure 5. Cooling equipment for stabilization.

2.5. Bottling, storage and delivery

The wine is bottled in a specific independent process. The wine is normally bottled in PET bottles of 5 liters and glass bottles of 0,75 liter. This operation normally consists in the filling, encapsulation and labeling of the bottles.

Figure 6. Bottling equipment

2.6. Storage

If delivery does not occur just after bottling, the product will require storage. Internal transport is usually performed with forklift trucks.

In the red wine production with aging, red wine can be aged for some periods before bottling, though this can vary from a few months to years (for example, 3 years in oak barrels and 2 years in bottles for "Gran Reserva" wines in Spain). Aging can take place also in stainless-steel or concrete tanks.

Figure 7. Aging oak barrels.

3. General data of energy consumption in wineries

Energy consumption for the production of wine in the European Union is around 1750 million kWh per year, so this sector is a significant consumer of energy. Energy consumption in France is around 500 million kWh, a similar value of 500 million kWh in Italy, 400 million kWh in Spain, and 75 million kWh in Portugal (estimated from ICEX, 2012). In this sector, primary energy source used is mainly electricity (more than 90%). Fossil sources (gas, diesel and fuel oil) are less than 10% of the total energy consumption.

In wineries, electricity is used for the electrical engines of the machinery, lighting, and cooling of the product in several processes. It is noteworthy that 45% of the energy is used in the processes of fermentation, mainly by heat pumps in the refrigeration of these processes. In some wineries 100% of the energy consumed is electrical; in some cases diesel (or other fuels) are used for hot water production or other uses.

For a reference winery in the four countries considered (France, Italy, Portugal and Spain), the following general values can be considered for red wine production without aging (the main typical industry):

- Industry size considered as a reference: 30.000 hectoliters of wine /year
- Typical ratio, electrical energy consumption/production: 11 kWh/ hl wine
- Typical ratio, thermal energy consumption/production: 1 kWh/ hl wine
- Typical electrical power installed: 800 kW
- Typical thermal power installed (boiler/vehicles/etc.): 20 kW boiler, 50 kW vehicles
- Typical electrical energy cost in the industry: 0.12 euros/kWh
- Typical thermal energy cost in the industry: 0.07 euros/kWh
- Typical ratio, electrical energy cost / thermal energy cost: 95% / 5%
- Seasonality of the electrical energy consumption: From August-September to October-November
- Seasonality of the thermal energy consumption: from October to February (in industries with fuel consumption for heating)

A winery of 30.000 hectoliters of wine/year, selected as a representative industry, has an average electricity consumption of about 330.000 kWh/year. Previous studies have shown that overall energy balance in this typical winery shows the following average values:

- Electricity consumption: represents 92% of total energy consumption in the winery.

- Distribution of electricity consumption in phases: reception 5%, fermentation 45%, pressing 7%, stabilization 8%, bottling and storage 18%, auxiliary activities 10%, lighting 7%.

- Fuel consumption (usually diesel): 8% of the total energy consumption. In some facilities fuel consumption is zero, since all the processes use electrical devices.

- Distribution of fuel consumption: bottling and storage 50% (washing of tanks and bottles with warm water), auxiliary activities 50% (heating, warm water production for several uses, diesel transport vehicles).

Although the average electricity consumption of the typical facility is about 11 kWh/hl, it should be noted that this ratio can be very different from one facility to another. Previous studies have determined that electricity consumption can vary from 3 kWh/hl to 25 kWh/hl. The size of facility is one important factor affecting energy consumption; big facilities (wine production higher than 50.000 hl/year) showed a mean value of electrical consumption of about 4 kWh/hl, while small facilities (wine production lower than 25.000 hl/year) showed a mean value of electrical consumption of about 16 kWh/hl. Other factor was the quality of the wine: wines of higher quality require higher electricity consumption since cooling needs usually are higher. Although size was the main factor affecting energy consumption, there was important differences in consumption among facilities with the same size with similar wine quality. This means that there is a considerable potential for energy saving in this type of industries.

4. Industrial processes and energy consumption

The first step of the process is the reception of the grapes and the extraction of the must. Energy consumption in these processes is electrical and it is due to the action of electrical engines and screw mechanisms to feed the hopper as well as the electrical consumption of the devices (compressed air, refractometer, etc.) used for sampling and quality measurement in the reception. Destemming also consumes electrical energy. The next process is the alcoholic fermentation. In this phase, the energy consumed is again electricity for the pumps moving the wine in the tanks and for the cooling equipment (heat pumps, etc.) that is used to maintain the temperature required by the fermentation processes.

In red wines, pressing is carried out after alcoholic fermentation. The energy consumption in this process is again electric (electric engines, pumping, presses, compressed air). In the malolactic fermentation, cold or heat are used for temperature control, produced by heat pumps. Final steps of processing are clarification, stabilization, filtration, bottling, storage and shipping. In these final stages, electric energy consumption is due to pumping, bottling and compressed air generation. Transport can be made with electrical forklifts (typical for inbound transportation) or with vehicles with fuel consumption (more typical for outbound transportation).

Pasteurization of the wine is not very usual, but can be used as an alternative in stabilization. This process has a lower electrical consumption than the conventional stabilization but the fuel consumption is quite high.

From the quantitative point of view, cooling processes (in alcoholic and malolactic fermentation, stabilization, and others) are clearly the main energy consumers in this type of facilities. Cooling can represent nearly 50% of the energy devoted to processes.

Table 1. Values of a standard production process, industry of 30.000 hectoliters of wine/year, from an analysis of eight wineries (Cooperativas agroalimentarias, 2010).

		VALUES OF THE TYPICAL TECHNOLOGY USED IN THE PROCESS (in brackets[ ], main alternative technology)			
PROCESS (sequential order)	**TYPICAL TECHNOLOGY (in brackets[ ], main alternative technology)**	**Electrical power installed (kW)**	**Electrical energy consumption (kWh/hl)**	**Thermal power installed (kW)**	**Thermal energy consumption (kWh/hl)**
Grape reception	Receival bin, screw mechanisms, and electrical engines	57	0,55	0	0
Extraction	Mechanical de-stemmers, rollers, and electrical engines	64			
Alcoholic fermentation	Refrigeration systems -heat pumps-, pumping, and electrical engines	276	5,00	0	0
Pressing	Heating systems -heat pumps- for malolactic fermentation, pumping, and electrical engines	76	0,75	0	0
Stabilization	Refrigeration systems -heat pumps- for stabilization, pumping, and electrical engines [Pasteurization, pumping, and electrical engines]	91 [25]	0,90 [0,10]	[116]	[1,75]
Bottling, storage and delivery	Electrical engines, and forklift trucks	102	1,95	50	0,5
Lighting	Fluorescents	10	0,75	0	0
Auxiliary processes	Air conditioning by heat pumps, and boiler for hot water production	124	1,10	20	0,5
	TOTAL	800	11,00	70	1,00

In addition to the processing steps, part of the energy consumption corresponds to "horizontal technologies" or auxiliary processes such as:

- General lighting: both inside and outside of the facility.
- General heating or air conditioning for human comfort.
- Offices, with an energy consumption depending on: computers, faxes, printers, etc. and working hours.

- Shop: with a variable consumption depending on the equipment.

- Wine quality laboratory with different processes using different lab equipments as spectrophotometer, hydrometer, etc.

Table 2. Typical technology used in the process, industry of 30.000 hectoliters of wine/year.

PROCESS (sequential order)	TECHNOLOGY	Quality control	Automation control technology	Information storage devices (if exist)	Typical type of maintenance
Grape reception	Receival bin, screw mechanisms, and electrical engines	Raw product control (sugar content and others)	No	Data base	Corrective maintenance
Extraction	Mechanical de-stemmers, rollers, and electrical engines		No	No	Corrective maintenance
Alcoholic fermentation	Refrigeration systems -heat pumps-, pumping, and electrical engines	Temperature control	Specific automation controllers	Data base	Preventive maintenance
Pressing	Heating systems -heat pumps- for malolactic fermentation, pumping, and electrical engines	Temperature control	Specific automation controllers	Data base	Preventive maintenance
Stabilization	Refrigeration systems -heat pumps- for stabilization, pumping, and electrical engines	Temperature control	Specific automation controllers	Data base	Reliability centered maintenance
Bottling, storage and delivery	Electrical engines, and forklift trucks	Wine quality control	Specific automation controllers & communication bus	Data base	Reliability centered maintenance
Lighting	Fluorescents	No	No	No	Corrective maintenance
Auxiliary processes	Air conditioning by heat pumps, and boiler for hot water production	No	Thermostats	No	Corrective maintenance

Technology applied in the processes offers opportunities for energy savings in this sector. In some processes, automation devices are connected to a PC and information is stored. Analysis of the stored information can show aspects of the process that can be improved. A appropriate maintenance programs can also contribute to a better management of energy consumption.

5. Alternative technologies and new perspectives

Alternative technologies that can improve energy efficiency may be classified into two groups: technologies specific of the winery sector, and "horizontal technologies" that can be used in any sector or facility.

Specific technologies for improving energy efficiency

- Optimizing the cooling processes. As it is above mentioned, cooling processes are clearly the main energy consumers in this type of facilities and improvements in these processes will usually have a strong influence on energy efficiency. A possible measure could be the use of systems for cold storage, with reductions in consumption of about 30 to 35% (for example, using ice). In some cases, heat and cold recovery systems (for example, heat exchangers) can be used to transfer cold from a process where it is produced to a process where it is used (for example, filling and emptying wine tanks in stabilization at less than 0ºC).

- Variable speed drives can be used for controlling the electrical engines (for example, compressors) of the cooling processes. The investment needed for incorporating these devices is relatively high, therefore these decisions require a specific economic analysis.

- Using automation devices with PID algorithms (or similar advanced control technologies) to control the cooling equipments. In some cases, energy saving can be reached with no investment, by using the appropriate alternative control available in the automation equipment.

- Substitution of heat pumps by geoexchange heat pumps is an alternative that should be evaluated in many cases.

- Cold stabilization can be made in shorter periods of time by the addition of chemicals. This possibility should be evaluated.

- In general, it is advisable an operations management that tries to avoid marked peaks in the processes (for example, in grape reception) as well as excessive periods of storage. This general measures could improve energy efficiency in several stages of the processes.

Table 3. Alternative technology / systems that improve the energy efficiency of the processes

PROCESS (sequential order)	TYPICAL TECHNOLOGY	Factors influencing energy consumption in the typical technology	ALTERNATIVE TECHNOLOGY / SYSTEMS	Estimated energy saving (%)	Estimated implementation cost	Estimated payback period (years)
Grapes reception	Receival bin, screw mechanisms, and electrical engines	Product volume, process peaks	Management focused on avoiding process peaks	10%	Low	1
Alcoholic fermentation	Refrigeration systems -heat pumps-, pumping, and electrical engines	Product volumen	Geoexchange heat pumps	20%	High	8
Alcoholic fermentation	Refrigeration systems -heat pumps-, pumping, and electrical engines	Product volumen	Using heat and cold recovery systems	15%	High	6
Pressing to storage	Heating systems -heat pumps- for malolactic fermentation, pumping, and electrical engines	Product volume, outside temperature	Geoexchange heat pumps	20%	High	8
Pressing to storage	Heating systems -heat pumps- for malolactic fermentation, pumping, and electrical engines	Product volume, outside temperature	Using heat and cold recovery systems	15%	High	6

Horizontal technologies for energy saving

- Pipe thermal insulation. This technique is clearly interesting both from an energy point of view and from and economical perspective. It should be carefully implemented, with a suitable maintenance. Estimated payback period is usually very low (about one year).

- Lighting technology offers several opportunities of energy saving with low or medium cost, such as the installation of more efficient lamps (for example, metal-halide lamps instead of mercury-vapor lamps) or the installation of electronic ballasts.

- Automation devices can produce lower electricity prices because of electricity tariffs. Typically electricity consumed at night is cheaper. Consequently automation devices could be installed to assure that electricity consumption is made in periods with low tariffs, for example, in the process of recharging electrical forklift trucks.

- Electric power factor correction is usually installed in this type of facilities (using capacitors) but their right performance should be checked.

Table 4. Alternative technology / systems that improve the energy efficiency of the processes

PROCESS (sequential order)	TYPICAL TECHNOLOGY	Factors influencing energy consumption in the typical technology	ALTERNATIVE TECHNOLOGY / SYSTEMS	Estimated energy saving (%)	Estimated implementation cost	Estimated payback period (years)
Stabilization	Refrigeration systems -heat pumps- for stabilization, pumping, and electrical engines	Product volume, outside temperature	Using heat and cold recovery systems	15%	High	6
Bottling, storage and delivery	Electrical engines, and forklift trucks	Product volumen	Automation for non-consumption in peak hours (electrical forklift trucks and others)	0% in energy, 20% in electrical cost	Low	1
Lighting	Fluorescents	Lamp efficiency	More efficient lamps	30%	Medium	4
Lighting	Fluorescents	Lamp efficiency	Electronic ballasts	12%	Medium	3
Auxiliary processes	Air conditioning by heat pumps, and boiler for hot water production	Outside temperature	Pipe thermal insulation	10% (thermal)	Low	1

6. Further information

Red wine can be aged in oak barrels for some periods before bottling, though this can vary from a few days to years. Aging can take place also in stainless steel or concrete tanks. With aging, the consequences on energy consumption can be important, since wine is stored in controlled ambient conditions, usually employing heat pumps for air conditioning for long periods of time, so the possibilities of energy saving are higher in this kind of facilities.

7. Conclusions

The European Union is the leader in the global wine market. Energy consumption in the production of wine from the European Union is around 1750 million kWh per year, so this sector is a significant consumer of energy. A winery of 30.000 hectoliters of wine/year, selected as a representative industry in the four countries studied (France, Italy, Spain and Portugal), has an average electricity consumption of about 330.000 kWh per year. Although size is the main factor affecting energy consumption, previous studies have shown that there are important differences in consumption among facilities of the same size; this means that there is a considerable potential of energy saving is this type of industries. The present document shows the production processes and the present energy consumption of the technologies, from the receipt of the grapes in the winery to the wine shipping; both specific and general (horizontal) energy efficiency improvement measures are described and analyzed for the sector.

8. References

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