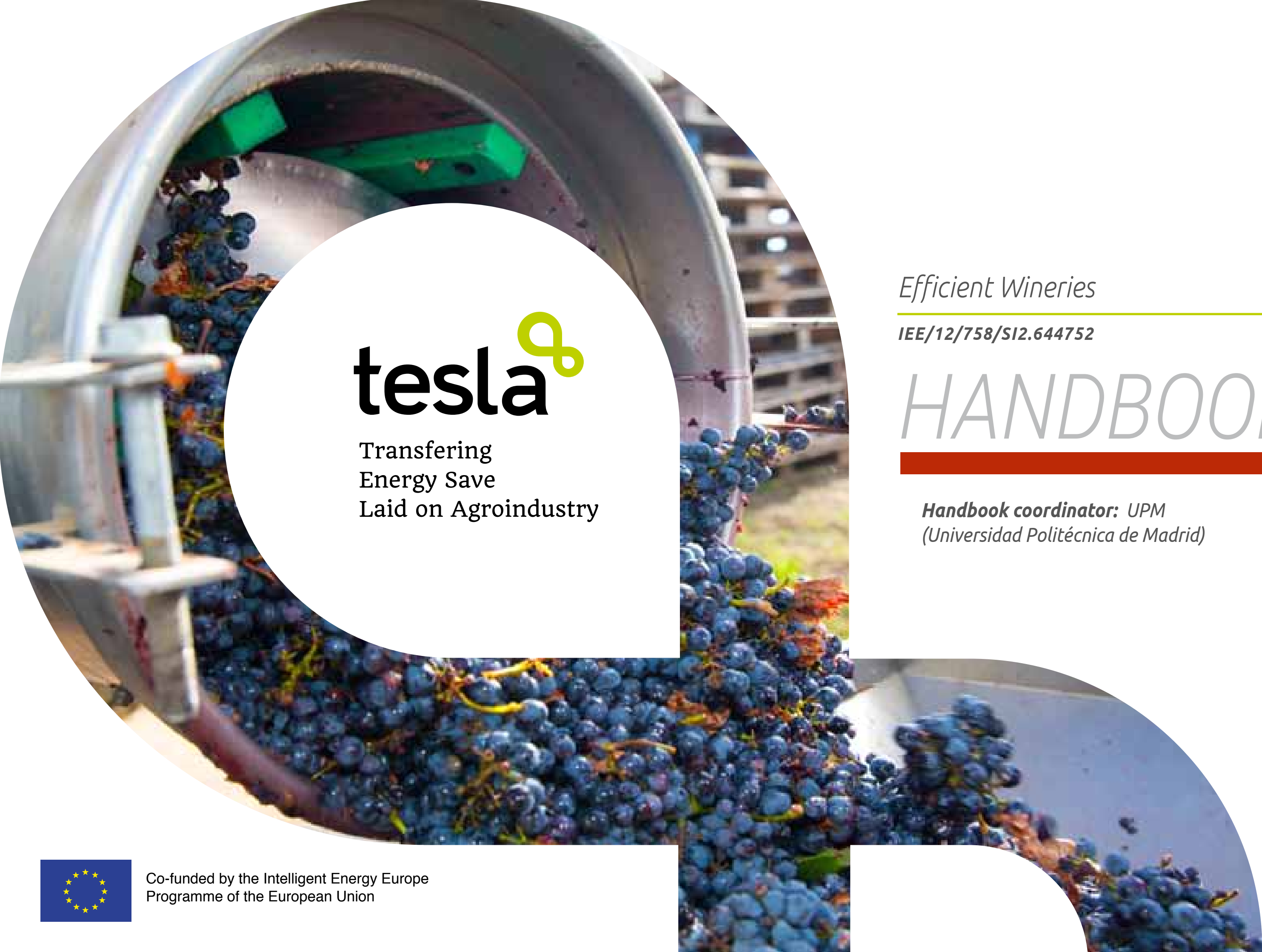

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Transfering
Energy Save
Laid on Agroindustry

Efficient Wineries

IEE/12/758/SI2.644752

HANDBOOK

Handbook coordinator: *UPM*
(Universidad Politécnica de Madrid)

Co-funded by the Intelligent Energy Europe
Programme of the European Union

Update version:
February 2014

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The following document has been executed jointly with CIRCE, UÉvora, Tecaliman and ENEA, and includes information provided by Spanish Co-ops, CoopdeFrance, CONFAGRI and Legacoop Agro.

About this report:
This report has been developed in the framework of the TESLA project (Intelligent Energy Europe) and has been founded by the European Commission.

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0. INDEX

1. INTRODUCTION

1.1. Characteristics of the winery sub-sector

The EU is a leading producer of wine producing some 175 millions hl every year. In global terms, it accounts for 45% of wine-growing areas, 65% of production, 57% of global consumption and 70% of exports (European Commission, 2008).

Since the introduction of the Common Market Organisation (CMO), the wine market has developed considerably. In brief, it has been characterised by a very short initial period of equilibrium, followed by a very marked increase in production against a constant level of demand, and finally, a continuous decline and a very noticeable qualitative change in demand from the 1980s.

It started out very liberal, with no limits on plantings and very few market regulation instruments (it is, being the aim just to face the annual variations in production). Then, it coupled freedom on plantings with the virtually guaranteed sales, and thus generating serious structural surplus. From 1978 it became very interventionist with the ban on planting and the obligation to distil the surplus. Towards the end of the 80s financial incentives for giving up vineyards were reinforced.

The reform of the CMO for wine in 1999 strengthened the goal of achieving a better balance between supply and demand on the Community market. It gave the producers the chance to bring production into line with a market demanding higher quality and it also allowed the sector to become more competitive in the long term by financing the restructuring of a large part of the current vineyards.

This reform was insufficient to reduce wine surpluses and considerable amounts had to be still disposed. A new reform of the wine market was needed.

The reform adopted by the EU in 2008 had the following goals:

- *Making EU wine producers even more competitive - enhancing the reputation of European wines and regaining market share both in the EU and outside.*

- *Making the market-management rules simpler, clearer and more effective – to achieve a better balance between supply and demand.*
- *Preserving the best traditions of European wine growing and boosting its social and environmental role in rural areas.*

1.2. Socioeconomic point of view in Europe and in the four TESLA countries

Vine-growing and wine production is an essential economic and labour intensive activity and plays a major socioeconomic role for many Member States and regional economies, and for the EU economy as a whole.

In 2004, wine production represented 5,4% of the EU's agricultural output and for some Southern European economies (France, Italy, Austria, Portugal, Luxemburg, Slovenia and Spain) it accounted for approximately 10% of the value of agricultural production (Comité Européen des Entreprises Vins, 2014).

The EU wine sector evolves in an extremely competitive context at all levels (national, EU and international), but it is composed by an overwhelming majority of small producers, and is therefore extremely atomised in comparison with other food and drinks industries:

- *1,3 million companies holdings vineyards for wine production in the EU-25 in 2005.*
- *Representing more than 20% of the total employment in EU agriculture.*
- *Employing over 3 million people, with family labour force still being very prevalent.*
- *Occupying more than 3 million hectares of land.*
- *With an average holding size of 2,6 ha in 2005.*

Of course, the socioeconomic dimension of wines extends beyond the agricultural activity in the vineyards as it also involves (as said by the Comité Européen des Entreprises Vins, in 2014):

- *The production of wine, which does not take place directly in the vineyard, but takes place in cooperative cellars or in private wineries – in 2004, more than 75.000 people were employed in the activities of wine production in the EU-25.*

- *Indirect economic activities linked to wine production such as trade and marketing of wine; production of oak casks, bottles, labels, capsules, corks etc.; development of wine tourism (hotels, bars, restaurants, etc.); distillation of wine; and production of wine spirits and wine by-products.*

1.3. Production

According to figures from the OIV (International Organization of Vine and Wine), in 2011 the global wine-growing surface area dropped 94.000 hectares compared with 2010, achieving the global total surface of 7.495.000 hectares. The total EC vineyard (UE-27) planted surface-area is diminishing progressively, dropping from 3.742.000 hectares in 2008 to 3.530.000 hectares in 2011. This process is the result of a combination of factors, such as the restructuring of vineyards and the impact of the wine-growing crisis, which additionally has become less differentiate in terms of specific areas and types of wine. However the shrinkage of the EU vineyard has been compensated by the maintenance of the planted surface areas in the rest of the world (ICEX, 2012). While vineyards and plantations' surface are being reduced in Argentina and Turkey, they are being increased in China and Australia, and have remained more or less constant in USA and South Africa.

TABLE 1. THE VINEYARD IN THE WORLD.				
COUNTRY VINEYARD AREA (Thousand of hectares)	**2009**	**2010**	**2011**	**% S/TOTAL**
Spain	1.113	1.082	1.032	13,8%
France	837	819	807	10,8%
Italy	812	798	786	10,8%
Portugal	244	243	240	3,2%
Romania	206	204	204	2,7%
Other EU countries	479	474	461	6,2%
EU Total	**3.691**	**3.620**	**3.530**	**47,1%**
U.S.A.	403	404	405	5,4%
Turkey	505	503	500	6,7%
China	485	490	495	6,6%
Argentina	228	228	218	2,9%
Chile	199	200	202	2,7%
South Africa	132	132	131	1,7%
Australia	176	170	174	2,3%
Non EU Total	**3.966**	**3.969**	**3.965**	**52,9%**
WORD TOTAL	**7.657**	**7.589**	**7.495**	**100,0%**

Source: Datos OIV, produced by OeMv and cited by ICEX, 2012.

Outside the EU, the production level in 2011 was slightly higher than in 2010 (108,9 millions hl in 2011 and 108,7 millions hl in 2010). USA is the non-European country with the highest wine production yielding 18,7 million hl in 2011, although it dropped 2 millions hl from 2010. Argentina holds the 2nd place, with 15,5 millions hl, even though the production decreased from the year before, when they rose considerably. Australia takes 3rd place, with a wine production of 11 millions followed by Chile with 10,6 millions, almost a million and a half up from 2010.

TABLE 2. EUROPEAN WINE AND RAPE MUST PRODUCTION (2011/2012 SEASON).

COUNTRY PRODUCTION (thousands of hectoliters)	2011/12	%S/TOTAL	VAR. % CON 2010/11
France	50.244	30,5%	10,7%
Italy	43.459	26,3%	-14,1%
Spain	40.324	24,4%	0,8%
Portugal	5.925	3,6%	-16,9%
Germany	9.395	5,7%	36%
Other EU	15.653	9,5%	1,5%
EU Total	**165.000**	**100%**	**1,5%**

Source: EU figures, compiled by OeMv and cited by ICEX, 2012.

According to OIV estimations, 2011 global production (not taking into account must and grape-juice) was around 265,8 million hectolitres, 700.000 hl more than in 2010. The biggest producer is France, with 49,6 million hl (18,7% of the global total), followed by Italy, with 41,6 million hl (15,6%), and Spain, with 34,3 million hl (12,9%) - as showed in Table 3.

TABLE 3. GLOBAL WINE PRODUCTION.

COUNTRY PRODUCTION (thousands of hectoliters)	2009	2010	2011
France	46.361	45.704	49.633
Italy	47.450	48.525	41.580
Spain	35.166	35.235	34.300
Other EU	33.921	26.912	31.371
EU Total	**162.898**	**156.376**	**156.884**
USA	21.690	20.887	18.740
Argentina	12.135	16.250	15.473
Australia	11.710	11.240	11.010
Chile	10.093	9.152	10.572
Non EU Total	**108.302**	**108.724**	**108.916**
GLOBAL TOTAL	**271.200**	**265.100**	**265.800**

Source: OIV figures, compiled by OeMv.

1.4. Turnover

From the economic point of view, wine sector has a very important role in European economy. Overall turnover received by the commercial activity of these companies placed in the four countries of TESLA project is:

ITALY Italian production value reached 8.900 M€ in 2013 (data from Mediobanca, Indagine sul settore vinicolo, April 2013).

SPAIN Winery sector production was around 4.900 M€ in 2011 (data from Anuario de Estadística 2011, Ministerio de Agricultura, Alimentación y Medio Ambiente).

FRANCE French production value reached 9.500 M€ in 2012 (data from INSEE).

PORTUGAL Winery sector production was around 1.300 M€ in 2010 (data from Agroges 2010, Plano estratégico para a internacionalizacao do sector dos vinhos de Portugal).

2. PROCESSES DESCRIPTION

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 productions are 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 weigh scales to determine the exact amount of product. Also samples are taken to measure the sugar content, the quality and other properties of the grapes.

Figure 1. Grape reception.

Figure 2. Destemming.

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 hopper. Then, the destemming and the crushing processes are executed closely by two mechanical operations:

Firstly, the destemming is the process of removing grapes from the rachis (the stem which holds the grapes), and the stems are disposed as residues. It is important to remove the stems in order to avoid the development of tannins and vegetable flavours in the obtained wine. Destemming is carried out by a worm gear (auger).

Secondly, the crushing is the process of breaking the skins to start the extraction of must (pulp) by squeezing the berries softly. Destemming and crushing processes will be executed in a different way if musts are destined to white wines. In this case, grapes can be crushed without being destemmed, in order to facilitate pressing by allowing juice to flow down between berries skins. It can be done only in white wines because their musts will not be fermented together with the skins (which are responsible of red wine colour).

2.2. Alcoholic fermentation

The product obtained from the crusher (pulp and skins in the case of red wines, and only pulp in the white wines) is transported using pumps to the tanks of fermentation where alcoholic fermentation takes place. The sugars contained in this pomace are converted into ethyl alcohol. This process requires the presence of yeast, microscopic fungi which are naturally present in the skins (although selected yeast can be also added to the process). Oxygen is the first trigger of

Figure 3. Fermentation tanks.

fermentation because yeasts need it in their growing phase. However, at the end of this fermentation process, the oxygen content should be smaller to prevent losses of ethanol and appearance of acetic acid instead ethanol.

The alcoholic fermentation is an exothermic process. It means that releases energy as heat. Therefore, temperature must be controlled because a 20-30°C temperature increase would kill yiest and stop the fermentation process. For that reason, tanks incorporate cooling systems (such as cooling "jackets") for controlling temperature. In this fermentation process, a layer of pulp (known as the cap) is formed in the surface of the tank pushed by the carbon dioxide produced. For that reason, the must is pumped from the lower part of the tanks to the upper part and is released as a shower, promoting the fermentation and activating the colour extraction from the pulp in red wines.

2.3. Pressing and malolactic fermentation

As for 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, while solids (skin residues) are usually used in distillation. In white wines production, pressing usually takes place immediately after desteming and before alcoholic fermentation. There are not important differences concerning energy consumption with respect to red wine production.

Once the tanks are filled with the must to be transformed

Figure 4. Presses.

in wine, malolactic fermentation is carried out in few days. This process occurs when lactic acid bacteria metabolize malic acid and produce lactic acid and carbon dioxide. This reduction of malic acid improves the taste of wine because it reduces its pH, increases polyphenol and glycerol concentrations, and also reduces the unpleasant harsh and bitter taste sensation.

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

2.4. Stabilization and fining

After the malolactic fermentation, the wine is pumped from one tank to another in order to remove the solid elements, which can transfer unpleasant sensorial qualities. In this stage sulphur dioxide (SO2) is also added as anti microbial agent and as an antioxidant, to stop fermentation and protect against oxygen effects.

Fining agents are used to remove tannins and microscopic particles that cloud the wine, and to reduce astringency. These clarifying substances are, for example, bentonite and gelatine. In the fining process the clarifying agents react with the wine components and forms sediments that are removed by filtration, or particles flocculating that are easily eliminated.

Finally, the resulting wine or “cupage” is obtained once the winemaker has corrected inadequacies and has mixed several wines (optionally). This process is followed by the filling of tanks to obtaining a homogeneous batch.

Afterwards, wine is stabilized at a temperature lower than zero degrees and it is maintained at this temperature for two weeks. By cooling the wine a physical transformation occurs and tartrate crystal, ferric complexes and other colloidal components precipitate and are removed by filtration as well as microorganisms. Filtration can be developed either by diatomaceous sand, by cellulose, or by centrifugation. At the end, a clear wine is obtained.

Figure 5. Cooling equipment for stabilization.

2.5. Bottling, storage and delivery

The bottling operation normally consists in the filling, encapsulation and labelling of the bottles. The wine is bottled in an independent process, sometimes carried out in the same facilities, or sometimes in other different place. The wine is normally bottled in glass bottles of 0,75 litre, although there are also other types of bottling such as plastic bottles of 5 litres, or "bag–in-box" containing 2-3 litres.

In the red wine production with aging, red wine can be aged for some periods before bottling. These periods can vary from few months to some 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 vessels or concrete tanks.

If delivery does not occur just after bottling, the product will require storage. Internal transports are usually performed by forklifts.

3. ENERGY ANALYSIS OF WINERIES

Energy consumption for the production of wine in the European Union is around 1.750 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, the main energy source used is electricity (more than 90%). Fossil sources (mainly diesel or other fuels such as gas or fuel oil) are also used for thermal processes (to heat water for bottling process or for heating) but they represent less than 10% of the total energy consumption, However in some wineries 100% of the energy consumed is electrical.

In wineries, electricity is used for the electrical motors of the machinery (pumps, presses, etc.), lighting, and cooling the product in several processes. It is noteworthy that 45% of the energy is used in the processes of fermentation, mainly by cooling systems in the refrigeration of these processes.

Considering a typical average winery (it is, for red wine without aging) belonging to any of the TESLA countries (Spain, France, Portugal or Italy), the following values could be obtained:

- Industry size considered as reference: 30.000 hectolitres of wine/year
- Average electrical energy consumption for this size: 330.000 kWh/year
- Electrical energy consumption/production: 11 kWh/ hl wine
- Thermal energy consumption/production: 1 kWh/ hl wine
- Power installed (for electric equipments): 800 kW
- Power installed (for thermal equipments): 20 kW for boilers, 50 kW for vehicles
- Electrical energy cost for industry: 0.12 €/kWh
- Thermal energy cost for industry: 0.07 €/kWh
- Energy costs: 95% electricity/5% thermal
- 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)

Previous studies (CO2OP project, Cooperativas Agro-alimentarias 2011) have shown that overall energy balance in this typical winery shows the following average values:

- Distribution of electricity consumption in the different phases: reception 5%, fermentation 45%, pressing 7%, stabilization 8%, bottling and storage 18%, auxiliary activities 10%, lighting 7%.
- Distribution of fuel consumption:
  - 50% for bottling, storage and delivery: for diesel forklifts and internal transport vehicles; for warm water needed to washing bottles and barrels; and for wine pasteurization;
  - 50% for auxiliary activities: heating and sanitary warm water.

Although the average electricity consumption of the typical winery is around 11 kWh/hl, it should be noted that this ratio can be very different from one winery 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 an average value of electricity consumption of about 4 kWh/hl, while small facilities (wine production lower than 25.000 hl/year) showed an average value of electrical consumption of about 16 kWh/hl.

Another factor affecting energy consumption is the quality of the wine: higher quality wines require higher electricity consumption since cooling needs are usually higher.

Besides that, previous studies showed that similar wineries (same size and same wine quality) had different energy consumptions, which means that there is a considerable potential for energy saving in this type of industries.

3.1. 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 motors 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 and crushing also consume electrical energy due to the action of the involved motors, such as auger, conveyors and squeezer.

The next process is the alcoholic fermentation. In this phase, the energy consumed is again electricity for the pumps moving the pulp and must in the tanks and for the cooling equipment that is used to maintain the temperature required by the fermentation process.

In red wines, pressing is carried out after alcoholic fermentation. The energy consumption in this process is again electricity (electric motors, 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 carried out by electric forklifts (typical for inbound transports) or by vehicles with fuel consumption (more typical for outbound transports).
Pasteurization of the wine is not very usual, but can be used as an alternative to stabilization. This process has lower electricity 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 most energy consumers in wineries. Cooling processes can represent nearly 50% of the consumed energy.
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 the facilities.
- General heating or air conditioning for human comfort.
- Offices, with energy consumed by: computers, faxes, printers, etc.
- Shop: with a variable consumption depending on the equipments installed on it.
- Wine quality laboratory: with different processes using different lab equipments as spectrophotometer, hydrometer, etc.

Technologies applied in the processes offer opportunities for energy savings in this sub-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. An appropriate maintenance programs can also contribute to a better management of energy consumption.

TABLE 4. VALUES OF STANDARD PRODUCTION PROCESSES (TIPYCAL TECHNOLOGIES USED) IN AN INDUSTRY PRODUCING 30.000 HECTOLITERS OF WINE/YEAR.

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	Receive bin, auger mechanisms and electric motors	57	0,55	0	0
Destemming and crushing	Mechanical destemmers, rollers and electric motors	64			
Alcoholic fermentation	Cooling systems and electrical motors	276	5	0	0
Pressing	Cooling systems for malolactic fermentation, pumping and electrical motors	76	0,75	0	0
Stabilization	Cooling systems for stabilization, pumping and electrical motors [Pasteurization, pumping and electrical motors]	91 [25]	0,90 [0,10]	0 [116]	0 [1,75]
Bottling, storage and delivery	Electrical motors and forklift	102	1,95	50	0,5
Lighting	Fluorescents	10	0,75	0	0
Auxiliary processes	Air conditioning and boiler for hot water production	124	1,10	20	0,5
TOTAL		800	11	70	1

Source: Cooperativas Agro-alimentarias, 2010

3.2. Energy balance (Sankey diagram)

The energy balance for a representative winery, yielding 30.000 hl of wine/year, is shown in Figure 6 in the form of a Sankey diagram.

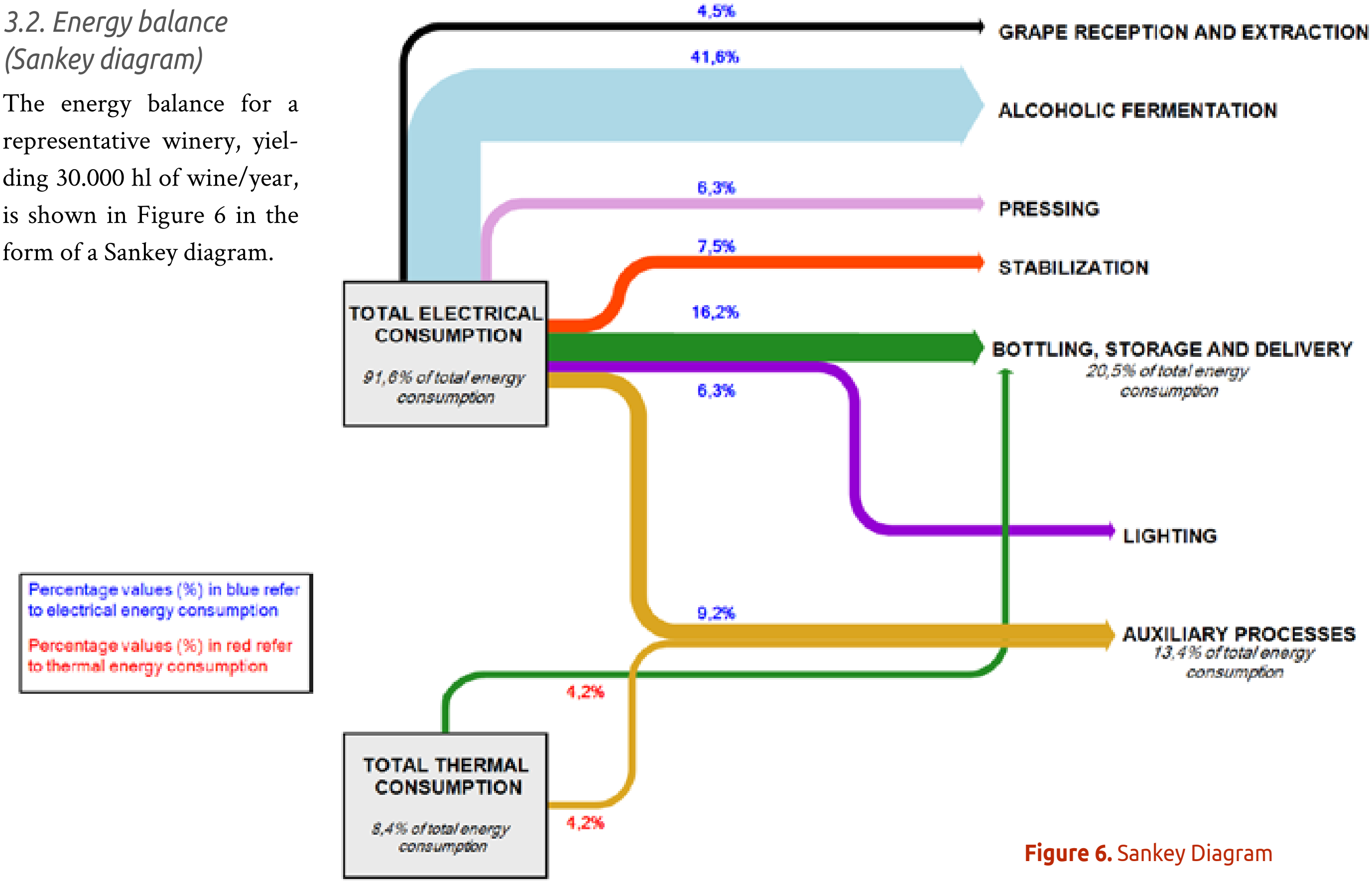

Figure 6. Sankey Diagram

3.3. Energy costs

The European energy context varies according to the country considered. Indeed, the energy cost will be different based on the national energetic policy.

Table 5 shows references to electrical and thermal energy costs in the typical wineries of the four TESLA countries.

TABLE 5. ENERGY COSTS IN THE FOUR TESLA COUNTRIES.

TESLA COUNTRY	Electrical energy cost (€ /MWh)	Thermal energy cost (€/MWh)
Italy	From 140 to 150	From 30 to 40
Spain	From 120 to 130	From 55 to 65
France	From 60 to 110	From 20 to 80
Portugal	From 70 to 90	From 60 to 80

3.4. Sub-sector particularities

This sub-sector has some specific characteristic affecting energy consumption: the first one is seasonality in production. Because of the periods of grape harvest in the four countries studied, energy consumption presents a peak between the months of August and October, coinciding with the campaign season, in which winemaking takes place. The rest of the year the only existing energy consumption corresponds to the area of packaging and storage, and auxiliary activities of the companies such as offices, general heating or air conditioning, etc.

A second particular aspect of the winery sub-sector is the aging of red wines. Red wine can be aged for some periods before bottling, though this can vary from a few days 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. 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.

4. ENERGY SAVING MEASURES

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

4.1. Energy efficiency in cooling systems

There are several ways to improve cooling production systems, apart from the purchase of a new, modern and highly efficient cooling machine.

UNCOUPLING COOLING PRODUCTION AND COOLING DEMAND, BY USING A COOLING STORAGE SYSTEM. This system is based on the use of change phase materials and it is made of spherical nodules in which interior is contained a change phase fluid. These spherical nodules are installed inside a tank in which cooling water has been frozen during a cheaper electricity period. This stored cooling energy is used later, during a peak cooling demand or during a cooling production stop due to maintenance operations. By means of control technologies, this storage system can be optimized jointly with the rest of cooling devices.

Potential savings will depend of the current situation of each industry. However, it is very important to remark that power demand using this technology can be reduced up to 70%, and also electrical power contracted can be changed by a cheaper one, so economic savings can be worthy of consideration.

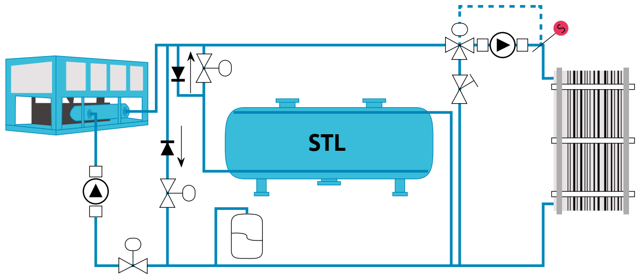

Figure 7. Cooling storage system scheme installed in parallel with the cooling system. (CIAT)

EFFICIENT COOLING MACHINES COMPONENTS. The electrical companies have different machines according to power requirements with increasing energy efficiency. These machines frequently use R134A as cooling fluid.

Figure 8. Cooling machine.

They are equipped with a high efficiency rotary screw compressor (instead of a piston compressor) and a new pipe evaporators system where condensers are manufactured in alloy aluminium with high thermal properties. Also, speed drives are installed in fans and compressor, allowing the regulation of the power consumption from 25% to 100% of its full load. Moreover these machines are equipped with soft starters which reduce starting peak consumptions.

4.2. Efficient wine storage in wood barrels

Red wine can be aged for some periods before bottling. This aging usually takes place in wood barrels (or other tanks providing similar characteristics to the wine) and energy demand in this process is due to storage temperature and humidity control. Thus, two ways of improving energy efficiency in this process have been identified, and are described here below.

GEOTHERMAL ENERGY TO IMPROVE COOLING PRODUCTION. Exchange energy with the earth is very efficient. The ground exchanges energy in a more efficient way than the exterior air. It is due to ground's thermal level which is more suitable and constant along the year.

This geothermal technology will allow the wineries to adjust and optimize cooling and heating devices temperature to reach a better performance of them. Also it will be possible to generate simultaneously cool and heat water to supply and to dehumidify air in order to avoid overcooling of wine cellar conditions.

Energy savings are obtained due to the highest thermal conditions of using geothermal energy, and also due to the installation of several free cooling systems for treating air. These systems use exterior low temperature and recover heat from the interior extracted air. Moreover, variable flow fans are installed in all processes in order to adjust operational conditions for both exterior and interior ambient, thus reducing energy consumption.

Besides that, conventional cooling machines may have a value of EER (Energy Efficiency Ratio) close to 1,5, while geothermal energy can increase the EER value up to 4.

AERO THERMAL ENERGY TO IMPROVE STORAGE CONDITIONS. There are several equipments treating air to control wine cellar conditions which recover waste heat coming from condensation processes related to humidity control. These equipments allow winemaker to control temperature and humidity in wine cellars, according to the wine characteristics.

These air treatment equipments use cooling machines and heat pumps, and have different stages to treat ambient conditions. The equipments must be well sealed, and have low thermal transmittance and low thermal bridge in order to reduce losses.

Variable flow fans are also installed in all processes in order to adjust operational conditions for both exterior and interior ambient, thus increasing performance.

Although energy saving will depend on previous situation and operational conditions, new air treatment equipments have a performance 20% higher than average of these equipments.

4.3. Change presses by decanters

In wine production one of the most important processes is to press the grape to obtain all liquid from them. Normally this process is done by pneumatic or mechanical presses, but it can be done by another way: a new innovative technology that separates instantly and continuously must from grape. Centrifugal forces are better than mechanical ones to get that solid parts float out of must, so it is possible to reduce the number of later treatments. New devices using centrifugal forces are available for production capacity of 50 ton/hour and can be used for almost all types of grapes. Moreover, decanters allow technicians to reduce the number of wine movements from one tank to another, thus reducing pumps energy consumption.

There is no available information about energy reduction due to this improvement since it is an innovative solution and affects to several processes such as pumping and pressing. It is a very recommendable measure for new wineries or in case the installation of a new press is being considered.

4.4. Efficient motors

The electricity consumption of motor systems is influenced by many factors. In order to benefit from the available savings potential, the users should aim to optimise the whole system that the motor sub-system is part of, before considering the motor section. The following points will be taken into account to improve motor systems efficiency.

HIGHLY EFFICIENT MOTORS. Energy efficiency classification of electric motors is shown by IEC 60034:2007 legislation. According to this classification there are four possible levels:

- *IE1 : standard efficiency*
- *IE2 : high efficiency*
- *IE3 : premium efficiency*
- *IE4 : super premium efficiency (currently it is not available in the market)*

The European directive EuP (Energy using Product), which concerns the motors defined by IEC 60034-30 legislation, requires to market high performance motors: IE2 from 16th June 2011; IE3 from 1st January 2015 for motors from 7,5 to 375 kW; and IE3 from 1st January 2017 for motors from 0,75 to 375 kW.

point. Under 40% full load, an electrical motor does not work at optimized conditions and the efficiency falls very quickly. However, motors in the larger size ranges can operate with reasonably high efficiencies at loads down to 30% of rated load. The efficiency of an electric motor according to the load is shown by the Figure 10.

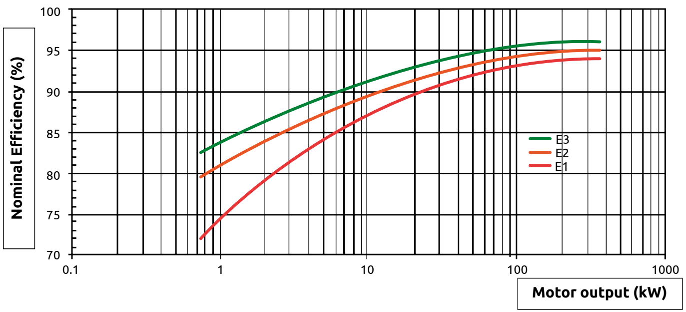

Figure 9. Comparison of the energy efficiency curves for the different motor levels (CIRCE, 2013).

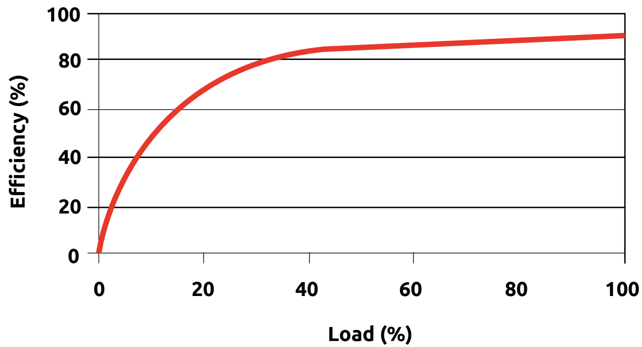

Figure 10. Efficiency of an electric motor according to the load (BREF, 2009).

PROPER MOTOR SIZING. The maximum efficiency is obtained for the motors working between 60 to 100% full load. The induction motor efficiency typically peaks near 75% full load and is relatively flat down to the 50% load

MOTOR CONTROLS. The aim is to limit to the minimum necessary the motor idling (no load run mode) for example by a presence sensor, a clock, a controlling process, etc. Thus, the way contributing to energy efficiency is switching off the motors when they are not needed, for example by a switch or a contactor to connect and disconnect the motor from the mains.

The adjustment of the motor speed through the use of variable speed drives (VSDs) can lead to significant energy savings associated to better process control, less wear in the mechanical equipment. When loads vary, VSDs can reduce electrical energy consumption typically from -4 to 50 %. The number "-4" is in the case of the addition of VSD in the electrical system without changing the speed.

Transmission equipment including shafts, belts, chains, and gears should be properly installed and maintained. The transmission system from the motor to the load is a source of losses. These losses can vary significantly, from 0 to 45%. Direct coupling has to be the best possible option (where technically feasible).

4.5. Compressed air system (CAS)

Almost every industry has compressed air systems for many different aims: press machines, cooling systems, compressors, conveyors, etc. This compressed air needed can be produced by the machine itself, or by one (or more) compressed air equipments supplying the overall industry necessities. Energy efficiency in compressed air systems can be controlled by the following measures.

OPTIMIZING SYSTEM DESIGN. Many existing CASs lack an updated overall design. The implementation of additional compressors and various applications in several stages along the installation lifetime frequently results in a suboptimal performance of a CAS. One fundamental parameter in a CAS is the pressure value which must satisfy 95% of all needs, using a small pressure-increasing device for the rest. Another fundamental design issue for a compressed air system is dimensioning the pipework and positioning the compressors. A properly designed system should have a pressure loss of less than 10% of the compressor's discharge pressure to the point of use.

VARIABLE SPEED DRIVE (VSD) AND STORAGE VOLUME. Every time the air requirements of the process fluctuate (over times of the day and days of the week) the VSD and the storage volume will help reducing energy demanded by the compressed air system. The savings can be up to 30%, although the average gain in a CAS, where one compressor with a variable speed drive is added, is about 15%. In the other hand, a storage volume helps to reduce the pressure demand fluctuations and to fill short-timing peak demands. Variable speed drives on compressors, have also other benefits: stable pressure, higher power factor which keeps reactive power low, and smooth start-up at low speeds extending the operating lifetime of the compressor.

REDUCING COMPRESSED AIR SYSTEM LEAKS. The reduction of compressed air system (CAS) leaks often has by far the highest potential gain on energy. Leakage is directly proportional to the system pressure (gauge). Leakages are present in every CAS and they are effective 24 hours a day, not only during production. The percentage of compressor capacity lost to leakage could be less than 10% in a well maintained large system, and up more to 25% in a poorly maintained 'historically grown' CAS. Preventive maintenance programmes for compressed air systems should therefore include leak prevention measures and periodic leak tests. An additional way to reduce leakage is to lower the operating pressure of the system: with lower differential pressure across a leak, the leakage flow rate is reduced.

FEEDING THE COMPRESSOR(S) WITH COOL OUTSIDE AIR. For thermodynamic reasons, the compression of warm air requires more energy than the compression of cool air. This energy can be saved simply by feeding the compressed air station with outside air. A duct can be installed connecting the outside and the intake of the compressor, or to the entire compressed air station. The outside intake should be placed on the north side or at least in the shade for most of the time.

OPTIMIZING THE PRESSURE LEVEL. The lower the pressure level of the compressed air generated, the more cost effective the production. However, it is necessary to ensure that all active consumers are supplied with sufficient compressed air at all times. The cheapest way to adjust the pressure range of a compressor is to use mechanical pressure switches. Pressure can also be readjusted by means of a frequency converter compressor functioning as a peak load compressor and adapting its speed drives to specific compressed air needs.

4.6. Variable speed drives

Variable speed drives can be installed in every process working at variable load, for example: centrifugal pumps, fans, grinds, hoppers, conveyors, compressors for compressed air systems or for cooling systems, etc. Using it, the energy consumption of motors is lower since consumption is adapted to real process needs.

Variable speed drives, also called adjustable speed drives, control the rotation speed of motors located in pumps, fans, conveyor belts or other machines. These drives operate converting constant electric grid input parameters (volt, frequency) in variable values. This change of frequency causes a change in the motor speed and also in the torque. It means that motor speed can be regulated according to external parameters such as temperature, flow or charge level in conveyors or hoppers. Speed control can be very important in the energy efficiency of processes.

Energy savings depends on motor power, load, motor operation profile, and yearly operation hours. A motor working with or without speed drive can vary its energy consumption up to 50%.

Figure 11. Variable speed drive.

4.7. Insulation

In several TESLA sub-sectors, it is necessary to transfer heat either for heating or for cooling processes. It takes place, for example, in cooling fermentation of wineries in which several pipes transport a cold fluid from cooling machines to the fermentation tanks; or in boilers where hot water or steam goes from boiler to the place in which it is used. In this kind of facilities, the maintenance conditions of insulating materials are very important for avoiding thermal losses and condensation problems. Thus, insulation materials must follow several recommendations: to avoid rust problems, to protect from UVA rays, to be dry (pay attention to leaks that affect insulating capacity of insulating materials), to be flexible and easy-to-install, and to have low thermal conductivity (0,04 W/m°C or lower). Common range of working temperatures for insulating materials is between -50ºC and 110ºC.

VALVES INSULATION. Besides that, the fittings, valves and other connections are usually not well insulated. Reusable and removable insulating pads are available for these surfaces. Considering an operating temperature of 150°C, room temperature 20°C, and valve size 150mm, potential energy savings for installing removable insulated valve covers are up to 970W (BREF, 2009).
Moreover, as a general rule, any surface that reaches temperatures greater than 50°C where there is a risk of human contact, should be insulated to protect personnel.

PIPES INSULATION. Potential savings achieved will depend on: pipe diameter and length (or insulating surface size), outside and inside temperature, insulating material transmittance, and insulating material thickness. Following, a simple example is presented: two pipes which transport a hot fluid, one with insulation material and the other without insulation material. In both cases, the fluid temperature is 60°C, air temperature is 15°C, pipe length 350m, pipe diameter 150 mm, and the insulation material is polyurethane with 31 mm thickness and thermal conductivity of 0,04 W/m°C. Comparison between heat losses in these two pipes shows that energy losses of the pipe with insulating material will be reduced in 85%, which means that a huge amount of energy can be saved simply by using thermal insulation in pipes.

Figure 12. Pipe insulation in good conditions.

4.8. Heating water or air

Hot water is needed in all industries for many different uses: from hygienic and sanitary water till preheating water since boilers or steam production. Several systems can be used for heating water. In this handbook two of them are mentioned, since they do not imply an increase in energy consumption.

SOLAR THERMAL FOR HEATING WATER. High performance solar collectors are equipped with a special glass with an energy transfer higher than 92%. The absorber is manufactured in copper with a selective treatment (TINOX) and they have a thermal resistance of 250 $m^2 {}^oC/W$, optical performance of 75% and transmittance coefficient of 2,9 $W/m^2 {}^oC$.

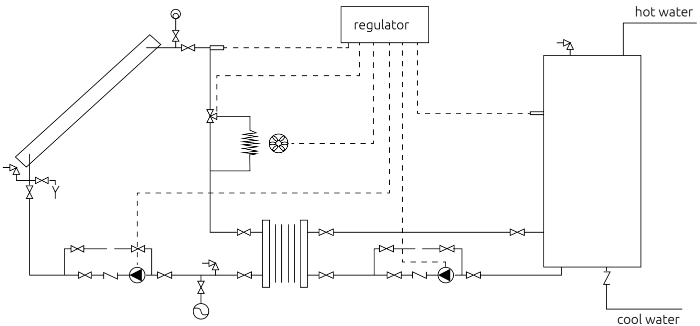

Figure 13. IMS solar thermal system scheme (CPC solar).

Potential saving achieved will depend on desirable solar energy cover rate. Common savings are around 50 - 70% depending on weather conditions and energy demand. It means that energy consumption in boiler can be reduced, and so, less fossil fuel will be consumed and less CO_2 will be emitted.

HEAT RECOVERY FROM AIR COMPRESSORS. Most of the electrical energy used by an industrial air compressor is converted into heat and has to be conducted outwards. In many cases, a properly designed heat recovery unit can recover a high percentage of this available thermal energy and put to useful work heating either air or water when there is a demand. Two different recovery systems are available:

- Heating air: the heat recovered can be used for space heating, for oil burners or any other application requiring warm air. Ambient air is passed through the compressor where it gains the heat resulting from the compressed air process. The only system modifications needed are the addition of ducting and potentially another fan to handle the duct loading and to eliminate any back-pressure on the compressor cooling fan. These heat recovery systems can be modulated with a simple thermostatically-controlled hinged vent.

- Heating water: it is also possible to use a heat exchanger to extract waste heat from the lubricant coolers found in packaged air-cooled and water-cooled compressors to produce hot water. Depending on design, heat exchangers can produce non-potable or potable water. When hot water is not required, the lubricant is routed to the standard lubricant cooler. Hot water can be used in boiler systems or any other application where hot water is required.

Heat recovery systems are available for most compressors on the market as optional equipment, either integrated in the compressor package or as an external solution. A properly designed heat recovery unit can recover approximately 50 - 90 % of this available thermal energy.

HEAT RECOVERY BY ECONOMIZERS OR CONDENSER. Install a heat recovery system in boilers allows recovering heat from exhaust gases. In boilers too many heat is lost by fumes so by recovering part of this heat, fuel energy consumption will be reduced. A heat recovering is only a heat exchanger installed in fume smokestack that transfers heat from fumes to the boiler's water or to other thermal processes.

The installation of economizer after the boiler allows reaching an energy saving up to around 5% (fumes temperature decrease cannot exceed a limit because it would entail corrosion in heat exchanger and in fume smokestack).
Condenser allows recovering energy that is contained in combustion fumes by means of condensate the water steam of them. The energy saving depends on combustion fumes temperature decrease. In real cases, the installation of condenser after the boiler allows reaching an energy saving up to 15%.

4.9. Lighting

In TESLA industrial sub-sectors is necessary a large amount of lighting inside buildings. Currently there are installed a large variety of lamps, mainly gas discharge lamps (fluorescents, high pressure sodium or mercury steam) or halogen technologies. These devices are very inefficient and can be easily replaced by new ones using new LED technologies. This LED technology has longer lifetime (more than 50.000 hours), less maintenance operations, colour index of 80%, colour temperature of 4.000 K, and energy saving up to 75% (compared with gas discharge lamps or halogens). Lighting flow is 10.000 lm (for 110 W) and 20.000 lm (for 210 W).

Besides that, light replacement is very easy due to LEDs design. The following table shows energy savings considering the replacement of fluorescent lamps by LEDs.

TABLE 6. ENERGY SAVINGS ACHIEVED.		
CURRENT SITUATION	**ENERGY EFFICIENCY SITUATION**	**POWER REDUCTION**
2x18W fluorescent tube (total installed power 42W considering an electromagnetic ballast)	LED18S (19W)	54%
2x58W fluorescent tube (total installed power 136W considering an electromagnetic ballast)	LED60S (57W)	58%
250W mercury steam lamp (total installed power 268 W considering auxiliary devices)	BY120P (110 W)	58%
400W mercury steam lamp (total installed power 428 W considering auxiliary devices)	BY121P (210 W)	51%

Source: Philips.

4.10. Capacitor batteries to decrease reactive energy

Many different devices, such as motors or discharge lamps, need an electromagnetic field to work. Since not all motors work at nominal charge, it causes a reactive energy consumption that must be paid within the electricity bill. This reactive energy consumption can be avoided by using capacitor batteries.
Capacitor batteries are available for different power, from 7,5 kVAr to 1.120 kVAr, and are installed next to power transformer of the facilities. Power factor compensation is usually done for the overall installation's machines.
This is more an economic saving measure than an energy saving measure, although this equipment has also benefits for the electricity grid due to the increase of energy transmission capacity obtained for the electrical grid.

4.11. Management tools

Industries have a lot of electrical devices to develop their processes. Consequently, a lot of electrical devices are distributed along the facilities, and having them in right operation conditions and with the highest efficiency value is very complicated. To control and monitor all processes from the energy point of view allows taking the best decisions to improve energy efficiency.

An energy management software is composed by measuring devices, a communication grid and a software program that allows to manage, monitor and use information to improve energy consumptions in the facilities.

These tools are recommended for the implementation of an energy management quality system in an industry according to EN 16.001/ISO 50.001 standards requirements.

Figure 14. Control panel.

4.12. High efficiency in power transformers

All industries' facilities have a power transformer to convert electricity that comes from the grid. However in old installations transformers are very old, use oil and their efficiency is not as high as possible. The worst the transformer current situation is, the higher the energy consumption will be. This measure will be specially recommended in those industries having high yearly operation hours, such as animal feed factories or fruits and vegetables processing plants.

Dry transformers reduce transformer losses up to 70% and are safe and free of maintenance, with an excellent capacity to support overload and an excellent resistance to short circuit.

5. 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 1.750 million kWh per year, so the wineries sub-sector is a significant energy consumer. A winery producing 30.000 hectolitres of wine per 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 energy consumption among facilities of the same size. It means that there is a considerable potential of energy saving in this type of industries.

From the quantitative point of view, cooling processes (in alcoholic and malolactic fermentation, stabilization, and others) are clearly the most energy consumers in wineries. These processes can represent nearly 50% of the consumed energy. Thus, the improvement of the involved technologies is the key factor for higher energy efficiency of the sub-sector:

- Using cooling machines with energy efficiency ratio close to 3 or higher.
- Using cooling storage systems, or in some processes, specific heat exchangers.
- Especially in new facilities, installing geothermal energy in connection with heat pumps or cooling machines.

These measures must be carefully selected taking into account the seasonality of the sector, which can become a problem for the payback of large scale investments. The number of hours of functioning per year of each type of equipment is an important factor for the feasibility of a substitution of technologies, showing many of them excellent possibilities. The design of new facilities offers interesting opportunities, such as the use of geothermal energy.

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Co-funded by the Intelligent Energy Europe
Programme of the European Union