tesla

Transfering
Energy Save
Laid on Agroindustry

Efficient Fruit and Vegetables Processing Plants

IEE/12/758/SI2.644752

HANDBOOK

__Handbook coordinator:__ ENEA (Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile)

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

Update version:
February 2014

Authors:
Arianna Latini, Corinna Viola, Matteo Scoccianti and Carlo Alberto Campiotti.
ENEA, Italian National Agency for New Technologies, Energy and Sustainable Economic Development.
UTEE-AGR, Technical Unit of Energy Efficiency in Agriculture.

Co-authors:
The following document has been executed jointly with CIRCE, UÉvora, Tecaliman and UPM, 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.

tesla

Transfering
Energy Save
Laid on Agroindustry

0. INDEX

1. Introduction

1.1. Analysis of the fruit and vegetables sub-sector 4
1.1.1. Production 5
1.2. Socioeconomic point of view 6
1.2.1. Turnover 8
1.2.2. Total number of fruit and vegetables processing plants and number of cooperatives 8
1.2.3. Number of employers 10

2. Processes description

2.1. Reception 12
2.2. Cleaning and drying 13
2.3. Sorting and calibration 13
2.4. Packaging 15
2.5. Cooling conservation 15

3. Energy analysis of fruit and vegetables processing plants

3.1. Electrical consumption 17
3.2. Thermal consumption 20
3.3. Energy balance (Sankey's diagram) 20
3.4. Energy costs 22

4. Energy saving measures

4.1. Energy efficiency in cooling systems 23
4.2. Insulation improvement in cooling chambers 24
4.3. Efficient motors 25
4.4. Compressed air system (CAS) 27
4.5. Variable speed drives 28
4.6. Insulation 29
4.7. Heating water or air 30
4.8. Capacitor batteries to decrease reactive energy 32
4.9. Lighting 32
4.10. High efficiency in power transformers 33
4.11. Management tools 33

5. Conclusions 34

6. References and sources 35

1. INTRODUCTION

The main objective of the TESLA project is to extend the Best Available Techniques (BATs) for the evaluation of the energy situation and the adoption of improving measures amongst the European Small & Medium Enterprises (SMEs) of the agro-food sector.

The whole agro-food system embraces three closely related components: agriculture, agro-food industry and distribution (retail trade). More in particular, the TESLA project focuses on the central component, which is characterized by transformation companies, that use agricultural products (primary production) to supply the food industry which produces food and beverages (transformation industry).

This handbook is specifically dedicated to the sub-sector of the fruit and vegetables processing plants, represented by the SMEs dealing with the fresh primary product, from the product reception following the harvesting up to the storage, and before launch it to the market.

1.1. Analysis of the fruit and vegetables sub-sector

Thus, this handbook of the TESLA project is fully referred to fresh products (1st gamma). Notwithstanding, processes related to sanitized fresh products of the 4th gamma are also briefly discussed. The 2nd and the 3rd gammas are only mentioned to point out some interesting issues dealing with the energy efficiency objective.

- **1st gamma:** Fruit and vegetables for direct market selling.
- **2nd gamma:** Fruit and vegetables preserved by being sterilized through thermal processes, dried or processed with the use of a mix of techniques.
- **3rd gamma:** Frozen products.
- **4th gamma:** Hygienically treated and ready-to-eat fresh products, to be maintained for a short time, packaged in a protective atmosphere.
- **5th gamma:** Softly cooked and ready-to-eat products, to be maintained for some weeks in controlled conditions.

As general scheme, after harvesting, the fruit and vegetables production has to be transported as soon as possible to the storage areas. At the reception, there is a soft control and evaluation of the sanitary state, which is usually done in internal labs by specific equipment (e.g.: refractometric extract for tomatoes, fruits, etc.; specific weight for potatoes, peas, etc.; consistency; boiling tests and other analyses). After that, the primary production is washed with water containing detergents and other sanitizers in order to remove field soil, surface micro-organisms, fungicides, insecticides and other pesticides. Then, the products are sorted to remove non-standard fruit and vegetables and select for quality grading (variety, dimensions, maturity, etc.). Next, fresh products can be packaged in boxes and/or with films, for being then sold in bulks or in smaller packages for families. After packing, the most important step before the delivering to the fresh consumption or to the market is the product storage.

1.1.1. Production

Across the EU there are wide regional variations in the types of planted fruit and vegetables. Such production in the EU is characterized by rapid and significant fluctuations in supply and demand for products which are, on the whole, highly perishable. EU policy is aimed at encouraging growers to improve both their product quality and the marketing as well. Around 15% of the value of the EU's agricultural primary production derives from the fruit and vegetables sub-sector, which then provides a range of remarkable fresh and processed products as quality and variety (European Commission, Directorate-General for Agriculture).

ITALY In 2012, Italian production of fresh fruits and vegetables reached more than 19 Mtons, with an average 11% reduction with respect to 2011 (ISTAT). According to CSO, in 2012, the total harvesting included 6,3 Mtons of fresh fruits (plus 3,6 Mtons of citrus fruits), 7,5 Mtons of fresh vegetables (apart from 4,7 Mtons of tomato for industry, not included in the total 19 Mtons), 973.000 tons of salads (lettuce, endive and radish), 312.000 tons of cabbages (cabbages, Savoy cabbages, brussels sprouts and others), and so on.

SPAIN Data from the Ministerio de Agricultura, Alimentación y Medio Ambiente (MAGRAMA) report that, in 2013, Spanish fruit and vegetables production reached 18 Mtons, of which approximately two parts were for export and the remaining part is for the internal consumption. More than 800.000 hectares were dedicated to fresh products (151.000 for vegetables, 56.000 for potatoes, 312.000 for citrus fruits and 280.000 for fruits (apart from citruses)).

FRANCE With its nearly 530.000 hectares dedicated to fruit and vegetables (including potatoes), France is the Europe's 3rd leading producer of fruit and vegetables, with 5.4 Mtons of fresh vegetables and 3 Mtons of fresh fruits produced every year (Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, 2013). Moreover, it i's the 1st European manufacturer of canned and the 2nd of frozen vegetables (FranceAgriMer).

PORTUGAL In Portugal, the fruit and vegetables production has increased in the last years, occupying an area of 33.370 ha (+8,5% in comparison with 2011). Fresh tomatoes had the higher production value with 96 Mtons, followed by carrots with 76 Mtons and cabbages with 75 Mtons. Greenhouse production represents the 16,9% of the total vegetable production (INE, 2013).

1.2. Socioeconomic point of view

Fruit and vegetables processing plants represent an important sub-sector of the "food & drink" industry – the leading manufacturing sector in Europe – in terms of economic turnover, value added, employment and number of companies (FOODDRINKEUROPE European Food and Drink Industry 2012 – Data & Trends, downloadable at www.federalimentare.it/m_banche_dati.asp).

In 2011, the economic turnover of the fruit and vegetables sub-sector was around 61 billion € (the 6% of the total "food & drink" industry turnover, amounting up to 1.017 billion €) and employed nearly 255.000 people (the 6% of the overall 4,25 M people involved in all sectors of the "food & drink" industry).

Approximately 11.320 of the 287.000 food companies registered in Europe in 2010 are fruit and vegetables processing plants and over the 99% of them are small and medium enterprises (SMEs). These SMEs generate almost half of the "food and drink" industry's turnover and employ over the 61% of the workforce (Sources: Eurostat, UN Comtrade, OECD).

TABLE 1. SOCIOECONOMIC CHARACTERISTICS OF THE FRUIT AND VEGETABLES PROCESSING PLANTS SUB-SECTOR IN THE FOUR TESLA COUNTRIES.				
FRUIT AND VEGETABLES PROCESSING PLANTS	ITALY	SPAIN	FRANCE	PORTUGAL
Production (tons/year)	19.000.000	18.000.000	8.400.000	807.938
Total number of fruit and vegetables processing plants	1.856	3.407	1.802	247
Number of cooperatives	1.273	1.034	300	60
Turnover (M€)	7.800	6.300	7.583	655
Number of employers	28.658	53.152	35.000	3.818

Sources: Osservatorio sulla Cooperazione Agricola Italiana 2011/Prometeia 2011 for Italy; Feria Internacional del Sector de Frutas y Hortalizas 2013/Observatorio Socioeconómico del Cooperativismo Español 2013 (datos 2012) (Cooperativas Agro-alimentarias)/FIAB 2008/MARM 2009 for Spain; Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt 2013/CoopdeFrance 2009 for France; GPP 2013/Confagri 2013 for Portugal.

Recently, in Europe, an increase in the exports (11%) as well in the imports (14%) has been registered for fruit and vegetables products (Export data: from 3.919 M€ in 2010 to 4.363 in 2011. Import data: from 6.655 M€ in 2010 to 7.565 in 2011. Source: Eurostat database COMEXT).

Table 1. Illustrates some socioeconomic information for the four European countries involved in the TESLA project (Italy, Spain, France, and Portugal). Each characteristic will be then discussed and analyzed relatively to the fruit and vegetables processing plants sub-sector of each participating country.

1.2.1. Turnover

ITALY Italian SMEs of the agro-food sector provide a total turnover of 35.052 M€. The 22% of the total turnover, corresponding to 7.800 M€, is due to companies operating in the fruit and vegetables sub-sector.

SPAIN According to FIAB data, in 2008, the agro-food sector presented an absolute turnover of 7.438 M€ in vegetables, 7.209 M€ in fruits (including citrus fruits), and 551 M€ in potatoes. The value of fresh fruit and vegetables, processed and commercialized by agro-industry companies, was around 6.300 M€/year.

FRANCE The turnover generated by cooperatives was 4.500 M€ (CoopdeFrance, 2009) and the turnover generated by all enterprises in 2010 was 7.583 M€.

PORTUGAL The agro-industrial sector turnover showed an annual average increase of 3,7% since 2000. According with GPP (2013) in 2012 it reached 655 M€.

1.2.2. Total number of fruit and vegetables processing plants and number of cooperatives.

This sub-sector is characterized by a wide diffusion of cooperative societies. Most of them are small companies, with just a little number of large companies.

ITALY The whole national territory is characterized by an extensive presence of cooperative enterprises (1.273 in 2011). However, there exists an economic difference between the North and the South of Italy, even if we have to consider that the food industry is economically the most important type of industry in the South.
The 80% of the turnover is generated by the 42% of the cooperatives in the North. In this area of the country, the average cooperative has a value of 11,4 M€, while in the Center 3 M€ and in the South 1,7 M€ (Source: Osservatorio della Cooperazione Agricola Italiana, 2011). The majority of agro-cooperatives are small and the average economic value of a typical fruit and vegetables processing plant is 6,1 M€.

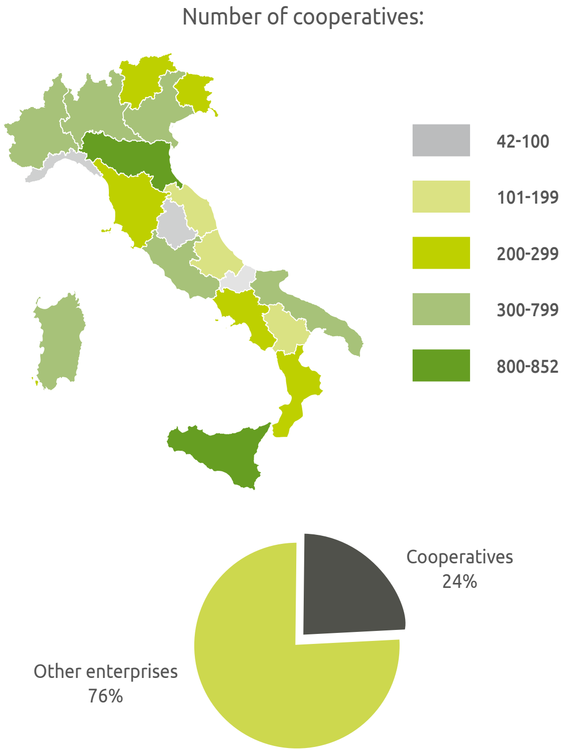

Figure 1. Number of fruit and vegetables cooperatives in Italy. The 24% of the total turnover in the agro-food sector is generated by cooperatives (Osservatorio della Cooperazione Agricola Italiana , 2011).

SPAIN According to the Fichero Coordinado de Industrias Agroalimentarias (FCIA), there were 4.900 enterprises involved in the fruit and vegetables preparation and processing, in 2009. The 85% of them was dedicated to fresh products, the 12% to preserves factories and only the 3% to juice producers.

Figure 2. Territorial distribution of fresh fruit and vegetables cooperatives in Spain (OSCAE, Observatorio Socioeconómico del Cooperativismo Agrario Español, 2009).

FRANCE In 2009, a total of 1.082 fruit and vegetables enterprises was registered and 300 of them were cooperatives. (data from CoopdeFrance and FranceAgriMer).

PORTUGAL The industries involved in the fresh fruits and vegetables sub-sector are around 247 (data from the Office of Planning and Policies, GPP, 2013), and approximately 60 of them are cooperatives (Confagri).

1.2.3. Number of employers

ITALY A typical cooperative with an economic turnover of 6,1 M€ gives occupation, on average, to 22,5 employers.

SPAIN Occupation in the fruit and vegetables sub-sector is half of the occupation generated by the whole agro-food sector in Spain.

FRANCE In 2009, the number of permanent employees in this sub-sector was 10.000, and the number of seasonal employees was 27.000 people (data from CoopdeFrance).

PORTUGAL In 2011, the number of employers in the fruit and vegetables sub-sector was estimated 3.818 (GPP, 2013).

Nowadays, the global food market is fragmenting into specific consumer segments, and the trend is towards the growth of supermarket retailing with consumers more and more attracted by food products which respect their lifestyle as well as their needs of good health and well-being. Whilst in the past most of the agro-food products was consumed by the family and commercialized by local markets, today the food products are provided by the supermarket chains, with the agro-food industry transformed from "supply push" to "demand pull". Despite that, fresh fruit and vegetables are again gaining a key value for human health and wellness.

However, this transformation has, on one hand, increased the availability of food products but, on the other hand, it has raised concerns on the implications of the growing demand of energy used by the food industry systems in OECD countries. Nowadays, both the agro-food supply chains and the food industry, need to look for solutions to face some of their major challenges: i) extreme fragmentation on the supply side; ii) serious unbalances in the distribution of value along the supply chain; iii) scarce propensity to innovate in technology; and iv) significant logistic critical points. Thus, within an increasingly globalized environment, EU food

industry needs to improve energy efficiency and energy use and, at the same time, to implement best practices in supply chain management focusing on the new needs of consumers and on the development of environmental sustainable production and processing.
This handbook inspects mainly the technical aspects associated with the energy consumption of the processing plants industry of fresh fruits and vegetables, seeking to identify the energy budget of each of the components in the fruits and vegetables manufacturing and processing.

2. PROCESSES DESCRIPTION

After harvesting, once raw products are inside the plant cooperative, they are subjected to specific processes before landing on the market. In all cases, the first phase includes processes of acceptance, reception and unloading cargo. For fresh products (1st gamma), a preliminary storage is mostly always required and, depending on the specific cooperative, treatments of cleaning, sorting, and calibration can also be performed. Other particular treatments related to fresh products can include sometimes washing, aseptic filling, and packaging in protective atmosphere. The disinfection of industrial plants and the use of equipment for refrigeration are other processes that often need to be considered. All these treatments also characterize the food processing chain that regards the 4th gamma products.

Figure 3. Unloading of trucks by a forklift.

The breakdown of the processes (like in the audits), performed in typical fruits and vegetables processing cooperatives, and the approximate duration of each process, are listed below and successively described:

- *Reception (~ 2 h)*
- *Cleaning and drying (~ 2 h)*
- *Sorting and calibration (~ 2 h)*
- *Packaging (~ 2 h)*
- *Cooling conservation (~ 1 day)*

2.1. Reception

Raw material is delivered at the receiving dock from a truck or other vehicle. An initial inspection of the fruit and vegetables is performed: traceability codes, batch size, product quality, vehicle condition, etc. All this information is usually registered in the cooperative database. Electric trucks and forklifts carry out loading and unloading for a pre-cooling process and/or a processing line.

Fruit and vegetables farmers must cool many of their products quickly; removal of field heat is important to maintaining produce quality and shelf life. The pre-storage of the products can be performed in freezers, pre-coolers, and/or a specific area conditioned for this purpose, where the products have to pass before going to the processing lines for handling and packaging.

Figure 4. Vertical air-flow pre-coolers reduce pre-cooling time, which increases fruit and vegetables shelf life and quality, and save energy costs.

Palletizing and/or dumping differ depending on type of dump used: i.e., if the product is collected in plastic bins, the dumper will be adapted to these plastic boxes. More and more companies are using machinery for palletizing.

Figure 5. Machine for palletizing.

2.2. Cleaning and drying

Washing and drying steps are not fixed in the process of fruit and vegetables handling and packaging, and depend on the morphology and other agro-food product characteristics.

Figure 6. Water dumping of apples (on the left) and a tunnel used for drying (on the right).

2.3. Sorting and calibration

The sorting process is common to many products in the sub-sector of fresh fruit and vegetables. Sorting can be made for color, size, or other physical properties. Companies currently market a large number of products: sorting machines must cover winter and summer campaigns, with equipment capable of classifying the widest range of possible products. Many other treatments can be used, like degreening, drenching, waxing, etc.

Figure 7. Equipment for washing and grading

DEGREENING. The main causes of greening are climatic conditions before harvesting. For example, citrus often reaches commercial maturity with traces of green colour on the epidermis (flavedo). Although not different from fruits with colour, consumers sense that they are not ripe enough and have not reached their full flavour. Degreening consists of chlorophyll degradation to allow the expression of natural pigments masked by the green colour. In proper built chambers, citrus fruits are exposed from 24 to 72 hours (depending on degree of greening) to an atmosphere containing ethylene (5-10 ppm) under controlled ventilation and high relative humidity (90-95%). Conditions for degreening are specific to the production area.

DRENCHING. Different treatments are performed to prevent and control pests and diseases at postharvest level. Among them, the drenching in chemical solutions is very useful in inhibiting scalds or other different disorders during the storage.

WAXING. Some fruits such as apples, cucumbers, citrus, peaches, nectarines and others, are waxed for the following reasons: to reduce dehydration, improve their postharvest life by replacing the natural waxes removed by washing, and to seal small wounds produced during handling. Waxes are also used as carriers of some fungicides or just to increase shine and improve appearance. Different types and formulae of waxes are available. These can be applied as sprays or foams, or by immersion and dripping or in other ways. Uniform distribution is important. Soft brushes, rollers or other methods are used to ensure that application on the surface of fruit is thorough and texture is smooth. Heavy application can block fruit gas exchange and produce tissue asphyxia, and causing internal darkening and development of off-flavors and off-odors. It is very important that waxes are approved for human consumption.

2.4. Packaging

Finally, specific machinery is used for package and delivery. A suitable quality control, depending on the type of product, is performed in this last phase.

Figure 8. Products grading and package preparation area.

Figure 9. Equipment for packaging.

2.5. Cooling conservation

Fruit and vegetables farmers must cool many of their products quickly. Removal of field heat is important to maintaining produce quality and shelf life. The cooling storage is the most energy consuming process in these cooperatives.

3. ENERGY ANALYSIS OF FRUIT AND VEGETABLES PROCESSING PLANTS

In general, the food industry uses energy mostly for food processing and preservation, packaging, and storage. Safe and convenient packaging is extremely important in food manufacturing and it is also energy intensive; in fact, the more recent packaging procedures require aseptic techniques and electro-chemical changes. Proper storage is also energy-dependent and, in particular for summer fruit and vegetables, it is crucial due to the high outside temperatures and the accelerated metabolism of the harvested plants. Freezing and drying represent the key methods for food storage, but in this handbook we do not pay a lot of attention to these processes that are more commonly used in 2nd, 3rd and 5th gammas.

The main input in these agro-industrial processes, besides the raw material, is the energy consumption. Modern agro-food system consumes large amounts of energy for the production of food products from vegetal or animal origin to meet the global food demand. The energy used for processing, transport and food preparation is usually around from three to four times the amount of energy used for primary production (Smil, 2008). More specifically, the food industry requires thermal energy for heating and cooling, and electricity in order to process the plant products. In addition, energy is also embedded in the materials (plastic or aluminum) used for packaging.

A small component (less than 10%) of the total energy consumed by the agro-manufacturing industry is for non-process uses, which include heating, ventilation, air conditioning, refrigeration, lighting for industrial facilities and on-site transport. When used, boiler fuels may achieve up to one third of the total energy consumption.

In addition, we report some data on energy consumption (in tons of oil equivalent, toe) in the fruit and vegetables sub-sector in France (Agreste, 2010):

- *Total fruit and vegetables sub-sector: 95.442 toe*
- *Processing and preserving of potatoes: 14.386 toe*
- *Preparation of fruit juices and vegetables: 9.910 toe*
- *Other processing and preserving of vegetables: 55.780 toe*
- *Processing and preserving of fruit: 15.367 toe*

TABLE 2. PERCENTAGES OF ENERGY CONSUMPTION FOR SPANISH FRUIT AND VEGETABLES INDUSTRIES BASED ON COOLING PROCESSES.

PROCESSING PHASE	%
Raw material reception, washing, sorting and sizing	19,5
Processing: cutting, grinding, calibration, peeling, etc. After-treatment operations, checking and packaging	12,2
Cooling/cold storage	46,4
Transport	2,0
Air conditioning	2,5
Lighting	7,8
Auxiliary processes	9,6
TOTAL ENERGY	100,0

Source: Data proceeding from the analysis of ten Spanish fruit and vegetables processing plants by Cooperativas Agro-alimentarias, 2010.

3.1. Electrical consumption

The following tables report the percentage of energy consumption required by each processing operations characterizing the fruits and vegetables sub-sector.

On average, the energy consumption accounts mainly for electricity used by the processes of cooling and refrigeration (46,4% in the Table 2), but the thermal energy required for maintain hygiene and sanitary state of fruit and vegetables is also considerable. The energy demand of the food industry can be classified depending on seven major energy sub-systems, namely: i) aeration (ventilation and air conditioning) ii) steam, iii) motor and pumps, iv) compressed air, v) cooling and refrigeration, vi) heating and lighting of infrastructure and buildings, and the vii) energy demanded by the internal transportation.

However, it should be outlined that the data presented in the following tables could not reflect the whole picture, because either the processing technologies or the primary raw materials (fruit and vegetables) treated can be quite different between the companies.

In fruit and vegetables processing plants for the fresh market, facilities are usually based in cooling/freezing processes, so a high percentage of the energy consumption is electrical. In some cases, energy consumption is directly proportional to the cooling needs (see also Figure 10 further on).

TABLE 3. ENERGY CONSUMPTION FOR STANDARD PRODUCTION PROCESSES IN A TYPICAL PORTUGUESE FRUIT AND VEGETABLES INDUSTRY (10.000 TONS OF PRODUCT/YEAR).

PROCESSING PHASE	Typical technology	Capacity (t/hour)	Electrical power installed (kW)	Electrical energy consumption (kWh/year)	Power (kW)	Diesel consumption (kWh/year)
Reception	Balance and/or electronic scale Washing machine (Drencher)	57	184	33.500	-	-
Conservation	Cold storage	-	270	536.000	-	-
Packaging	Calibrator Packaging machine	6	39	67.000	-	-
Expedition	Chamber expedition	6	19	33.500	-	-
Lighting and other electrical auxiliary equipment	Fluorescents	-	12	56.300	-	-
Auxiliary equipment	Forklifts	14	-	-	10	14.560
TOTAL	-	-	523	726.300	10	14.560

Source: Data proceeding from the analysis of a representative facility by University of Évora.

TABLE 4. INDUSTRIAL PROCESSES AND ASSOCIATED ENERGY CONSUMPTION IN TYPICAL ITALIAN INDUSTRIES BASED ON THERMAL PROCESSES.

PROCESSING STEP	Electrical energy (kWh per ton of processed product)	Thermal energy (kWh per ton of processed product)	Electricity for water pumping (kWh per ton of processed product)
Raw materials reception	3,4	-	-
Washing, sorting and sizing	2,1	51	-
Cutting, grinding, calibration, peeling, etc.	3,4	72	3
Blanching and drying	1,5	209	-
Cooling and rinsing	3,9	-	3
After-treatment operations, checking and packaging	3,0	50	-
Heat treatment for stabilization	-	229	8
Cooling	1,1	-	-
Storage	1,0	-	-
TOTAL ENERGY	19,4	611	14

Source: LG MTD Industria Alimentare, 2008.

3.2. Thermal consumption

In the fruit and vegetables processing plants sub-sector the thermal consumption is not very relevant. A data elaboration lead by Cooperativas Agro-alimentarias gives an idea about the distribution of energy consumption among some SMEs audited in 2010: thermal consumption is only the 14% while the electrical one is the 86%. This small thermal consumption is mostly required for the heating of cleaning water, but also by forklifts for the internal transport of the fruit and vegetables, by burners used for drying some fresh products, etc.

When considering food of the 2nd and 3rd gammas the thermal consumption increases considerably to allow the high energy demanding processes of pasteurization and freezing. Table 4 reports data regarding both electrical and thermal energy consumption per ton of processed product in a typical Italian fruit and vegetables processing plant with a consistent consumption of thermal energy (particularly common for plants dedicated to 2nd gamma fruit and vegetables).

3.3. Energy balance (Sankey's diagram)

The energy balance of industrial processes and associated energy consumption in cooperatives based on cooling processes, proceeding from a 2010 analysis by Cooperativas Agro-alimentarias of ten Spanish fruit and vegetables processing plants, is represented in Figure 10 in the form of a Sankey's diagram.

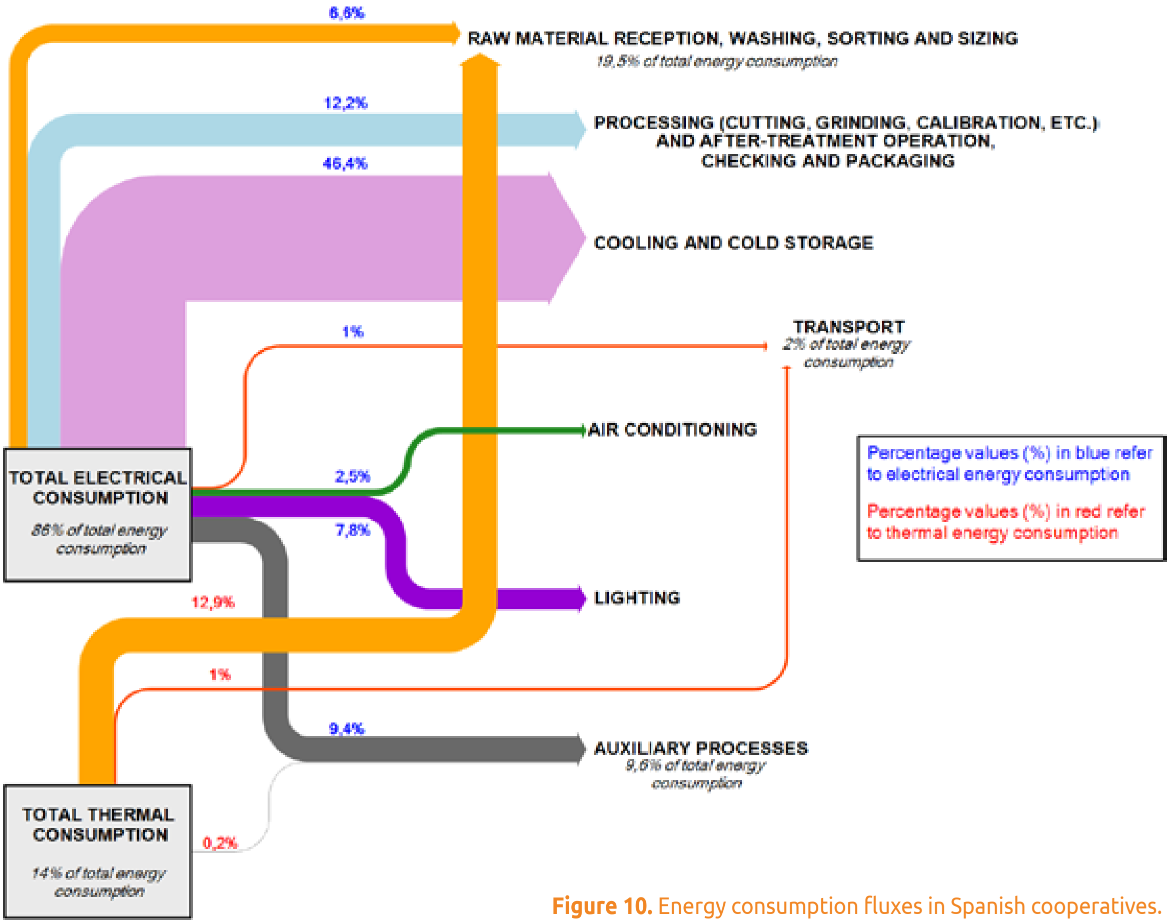

Figure 10. Energy consumption fluxes in Spanish cooperatives.

3.4. 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, and taking into account the different fossil fuels that can be used for thermal energy. Table 5 shows reference electrical and thermal energy costs in typical fruit and vegetables processing companies of the four TESLA countries.

TABLE 5. ENERGY COSTS IN THE FOUR TESLA COUNTRY-PARTNERS.

TESLA COUNTRY	Electrical energy cost (€/MWh)	Thermal energy cost (€/MWh)
Italy	144	37
Spain	125	60
France	From 60 to 110	From 20 to 80
Portugal	80	70

4. ENERGY SAVING MEASURES

After a brief analysis of the fruit and vegetables sub-sector of the food industry in the four Tesla countries, the 4th chapter of this handbook focuses on possible proposals and actions that can be put in operation to save energy and/or improve energy efficiency of processing plants and services committed in this sub-sector.

The cooling storage is the most energy demanding process, since it generally takes place during several months per year and under very high external weather temperature conditions. The consumption of electricity due to cooling generation can be up to 53% of the total electricity consumed by the company. Thus, efficient cooling production systems and cooling chambers (materials used in the structure and chamber organization) represent important energy saving measures.

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 change by a cheaper one, so economic savings can be worthy of consideration.

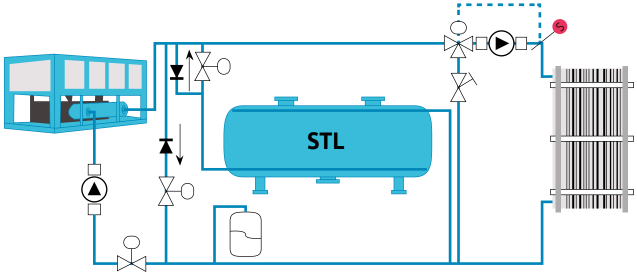

Figure 11. Scheme of the cooling storage system installed in parallel with the cooling system (CIAT).

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. 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.

Potential savings are considerable, taking into account that old machines (with alternative compressor and without regulation options) have an EER value close to 1,5 while these efficient cooling machines have an EER close to 3. (NOTE: EER is the Energy Efficiency Ratio and it means that with 1 kWh of electricity, 1,5 (or 3) kWh of cooling are produced).

Figure 12. Cooling machine.

4.2. Insulation improvement in cooling chambers

The substitution or the improvement of panels installed in walls/roofs by thicker polyurethane panels that guaranty lower thermal transmittance will allow better insulating conditions than other materials, and requiring only a medium investment.

Real energy savings will depend on the chamber surface, on the thermal transmittance (U) of the previous and the new insulating panels, and on the external and internal temperature. Considering the case of a cooling chamber (internal dimensions: 10 m x 10 m x 3.5 m) which initially has a wall and roof based on polystyrene panels with a thickness of 80 mm and U = 0,4 $W/m^{2}°C$, if the insulation materials are changed by polyurethane panels with a thickness of 100 mm and U = 0,25 $W/m^{2}°C$, having thermal conditions of 29°C outside of the chamber and 10°C inside, the power demand can be reduced up to 20%.

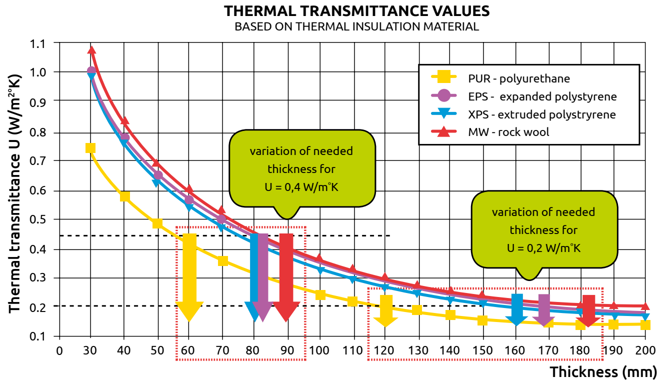

Figure 13. Thermal transmittance for different materials and thickness.

4.3. 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.
Figure 14 shows the differences between each motor type.

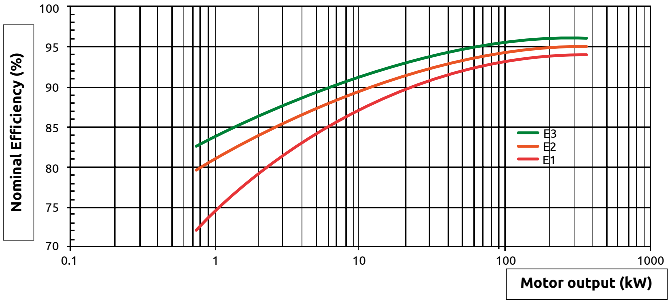

Figure 14. Comparison of the energy efficiency curves for the different engine levels (CIRCE).

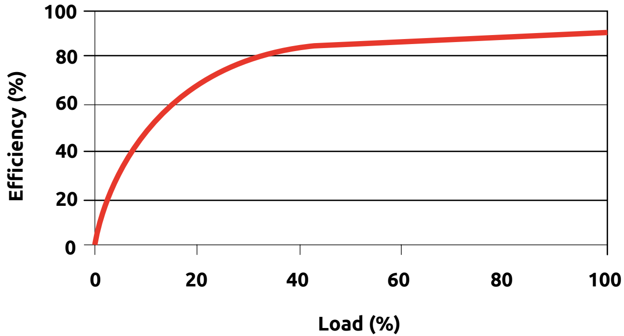

Figure 15. Efficiency of an electric motor according to the load (BREF, 2009).

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 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 in Figure 15.

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 engine 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 redu-

ce electrical energy consumption particularly in centrifugal pumps, compressors and fan applications. Materials processing applications like hammer mill for example, as well as materials handling applications such as conveyors, can also benefit both in terms of energy consumption and overall performance through the use of VSDs.
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).

4.4. 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 DRIVES (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.

4.5. 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%.

4.6. 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, kind of facilities, the maintenance conditions of insulating materials are very important for is 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 usually is between -50°C and 110°C.

PIPES INSULATION. Potential savings achieved will depend on: pipe diameter and length (or insulating surface size), temperature difference, insulating material thermal resistance 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 350 m, 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.

VALVES INSULATION. Besides that, the fittings, valves and other connections are usually not well insulated. Re-usable 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.

Figure 16. Pipe insulation in good conditions.

4.7. Heating water or air

Hot water is needed in all industries for many different uses: from hygienic and sanitary water till preheating water for boilers or steam production. Several systems can be used for heating water. In this handbook three 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°C, optical performance of 75% and transmittance coefficient of 2,9 $W/m^2{}^\circ C$.

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.

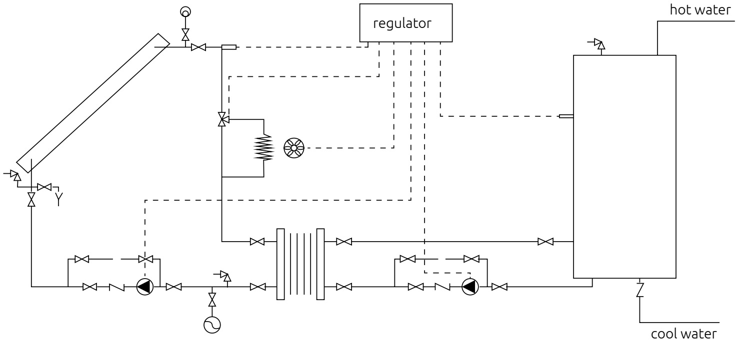

Figure 17. IMS solar thermal system scheme (CPC solar).

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 applications requiring warm air. Ambient air is passed through the compessor where it gains the heat resulting of 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 air can be used for example to warm room temperature.

- 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 ECONOMIZER 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 process. 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%.

4.8. 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 1120 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.

4.9. Lighting

In TESLA industrial sub-sectors a large amount of lighting inside buildings is necessary. Currently there are installed a large variety of lamps, mainly gas discharge lamps (fluorescents, high pressure sodium or mercury steam) or halogen technologies. These 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

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.

following table shows energy savings considering the replacement of fluorescent lamps by LEDs.

4.10. High efficiency in power transformers

A power transformer converts electricity that comes from the grid. Very old transformers still use oil and are not very efficient, thus energy consumption is high. On the contrary, dry transformers reduce energy losses up to 70%, are safe, free of maintenance and present a good capacity to support overload and to resist to short circuit.

4.11. Management tools

An energy management tool helps finding the best sustainable way to improve energy uses and reduce energy costs, through a better knowledge and the monitoring of energy flows, thus decreasing GHGs emissions and, in general, improving the industry image. A “virtual energy manager” is composed by measuring devices, a communication grid and a software, and it is recommended in an industry according to UNI EN 16.001/ISO 50.001 standards requirements.

5. CONCLUSIONS

In the last decade, there has been a growing interest for improving energy efficiency in the agro-food industry sector in order to decrease energy costs and GHGs emissions. The adoption of minimum energy performance standards for machinery (motors, cooling systems, and water boilers), and the use of renewable energy represent effective solutions to cut down the energy consumption and reduce the environmental impacts. The application of energy efficiency measures and interventions in steam systems (boilers, heat distribution), compressed air systems (bottling, dehydration, conveying, spraying coatings, cleaning), cooling and refrigeration processes, heating, and lighting of facilities can certainly allow to achieve a total energy saving from 15 to 25% (Kaminski and Leduc, 2010). Other general potential improvement actions are reported below.

Several measures could allow a lower consumption of electricity. For example, food storage can be improved by better using the schemes of ventilation or installing high efficiency variable speed fans with inverters. Thermal fluxes can be used for heating both the water required for cleaning treatments and the working areas in winter. Of interest is also the application of MEPS, Minimum Energy Performance Standards, in order to encourage the use of more efficient compressors and to improve the designs of heat exchangers, light, fans and controls.

Renewable energy represents an important field of application that should be considered from food industry companies to reduce their energy costs. Production of heat from available on-site biomass or steam raising and cogeneration can provide heating water and energy power to industrial plants for fruit and vegetables drying, with a significant energy efficiency improvement. Optimizing combustion efficiency, heat recovering from exhaust gases and optimum size high efficiency electric motors can also yield 20-30% energy savings.

An analysis of energy bills, the identification of each equipment preservation current situation and its working parameters of use, and a careful analysis of the production processes should be done to have a more conscientious management of energy uses and consumptions in the company.
Furthermore, governmental incentives (according the UNI EN 16.001/ISO 50.001 standards requirements) to support energy efficiency actions and energy saving to private investors are very important.

6. REFERENCES AND SOURCES

-- *Agreste, 2010.*

- *Circe, Best Practices Collection, 2014.*

- *Cleland D., Toward a sustainable cold chain. International Institute of Refrigeration. Cambridge. 2010.*

- *Confagri, 2013.*

- *CoopdeFrance, 2009.*

- *Cooperativas Agro-alimentarias.*

- *CSO (Centro Servizi Ortofrutticoli). Tutti i numeri dell'ortofrutta italiana, la panoramica completa 2012.*

- *European Commission, Directorate-General for Agriculture.*

- *Eurostat; Eurostat database COMEXT.*

- *FAOSTAT, 2006-2009.*

- *FCIA. Fichero Coordinado de Industrias Agroalimentares.*

- *Feria Internacional del Sector de Frutas y Hortalizas 2013.*

- *FIAB, 2008.*

- *FOODDRINKEUROPE European Food and Drink Industry 2012 – Data & Trends.*

- *FranceAgriMer, Etablissement National des Produits de l'Agriculture et de la Mer.*

- *GPP, Office of Planning and Policies, 2013. Fruticolas, Horticolas e Flores. Código NC: 06; 07; 08; 20.; Programa de Desenvolvimento Rural do Continente 2014-2020. 1b-Anexo_Diagnostico. 48 pp.*

- *INE, 2013. Estatísticas Agrícolas 2012. Instituto Nacional de Estatística, I.P.. 180 pp.*

- *Kaminski J., Leduc G., 2010. Energy efficiency improvements options for the EU food industry. POLITYKA ENERGETYCZNA. Tom 13, zeszyt 1. PL ISSN 142-6675.*

- *ISTAT, 2009-2012. Italian Institute for Statistics.*

- *LG MTD Industria Alimentare (Linee Guida per l'identificazione delle Migliori Tecniche Disponibili), 2008.*

- *MAGRAMA Ministerio de Agricultura, Alimentación y Medio Ambiente.*

- *MARM, 2009.*

- *Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, 2013.*

tesla

Transfering
Energy Save
Laid on Agroindustry

www.teslaproject.org
tesla@agro-alimentarias.coop

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