Available online at www.sciencedirect.com

ScienceDirect

Agriculture and Agricultural Science Procedia 8 (2016) 657 – 663

Agriculture and Agricultural Science Procedia

Florence "Sustainability of Well-Being International Forum". 2015: Food for Sustainability and not just food, FlorenceSWIF2015

Identifying strategies for energy consumption reduction and energy efficiency improvement in fruit and vegetable producing cooperatives: a case study in the frame of TESLA project.

Arianna Latini[a]*, Carlo Alberto Campiotti[a], Enrico Pietrantonio[b], Corinna Viola[a], Victor Peral[c], Joaquín Fuentes-Pila[c], Juan Sagarna[d]

[a]*ENEA – Italian National Agency for New Technologies, Energy and Sustainable Economic Devlopment. Via Anguillarese 301, 00123 Rome, Italy.*
[b]*D.R.E.Am. Italia. Via Enrico Bindi 14, 51100 Pistoia, Italy.*
[c]*Technical Univerisity of Madrid. Department of Agricultural Economics, Statistics and Business Management. Av. Puerta de Hierro 2, 28040 Madrid, Spain.*
[d]*Agri-food Cooperatives Spain. Calle Agustín de Bethencourt 17, 28003 Madrid, Spain.*

Abstract

TESLA (Transfering Energy Save Laid on Agroindustry) is a EU project pointing to the reduction of energy consumption and the improvement of energy efficiency in key agro-food sectors' cooperatives, as those processing fruit and vegetables. After a general analysis of energy consumptions during the first phase of the project, the processes responsible for the higher energy consumptions in these fruit and vegetable industries, as cold storage, have been identified. In the second phase of the project, a few case studies aimed at proposing customized solutions for reducing energy wastage and for improving energy efficiency in specific selected cooperatives have been performed. In this manuscript we report preliminary results of a case study carried out in an Italian horticulture cooperative having several production lines for fresh (1st range) and minimally processed (4th range) fruit and vegetable products. In this cooperative, an in-depth energy audit has been performed, and additionally a process simulation software has been applied to model, evaluate and improve the operations in this processing centre and in the supply chain from the primary production sites. Such case study may be used as an example for similar cooperatives of the fruit and vegetables sector, thus contributing in making this sector more economically and energetically sustainable.

* Corresponding author. Tel.: +39-06-30484332; fax: +39-06-30484517.
E-mail address: arianna.latini@enea.it

2210-7843 © 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of Fondazione Simone Cesaretti
doi:10.1016/j.aaspro.2016.02.088

Keywords: fruit and vegetable sector; fruit and vegetable cooperatives; energy consumption; energy efficiency.

1. Introduction

In EU-28, fruit and vegetable sector represents a key sector in agriculture. Indeed, its production corresponds approximately to 17% of the total EU agricultural output value (with vegetables accounting for 10% and fruits for 7%), thus characterizing a substantial part of the agro-food consumption (European Parliament Study, 2015). A typical feature of most fruit and vegetable products that affect the whole sector (distribution in particular) is their high perishability (they represent high wasting food items); as a result, they have to be consumed soon after harvesting or have to be processed directly into a less perishable form after harvest. Evidently, for highly perishable products efficient logistics is more critical than for less perishable products (Bijman, 2012). Food safety is also an important issue in the fruit and vegetable sector, and since the consumption of fruit and vegetables is considered of crucial importance for public health, in order to prevent food safety risks, all stakeholders in the supply chain are obliged to apply either "Good Hygienic Practices" (GHP) at food primary production chain or "Hazard Analysis and Critical Control Points" (HACCP) systems at the food industry and distribution stages.

The cooperatives involved in this specific sector are implementing several innovations in order to meet customer changing needs and life habits. Besides fresh horticultural produce (1st range) – and excluding products obtained through higher energy-intensive elaboration, as for sterilized (2nd range) and frozen products (3rd range) –, several companies are marketing fresh-cut, packaged and ready-to-eat salads (4th range) that undergo minimally processing (MP) and that are becoming more and more coloured and differentiated in terms of fruit and/or vegetable ingredients. MP of fruit and vegetables allows the products to maintain their freshness without losing their nutritional quality, but at the same time these products should have a shelf-life sufficiently long to make their distribution feasible within the region of consumption (Siddiqui *et al.*, 2011).

Given the 2012 European Energy Efficiency Directive (EED), establishing that all EU countries are required to use energy more efficiently at all stages of the energy chain from its production to its final consumption, as well the growing cost of energy resources, several industries – including fruit and vegetable processing cooperatives – have to search for ways to minimize the consumption of energy, particularly heat energy. TESLA (Transfering Energy Save Laid on Agroindustry; www.teslaproject.org) is a 3-year lasting project (2013-2016) funded by the EU's Intelligent Energy - Europe programme (IEE/12/758/SI2.644752), which aims at reducing energy consumption and improving energy efficiency in agro-food cooperatives related to four specific agro-food sectors – namely, fruit and vegetable processing plants, olive oil mills, wineries and animal feed factories – from Spain, Italy, France and Portugal. In the frame of the TESLA project, an accurate study of typical fruit and vegetable cooperatives has been carried out in order to evaluate their energy consumptions. After a general analysis of (electrical and thermal) energy consumptions, based on literature as well as on real-life data proceeding from a number of energy audits that have been performed in some fruit and vegetable cooperatives dealing with fresh produce, the processes responsible for the higher energy consumptions in these food industries have been identified (TESLA project deliverables D.4.4 and D.6.6). In most cases, cold storage represents a key cost for cooperatives, due to the need of keeping cool a large area where fresh ingredients are stored.

Besides a more general analysis, TESLA project is performing a few case studies in specific selected cooperatives, aimed at proposing customized solutions for reducing energy wastage and for improving energy efficiency. Here we report preliminary results of a case study carried out in an Italian horticulture cooperative having several production lines for 1st and 4th range products. In this cooperative, an in-depth energy audit has been performed, following an audit guide that has been developed during the first stage of the TESLA project (Section 3.1). The energy audit has allowed to the cooperative managers being aware of both their energy requirements and consumptions. Moreover, it has been possible to suggest specific measures aimed at reducing energy consumptions and improving energy efficiency as well as simultaneously improving operational efficiency. The tools and methodologies applied allow estimating the costs and payback times for the solution proposed.

Furthermore, the process simulation software SIMUL8 is being applied to model, evaluate and improve the operations in the fruit and vegetable processing centre and in the supply chain from the primary production sites. In this way, more efficient solutions allowing energy savings, energy efficiency improvements and operational efficiency enhancements are being identified. This case study will be used for proposing operations and supply chain management strategies that could be applied for improving energy efficiency and reducing excessive energy consumption in similar fruit and vegetable processing cooperatives, thus contributing also to make this sector more sustainable in both economic and environmental terms.

2. Fruit and vegetable producing cooperatives

2.1. Description of production processes

Fruit and vegetable producing cooperatives use to vary outstandingly in number and type of provided final products and services, depending on several factors such as the location and its climate conditions, number of employees, level of innovative technology introduced in the factory, etc… In the simplest case of fresh fruit and vegetable production (1st range) in processing cooperatives, common operating processes are: *i*) reception, *ii*) cleaning and drying, *iii*) sorting and calibration, *iv*) packaging and *v*) cooling conservation (TESLA project deliverable D.6.6). After harvesting from the primary production sites, the raw fruit and vegetable materials have to be transported as soon as possible to the storage area at the cooperative industry (pre-storage), where a preliminary check and evaluation of the sanitary state is performed during the reception phase. Next, in general, a washing/cleaning process is carried out and then undesirable products are removed during a sorting process based on visible physical characteristics of the products. Finally, final transformed fresh products are packaged and kept in refrigerated areas before being delivered.

Minimally processed fruit and vegetables are cleaned, cut, appropriately packaged and commercialized as ready-to-eat products that have not been subjected to any thermal treatment and are preserved by relatively mild techniques. They can be maintained only for a limited time and under cold conditions (chilled storage). Additional operating processes occur in cooperatives handling with 4th range fruit and vegetables, such as: peeling or husking, slicing, chopping, blenching. In general, strict hygiene and good manufacturing practices are used and all processing occur at low temperatures. A particular attention has to be paid also to the washing water that has to have a good quality, with controlled sensory, microbiology, pH parameters and presence of mild additives for disinfection. To overcome the limitations of common sanitizing techniques, food industry is currently studying non-thermal techniques such as ozone based treatments, ultraviolet radiation, pulsed light, cold plasma, ultrasounds and novel packaging practices (Ramos *et al*., 2013).

2.2. Energy consumption

In the fruit and vegetable sector, the top energy-consuming processes are *a*) those requiring cooling and refrigeration by cold storage refrigerating equipment, which use to consume more than 20% of total electricity used for the obtainment of the final product, and *b*) those using thermal energy for heating, in particular for drying horticultural products for industrial transformation and pasteurization of fruit juices, jams, canned tomatoes and other canned fruit and vegetables (not for fresh consumption), which use to consume more than 70% of total thermal energy required.

In cooperatives working with MP fruit and vegetables, the higher energy consumption is due to the maintenance of a 4°C temperature in processing areas and to the final conservation of the products after processing and before final users buy them. Furthermore, in MP production, the excessive use (and waste) of plastics, aluminum and this kind of materials used for its packaging and preserving may weight even more in terms of energy consumption when considering the indirect energy costs embedded in these materials. Research is putting a lot of efforts in proposing technology innovation using more sustainable packaging materials.

3. Case study: energy efficiency improvement in a fruit and vegetable cooperative

The “San Lidano” cooperative, located in the province of Latina (Lazio, Italy), has been considered in this case study. The cooperative was founded in 1997, but the plant installation (total surface about 1,000 m^2) was completed in 2013. San Lidano has a production site specialized in the primary processing and packaging of fresh horticultural products (such as salads, chicory, carrots, spinach, tomatoes, cabbages, etc.), yielding about 3,650 tons as average annual production. Its main customer is represented by the large-scale retail chain.

Fig. 1. Schematic representation of the production processes in the San Lidano cooperative.

This cooperative undertakes a short and controlled production chain, as described below and represented in Figure 1.

- Production and Harvest: the cooperative is self-sufficient in terms of production, and the harvest occurs throughout the year, applying Good Agricultural Practices.
- Processing and Packaging: once raw materials arrive at the plant, their processing occurs within 24 hours using modern technologies for washing, sanitizing and packaging.
- Distribution and Commercialization: thanks to the strategic logistics of its facilities, the factory distributes and markets its products throughout Italy in the shortest possible time.

This cooperative may be considered as a "benchmark" for other fruit and vegetable producing cooperatives, and in fact it has shown to pay a lot of attention to environmental and sustainability issues. Just for example, all working areas are equipped for the collection of post-processing and washing water. This water, rich in vegetable wastes, is then conveyed to an external system for waste treatment.

Inside the cooperative installation, all processes have place in cooled warehouses, with a temperature between 5 and 15°C. Glycol at -12°C is used to cool the water pumped in the pipelines to the warehouses.

3.1. Energy audit performance

To reach the main goal of the TESLA project – that is to foster the knowledge and use of the best available practices for increasing energy efficiency and therefore energy savings –, the initial project activities have been related to the assessment of total energy consumptions by the targeted installations; indeed, 110 energy audits have been carried out in different agro-food cooperatives. Each energy audit has been performed in accordance to the methodological protocol set up at the beginning of the project, in conformity with the EN 16247:2012 standards. This is based mainly on collection of all useful information provided by cooperative managers and technical staff, and all measurements done by network analyzers and other devices (more information can be found in the Tesla project official web site: www.teslaproject.org). Each audit has been finalized in about 15 days of work, including 3-4 visits to the cooperative installation.

In the San Lidano processing plant, the annual trend of energy consumption has been estimated, taking into account energy bills (electricity and natural gas) and reactive energy consumptions. The main energy sources used are electricity for motors and lighting (up to 92% of total energy consumption) and gasoil (LPG) for steam production in a drying tunnel (8% of total energy consumption). The whole activity in the plant has been split up in the main following production processes: raw material reception, cleaning and drying, packaging, cooling conservation, lighting, air conditioning of offices and dressing rooms for employees, compressed air production, forklifts loading and unloading, and vegetable waste recovery (see Fig. 2). For each process, electrical consumptions of the whole line and the main devices have been measured and analysed. Moreover, during the visits to the cooperative, an inventory of all characteristics of all motors has been implemented, thus gathering information about their power, cost, year of production, theoretical efficiency, and daily hours of operation.

The analysis of the data obtained from energy audit, resulted in the determination of: *i*) energy fluxes related to each different production process (Fig. 2); *ii*) real average energy consumption per unit of product and per production phase; *iii*) assessment of real load factor and practical sizing of the motors (considering the real hours of operation and the power used); *iv*) assessment of the performance indicators to compare the case of study with other cooperative installations of the same agro-food sector (process-by-process through energy consumption per energy source, per process, and per production line); and *v*) recommendation of measures for energy efficiency improvement.

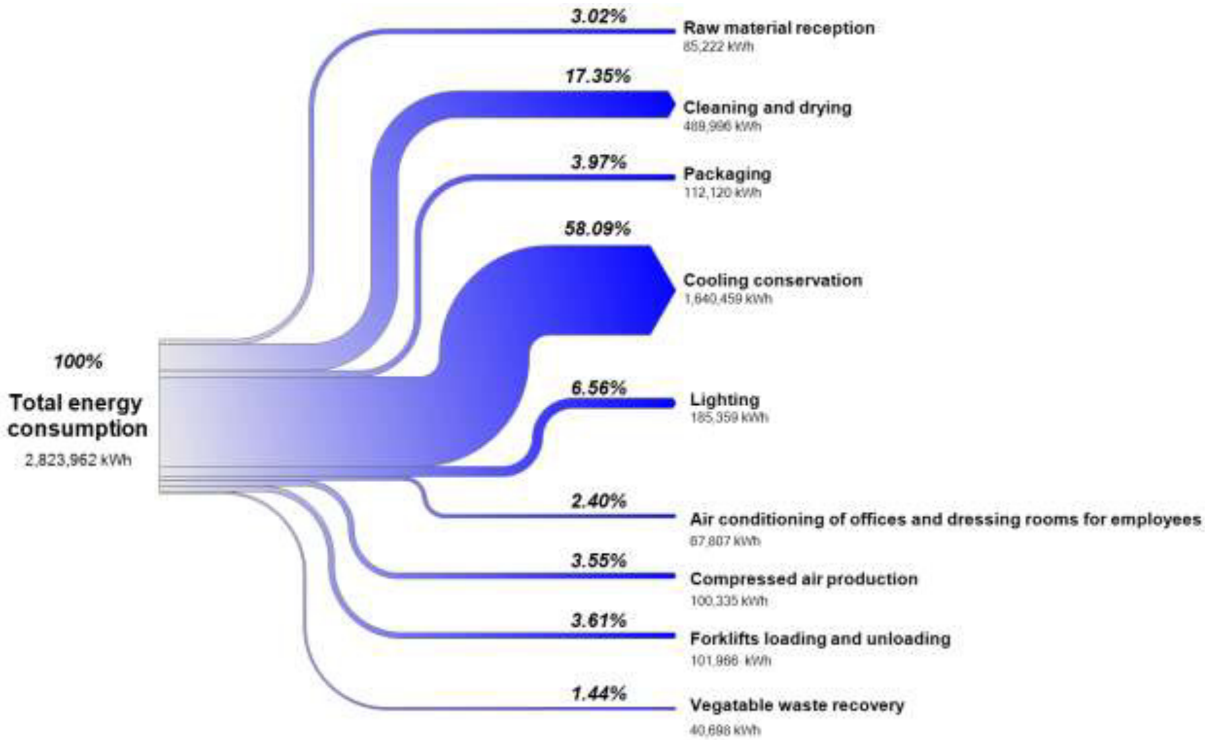

Fig. 2. Sankey diagram showing the average energy consumptions in the production processes of the audited fruit and vegetable cooperative.

The higher energy consumption is due to the cooling system, indeed the whole building is kept at low temperature given the lack of cold rooms and refrigerators. More in particular, one area is maintained at +4°C for the minimally processed products and a separated area is at +14-15°C for the raw material reception. Cooperative production is constant during all year, but the product types vary according to their seasonality. Since the cooperative already shows a high energy efficiency level, it has been necessary to recommend only few saving energy measures. In particular, the replacement of the actual lighting system made of neon lamps (low pressure gas discharge lamps) with a new lighting system based on LED could lead to an important economic saving. Anyway, considering the high investment required for the substitution all at once of the lighting system, the suggestion is to replace the lamps as they result damaged.

3.2. Simulations for improving energy efficiency in operations and supply chain

For identifying and assessing operational and supply management strategies aimed at achieving energy efficiency improvements, an approach based on the Lean & Green Systems Thinking has been applied. A Lean & Green Production System can be defined as a system designed for improving operational efficiency and sustainability simultaneously and continuously, in order to enhance radically the ability of either an organization or a supply chain for generating and delivering value to its customers and to the society as a whole. Continuous improvement cycles in a Lean Production System start by the understanding of the value needs of customers (and other key stakeholders) and, after this first step, the value flows are analyzed with the objective of minimizing the eight Lean wastes. The eight Lean wastes are the following ones: *i*) overproduction; *ii*) defects; *iii*) unnecessary inventory; *iv*) transporting; *v*) waiting (idle people and machines); *vi*) inappropriate processing; *vii*) unnecessary motion; and *viii*) lost people potential (Zokaei *et al*., 2014). On the other side, Green Production Systems could be defined as the result of applying a set of principles, strategies, methodologies and tools for identifying, quantifying, assessing and managing the flows of environmental wastes, which will be called Green Wastes. It is also possible to identify eight Green Wastes: *i*) excessive energy consumption; *ii*) physical waste (solid or liquid); *iii*) excessive water usage; *iv*) air emissions (including greenhouse gases); *v*) land contamination; *vi*) discharges to water and effluent; *vii*) noise and nuisance; and *viii*) lost people potential (Zokaei *et al*., 2014).

One of the main methodologies used in the Lean & Green initiatives for the simultaneous and continuous reduction of the eight Lean Wastes and eight Green Wastes is the Sustainable Value Stream Mapping (Faulkner and Badurdeen, 2014). Because the TESLA project focuses on improving energy efficiency, the Sustainable Value Stream Mapping methodology applied is simplification of the Sus-VSM methodology proposed by Faulkner and Badurdeen (2014). It only takes into account metrics for evaluating energy consumption, physical waste and carbon footprint as well as the usual Lean metrics for evaluating operational performance. For developing the Current Value Stream Map, the data collected in the energy audit are used. Since variation in operational data is especially high when processing fruit and vegetables, a risk environment for decision making has been assumed. For this reason, the Value Stream Maps are developed by using the simulation software SIMUL8, a simulation software of discrete events. Distributions are estimated by using experts' opinion, mainly the feedback provided by the managerial and technical staff of the cooperative and the energy efficiency auditor.

After developing the Current Value Stream Map, a visit to the cooperative was carried out for validating the developed model and identifying problems and improvement opportunities. In a meeting with the participation of the operations manager, the maintenance head, the energy auditor and researchers from UPM and ENEA, a major Lean & Green waste stream was identified. Periodically, the amount of products in process discarded by the optical selection equipment because of defective quality was excessively high. This was a waste both from a Lean perspective ("defects" and "waiting") and from a Green perspective ("physical waste", "excessive energy consumption", "excessive water usage", and higher carbon footprint of the final product). These products in process discarded by quality problems negatively affect to energy efficiency because we are using energy for processing products that cannot be delivered due to defective quality. After analyzing the whole supply chain and the primary production and manufacturing processes, it was concluded that the major causes of this Lean & Green waste were:

i) Excessive Inventory: Most of the clients of this cooperative are large retailers that frequently make orders with special features. This means that the cooperative has to be ready for processing these orders when they are received. For this reason, a variety of raw materials has to be maintained in the raw materials reception inventory as a buffer inventory. On the other hand, because of demanding quality requirements, raw materials have to be harvested in the "optimal" moment from an agronomical point of view. This fact also leads to higher inventories as well as to a decoupling between offer and demand that prevent implementing a full "pull systems" in the supply chain.

ii) Cold storage: The optimal conservation temperature of these kind products (lettuce and baby leaf) is 4 ºC. Higher temperatures lead to a faster deterioration. The storage area for raw products in this cooperative was at a temperature of 14-15 ºC. This storage area is originally designed for short waiting periods (from truck unload until entering the process) but because of the abovementioned logistic issues, the waiting periods in this area are longer than expected and the temperature is far from the optimum. In addition, transport from the production areas (several raw materials suppliers are at distances up to 500km from the cooperative) is done at ambient temperature.

Future Stream Maps have being developed for evaluating the following operational and supply management strategies:

i) The implementation of automated quality control procedures for avoiding the entrance of defective raw materials in the processing area and the improvement of inventory management by using Communication and Information Technologies.

ii) The use of buffer inventories strategically situated in the production areas. The application of fast cooling technologies such the use of a vacuum cooling system, which is specially successful in the type of products studied (vegetables, lettuce and baby leaf), together with a cold storage at 4ºC, could allow reducing the decoupling between offer and demand. Raw materials will be send to the processing plant when needed trying to achieve a just in time delivery.

iii) Cold transport, or at least under isothermal conditions, for ensuring that the cold chain of the product is strictly maintained, from the field until the final product is delivered to the retailer.

Because these measures require an increase in energy consumption, this increase should be compensated with measures for reducing substantially energy consumption in the processing plant. A value chain perspective is needed for fulfilling the strategic goals of simultaneously reducing the energy consumption and improving the energy efficiency in the whole chain.

4. Conclusion

The fruit and vegetable sector presents peculiar features with respect to other agro-food sectors, such as the perishable nature of its products and their strong vulnerability to weather changes (abiotic and biotic challenges). The EU actively support this sector in several ways, for example by encouraging growers to join producer organizations in order to receive support for implementing operational programs. The TESLA project utilized this channel to investigate energy consumptions in several EU agro-food cooperatives and then to propose measures for improving energy efficiency and reducing energy costs in these cooperatives. Here, we have reported the case study of a modern fruit and vegetable producing cooperative, sensible to energy saving and environmental protection, in Italy. An energy audit of this cooperative has been followed by the application of Lean and Green methodological approach and interesting suggestions for improving energy efficiency and sustainability have emerged.

Acknowledgements

TESLA project is co-funded by Intelligent Energy Europe Programme of the European Union. The authors of the current manuscript wish to acknowledge all TESLA project partners, including: Cooperativas Agro-alimentarias, CIRCE and Technical University of Madrid from Spain; ENEA and Legacoop Agroalimentare from Italy, Coop de France and Tecaliman from France, Confagri and Evora University from Portugal. In addition, authors are very grateful to Dr. Marta Mascelli and Chiara Chiostrini from D.R.E.Am. Italia for the energy audit performance at the San Lidano cooperative; Dr. Flaminia Vita from Legacoop for the accurate selection of the San Lidano cooperative reported in this case study; Dr. Luciano Di Pastina and Dr. Paolo Cappuccio, respectively the President and the Responsible Technical Manager of the San Lidano cooperative, including all its technical staff.

References

Bijman J., 2012. Support for Farmer’s Cooperatives, Sector report Fruit and Vegetables. Wageningen: Wageningen UR.

Campiotti C.A., Latini A., Scoccianti M., Biagiotti D., Giagnacovo G., Viola C., 2014. Energy efficiency in Italian fruit and vegetables processing industries in the EU agro-food sector context. Rivista di Studi sulla Sostenibilità 2, 159-174.

European Parliament Study: Towards New Rules for the EU’s Fruit and Vegetables Sector – An EU Northern Member State Perspective. Feb. 2015.

Faulkner W. and Badurdeen F., 2014. Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance. Journal of Cleaner Production 85, 8-18.

Latini A., Viola C., Scoccianti M., Campiotti C.A., 2014. An energetic outlook of the Italian food and drink industry. Quality-Access to Success 15, S1, p. 333.

Ramos B., Miller F.A, Brandão T.R.S., Teixeira P., Silva C.L.M., 2013. Fresh fruit and vegetables – An overview on applied methodologies to improve its quality and safety. Innovative Food Science and Emerging Technologies 20, 1-15.

Siddiqui M. W., Chakraborty I., Ayala-Zavala J. F., Dhua R. S., 2011. Advances in minimal processing of fruits and vegetables: a review. Journal of Scientific & Industrial Research 70, 823-824.

TESLA project: Current process description Fruit & Vegetables Processing Plants. Project deliverable D.4.4, Nov 2013.

TESLA project: HANDBOOK - Efficient Fruit and Vegetables Processing Plants. Project deliverable D.6.6, Feb 2014.

Zokaei K., Lovins H., Wood A., Hines P., 2013. Creating a lean and green Business System: Techniques for Improving Profits and Sustainability. CRC Press. Taylor & Francis Group.