# New energy efficiency services in the industrial sector. A case study from an ESCO operating in the bio-ethanol industry. Analysis of experience

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ESCOs, $CO_2$ reduction, energy management, energy monitoring, demand-side management, human factor

## Abstract

The paper is based on a case study of an energy service company providing energy delivery and energy efficiency services to an industrial plant in Latvia.

*ESCO-1* is an energy service company that was founded as an energy partnership between the ESCO Energonams and an industrial partner, in which the industrial partner holds the majority of shares. In this scheme, ESCO-1 has taken over operation and maintenance of the energy supply at the industrial plant using energy delivery contracting (EDC). The ESCO then added new energy efficiency services including the implementation of energy efficiency improvement measures to reduce final energy demand at the industrial plant using energy performance contracting (EPC) combined with the ongoing EDC.

The paper provides an analysis of energy savings by the ESCO company, both at supply and end-user side. The article analyses the measures implemented by ESCO-1, which has been operating for three years. It describes the principles under which the ESCO has been established, and the methods for its operation and planning.

The paper shows how human factors are important for successful ESCO operation in the industrial sector, in particular at the initial phase. The analysis shows how this ESCO scheme is a win-win solution, in particular for risk sharing and raising of capital.

## Introduction

Energy demand is continuously growing worldwide, and is at the core of climate change caused by greenhouse gas (GHG) emissions. The European Commission has adopted the "Energy Roadmap 2050" to reduce $CO_2$ emissions by 80–95 % by 2050 (COM, 2011). One of the legislative instruments at the EU level is the Directive 2006/32/EC on energy end-use efficiency and energy services. Under this Directive, every EU member state is called to reduce end use energy by 9 % by 2016 (EPD, 2009).

ESCOs are now a well-recognised business model at the European level. The available scientific literature while not extensive, provides some insights into ESCO operations. Goldman et al. (2005) carried out an empirical analysis of US ESCO market trends and performance. The paper highlights both the financial and non-financial policy tools as facilitators to start-up ESCO projects in large public, commercial and industrial entities. Bertoldi et al. (2005; 2006; 2007) discuss ESCO diffusion in the EU market. The study shows differences in ESCO development among countries and points out driving factors such as institutional support, market structure and rules, ESCO definition and other factors. In their latest report Marino et al. (2010) have concluded that between 2007 and 2010, the ESCO market in the European Union has grown only slowly, in part, because of the economic downturn in a number of countries. They also mention that latest findings reveal that the ESCO market is very complex and turbulent.

The complexity of energy service market determines an important need to recognize, understand and manage the dynamic, and in many cases, non-linear interactions among many variables, influenced by delays that create both short and long term impacts.

In this paper, a case study of an ESCO application in the industrial sector is presented; in this specific case the ESCO initially provided energy delivery to an industrial company producing bio-ethanol, and subsequently provided additional energy efficiency services based on energy performance contracting.

Particular attention is given to addressing energy efficiency issues in relation to human behavioural aspects in the industrial sector. For this analysis, system dynamics, used as a "white box" modelling tool, is very useful to reveal the structure of the system as well as to determine the short and long term behaviour of complex dynamic system. The literature sources on the system dynamics modelling of ESCO market are very few. Capelo (2011) has approached the ESCO market in Portugal using system dynamics modelling and has presented the preliminary stock and flow diagrams for energy performance contracting.

This paper has four sections. The first section provides an analysis of the contractual model used between the ESCO and the industrial partners. Section 2 describes the situation at the industrial site before ESCO. The third section focuses on setting and planning energy efficiency targets and about human factors that the ESCO faces working with industrial partners. Section 4 shows the energy savings achieved by the ESCO with energy delivery contracting and energy performance contracting.

## Conceptual model of the partnership between the ESCO and the industrial partner

"ESCO-1" is an energy service company that was founded through an energy partnership contract between another ESCO (Energonams) and an industrial partner (bio-ethanol plant). In this specific case, the industrial partner has the majority of shares (see Figure 1).

The bio-ethanol plant contacted Energonams for an energy audit of its boiler house; mainly for solving a technical problem with the steam boilers. The implementation of the audit took about one month. The results of the energy audits showed a high potential for energy efficiency and cost savings. The management of the bio-energy plant become very interested and, at the same time concerned, in acknowledging their inefficient operation of the boiler house. For management, it was hard to believe that the boiler house was not properly operated by their technical staff.

Energonams proposed an EDC for steam supply where, however, the capital would be made available from the bio-ethanol plant. The energy audit and the offer of Energonams were discussed in a number of meetings, spread over a period of about six months.

In these meetings, the management of the bio-ethanol plant wished to keep control of the boiler house and energy supply, although showing high interest in the energy delivery scheme proposed by Energonams. For this reason, it was decided to establish a new entity ESCO-1, where the bio-ethanol plant had the majority of shares.

In this scheme, ESCO-1 has taken over operation and maintenance of the energy supply at the industrial plant, using energy delivery contracting (EDC). The EDC included a guarantee on the heat tariff level with a penalty should the demand for steam be higher that the agreed pick load.

ESCO-1 then added new energy efficiency services, including the implementation of energy efficiency improvement measures to reduce final energy demand at the industrial plant, through an EPC combined with the ongoing EDC. This was carried out with the support of the ChangeBest project under the Intelligent Energy Europe programme (www.changebest.eu). In this EPC scheme, capital was raised in ESCO-1 as: equity of ESCO-1 from profit generated by energy savings, co-financing from the industrial plant and know-how investments by Energonams. The total investment was €43,000.

From Energonams' perspective, ESCO-1 is a special investment vehicle; this allows for keeping investments on the balance sheet of ESCO-1 clearly separate from Energonams, which plays the role of a project development company. Energonams is paid from the dividends on an annual basis.

For the Industrial Company, this model allows it to keep control of a strategic aspect of its production, which is energy generation and supply. At the same time, it brings in a professional third party, which has the right skills and knowledge for capital investment, optimisation and costs savings in energy generation, supply and implementation of energy efficiency measures.

## The situation before ESCO operation at the industrial site

The industrial partner owns two bio-ethanol industrial sites. ESCO-1 started to operate in one of these sites located in a rural area in Latvia. At this site, steam was generated by two

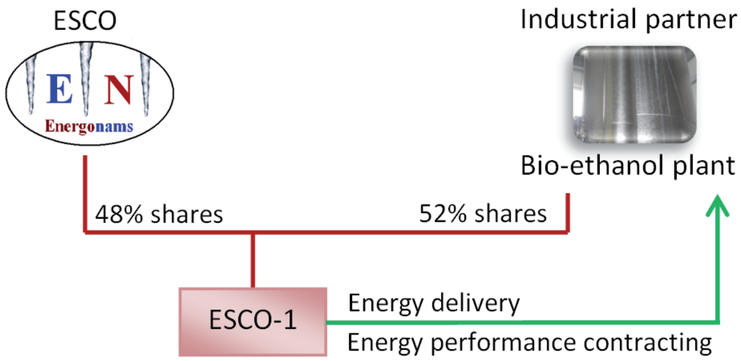


*Figure 1. Energy partnership between the ESCO company Energonams and industrial partner. ESCO-1 provides energy supply and efficiency services to the industrial partner.*

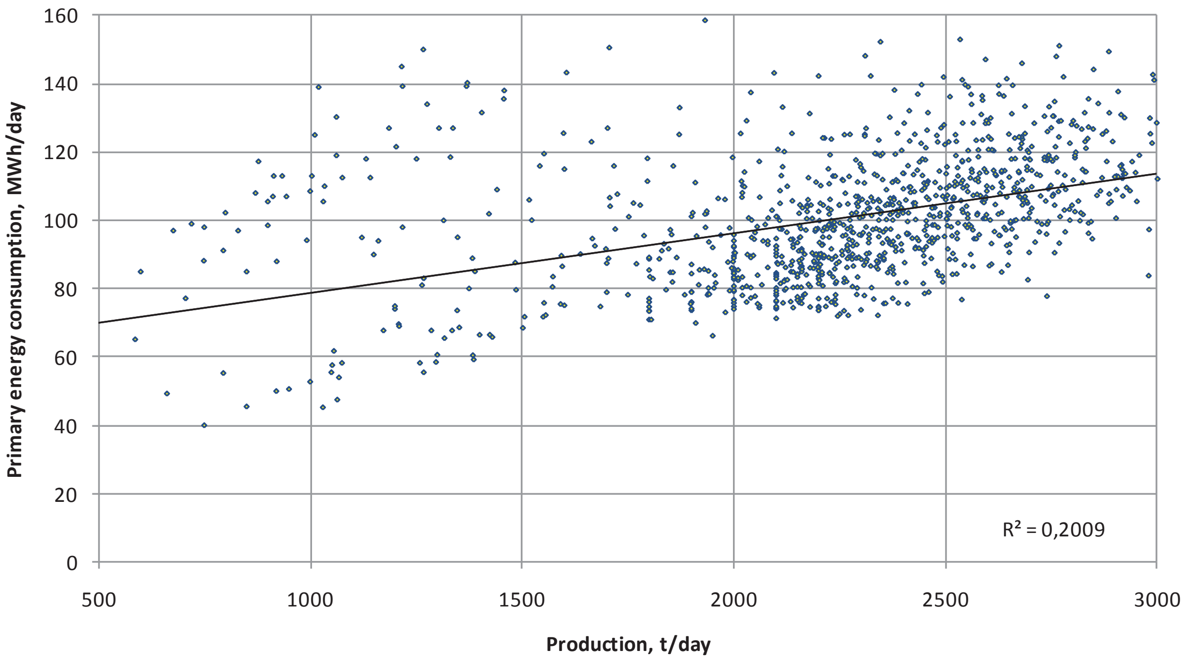


*Figure 2. Primary energy consumption for steam generation versus bio-ethanol production before ESCO-1.*

steam boilers of 4.65 MW capacity each, using heavy fuel oil (HFO), for a total capacity of 9.3 MW in the boiler house. In the bio-ethanol plants, steam is mainly used in for the fermentation process, the distillation towers and the by-product drying process.

ESCO-1, after its establishment and the EDC agreement, based on the energy audit carried out by Energonams, carried out a detailed feasibility study and business plan for the boiler house, using the knowledge and expertise provided by Energonams' engineers.

Beside boiler efficiency, primary energy consumption for steam generation required for production of bio-ethanol of industrial plant was carefully monitored and analysed (see Figure 2). The correlation between these two dependent variables was very weak, although all generated steam was used for production of bio-ethanol.

This analysis highlighted a number of problems related to energy management, both at the production site and in the operation of the boiler house. Indeed energy consumption before the involvement of ESCO-1 was not really controlled: the amount of produced bio-ethanol practically did not correlate to fuel consumption.

The energy audit highlighted a number of specific problems with the boilers:

- Combustion efficiency was measured at a level of 84 87 %, rapidly declining to less than 75 % when working at partial loads.
- The two boilers could not be used independently; a problem with the nozzles of the burner required frequent daily cleaning. In this way boilers were used in sequence one backing up the other, hindering effective operation of the boiler house.
- The temperature of the heavy fuel oil was too high for one of the boilers, further lowering the overall efficiency. There were solid oil residues from un-combusted oil on the nozzles of the burner.
- On one field visit of Energonams' engineers, the water feeding system was found to have been left without water softener.

## Planning an ESCO project in industry using the System Dynamics Model

The system dynamics model is utilized to better understand the interactions and feedbacks from all players regarding the ESCO-1 potential for energy savings. The approach used is called "white box" or causal-descriptive modelling tool. The system dynamic model is developed using the graphical programme Powersim, designed to build non-linear, dynamic systems with delays (see Figure 3). In this specific case, a combination of system dynamics modelling, microeconomics theory and ESCO-1 project experience in the energy efficiency improvement of bio-ethanol industrial plants has been used for planning and developing the simulation model.

The system dynamic model is made of four sub-models (see Figure 3), called:

- *Stock and flow diagram of ESCO-1 costs and profit sub-model*, which shows how ESCO costs, energy tariff and energy consumption baseline, affect ESCO profit and further investments in energy efficiency measures. ESCO costs comprise internal and external transaction costs, investment costs, energy costs (fuel costs) and financing costs.
- *Stock and flow diagram of financial sources sub-model.* Financial resources in ESCO-1 are raised by own equity from profit generated by energy savings, possible subsidy scheme, bank loan. The subsidy provided by government is illustrated by subsidy fraction. The inflow of ESCO's equity is generated by energy savings from the implemented

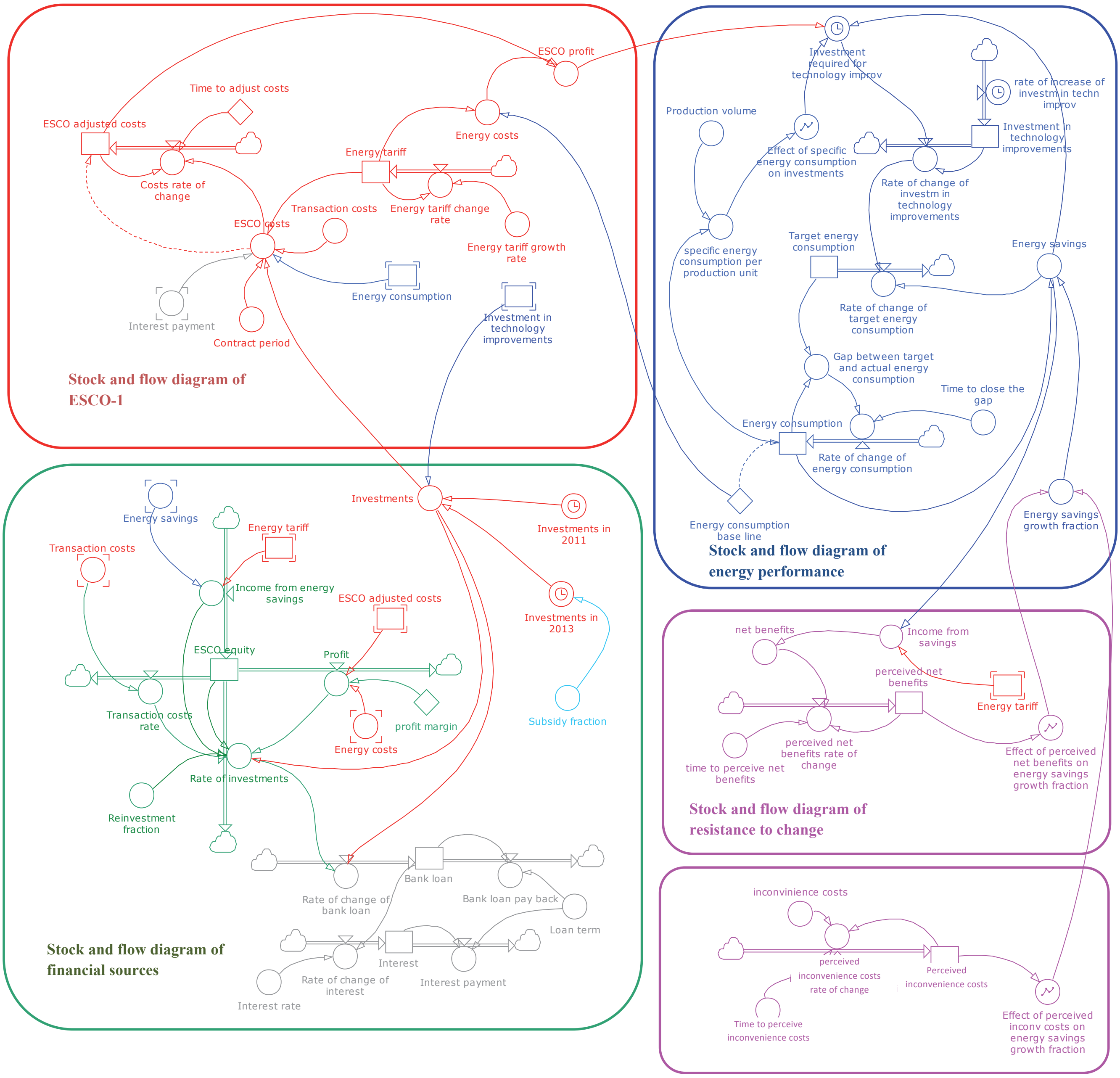


*Figure 3. Stock and flow diagram of the system dynamic model used by ESCO-1 for planning energy efficiency activities with an industrial partner. The model comprises four interlinked sub-models.*

energy efficiency measures. This money is spent on ESCO operational costs and profit and the rest is reinvested into new measures for new economically viable technology and solutions. The bank loan is taken if project cash flow needs additional resources in addition to subsidies and ESCO's own financial sources and resources from the industrial partner.

- *Stock and flow diagram of energy performance sub-model*, which is based on the stocks of actual energy consumption and target energy consumption. The rate of change of energy consumption is determined by the gap between target energy consumption and actual energy consumption. The target energy consumption is defined in the performance contract but it can be lowered if new energy efficient technologies enter the scheme. Effect of specific energy consumption on investments determines when any new technology is economically feasible to be installed by ESCO-1.
- *Stock and flow diagram of resistance to change sub-model.* Individual's resistance to energy performance contracting among the employees of the industrial partner is counted in the structure of the model as individual's net benefits and inconvenience costs. The higher the net benefits, the less the resistance to ESCO-1 activities, hence sharing savings with employees improves energy performance. The inconvenience costs comprise internal and external barriers faced by employees against the activities of ESCO-1, such as fear of new "unknown" tasks, security (loss of job), habits, selective information processing, etc... The higher the inconvenience costs, the higher the resistance to change and less energy savings are possible by ESCO-1. Inconvenience costs create

reinforcing feedback loop that can be weakened for example by training, better communication and negotiation.

This dynamic model helped ESCO-1 to set realistic targets for potential energy savings, considering a large variety of socio-economic variables, which affects their operation with the industrial partner. The model for ESCO-1 operating in the bio-ethanol plant includes important relationships and interactions among ESCO-1, employees of industrial partner and energy performance. It illustrates how the major four sectors are related in the common structure to show diverse nature of the problem. The main sub-models are under ESCO-1 costs and profit and ESCO-1 energy performance. These sub-models are closely linked with financial resources sector that supports investments in energy performance activities. The fourth sector describes the industrial partner employees resistance to change and addresses the barriers that exist for ESCO-1 activities within the enterprise. For example, the directors of department (e.g., chief technical engineer and process engineer) were very often hostile in providing the necessary information for the audit, like process layout documentation and information for mass and energy balances, and were not forthcoming with regard to field staff for visiting the plant. Often, the provided information was inaccurate or even wrong.

Human factors play a significant role for successful ESCO operation in the industrial sector, particularly at the initial phase. Relatively slow implementation of energy efficiency measures is connected with resistance of specialists of the industrial partner. ESCO-1 activities started with strong involvement of the specialists of the industrial partner, including dedicated training sessions. Discussions about the technological processes and a common vision for development are required for the local staff of the industry to develop a positive attitude toward the energy efficiency measures and the ESCO's activities. This positive attitude must be based on continuous improvement and feedback to the staff of the industrial partner. Consultations and cooperation during the energy audits with the specialists of the industrial partner resulted in finalisation of alternative measures and selection of priorities. The organisation of a team of specialists in plant forestalled resistance to the energy efficiency measures.

The results of the simulation are shown in Figure 4. ESCO-1 was funded in 2009. The baseline energy consumption was developed using historical data and the data collected during the energy audit. In energy terms, this was 50,000 MWh/year. The results of the simulation showed a potential target of 40,000 MWh/year. The actual energy consumption is adjusted to target consumption in 2011. The target then falls to 37,903 MWh/year in 2017, when ESCO-1 will install additional energy efficient technology.

## The situation after ESCO operation at the industrial site

After its establishment in 2009, ESCO-1 took over operation and maintenance of the boiler house, bringing in programmed maintenance practices, energy management and energy monitoring practices.

ESCO-1 introduced proper boiler water treatment programmes with regular water analyses, adequate regulated blow-downs, correct maintenance, periodic safety checks and periodic inspection In the beginning only a few small capital investments at the boiler were carried out, to solve the basic problems identified by the energy audit, dealing with pre-heating of heavy oil fuels and cleaning of the burners. The capital costs were covered by the industrial partner, while Energonams added all necessary human resources and know-how.

The results were very satisfactory. ESCO-1 managed to improve the overall efficiency of the boiler house from 84–87 % (measured during the energy audit) to 94 %. Data monitoring showed that fuel consumption versus bio-ethanol production was aligned to a normal correlation (see Figure 5).

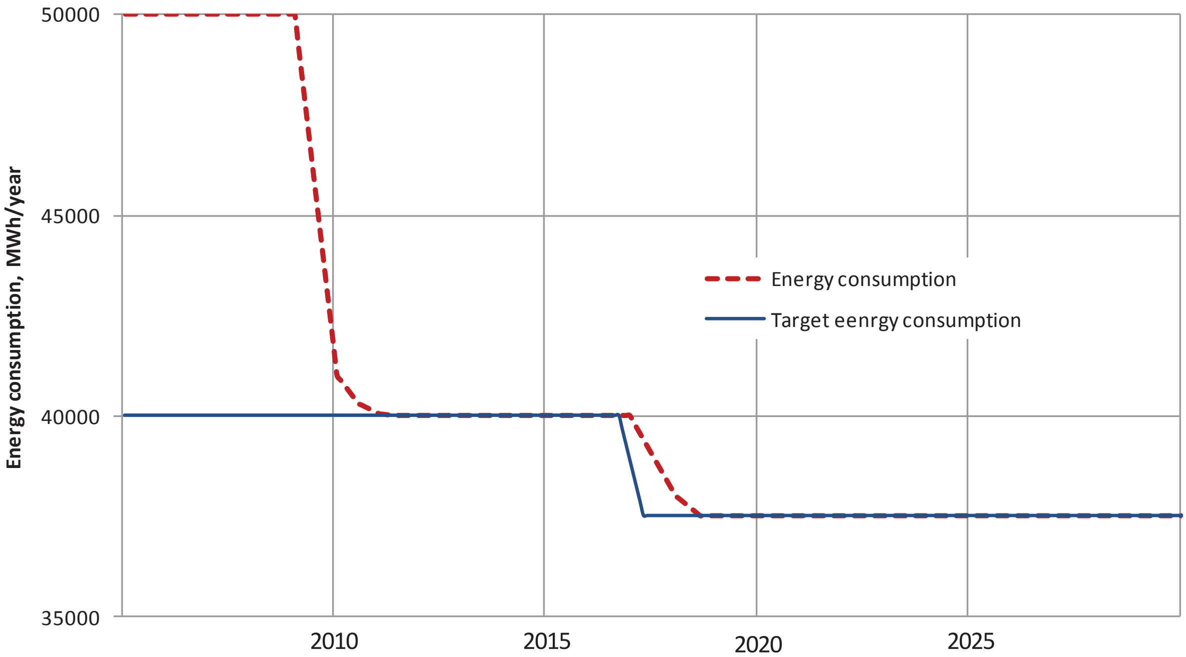


*Figure 4. Actual and target energy consumption computed from the System Dynamic Model.*

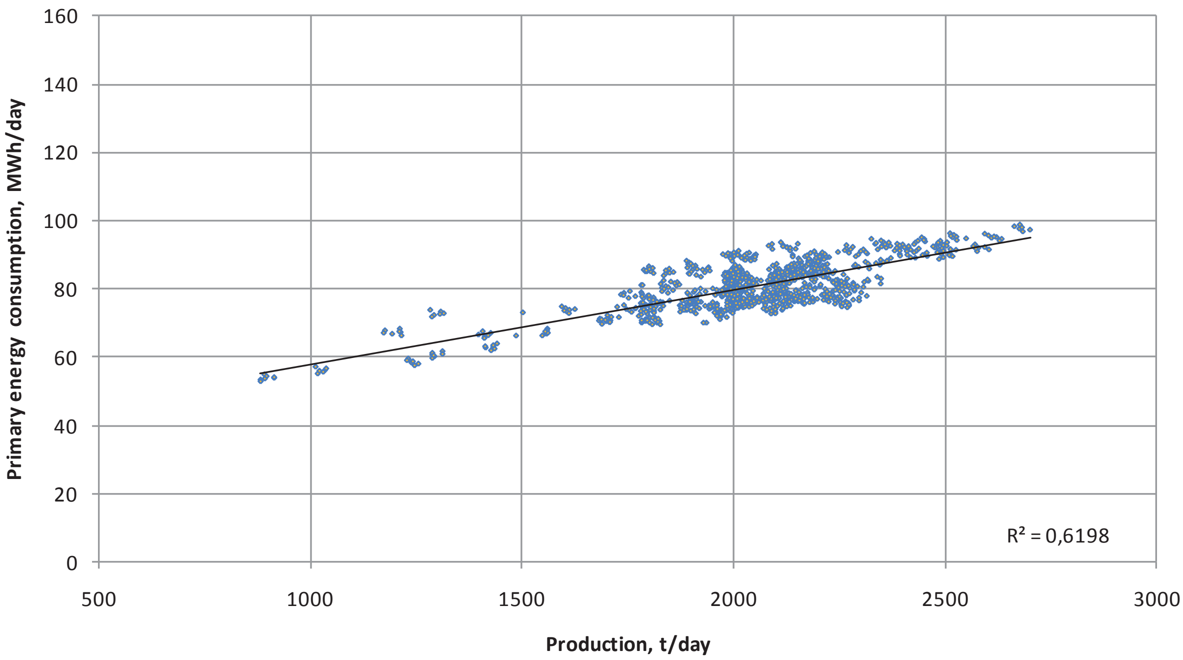


*Figure 5. Primary energy consumption for steam generation versus bio-ethanol production during two years of ESCO-1 operation.*

For achieving this result ESCO-1, besides operating the boiler house, has promoted improved energy management practices at the industrial plant, in particular regarding the operation of the fermenters and distillation towers. On average ESCO-1 achieved primary energy savings of about 7,000 MWh/year by increasing combustion efficiency and proper operation of the steam boilers.

This result was considered a success. Economically, the simple payback period is below three years and now the bio-ethanol plant can operate with a secured steam supply.

In the framework of the ChangeBest project, ESCO-1 added an energy performance contract to its energy delivery services for the industrial partner. Under this new contract ESCO-1 implemented a number of energy efficiency improvement (EEI) measures at the industrial site.

For this new service ESCO-1 carried out a second energy audit of the industrial site, this time focusing on the industrial processes. From this audit ESCO-1:

- identified the most important EEI measures;
- estimated the potential energy savings by each EEI measure;
- estimated the investment needed;
- acquired information for the baseline study.

Energy audit was carried out by Energonams as contribution to the necessary investment costs.

The EPC was prepared and signed based on the information collected in the audit and in agreement with the industrial partners. The services under the EPC are carried out with a network of companies, which are subcontracted:

- Engineering companies for technical design;
- Installation companies for actual implementation of EEI measures. When possible, available technical and maintenance staff from the industrial plant has been used for installation.
- ESCO-1 is the principal contractor and responsible for quality control and project supervision.

For this first field test, the EPC included a few promising measures, with low investment costs. Capital was raised by ESCO-1 as equity investment from the profit of the current EDC and from the industrial partner.

The investment includes the following measures:

- Installation of thermal insulation for the fermentation towers;
- Installation of thermal insulation for steam pipe distribution network;
- Replacement of some segments of the steam distribution network, reducing steam leakage;
- Replacement of one steam trap, increasing return of condensate; and
- Development and implementation of energy management procedures for the fermentation process and distillation process.

All energy savings from the EPC are granted to ESCO-1. The settlement is calculated on a yearly basis.

The results were monitored and verified by ESCO-1. Primary energy consumption versus bio-ethanol production was used as baseline indicator. The indicator is calculated and monitored on a daily basis. From the analysis of data for 120 days after the installation of the thermal insulation, energy savings of about 5 % have been verified. This means about 1,400 MWh/year of primary energy savings.

The implementation of this project allowed ESCO-1 to further improve the operation of the boiler house. In fact, peak

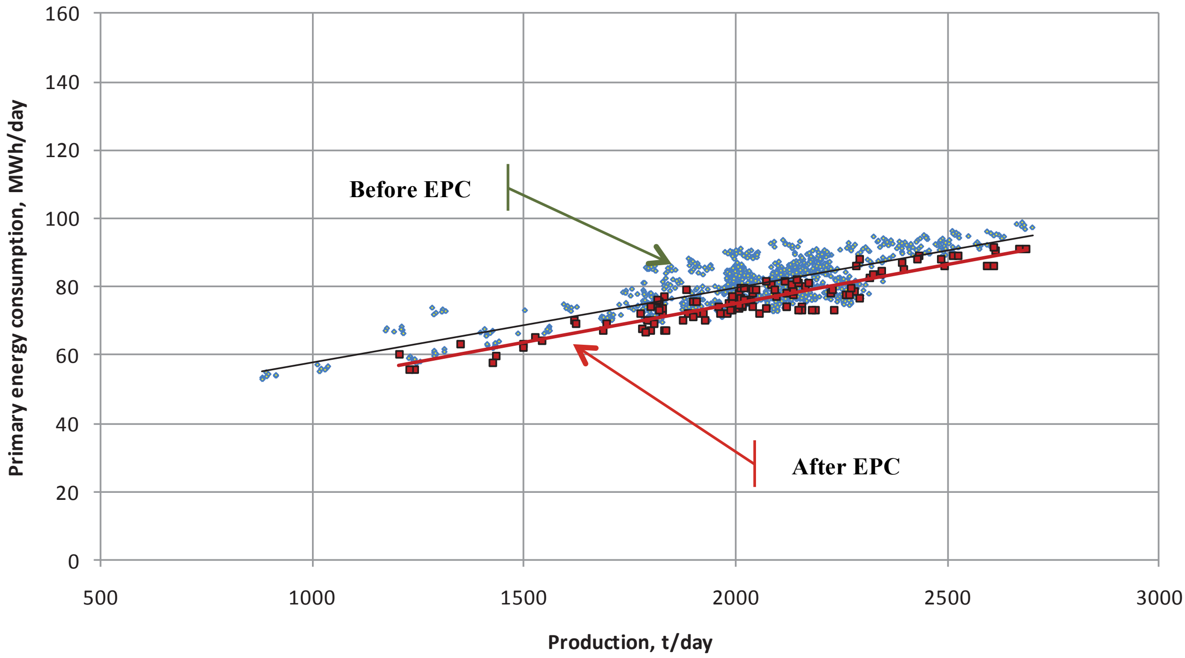


*Figure 6. Primary energy consumption for steam generation versus bio-ethanol production after ESCO-1 operation of the boiler house (round dots) and after the implementation of EEI (square dots).*

loads for steam demand were reduced. This helped to further improve the boiler house overall efficiency. The total energy savings since ESCO-1 was established therefore increased to about 9,000 MWh/year, of which 7000 MWh/year was achieved with the first investment and regulation of the steam boilers, 1,400 MWh/year as part of the EPC and additional 600 MWh/year from an additional increase of energy efficiency of the steam boilers after the implementation of the EPC.

The economic benefits of the EPC were good enough to cover the economic losses due to a decrease in steam demand from the bio-ethanol plant. Indeed the EDC set a guaranteed tariff in Euro/ton of steam. The implementation of EEI measure at the bio-ethanol plant has decreased steam consumption. So the net revenue for ESCO-1 is the revenue from the EPC minus the avoided costs for steam generation.

## Conclusions

In general, energy contracting is a service that helps to make industrial plant operation more efficient. With Energy Delivery Contracting, the industrial partner can concentrate on its core business, with a guarantee of efficient energy supply from a professional third party.

From the moment that the ESCO added Energy Performance Contracting, the industrial partner benefited from new or upgraded energy equipment and optimized operations. Moreover, the guarantee of savings by the ESCO made financing easier.

The establishment of a new company, with the ESCO and the industrial partner as shareholders, has a number of important benefits. The most important is that the top management and owners of the industrial plants are directly involved in the decision-making process. Their interest in energy delivery and energy efficiency notably improved.

For ESCOs operating in the industrial sector, the human factors at the site are often a severe barrier. Using this form of partnership, the new ESCO-1 is seen as a cooperative partner and as part of the "family". This makes communication and training more effective and constructive. This is extremely important for achieving energy savings with soft measures like demand side management programmes.

Another significant barrier to ESCO operation in the industrial sector is financing. The scheme used by Energonams with this bio-ethanol plant, partly mitigated this barrier, The management of the industrial plant is directly involved as shareholder on the board of the new ESCO company. In this way, investment in energy efficiency and energy supply become much more integrated in the general industry investment plan. The continuous dialogue with management keeps energy efficiency on the agenda. The level of professionalism and knowledge brought by Energonams was important for the preparation of proposals for subsidies for the energy efficiency project and renewable energy project, for example from the Green Investment Scheme in Latvia.

The guarantee of energy savings provided by the ESCO also helped in the dialogue with commercial banks, which are familiar with ESCO schemes.

There are a number of fiscal advantages in the scheme. For the ESCO, the new company can be seen just as a special investment vehicle. In this case Energonams stays as a development company, while ESCO-1 makes the capital investments in the industrial site.

This model is currently under replication at the second bio-ethanol industrial site.

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