Stand-alone versus integrated energy audit programmes – a comparison of Flemish programmes

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Abstract
This paper compared three energy audit programmes, implemented in Flanders, Belgium to test whether the type of energy audit has an impact on the type of the energy efficiency measures identified and whether stand-alone and integrated energy audit programme have different implementation rates of the identified energy efficiency measures. The three programmes are an integrated programme (voluntary agreement) with energy diagnosis type audits, a regional stand-alone energy audit programme with walk-through audits, and a local integrated energy audit programme with walk-through audits.

This paper proposes a method to describe these energy audit programmes. The basis of this method is a list of key elements that determine the nature of the energy audit programme. The method groups these key elements per involved party and per phase of the programme. This paper also proposed a taxonomy to categorize energy efficiency measures. The taxonomy organises the measures according to two dimensions: the type of modification and the type of end-use that is targeted.

The comparison of the three Flemish energy audit programmes reveals that walk-through audits tend to focus on less challenging energy efficiency measures, such as good housekeeping measures, and that energy diagnosis type audits are more successful in identifying more challenging measures, such as process related ones.

The comparison of the three Flemish energy audit programmes indicates a higher implementation rate for the more integrated programmes than for the stand-alone energy audit programmes, but also lower energy saving potential. The comparison could however, due to statistical uncertainty, not provide hard evidence that these differences can be explained by the type of energy audit programme.

Introduction
The European Energy Efficiency Directive 2012/27/EC defines an energy audit as "a systematic procedure with the purpose of obtaining adequate knowledge of the existing energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation or a private or public service, identifying and quantifying cost-effective energy savings opportunities, and reporting the findings". The purpose of an energy audit is hence to bridge the knowledge gap on the energy consumption and the possible actions to save energy. Studies on barriers on industrial energy efficiency, such as Trianni, A., Cagno, E., 2012 or Fleiter et al., 2012, confirm that this knowledge gap is still wide spread, also in the industry. Not surprisingly, an energy audit is a key component in many energy efficiency programmes and a first step in improving energy efficiency in industry (Caffal, 1995; Bunse et al., 2011).

Energy audits can vary in depth, details and accuracy. Standard ISO 50002:2014 (2014) differentiates between three types of energy audit:

1. Walk-Through Audit: aiming at identifying maintenance, operational or deficient equipment issues and resulting in identification and a qualitative assessment of energy saving opportunities.
2. Energy Diagnosis: includes economic calculations, eventually also some metering campaigns to identify actual energy consumption and losses; resulting in an energy balance of

the facility and a financial analysis of each of the identified energy efficiency measures.

3. Investment Grade Audit: includes a detailed account of energy use and a quantitative study of the implementation with detailed investments and operational and maintenance costs and an analysis of the investment model.

Besides the variation in type of energy audits, the way they are embedded in energy efficiency programmes can vary as well. Price and Lu (2011) carried out a survey of twenty-two energy audit programmes targeting the industry in sixteen countries around the world. They made a distinction between stand-alone energy audit programmes and integrated energy audit programmes. The former type focuses mainly on the execution of as many energy audits as possible. The latter kind combines energy audits with other supporting policy measures, to increase the implementation rate of the suggested energy saving measures in the energy audit report. Supporting measures may include energy efficiency targets for the participants (mandatory or voluntary), guidance on the implementation of the identified energy efficiency measures or knowledge exchange between companies. Price and Lu (2011) conclude from their analysis that, because of this integration with other policy measures, integrated policy programmes with energy audits can be a good model. They also observed that the different stand-alone energy audit programmes from various countries have key elements in common, such as the provision of standardized manuals for energy auditing or follow-up calls and/or visits after energy audits, leading to the conclusion that one country can learn from the good practices from another.

The aim of this paper is to compare three energy audit programmes in Flanders, Belgium. Each of these programme target the industry and has an energy audit as a key component; however, they differ in the size of companies targeted, as well as the extent of the energy efficiency programme:

- The Auditing Covenant: a voluntary agreement targeting medium-sized industrial companies, operational in the whole of Flanders from 2005 until 2014; the participants commit themselves to carry out an energy diagnosis type audit and to implement all energy efficiency measures with a minimum economic feasibility.
- A stand-alone energy audit programme, operational in the whole of Flanders from 2008 and 2013 (first programme) and from 2013 to 2015 (second programme), offering walk-through type energy audits free of charge (both programmes), followed by energy diagnosis type of energy audits for the most promising energy efficiency measures at reduced cost (first programme only).
- A local more integrated energy audit programme, in the City of Ghent, targeting industrial companies that are out of the scope of the Auditing Covenant. A walk-through energy audit was offered to the participants at reduced cost; the participants committed themselves to implement all energy efficiency measures with a minimum economic feasibility; they received in return guidance on how to implement these measures.

Another programme that could be added to the list is a first learning network on energy efficiency. Nine industrial companies from the Province of Limburg participate to this network that lasts for four years. A walk-through type energy audit is carried out in first year by an independent energy consultant. The participants then agree on a common energy efficiency target based on the energy audit results. They then meet quarterly during these four years to learn more about energy saving measures and to exchange experience on the implementation. As this learning network has started in the beginning of 2016, no final results on the energy audits are available at the time of drafting this paper. As a consequence, this integrated energy audit programme is not included in this analysis.

The comparison of the above-mentioned energy audit programmes aims at understanding whether the type of energy audit has an impact on the type of the energy efficiency measures (EEMs) identified and whether the type of energy audit programme – stand-alone versus integrated – has an impact on the implementation rates of these measures.

The structure of the paper is as follows: the next chapter explains the method to describe the energy audit programmes and the method to characterise the energy efficiency measures. The third chapter describes the three energy audit programmes and the energy efficiency potential that was identified by these programmes. The fourth chapter compares the three energy audit programmes to answer the research questions. The last chapter discusses the findings and draws some conclusions from this analysis.

Methodology

METHOD TO DESCRIBE THE ENERGY AUDIT PROGRAMMES

An appropriate method to describe energy audit programmes is by means of a list of key elements; key characteristics that allow to differentiate in a significant way between programmes.

Price and Lu (2011) applied a set of six key elements at analyse the six stand-alone energy audit programmes, they have spotted in their survey:

- The extent in which the cost of energy audits are reduced by government interventions: partly or entirely.
- Whether the programme provides standardized manuals and tools for energy auditing that can improve the quality of the energy audit.
- The provision of training for energy auditors to improve their skills.
- Certification of energy auditors to ascertain their quality.
- The provision of follow-up calls and/or visits after energy audits to stimulate the implementation of the identified energy efficiency measures.
- Whether or not databases are built with the energy audit results that can be consulted to inspire other industrial companies about the energy efficiency potential and whether or not the programme provides case studies as showcases of the energy efficiency potential.

To describe the sixteen integrated energy audit programmes, Price and Lu (2011) applied a set of five key elements:

- Whether participation to the energy audit programme is voluntary or mandatory.
- Whether conducting energy audits is mandatory or voluntary.
- Whether the participants need to meet energy efficiency targets.
- Whether or not the implementation of an energy management scheme is mandatory.
- Incentives to the participants: either subsidies for the energy audits, and/or exemption of an energy or CO_2 tax.

Cornelis (2016) reviewed literature on voluntary agreements on industrial energy efficiency specifically. This review revealed eleven success factors. Three of these eleven factors seem to be key:

- The motivation of both industry and the government to enter into an agreement.
- Ambitious energy saving targets.
- Incentives for participation and penalties for non-compliance.

The following eight success factors are cited to a lesser extent by the reviewed studies:

- The extent in which the voluntary agreement is embedded the other policy mixes.
- Flexibility in implementing the agreement.
- Commitments to individual participants rather than to the participants as a group.
- Powerful, competent authorities.
- Stringent monitoring and verification procedures.
- The implementation of energy management schemes.
- Involvement of third parties, such as consultants, supporting the individual participants in fulfilling their obligations under the agreements.
- Knowledge sharing, information exchange amongst the individual participants, supported by the administrator and/or third parties (consultants, technology providers).

Table 1 combines these key elements. They are grouped per involved party: the authorities, which include the office in charge of managing the programme, the participants and the energy auditors. The key elements are further subdivided into three phases: the start of the programme, the execution of the energy audits and the support to the implementation of the energy efficiency measures, identified by the energy audits. Some indicators, indicating the effect of the energy audit programme are added as well. These key elements will be used to describe the three Flemish energy audit programmes.

TAXONOMY TO CATEGORIZE THE ENERGY EFFICIENCY MEASURES

This paper wants to test whether conducting a different type of energy audit leads to different energy efficiency measures. This test hence requires a method to categorise the identified energy efficiency measures (EEMs).

The taxonomy, proposed in this paper, is organised according to two dimensions, inspired by schemes proposed by Fleiter et al. (2012) and Trianni et al (2014). First, the EEMs are categorised according to the type of modification. A distinction is made between:

- Procedures: general good housekeeping measures, awareness raising, monitoring of energy data, the implementation of an energy management scheme, improved maintenance of equipment, …
- Optimisation: EEMs optimising the loads of equipment, either by switching them off, shifting its function in time or by installing control units; EEMs in which the set-points of

Table 1. Selection of the key elements to describe the energy audit programmes.

	Start of the programme	Conducting energy audits	Follow-up of energy audit results
Authorities	• Motivation to start project? • Scope of the programme? • Targets for the programme?	• Manuals, tools?	• Support to implementation? • Monitoring, verification procedures? • Databases, showcases? • Knowledge sharing?
Participants	• Obligation to participate? • Targets for the participants? • Obligation to conduct an energy audit? • Obligation to implement energy efficiency measures? • Incentives?	• Type of audit?	• Obligation to implement energy management scheme?
Energy auditors		• Training? • Certification?	
Effect	• Outreach?	• Identified energy saving potential?	• Actual implementation rate?

the equipment are adjusted to allow a more energy efficient operation.

- Technology add-on: any EEM that add components or modify the plant design to increase the energy efficiency, such as insulation measures or heat recovery.
- Technology replacement: any EEM involving the replacement of equipment (partly or entirely) by a more energy-efficient device.

Second, they are categorized according to type of end-use in the industrial company that is targeted by the EEM. A distinction is made between:

- General: EEMs that target no specific system of the industrial company and that consist of evaluation and follow-up measures.
- The electricity system: EEMs that are directly related to improve the power system; these include:
  - Any modification to an electric engine to the electricity system, even when it is explicitly indicated that the engine is connected to another system, such as for instance compressed air.
  - Any installation of a variable speed driver (VSD) is allocated to this category as well.
  - Any installation of a renewable electricity production unit (PV, cogeneration, heat pump, …).
- Building related EEMs, further subdivided into measures that aim to optimise:
  - The building envelope.
  - The heating, ventilation and air conditioning system (HVAC) within the building.
  - The lighting system.
- Air carriers: further subdivision could be made into EEMs targeting the compressed air system and the vacuum system. This is not done in this study as no EEMs targeting the vacuum system in SMEs were identified.
- Heat carriers: further subdivided into EEMs targeting:
  - The steam system, and
  - The thermal oil system.
- Cooling carriers, aiming at systems dispatching excess heat from processes; this includes cooling towers, chillers, fridges and deep freezers. It does not include systems aiming at conditioning the inside air of a building. It should be noted that making a clear distinction between both is challenging at times.
- Production processes, which is not further subdivided.

Table 2 lists some typical EEMs in the cross sections of both dimensions. The application of this taxonomy to the individual identified EEMs of the three Flemish energy audit programme is based on their description by the energy auditor. This categorisation is challenging at times because, typically, the description is no longer than one sentence and sometimes one word.

Description of the energy audit programmes

THE AUDITING COVENANT

Start of the programme

The Auditing Covenant was proposed by the Flemish Government within the framework of the first Flemish Climate Policy Plan 2002–2005. It started in 2005 and expired at the end of 2014. The covenant targeted medium-sized industrial companies, more particularly industrial companies with an annual primary energy consumption of between 0.1 and 0.5 PJ and that are not covered by the European ETS. The programme had an indicative target: the Flemish Government expected to save 10 % of primary energy by 2013 compared to a business-as-usual scenario.

The Auditing Covenant is a voluntary agreement; companies from the target group were free to accede. Once acceded, they had the obligation to conduct an energy audit within the first year of the programme and to renew it within the fourth year. All EEMs with an internal rate of return (IRR) of at least 15 % (first energy audit) or 13.5 % (second energy audit) has to be implemented within four years. No other energy efficiency or energy saving target was imposed on the participants. In return for these obligations, the participants received tax reductions on electricity and some fuels.

Conducting the energy audits

The Verification Office, in charge of administering the covenant, issued templates for the energy audit reports and for listing the identified EEMs. The office also approved the energy auditors, who were selected by the participants. No manuals were offered to the energy auditors, nor were trainings organised. The type of energy audit was an energy diagnosis.

Follow-up of the energy audit results

The implementation of the cost-efficient EEMs (an IRR of at least 15 % or 13.5 %) was imposed by the Audit Covenant. The Verification Office had hence the task to verify that this implementation took place. To this end, monitoring and verification procedures were issued. A software tool to facilitate the monitoring process was developed as well, but eventually the participants did not use it. This implementation process was not supported by illustrative showcases, instructive databases or by knowledge sharing amongst the participants. Nor was there an obligation to implement an energy management scheme.

Effect of the Auditing Covenant

In total 229 industrial companies acceded to the Auditing Covenant at the start. Their annual primary energy consumption amounted to 44 PJ, representing about 10 % of total industrial energy consumption of Flanders.

The first energy audit resulted in 2,324 EEMs, which altogether would save 4.7 PJ of primary energy if all implemented. Table 3 shows the breakdown of the identified EEMs according to the proposed categorisation. About half of these EEMs (1,334 EEMs – 2.0 PJ primary) had an IRR of at least 15 % and were hence mandatory to implement. Eventually 1,785 EEMs were implemented, corresponding to an annual primary energy saving of 2.5 PJ. For more details on the Audit Covenant is referred to Cornelis and Reunes, 2012, and Cornelis, 2014.

Table 2. Categorisation of the some typical energy efficiency measures in industry, applied in this study.

	Procedures	**Optimisation**	**Technology add-on**	**Technology replacement**
General	Energy audits The implementation of an energy management scheme Any other monitoring of energy data Awareness raising actions amongst employees	Switching off office equipment (such as computers)		
Electricity system	Monitoring of the no load losses	Installation of a variable speed driver (VSD) Charging batteries at night-time rather than at day time	Installation of batteries to correct of cos ϕ deviations Installation of photovoltaic panels, Installation of cogeneration units	Replacement by High Efficiency engines
Building envelop			Insulation of roofs and walls Installation of overhangs	Replacement of windows
HVAC		Reduction of the room temperature Motion detectors to control gate movements	Heat recovery Installation of destratificators Installation of solar hot water boiler	Replacement by a more efficient device, such as a condensing boiler or a heat pump Fuel switch (typically from heating oil to natural gas)
Lighting	Awareness raising to switch off the light when leaving the room	Installation of motion detectors		Relighting Relamping
Compressed air	Leak detection	Reduction of the compressed air pressure Postponement of operation	Heat recovery Suction of outdoor air instead of indoor air Redesign of compressed air network	Replacement of nozzles, compressor, any other component
Steam	Monitoring of the heat losses Inspection of condense return tanks	Reduction of steam pressure	Insulation The installation of an economiser or a flue gas condenser Any other type of heat recovery	
Thermal oil	Monitoring of the heat losses		Insulation	
Cooling systems	Improved maintenance, for instance more regular de-icing	Installation of a device to control the condensing pressure	Insulation Heat recovery Free cooling Any other modification of the concept of the cooling system	
Production processes		Reduction of temperature of furnaces	Heat recovery	Replacement of process equipment by a more energy efficient type Redesign of the production process to a more energy efficient process

Table 3. Energy efficiency measures identified in the first phase of the Audit Covenant.

	PES: Primary Energy Savings	Procedures	Optimisation	Technology add-on	Technology replacement	SUM
General	*Total number of EEMs*	*63*				*63*
	PES (GJp)	**125**				**125**
Electricity	*Total number of EEMs*		*261*	*34*	*68*	*363*
	PES (GJp)		**309**	**393**	**15**	**717**
Building	*Total number of EEMs*	*11*	*56*	*41*	*33*	*142*
	PES (GJp)	**19**	**63**	**77**	**48**	**207**
Lighting	*Total number of EEMs*	*2*	*98*	*5*	*110*	*215*
	PES (GJp)	**1**	**32**	**2**	**89**	**123**
Compressed air	*Total number of EEMs*	*114*	*101*	*92*	*22*	*329*
	PES (GJp)	**120**	**105**	**87**	**49**	**361**
Steam	*Total number of EEMs*	*36*	*63*	*235*	*17*	*351*
	PES (GJp)	**59**	**84**	**577**	**53**	**773**
Thermal oil	*Total number of EEMs*		*1*	*27*	*1*	*29*
	PES (GJp)		**1**	**46**	**1**	**48**
Cooling installations	*Total number of EEMs*	*5*	*116*	*104*	*21*	*246*
	PES (GJp)	**12**	**156**	**234**	**56**	**459**
Process	*Total number of EEMs*	*16*	*238*	*260*	*72*	*586*
	PES (GJp)	**34**	**430**	**968**	**412**	**1,843**
SUM	*Total number of EEMs*	*247*	*934*	*777*	*345*	*2,324*
	PES (GJp)	**369**	**1,179**	**2,383**	**723**	**4,655**

FIRST REGIONAL ENERGY AUDIT PROGRAMME, OPERATED BY ENTERPRISE FLANDERS

The Flemish agency Enterprise Flanders implemented two energy audit programmes, a first from Nov 2008 to Oct 2013, a second from Nov 2013 to Dec 2015. The two programmes are discussed one by one.

Start of the first regional energy audit programme

Enterprise Flanders – now Flanders Innovation & Entrepreneurship – is a government agency, supporting companies in many aspects, amongst others with advice on the energy saving and the renewable energy potential in the companies by conducting a walk-through energy audit (Enterprise Flanders, 2014).

The agency ran an ERDF[1] project 'Rational Energy Use in SMEs' from November 2008 to October 2013 to enforce this service. The project allowed to offer more walk-through energy audits. In addition, it allowed to offer more detailed energy audits (thematic advice) to assess the technical and economic feasibility of some of the promising energy efficiency measures that were identified in the walk-through audits.

This energy audit programme targeted companies with an annual electricity consumption of at least 20 MWh or an annual fuel consumption of at least 50 MWh. Companies that can accede the Audit Covenant were excluded from this programme.

The walk-through energy audits were offered without charge. The thematic advices were offered at one third of the cost with a maximum subsidy of €3,000; later modified into a reduction of 50 % with a maximum subsidy of €5,000.

Conducting the energy audits in the first programme

The walk-through energy audits were carried out by seven account managers of Enterprise Flanders itself.

The first step in these audits was an analysis of the electricity and fuel invoices of the last twelve months. This analysis included a comparison of the electricity consumption at daytime and night-time with the monthly average active and reactive power. Benchmark values on the fuel consumption (e.g. on specific fuel consumption/m² for heating) were derived from the energy data as well.

The second step consisted of listing the most energy consuming equipment and by estimating their number of operational hours per year. This allowed to estimate the energy consumption and the associated energy cost of these devices. As a final step, energy efficiency measures were proposed; this included an estimation of the energy savings, the investment costs and the pay-back time. These findings were summarized in a report and consequently discussed with the managers of the examined company.

1. European Regional Development Fund.

The thematic advices were carried out by external energy consultants. They were selected by the companies; they elaborated the technical-economic feasibility of some of the EEMs more into depth.

Follow-up of the energy audit results in the first programme

The companies could apply for a more thorough analysis of the technical and economic feasibility of the most promising EEMs resulting from the walk-through audit; these were the thematic advises, described above. The programme offered, apart from this, no additional support to foster the implementation of these EEMs.

Effect of the first regional energy audit programme

Walk-through energy audits were carried out for in total 520 companies[2] (Enterprise Flanders, 2014). About one third of these (194 in total) had less than 10 employees, another third 10 to 50 employees. Half of the companies had an annual electricity bill less than €25,000 and three quarter had an annual fuel bill less than €25,000. The aggregated annual primary energy consumption of these companies[3] is 3.01 PJ electricity and 1.37 PJ fuel (1.09 PJ of natural gas and 0.28 PJ of heating oil).

The walk-through energy audits resulted in 1,715 identified EEMs: 1,173 to save electricity and 542 to save fuel. The energy savings could be estimated for 1,276 of these 1,715 EEMs. Their aggregated primary energy savings amount to 0.14 PJ electricity or 4.72 % of the total electricity consumption and to 0.14 PJ fuel or 9.46 % of the total fuel consumption.

The top five categories of EEMs were (ranked according to their number – about five sixth of all EEMs):

1. Lighting (about 670 EEMs).
2. Heating system (about 320 EEMs).
3. Compressed air (about 280 EEMs).
4. Electricity (about 130 EEMs).
5. Building envelop (about 100 EEMs).

These walk-through energy audits were followed by 106 thematic audits carried out by independent consultants, resulting in 250 identified EEMs. Table 4 presents the breakdown of these EEMs according to the energy system. Their aggregated primary energy savings (the installation of a PV or cogeneration unit is not included in these figures) amount to 0.075 PJ electricity and to 0.060 PJ fuel.

A survey was carried out at the end of the programme to learn more about the motivation of the participants to ask for an energy audit, the quality of the energy audit and the implementation rate of the proposed EEMs. A questionnaire was sent to the participating companies; one in three companies that received the walk-through audit (168 of the 520) responded to it. Less than half of the respondents indicated to consider the energy efficiency potential as a result of the programme; more than half already had a history of improving the energy efficiency of their company before the programme. About 72 % of the respondents indicated that they would implement the suggested EEMs. Half of the companies that received subsidies for the thematic advice (20 of the 40) responded the questionnaire as well. In total 16 of these 20 indicated that the thematic advice resulted in an investment decision.

Start of the second regional energy audit programme

Enterprise Flanders concluded from the overall energy audit results and from the response to the questionnaire that the first programme was effective in stimulating the energy efficiency in industrial SMEs. Hence, it was decided to continue the energy audit programme. The second project targeted the same type of companies. It only offered walk-through energy audits, free of charge (Enterprise Flanders, 2015).

Conducting the energy audits in the second programme

The energy audits were, in contrast to the first project, not carried out by the staff of Enterprise Flanders, but by five independent energy consultants who were selected following a public tendering procedure. The procedure of the walk-through audits was the same as in the first project.

Follow-up of the energy audit results in the second programme

This second programme did not offer a more in-depth analysis of the most promising EEMs, nor did it foster their implementation.

Effect of the first regional energy audit programme

Exactly 400 energy audits were carried out in this second project (Enterprise Flanders, 2015). There was a more even distribution in size of companies compared to the first project. The mean electricity consumption was 400 MWh/a; the mean fuel consumption 266 MWh/a. The aggregated annual primary energy consumption of these companies[4] is 3.72 PJ electricity and 1.39 PJ fuel (0.96 PJ of natural gas and 0.43 PJ of heating oil and propane).

The energy audits resulted in 2,812 identified and quantified EEMs. The total identified electricity savings amount to 0.74 PJ primary, corresponding to 20 % of the total electricity consumption. The total identified fuel savings amount to 0.24 PJ primary, corresponding to 16.8 % of the total fuel consumption.

The top five categories of EEMs were (ranked according to their number):

1. Relighting and relamping (671 EEMs).
2. Replacement of the boiler (258 EEMs).
3. Installation of a variable speed driver (235 EEMs).
4. Other modifications to the heating system (184 EEMs).
5. Good housekeeping measures (185 EEMs).

These five categories of EEMs represent about 52 % of the total identified primary savings. An additional 22 % could be saved by producing electricity themselves via a PV installation or a cogeneration unit. Table 5 shows the breakdown of all identified EEMs according to the proposed categorisation.

2. Audits were also carried out for 259 new to build companies. Results are not provided of these audits.

3. Data available of 512 out of the 520 companies.

4. Data available of 398 out of the 400 companies.

Table 4. Energy efficiency measures resulting from the thematic energy audits of the first project of Enterprise Flanders.

	Nr of EEMs	Total savings (GJ_p)	Relative savings (% bill)	Pay-back time (a)	Main types of EEMs (number of EEMs)
General / electricity	13	E: 3,885	E: 6.6 %	4.7	Installation of VSD; monitoring and analysis of energy consumption; charging batteries at night-time (n.i.).
Electricity – PV	14	E: 24,560	n.i.	8.1	Installation of photovoltaic panels (14).
Electricity – CHP	4	n.i.	n.i.	6.0	Installation of a cogeneration unit (4).
Heating	69	F: 31,611	F: 8.2 %	7.4	Control of heating equipment (22); insulation (17); replacement of boiler by a condensing one (13); heat recovery (7); installation of ceiling ventilation (4) and others (6).
HVAC	26	E: 7,148 F: 1,348	E: 4.4 % F: 3.1 %	2.0	Control of HVAC system (n.i.).
Heating – HP	12	n.i.	n.i.	18.7	Installation of a heat pump.
Lighting	46	E: 17,053	E: 7.2 %	3.2	Relighting (30); motion or daylight detectors (16).
Compressed air	18	E: 6,668	E: 4.5 %	0.6	Leak detection and repair (9); replacement of compressor by a VSD controlled one; reduction of pressure; replacement of filters (n.i.).
Steam	12	F: 6,508	F: 2.2 %	2.1	Insulation; reduction of steam pressures; prevention of downtime losses (n.i.).
Cooling (°)	10	E: 14,310	E: 3.5 %	3.4	Control of cooling installation (n.i.). (°) One measure, which deals with the replacement of the complete cooling installation, is not included in these figures in view of the substantial savings compared to the other nine measures.
Process – heat	26	F: 20,449	F: 7.3	4.3	Replacement of boiler by a condensing one; installation of a flue gas condenser; insulation of equipment; optimised control of process equipment; heat recovery (n.i.).

E: electricity; F: fuel; n.i.: number of EEMs not indicated.

A survey was carried out at the end of this second energy audit programme as well. The response rate was about 40 % (369 questionnaires sent out – 143 returned). More than half of these respondents indicated to have change their attitude towards energy and about three quarter indicated that the energy audit resulted in an investment decision. The highest implementation rate was observed for EEMs touching the compressed air (68 %), ventilation (67 %), steam (62 %) and lighting (61 %) systems. The implementation rate of EEMs changing procedures (70 %) or optimising the operation of equipment (69 %) was higher than of EEMs replacing equipment (56 %) or adding equipment (44 %). On average 49 % of the EEMs were implemented, responding to 47 % of the identified energy saving potential.

One of the questions of the survey concerned the willingness to pay for the energy audit when it would no longer be offered free of charge. The full cost of the walk-through energy audit was about €2,000. About half of the respondents (49 %) indicated that they did not want to pay at all for such an audit; only 3 % was willing to pay its full cost.

THE ENERGY AUDIT PROGRAMME OF THE CITY OF GHENT

Start of the local energy audit programme

The City council of Ghent has the ambition to turn Ghent into a climate neutral city by 2050 (City of Ghent, 2014). As 40 % of the city's CO_2 emissions origin from private companies, it was decided to implement an energy audit programme aiming at reducing their demand for energy. A pilot programme was started as part of an InterReg-project[5]. The pilot started at the end of 2012 and the final evaluation took place in June 2014.

The scope of the programme was private companies, both of the industrial and tertiary sectors. Companies that are covered by the European Emission Trading Scheme and/or participants of the Audit Covenant were excluded.

Each participant signed a declaration with several commitments; one of the commitments was to implement all identified EEMs with a payback time of less than 2 years.

The participants to the pilot were offered a 90 % reduction of the cost of the coaching trajectory (worth €4,000, excluding VAT). Half of the cost was covered by the InterReg funding, 22 % by a federal fund and 28 % by the City of Ghent.

Conducting energy audits and follow-up of the energy audit results in the local energy audit programme

The ambition of the programme was to go beyond a stand-alone energy audit, which was considered as not sufficient to trigger enterprises to take action and reduce their carbon footprint. To this end, the pilot programme took a three steps' approach:

- Step 1: energy audit and calculation of potential energy and financial savings.

5. The INTERREG IVA 2 ACE – Answers to the Carbon Economy project – http://www.ace-low-carbon-economy.eu/en/.

Table 5. Energy efficiency measures resulting from the second energy audit project of Enterprise Flanders.

		Procedures	Optimisation	Technology add-on	Technology replacement	SUM
General	*Total number of EEMs*	*185*	*25*			*210*
	Number with estimated savings	184	25			209
	Prim. energy savings (GJp)	**93.189**	**856**			**94.045**
Electricity	*Total number of EEMs*	*60*	*235*	*157*	*22*	*474*
	Number with estimated savings	60	226	154	14	454
	Prim. energy savings (GJp)	**35.656**	**39.501**	**206.039**	**1.816**	**283.013**
Building	*Total number of EEMs*		*4*	*100*	*30*	*134*
	Number with estimated savings		3	100	29	132
	Prim. energy savings (GJp)		**136**	**30.909**	**3.570**	**34.615**
HVAC	*Total number of EEMs*	*5*	*101*	*184*	*258*	*548*
	Number with estimated savings	4	101	179	258	542
	Prim. energy savings (GJp)	**283**	**13.098**	**54.823**	**79.805**	**148.008**
Lighting	*Total number of EEMs*		*122*		*671*	*793*
	Number with estimated savings		121		671	792
	Prim. energy savings (GJp)		**6.236**		**213.859**	**220.095**
Compressed air	*Total number of EEMs*	*160*	*77*	*105*	*52*	*394*
	Number with estimated savings	160	74	104	50	388
	Prim. energy savings (GJp)	**22.187**	**8.959**	**12.405**	**1.341**	**44.891**
Steam	*Total number of EEMs*		*1*	*39*	*1*	*41*
	Number with estimated savings		1	39	1	41
	Prim. energy savings (GJp)		**375**	**13.417**	**179**	**13.971**
Thermal oil	*Total number of EEMs*			*5*		*5*
	Number with estimated savings			5		5
	Prim. energy savings (GJp)			**1.306**		**1.306**
Cooling installations	*Total number of EEMs*	*4*	*78*	*48*	*15*	*145*
	Number with estimated savings	4	48	44	15	111
	Prim. energy savings (GJp)	**81**	**15.131**	**18.240**	**32.093**	**65.545**
Process	*Total number of EEMs*	*2*	*8*	*35*	*23*	*68*
	Number with estimated savings	2	8	35	22	67
	Prim. energy savings (GJp)		**1.139**	**16.406**	**6.959**	**24.504**
SUM	*Total number of EEMs*	*416*	*651*	*673*	*1.072*	*2.812*
	Number with estimated savings	414	607	660	1.060	2.741
	Prim. energy savings (GJp)	**151.396**	**85.430**	**353.545**	**339.622**	**929.993**

- Step 2: draw up an energy action plan (validated by management).
- Step 3: coaching on implementation of measures and refining of investment analysis.

This coaching consisted of a discussion with the management on how to implement the promising EEMs, including the identification of potential bottlenecks or subsidies.

An energy consultant was appointed by the City of Ghent to conduct the energy audits. An electronic tool was developed to smoothen the audit process; its aim was to present an overview of the company's energy data and of the identified EEMs.

Effect of the local energy audit programme

Fifteen companies applied to participate to the pilot programme. They had diverse economic activities (automotive, food industry, cooling and storage, research centre, textile, hospital, steel construction, plastic processing, lubricants, printing, concrete and engines). The participants had a primary energy consumption between 4 and 100 TJ (on average 38.5 TJ; total 577 TJ).

More than 200 EEMs were proposed by the energy consultant, corresponding to a total potential energy saving of 71 TJ primary energy or to 13 % of the energy cost (varied from 1 % up to 29 % depending on the company). The top 5 EEMs were

– see Table 6 for a breakdown according to the proposed categorisation of EEMs:

1. The optimisation of the HVAC-system (21 EEMs).
2. General good housekeeping measures (21 EEMs).
3. Modification to the steam system (insulation or heat recovery mainly) (19 EEMs).
4. Process optimisation (15 EEMs).
5. Installation of sensors for the lighting system (12 EEMs).
6. Insulation of the building envelope (12 EEMs).

It was observed that 55 % of the total savings can be attributed to only ten EEMs in various categories. The distribution of the identified savings might hence be less representative.

Half of the identified EEMs were implemented (or planned at the time of the follow-up), corresponding to 35.5 TJ primary energy (6.2 % of the total). Investments with payback periods between 2 and 6 years were often still to be implemented, as they faced competition with investments in production processes.

20 % of the participating enterprises obtained an ISO 50001 certificate as a result of their participation to this pilot programme. The remaining 80 % of the participants have gained

Table 6. Energy efficiency measures resulting from the pilot energy audit project of the City of Ghent.

		Procedures	Optimisation	Technology add-on	Technology replacement	SUM
General	*Total number of EEMs*	*21*				*21*
	Number with estimated savings	5				5
	Prim. energy savings (GJp)	**1.743**				**1.743**
Electricity	*Total number of EEMs*	*11*	*1*			*12*
	Number with estimated savings	2				2
	Prim. energy savings (GJp)	**2.358**				**2.358**
Building	*Total number of EEMs*	*1*	*6*	*12*		*19*
	Number with estimated savings	1	6	5		12
	Prim. energy savings (GJp)	**472**	**1.335**	**125**		**1.932**
HVAC	*Total number of EEMs*	*10*	*21*	*11*	*1*	*43*
	Number with estimated savings	4	13	5		22
	Prim. energy savings (GJp)	**1.171**	**12.678**	**331**		**14.179**
Lighting	*Total number of EEMs*	*3*	*12*	*1*	*8*	*24*
	Number with estimated savings	2	9	1	4	16
	Prim. energy savings (GJp)	**351**	**498**	**54**	**1.409**	**2.312**
Compressed air	*Total number of EEMs*	*11*	*7*	*7*	*1*	*26*
	Number with estimated savings	10	4	4		18
	Prim. energy savings (GJp)	**5.105**	**479**	**10.572**		**16.156**
Steam	*Total number of EEMs*	*11*	*5*	*19*	*1*	*36*
	Number with estimated savings	6	3	9	1	19
	Prim. energy savings (GJp)	**4.508**	**4.211**	**8.551**	**254**	**17.524**
Thermal oil	*Total number of EEMs*			*1*		*1*
	Number with estimated savings			1		1
	Prim. energy savings (GJp)			**1.625**		**1.625**
Cooling installations	*Total number of EEMs*		*1*	*4*		*5*
	Number with estimated savings		1	1		2
	Prim. energy savings (GJp)		**867**	**1.890**		**2.757**
Process	*Total number of EEMs*		*15*	*7*	*1*	*23*
	Number with estimated savings		4	3	1	8
	Prim. energy savings (GJp)		**2.936**	**1.474**	**6.401**	**10.811**
SUM	*Total number of EEMs*	*68*	*68*	*62*	*12*	*210*
	Number with estimated savings	30	40	29	6	105
	Prim. energy savings (GJp)	**15.708**	**23.005**	**24.622**	**8.064**	**71.398**

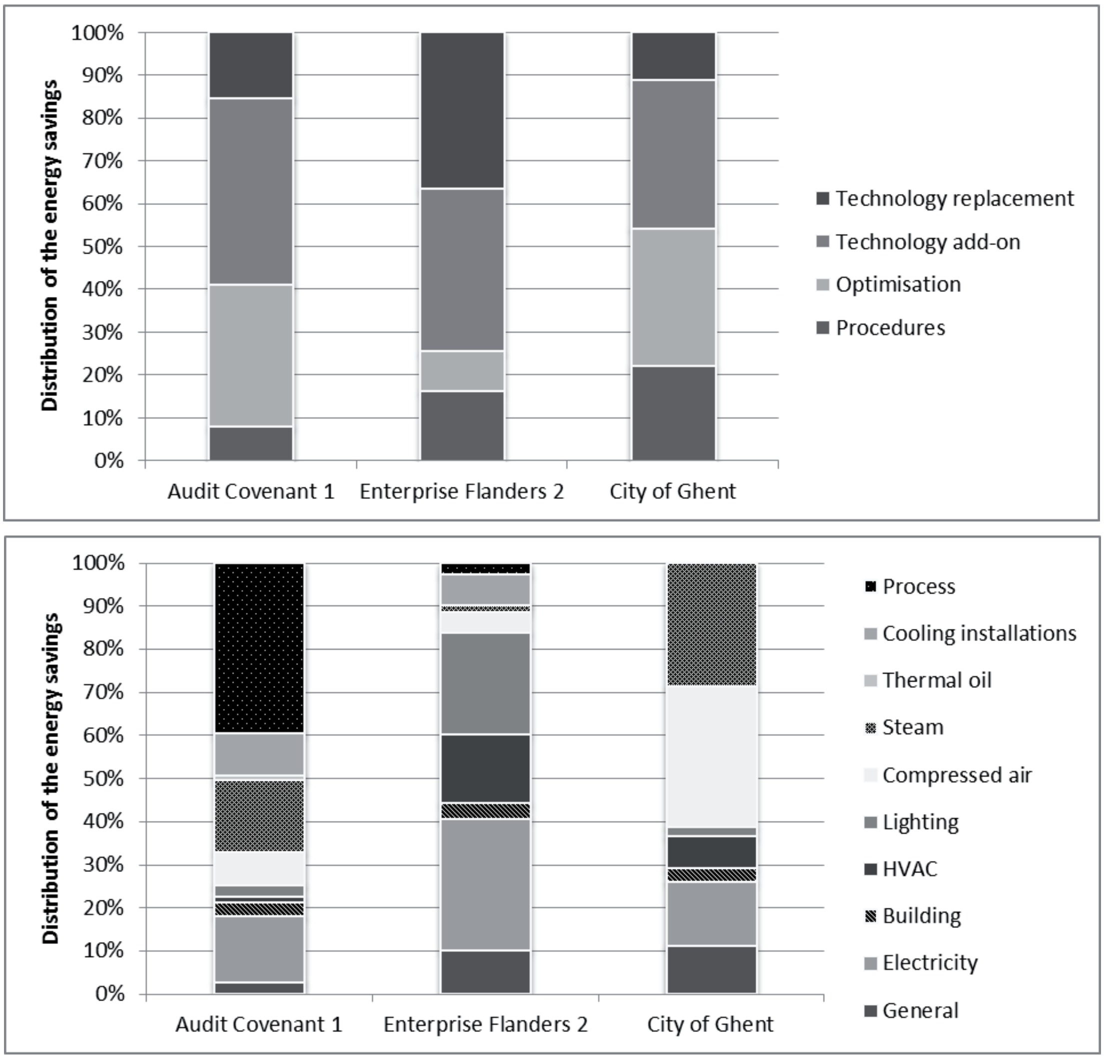

Figure 1. Distribution of the energy savings: top: according to type of modification; bottom: according to end-use.

a better structure in following up energy usage and necessary recurring measures for reducing the energy consumption.

The City of Ghent has decided to renew the programme based on the results of the pilot programme. It started by the end of 2014; the number of participating companies amounted to 30 by the beginning of 2016. The object is to reach more than 100 companies by the end of 2019.

Comparison of the energy audit programmes

DOES ANOTHER TYPE OF ENERGY AUDIT IDENTIFY DIFFERENT ENERGY EFFICIENCY MEASURES?

A first research question of this paper is whether the type of energy audit has an impact on the type of the energy efficiency measures (EEMs) identified. Figure 1 compares to this end the distribution of the identified EEMs of:

- The first phase of the Audit Covenant: energy diagnosis type audits (see Table 3); only the first phase is analysed in this paper. This was the first entrance for the participants into an energy audit programme, just like the regional and the local programme, which makes the results of the programme more comparable.
- The second regional programme (walk-through audits – see Table 5); only the second programme is analysed in this paper, because the individual EEMs of the first programme could not be categorised according to the method proposed in this paper
- The local pilot programme of Ghent (walk-through audits – see Table 6); please note that this programme only had fifteen participants and that only ten EEMs account for 55 % of the total savings. The distribution of the EEMs in the local programme of Ghent might not be representative for similar programmes.

It can be observed from Figure 1 that:

- The Audit Covenant identified mainly utility related EEMs (electricity, compressed air, steam, thermal oil, cooling – 51 %), followed by process related EEMs (40 %); working environment related EEMs (building, lighting, HVAC – 7 %) and general EEMs (3 %) contributed less to the total identified energy saving potential. Main types of modification were technology add-on (43 %) and optimisation (33 %).
- The second regional programme identified as much energy saving potential in the utility (44 %) as in the working envi-

ronment related EEMs (43 %). General EEMs contributed to 10 % of the total energy saving potential and hardly any process related EEMs (3 %) were identified. Main types of modification were technology add-on (38 %) and technology replacement (37 %).

- Three quarter of the energy saving potential, identified in the local programme is utility related (76 %). Working environment related EEMs and general ones contributed 13 %, resp. 10 %, to the total energy saving potential, while no process related EEMs (0 %) were identified. Main types of modification were technology add-on (34 %), optimisation (32 %), and to a lesser extent, procedural EEMs (22 %).

These significant differences in the EEM distribution between the programmes make it difficult to make firm conclusions about the relation between the type of energy audit and the categories of identified EEMs. Yet, three observations can be made:

- Hardly any process related EEM was identified by the walk-through energy audits in the regional and local programme, whereas 40 % of the identified energy savings by the energy diagnosis type audits of the Audit Covenant is process related.
- The share of general EEMs in the total identified energy savings is three times higher in the regional and local programme than in the Audit Covenant.
- The share of procedural EEMs in the total identified energy savings is two-three times higher in the regional and local programme than in the Audit Covenant.

This indicates the energy diagnosis type energy audits are more successful in identifying more challenging EEMs, such as process related ones.

HAVE MORE INTEGRATED ENERGY AUDIT PROGRAMMES HIGHER IMPLEMENTATION RATES THAN STAND-ALONE ENERGY AUDIT PROGRAMMES?

The second research question of this paper is whether integrated energy audit programmes (Audit Covenant and local programme of Ghent) have higher implementation rates than stand-alone ones (second regional programme by Enterprise Flanders). Table 7 compares to this end the implementation rate of the three analysed audit programmes, calculated as the share of the energy savings of the implemented or planned EEMs versus the total identified energy savings of all EEMs. Table 7 also indicates the relative energy savings, calculated as the total identified savings versus the total energy consumption of the participants.

The implementation rate of the Audit Covenant indeed seems to be higher than the rate of the local programme in Ghent, in turn higher than the regional programme operated by Enterprise Flanders (row G). The order of the relative identified energy savings of the three programmes is just the opposite: highest for the regional programme – lowest for the Audit Covenant (row F). This is also the order for the product of the implementation rate and the relative energy savings (row H).

These results could indicate that more integrated energy audit programmes lead to higher implementation rates of the identified EEMs than stand-alone ones. The lower relative energy savings might indicate that less energy-intensive companies have a higher energy saving potential than more energy-intensive ones. However, the differences between the energy audit programmes are small, especially between the regional and the local one. In fact, these small differences might statistically not be significant, but the data samples do not allow to test this hypotheses.

Hence, the conclusion of this analysis of the Flemish energy audit programmes is that it does not provide firm evidence that integrated energy audit programmes have higher implementation rates that stand-alone energy audit programmes.

Discussion and conclusion

This paper compared three energy audit programmes, implemented in Flanders, Belgium to test:

- whether the type of energy audit has an impact on the type of the energy efficiency measures (EEMs) identified and;
- whether stand-alone and integrated energy audit programme have different implementation rates of the identified energy efficiency measures.

The programmes were: the Audit Covenant, an integrated programme (voluntary agreement) with energy diagnosis type audits; a regional stand-alone energy audit programme with walk-through audits operated by Enterprise Flanders and; a

Table 7. Comparison of the absolute and relative savings.

		Auditing Covenant 1	Enterprise Flanders 2	City of Ghent
A	Type of programme	Integrated	Stand-alone	Integrated
B	Total energy consumption (PJp)	44.5	5.11	0.577
C	Number of participants	229	400	15
D	Average energy cons. (TJp/part.) (B / C)	194	12.8	37
E	Total identified energy savings (TJp)	4.7	0.78	0.071
F	Relative energy savings (E / B)	10 %	15 %	13 %
G	Implementation rate	56 %	47 %	50 %
H	Relative implemented savings (F x G)	5.6 %	7.1 %	6.5 %

local integrated energy audit programme with walk-through audits, implemented in Ghent.

A method to describe energy audit programmes was proposed in this paper. The basis of this method is a list of key elements that determine the nature of the energy audit programme. The method groups these key elements per involved party and per phase of the programme.

The application of this method to the three energy audit programme revealed that there are many ways to make energy audit programmes more integrated. The implementation of identified energy efficiency measures can be stimulated by providing more detailed audits of the most promising measures (as in the first programme of Enterprise Flanders), by providing guidance to the implementation (as in the pilot of Ghent), by having a commitment of the participants to implement (as in the Audit Covenant and the pilot of Ghent) or by organising coaching sessions for knowledge exchange (as in learning networks – not analysed in this paper).

One of the key elements to describe these programmes is how the results of the energy audits are verified. This verification aspect is a key element in a voluntary agreement in which the implementation of the energy efficiency measures must be enforced. The Audit Covenant is, in line with that, administered by a competent and well-staffed verification office. The capacity to verify the results of the energy audits is not that high in the regional and local programme. The administrators of these programme could hence benefit from a collaboration of the verification office of the Audit Covenant.

This paper also proposed a taxonomy to categorize energy efficiency measures. The taxonomy organises the measures according to two dimensions: the type of modification (procedures, optimisation, technology-add on or technology replacement) and the type of end-use that is targeted (general, working space related [building, lighting, HVAC], utilities [electricity, compressed air, steam, …] and processes). This taxonomy was used to test the first research question of this paper. Application of this taxonomy to the three Flemish energy audit programmes revealed that walk-through audits tend to focus on less challenging energy efficiency measures, such as good housekeeping measures, and that energy diagnosis type audits are more successful in identifying more challenging EEMs, such as process related ones. As a significant part of the energy consumption within an industrial company is process related, an energy audit programme should hence find ways to identify process related energy efficiency measures in order to increase its effectiveness.

This paper tested, as a second research question, whether integrated energy audit programmes have higher implementation rates than stand-alone ones. The implementation rate of the most integrated programme (Audit Covenant) indeed seems to be higher than the rate of the less integrated one (local programme in Ghent), in turn higher than the stand-alone one (regional programme operated by Enterprise Flanders). However, when combining the implementation rate with the relative energy savings, a reverse order is observed. This could be influenced by the degree of energy-intensity of the participant companies; the differences between the programmes are also small and might statistically be not significant. As a conclusion, the analysis of this paper could not confirm that integrated energy audit programmes have higher implementation rates than stand-alone ones.

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