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The impact of energy policy on energy efficiency in Europe: a case study of waste heat recovery with an organic Rankine cycle in Flanders

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Abstract:

In the transition to a less resource-dependent and climate-sustaining energy system the focus is on energy supply from renewable sources and efficiency in energy use. Renewable energy is vital for reducing the carbon intensity of power production. Energy efficiency refers to producing the same output with less energy inputs and is increasingly recognized for its potential to limit future required supply capacities. This paper discusses waste heat recovery as measure to improve industrial energy efficiency, more specifically by means of organic Rankine cycles (ORC). For an innovative technology its success depends on technical assets, but also on economic and market-originating matters. Additionally, governments can influence development processes by encouraging investments or addressing development barriers. The focus in this paper is on this policy dimension. The European Union (EU) has ambitious energy efficiency plans: 20% improvement by 2020 and 27% by 2030. In Belgium, ORCs applied for waste heat recovery receive a fiscal advantage from the federal government. The Flemish Region offered investment support but due to budget cuts this support was cancelled by the end of 2014. This study demonstrates the impact of the financial support measures for a real waste heat recovery ORC project, undertaken in 2013. The system received both fiscal and investment support and was evaluated profitable with a positive net present value (NPV) and an internal rate of return (IRR) of 14.21 %. If no government support would have been offered, but corporate income taxes still levied, the project's financial assessment aggravates drastically: with a negative NPV and IRR of 7% the investment would not have been feasible. The federal fiscal advantage offers welcome support, but the main contribution stemmed from the Flemish investment support. The revocation of this measure may lead to withdrawal of potential ORC projects, give the perception that ORC systems are not interesting and create uncertainty regarding policy consistency.

Keywords:

Policy, Energy efficiency, Waste heat recovery, Organic Rankine cycle (ORC), Financial analysis.

1. Introduction

Traditionally, most countries organized their energy sectors as supply-induced systems. The desirability of such system organizations is challenged by a number of trends, such as the limits of non-renewable energy resources, the capability of the earth's climatic system for processing all greenhouse gas emissions as well as security of supply issues. Addressing these concerns offers the opportunity to change the structure of our energy systems in an improved, streamlined manner. This includes diversification and distributed energy production by using renewable energy sources, complemented with an improved efficiency in energy use. In the tandem renewable energy – energy efficiency a major share of attention traditionally goes to replacing traditional fossil energy sources by renewable sources for supply. The potential of energy efficiency is unambiguous but varies broadly in terms of practical approaches and applications.

This paper discusses the recovery of industrial waste heat as an energy efficiency measure and more specifically the policy perspective on this practice. Section two clarifies the concept of waste heat recovery as an activity to improve industrial energy efficiency. Waste heat can potentially be valorized in heating or cooling applications or as input for electricity generation. The focus in this paper is on electricity generation, more specifically with organic Rankine cycle (ORC) technology. ORC systems utilize organic working mediums and thereby unlock the potential to generate electricity from lower grade heat sources. Conventional steam Rankine cycles are often not suitable for waste heat recovery due to the lower temperatures of the waste heat. In section three the scope shifts from this technical point of view to the policy perspective. The aim is to complement the large body of technical literature on this topic and discuss ORC systems for waste heat recovery (WHR) in the current context. At the European level the goals for enhanced energy efficiency are set out in the Energy Efficiency Directive. The specific policy context is clarified briefly and the financial support instruments by the federal and Flemish governments are elaborated further. Section four utilizes the data from an existing case in Flanders to discuss the impact of these policy instruments on a practical waste heat electricity production project. The current policy instruments are put into perspective and their impact on the financial feasibility of the project is assessed. Finally, an alternative policy instrument in the form of production support is analyzed for comparison. A concluding section discusses the findings of the underlying study and paths for future research.

2. Waste heat recovery to improve industrial energy efficiency

Energy efficiency refers to the achievement of more output with the same input or, equivalently, utilizing less energy input to generate the same output. It is a concept that covers many things, such as technical improvements in household appliances or buildings isolation, minimization of losses in energy transport or energy cascading to improve primary energy consumption. This paper considers energy efficiency in the context of industrial waste heat recovery. Waste heat, also called surplus heat, is often generally defined as *'heat that is dissipated to the environment'* [1]. Yet, utilizing such a general definition neglects important information such as quality, temperature or origin of the heat stream and bears the risk of classifying useful residual heat as waste. Bendig, Maréchal [1] review waste heat as a concept more profoundly and come to the following definition: *"the sum of the exergy that is available in a process after pinch analysis, heat recovery, process integration and energy conversion (utility) integration with the help of exergy analysis"* [1]. Applying this definition of waste heat avoids undertakings in secondary waste heat recovery installations in cases where this would be inferior to in-process efficiency improvements or heat valorization. In case the in-process improvement potential is inexistent or fully exploited, waste heat valorization in secondary processes does constitute a valuable option to investigate. The firm's energy input yields additional useful output. This implies an improvement in terms of energy efficiency, but may also be beneficial from an economic point of view. The secondary activity should answer a useful requirement and may thereby offset part of the firm's expenses for provisioning of these needs or even generate additional income.

Useful applications for waste heat are e.g. heating, cooling or electricity generation. This paper investigates the case of waste heat electricity generation. Several technologies are suitable for electricity generation from low temperature waste heat streams. From these the organic Rankine cycle (ORC) can be considered the most mature, as demonstrated by lab tests [2, 3] and an increased number of applications [4, 5]. The ORC is conceptually based on the conventional steam-driven Rankine cycle. The difference lies in the use of an alternative fluid as working medium instead of water. The basic setup of the ORC is known as the subcritical ORC (SCORC) and has the same component setup as the conventional steam cycle: evaporator, expander, condenser and pump, completed by the working fluid (Fig. 1). The cycle operates as follows. The hot working fluid leaving the expander (1) is condensed and a cooling loop (7-8) absorbs the heat from the cooling process. Next, the condensed working fluid is pressurized in the pump (2-3). In the evaporator the working fluid is superheated (4), meanwhile gradually reducing the temperature of the heat carrier (5-6). Finally, the superheated vapor is expanded in the turbine/expander and the cycle is repeated. Variations of this basic setup may increase power output and are an ongoing subject of research [6], but most commercial applications take the SCORC setup.

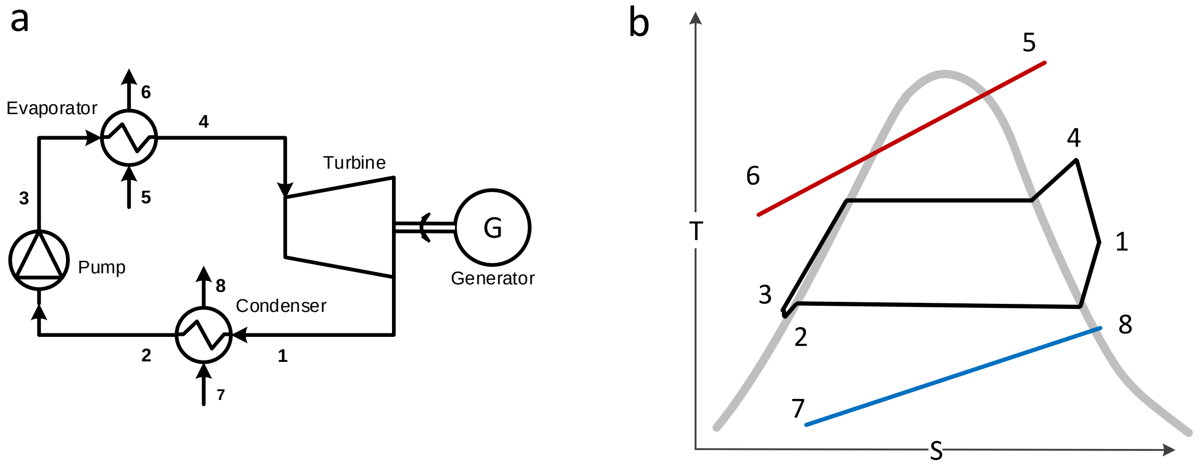

Fig. 1: (a) Components setup of the basic SCORC, (b) Ts-diagram of the basic SCORC

The importance of waste heat recovery for energy efficiency in general stems from the substitution of valuable primary energy sources by waste heat. The potential of industrial WHR is generally assumed large, but a detailed study on the full potential in Europe is not available and country estimates are scarce. Hammond and Norman [7] estimate a 37-73PJ/y of surplus heat that is technically recoverable from UK sites participating in the EU Emissions Trading Scheme (ETS). Schepers and van Lieshout [8] estimate the total potential of waste heat in The Netherlands at 102.6 PJ/y. Estimates of waste heat potentials differ according to the scope applied. A study of waste heat sources, as in [8], provides the necessary insight in the availability of waste heat. This number decreases when the technically recoverable potential is considered, as in [7], and even further when considering the economic potential (see [9]). An actual figure of the energy efficiency improvement that is possible by means of waste heat recovery is not available, but the estimates of the waste heat availabilities suggest an important potential.

3. The policy perspective on electricity from waste heat

The assessment of a technology or practice can take many perspectives, i.a. technical suitability, ecological impact, financial feasibility or societal desirability. The policy perspective is an overarching outlook that can influence each of these aspects, starting from the identification of a societal need. Public authorities at various levels can, conditional to the scope of their competences, define policy goals and issue legislative requirements. The aim of this section is to shed light on the extent to which WHR is addressed and encouraged at various policy levels. Starting at the European level, the analysis descends to the level of the Flemish Region, Belgium.

3.1. European policies for energy efficiency and waste heat recovery

Regarding energy efficiency, the European Union (EU) set itself with a clear goal: an increase of 20% in energy efficiency by 2020 [10]. For 2030 the ambition has recently been set at an indicative target of 27% energy efficiency improvement compared to projections [11]. The European Commission (EC) publishes on the setting, viewpoints and objectives for energy policy in the EU. The EC acknowledges energy efficiency as a major, cost-effective manner to address issues of security of supply and reduction of greenhouse gases and other pollutants. Yet, the 2011 Energy Efficiency Plan [12] was launched to boost action to achieving the 2020 goal, as the EU was on track to achieve only half of the 20% reduction goal. It suggests policies and measures for the buildings, transport, industry and energy sectors, points at the exemplary role for the public sector and the challenge to empower customers to enhance the efficiency of their energy use [12]. For the EU energy sector, consumer of about 30% of primary energy, recommended measures are increased use of cogeneration and district heating and cooling and safeguarding that new/replaced generation capacity meets best available technology (BAT) standards [12]. The European manufacturing industry is responsible for about 20% of primary energy consumption in the EU. Advances in energy efficiency have been substantial in this sector but there remains potential [12]. To employ this potential the obstacles to address are the lack of information, lack of access to capital and short term pressures of the business environment [12]. Measures proposed for this sector include information support, financial incentives and (obligatory) energy audits, ecodesign requirements for standard industrial equipment and voluntary agreements to implement energy efficiency processes and systems [12]. The legislative framework for industrial energy efficiency in the EU is the Energy Efficiency Directive (EED) [13]. Launched in 2012, the EED includes action for improved energy efficiency across the entire energy supply chain and end-use sectors. Focusing solely on the industry, the actions and requirements enclosed in the EED are represented in Table 1 [13]. Directives have binding legislative powers, this means member states are bound to implement its requirements in their legislative body. The manner in which this happens is free to decide. Implementation of the EU goals may differ per country and does not impede a member state to issue additional policy measures.

Table 1. Actions for industrial energy efficiency in the EED[13].

Efficiency in energy use	Efficiency in energy supply	Horizontal provisions
▪ Energy efficiency obligation schemes (Art.7) ▪ Energy audits and energy management systems (Art.8)	▪ Promotion of efficiency in heating and cooling (Art.14)	▪ Availability of qualification, accreditation and certification schemes (Art.16) ▪ Information and training (Art.17) ▪ Energy services (Art.18) ▪ Other barriers to promote energy efficiency (Art.19)

3.2. Belgian policies for energy efficiency and waste heat recovery

In the federal state Belgium the policy competences are distributed among the federal state and the three Regions (Flanders, Wallonia and the Brussels Capital Region). The federal government has limited competences regarding energy policy, but can influence (energy) investments via fiscal policies. The Regions are responsible for renewable energy, energy efficiency, district heating and waste energy recovery. This implies the policies differ among the three Regions. This paper focuses on the situation of the Flemish Region, situated in the northern part of Belgium. Flanders is an industrialized region with 18.7% of its gross added value stemming from industrial activities [14].

The Flemish Region employs voluntary agreements to address the industry’s energy efficiency potential. Until the end of 2014 two agreements were in force, the *benchmarking-covenant* (BC) [15] for the energy intensive industry (primary energy use > 0.5 PJ/y) and the *auditcovenant* (AC) [16] for industrial firms not addressed by the BC and a primary energy use > 0.1 PJ/y. As of the beginning of 2015 the BC and the AC have been replaced by two energy policy agreements (EPA) for the energy intensive industries (primary energy use larger than 0.1 PJ/y). Again, two parallel agreements are set up: one for industrial installations registered in the EU ETS [17] and one for non-ETS industrial installations [18]. Participation in the applicable agreement is voluntary, but oftentimes necessary to apply for other forms of support. Firms participating in one of the agreements are required to undertake measures identified as profitable, this means an internal rate of return (IRR) after taxes larger than 14% for ETS-companies [17] and larger than 12.5% for non-ETS companies [18]. The measures are identified via energy audits to be performed every four years. Potentially profitable measures fall below this cutoff point but have an IRR larger than 10%. For these measures the IRR calculations should be updated every year [17, 18]. Measures with an IRR below 10% can be discarded and need no future recalculation [17, 18].

Additionally, the federal and the Flemish Region utilize various instruments to financially encourage investments in energy efficiency and renewable energy (see Table 2). The federal government offers an increased investment deduction (IID) for investments enhancing rational energy use, improving industrial processes from an energetic point of view or for energy recuperation in industry [19]. The support is organized as an exemption on the taxable profits or benefits for an amount represented by a percentage of the investment [19]. This fiscal investment deduction decreases the profits or benefits in the taxation period corresponding to the period when the asset has been obtained [19]. ORC systems applied for WHR from an existing installation are eligible for support via this fiscal deduction. [9]

Similarly, the Flemish ecology premium (EP-PLUS) is an investment support instrument for ecology investments. The EP-PLUS applies since February 2011 and is based on a list of known technologies eligible for support. Companies can apply for a maximum support of € 1 million per three years, under the condition of participation in the appropriate energy policy agreement [20]. The actual amount receivable depends on several factors: the additional costs of the ecology investment, the subsidy percentage itself as a function of the technology and the company size and the optional subsidy bonus. The ORC for WHR has been included in the list of technologies since the initiation of the EP-PLUS program, but due to budget cuts the list has been reduced drastically in November '14 and no longer includes the ORC. However, in previous versions of the list the ORC was categorized as highly interesting so it is not unthinkable the technology would be included again in future releases. Exploitation support in Flanders is granted through certificates for combined heat and power (CHP) and renewable electricity production. CHP-certificates support high-efficiency cogeneration installations that realize a saving compared to separate production. Per 1,000 kWh heat-power savings the installation receives free CHP-certificates. The amount of certificates distributed per 1,000 kWh savings depends on the type of application. [21, 22] Tradable green certificates (TGC) are issued for electricity generated from renewable sources. The number of certificates monthly granted to an installation depends on the MWh of renewable electricity produced and a correction factor per technology [21, 23]. The Flemish investment support for green heat, waste heat and bio methane injection aims to support investments with useful heat as output and does not apply in a setting of electricity production [24, 25].

Table 2. Federal and Flemish policy instruments for waste heat recovery.

Federal policy	Flemish policy
▪ Increased investment deduction (IID)	▪ Energy policy agreements ▪ Ecology premium (EP-PLUS) ▪ CHP-certificates ▪ Tradable green certificates (TGC) ▪ Investment support for green heat, waste heat and bio methane injection

4. Policy instruments and the impact on project appraisal

For an individual firm considering an investment the decision is made following an evaluation of project cash flows. A project is accepted when the net present value (NPV) is positive. For a project concerning electricity production from waste heat this implies:

$$NPV = -(C_{0RC} + C_{INT}) + \sum_{t=1}^{n} \frac{p_{p,t} \cdot q_{p,t} + p_{s,t} \cdot q_{s,t} - O\&M_t + SV}{(1+i)^t} \, . (1 - T_t) \geq 0. \quad (1)$$

The system is driven by free waste heat supplies, which makes the initial investment costs of the ORC (C_{0RC}) together with the costs for integration and installation in the existing plant (C_{INT}) the principal cost components of the investment. Annual operation and maintenance costs ($O\&M_t$) are mostly low since an ORC system works under lower pressures and operates independently. The positive annual cash flows stem from the savings on the purchased electricity ($p_{p,t}.q_{p,t}$) due to the ORC production ($q = q_{p,t} + q_{s,t}$) and the income from electricity sales to the grid ($p_{s,t}.q_{s,t}$). This paper assumes all produced electricity will be used in-house so $p_{s,t}.q_{s,t} = 0$. The salvage value (SV) represents the costs or benefits that occur at the end of the project period. For simplicity these are assumed zero. The corporate income tax rate (T_t) in Belgium amounts 33.99%. Finally, an NPV calculation is influenced by the time span n and the discount rate i. Governments aiming to encourage certain investments can issue instruments with a social (e.g. sensitization), an economic (e.g. financial stimuli) or a juridical (e.g. command-and-control) nature. Influencing the individual firm's decisions with economic incentives is possible directly by acting on the investment costs, by offering a subsidy per produced kWh or indirectly with fiscal measures.

This section assesses the impact of both existing and alternative policy instruments in Flanders on a case of WHR with an ORC system. The numerical assessment is based on an actual ORC system, built in Flanders in 2013. The case was undertaken in a large industrial firm registered in the EU ETS. A 100,000 m³/h flue gas waste heat stream was available at the end of the plant's main process and is now being recovered for electricity production.

4.1. The actual policy setting: investment support and fiscal deduction

At the time of investment in the ORC installation the Flemish government offered direct investment support, added with indirect fiscal measures from the federal government. The system utilizes waste heat to generate electricity, it generates no useful heat output and does not use any renewable energy source as input. This means no support via TGC or CHP certificates was possible. The NPV assessment is affected by the ecology premium ($EPPLUS$) and the increased investment deduction (IID).

$$NPV = -(C_{ORC} + C_{INT}) + EPPLUS_{t=1} + \sum_{t=1}^{n} \frac{p_{p,t}\cdot q_{p,t} + p_{s,t}\cdot q_{s,t} - O\&M_t + SV}{(1+i)^t} \,.(1 - T_t.(1 - IID_{t=2})) \geq 0 \qquad (2)$$

The EP-PLUS is obtained in year 1, the fiscal support IDD in the following year ($t = 2$). Table 3 displays assumptions made for this analysis. The company-specific parameters cannot be presented completely for reasons of confidentiality. Other assumptions are obtained from the Flemish Energy Agency (VEA) [26] to allow for comparison with the results of section 4.4. The depreciation period was set to 5 years in order to compare the results with the profitability requirements set out in the EPAs.

Table 3. Assumptions for the case study.

Parameter	Value	Parameter	Value
ORC lifetime	20 y	Depreciation period	5 y
Electricity production	± 1,600 MWh/y	Discount rate	12 %
General inflation	2 %	Electricity price infl.	3.5 %

4.1.1. Actual project appraisal

At the time of purchasing the EP-PLUS offered investment support for an amount of 35.75% of the essential components of the investment. Together with an increased investment deduction percentage of 14.5% this yields an NPV of 131,890.80€. The IRR demonstrates the return a project delivers on the money invested and amounts 14.21%. Fig. 2 displays the cumulative cash flow of the project, with break-even point after 5.71 years.

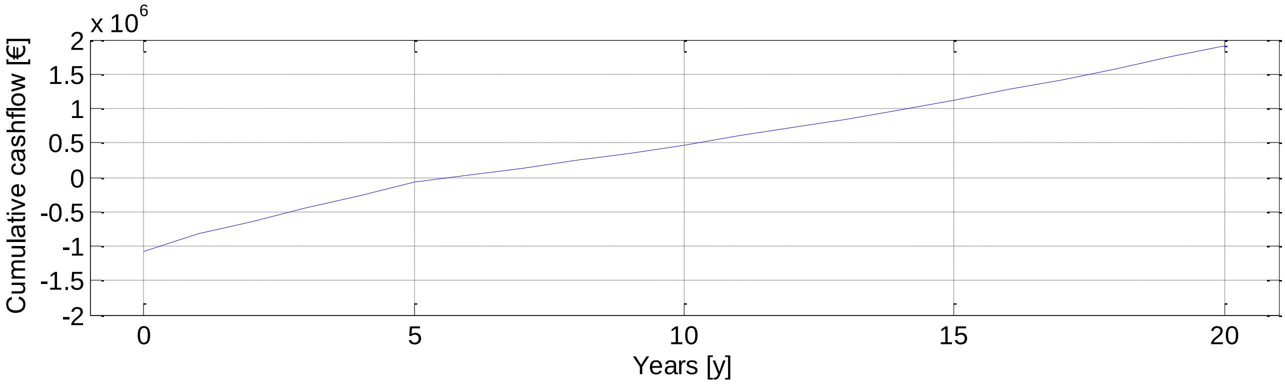

Fig. 2: Cumulative cash flow of the case study

4.1.3. Impact of the government support

Fig. 3 and Fig. 4 demonstrate the impact of the government instruments on the financial feasibility of the ORC project, measured by the NPV and the IRR respectively. Scenario 1 includes no government intervention, neither from taxes nor in any form of support. This scenario is not realistic but serves the purpose of comparison. The scenario gives a negative value for the NPV and yields a return of 8.53 %. The more realistic scenario 2 includes corporate income taxation but no support instruments. In this scenario the corporate income taxation aggravates the analysis and project would probably not be undertaken: the IRR drops to 7 % and the NPV remains negative. Scenario 3 demonstrates the impact of solely the increased investment deduction, in a realistic setting with corporate income taxation. The fiscal support does yield an improvement of the results but this seems not enough to attenuate the effect of the corporate income taxation. Scenario 4 includes corporate income taxation and the EP-PLUS, but not the increased investment deduction. This scenario demonstrates the impact of the EP-PLUS is truly supportive. The IRR improves to 13.00 % and the NPV is slightly positive with 62.31 k€. The actual scenario with both support instruments is obviously best.

The results of this scenario analysis are specific for this case study and are therefore not generalizable. Other assumptions regarding inflation, load hours or electricity purchase price may influence this analysis. Yet, it demonstrates in the actual stimulating effect of the government instruments in practice. The numerical example clearly suggests a stimulating effect from the EP-PLUS. The additional federal fiscal support is certainly welcome to further improve the financial feasibility.

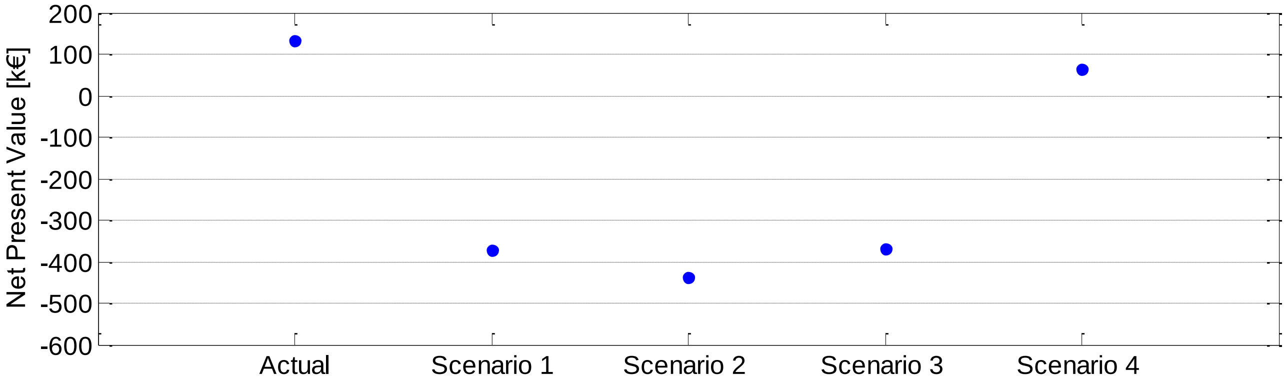

Fig. 3: Impact of government instruments on NPV

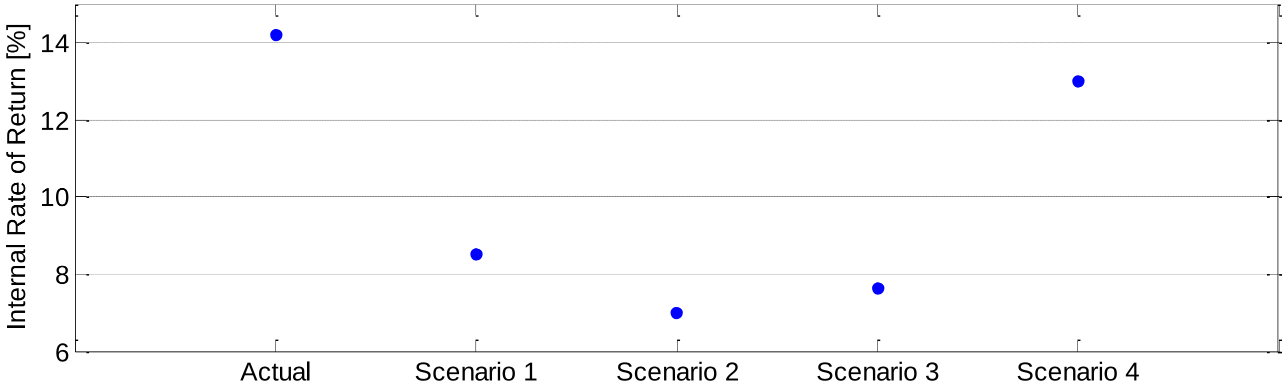

Fig. 4: Impact of government instruments on IRR

4.2. Current policy situation

The current situation is somewhat different than that of 2013. Unfortunately, budget cuts have reduced the list of technologies eligible for EP-PLUS support from 169 technologies to 30 as of 17/11/2014. The ORC for WHR is currently no longer included in this list. However, in earlier releases of the list the ORC was marked as a technology believed to have an important potential impact, therefore receiving a high subsidy figure. This, together with the fact that the technology was eliminated together with 138 other technologies, implies the technology was probably not discarded because it was no longer deemed interesting. It is not unthinkable that the ORC could be included again in a future release of the list when more budget is available. The elimination of the ORC from the list can have a financial impact and influence the general viewpoint on the technologies' suitability. The withdrawal of the EP-PLUS may cause firms to abandon projects that were in an investigation and evaluation phase because the most important financial stimulus disappeared. It might be that pioneering firms will still undertake these investments without the support, but if the overarching aim is to encourage the broader industrial sector this would probably not happen in the current situation.

Fortunately, the increased investment deduction still applies. The federal government was also confronted with budgetary limits and eliminated the base investment reduction. To keep supporting investments in energy and environmentally beneficial assets it was decided to continue offering the increased investment deduction. The rate for investments subject to tax year 2015 is 13.50 %. If the project under investigation were invested in today, with an IID of 13.5 %, it would yield a NPV of minus 374.57 k€ and IRR of 7.60 %.

4.3. External sensitivity analysis

Many parameters influence the project’s feasibility, either within (e.g. electricity price, load hours) or without (investment costs, financial incentives) the span of control of the individual firm. The investment costs will change according to the company’s specific needs for integration of the ORC system, but cannot be changed by the company itself. Similarly, the company can apply for government support when available but has no influence on its extent. Table 4 shows the maximum value of the specific investment costs (SIC) and the required rate of the EP-PLUS to categorize the project as (potentially) profitable according to the EPAs. All other parameters are assumed unchanged, the increased investment deduction is fixed at 13.5%.

Table 4. Maximum SIC and minimum EP-PLUS following definition in EPAs.

	Company in EU ETS	Company not in EU ETS
Profitable	*IRR ≥ 14%*	*IRR ≥ 12.50%*
SIC	6415.91 €/kWe	7305.93€/kWe
EP-PLUS	35.28 %	29.00 %
Potentially profitable	*IRR ≥ 10%*	
SIC	9225.60 €/kW$_e$	
EP-PLUS	16.15 %	

Hence, for the investment to be classified as (potentially) profitable the firm could look for ORC systems that have a SIC value below the values indicated in Table 4. These SIC values are valid for this specific firm situation and exclude the costs of integration and installation ($C_{INT} = 0$). Similarly, if the government wants to lift the IRR of the project above its own defined profitability goal, the EP-PLUS percentages should be as in Table 4. The values of the IRR are calculated for the total project and include the original costs for integration. Offering investment support to achieve the 14% IRR is in line with the support received for the actual case study. The EP-PLUS percentages required to lift the IRR above 12.5 % and 10 % are smaller. The government could provide support to make the investment feasible, without the need to give excessive support. Again, these results apply for this specific situation and may change when other parameters change.

4.4. Alternative instruments

Currently, the Flemish and federal government issue instruments to influence the individual firm's NPV calculation (formula (1)) by acting directly on the investment costs (EP-PLUS) and indirectly via fiscal measures (IID). Another potential stimulating method could be subsidizing produced kWh. This section evaluates the possibility for and the impact of alternative policy instruments.

4.4.1. Production support

In case of a subsidy for electricity produced from waste heat the NPV formula looks as follows:

$$NPV = -(C_{0RC} + C_{INT}) + \sum_{t=1}^{n} \frac{(p_{p,t} + s_t).q_{p,t} + (p_{s,t} + s_t).q_{s,t} - O\&M_t + SV}{(1+i)^t} . (1 - T_t) \geq 0 \qquad (3)$$

with s_t the subsidy. Assume again the ORC is used for electricity production only, e.g. because there is no potential for useful heat output, and all produced electricity is consumed in-house ($q_{s,t} = 0$). The production support could e.g. be organized by including electricity from waste heat in the existing system of tradable green certificates. This approach avoids additional administrative burdens because the TGC-system is already operational. The producers of waste heat electricity would obtain an amount of certificates per MWh and the certificates can be sold to electricity suppliers at a negotiated price or to distribution network operators at a fixed minimum price, if connected to their grid. In the current TGC system in Flanders the minimum support for installations started after 01/01/2013 amounts €93 per certificate. The quantity of certificates received differs per type of technology and is calculated as a function of the amount of electricity produced and a correction factor ('*bandingfactor*') for the technology type. This correction factor (Bf) is a function of the unprofitable top (OT) for the technology, indicating how much €/MWh would be required for a profitable exploitation of the system, and an additional correction divisor ($BD = €97$). The amount of certificates obtained per MWh is calculated as:

$$TGC = q_t . Bf = q_t . \frac{OT}{BD} . \qquad (4)$$

This section uses the knowledge of the case study in Flanders and the assumptions made by the Flemish Energy Agency (VEA) [26] to make an estimate of the OT of ORC systems applied for waste heat recovery. The assumptions are again those of Table 3, but the OT is calculated using a lifetime and depreciation period of 10 years. An approximation of the methods used by VEA gives an OT of 99.49 €/MWh, this yields a Bf of 1.03. This means one certificate would be obtained per 974.66 MWh production, but the correction factor is limited to its maximum value 1, yielding one certificate per MWh. For the project's financial feasibility this certificate system would be beneficial. In the current setting (IID = 13.5 %) and incorporating one certificate per MWh, with a minimum support of €93 per certificate, the project would yield 183.33 k€ with an IRR of 14.27 %. This is a significant improvement compared to the project return without the production support (NPV = -374.52 k€ and IRR = 7.6 %). Using this production support scheme the ORC system would be assessed profitable.

If the production support would have existed at the time the WHR project was actually undertaken (IID = 14.5 %), and the EP-PLUS is assumed zero, the project would yield 188.13 k€ with an IRR of 14.34 %. This is somewhat higher than the actual support obtained with the EP-PLUS (NPV = 131,890.80 € and IRR 14.21%).

5. Conclusions and future research

This paper discusses the use of industrial waste heat streams for electricity generation with organic Rankine cycle systems. The primary energy sources normally used for electricity generation can partly be offset by utilizing recuperated waste heat as input sources. This implies that the same amount of energy generates additional output, which implies an improvement in energy efficiency and potentially a saving of primary energy in general. The actual energy efficiency potential is unknown, but estimates of waste heat availabilities display important capacities. A large body of literature exists on the technical specificities of ORC systems. Yet, a technology's success requires not only technical possibilities, but also depends on economic and market-originating circumstances. A firm's individual decision to undertake WHR projects will generally be steered by the financial attractiveness of the project. Policy goals and instruments may influence this assessment in one way or the other. This paper aims to complement the technical literature with a discussion of the policy perspective.

The EU strives for a 20% improvement in energy efficiency by 2020 and suggests options for improvements in various areas. The Flemish Region encourages the industry with voluntary energy policy agreements and various financial support schemes. The federal government does not have the direct competence to influence energy efficiency policy but offers support with a fiscal deduction measure. The results of the numerical analysis are not generalizable and apply for this specific case study. Yet, the analysis clearly demonstrates the encouraging effect of the EP-PLUS on the investment decision. For the project under investigation the support by the EP-PLUS was decisive in the investment decision. Unfortunately, the EP-PLUS support scheme has recently excluded ORC technology from the scope of the support. The reason for this was budgetary and not because the ORC was no longer deemed interesting. This leaves the option for future re-inclusion of the technology but this aspire is uncertain. Nonetheless, the cancellation of the ORC from the support scheme may give the – incorrect – idea that ORCs would no longer be interesting and could create uncertainty with regard to policy consistency. The numerical analysis is influenced by both internal and external parameters. Internal parameters are company-specific (e.g. electricity price paid, load hours, discount rate), external parameters lie beyond the control of the individual firm. The investment costs paid for the ORC system and the amount of government support cannot be influenced by the firm. But a firm may assess the maximum allowable SIC of the ORC to classify the project as profitable. Similarly, governments may assess the minimum required percentage of investment support to reach the profitability requirements in the EPAs. An alternative instrument to support waste heat electricity could be the inclusion into the current TGC system. An approximation of the Flemish Energy Agency's calculation of the amount of production support for renewable energy would yield one TGC per MWh of waste heat electricity produced. Assessing the impact of this production support for a period of 10 years yields positive results. The results are more or less in line with, but slightly better than, the results obtained with the EP-PLUS scheme.

The scope of this paper was delimited to waste heat valorization through electricity production with ORC systems. Future research lies in the assessment of alternative support possibilities and comparison of the electricity production option with other valorization options such as heat only or cogeneration.

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Nomenclature

C_{ORC}	investment costs of the ORC, €
C_{INT}	installation costs of the ORC, €
t	year, y
n	ORC lifetime, y
i	discount rate
$p_{p,t}$	purchase price electricity, €/MWh
$q_{p,t}$	amount of electricity used for in-house consumption, MWh
$p_{s,t}$	sales price electricity, €/MWh
$q_{s,t}$	amount of electricity sold, MWh
$O\&M_t$	annual operation and maintenance costs, €/y
SV	salvage value, €
T_t	corporate income tax rate, %
s_t	production subsidy

Abbreviations

Abbreviation		Abbreviation	
AC	auditcovenant	EU	European Union
BAT	best available technologies	IID	increased investment deduction
BC	benchmarking-covenant	IRR	internal rate of return
CHP	combined heat and power	ORC	organic Rankine cycle
EC	European Commission	SCORC	subcritical ORC
EED	Energy Efficiency Directive	SIC	specific investment costs
EPA	energy policy agreement	TGC	tradable green certificates
EP-PLUS	Ecologiepremie Plus (Flemish ecology premium)	VEA	Vlaams Energieagentschap (Flemish Energy Agency)
ETS	Emissions Trading Scheme (EU)	WHR	waste heat recovery

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