PITAGORAS

Sustainable urban planning with innovative and low energy thermal and power generation from residual and renewable sources

# D5.5: Final version of Market analysis and business models

## - Analysis of financing policies –

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# ABBREVIATIONS

| | |
|---|---|
| ADEME | French Environment and Energy Management Agency (in French in the acronym) |
| BOP | Balance of Plant |
| DH | District Heating |
| DR | Discount Rate |
| EAF | Electric Arc Furnace |
| EEC | Energy Efficiency Certificates |
| EIB | European Investment Bank |
| ESIF | European Structural and Investment Funds |
| EU | European Union |
| FIT | Feed-in Tariff |
| ICO | Official Credit Institute (in Spanish in the acronym) |
| IDAE | Energy Diversification and Savings Institute (in Spanish in the acronym) |
| IR | Interest Rate |
| ORC | Organic Rankine Cycle |
| SMEs | Small and Medium Enterprises |
| TOE | Tonne of Oil Equivalent |

# 1. INTRODUCTION

## 1.1. SUMMARY

One of the main targets of the Pitagoras project consortium has been to foster the replication of the waste heat recovery concept based on ORC technology, in a similar way as the developed in Brescia demo plant. In PITAGORAS-D5.2, a quantification of the market potential in the target countries of the project, namely Austria, Czech Republic, France, Germany, Italy, Poland, Slovakia, Spain and Sweden, was performed. In PITAGORAS-D5.3, a sensitivity analysis of the market potential behaviour was performed. Such tasks were carried out as preliminary steps for business model establishment.

However, one of the main drawbacks for the implementation of heat recovery based on Organic Rankine Cycle (ORC) technology, are the profitability and the upfront cost required to put in operation the energy recovery plant and the equipment for heat distribution or heat-to-electricity conversion. Therefore, for the business model study it is of great significance to study the impact that different financing aid alternatives would have in the profitability of Pitagoras concept.

Accordingly, in this study several financing policies that can be promoted from the public administration are proposed and their impact on the business model are tested. To select a set of realistic policies, a benchmark of current financing alternatives in the 9 studied countries, i.e. Austria, Czech Republic, France, Germany, Italy, Poland, Slovakia, Spain and Sweden, has been carried out. Yet, they have been complemented with other ones because the aim of this work is to address not only the existing financing possibilities, but also other options that could be explored in the future. By doing so, assessment to policy-makers can be provided in order to better inform the design of new financing policies to foster the steel industry profitability and competitivity.

The study is not carried out analysing the measures available in a country only for such country. On the contrary, a selection of measures is made based on existent ones, even in a single country, and on financing alternatives for other kinds of industry or industrial initiatives that could be extrapolated to the steel manufacturing industry. Afterwards, the impact of these options has been analysed in both aggregated terms and for each country. With this comparative analysis, it can be seen which measures impact more and if there are differences on their impact in between countries.

In particular, the effects of subsidy to the required initial investment, low-interest loans and energy efficiency tradable certificates have been studied. To compare the performance of such measures, the capacity of private investment mobilisation and $CO_2$ emissions savings have been used as comparative outputs, normalized with the public investment required.

Results show that the best ratios of return on public investment are obtained when the financing costs are removed, i.e. assuming zero-interest loans. However, although being an efficient use of public money, this financing policy is not as effective as the other two encouraging a number of investments in line with the Pitagoras concept, since a much smaller market size is activated. On the contrary, the subsidies and the energy efficiency certificates policies are those which show more capacity of activating new investments and subsequent $CO_2$ emissions savings in the studied countries.

The energy efficiency certificates policy shows the best trade-off between rates of return on public investment and volume of new investments activated. Notwithstanding, the efficiency of this measure relies on a sustained price of them in their free-trade market. If it sought to provide more certainty to investors, the measure of subsidies could be more appropriate since it reduces the upfront cost which is one of the main

barriers to adopt the proposed heat recovery scheme. In addition, it can be more controlled than the energy efficiency certificates, increasing the shares of investment subsidised according with regional development plans of the countries. The main drawback of this policy is that, from those studied, is the less efficient making public investment profitable.

## 1.2. PROJECT CONTEXT AND TASK PURPOSE

The present document is contextualized in the WP5 as the third and final version of the Market analysis and business models, from which the first and second version were previously developed.

- In the first version of the "Market analysis and business models", PITAGORAS-D5.2, the economics of this concept were modelled and simulated for all the existing steel manufacturing plants in the studied countries. Afterwards, the potential market in the countries of study was obtained according with the viability criteria of obtaining a positive Net Present Value (NPV) with a discount rate of 5% and a lifetime of 10 years.
- The second version of the "Market analysis and business models", PITAGORAS-D5.3, consists on a sensitivity analysis of the model developed and used in the previous deliverable. A study of how the most important input parameters of the model affected the market potential was carried out.
- This deliverable, the "Final version of Market analysis and business models", is an impact analysis on publicly supported financing policies for the Pitagoras concept of electricity and heat generation from heat recovery in the steel manufacturing industry. Using the model developed and tested in the first and second versions of the "Market analysis and business models", the effects of three possible financing policies on the market potential have been studied.

The work here performed is significant to two tasks within WP5:

- the business models, since it analyses the relevance and effect of several inputs to the potential and the profitable market available
- the individual exploitation plans

# 2. FINANCING POLICIES STUDIED

## 2.1. INTRODUCTION

As previously claimed, the purpose of this work rather than being a sensitivity analysis of several financing measures, is to make a consistent proposal of a set of financing policies and to address their impact in the 9 studied countries independently.

Therefore, this work is considered an impact analysis and it is carried out modelling and simulating the financing policies proposed and analysing the changes induced to the market potential measured by the selected outputs.

## 2.2. STUDIED OUTPUTS

In this analysis, two different response variables have been selected as relevant to study. Both variables are calculated as incremental variables with respect to the base-case scenario – subtracting the plants that were already viable – and normalized by the public investment required to put in operation the financing policies. By doing so, the effect of having different scales of money required for each financing policy is removed, only the return of such public investment measured. Therefore, the comparison between countries and between financing policies is significantly easier.

As claimed before, they are studied by country and in aggregation of all studied countries.

### 2.2.1. Mobilized private investment

The first response variable is purely finance-related: the private investment in € mobilized by each € invested by the public administration.

This variable is obtained by adding up the private investment that otherwise would have not been made and dividing it by the public investment required.

### 2.2.2. $CO_2$ savings

The second response variable is more related with the technological return: the $CO_2$ savings in tons of $CO_2$ by each € invested by the public administration.

This variable is obtained by subtracting to the aggregated $CO_2$ emissions saved the savings in the base-case scenario and dividing it by the public investment required reach those extra savings.

## 2.3. FINANCING POLICIES PROPOSAL

Three financing policies are proposed in this study. The selection of them is intended to be representative of different financing alternatives currently available or that could be implemented in the future. Therefore, it is based on the results of the benchmark performed of currently available measures altogether with proposals based on existing financing alternatives for other kinds of industry or industrial initiatives.

The aim of analysing not only the existing possibilities, but also other options that could be explored in the future is to provide assessment to policy-makers in order to better inform the design of financing policies to be developed to foster the steel industry profitability and competitivity.

The following parameters have been modified in the model presented in PITAGORAS-D5.2 and tested in PITAGORAS-D5.3. Thereafter, it has been studied how these parameters affect the response variables.

### 2.3.1. Subsidies

According with the benchmark performed, the subsidies are the financial aid measure currently more widespread across the studied countries. Although they are available in Austria, Czech Republic, France, Poland and Spain, the extent to which they are given differ between countries depending of which equipment is considered eligible for subsidy, the company size, the country region or the energy produced/recovered.

Generally speaking, the subsidies are about 30% of eligible costs, being those the costs of equipment for heat recovery and distribution. Subsidies to electricity generation equipment, even for cases where electricity is produced from recovered heat, are not as deployed as those to heat recovery and distribution.

The subsidies' alternative is studied considering the current scheme. Thus, a reduction on the upfront investment costs of the plant, expressed as the Balance of Plant (BOP) is introduced as possible variation. The cost of the ORC turbine is not subsidised in any case, so it is left unchanged.

It must be noted that the eligible equipment for subsidies vary among the studied countries, so real-case scenarios will be different among countries. However, as the ORC turbine ancillary equipment costs are included in the turbine cost, the BOP accounts for all the equipment related with the heat recovery, storage and distribution, making these differences negligible if the subsidy is introduced at BOP level. Consequently, the following hypothesis has been introduced in the model:

- 30% reduction on the BOP, corresponding to the application of a 30% reduction subsidy to all the plant excluding the ORC turbine and its ancillary equipment.

Such subsidies could be provided by public funds for energy efficiency or renewable energy investments, at a country scale via Industry ministries such as the French Environment and Energy Management Agency (ADEME) [1] or at a European scale via funds such as the European Structural and Investment Funds (ESIF) that is in process of allocating 18 billion € to energy efficiency and 6 billion € to renewable energy, including district heating [2] by 2020.

### 2.3.2. Low interest loans for investment financing

Another financing alternative is the creation of financing lines consisting on low rate of interest loans supported by public financing organisms. These loans could be provided at a country scale, similarly as

currently done in Poland through the state-owned bank BGK [3] or in Spain by State agencies such as the Official Credit Institute (ICO) [4], or at a European scale such as the European Investment Bank (EIB) [5]. However, case-to-case decisions apply to set the interest rate.

The effect of low interest loans is modelled as a reduction of the Interest Rate (IR) at which the initial investment percentage borrowed is financed. Since the determination of a certain interest rate would be arbitrary as a consequence of the case-to-case decisions usually applied, the study will assume the hypothesis of no financing costs at all in order to address the most extreme situation:

- 0% IR, corresponding to a loan without financial costs.

### 2.3.3. Energy efficiency/Renewable energy certificates

The energy efficiency or renewable energy certificates are tradable instruments that are entitled to industrial consumers for energy efficiency initiatives or renewable energy production. Usually, they are combined with the requirement of achieving certain targets of energy savings or renewable energy production.

The main difference of this mechanism is that it does not cost anything to public administration, since the lack of fulfilment of energy savings requirements is fined with penalties paid by industrial consumers, encouraging them to buy certificates to industries adopting energy efficiency measures. Hence, the system is analogous to the carbon emissions trading, but instead of being related with the carbon emissions saved it is linked with the energy consumption reduction. This retribution scheme is currently operational in Italy under the name of "White Certificates" or "Energy Efficiency Certificates" (EEC) [6]. However, although the public administration is not putting the money into the table, the money rewarded to industries adopting energy efficiency measures can be considered public investment as well, because the industries not meeting their energy efficiency requirements – mainly electricity and gas utilities – must acquire white certificates in the market and these costs are likely to be passed on the consumers of their goods.

This scheme of remuneration to energy savings has relevant advantages with respect to feed-in tariffs (FIT) mechanism to which it can be resembled. The FIT is the retribution scheme to renewable energies adopted in several countries around the world among which Czech Republic, France, Germany, Italy or Spain are found. The major advantage is that it is not required to put public money into the table as with FIT is because they consist the establishment of long-term contracts of energy purchase at a certain price greater than the market price set in energy auctions.

For the modelling of the energy efficiency certificates, the useful energy obtained from recovered heat, being it electricity or heat, is converted to tons of oil equivalent (TOE). According with [7], the conversion factors are 0.187 toe/$MWh_e$ and 0.086 toe/$MWh_{th}$. Since one certificate is given for each TOE of energy saved or produced from a renewable energy source, the saved TOEs are equivalent in number to tradable certificates. The market price of these certificates in Italy was historically at around 100 €/certificate but it has experienced a subtle rise during the last year up to 230 €/certificate, as shown in Figure 1, elaborated with historical data from the Italian energy market operator [8].

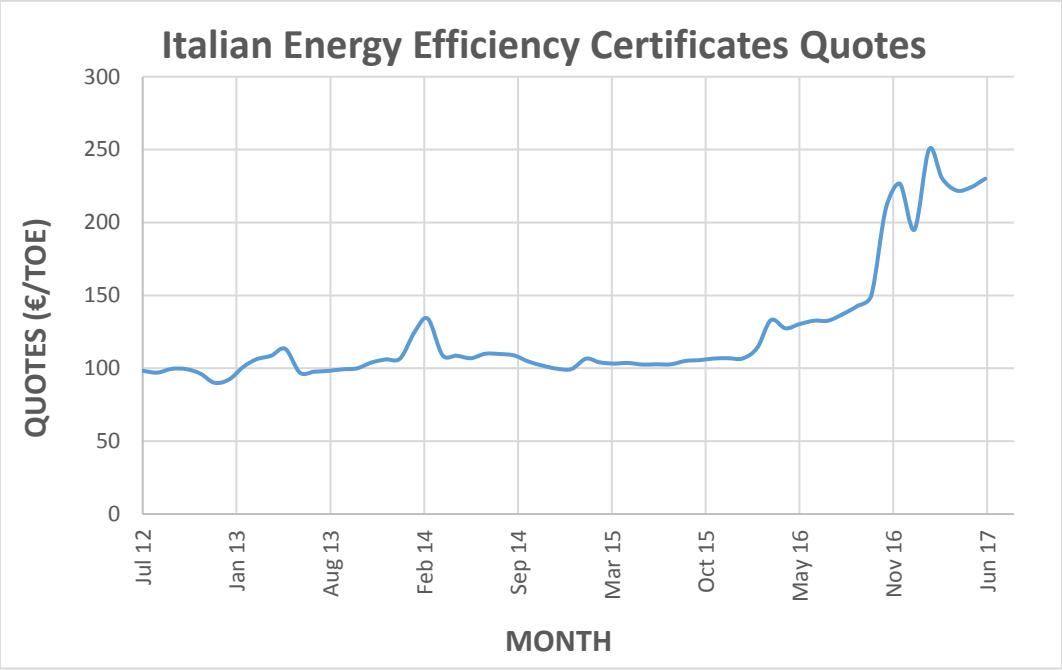


*Figure 1: Historical quotes of Energy Efficiency Certificates in Italy (July 2012 – June 2017)*

As Figure 1 shows, there is a major difference between the average value of the energy efficiency certificates and the current value, as a result of the historically low prices compared with the recent ones. As this difference hugely affects the results of the market potential, two different quotes have been selected for simulation: the average value and the most recent value. The market as it is designed does not tend to lower the prices once they have risen because as more energy efficiency measures are undertaken, more difficult are to carry out new ones thus increasing the demand of energy efficiency certificates. Therefore, at least for Italy, even greater quotes could be expected. However, as the purpose of this study is to address the possibilities of the proposed policies in all the studied countries, the average quote is also a value worth studying as it could be representative of quotes if the energy efficiency certificates policy was adopted at the EU level.

Hence, the economic valorisation of such certificates is set as follows for the purpose of the present study:

- 125 €/certificate (or €/TOE), the average quote of last 48 months
- 230 €/certificate (or €/TOE), the last quote, corresponding to June 2017

## 2.4. FINANCING POLICIES EXISTENCE IN STUDIED COUNTRIES

After the benchmark performed by the partners of the Pitagoras consortium, the availability of the proposed financing policies in all the studied countries has been summarized in the table below.

It must be noted that it is shown the availability or not of a certain policy, but the rates or amounts of money given as public aids differ from country to country (and even between different regions of a country). Considering the high degree of heterogeneity of these policies, for the sake of clarity it has been considered more advisable to present the results in terms of availability and not distinguishing the particularities of each country.

*Table 1: Financing policies availability per country summary*

| Country | Subsidies | Low-interest loans | Energy efficiency certificates |
|---|---|---|---|
| **Austria** | X | - | - |
| **Czech Republic** | X | - | - |
| **France** | X | - | - |
| **Germany** | X | X | - |
| **Italy** | X | - | X |
| **Poland** | X | X | - |
| **Slovakia** | NA | NA | - |
| **Spain** | X | X | - |
| **Sweden** | NA | NA | - |

Although in many countries the possibility of low-interest loans has not been included in the summary, they are available via the European Investment Bank (EIB) [5], an organism directly dependent of the European Union (EU).

# 3. RESULTS

As claimed in §2.2, the results are presented in terms of private investment activated as a result of the financing measure studied. The results are presented in absolute terms and in relative – normalized – terms, whenever possible.

For each of the EAF the cashflow and its NPV are calculated as described in PITAGORAS-D5.2. The results present the figures obtained aggregating by country the plants that are economically viable, i.e. that have a positive NPV, with the financial aid measure but that were not viable without it. They have been classified in the three modes of operation, namely:

- "Only electricity generation": in this scenario, only an electrical valorisation of the waste heat stream is considered
- "Only heat generation": only heat recovery is assumed so no turbine investment is expected, neither electricity revenues
- "Hybrid": this scenario is the same as the one implemented in Brescia; during winter, heat is sold to the district heating network and during summer, when urban heat demand drops, waste heat is used for generating electricity self-consumed by the plant, thus generating electricity savings upon the facilities electrical bill

## 3.1. SUBSIDIES

The financing measure of giving a 30% subsidy on the investment required for the energy recovery, storage and distribution equipment has a significant impact in absolute terms with about 250 M€ of potential private capital mobilisation and up to more than 200 thousand tons of $CO_2$ savings.

The public investment corresponds to the 30% of the BOP.

### 3.1.1. Mode 1: Only electricity generation

With the scenario of only electricity production, the following results have been obtained:

*Table 2: Market potential of subsidies policy. "Only electricity generation" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Electric power (MW) | Electricity production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|---|
| **Austria** | 1 | 50 | 8.13 | 1.625 | 8.865 | 532.79 | 5.77 | 1.66 |
| **Germany** | 5 | 135 | 21.94 | 4.39 | 23.610 | 10031.92 | 18.68 | 5.36 |
| **Italy** | 33 | 1550 | 251.88 | 50.38 | 233.862 | 53601.38 | 181.49 | 52.11 |
| **Poland** | 5 | 688 | 111.8 | 22.36 | 93.417 | 62645.47 | 58.59 | 16.82 |
| **Total** | **44** | **2423** | **393.74** | **78.75** | **359.755** | **126811.55** | **264.53** | **75.95** |

Normalizing the new private investment and the extra $CO_2$ emissions saved with the public investment the following figures are obtained:

*Table 3: Subsidies ratios of return on public investment. "Only electricity generation" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Austria** | 3.48 | 321.61 |
| **Germany** | 3.48 | 1870.84 |
| **Italy** | 3.48 | 1028.59 |
| **Poland** | 3.48 | 3723.92 |
| **Average** | **3.48** | **1669.61** |

It is observed that the capacity of private capital mobilisation is at about 3.5 € per € invested by the public administration for this mode of operation.

Regarding the $CO_2$ emissions, the savings are proportional to the $CO_2$ intensity of the electricity mix and the capacity factor of each country, having greater potential savings in Poland which is the country with higher $CO_2$ emissions mix from those studied.

### 3.1.2. Mode 2: Only heat generation

With the scenario of only heat production, the following results have been obtained:

*Table 4: Market potential of subsidies policy. "Only heat generation" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Heat production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|
| **Germany** | 19 | 2070 | 336.38 | 1086.06 | 121856.21 | 130.96 | 56.13 |
| **Italy** | 14 | 1695 | 275.44 | 767.22 | 86082.23 | 104.16 | 44.64 |
| **Poland** | 4 | 560 | 91 | 228.11 | 25594.10 | 33.11 | 14.19 |
| **Total** | **37** | **4325** | **393.74** | **2081.40** | **233532.54** | **268.23** | **114.96** |

Normalizing the new private investment and the extra $CO_2$ emissions saved with the public investment the following figures are obtained:

*Table 5: Subsidies ratios of return on public investment. "Only heat generation" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Germany** | 2.33 | 2171.08 |
| **Italy** | 2.33 | 1928.41 |
| **Poland** | 2.33 | 1803.51 |
| **Average** | **2.33** | **2031.47** |

It is observed that the capacity of private capital mobilisation is at about 2.3 € per € invested by the public administration for this mode of operation.

Regarding the $CO_2$ emissions, the savings are proportional to the capacity factor and thus the thermal energy recovered by installed unit.

### 3.1.3. Mode 3: Hybrid electricity and heat generation

In this third scenario of hybrid electricity and heat production, the following results have been obtained:

*Table 6: Market potential of subsidies policy. "Hybrid" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Electric power (MW) | Electricity production (GWh) | Heat production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|---|---|
| **Germany** | 10 | 681 | 110.66 | 22.13 | 59.550 | 208.424 | 48687.92 | 74.17 | 21.30 |
| **Italy** | 18 | 1845 | 299.81 | 59.96 | 139.186 | 487.152 | 86559.88 | 178.27 | 51.19 |
| **Total** | **28** | **2526** | **410.48** | **82.10** | **198.736** | **695.576** | **135247.79** | **252.44** | **72.48** |

The normalized private investment and $CO_2$ emissions saved are:

*Table 7: Subsidies ratios of return on public investment. "Hybrid" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Germany** | 3.48 | 2286.06 |
| **Italy** | 3.48 | 1691.08 |
| **Average** | **3.48** | **1865.90** |

The potential for private investment is 3.4828 times the public investment. The average emissions savings potential is almost 2000 $tCO_2$ per € of public investment.

## 3.2. LOW-INTEREST LOANS

The financing measure of providing a low-interest credit line has the higher return ratios of invested private capital and $CO_2$ emissions saved per € of public investment, with almost 20€ of private investment and between 5500 and 13700 tons of $CO_2$ saved, respectively.

The public investment here consists on the entire financing costs of the loan.

### 3.2.1. Mode 1: Only electricity generation

In the scenario of only electricity production, the following results have been obtained:

*Table 8: Market potential of low-interest loans policy. "Only electricity generation" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Electric power (MW) | Electricity production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|---|
| **Germany** | 4 | 117 | 19.01 | 3.80 | 20.462 | 8694.32 | 20.41 | 1.05 |
| **Italy** | 8 | 480 | 78 | 15.60 | 72.422 | 16599.14 | 67.46 | 3.47 |
| **Total** | **12** | **597** | **97.01** | **19.40** | **92.884** | **25293.12** | **87.87** | **4.52** |

With the proposed normalisation, the following returns on public investment are observed:

*Table 9: Low-interest loans rates of return on public investment. "Only electricity generation" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Germany** | 19.42 | 8274.09 |
| **Italy** | 19.42 | 4778.15 |
| **Average** | **19.42** | **5590.02** |

The private capital mobilisation potential is almost 20 times the public money invested. With $CO_2$ emissions savings, variations depending on the electricity mix being replaced are observed.

### 3.2.2. Mode 2: Only heat generation

In the scenario of only heat production, the following results have been obtained:

*Table 10: Market potential of low-interest loans policy. "Only heat generation" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Heat production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|
| **Germany** | 3 | 440 | 71.5 | 230.854 | 25901.80 | 36.65 | 1.89 |
| **Total** | **3** | **440** | **71.5** | **230.854** | **25901.80** | **36.65** | **1.89** |

After the normalisation, the following results are observed:

*Table 11: Low-interest loans rates of return on public investment. "Only heat generation" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Germany** | 19.42 | 13724.69 |
| **Average** | **19.42** | **13724.69** |

With viable plants in only one country, the potential observed is scarce. The private investment mobilisation potential is at 19.4€ and the $CO_2$ emissions savings potential at more than 13700 tons, with relation to each euro of public investment, but a total private investment mobilization potential of around 37M€ is observed only.

### 3.2.3. Mode 3: Hybrid electricity and heat generation

In the scenario of hybrid electricity and heat production, the following results have been obtained:

*Table 12: Market potential of low-interest loans policy. "Hybrid" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Electric power (MW) | Electricity production (GWh) | Heat production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|---|---|
| **Germany** | 6 | 475 | 77.19 | 15.44 | 41.536 | 145.377 | 33960.00 | 63.93 | 3.29 |
| **Italy** | 1 | 150 | 24.38 | 4.88 | 11.316 | 39.606 | 7037.39 | 16.69 | 0.86 |
| **Total** | **7** | **625** | **101.56** | **20.31** | **52.852** | **184.983** | **40997.39** | **80.62** | **4.15** |

And the normalised results are:

*Table 13: Low-interest loans rates of return on public investment. "Hybrid" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Germany** | 19.42 | 10315.25 |
| **Italy** | 19.42 | 8187.65 |
| **Average** | **19.42** | **9874.78** |

Although there are few plants viable, they are found in two different countries, thus different $CO_2$ emissions savings rates of return are observed, about 8000 $tCO_2$ in Italy and more than 10000 $tCO_2$ in Germany. The rates of return for private investment are equal to those observed in Modes 1 and 2.

## 3.3. ENERGY EFFICIENCY CERTIFICATES

The financing measure of adopting an energy efficiency certificates scheme has the major impact of the studied measures in absolute terms with potential private capital mobilisation ranging between 300 and 1250 M€ and up to more than 625 thousand tons of $CO_2$ savings, depending on the mode of operation and the energy efficiency certificates quotes.

The assumed prices of each energy efficiency certificate, equivalent to tons of oil equivalent saved, are 125 €/TOE and 230 €/TOE.

### 3.3.1. Mode 1: Only electricity generation

In the scenario of only electricity production, the following results have been obtained:

*Table 14: Market potential of energy efficiency certificates policy @125 €/TOE. "Only electricity generation" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Electric power (MW) | Electricity production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|---|
| **Austria** | 1 | 50 | 8.13 | 1.63 | 8.865 | 532.79 | 7.43 | 1.10 |
| **Germany** | 5 | 135 | 21.94 | 4.39 | 23.610 | 10031.91 | 24.04 | 2.93 |
| **Italy** | 26 | 1305 | 212.06 | 42.41 | 196.898 | 45128.91 | 193.11 | 24.42 |
| **Poland** | 5 | 688 | 111.8 | 22.36 | 93.417 | 62645.47 | 75.41 | 11.59 |
| **Total** | **37** | **2178** | **353.93** | **70.79** | **322.790** | **118339.08** | **299.98** | **40.04** |

*Table 15: Market potential of energy efficiency certificates policy @230 €/TOE. "Only electricity generation" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Electric power (MW) | Electricity production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|---|
| **Austria** | 4 | 145 | 23.56 | 4.71 | 25.709 | 1545.08 | 23.57 | 5.87 |
| **France** | 4 | 570 | 92.63 | 18.53 | 67.271 | 2341.03 | 61.78 | 15.35 |
| **Germany** | 5 | 135 | 21.94 | 4.39 | 23.610 | 10031.91 | 24.04 | 5.39 |
| **Italy** | 53 | 2084 | 338.65 | 67.73 | 314.432 | 72067.93 | 329.26 | 71.76 |
| **Poland** | 10 | 1073 | 174.36 | 34.87 | 145.693 | 97701.44 | 125.49 | 33.25 |
| **Slovakia** | 1 | 60 | 9.75 | 1.95 | 8.277 | 736.66 | 8.44 | 1.89 |
| **Spain** | 16 | 1935 | 314.44 | 62.89 | 229.382 | 69732.19 | 220.05 | 52.18 |
| **Total** | **93** | **6002** | **975.33** | **195.07** | **814.374** | **254156.24** | **792.61** | **185.68** |

With the proposed normalisation, the following returns on public investment are observed:

*Table 16: Energy efficiency certificates @125 €/TOE rates of return on public inv. "Only electricity generation" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Austria** | 6.75 | 484.55 |
| **Germany** | 8.21 | 3425.73 |
| **Italy** | 7.91 | 1847.91 |
| **Poland** | 6.51 | 5406.67 |
| **Average** | **7.49** | **2955.80** |

*Table 17: Energy efficiency certificates @230 €/TOE rates of return on public inv. "Only electricity generation" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Austria** | 4.02 | 263.34 |
| **France** | 4.02 | 152.49 |

| | | |
|---|---|---|
| **Germany** | 4.46 | 1861.81 |
| **Italy** | 4.59 | 1004.30 |
| **Poland** | 3.77 | 2938.41 |
| **Slovakia** | 4.47 | 389.98 |
| **Spain** | 4.22 | 1336.47 |
| **Average** | **4.27** | **1368.77** |

The private capital mobilisation potential is about 7 times the public money spent on average when certificates' quotes are at 125 €/TOE. With greater quotes, 230 €/TOE, the efficiency of such measure decreases to between 3.8 and 4.6 times the public money spent of private investment mobilisation.

With $CO_2$ emissions savings, variations depending on the electricity mix being replaced and on the capacity factor are observed. Nevertheless, the ratio of emissions savings on public investment is also reduced with greater quotes. The averages are almost 3000 $tCO_2$ and around 1350 $tCO_2$ per each € of public investment, respectively.

As shown below with lower ratios for the other two modes of operation, the "Only electricity generation" mode of operation is the one with greater rates of return on public investment.

### 3.3.2. Mode 2: Only heat generation

In the scenario of only heat production, the following results have been obtained:

*Table 18: Market potential of energy efficiency certificates policy @125 €/TOE. "Only heat generation" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Heat production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|
| **Austria** | 3 | 120 | 19.50 | 63.828 | 7161.51 | 14.71 | 3.64 |
| **France** | 3 | 450 | 73.13 | 159.326 | 17876.36 | 37.23 | 9.09 |
| **Germany** | 22 | 2216 | 360.10 | 1162.664 | 130450.90 | 204.01 | 66.32 |
| **Italy** | 28 | 2725 | 442.81 | 1233.438 | 138391.79 | 254.06 | 70.36 |
| **Poland** | 6 | 788 | 128.05 | 320.985 | 36014.55 | 67.76 | 18.31 |
| **Spain** | 6 | 840 | 136.50 | 298.730 | 33517.54 | 70.93 | 17.04 |
| **Sweden** | 2 | 225 | 36.56 | 89.711 | 10065.63 | 20.27 | 5.12 |
| **Total** | **70** | **7364** | **1196.65** | **3328.683** | **373478.27** | **668.97** | **189.87** |

*Table 19: Market potential of energy efficiency certificates policy @230 €/TOE. "Only heat generation" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Heat production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|
| **Austria** | 4 | 145 | 23.56 | 77.126 | 8653.49 | 18.26 | 8.09 |
| **France** | 15 | 1505 | 244.56 | 532.856 | 59786.48 | 139.29 | 55.93 |
| **Germany** | 27 | 2351 | 382.04 | 1233.494 | 138398.04 | 222.63 | 129.46 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Italy** | 75 | 4439 | 721.34 | 2009.260 | 225438.95 | 469.14 | 210.88 |
| **Poland** | 13 | 1203 | 195.49 | 490.032 | 54981.61 | 112.80 | 51.43 |
| **Slovakia** | 1 | 60 | 9.75 | 24.831 | 2786.06 | 6.54 | 2.61 |
| **Spain** | 26 | 2660 | 432.25 | 945.979 | 106138.88 | 245.00 | 99.29 |
| **Sweden** | 8 | 635 | 103.19 | 253.186 | 28407.44 | 63.00 | 26.57 |
| **Total** | **169** | **12998** | **2112.18** | **5566.764** | **624590.95** | **1276.65** | **584.27** |

After the normalisation, the following results are observed:

*Table 20: Energy efficiency certificates @125 €/TOE rates of return on public inv. "Only heat generation" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Austria** | 4.04 | 1966.99 |
| **France** | 4.10 | 1966.99 |
| **Germany** | 3.08 | 1966.99 |
| **Italy** | 3.61 | 1966.99 |
| **Poland** | 3.70 | 1966.99 |
| **Spain** | 4.16 | 1966.99 |
| **Sweden** | 3.96 | 1966.99 |
| **Average** | **3.52** | **1966.99** |

*Table 21: Energy efficiency certificates @230 €/TOE rates of return on public inv. "Only heat generation" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Austria** | 2.26 | 1069.02 |
| **France** | 2.49 | 1069.02 |
| **Germany** | 1.72 | 1069.02 |
| **Italy** | 2.22 | 1069.02 |
| **Poland** | 2.19 | 1069.02 |
| **Slovakia** | 2.51 | 1069.02 |
| **Spain** | 2.47 | 1069.02 |
| **Sweden** | 2.37 | 1069.02 |
| **Average** | **2.19** | **1069.02** |

In this second mode of operation, only slight variations between countries are observed. The investment return and $CO_2$ emissions savings return ratios on public investment are between 3 and 4 € and about 2000 $tCO_2$ per € in the case of 125 €/TOE quotes and between 1.7 and 2.5 € and about 1000 $tCO_2$ in case certificates' quotes reach 230 €/TOE.

### 3.3.3. Mode 3: Hybrid electricity and heat generation

In the scenario of hybrid electricity and heat production, the following results have been obtained:

*Table 22: Market potential of energy efficiency certificates policy @125 €/TOE. "Hybrid" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Electric power (MW) | Electricity production (GWh) | Heat production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|---|---|
| **Germany** | 10 | 681 | 110.66 | 22.13 | 59.550 | 208.424 | 48687.92 | 95.47 | 19.27 |
| **Italy** | 21 | 2065 | 335.56 | 67.11 | 155.783 | 545.240 | 96881.38 | 259.79 | 50.42 |
| **Poland** | 5 | 688 | 111.80 | 22.36 | 46.709 | 163.480 | 49665.17 | 78.55 | 15.12 |
| **Total** | 36 | **3434** | **558.03** | **111.61** | **262.041** | **917.144** | **195234.47** | **433.82** | **84.82** |

*Table 23: Market potential of energy efficiency certificates policy @230 €/TOE. "Hybrid" mode*

| Country | # of plants | Furnace capacity (t) | Heat power recovered (MW) | Electric power (MW) | Electricity production (GWh) | Heat production (GWh) | $CO_2$ emissions saved (t) | Private Invest. (M€) | Public Invest. (M€) |
|---|---|---|---|---|---|---|---|---|---|
| **Austria** | 4 | 145 | 23.56 | 4.71 | 12.854 | 44.990 | 5820.41 | 24.55 | 7.66 |
| **France** | 5 | 680 | 110.50 | 22.10 | 40.127 | 140.443 | 17154.08 | 77.78 | 23.90 |
| **Germany** | 15 | 816 | 132.60 | 26.52 | 71.355 | 249.742 | 58339.71 | 120.51 | 42.50 |
| **Italy** | 53 | 3545 | 576.06 | 115.21 | 267.434 | 936.018 | 166316.94 | 493.34 | 159.27 |
| **Poland** | 10 | 1073 | 174.36 | 34.87 | 72.846 | 254.962 | 77457.46 | 130.72 | 43.38 |
| **Slovakia** | 1 | 60 | 9.75 | 1.95 | 4.139 | 14.485 | 1993.53 | 8.79 | 2.46 |
| **Spain** | 16 | 1935 | 314.44 | 62.89 | 114.691 | 401.419 | 79905.29 | 229.21 | 68.31 |
| **Sweden** | 2 | 225 | 36.56 | 7.31 | 14.952 | 52.332 | 6028.61 | 27.26 | 8.90 |
| **Total** | **106** | **8479** | **1377.84** | **275.57** | **598.397** | **2094.390** | **413016.03** | **1112.17** | **356.38** |

And the normalised results are:

*Table 24: Energy efficiency certificates @125€/TOE rates of return on public inv. "Hybrid" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Germany** | 4.95 | 2525.98 |
| **Italy** | 5.15 | 1921.36 |
| **Poland** | 5.20 | 3285.07 |
| **Average** | **5.11** | **2301.84** |

*Table 25: Energy efficiency certificates @230€/TOE rates of return on public inv. "Hybrid" mode*

| Country | Normalized Private Invest. | Normalized $CO_2$ emissions saved (t/€) |
|---|---|---|
| **Austria** | 3.21 | 760.29 |
| **France** | 3.25 | 717.81 |
| **Germany** | 2.84 | 1372.81 |
| **Italy** | 3.10 | 1044.22 |
| **Poland** | 3.01 | 1785.36 |
| **Slovakia** | 3.57 | 808.81 |
| **Spain** | 3.36 | 1169.81 |

| | | |
|---|---|---|
| **Sweden** | 3.06 | 677.00 |
| **Average** | **3.12** | **1158.91** |

The hybrid mode of operation shows ratios of return on public investment of more than 5€ of private investment mobilized and more than 2300 $tCO_2$ for each euro of public investment for quotes of 125 €/TOE. These figures decrease to slightly more than 3€ and 1150 $tCO_2$ for quotes of 230 €/TOE.

## 3.4. RESULTS SUMMARY

As a visual summary of the obtained results, the private investment mobilised by each financing measure and the required public investment to put such private capital into operation are graphically represented altogether with the ratios of return on public investment. Figures 2-3 show such results:

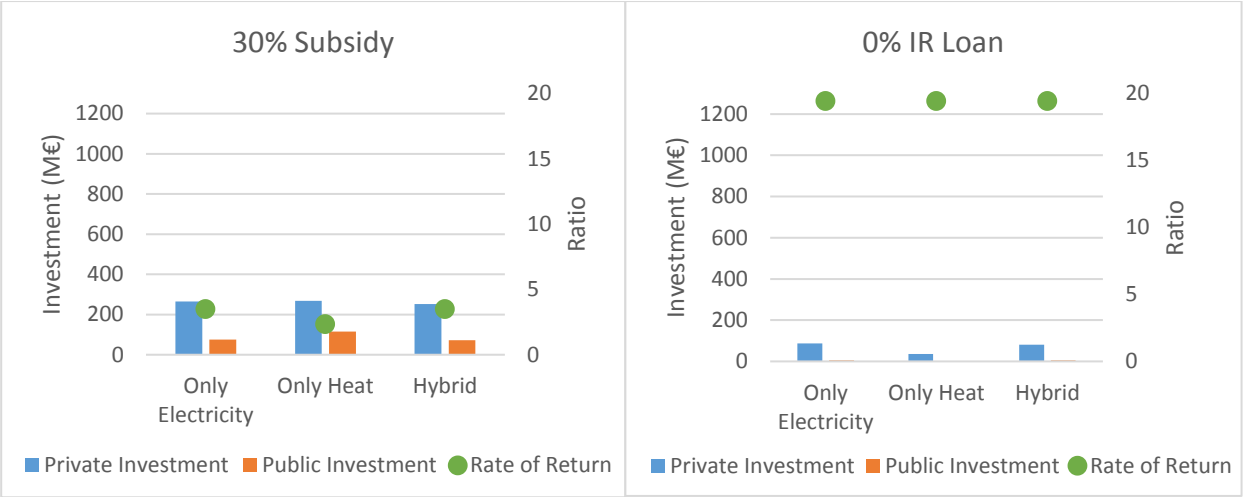


*Figure 2: Comparison of public investment, private investment and rate of return under the three modes of operation for the Subsidies measure (left) and the 0% interest rate loans measure (right)*

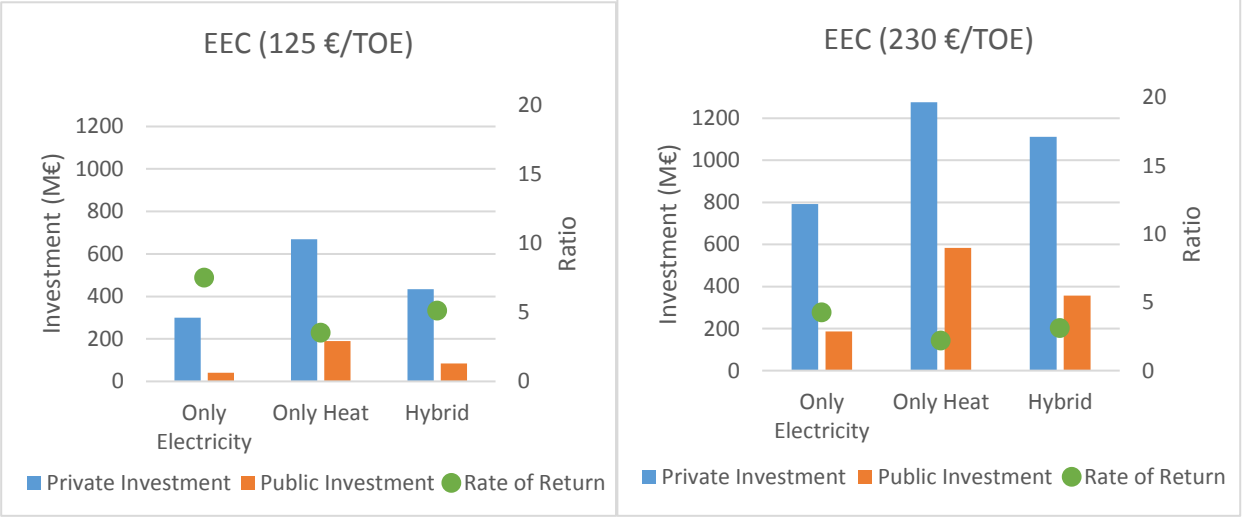


*Figure 3: Comparison of public investment, private investment and rate of return under the three modes of operation for the average EEC quote (left) and the latest EEC quote (right)*

# 4. CONCLUSIONS

In the context of fostering the replication of the waste heat recovery concept based on ORC technology, the improvement of profitability and reduction of upfront investment are two drawbacks worth studying with aim to be counteracted at some level.

To do so, the impact a set of public policies to foster investment in heat recovery installations for steel manufacturing power plants has been analysed in Austria, Czech Republic, France, Germany, Italy, Poland, Slovakia, Spain and Sweden.

The financing alternatives that have been considered worth studying are three. The first one is the measure of public subsidies, an option currently available in some countries among which Austria, Czech Republic, France, Poland and Spain are found. The subsidised amount considered is about 30% of investment costs for eligible parts, which are usually related with the final use of recovered heat as heat, for example in district heating networks.

The second option consist on low interest rate loans financed by public banks or financing organisms. As the interest rate is usually set under a case-to-case analysis, the simplifying assumption of no financial costs has been modelled and simulated. This is translated in a 0% IR loan for the investment financing.

The third alternative are energy efficiency certificates for electricity and heat production, similar to the "white certificates" in Italy or the "green certificates" in the UK. Following the scheme currently implemented in Italy, for both electricity and heat production each MWh of energy saved is converted to tons of oil equivalent (TOE), and one certificate is granted for every TOE of energy saved. As the quotes of the certificates are set in a free market constantly fluctuating, two different assumptions have been simulated: the average quote of the last 4 years in Italy (125 €/toe) and the quote of the last month available (June 2017) (230 €/toe).

The effect of these policies has been compared between them and between countries by means of two normalized response variables: the additional amount of private investment mobilised and the additional $CO_2$ savings achieved. The normalisation has been performed dividing the metrics by the amount of public investment required to enforce these policies in all the plants viable according with the defined criteria of positive net present value (NPV) at a 7% discount rate (DR) and 10 years of exploitation period.

One of the analysed alternatives has been the provision of subsidies (considered as around 30% of eligible costs). This option performs similarly with the three modes of operation. For this alternative, roughly, for the three modes of operation, the private capital mobilisation potential is around 250 M€. The rate of return on public investment is between 2.33€ ("Only heat generation") and 3.48€ ("Only electricity generation" and "Hybrid") for private capital, meaning that each € provided by public administrations as subsidy for this kind of projects has the potential to put in the market between 2.33 and 3.48 € of private investment and promote an additional market of around 250M€ in the considered countries. Regarding $CO_2$ emissions savings, it is comprised in a range between 321 and 2286 tons (depending on the mode of operation, the capacity factor and the carbon intensity of country's energy mix). By countries, this measure proves to be worth implementing in Austria, Germany, Italy and Poland, although Austria only shows successful cases with "Only electricity generation" operation and Poland in all except the "Hybrid" mode.

It is worth mentioning that in those countries where even a 30% subsidy is insufficient to foster private investment in heat recovery for electricity or heat production, more specific subsidy schemes considering the level of industrial development of certain regions or the type of concept being subsidised could be effective. For instance, the Spanish Energy Diversification and Savings Institute (IDAE in its Spanish acronym) subsidy plan [9] increases the ratio of investment subsidised for certain regions with lower industrial development to 35 or even 45%, ratios that would make some investments viable in Spain, France or Slovakia, for example.

Regarding the low-interest loans measure, in absolute terms it has much less potential than subsidies; as it is shown by the obtained results the potential to increase the market volume through new waste heat recovery plants implementation is much lower than with subsidies (in any case below 90M€ compared to around 250M€ that is estimated with the provision of subsidies). However, the rates of return obtained are significantly greater. Namely, they reach 19.4€ for private capital mobilization and carbon emissions savings between 4778 and 13724 tons of $CO_2$ emissions for each € of public money invested. This is considerable higher than the rates of return obtained for the subsidies alternative (2.3-3.5) This measure gives $CO_2$ emissions savings returns on investment greater in those modes of operation based on thermal energy valorisation ("Only heat generation" and "Hybrid" modes of operation), so it is worth studying its implementation in countries where the thermal energy can be easily sold in a DH.

However, this measure only shows viability improvement in Germany and Italy ("Only electricity generation" and "Only heat generation") or only Germany ("Hybrid"), so as a measure to be implemented throughout the EU it is clearly overcome by the other two.

The third alternative studied are the energy efficiency certificates, a retribution scheme in line with the so-called "White Certificates" currently implemented in Italy. With this financing tool, the public money invested is not put directly by the public administration, but by the consumers as companies acquiring white certificates are likely to impact the extra costs incurred from this certificates' acquisition to their consumers.

This financing measure provides significant ratios of private investment mobilisation on public investment for "Only electricity" and "Hybrid" operation modes: around 7 and 5 times the public investment, respectively. These are the operation modes with electricity production, so this measure is currently paying off well the investments made on electricity production from waste heat. However, it is in the second mode of operation where greater volumes of private investment are encouraged: the potential is up to 660 M€ of private investment, although the rate of return is close to 3.5, meaning that lots of public money would have to be put into the market – probably with increases in the price of goods produced in industries not adopting energy efficiency measures – to achieve such a level of private investment.

These are figures for last 4 years' average quote of energy efficiency certificates in Italy of 125 €/TOE. With the latest quote checked of 230 €/TOE, the amounts of mobilised private investment rocket up to 2 to 2.5 times having the potential to reach more than 1250 M€ for the "Only heat generation" mode of operation. However, this is not at no cost. The ratios of return on public investment are significantly reduced: almost cut by half.

Therefore, if high return ratios for public money invested are sought, low interest loans should be fostered. However, that would not increase substantially the market potential of waste heat recovery projects, in other words, that would not lead to high volumes of energy savings because only few plants would become viable with that financing aid measures, and only in Germany and Italy. Thus, if more energy savings are pursued, the energy efficiency certificates implementation would be the best alternative as they show the best overall behaviour making more plants viable for the heat recovery scheme proposed, and with significant ratios of return on public investment.

By countries, the best behaviour is observed in Germany and Italy for the three modes of operation and the three financing policies proposed. However, Poland and Austria are quite sensitive to financing measures, especially in the "Only electricity generation" mode. In particular, the energy efficiency certificates and the subsidies would have a very significant outcome in the four mentioned countries. The "Hybrid" mode of operation only shows viability in Germany and Italy, although the financing aid policies studied have a huge potential of plant viability increase in such countries. Namely, in Germany it is observed a viability shift on 30%, 20% and 30% of existent potential plants for subsidies, low-interest loans and EECs, whereas for Italy

figures rise up to 40%, 3% and 44% of market potential, respectively. The “Only heat generation” mode of operation shows more sensitivity and therefore plant viability improvement with the energy efficiency certificates measure, even though also great returns are observed when it is subsidised.

According with the results obtained, if an equilibrium between rate of return on public investment and total amount of private capital mobilised is sought, the best financing policy from those addressed would be the energy efficiency certificates adoption. Although it does not have the huge rates of return on public investment that low-interest loans have, the aggregated volume of private investment put in the sector far counteracts the lower rates of return. However, the efficiency of this alternative paying off the heat recovery model studied relies on the valorisation of the certificates obtained about 125 €/TOE as currently is in Italy. Since the price of these certificates is set in a free-market scheme, the investment is subject to more uncertainty than subsidies are.

Considering that certainty on the rates of return on investment is a major factor for huge investments, the subsidy alternative could also be a measure worth implementing. Lower rates of return on public investment would be achieved, but similar figures of aggregated private investment and $CO_2$ emissions savings could be reached. Moreover, the policy of subsidy on upfront investment allows increasing the subsidy shares to foster energy efficiency in certain regions. Although that would lower even more the rates of return on public investment, it can be in some situations an alternative worth studying if regional development is sought thanks to its controllability, in opposite to the price of energy efficiency certificates that is set on a free market.

With regards to the third financing policy of low-interest loans, despite the great rates of return on public investment, it does not have a relevant impact in the studied countries, only a few plants would become viable in Germany and Italy. Hence, it seems an alternative worth studying as a complement to the other financing policies to encourage more the investment in heat recovery alternatives in line with the Pitagoras concept here addressed.

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