WASTE HEAT RECOVERY FOR POWER GENERATION

Panorama of public policies supporting power generation from industrial waste heat

October 2012

Study carried out for the ADEME by ENEA Consulting and Enertime
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SUMMARY REPORT

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1 Preamble

This document is the summary of a panorama of the energy context, the potential operational feedbacks and the public policies supporting Waste Heat Recovery for Power Generation (WHRPG) in 26 countries among industrialized and strongly developing ones[1].

The scope of the study is limited to industry, which particularly includes the energy sector, such as oil refining, and highly exothermal sectors (glass-making, metallurgy, cement-making, etc.). It should be noticed that combined heat & power (also known as cogeneration), waste-to-energy processes and valorization into heat are not included in the scope of the study.

The study was carried out in two phases:

- The first phase consisted of capitalizing on public data from databases and statistics (European Commission's database, statistics from the IEA…), and of preliminary contact with the main national public actors from the countries under study.
- The public policies announced by the governments were analyzed in a second phase. Interviews and questionnaires allowed to consolidate the information and to gather experience feedbacks from the industry: more than 170 people were contacted; 37 actively took part in the study (interviews and/or answer to a questionnaire).

Following a brief history of the sector, an overall vision of the supporting policies and of the implemented projects is provided. Then, influencing factors are studied, and eventually, French perspectives as suggested by ENEA Consulting and Enertime are investigated.

Note – cogeneration and waste heat recovery: a cogeneration system is usually defined as a system which produces electricity through combustion, and then uses the heat (available as steam or hot water) to produce additional electricity or directly as heat. Therefore, the principle relies on the valorization of the heat, which is a by-product of the power generation. In some of the countries under study, the terms "CHP" or "cogeneration" include power generation from waste heat in a thermodynamic bottoming cycle, in which the heat is produced first and the electricity is the by-product.

2 History

WHRPG started in the 1980s in Japan, within the cement industry. It grew mainly in Eastern Asia (China and Japan) from 2000, at a time when energy prices increased. In Europe, the tests carried out in the 1990s did not prove profitable enough to convince the industrial actors, because of the low energy prices.

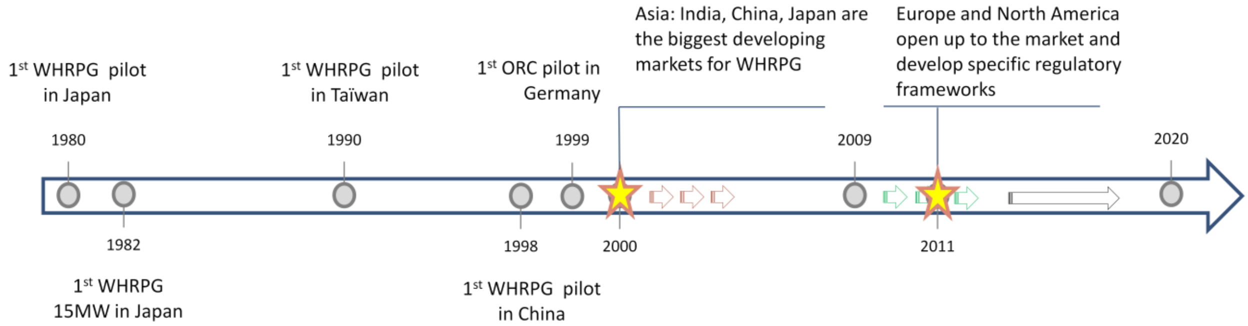
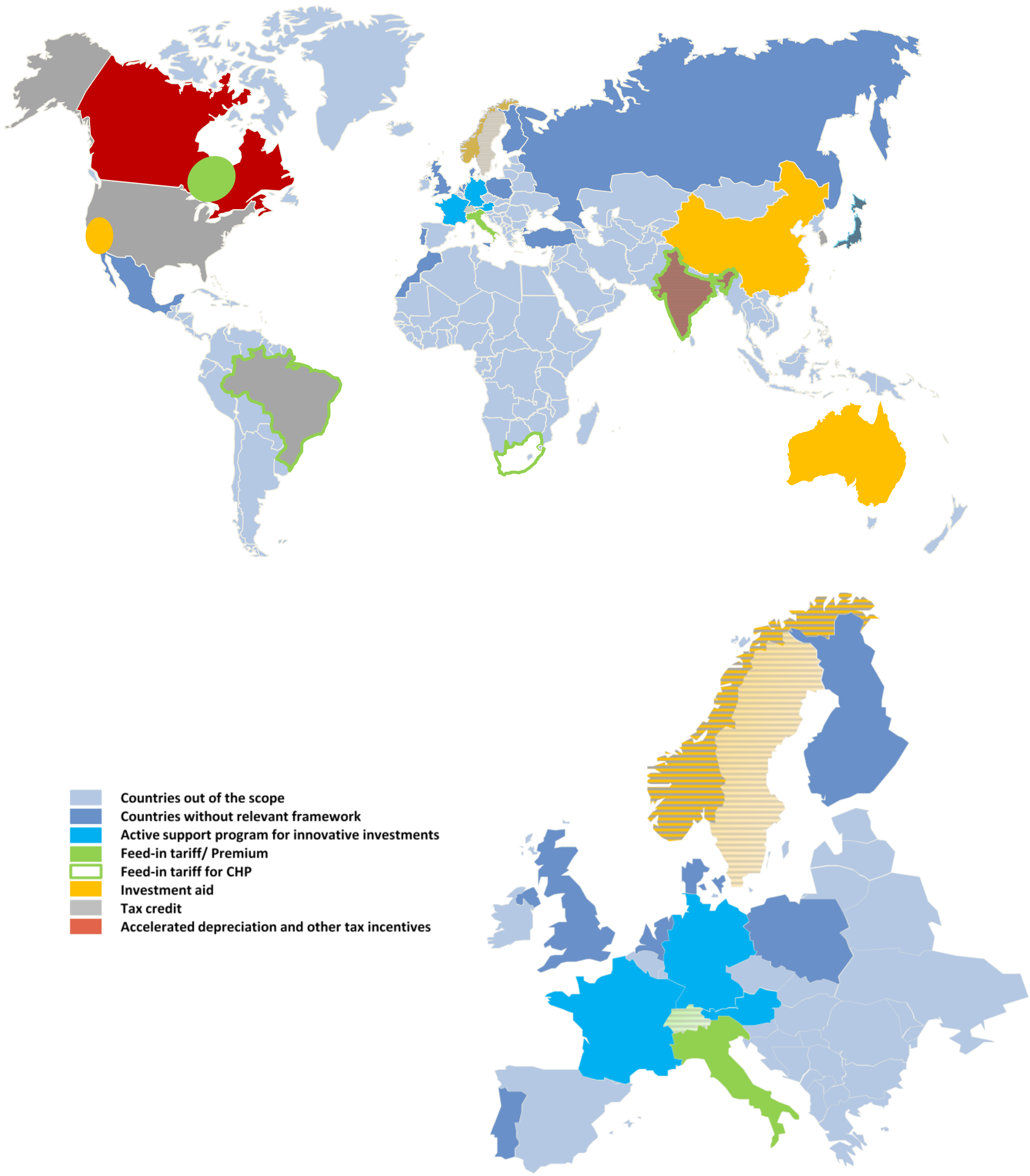


Figure 1 : Development of WHRPG systems in the cement industry, the most active sector

[1] USA, Canada, Mexico, Brazil, South Africa, Australia, India, Japan, China, South Korea, Turkey, Morocco, Portugal, France, Italy, Switzerland, Austria, Germany, Poland, the Netherlands, Denmark, United Kingdom, Norway, Sweden, Finland, Russia

3 Public policies supporting WHRPG

The figure below displays the support frameworks (outside CDM[2]) for WHRPG, in Europe and worldwide. Hatching is used where several kinds of policies are implemented. Light colors mean that the regulatory framework is scheduled but has not been set up yet.



[2] Clean Development Mechanism. This is an economic mechanism within the carbon finance, elaborated under the Kyoto Protocol: a company from an industrialized country invests in a technological improvement in a developing country and benefits from the associated carbon credits.

Figure 2 : Map of the support frameworks (outside CDM) for WHRPG in Europe and worldwide.

Worldwide, only a few countries initiated a supportive approach for WHRPG (outside projects eligible for CDM). The situation in developed countries on one side, and in developing countries on the other side, proves to be very different and must be considered separately.

3.1 The situation in developed countries

In developed countries, the improvement of industrial processes in order to manage energy resources in a better way has been a priority for the last two decades. There is less room for improvement than in emerging countries (see Figure 4), but there is a real potential for the use of industrial waste heat, which is generally supported in countries where electricity prices are high (see Figure 6).

The following policies are to be highlighted:

Canada (2011)	▪ Depreciation of WHRPG accelerated by 50% ▪ Program ERSOP in Ontario: feed-in tariff of 70 €/MWh for the electricity produced from waste heat, for projects selected through calls for tenders
USA	▪ Project to amend the federal law in order to allow 30% tax credit on WHRPG projects ▪ A dozen States have acknowledged that waste heat is a renewable energy source ▪ California (2011): investment aid of 0,8€/W, up to 3 MW
Australia	▪ Large manufacturers are forced to put in place energy efficiency measures and public reporting (“Energy Efficiency Opportunities” program) ▪ Investment aid through this EEO program and the CTIP program, up to 30% of the investment.
Japon	▪ Accelerated depreciation and soft loans ▪ Investment aid up to 50%
Italie (2011)	▪ Extension of the scope of White certificates to include WHRPG, with a new scale in 2011: one certificate is now worth 60 €/MWh_e)
Norvège (2011)	▪ Investment aid up to 20% and deduction tax exemption on the electricity produced and self-used.

All those mechanisms are very recent; most of them were put in place in the middle or at the end of 2011. Experience feedbacks about the application of these policies are still weak or of little interest. However, according to the people interviewed in Italy, Norway and the USA, the regulations that have been put in place are efficient and foster the development of WHRPG projects.

In Europe, the valorization of waste heat into electricity is not a priority highlighted by national policies so far, and only a few countries have already put in place a financial and policy support framework to foster the development of WHRPG. Out of the 13 countries whose policies have been evaluated, only 2 countries distinguish themselves: Italy and Norway already have a specific and defined framework. Germany supports WHRPG projects with innovation and research purposes in the industry, or through support mechanism dedicated to renewable energies when the primary energy used is renewable (biomass, biogas). Finally, some mechanisms are under study in Sweden and in Switzerland, where a system relying on premiums[3] will be implemented in 2014.

[3] A premium is a bonus paid by the State to the producer for each MWh produced. It adds up to to the selling price on the market if the MWh is sold; it can also be paid in the case of self-consumption.

Several hurdles prevent the WHRPG niche market from expanding in developed countries, and particularly in Europe. Technical and economic considerations explain this situation.

Technical considerations: the remaining heat sources that can be recovered in the industry have a relatively low temperature, which limits the efficiency and the relevance of setting up WHRPG systems.

ORC and Kalina systems are still uncommon in the industry, as they need to prove their reliability. Ancillary equipment, such as heat exchangers, must also be improved and adapted to low-grade heat sources, and need to resist better to corrosion and fouling.

Moreover, unlike in developing countries, these systems are likely to be installed within existing facilities, which add additional constraints: minimizing the impact on the industrial process, compactness and ease of installation.

Besides, heating networks are already well developed in several European countries (Austria, Sweden, Denmark, Finland, and Netherlands) and are expanding in some others (United Kingdom, Norway, France, Germany, Poland). Since 2010, the EU and some national governments (UK, Norway) have focused on developing heating networks fueled with “green” heat sources, which includes waste heat recovery. Depending on economic and geographical conditions and on temperature levels, there may be a competition with the valorization into electricity during cold periods.

Economic considerations: the return on investment is too weak in most cases (low electricity price, high CAPEX, difficulties to get funding…), particularly in the context of growing pressure on the allocation of CAPEX budget for energy equipment, which is not considered as a priority by industrial actors for which the generation of electricity is not a core business.

Besides, in Europe, a project subsidized by a European or a national aid is forced by law to have a return of investment longer than 5 years, when industrial actors are usually willing to invest in an energy efficiency project only if the ROI does not go over 3 years.

3.2 The situation in emerging countries

Developing countries have to deal with their strong economic growth and do not always have the necessary infrastructure (in particular in terms of electricity network) to handle the energy demand from an expanding industrial sector (see Figure 5). In this context, countries like China, Brazil, South Africa or India encourage industrial actors to invest in energy efficiency measures in order to relieve the infrastructure and to curb the increase of the energy consumption.

In these countries, the support to WHRPG projects is significant and WHRPG is considered to be an energy efficiency measure. They are supported financially (e.g. accelerated depreciation like in India) or mandatory (e.g. in China, where it is impossible to get an operation permit for a cement factory if no WHRPG plants are included in its design).

Besides, the implementation of carbon taxes in Asian countries, such as India, penalizes large industrial greenhouse gases emitters and therefore encourages them to invest in energy efficiency. In China, an industrial plant may be closed by the government if it does not comply with the maximum permitted emission rate.

Finally, the possibility to get external financing through the sale of carbon credits stemming from avoided emissions, within the CDM framework, is an additional source of funding.

4 WHRPG projects worldwide

There are more than a thousand WHRPG systems worldwide, of which more than 900 are installed in China, very active in this sector since the mid 2000s. About 100 units are spread in Japan, India, South Korea and the USA.

Slowly, projects appear in Europe, leaded by Italy, which can rely on the R&D dynamism of companies such as Turboden, European leader on the Organic Rankine Cycle, and on its support framework. Germany is also staying ahead, with a dozen identified industrial sites; most of them use steam turbine, while the remaining 3 or 4 are innovation projects based on ORC systems.

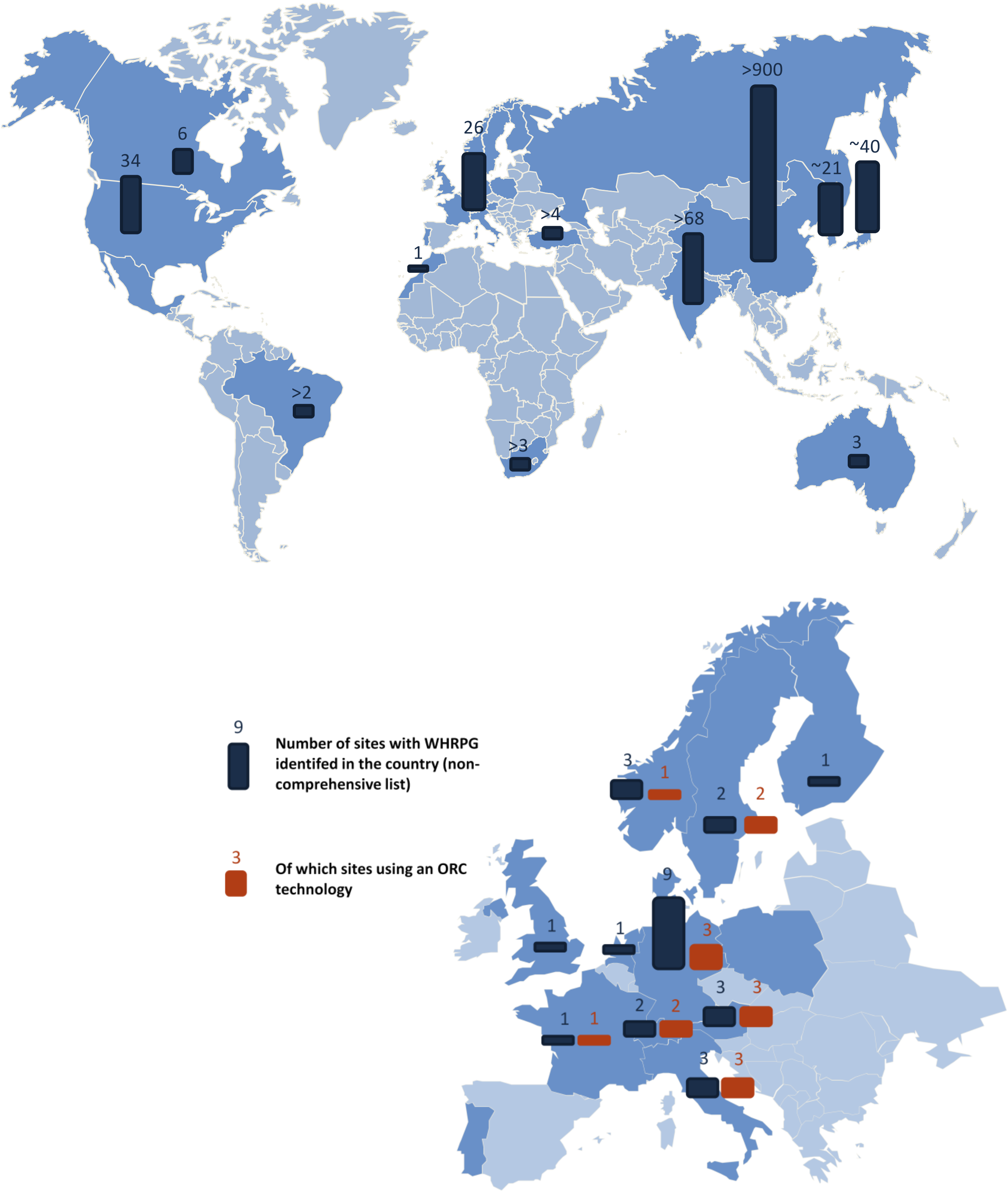


Figure 3 : number of identified WHRPG systems per country (non-exhaustive list)

5 Key driving factors

5.1 Energy intensity

The industrial energy intensity is of course playing a role in the development of WHRPG. For example, in Europe, where the industry is relatively energy efficient, heat sources are more difficult to harness. At the opposite, a lot of new heavy-industry installations are developing in China, which then offers favorable conditions for the implementation of WHRPG systems.

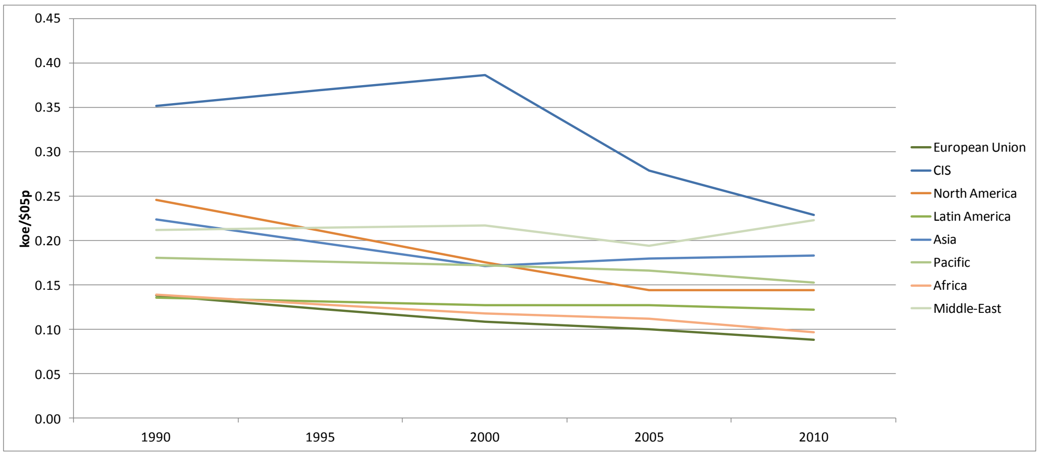


Figure 4: Comparison of the evolution of the industrial primary energy intensity in each region of the world, between 1990 and 2010 (*Source: WEC*)

5.2 Quality of networks

The quality of networks is also a driving force. In some countries, where electric outages are common because of the weakness of the network, bottlenecks, or excessive demand, there is much at stake for industrial actors, which are therefore encouraged to produce their own electricity in order to be more self-sufficient and free from the network defaults. Network issues also justify setting up national policies to relieve the electricity network, particularly by promoting cogeneration (which includes WHRPG). Among the countries under study, this is the case in India, Brazil, Mexico, Turkey and South Africa.

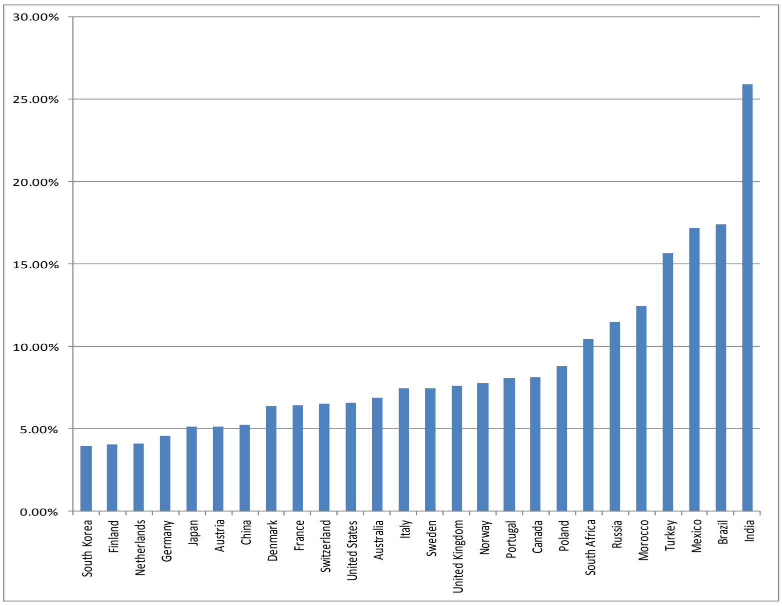


Figure 5: transmission & distribution losses compared to power generation (in %) in 2009 (*Source: IEA*), representing the “overall condition” of electricity networks

5.3 Electricity price

The electricity price for the industry shows significant differences among the countries under study (from 0,05 €/kWh in Norway or the USA to 0,125 €/kWh in Italy and 0,137 €/kWh in Brazil). France has a relatively low price for electricity compared to the countries in the scope of the study.

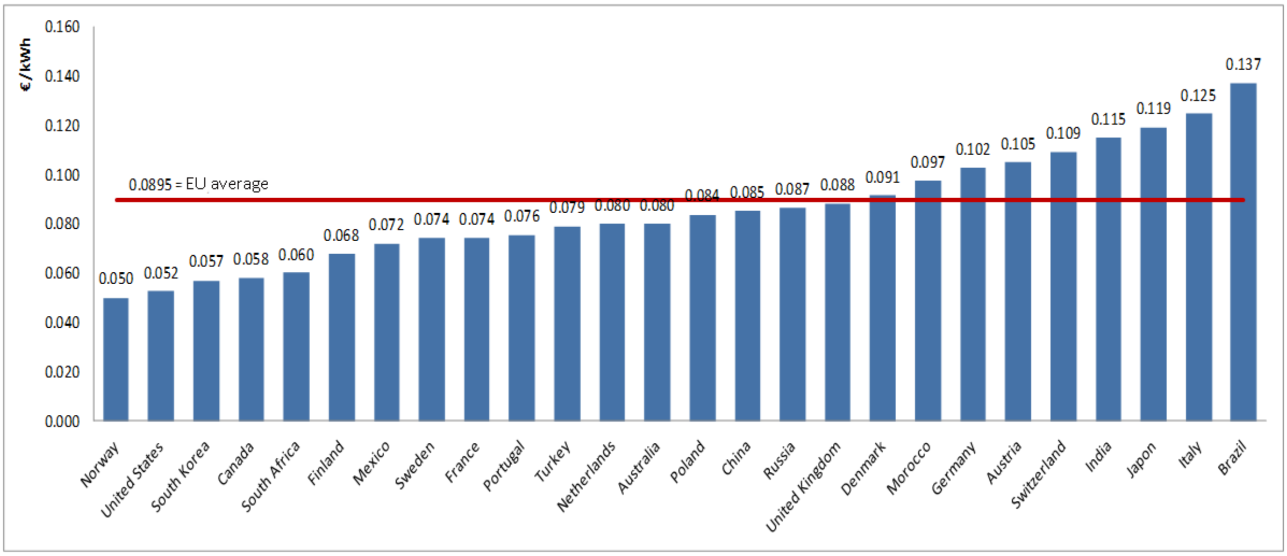


Figure 6: Electricity prices for the industry in 2011-2012 in the 26 countries under study (*Source: IEA 2011, Eurostat, national energy regulatory authorities*)

The cost of electricity consumed by industrial actors is an important factor when making a decision to invest in WHRPG. When the electricity purchased from the grid is expensive and represent a significant part of the production cost of the finished goods, manufacturers are likely to take into consideration such an investment, even if no public financial support is provided and if the payback time is much longer than what they usually require (3 years) (see for example the cement factory “Ciments du Maroc” in Morocco, and projects in Brazil).

In Europe, Italy is clearly the country where the electricity price for industrial customers is the highest. The fact that this country is the first which implemented a clear support scheme can be explained by a will of casting light on the WHRPG concept, and of subsidizing the injection of low-carbon electricity in the network at a low cost: the selling price above which a project is profitable will be reached with a lower subsidy compared to a country where the electricity is cheaper and where the subsidy will thus need to be higher.

The projects under development in the USA and in Canada are located in states where the electricity price is above the national average. This is the case in Ontario, where the electricity costs close to 0,09 €/kWh; this is significantly higher than in neighboring Quebec (0,02 to 0,04 €/kWh) which benefits from its abundant hydroelectric resources.

However, despite of its quite cheap electricity, Norway has also put in place such a scheme. The price of electricity is therefore not the only driving factor taken into consideration by public policies.

6 Perspectives in France suggested by ENEA Consulting and Enertime

The current energy context in France does not encourage the development of WHRPG projects, which is nowadays almost non-existent in the country. The main reasons are:

- A low electricity price for industrial customers
- A solid and reliable electricity network
- The lack of policies to support industrial actors willing to invest in these technologies
- The restrictive investment criteria in terms of expected profitability. The industrial culture requires very ambitious return-on-investment targets for energy efficiency measures (often less than 3 years, sometimes even less), limiting investments with a return on a longer run (4 to 10 years depending on the project)
- Even though the thermal valorization of waste heat is currently not very common, particularly because of the under-development of district heating networks, the support to the development and the expansion of these networks should provide opportunities for the low-temperature thermal valorization (e.g. for waste heat from a first high-temperature valorization, as electricity or heat) to the industrial actors located in urban areas.

Based on what already exists in the countries in the scope of this study, some schemes could be implemented in France to support these projects, when appropriate. By order of relevance:

1. Feed-in tariff: well-known scheme in France, as it is used to promote the production of electricity from renewable sources; it could be used to promote WHRPG.

For example, the Canadian example is based on a feed-in tariff that is subject to yearly calls for tenders with a fixed volume (50 MW for the first year). The selected candidates are then allowed to sell the electricity at a guaranteed tariff over several years.

The call-for-tenders scheme, which France is increasingly using as a support scheme for several renewable energies (Solar PV, offshore wind), seems to be particularly suitable in the case of WHRPG. Considering the specificities of industrial facilities, it is easier to select the best projects *a posteriori* based on applications, rather than to define *a priori* conditions for the set-up of a feed-in tariff. Besides, as the production cost of an electrical MWh strongly depends on the site (heat source temperature, cleanness of the hot gases…), a call-for-tenders scheme would avoid deadweight effects, which would be counter-productive for the sector, and would help valuating the electricity produced from waste heat at the right price. A price range that would prove attractive enough should therefore be defined in order to get the expected leverage within the industry.

2. Direct subsidizing of facilities: a second option is to set up an investment subsidizing scheme, inspired by what is done in Norway. This is closer to the way the French “Fonds chaleur renouvelable” works. This is the most incentive format from the industrial point of view, because the aid is completely provided during the first years of operation of the system. However, the European constraints might be an obstacle to direct subsidizing of French companies.

3. Access to Certificats d’Economie d’Energie (CEE – Certificate of Recognition for Energy Conservation): so far, power generation equipments are not eligible for CEEs as defined by the Ministry in charge of Energy. Making them eligible could encourage industrial actors to equip their sites. The leverage effect of this scheme would however remain quite low compared to the two described above.

ABOUT ADEME

The French Environment and Energy Management Agency (ADEME) is a public agency under the joint authority of the Ministry for Ecology, Sustainable Development, Transport and Housing, the Ministry for Higher Education and Research, and the Ministry for Economy, Finance and Industry. The agency is active in the implementation of public policy in the areas of the environment, energy and sustainable development.

ADEME provides expertise and advisory services to businesses, local authorities and communities, government bodies and the public at large, to enable them to establish and consolidate their environmental action. As part of this work the agency helps finance projects, from research to implementation, in the areas of waste management, soil conservation, energy efficiency and renewable energy, air quality and noise abatement.

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