SAHC Project

Promotion of Solar Assisted Heating and Cooling in the agrofood sector

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D9
Suggestion of EU regulation to promote solar plants in industrial productions

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Executive summary

The main barriers for the adoption of Solar Plants in industrial applications are mostly economical and technical. Nevertheless, the proper and timely regulatory framework could substantially assist the adoption of SAHC applications in industry. Particular focus should be given on the tracking of the implementation of existing regulations so as to promote the advantages of SAHC systems towards the fulfilment of RE targets. On EU level, regulations should promote both market mechanisms as well as R&D, while also enhance the diffusion of information between the manufacturers and the end users. Member States should be obliged to maintain statistical data regarding the energy requirements for heating and cooling whereas a highly standardized performance of heating and cooling applications should be ensured through appropriate test and certificate methods.

The main aim of SAHC project is to remove barriers to the adoption of solar assisted heating and cooling plants in the agrofood sector, providing the managers of agro-food companies, energy managers, plant designers and energy service companies with a decision support software and guidelines enabling a preliminary assessment of the technical and economical feasibility of the application of such kind of plants in production processes. On the other hand, the barriers to the implementation of solar plants, have been evaluated during the project.

The present document contains the following sections:

- Section 1 describes the potential savings, installation costs and evaluation of the integration of solar cooling to solar thermal plants in some key agrofood sectors, taken as reference, in particular: hard cheese, milk and wine. These results are obtained from simulation campaigns carried out through the simulation tool produced during the project. Results of 17 feasibility studies realized in agrofood companies selected in Italy, Greece, Spain, Portugal and France in dairy, wine, soft drinks and breweries sector are also available in Deliverable 7. The potential of application is then provided matching this potential with the market evaluation in the target sectors carried out at the beginning of the project.

- Section 2 provides an overview of the incentives available for the installation of solar thermal plants, as compared with other RES, and possible measures to promote the effective application of Solar Assisted Heating and Cooling plants in agrofood, at European and National level. In particular the incentive measures that could be applied are presented.

The results of the simulations and feasibility studies carried out in the SAHC project have shown that the application of solar thermal in agrofood industry for heating-only purposes is energetically and economically sustainable, however when comparing the investment with other kind of RES, in particular PV, which benefits of high level of incentives, a promotional framework for solar thermal is needed to make the application competitive. On the other hand, solar cooling is presently not financially viable, due to high cost of the chiller, auxiliaries and engineering, while integration of solar heating and cooling is only convenient with high cooling solar fractions (and then relevant plant size), due to the high investment costs for the chiller, especially for small sizes. On the other hand, it can allow to increase solar collector plant and to benefit of higher energy savings of the order of 20-50% with respect to heating-only plants.

Concerning the proposed promotional framework for SAHC plants in industry, a common framework should be identified at EU level, leaving the adoption and the quantification at National level. The general lines of the proposed framework to promote solar thermal plants for heating and cooling in industry was provided, based on the environmental cost effectiveness of the incentive, and the cost/benefit derived from the case studies.

The promotion of solar thermal plants could be included in a general Feed-in-Tariff mechanism for RES-heating, with different tariffs for the different sources (air and ground-source heat pumps,
solar thermal, biomass boilers, renewable combined heat and power, use of biogas and bioliquids), whose potential has been so far underestimated with respect to RES-electricity. This mechanism has proved to be the most effective promotional mechanism for RES, encouraging the optimal design and operation of the plants and guaranteeing the return of the investment. The UK Renewable Heat Incentive (RHI), entering into force in April 2011, should be considered as an example. However, in the RHI the renewable cooling is excluded; we believe the potential application in Southern Europe for this technology is relevant and this should be considered in these countries. The following estimation of the tariffs for heating, cooling and integrated heating and cooling in industry was proposed, specifically targeted to Southern European countries targeted by SAHC project:

- solar heating in industrial process: 8-10 Eurocents/kWh heat for 20 years; this would allow to achieve ROIs of 7-11 years, which is reasonable for an industrial investment.
- solar cooling: 20 Eurocents/kWh for 20 years to make the ROI of about 10 years. This value is referred as incentive to the solar cold produced by the chiller.
- solar heat to be used for both heating and cooling in industry, with a minimum percentage (e.g. chiller size to collector ratio): 10-15 Eurocent/kWh for 20 years, which would bring the economic profitability to the same level of the heating-only incentive of 8-10 Eurocents/kWh. Different levels of tariffs could be applied for SAHC depending on the size of the collectors and size of the chiller, since small size plants are strongly affected by the high price of small size chillers and partly also of the collectors and auxiliaries.

The comparison of the proposed incentive with the avoided external costs related to the environmental, social and health impact of the generation, was carried out, as well as the evaluation of the environmental profitability of the investment, in terms of CO2 emissions saved per kWh produced. The values were compared with the average existing incentive for PV:

- The marginal advantage (difference between incentive and avoided external costs) of solar heating and cooling would be much more limited with respect to the differential of PV;
- The proposed incentive for solar thermal in industry would have a double environmental profitability with respect to PV, while solar cooling has by itself a limited profitability. The proposed incentive for solar heat used for both heating and cooling in industry (SAHC) would overcome the profitability of PV, while allowing much higher savings in absolute value with respect to heating-only.

One of the most promising technologies, as for solar heating and cooling, seems to be the use of Parabolic Through Collectors, which would help moving to double and triple-effect absorption machines. However, nowadays PTCs are not still widely sold (for the SAHC project curves the data come only from two manufacturers), and the first experiences with them show that despite the theoretical numbers seem sincerely good, most experiences are giving really bad solar yields, because of different factors (fouling problems, dirt problems, concentration error, bad installation techniques ...).
1 Potential of Solar Assisted Heating and Cooling in agrofood

The potential of Solar Assisted Heating and Cooling in agrofood sector was estimated through simulation campaigns carried out using the simulation software produced in the SAHC project and evaluating the results of feasibility studies carried out during the project.

Key studies were produced for 3 sectors: parmesan, milk, wine, evaluating the technical economical feasibility of the application and the potential applicability in Europe.

1.1 HARD CHEESE (PARMESAN)

1.1.1 Results of simulations and feasibility studies

The use of SAHC plants in parmesan production is related to the production of hot water for washing of equipment, tanks and surfaces and heating/cooling of storehouse for cheese seasoning. More details can be found in Deliverable 3.

To evaluate the economic-energetic-environmental benefit of the application of SAHC plants in the production of hard cheese, Parmigiano Reggiano (PR) and Grana Padano (GP), a simulation campaign was carried out through the SAHC expert system, to evaluate the dependence of the results with respect to:

1. production size in terms of annual production. The average production is considered to be 600 tons/year, which is an average-large size for PR and average-small size for GP. In the simulations the existence of a storehouse proportional to the production size has been considered,
2. size and type of the solar plant, in terms of collectors kind and total surface,
3. impact of the addition of cooling to a solar thermal plant, in terms of size of the chiller (and consequently cooling solar fraction).

The influence of latitude was not considered, since the production is only allowed in a limited area in the North of Italy.

The evaluations and indexes presented in the case study are:

1. Energetic sustainability, evaluated in terms of Tons of Oil Equivalent (TOE) of primary energy substituted by the solar heating and cooling plant.
2. Economic sustainability of the plant, evaluated through the minimum incentive needed for the solar energy produced (/kWh) to have a Net Present Value equal to zero in its useful life, considered to be 25 years; this is the minimum condition for the plant to self pay itself. A negative value for this index means that the plant can pay itself without incentive to energy production, i.e. a return of investment lower than 25 years. On the other hand, the higher this index, the lower the economic sustainability of the plant.
3. Environmental sustainability of the investment, evaluated through the cost of avoided CO2 (/kgCO2): installation and operation cost for the whole plant life divided by the avoided emissions achieved thanks to the plant. This is an index which can be compared to other kind of investment in RES to evaluate the environmental impact of the investment.

Influence of the production size and collectors area

The production size and the plant size have been modified, increasing collector area and maintaining the size of the chiller proportional to the production size. The energetic sustainability of the SAHC plant is shown in Figure 1, where the specific value of TOE saved over production size (ton of oil saved per ton of parmesan produced) and the ηSSY (efficiency of the solar plant) are
reported vs the specific size of the plant (Total Collector Area/Annual Production), and in Figure 2, where the Solar Fractions (SF) for heating and cooling are shown vs the specific size of the plant.

Different collectors type are considered: Flat Plate Collectors (FPC), Evacuated Tube Collectors (ETC) and Parabolic Trough Collectors (PC). The last type of collectors is still in demonstration phase, and its results should be analysed as such.

The specific savings achievable by the plant are in the range of 25-50 kg of oil per ton of production and this value increases with the plant size. However the efficiency decreases, due to higher losses in bigger plants, ranging from 40% to 20%. The most convenient dimensioning seem to be in the range of 1 square meter of collectors area per ton/y of production, which allows to reach a reasonable value of efficiency of 25-30%. The higher efficiencies are obtained with ETC but the highest savings can be achieved with PC. FPC achieve about 15% less savings respect to ETC and PC.

With this specific size of the solar plant, the SF for heating is in the range of 55% (FPC) to 70%, while the SF for cooling is more dependent on the kind of collector used, going from 40% (FPC) to 80% (PC), since this strongly influences the temperature achievable and the possible use of the energy from solar source to drive the chiller.

In conclusion, from the analysis carried out, it results that from the energetic point of view, higher values of SF are convenient, with respect to commonly considered values for industrial application (15-30%).

![Figure 1: energetic sustainability of SAHC plants depending on annual production and plant size](image-url)
Figure 2: Solar fraction for heating and cooling depending on specific plant size and type of collectors

From the economic point of view, the minimum incentive to make the plant profitable (NPV=0) in terms of €/kWh produced from the solar plant, is shown in Figure 3 for different production sizes and collectors area. It results that 600 tons/year is the average production size limit below which the SAHC plant is not self sustainable without any incentive. At this production size, the use of FPC and ETC is indifferent at plant size of 600 square meters.

For larger productions, the scale economy for collectors and chiller investment make the investment more convenient, and more convenient with ETC than with FPC, but always with ROIs of the order of the lifetime of the plant. For smaller production, the minimum incentive needed is of the order of 5-10 €cents/kWh and the use of FPC is more convenient than ETC.

The PCs seem to be always more convenient, given the higher temperatures achieved, even though they are only interesting in climates with predominant direct radiation over diffuse radiation, and require higher maintenance. Hence their use must be anyway carefully evaluated.

Figure 3: minimum subsidies needed to make the plant profitable, for different productions and collectors type and size
The economic and environmental sustainability is taken into account in Figure 4 and Figure 5, where the specific cost of avoided TOE and CO2 are presented, for different production sizes, plant size and collectors type.

The specific investment and operational costs for avoided TOE ranges in the order of 500-1000 €/TOE for larger productions, up to 1500 for smaller production sizes. The specific cost of avoided CO2 emissions is in the order of 400-600 €/ton, up to 800 for smaller productions and down to 250 for PC.

The optimal dimensioning for FPC from the environmental sustainability ranges from 1 m²/ton production for smaller productions to 0.5 m²/ton for larger productions, while for ETC bigger dimensioning allows reduction of cost.

Figure 4: specific cost of avoided TOE for different production size and plant size

Figure 5: specific cost of avoided emissions for different production size and plant size
Impact of the addition of cooling

The simulations carried out to evaluate the impact of the addition of chiller in the solar plant are referred to the average production size of 600 ton/year, modifying the collector area and the chiller size from 0-80 kW.

From the energetic point of view, the addition of the chiller, even in the smaller size considered (40 kW), determines a relevant increase of the efficiency of the collectors and then an increase of the energy savings achievable (TOE) with the same plant size (refer to Figure 6). The improvement of the energy savings achieved by the addition of the chiller to the solar plant is higher with increasing plant sizes. For the plant size of 600 m², the energy savings improvement due to the introduction of cooling is of the order of 25%. This is due to the increase of use of the plant during summer.

![Figure 6: Energetic influence of cooling](image)

From the economic point of view (refer to Figure 7), the use of the solar plant for heating only is generally more convenient with respect to the combined production of heating and cooling. In particular for small plant size (small solar fractions) the introduction is particularly negative, due the high specific cost of small chillers. For higher solar fractions, the introduction of cooling is more interesting and becomes convenient above a certain solar fraction limit. In any case, the plant is barely profitable without incentive.

The same tendency is shown by the specific cost of TOE. Therefore, given the high specific cost of the chiller in the small size, in particular below 100 kW, the introduction of the cooling is convenient only maximising the cooling solar fraction (above 50% of the storehouse cooling needs in the case of parmesan).
Figure 7: economic impact of cooling

1.1.2 Potential installation and savings

The use of solar assisted heating and cooling plants in hard cheese production can be a profitable solution, from the energetic point of view. The introduction of the cooling in a solar plants in hard cheese production improves the efficiency and the use of the solar plant, increasing the energy savings achieved with the same plant size of about 20-50% and therefore the energetic and environmental profitability of the surface available for the installation of the solar plant. The average savings achievable with a SAHC plant are of the order of 25-50 kg oil equivalent for each ton of production, corresponding to 0.60-1.2 ton oil equivalent saved in 25 years for each ton/year of production capacity.

The optimal dimensioning for FPC from the environmental sustainability ranges from 1 m²/ton/y production for smaller productions to 0.5 m²/ton/y for larger productions, while for ETC bigger dimensioning allows reduction of cost. As for the chiller, an average size for the installation is 0.1 kW/m² collectors.

From the economic point of view, the introduction of the cooling becomes competitive respect to heating-only from a certain plant size (around 600 tons/year of production), with high cooling solar fractions. Incentives are needed to support the introduction of the chiller, at least for small size plants. In relative terms, the introduction of cooling shifts the optimal plant size to higher values. The specific investment needed per ton of avoided CO2 emissions is in the order of 400-600 €.

The GP production in Italy is represented by 163 cheese factories in 2006 located in 5 regions and 14 provinces with a total yearly production of about 160,000 tons (average size of 980 tons/y). The PR production is represented instead, by 466 cheese factories (in 2006) located in two regions and 5 provinces, for a total production 120,000 tons (average size of 260 tons).

Considering the potential installation of 1 m²/ton for PR and 0.5 m²/ton for GP, the total potential of SAHC installations should therefore be of the order of 200,000 m² of solar collectors, corresponding to 140 MWth, and about 20 MW of installed size for cooling. The related investment for solar collectors for this potential is of the order of 90 M€ (if considering FPC), while for chillers is...
of the order of 25 M€. Considering also the auxiliaries, design and installation, the investment is of the order of 180-200 M€.

The energy savings that could be achieved by this potential installation are of the order of 10.000 TOE/year (or 116 GWh/year). The effective environmental benefit deriving from the investment would be of the order of 22000 ton CO₂/year. In such conditions, the specific investment in terms of energy savings and environmental benefit would be of 850 €/Toe and 430 €/ton CO₂ respectively.

Of course this potential is limited by the surface availability for the installation of the solar field, the availability of small size chillers for the smaller productions and the presence and dimension of the storehouses, which is not directly linked to the production capacity. Of course for smaller size, the market penetration would depend on the existence of incentives, that for the average sizes considered should range from 5 to 10 c€/kWh.

1.2 MILK
1.2.1 Results of simulations and feasibility studies

The use of SAHC plants in milk is related to the production of hot water for milk pasteurization (90°C) and bottle washing (60°C), and cold water for precooling after pasteurization. More details can be found in Deliverable 3. Contrarily with the other case studies carried out, where the cooling needs were always linked to the storehouse (seasonal), in this case the cooling need is linked to a specific process, hence not changing over the year.

To evaluate the economic-energetic-environmental benefit of the application of SAHC plants in the milk production, a simulation campaign was carried out through the SAHC expert system, to evaluate the dependence of the results with respect to:

1. production size in terms of annual production.
2. size and type of the solar plant, in terms of collectors kind and total surface,
3. impact of the addition of cooling to a solar thermal plant, in terms of size of the chiller (and consequently cooling solar fraction).

The evaluations and indexes presented in the case study are:

1. Energetic sustainability, evaluated in terms of Tons of Oil Equivalent (TOE) of primary energy substituted by the solar heating and cooling plant.
2. Economic sustainability of the plant, evaluated through the Net Present Value and Payback period.
3. Environmental sustainability of the investment, evaluated through the cost of avoided CO₂ (€/kgCO₂): installation and operation cost for the whole plant life divided by the avoided emissions achieved thanks to the plant. This is an index which can be compared to other kind of investment in RES to evaluate the environmental impact of the investment.

Influence of the production size, collectors area and impact of the addition of cooling

The production size and the plant size have been modified, increasing collector area and maintaining the size of the chiller proportional to the production size. Different collectors type are considered: Flat Plate Collectors (FPC), Evacuated Tube Collectors (ETC) and Parabolic Trough Collectors (PC).

The main result arising from these simulations is that under a specific size of the plant (total collector area/annual production), the cooling need is not satisfied, making the installation of the chiller not useful. This is due to the hypothesis made for the 3 energy needs: hot water for
pasteurization (90°C) and bottle washing (60°C) and cold water for milk precooling after pasteurization, which requests hot water for the chiller at 90°C. This energy needs are constant all over the year, contrarily to the other case studies, and there is a prevalence of the request at 60°C with respect to the other two (about 3 times the same of them). Since the control logic of the plant was defined to satisfy before the lower temperature needs, to maximise energy efficiency, the use of the thermally driven chiller only starts when there is enough energy available from the solar resource, which means a Solar Fraction heating of at least 60-70%, which involves large collector areas, bigger than the ones usually considered in solar thermal plants for industries (max 30%).

The results of simulations have provided the following indicative minimum specific size of the plant to make it possible the use of the chiller, depending of the size of collector: 0.20 m²/(ton/year) for FPC, 0.15 m²/(ton/year) for ETC and 0.10 m²/(ton/year) for PC (refer to Figure 8 and Figure 9). Further increase of the specific collector area imply a reduction of the solar efficiency, with increasing total costs and pay back times, even achieving higher solar fractions and then higher energy savings. This is more evident with FPC, where an increase of specific cost of TOE is also experienced.

**Figure 8: energetic sustainability of SAHC plants depending type of collectors and plant size**

**Figure 9: energetic sustainability of SAHC plants depending type of collectors and plant size**
The energetic sustainability of SAHC plant is shown in Figure 10, where the specific value of TOE saved over production size (ton of oil saved per ton of milk produced) and the specific cost of TOE are reported vs different plant sizes (annual productions). The specific value of TOE saved remains quite constant at increasing the production size, but changes with the kind of collector considered, ranging from 8-12 kg oil per ton of production. For the smallest production size (2000 tons/year) the presence of a slightly oversized chiller (15 kW) increases the specific cost of the savings achieved. The specific cost of TOE is strongly influenced by the scale economy, in particular for ETC. With their use the specific cost ranges from 800 €/TOE for a small plant to 300 €/TOE for a much bigger plant. For FPC the cost ranges from 750 to 450 €/TOE. PC achieve higher productions and smaller specific costs (440 to 220 €/TOE) but as already mentions their use must still be carefully evaluated.

![Figure 10: energetic sustainability of SAHC plants depending on annual production](image)

From the economic point of view, the plant results to be always profitable in its lifetime, with Net Present Value always >0 and Payback time <25 years (refer to Figure 11). The profitability increases with the plant size. However, for the small plant sizes, even if the total economic balance is positive, the real industrial interest towards the solution is linked to the existence of specific incentive measures, to achieve break even in less than 10 years. The PC always seem more convenient, with return of investment in the range of 12-6 years, even though they are only interesting in climates with predominant direct radiation over diffuse radiation, and require higher maintenance. Hence their use must be anyway carefully evaluated.

![Figure 11: economic sustainability of SAHC plants depending on annual production](image)
The specific investment needed for each ton of avoided CO₂ emissions is in the order of 150-300 €, up to 400 for smaller productions and down to 120 for PC.

The overall positive results of this case study, with short payback times, is mostly due to the high weight of the heating need at medium temperature (60°C) in the overall energy balance, which makes the plant very similar to a heating-only solar plant.

### 1.2.2 Potential savings

The use of solar assisted heating and cooling plants in milk production can be a profitable solution, from the economic and energetic point of view, only for large enough solar plants, compared to the production capacity of the company, that is specific collector size higher than 0,20 m²/(ton/year) for FPC, 0,15 m²/(ton/year) for ETC and 0,10 m²/(ton/year) for PC. The need of large surface available for the installation of the solar collector field, as well as the high initial investment needed, make the introduction of solar cooling particularly difficult in this production.

The introduction of the cooling in a solar plants in milk production improves the efficiency and the use of the solar plant, but the increment of the energy savings achieved with the same plant size is very limited due to the low cooling demand of the process, respect to the heating need at 60°C. The average savings achievable with a SAHC plant are of the order of 8-12 kg oil equivalent for each ton of production, corresponding to 0,20-0,3 ton oil equivalent saved in 25 years for each ton/year of annual production.

The optimal dimensioning for the chiller, is 10 kW per 1500 ton/y.

The specific investment needed for each ton of avoided CO₂ emissions is in the order of 150-300 €, up to 400 for smaller productions. With PC this value could decrease to 120, when the functionality of the system is fully demonstrated.

In conclusion, incentives are needed to support the introduction of the chiller, at least for small size plants, that should range from 5 to 10 c€/kWh to reach VAN=0.

### 1.3 WINE

#### 1.3.1 Results of simulations and feasibility studies

The use of SAHC plants in wine production is related to the production of hot water for cleaning barrels, tanks and bottles, and cooling of ageing rooms. More details can be found in Deliverable 3. As indicated in D3, the wine sector is characterised by a wide range of production sizes (from few thousands to hundreds thousands hl/y) and production process solutions. The evaluation is here mostly addressed to small size productions, which are the most numerous, have a high potential of intervention but are the most critical for the economic and energetic convenience of the application.

Then, a simulation campaign was carried out through the SAHC expert system, to evaluate the dependence of the results with respect to:

1. production size in terms of annual production. In the simulations the existence of a ageing room and store proportional to the production size has been considered,
2. size and type of the solar plant, in terms of collectors kind and total surface,
3. impact of the addition of cooling to a solar thermal plant, in terms of size of the chiller (and consequently cooling solar fraction).
4. influence of latitude (North-Centre-South of Italy).
The evaluations and indexes presented in the case study are:

1. **Energetic sustainability**, evaluated in terms of Tons of Oil Equivalent (TOE) of primary energy substituted by the solar heating and cooling plant.
2. **Economic sustainability** of the plant, evaluated through the minimum incentive needed for the solar energy produced (€/kWh) to have a Net Present Value equal to zero in its useful life, considered to be 25 years; this is the minimum condition for the plant to self pay itself. A negative value for this index means that the plant can pay itself without incentive to energy production, i.e. a return of investment lower than 25 years. On the other hand, the higher this index, the lower the economic sustainability of the plant.
3. **Environmental-economic sustainability**, evaluated through the cost of avoided CO\(_2\) (€/kgCO\(_2\)): installation and operation cost for the whole plant life divided by the avoided emissions achieved thanks to the plant. This is an index which can be compared to other kind of investment in RES to evaluate the environmental impact of the investment.

### Influence of the production size and collectors area

The study was conducted specifically for a small-medium winery. The minimum size considered is 4000 hl/year and the maximum is 14000 hl/year. The site of the plant is in the centre of Italy (Rome).

For smaller companies, the optimal size of the chiller should be lower than 10 kW, but absorption chillers are not currently available in the market in such sizes. Then the production size and the plant size have been modified, increasing collector area while maintaining the size of the chiller constant and equal to 10 kW. The energetic sustainability of the SAHC plant is shown in Figure 12, where the specific value of TOE saved over production size (ton of oil saved per hl of wine produced) and the ηSSY (efficiency of the solar plant) are reported vs the specific size of the plant (Total Collector Area/Annual Production), and in Figure 13, where the Solar Fractions (SF) for heating and cooling are shown vs the specific size of the plant. Different collectors type are considered: Flat Plate Collectors (FPC), Evacuated Tube Collectors (ETC) and Parabolic Trough Collectors (PC).

The specific savings achievable by the plant are in the range of 20-55 kg of oil per 100 hl of production and this value increases with the plant size. However the efficiency decreases modestly, due to minimal effect of higher losses in bigger plants, and ranging from 40% to 25%, depending mainly on the type of collector. The most convenient dimensioning seem to be in the range of 0.8 - 1 square meter of collectors area per 100 hl of production, which correspond to larger plant size. The higher efficiencies are obtained with ETC. FPC achieve about 30% less savings respect to ETC.

With this specific size of the solar plant, the SF for heating is in the range of 30% (FPC) to 75%, while the SF for cooling is more dependant on the kind of collector used, going from 50% (FPC) to 100% (PC), since this strongly influences the temperature achievable and the possible use of the energy from solar source to drive the chiller. These results are then a direct consequence of the above mentioned oversizing of the absorption chiller, due to the lack of models below 10 kW.

In conclusion, from the analysis carried out, it results that from the energetic point of view, higher values of SF are convenient, with respect to commonly considered values for industrial application (15-30%).

From the economic point of view, the minimum incentive to make the plant profitable (NPV=0) in terms of €/kWh produced from the solar plant, is shown in Figure 14 for different production sizes and collectors area. It results that 10000 hl/year is the average production size limit below which
the SAHC plant is not self sustainable without any incentive. At this production size, the use of FPC and ETC is almost indifferent at plant size over 85 square meters.

For larger productions, (refer to Figure 15) the scale economy for collectors and chiller investment tends to make the investment more convenient, but always with ROIs greater of the lifetime of the plant. For smaller production, the minimum incentive needed is of the order of 10-25 €cents/kWh and the use of FPC is more convenient than ETC.

The PCs again would be more convenient, given the higher temperatures achieved, even though they are only interesting in climates with predominant direct radiation over diffuse radiation, and are not fully commercial solution. Hence their use must be anyway carefully evaluated.

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Figure 14: minimum subsidies needed to make the plant profitable, for different productions and collectors type and size (for smaller production)

Figure 15: minimum subsidies needed to make the plant profitable, for different productions and collectors type (from small-medium to medium-large production)
The economic and environmental sustainability is taken into account in Figure 16 and Figure 17 where the specific cost of avoided TOE and CO$_2$ are presented, for different production sizes, plant size and collectors type. The specific cost of avoided TOE tends to be high and ranges in the order of 750-1500 €/TOE for larger productions, up to 2800 for smaller production sizes. The specific cost of avoided CO$_2$ emissions is in the order of 750-1000 €/ton, up to 1500 for smaller productions and down to 300 for PC.

The optimal dimensioning for FPC from the environmental sustainability ranges from 0.8 m$^2$/100 hl production for smaller productions to 1 m$^2$/100 hl for larger productions, while for ETC bigger dimensioning allows reduction of cost.

![Figure 16: specific cost of avoided TOE for different production size and plant size](image16)

![Figure 17: specific cost of avoided emissions for different production size and plant size](image17)
Impact of the addition of cooling

The simulations carried out to evaluate the impact of the addition of chiller in the solar plant are referred to the average production size of 10000 hl/year, modifying the collector area and the chiller size from 0-20 kW.

From the energetic point of view, the addition of the chiller, even in the smaller size considered (10 kW), determines a relevant increase of the efficiency of the collectors and then an increase of the energy savings achievable (TOE) with the same plant size (refer to Figure 18) only for PC and, partially, ETC. However the improvement of the energy savings achieved by the addition of the chiller to the solar plant is higher with increasing plant sizes. For the plant size of 80 m², the energy savings improvement due to the introduction of cooling is of the order of 40% for the PC and 10% for ETC. This is due to the increase of use of the plant during summer.

![Figure 18: Energetic influence of cooling (small winery)](image)

From the economic point of view (refer to Figure 19), the use of the solar plant for heating only is always more convenient with respect to the combined production of heating and cooling. In particular for small plant size (small solar fractions) the introduction is particularly negative, due the high specific cost of small chillers. For higher solar fractions, the introduction of cooling is more interesting and tends to reach the same levels of convenience of the solar plant for heating only. In any case, the plant is rarely profitable without incentive.

The trend shown by the specific cost of TOE is a consequence of the opposite effects of the addition of the chiller, in energetic and economic terms. Therefore, given the very high specific cost of the chiller in the smaller size, in particular below 35 kW, the introduction of the cooling is never convenient for FPC with absorption cooling, while is irrelevant for ETC and PC only maximising the cooling solar fraction (above 80-100% of the ageing rooms and store cooling needs in the case of wine)
Another set of simulations was carried out to evaluate the impact of the addition of chiller in the solar plant for bigger wineries. The simulation were carried out for 3 production levels (10,000 – 30,000 – 60,000 hl/year) comparing the results with the heating-only case, which is indicated in Figure 20 with 0 kW, and with chillers proportional to annual productions (10-30-70 kW). Also in this conditions, from a purely economical point of view, the introduction of the chiller is not convenient, while energetic and environmental benefits can be achieved (Figure 21).

The minimum subsidies needed for SAHC plants with FPC decrease from 10 to 2 c€/kWh moving from a production of 10,000 to 60,000 hl/y; for ETC the improvement is even higher, while for PC the plant results always convenient.
Influence of latitude

The simulations carried out to evaluate the impact of the latitude of the solar plant site, are referred to the average production size of 10000 hl/year. The total collector area is 60 m² and the chiller size is 10 kW, corresponding to the first set of simulations shown before. In this case 3 latitudes are considered: Palermo, Roma and Torino, respectively in the South, Centre and North of Italy. Also 3 types of collectors are considered (FPC, ETC, PC).

The results of the simulations reported in Figure 22, Figure 23 and Figure 24, indicate as expected an improvement of the performances moving from North to South, which is due to the increase of solar radiation, but also to the higher degree of exploitation of the chiller, because of the higher cooling needs for the storehouses. The energy savings achievable with the same plant increase of 25-45% depending on the kind of collector. The minimum incentive needed decrease from 25 €c/kWh to 10-14 €c/kWh; in particular the FPC are more convenient than ETC in the South and vice versa in the North, where also PC would need an incentive of 6 €c/kWh to reach break even. The influence of the latitude is therefore very relevant to make the plant convenient, in particular for the small size plants considered.
1.3.2 Potential installation and savings

The use of solar assisted heating and cooling plants in wine production can be a profitable solution from the energetic point of view, in some specific conditions, in particular for the integration of part of the cooling needs for ageing rooms during summer to the heating needed for cleaning barrels, tanks and bottles. In fact, the introduction of the cooling in a solar plants in wine production improves the efficiency and the use of the solar plant, increasing the energy savings achieved with the same plant size of about 10-40% and therefore the energetic and environmental profitability of the surface available for the installation of the solar plant.

However, the dimensioning of the chiller, limited by the minimum size available on the market, influence the cost of the solution, and limit the applicability to a minimum size of the storehouse and then of the facility, which depends on the latitude. Hence, from the economic point of view, the application in small size wineries is hardly competitive, due to the high cost of small size chillers and collectors (in particular for ETC), while it can result more competitive in larger productions.

The optimal dimensioning for FPC from the environmental sustainability ranges from 0.8 m² per 100 hl/y production for smaller productions to 1 m² per 100 hl/y for larger productions, while for ETC bigger dimensioning allows reduction of cost. As for the chiller, being the size limited by the market to sizes > 10 kW it is hard to give specific values.
The average savings achievable with a SAHC plant are of the order of 20-55 kg oil equivalent for each 100 hl of production, corresponding to 0.5-1.4 ton oil equivalent saved in 25 years for each 100 hl/year of annual production. The specific investment needed for each ton of avoided CO₂ emissions is in the order of 750-1500 €, up to 1500 for smaller productions and down to 300 for PC.

To make the introduction of the cooling competitive, an incentives to support the high costs of the introduction of the chiller is needed, certainly for small-medium winery. In relative terms, the introduction of cooling shifts the optimal plant size to higher values. The minimum subsidies needed for SAHC plants are strongly dependant on the production size and the latitude, going from from 10 to 2 c€/kWh moving from a production of 10.000 to 60.000 hl/y with FPC in South of Italy, double in North of Italy. For the use of ETC the improvement is even higher, while for PC the plant results always convenient.

The total wine production in Europe is in the order of 175.000.000 hl/year, mostly in France (60 M.hl), Italy (40 M.hl), Spain (40 M.hl) and Portugal (10 M.hl).

But the real potential is limited by several factors: the surface availability for the installation of the solar field (usually limited to the roofs in small wineries), the availability of small size chillers for the smaller productions and the presence and dimension of the storehouses, which is not directly linked to the production capacity. Of course the market penetration would depend strongly on the existence of incentives, that for the small-medium sizes considered should range from 10 to 25 c€/kWh. Considering the target application in medium large wineries and in few small size wineries, where the economic conditions are less convenient, it is possible to estimate a reference market of 5-8% of the total market size in Europe.

With a rough estimation of 0,8-1 m²/100hl the total potential of SAHC installations should therefore be of the order of 100.000 m², corresponding to 70 MWth. The related investment for solar collectors for this potential is of the order of 50 M€ (if considering FPC).

The energy savings that could be achieved by this installations are of the order of 4000 TOE/year (or 47 GWh/year). The effective environmental benefit deriving from the investment would be of the order of 9000 ton_CO₂/year.
2 Overview of promotional frameworks and suggested improvements

2.1 EU LEVEL

2.1.1 Evaluation of RES promotional framework

There are no specified regulations for solar thermal plants in industry. However, it should be noted that the EU has set the so called 20-20-20 target which urges for a 20% reduction in greenhouse gas emissions by 2020 compared to 1990 levels, a 20 % reduction in energy consumption through improved energy efficiency by 2020 and a 20 % increase in the use of renewable energy by 2020. To reach the target on renewables, the “Renewables Directive” 2009/28/EC has been adopted, which sets national targets for each member state through promoting the use of renewable energy in the electricity, transport, heating and cooling sectors. According to the Directive, Member States are urged to accelerate the setting of minimum levels for the use of energy from renewable sources in buildings. In addition, local and regional administrative bodies in individual Member States should facilitate the installation of equipment and systems for the use of electricity, heating and cooling from RES and for district heating and cooling.

The Directive makes reference to the incidence of the Renewable Energy Sources (RES) in the final use, instead of considering the effect on the primary energy. The motivation of this choices lies in the will to “not discriminate between different types of renewable energy” and to avoid that “accounting in primary energy gives greater weight to thermal and nuclear energy and therefore increases in these energy sources would make the achievement of any given renewable energy share harder to achieve”.

This should suggest reconsideration at national level of the priorities of promotion of thermal and electricity production from RES. In fact, since the thermal and electricity kWh produced from RES is counted in the same way, it is advisable for the Member States to increase promotion of the thermal RES, while so far the incentives have been mainly directed to production of electricity from RES.

On the other hand, the evaluation carried out in the project and reported in this document are based on the primary energy saved, since we considered the effect that the installation (and incentive) would have on environment, in terms of avoided emission, considering average reference efficiencies of production for electricity, heating and cooling. This decision was based on technical-scientific motivations and not to take advantage of the distortion which could derive from the straightforward interpretation of the Directive.

Promotional schemes for Renewable Energy Sources (RES) respond to economic and industrial criteria. Incentives are presently defined to bridge the gap of competitiveness of RES technologies with respect to technologies based on conventional sources, and are not related to the avoided external costs. In particular the external cost connected with the CO2 emissions, which should be the priority in environmental policies, are rarely taken into account. Even though it is clear that the reduction of CO2 emissions can not be the only driver in identifying the promotion of renewable sources, it would be advisable to revise the incentive criteria, taking into account a more balanced contribution on the basis of energy, climate and sustainability issues. This reform should take into account 2 aspects, when revising the incentive to the RES technologies:

1. Environmental cost effectiveness of the incentive.
2. Potential market, economic sustainability and prospects for cost reductions
The evaluation of these criteria applied to SAHC system is presented, starting from the results of the feasibility studies and the simulations carried out during the project and providing some comparison with other kinds of RES.

**Environmental cost effectiveness**

The consideration of the environmental cost-effectiveness of incentives is related to the fact that the incentive should be somehow related to the environmental benefits produced by the implementation and diffusion of the RES technology. This can be evaluated through the cost of the incentive paid related to the avoided emissions of more in general to the external costs avoided for the substitution of fossil energy, i.e. the measurement of socio-environmental damages provoked by energy production and consumption.

The external costs of the electricity generation from the different energy sources has been estimated by the European Environmental Agency for the energy mix of the European countries, based on the ExternE methodology\(^1\). The external costs of the different electricity sources are shown in Figure 25. The minimum and maximum external costs for each countries are shown in Figure 26. The average estimated for the EU27 is about 40 Euro/MWh, and emissions of 405 kgCO2/MWh. For the production from RES the external cost can be estimated to be on average 5 Euro/MWh, in particular: 1-3 for wind, 2-4 for PV, up to 11 for biomass). Considering the application of ETS, that will come into force in 2013, following the entry into force of Directive EC 2009/29 which will internalise the cost of emissions, which at the present price of CO2 should be about 7 Euro/MWh, the external costs of fossil generation will be 33 Euro/MWh, Hence the avoided external cost achievable through the production from RES instead of the conventional technologies is the difference between this value and the one associated to the production from RES, that is 22-32 Euro/MWh, that should be the incentive for RES-e only following the external costs. This value, when adjusted to specific country external costs, would range from 10-50 Euro/MWh for most of the countries.

![Figure 25: External cost for electricity generation (ExternE-Pol project source)](image)

\(^1\) ExternE-Pol project: Externalities of Energy: Extension of accounting framework and Policy Applications. Refer also to EC publication “Research results on socio-environmental damages due to electricity and transport” for Country based indications.
The ExternE project has identified the external costs for the production of heat from different fuels, technology and size (refer to Figure 27). For the production of heat in industry with gas and light oil, the external costs are estimated to be from 6 to 10 Euro/MWh. Estimating the internalization of costs of the order of 2 Euro/MWh, the differential becomes **4-8 Euro/MWh**, that should be the incentive for RES-h only following the external costs evaluation.

As for the production of cold with standard electric compression chiller (COP=3), the external costs associated with the electricity needed for the production of cold, already considering the internalised costs, are of the order of 11 Euro/MWh. Making the conservative hypothesis that the external costs related to the electricity driven and thermal driven cooling equipment are comparable, the value of the differential between standard cooling and solar cooling is of the order of **11 Euro/MWh**, that should be the incentive for RES-c only following the external costs considerations. This is translated to **8-13 Euro/MWh** for the RES-h feeding the heat driven chiller (considering absorption chiller with COP of about 0,7).
Considering a SAHC with 30% of the solar heat used for cooling, the value of the avoided external costs range from 5 to 10 Euro/MWh heat produced from solar plant.

Considerations about avoided external costs for the generation of energy from different RES are summarised in Figure 28. Of course this depends on the different nature of the energy (electrical, heating, cooling).

![Avoided external costs (Eur/MWh)](image)

**Figure 28: Avoided external costs for the different kinds of RES**

**Market and economic sustainability**

Another important criterion for the defining an adequate level of financial support for RES is the evaluation of the market opportunities and the guarantee of an economical profitability, i.e the incentive should be slightly higher than the marginal generation costs.

The results of the simulations and feasibility studies carried out in the SAHC project have shown that the application of solar thermal in agrofood industry for heating-only purposes is energetically convenient and economically sustainable, with pay back times of the order of 13-15 years and IRR of about 8-10%, without any incentive. This could theoretically suggest disregarding incentives; however the comparison with other kind of investments and other kinds of RES should also be considered. In particular the investment in PV, with the level of incentives in most EU countries of in the range of 300-500 Euro/MWh, allows ROI of less than 10 years and IRR of 10-20% with easier design and installation and safer revenues. For this reason, a promotional framework for solar thermal is needed to make it competitive with this technology.

On the other hand, Solar Cooling is an emerging technology which will find its profitability with the evolution of the technology itself through efficiency gains and cost reductions in the short term. However, at present the investment for a pure solar cooling plant is not economically sustainable, due to the high cost of installations.

The integration of Solar Heating and Cooling is energetically interesting, since the addition of cooling can improve the efficiency and the use of the solar plant, making it possible to realise larger plants and increase the energy savings of 20-50% depending on the process needs. Incentives are needed to guarantee economic profitability, apart form the case of Parabolic Collectors, which could be profitable without but have limited market so far and are applicable only in situations with predominant direct radiation. To make the installation competitive with Flat Plate and Evaluated Tube Collectors, the minimum incentives evaluated to reach break even in 25 years are of the order of 5-10 Eurocents/kWh, depending on the production and size. In particular the economy of scale is very relevant, since the cost of the chiller is still high for small sizes. This incentive is however not sufficient to make the installation competitive with alternative investment and technologies, e.g. PV. In the following paragraph considerations are made to achieve a sustainable incentive level.
2.1.2 Suggested specific promotional measures for solar heating and cooling

EU Regulations could promote the achievement of the renewable target more easily through the promotion of solar thermal plants rather than PV plants, especially due to the upcoming revised directive on restrictions of certain dangerous substances in electrical and electronic equipment (ROHS). As ROHS restricts the use of specific substances in electrical and electronic equipment including PV manufacturing materials, solar thermal heating and cooling systems are expected to gain interest in the coming years.

Taking into consideration the political priorities which are currently in place, concerning the climate change obligations and the security of energy supply, EU regulations could support the following:

1) Investment Policy implementation so as to support the acquirement of know – how on SAHC systems and to fund the respective Research & Development. This measure could be particularly effective when combined with private solar companies that would get incentives in investing in SAHC know how development.

2) Market Policy implementation for the creation of prospective customers that will actually purchase and use the SAHC technology. Potential customers on EU level should be motivated in a manner by which it is outlined to them that the relevant technology will add energy independence and improved economics.

3) Interface Policy implementation so as to confront the gap between the designers, the manufacturers and the end-users. This involves the proper training and certification procedures of installation companies that are the ones that actually install the equipment taken from manufacturers and that actually configure the application on the local characteristics and structure of a site. In addition, provisions should be made for the quality control of installation companies through e.g. inspection programs.

4) Enhancement of each Member state governmental policy through promotion of the advantages of the application of solar technology in industry towards the compliance of Member State’s national RE targets. Advantages to be pointed out are:
   a. Solar cooling may contribute to the replacement of fossil fuel demand by use of solar heat consequently to the European policy targets on the increased use of RE;
   b. Reduction of greenhouse gas emissions through savings in primary energy and avoidance of environmental harmful refrigerants;
   c. Support in stability of electricity grids by less electricity and peak power demand;
   d. Optimized use of solar thermal systems through use of solar heat for combined assistance of space heating, cooling and domestic hot water preparation.

5) Enhancement of Member state governmental policy through enhancement of control strategies over RE applications performance: Public Authorities should be thoroughly trained and motivated to perform investigation of the legal requirements of an industrial plant especially when undergoing the phase of planning or fully renovating of the building and to perform inspections in order to evaluate whether the solar plants operate according to the requirements.

6) Strengthen the replication potential of existing effective regulations in some Member States so as to evoke an example for additional Member States.

In order to particularly promote the application of solar heating and cooling technology, they should be integrated in existing or upcoming legislation regarding energy efficiency in industry as well as building regulations. Member States should be obliged to maintain statistical data regarding the energy requirements for heating and cooling whereas a highly standardized performance of heating and cooling applications should be ensured through appropriate test and certificate methods.

A common promotional framework could be identified at EU level, leaving the adoption and the quantification at National level. In this paragraph, the general lines of the proposed framework to promote solar thermal plants for heating and cooling in industry is provided, based on the
environmental cost effectiveness of the incentive, and the cost/benefit derived from the case studies. In the successive paragraphs, specific indications for the promotion at National level are provided, in particular when compared with the main competing technologies.

Concerning the incentive mechanism, the possible solutions that could be evaluated are:

1. Feed in tariffs, to pay for the thermal energy produced from the solar source, used for both heating and cooling (or for cooling only)
2. Incentive on the investment, for the whole investment (collectors + chiller + auxiliaries) or the chiller only
3. Subsidized credit for the investment

The promotional framework for SAHC plants that is considered to be the most effective incentive solution is based on a Feed-in-tariff mechanism. Feed-In Tariffs are being adopted for RES electricity since many years and have proved to be the most effective promotional mechanism for RES, encouraging the optimal design and operation of the plants and guaranteeing the return of the investment. The most important elements of every Feed-In Tariff are the level of the tariff and the length of time that it is guaranteed for. The time factor is very important: developers need the security of knowing that they will be able to achieve a guaranteed rate over a long period of time. This ensures proper compensation for the risks and costs of research, development and start-up that accompany renewable technologies. This incentive could be included in a global RES-h incentive framework, with different tariffs for the different sources, air and ground-source heat pumps (and other geothermal energy), solar thermal, biomass boilers, renewable combined heat and power, use of biogas and bioliquids. The UK Renewable Heat Incentive (RHI), entering into force in April 2011, should be considered as an example. However, in the RHI the renewable cooling is excluded; however, we believe the potential application in Southern Europe is relevant and this should be considered in these countries.

The risks of the application of the Feed in Tariff could be in:
- Paying the tariffs on a metered basis could have the undesirable effect of encouraging the generation of surplus heat in order to obtain more financial income. This could result in excess heat being generated and dumped. Such risk is not so relevant for solar thermal respect to other RES-h, in particular in industrial process heating and cooling (i.e. large-scale industrial heat) where oversizing of the plant is not convenient.
- Problems of accurate and standardized heat metering, which is less common with respect to electricity. However, standards for the design and installation of heat meters exist and different products are available

Hence, for the application of feed in tariff to a solar thermal plant targeted to large installations, as well as process heating and cooling in industrial application, it could be feasible the adoption of a metering.

Following the results of feasibility studies and simulations, we believe the minimum Feed in tariff to be applied to really promote solar heating in industrial process in Southern European countries targeted by the project is 8-10 Eurocents/kWh heat for 20 years. The metering could be applied to the solar heat going to the processes (after losses in the collector field and storage tank, regardless the temperature level.

With this level of incentives, which has an economical effect comparable to a grant of 40% of the initial investment, which is presently guaranteed in most of the countries, solar heating for agrofood industrial processes would become competitive with other kinds of investment and reach a ROI of 7-11 years, which is reasonable for an industrial investment. It is worth considering that the UK RHI scheme foresees a feed in tariff of 19-20 Eurocent/kWh for 20 years for solar heating, which is in line considering the different values of solar radiations available in the two cases.
The minimum incentive for Solar Cooling should be of the order of 20 Eurocents/kWh for 20 years to make the ROI of about 10 years. This value is referred as incentive to the solar cold produced by the chiller.

The 2 incentives could be kept separate, with 2 metering systems, or an average could be applied to the useful solar heat produced, in case also solar cooling is applied with a minimum percentage (e.g. chiller size to collector ratio). The corresponding average incentive is in the range 10-15 Eurocent/kWh heating for 20 years, which would bring the economic profitability to the same level of the heating-only incentive of 8-10 Eurocents/kWh. Different levels of tariffs could be applied for SAHC depending on the size of the collectors and size of the chiller, since small size plants are strongly affected by the high price of small size chillers and partly also of the collectors and auxiliaries.

The level of incentives considered are relatively higher with respect to the evaluation of the avoided external costs described in the previous paragraph. This depends on the marginal generation costs with respect to competitive technologies. However, the marginal advantage (difference between incentive and avoided external costs) would be much more limited with respect to the differential of PV (refer to Figure 29).

Only considering the CO2 emissions saved per kWh produced by RES (electric, thermal and cooling), the environmental profitability of the public investment provided through the incentive has been calculated. The proposed values of incentive for solar heating, cooling and SAHC for the application to industrial plants in Southern Europe, is compared with PV in Figure 30, in terms of emissions saved per Euro invested. On the other hand, the cost of the avoided CO2 emissions in terms of incentives is shown in Figure 31. The proposed incentive for solar thermal in industry would have a double environmental profitability with respect to PV, while solar cooling has by itself a limited profitability. The proposed incentive for solar heat used for both heating and cooling in industry (SAHC) would overcome the profitability of PV, while allowing much higher savings in absolute value with respect to heating-only.

The hypothesis considered in this paragraph and the results are summarised in Table 1.
Figure 30: Environmental profitability of the incentives proposed for Southern Europe

Figure 31: cost of avoided CO2 emissions for the proposed incentives in Southern Europe

### Table 1: avoided external costs, incentives and environmental profitability hypothesis

<table>
<thead>
<tr>
<th>Avoided External cost vs incentives (Euro/MWh)</th>
<th>PV</th>
<th>Solar heating</th>
<th>Solar cooling</th>
<th>SAHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>avoided external min</td>
<td>22</td>
<td>4</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>avoided external max</td>
<td>32</td>
<td>8</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>avoided external average</td>
<td>27</td>
<td>6</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>incentive min</td>
<td>300</td>
<td>80</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>incentive max</td>
<td>500</td>
<td>100</td>
<td>200</td>
<td>147</td>
</tr>
<tr>
<td>incentive average</td>
<td>400</td>
<td>90</td>
<td>200</td>
<td>123</td>
</tr>
<tr>
<td>marginal advantage</td>
<td>373</td>
<td>84</td>
<td>189</td>
<td>116</td>
</tr>
</tbody>
</table>

| Environmental profitability of incentive      |     |               |               |      |
| incentive (Euro/MWh)                          | 400| 90            | 200           | 123  |
| CO2 avoided (kg/MWh)                          | 405| 200           | 135           | 165  |
| environmental profitability (kgCO2/Euro)      | 1,01| 2,22         | 0,68          | 1,34 |

**Note:** The table contains data on avoided external costs, incentives, and environmental profitability for different technologies in Southern Europe.
2.2 GREECE

Recently, the Greek Government has made some important steps on the promotion of renewable energy sources in buildings as well as their integration to the national grid. According to the new Directive 2009/28/EC on the promotion of the use of energy from renewable sources, member states have national targets for the share of energy from renewable sources in gross final consumption of energy in 2020. For Greece the increase of the RES share in the final energy consumption from today’s share of 6.7% is set to 18% in 2020. However, according to the recent Plan of the Greek State for the “Acceleration of development of Renewable Energy Sources for the confrontation of Climate Change” the public deliberation of which has been concluded in January 2010, the Greek State goes one step forward and sets as a target the increase of the RES share in the final energy consumption to 20% in 2020. This means a target of 40% electricity consumption from RE in 2020. In addition the permitting procedure is being shortened, so as to conclude the total permitting process for RES projects in less than a year instead of 3-5 years which is the case today.

According to the Directive 2002/91/EC, the Greek State has recently issued the Common Presidential Decision on the Energy Performance of Buildings (“KENAK”). It is expected that energy consumption in buildings will be reduced by 11%, while new public buildings will have to be energy autonomous by 2019.

In addition, the plan on energy pricing from PV panels, the public deliberation of which has been concluded in January 2010, seems to be unfavorable for the further development of PVs. With this background there are significant possibilities for solar thermal systems’ application.

Apart from the new legislation on RES that has been released, the measures that could be proposed, in order to particularly promote the application of SAHC systems in agrofood industrial plants, are the following:

- Clear imposition of the national renewable heat obligation not only to the domestic sector, but to the industrial sector as well, through the implementation of financial support schemes (e.g. the National Strategic Reference Framework ESPA - 2007-2013). In other words, financial incentives for installing solar thermal systems in existing or new AgroFood industrial buildings, depending on the annual energy production of the system.

- Implementation of industrial energy standards in the form of a Presidential Ordinance:

- Enforcement of a mandatory share of renewable energy sources to the total energy demand of the newly built industrial buildings.

- Consideration of the installation of SAHC systems as a prerequisite for the authorization procedure during the construction of a new or the refurbishment of an Agrofood industrial plant.

- Further Incentives for the implementation of solar thermal assisted cooling applications in the form of favorable discount rebate on purchase and installation. Subsidizing a specific amount of installations per year would add a significant support to the technology. An additional incentive would be the assurance to potential customers of the easiness of the application of SAHC systems and that the authorization required is not complex and not time-consuming.

- Provisions in the legislative framework for confronting or even discharging restrictions such as the allowed maximum height according to the building’s license.
(e.g. in the ‘Urban Planning Legislation’) without causing any injustice to the entities involved.

An overall target of the Hellenic government should be the amendment of the existing regulatory background and the supervision regarding the implementation of the new legislations. Governmental authorities should implement a transparent and effective way of tracking the role, authorities and deliverables of ministries, energy authorities, public administration and other state services, industry organizations, and other relevant companies and organizations in order to ensure compliance with the European regulatory requirements.

2.3 SPAIN

Código Técnico de la Edificación (CTE – DB HE4)

Currently, in Spain, the new construction of buildings is regulated by the CTE (Código Técnico de la Edificación), set of binding rules concerning safety and quality in the new construction buildings from March 2006.

This set of rules contains some documents that make mandatory the implementation of solar energy in new or renovated buildings. These documents are:

- DB HE-4: requires the implementation of thermal solar energy to generate a portion (around 50-70%) of the estimated sanitary water that will be demanded for buildings with this type of need.

This thermal energy can be replaced by other renewable sources (biomass), CHP or waste heat recovery.

DB HE-5: requires the implementation of PV energy for buildings included in the table. This energy source can be replaced by others renewable sources too.

<table>
<thead>
<tr>
<th>Type of use</th>
<th>Application boundary (min. m² built)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supermarket</td>
<td>5,000</td>
</tr>
<tr>
<td>Mall and entertainment</td>
<td>3,000</td>
</tr>
<tr>
<td>Storage shed built</td>
<td>10,000</td>
</tr>
<tr>
<td>Administrative</td>
<td>4,000</td>
</tr>
<tr>
<td>Hotels and hostels</td>
<td>100 (places)</td>
</tr>
<tr>
<td>Hospitals</td>
<td>100 (beds)</td>
</tr>
<tr>
<td>Fairground pavilions</td>
<td>10,000</td>
</tr>
</tbody>
</table>

The CTE is a national implementation. Moreover, each autonomous region and some city councils have their own rules which provide that specified in the CTE but could be more restrictive.

RD 661/2007

Currently, in Spain, the renewable and CHP generation are graceful with a special tariff system that seeks to promote the deployment and stimulate the markets involved.
This system comprises the following technologies:

- CHP (NG, gas-oil, LPG, biomass, biogas, heat recovery)
- Biomass
- Biogas
- Solar energy (photovoltaic or thermal energy)
- Wind energy
- Hydropower
- Urban solid waste

The RD661/2007 grants different purchase prices for each technology and established their respective power limits to review the cost of the purchased energy.

The PV power exceeded its limit in early 2008, so in September 2008 appeared the RD1578/2008 were the purchase price for PV power decreases 20% (34c€/kWh for less than 20kW and 32c€/kWh for more than 20kW) and imposes a quota system to connected PV plants to the national grid and a decrease of the corresponding purchased price.

It seems that this type of systems for be connected will be extended to all the technologies mentioned before.

**Other grants and funding**

The IDAE, government agency, offers several lines of support and funding for energy efficiency projects. Namely:

- Third party funding: For efficiency and renewable energy projects. IDAE assumes the costs of equipment and recover the investment with a profit by the energy savings produced. After the installation goes to the industrial property.
- Project financing and leasing services: For efficiency and renewable projects. IDAE provides advisory services and collaboration in all phases of project implementation, and then finances.
- Aid program in strategic projects: Framed in the Plan de Acción 2008-2012. In 2009 the available budget was 120M€. The beneficiaries are industrial enterprises, services companies and ESCOs. The projects included in this pan are:
  - Strategic projects: Actuations that aim the significantly reduce energy consumption of processes or facilities in order to increase the competitiveness of the applicant companies.
  - Unique innovative project: energy optimization projects with industry wide change process, fulfilling certain peculiarities such as: nature of the project illustrated in this sector, energy savings generated, degree of ecoinnovation, etc.
  - Sector projects: joint projects in a specific sector companies with similar objectives in applying technology and energy group which ensures a higher degree of implementation of these new technologies.

- Program Voluntary Agreements with companies in the field of biomass heat in buildings (*Biomcasa*): With this program aims to establish a funding system that promotes a quality offer and tailored to the needs of users of hot water and air conditioning in buildings, using biomass, all under the Plan de Energías Renovables in Spain 2005-2010.

Moreover, many autonomous communities offer their own lines of grants and funding for renewable energy implementation.
2.4 France

Grenelle law

In the first Grenelle law (3rd August 2009), the French parliament adopted a budget for the development of production and distribution of renewable heat from solar energy, biomass, geothermic and biogas. A heating fund of 1 billion on 3 years (2009-2011) is foreseen in the finance law project of 2009. This fund will be administered by ADEME. It is devoted to multi family buildings, local authorities and all companies (agriculture, industry and commercial).

The principle is to calculate the subsidies in order to allow the renewable heat to be sold 5% lower than the heat produced by non renewable energy.

For private individual, the tax credit of 50% is extended up to 2012 and new incentive tools are set to promote the thermal retrofit of buildings (zero rate loan, ad valorem tax exemption) which are expected to favour the development of renewable energies.

The first Grenelle law also sets a goal of 30% of farms with a low energy dependence by 2013. A tax credit will be proposed by the government in order to achieve energy performance diagnostic of the farms.

Other incentives


However, the solar thermal and PV energy are in competition for taking advantage of roof surface of agro food sector. Here below, a comparison between both technologies in terms of financial framework is carried out.

Comparison between solar PV and solar thermal energy

Solar thermal and solar PV appear as two competing technologies.

Since few years, the solar PV is largely promoted in France with the new electricity buyback rates defined by the French government. From 1st January 2010, the buyback rates are:

- For PV panels fully integrated in the building, the buy back rate will be 60.2 c€/kWh.
- For PV panels with simplified integration in the building, a new buyback rate of 45c€/kWh is defined. This new tariff aims to promote the PV panels in professional buildings (farm buildings, industrial and commercial buildings…). This tariff is devoted to the installation with a power higher than 3 kW peak (which corresponds to a panel surface of about 30 m²). The French government wishes to favour the fully integrated PV in individual buildings.
- For PV installed on the ground, the buyback rate will be maintained to 32.8 c€/kWh. For installations of power higher than 250 kW peak, the tariff will varies between 32.8 c€/kWh for the most sunny regions of Metropolitan France and 39.4 c€/kWh for the less sunny regions of Metropolitan France. For these solar installations, a building permit, an impact study and a public inquiry will be requested.

The buyback contract is concluded for a period of 20 years.

The taxation for PV is also advantaged:
• for professionals, the depreciation can be accounted on 12 months, and the business tax is exempted.
• for farming, the PV incomes should be declared in farm benefits under conditions.

The government decided in 2009 to simplify the administrative and financial process with the suppression of the statement requirement and the certificate issued by DEAL/DRIRE. Only a sworn statement is now requested.

Furthermore, the estimated lifetime of a PV module is 30 years. The modules' performance are generally guaranteed for providing over 80% of the initial power after 25 years which makes photovoltaics a very reliable technology in the long term. Solar modules are almost maintenance-free and offer an easy installation. However, this argument should be tempered. Indeed, the inverter which is used to convert the direct current (DC) power produced by the system to alternative current (AC) power has a much more shorter lifetime.

Concerning the solar thermal, the subsidies are focused on private individuals and local authorities. The “plan soleil” carried out by ADEME in 1999 aimed to promote the Combined solar systems (CSS) and solar domestic hot water (SDHW) systems. This program helped to the development of the solar domestic hot water system in France. It was based on a referencing of equipments, a brand Qualisol which has been created to guarantee the quality of the installations and subsidies for private individuals. In order to guarantee the quality of solar installations, the charter Qualisol has been set in collaboration with professionals. The sales overpassed 15000 SDHW systems in 2005. In 2006, the registered installers were 6800. The direct subsidies from the State to private individuals have been replaced by a tax credit since January 2005. Moreover, some complementary subsidies can be given by the regions. The objectives of the “plan soleil” have been over passed as shown of the following graph.

Furthermore, a zero rate loan has been set by the government in February 2009 for the thermal retrofit of housing. The CSS and SDHW are included in this zero rate loan.

Concerning private companies, ADEME can provide some subsidies for the pre-diagnosis study and for the investments.
The solar pre-diagnosis is in any case necessary before investment decision. It should be carried out by an independent consultant. The subsidy can represent 70% of the solar pre-diagnosis study cost in a limit of 2300€ or 3800€ if the pre-diagnosis study includes implementation recommendations.

A subsidy can be provided by ADEME for investment in solar hot domestic water in multifamily buildings and in tertiary sector. For companies in a competitive sector, the subsidy can not overpass 40% of the eligible costs. Moreover, a limitation of total subsidies for small and medium companies is fixed to 100 000€ by company on three years.

Concerning the **solar cooling**, this technology is still considered by ADEME has a technology in demonstration phase which is not mature. ADEME can subsidize some demonstration projects on solar cooling.

### 2.5 Italy

#### Incentives for RES-e and PV

The Italian system for the promotion of RES is mostly targeted to the promotion of the generation of electricity. This approach is in fact easier to apply for the measure of the electricity generated and without additional costs for the State, being paid by a component of the electricity bills of all consumers. However, given the approach chosen by the EC directive to account for the final user energy, this system is not efficient and will imply huge costs to achieve the target of 17% of RES on final energy agreed with the EC for 2020.

In fact, estimating an energy consumption at 2020 of 1.800 TWh/y, this target implies a generation from RES of 260 TWh/y, having already accounted for the part due to the use of biofuels. This would mean a tripling of the generation from RES with respect to 2005 ,i.e. additional 175 TWh. On the other hand, following the Italian Position Paper of 2007, which had defined the share of different RES to be installed by 2020 to reach the target of 20% renewable (in terms of primary energy), the electricity production derived from the envisaged mix of renewable energy sources (RES-e) would only produce 60 TWh/y, which is one third of the needs coming from the Directive. However, to reach this unsufficient target, the investment needed has been estimated to be of the order of 86 billions of Euro\(^2\) and the incentives to be paid by electricity consumers are much higher, of the order of 140 billions of Euro\(^3\). Calculations made by ENEA to reach this value consider an average value of incentive for RES electricity in the next 15-20 years, starting from values at 2008 and considering a 3% decrease every 3 years. The incentives available for RES-e in Italy are:

- Green certificates for all RES electricity (excluding PV) taking into account the correction coefficients introduced in 2008, which is around
- new “Conto Energia” for PV introduced by D.M. 19/02/2007.

Starting from these calculations, we have introduced the following considerations:

1. if the same approach and mix of RES-e defined in the Position Paper 2007 is followed, Italy should install the triple of the amounts foreseen in 2007, to meet the target derived from the Directive in terms of final energy production from RES-e,

\(^2\) Investment in renewable energy sources: impact on the Italian manufacturing industry – Centre for research on energy and environmental economics and politics (IEFE) Università Bocconi
\(^3\) Usi termici delle fonti rinnovabili - Andrea Fidanza, Carlo Manna – ENEA Ufficio Studi (Novembre 2009)
2. discussion is undergoing to reduce the incentive for PV of 6-8% year for the next 3 years starting from 2011. We have considered a reduction of 6% per year in the first 3 years and then a 3% reduction every 3 years, as for the other sources.

3. we have calculated the environmental impact of the investment put for the incentive for each kind of RES-e, in terms of Euro/avoided CO2, considering an average value of avoided emission for Italy of 550 kgCO2/MWh.

The Table 2 Figure 33 shows the results of such calculations.

<table>
<thead>
<tr>
<th>Technology</th>
<th>power (MW)</th>
<th>use (h/y)</th>
<th>production (TWh/y)</th>
<th>incentive (€/MWh)</th>
<th>annual cost (M€)</th>
<th>years of incentive</th>
<th>total cost (GE)</th>
<th>total production (TWh)</th>
<th>emission avoided (ktons CO2)</th>
<th>environmental investment (€/tCO2)</th>
<th>environmental profitability (kgCO2/Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroelectric</td>
<td>8.619</td>
<td>3.500</td>
<td>30.17</td>
<td>76</td>
<td>2.293</td>
<td>15</td>
<td>34.39</td>
<td>452.58</td>
<td>248.674</td>
<td>138.18</td>
<td>7.24</td>
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<tr>
<td>Wind onshore</td>
<td>25.263</td>
<td>2.000</td>
<td>50.53</td>
<td>76</td>
<td>3.840</td>
<td>15</td>
<td>57.60</td>
<td>757.89</td>
<td>416.840</td>
<td>138.18</td>
<td>7.24</td>
</tr>
<tr>
<td>Wind offshore</td>
<td>6.000</td>
<td>2.500</td>
<td>15.00</td>
<td>83</td>
<td>1.245</td>
<td>15</td>
<td>18.68</td>
<td>225.00</td>
<td>123.750</td>
<td>150.91</td>
<td>6.63</td>
</tr>
<tr>
<td>PV integrated</td>
<td>22.751</td>
<td>1.200</td>
<td>26.70</td>
<td>329</td>
<td>8.188</td>
<td>20</td>
<td>175.78</td>
<td>534.02</td>
<td>293.713</td>
<td>598.40</td>
<td>1.67</td>
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<tr>
<td>PV field</td>
<td>2.499</td>
<td>1.200</td>
<td>3.00</td>
<td>272</td>
<td>8.15</td>
<td>20</td>
<td>16.31</td>
<td>59.98</td>
<td>32.987</td>
<td>494.40</td>
<td>2.02</td>
</tr>
<tr>
<td>CSP</td>
<td>3.000</td>
<td>3.000</td>
<td>9.00</td>
<td>165</td>
<td>1.485</td>
<td>25</td>
<td>37.13</td>
<td>225.00</td>
<td>123.750</td>
<td>300.00</td>
<td>3.33</td>
</tr>
<tr>
<td>Traditional geothermal</td>
<td>864</td>
<td>7.500</td>
<td>6.48</td>
<td>62</td>
<td>402</td>
<td>15</td>
<td>6.03</td>
<td>97.20</td>
<td>53.460</td>
<td>112.73</td>
<td>8.87</td>
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<tr>
<td>Innovative geothermal</td>
<td>900.7.000</td>
<td>6.30</td>
<td>6.30</td>
<td>391</td>
<td>5.86</td>
<td>15</td>
<td>5.86</td>
<td>94.50</td>
<td>51.975</td>
<td>112.73</td>
<td>8.87</td>
</tr>
<tr>
<td>biomass and biogas</td>
<td>1.140</td>
<td>6.000</td>
<td>6.84</td>
<td>98</td>
<td>6.70</td>
<td>15</td>
<td>10.05</td>
<td>102.60</td>
<td>56.430</td>
<td>178.18</td>
<td>5.61</td>
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<tr>
<td>MSW</td>
<td>828</td>
<td>7.000</td>
<td>5.80</td>
<td>83</td>
<td>481</td>
<td>15</td>
<td>7.22</td>
<td>86.84</td>
<td>47.817</td>
<td>150.91</td>
<td>6.63</td>
</tr>
<tr>
<td>biogas from MSW</td>
<td>858</td>
<td>4.200</td>
<td>3.60</td>
<td>56</td>
<td>202</td>
<td>15</td>
<td>3.03</td>
<td>54.05</td>
<td>29.730</td>
<td>101.62</td>
<td>9.82</td>
</tr>
<tr>
<td>dedicated biomass</td>
<td>1.062</td>
<td>6.000</td>
<td>6.37</td>
<td>125</td>
<td>797</td>
<td>15</td>
<td>11.95</td>
<td>95.58</td>
<td>52.569</td>
<td>227.71</td>
<td>4.40</td>
</tr>
<tr>
<td>waves</td>
<td>2.400</td>
<td>2.000</td>
<td>4.80</td>
<td>183</td>
<td>676</td>
<td>15</td>
<td>13.18</td>
<td>72.00</td>
<td>36.600</td>
<td>332.73</td>
<td>3.01</td>
</tr>
<tr>
<td>TOTAL</td>
<td>75.684</td>
<td>174.58</td>
<td>22.26</td>
<td>397.16</td>
<td>2.857.26</td>
<td>1.571.494</td>
<td>252.73</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Estimation of the costs of incentives needed to meet the target of the RES-e in Italy (present policy)

From the results of the calculation it should be noted that:

1. the total investment in terms of incentives for RES-e (paid through the electricity bills) is of the order of 400 billions of Euro, which seem not sustainable for the country
2. about 48% of this investment would go for PV which would grant 17% of the production
3. the average incentive for RES-e excluding PV, waves and CSP is of the order of 80 €/MWh, while is of the order of 300 €/MWh for PV (3.75 times higher).
4. the average cost of the avoided CO2 is 252 €/ton, but is of the order of 180 €/ton as average of all RES-e excluding PV, while is 500-600 €/ton for PV (3 times higher).

This cost is of one order of magnitude high with respect to the cost of CO2 in EU-Emission Trading System (ETS) which is of the order of 20 €/ton, and is much higher with respect to other kind of investments in energy efficiency and RES-h, as shown below.

An alternative scenario was proposed to move part of the incentives for RES-e to RES-h to reach the target of 17% renewable energy set as objective for Italy in 2020. This scenario is strongly based on the use of RES-h (87% of the energy produced), in particular: biomass (60%), heat pumps (20%) and solar thermal (7%). With these hypothesis, the cost of incentives would be 120 G€, instead of the 400 G€ calculated before for the RES-e. The incentives for these RES-h was estimated to be 3 Eurocents/kWh, which seems low for the effective promotion of solar thermal.

Incentives for RES-h and solar thermal

The heating (and cooling) from Renewable Energy Sources (RES-h) have a much lower penetration in the final use in Italy, representing in 2005 4,4% in the residential sector and only 1% in industry.

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4 A. Rota (Politecnico di Milano) and G. Manzoni (Enginet Srl) - FONTI ENERGETICHE RINNOVABILI: PER PRODUZIONE DI ELETTRICITÀ O DI CALORE? “L'Energia Elettrica” May/June 2009, numero 3 - volume 86
The production of RES-h can access to the promotional mechanism of Energy Efficiency Certificates, which presently have a value of about 70-80 €/tep, corresponding to 7 Euro/MWh for 5 years. Considering that the duration of the incentive is 3 times less, the overall value of the incentive for RES-h is 30 times lower than the incentive available for RES-e.

The installation of “solar thermal collectors for the production of hot water for residential or industrial use” was included since 2007 (DM 19/02/2007), extended so far up to 2010, as one of the possible measures to be implemented in the energy efficient rehabilitation of buildings. The user can access to the fiscal detractive of 55% of the initial investment in 3 to 10 years, up to a maximum value of cost of installation of 109.000 Euro and a detractive of 60.000 Euro.

The application of this measure was very good: 60.000 requests were made for a total installation of 300.000 m2 in 2 years, doubling the yearly installations in 2 years (2008 vs 2006). The fiscal detractive is not linked to the effective energy savings achieved and is introducing market distortions with strong cost oscillations and increase of costs of the collectors.

A negative point of this regulation is that it is not applicable to the whole costs of installation of a solar cooling plant (resolution 299 of the Italian Tax Agency) but only to the costs of solar collectors.

There are other regional measures which promote the installation of solar thermal plants, generally in the order of 25-30% of the installation cost, which can not be cumulated with the 55% detractive.

Suggestions

In Italy presently there is a privilege condition for incentives of some RES-e, which benefit of extra profits (difference between revenues and cost)\(^6\). In particular PV benefits of profits of 10-17 c€/kWh, as shown in Figure 32.

![Figure 32: Extra profits on different RES-e (revenues – costs) including incentives (source Amici della Terra 2010)](image)

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\(^5\) LA TECNOLOGIA SOLARE TERMICA (a cura di G. Braccio, D. Marano - ENEA, S. Notarnicola – Ambiente Italia, V. Sabatelli – ENEA, V. Verga – Assolterm)

The increased promotion of RES-h instead of RES-e could allow the achievement of the 17% target agreed at EU level, avoiding paying huge penalties. The public investment for the incentives in promoting solar thermal and other RES-h would be more beneficial for the achievement of such target. The presence of fragmented promotional measures for solar thermal is not useful for strengthening the solar thermal industrial sector, and can even create market distortions, such as the increase of price of collectors experienced in the last years.

The use of fiscal detractions for energy efficiency in buildings as support for solar thermal, which is based on short terms measures introduced in the Financial laws, has achieved good results for the installation of solar thermal in residential sector. However, the promotion of solar heating and cooling in industry, requires a specific and long term promotional measure, guaranteeing revenues over the years. The Energy Efficiency Certificates (White Certificate) mechanism, is a good strategy to promote energy saving in industry and already promotes the implementation of the energy efficiency measures in industry through Energy Service Companies, which could be a very important market driver for solar thermal energy in industry. The installed area of solar thermal collectors which have granted of this measure from the start of the mechanism (2004) is about 500,000 square meters. However, to promote the industrial large scale application of Solar Heating (and Cooling) the adaptation of this mechanism with introduction of a feed-in-tariff mechanism for large scale solar plants could be a good option. The value of the incentives must be related to the avoided emissions, to the marginal generation costs with respect to standard solutions and to the potential price reduction and market size. The present benefit of 0.7 c€/kWh for 5 years which can be achieved with the value of white certificates is not sufficient to create a stimulus for the implementation of large solar thermal plants for heating and cooling. An adequate value would grant the industrial user and the ESOs with long term revenues.
3 Conclusions

The European solar thermal market has increased steadily in the last decade, recording an average growth of 12.4% between 2000 and 2007 for flat-plate collectors and evacuated tube collectors\(^7\), with an annual installed capacity more than doubled. Moreover, in the last 2 years the market of Solar Thermal has experienced an increase of 100%, reaching an annual record of 4.75 millions m\(^2\) of installations and an overall installed capacity of 27 millions m\(^2\) (half in Germany)\(^8\).

The market is strongly dominated by domestic applications, with limited number of industrial applications, even though the energy consumption for low temperature heating in industry account for about 20% of the total final energy consumption for heating and cooling in EU27 in 2006\(^9\) and 30% in Mediterranean countries. Cooling also accounts for more than 60% of the space heating demand in residential and tertiary sectors. Therefore, there is a high potential for combined solar thermal systems for heating and cooling, in particular in the medium to large scale systems in the service sector (offices, hotels, etc.) and in industrial cooling.

The potential of solar thermal for heating and cooling demand has been evaluated to be of about 47% in the best scenario, as indicated in Figure 33. The contribution of the industrial low temperature heat to this target is 20% of the total installations\(^10\). Under the same scenario, for Mediterranean countries, the total potential is estimated to be 63% and the contribution of the industrial sector in the order of 25%. To reach this potential it is necessary to have sufficient and cost competitive solutions for solar thermal cooling. Previous studies have identified the potential of solar thermal in industry to be of the order of 3-4% of the total industrial energy consumption in EU25, corresponding to more than 100 GWth, only considering the energy needs at temperatures lower than 100°C.

![Figure 33: Total heating and cooling demand of EU-27 and contribution of solar thermal by sector according to the Full R&D and Policy Scenario (source RESTMAC project)](image)

The case studies carried out in the SAHC project have shown that there is a good energy saving potential for the integration of cooling into solar thermal in agrofood sector, increasing the energy saving and reduction of emission of 20-50% with respect to heating-only solution, and therefore the

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\(^7\) IEA Solar Heating and Cooling Programme and the European Solar Thermal Industry Federation (ESTIF, 2008)

\(^8\) Estif (European Solar Thermal Industry Federation) – ESTEC 2009

\(^9\) AEE INTEC calculations based on EU 2008

\(^10\) Potential of Solar Thermal in Europe - Werner Weiss (AEE – Institute for Sustainable Technologies) and Peter Biermayr, (Vienna University of Technology). Project RESTMAC - TREN/05/FP6EN/S07.58365/020185
energetic and environmental profitability of the surface available for the installation of the solar plant.

Case study in hard cheese production in Italy has estimated a maximum potential for SAHC installations of the order of 200,000 m² of solar collectors and about 20 MW of installed size for cooling (installation in all production facilities of Parmigiano Reggiano and Grana Padano), with an investment of the order of 180-200 M€ and potential savings of 116 GWh/year.

Case study for the application in wineries, has roughly estimated a potential of 100,000 m², corresponding to 70 MWth, in a limited number of medium large size wineries in Europe. The related investment for solar collectors for this potential is of the order of 50 M€ (if considering FPC) and potential savings of the order of 47 GWh/year.

Case study for the application of SAHC in milk production showed that the solution is profitable only for large enough solar plants, compared to the production capacity of the company. The need of large surface available for the installation of the solar collector field, as well as the high initial investment needed, make the introduction of solar cooling particularly difficult in this production.

The evaluation of the 3 case studies suggest to promote the integration of cooling to solar heating specifically to meet seasonal demands (air conditioning or storehouse/tanks cooling) rather than process cooling, in order to exploit the excess production during summer to increase the energy savings with the same size (or slightly increased) collector field.

The results of the simulations and feasibility studies carried out in the SAHC project have shown that the application of solar thermal in agrofood industry for heating-only purposes is energetically convenient and economically sustainable, with pay back times of the order of 13-15 years and IRR of about 8-10%, without any incentive. This could theoretically suggest disregarding incentives; however when comparing the investment with other kind of RES, in particular PV, which benefits of high level of incentives, a promotional framework for solar thermal is needed to address the industrial application.

On the other hand, solar cooling is presently not financially viable, due to high cost of the chiller, auxiliaries and engineering. A sensitivity analysis was performed to evaluate the effect of economic parameters on the financial viability of the solar cooling plant. It is expected that solar cooling would reach a payback of 20 years in Southern Europe if the following conditions are altogether met:

- Electricity price: +4%/y
- Gas price: +4%/y
- Increase in performance: +10%
- Reduction of engineering costs ⇒ 6%
- Reduction of control and monitoring costs ⇒ +50% over reference
- Reduction of maintenance costs ⇒ +50% over reference
- Reduction of solar collector investment ⇒ -30%
- Reduction of solar cold production chiller investment ⇒ -25%
- Subsidies on overall investment costs: 25%

The integration of solar heating and cooling is only convenient with high cooling solar fractions and relevant plant size, due to the high investment costs for the chiller, especially for small sizes. This could be not feasible due to area constraints, not the optimal energetic dimensioning for the overall plant and not sustainable in terms of initial investment. The cooling part of the plant is in fact not economically convenient when compared with standard cooling equipments, and in most cases
decreases the ROI of the whole plant. On the other hand, it can allow to increase solar collector plant and to benefit of higher energy savings of the order of 20-50% with respect to heating-only plants.

For this reason, to benefit of this increase of energy saving achievable from the integration of the cooling, specific incentives and/or promotional measures are needed. These incentives would create a market push for European chiller producer, which are specifically addressing the production of small size equipments, which are the most affected by the problem of high investment. The promotional measures could create a market of tens of MW for the chillers, extrapolating data from the cases studies carried out. This would support the evolving of the chiller production, making it possible the reduction of costs and the integration of solar cooling into solar thermal plants convenient.

Concerning the proposed promotional framework for SAHC plants in industry, a common framework should be identified at EU level, leaving the adoption and the quantification at National level. The general lines of the proposed framework to promote solar thermal plants for heating and cooling in industry was provided, based on the environmental cost effectiveness of the incentive, and the cost/benefit derived from the case studies. The promotion of solar thermal plants could be included in a general Feed-in-Tariff mechanism for RES-heating, with different tariffs for the different sources (air and ground-source heat pumps, solar thermal, biomass boilers, renewable combined heat and power, use of biogas and bioliquids), whose potential has been so far underestimated with respect to RES-electricity. This mechanism has proved to be the most effective promotional mechanism for RES, encouraging the optimal design and operation of the plants and guaranteeing the return of the investment. The UK Renewable Heat Incentive (RHI), entering into force in April 2011, should be considered as an example. However, in the RHI the renewable cooling is excluded; however, we believe the potential application in Southern Europe is relevant and this should be considered in these countries. The following estimation of the tariffs for heating, cooling and integrated heating and cooling in industry was proposed, specifically targeted to Southern European countries targeted by SAHC project:

- solar heating in industrial process: 8-10 Eurocents/kWh heat for 20 years; this would allow to achieve ROIs of 7-11 years, which is reasonable for an industrial investment.
- solar cooling: 20 Eurocents/kWh for 20 years to make the ROI of about 10 years. This value is referred as incentive to the solar cold produced by the chiller.
- solar heat to be used for both heating and cooling in industry, with a minimum percentage (e.g. chiller size to collector ratio): 10-15 Eurocent/kWh for 20 years, which would bring the economic profitability to the same level of the heating-only incentive of 8-10 Eurocents/kWh. Different levels of tariffs could be applied for SAHC depending on the size of the collectors and size of the chiller, since small size plants are strongly affected by the high price of small size chillers and partly also of the collectors and auxiliaries.

The comparison of the proposed incentive with the avoided external costs related to the environmental, social and health impact of the generation, was carried out, as well as the evaluation of the environmental profitability of the investment, in terms of CO2 emissions saved per kWh produced. The values were compared with the average existing incentive for PV:

- The marginal advantage (difference between incentive and avoided external costs) of solar heating and cooling would be much more limited with respect to the differential of PV;
- The proposed incentive for solar thermal in industry would have a double environmental profitability with respect to PV, while solar cooling has by itself a limited profitability. The proposed incentive for solar heat used for both heating and cooling in industry (SAHC) would overcome the profitability of PV, while allowing much higher savings in absolute value with respect to heating-only.
One of the most promising technologies, as for solar heating and cooling, seems to be the use of Parabolic Through Collectors, which would help moving to double and triple-effect absorption machines. However, nowadays PTCs are not still widely sold (for the SAHC project curves the data come only from two manufacturers), and the first experiences with them show that despite the theoretical numbers seem sincerely good, most experiences are giving really bad solar yields, because of different factors (fouling problems, dirt problems, concentration error, bad installation techniques …).