Next-CSP

High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage

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Deliverable *(D9.3)*

WP9 – WP Exploitation, Communication and Dissemination of results
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Disclaimer

List of abbreviations

CA	Consortium Agreement
CAPEX	Capital Expenditures
EC	European Commission
EPC	Engineering, Procurement and Construction
EU	European Union
IP	Intellectual Property
KPI	Key Performance Indicator
LCOE	Levelized Cost of Electricity
O&M	Operation and Maintenance
OPEX	Operation Expenditures
PEDR	Plan for the exploitation and dissemination of the results
PPT	Powerpoint
SME	Small and Medium Enterprise
TOD	Time of Delivery
UPC	Ultra-supercritical
VC	Venture capital
WP	Work packages

Executive Summary

This deliverable presents the Next-CSP Key Exploitable Results (KERs) and the potential for post-project future exploitation.

These activities are part of the WP9 Dissemination and Exploitation whose aim is to establish the exploitation and dissemination plan for the project, to promote the dissemination of results and ensure relevant communication activities to raise awareness on the project.

This report contains the following information regarding exploitation:

- Description of the project concept and technology;
- Market potential and results of the market study conducted in the framework of the project under WP7;
- Presentation and analysis of the KERs mapped in the framework of the Next-CSP project and individual exploitation plans, incuding a research and commercialization roadmap, risk analysis and preparation of lean canvas.

This report was prepared by Euronovia, the leading beneficiary in charge of dissemination, communication and exploitation activities, in collaboration with the CNRS, EDF and EPPT.

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1. DESCRIPTION OF THE PROJECT CONCEPT AND TECHNOLOGY

The Next-CSP project aimed at developing a prototype 1.2 MWe Concentrated Solar Power plant that uses solid particles as both heat transfer and storage medium. The project paves the way towards commercial developments of this technology by studying its scale-up to industrial size. To this end, the deliverable D7.1 describes the preliminary design of a typical 150 MWe plant to be built around 2030 after the demonstration phase.

The Next-CSP prototype is composed of two separated subsystems, a particle loop and a thermal energy conversion loop (turbine) coupled by a heat exchanger. The particle loop consists in a 2.5 MW_{th} solar receiver, a hot store and a cold store. A hybrid 1.2 MW_e gas turbine is the second sub-system. The turbine is powered by compressed air heated in the particle heat exchanger. This latter component is a six-stage fluidized bed tube-in-shell vessel. The solar receiver is the most innovative part of the prototype. It is made of forty 3 m-long tubes inside which fluidized particle are flowing upward. The tubes are irradiated by concentrated solar energy and the absorbed thermal power is transferred to the particles. The complete prototype is installed at the focal area of the Themis tower, a 5 MW_{th} central receiver solar concentrating facility equipped with 109 heliostats, 54 m^2 each.

CSP plants operate in well-irradiated areas that face steep variability of the net demand, including high power generation with photovoltaic panels (sometimes over-generation) during daytime. Consequently, only peaker or midpeaker CSP plants make sense, and even more so in the future. The dispatch strategy chosen for our plant consists of 5 full load equivalent hours of power generation during the evening. This dispatch strategy corresponds to a thermal power output of the solar island of 320 MWth, taking all heat losses into account.

The receiver technology developed in Next-CSP (Upward Flowing Fluidized Bed) limits the thermal power to about 50-55 MWth per receiver due to technological constraints regarding the tube height and the geometry of the cavity. Besides, a cavity receiver is mandatory in order to mitigate the radiative thermal losses. The commercial plant features six-eight towers, each one with a cavity receiver and a North field (for a plant located in the northern hemisphere) that shares the same power block.

The simulations were performed with a direct normal irradiation and a latitude corresponding to Tucson, AZ (USA) or Ouarzazate (Morocco). A tower height of 93 m was chosen as the result of a tradeoff between optical efficiency and reasonable parasitic power consumption to lift the particles to the receivers. The resulting dimensions of the solar field are approx. 600 m x 600 m (max. North-South tower-heliostat distance and East-West width of the solar field).

Since the plant does not generate power during daytime, the thermal storage corresponds to a full day of solar collection. In order to simplify the conveying network, four particle hoppers are used: two containing the hot (~819°C) particles and two containing the cold (~609°C) particles. Each hopper contains 15 000 tons (7 500 m3) of particles. The design of the hoppers aims at limiting their total height in order to limit the parasitic consumption required to lift the particles above them: their internal diameter and total height are respectively 30 m and 16 m.

In order to limit the conveying distances, a "star" configuration of the conveying network was chosen. Further to extensive discussions between EPPT and EDF, the most appropriate solutions for both horizontal and vertical handling of the particles were selected, and reported upon in Deliverable 1.5:

- To convey the particles between the storage and the towers, mass flow conveyors were chosen because of their continuous operation, their moderate power consumption and their low heat losses. Slopes up to 30° are possible and simplify the design of the conveying network.
- Rather than being dropped from the receiver to ground level, a gradual discharge chute will be used, thereby avoiding attrition and shadowing effect of conveyors along the towers.
- In order to lift the particles to the receivers, bucket elevators were chosen because of their quasi continuous operation. Thanks to inclined mass flow conveyors, the buckets are loaded 35-40 m above ground. Each tower features four elevators (2 in series x 2 in parallel).

The auxiliary consumption of the whole conveying network is reasonable and takes place mainly during daytime: it can be supplied in a cost-effective way by a small photovoltaic farm equipped with a limited amount of batteries. On the other hand, the thermal losses that occur during the conveying of the particles penalize heavily the plant efficiency. They were roughly estimated at ~5% in the final design.

Unlike the gas turbine of the Next-CSP pilot plant that works in open cycle with an additional firing, the power cycle of the scaled-up plant is a combined cycle gas turbine whose heat input is 100% solar. As shown in Deliverable D6.2, the resulting low Turbine Inlet Temperature (TIT = 780°C) requires a double reheat on the gas turbine to ensure a net cycle efficiency of 48.6%. No significant hurdle exist to build such a gas turbine, other than convincing a manufacturer to do it.

Gas turbines in general are extremely sensitive to pressure drops and our particular turbine struggles with a low TIT. Therefore, the particle-to-air heat exchangers must fulfill two antagonist criteria: low pressure drop and low temperature difference. This results inevitably in bulky (thus costly) heat exchangers. However, preliminary calculations showed that a set of exchangers of reasonable size and cost can be designed. This was studied in more detail in Deliverables D7.2 and D7.3. This permits to affirm that:

- A 150 MWe scaled-up solar tower based on the Upward Flowing Fluidized Bed concept is feasible, but only with a multi-tower configuration that requires ~4 km of particle conveying;
- Medium scale units (~20 MWe) are possible with a single tower, thus without particle conveying between towers (only vertical conveying);
- In order to allow the plant to be significantly more efficient than a molten salt tower, specific attention must be paid to further mitigate the thermal losses of the conveying network;
- If very cheap particles prove appropriate for our use, they would allow for a much bigger storage that could provide extra value to the electrical grid.

2. MARKET POTENTIAL

A market study was conducted by EDF in the framework of WP7:

- With deliverable D7.2 the consortium performed a Risk Analysis of the scale-up from the pilot plant developed in Next-CSP to the future utility-scale plant, including top-priority mitigation measures and an assessment of the overall risk affecting the scaling-up of the Next-CSP concept at utility scale.
- Deliverable D7.3 assesses Capital and Operation Expenditures (OPEX and CAPEX) and the Levelized Cost of Electricity (LCOE) as well as the additional value of the power generated by Concentrating Solar Power with massive in-built storage – including the future Next-CSP utility-scale plant – compared to that of photovoltaic power generation.

The main conclusions of these analyses are summarized in the paragraphs below.

2.1. Positioning of CSP in future renewable electric networks

2.1.1. Need for flexible renewable generation and/or utility-scale storage in future electricity networks

In the mid-term future, the electricity networks will be subject to the following constraints:

- The growing share of variable Wind and PV increases the variability of the net demand (demand minus intermittent generation). The net demand generally peaks during the evening with a steep ramp-up at the end of the afternoon.
- Smart power grids with enhanced capacity, demand-side management, etc. will not suffice to balance future electricity systems with high renewable shares (> approx. 40%): flexible renewable generation and/or utility-scale storage will be needed.

Bottom line: cost is important, but value is crucial, and flexibility means value. Flexible renewables including CSP are enablers, not competitors, of intermittent renewables such as Photovoltaic.

2.1.2. Potential Alternatives to CSP for Flexible Renewable Power Generation

Which flexible renewables can compete with CSP for power generation?

- Not hydro or biomass since water is scarce wherever CSP generation can be envisioned;
- Not geothermal since no area is suited to both geothermal and CSP to the best of our knowledge;
- Not Compressed Air Energy Storage because no saline cavities exist in CSP-friendly areas.
- The round-trip efficiency of pumped heat energy storage (about 40%) limits its potential. Converting coal plants into such units can be very cost-efficient but the limited deployment potential is limited.

Considering the above, the sole potential competitor of CSP is utility-scale Photovoltaic combined with electrochemical storage, referred to below as “PV + Batteries”. PV works well wherever CSP does.

2.1.3. Future CSP plants must be peakers in most cases

The value of the power generated by a peaker CSP plant can be several times that for a base load plant. A good example is the recent Request for Proposal made by Arizona Public Service that included a Time of Delivery (TOD) schedule divided in 4 categories, each with a price multiplier: 0, 1 (i.e. base price), 3, and 9. The latter corresponds to late afternoon/early evening in summer. A peaker CSP plant that generates power during 5 peak hours per day (hence a Capacity Factor of ~17.5%) has a weighted average coefficient on price that is 3.23 times that of a base load plant with a Capacity Factor of 63%. In contrast, its LCOE is only 46% higher (because of its larger power cycle for the same yearly generation). 3.23 times more value at 1.43 times the cost: the peaker plant clearly wins.

2.2. LCOE of a peaker utility-scale Next-CSP plant vs. LCOE of a Molten Salt Tower

A future utility-scale plant based on the concept studied in Next-CSP (referred to below as "Next-CSP Plant") was compared to a similar molten salt tower that is the current benchmark for CSP. The plants considered are 150 MWe peakers generating 1,500 full load equivalent hours of power generation per year (5 night-time hours per day, weather permitting).

2.2.1. Determination of the Capex of the turnkey power plants

The plants are broken down into five main subsystems: solar island, storage system, particle handling / molten salt pumping, particle-air heat exchangers / steam generator, and power cycle. The EPC (Engineering, Procurement and Construction) cost of the whole plant is the sum of the EPC costs of all subsystems plus a percentage that accounts for balance of plant, interconnection, instrumentation and control, and site preparation. The Capex (Capital Expenditures) of the turnkey power plant is then obtained by adding a percentage corresponding to the indirect EPC costs (engineering, contingencies, management, etc.) and the owner's costs (infrastructure, land, etc.). The costs are summarized in Table 1 below.

Table 1 indicates clearly that storage with particles is much cheaper than with molten salt. Nevertheless, particles conveying is an extra cost with respect to molten salt tower that balances the gain obtained with the storage.

Table 1 – EPC cost breakdown and Capex of Next-CSP and molten salt tower plants

	Next-CSP Plant (M€)	**Molten Salt Tower (M€)**
Solar Island	74.4	81.9
Storage System	16.5	28.9
Particle Handling System / MS Pumping	17.4	4.5
Particle-Air HEX / Steam Generator	6.8	5.0
Power Cycle	122.0	122.0
EPC Cost of Whole Plant	246.6	252.0
Capex of Turnkey Plant	295.9	302.4

2.2.2. O&M cost and LCOE of the Next-CSP and Molten Salt plants

The typical O&M (Operation and Maintenance) cost of a base load molten salt tower built in Morocco is about 9 €/MWh; the future O&M practices improvements will offset the extra cost caused by the bigger power cycle of the peaker plants studied here. The O&M costs of particle handling systems are notoriously high as a percentage of their Capex, hence an additional 3 €/MWh for the Next-CSP plant.

As a result, the O&M costs of the Next-CSP and molten salt plants are respectively 12 €/MWh and 9 €/MWh.

The LCOE (Levelized Cost of Electricity) resulting from the amortization of the Capex of the turnkey plants (given in Table 1) are determined according to a plant lifetime of 25 years and a real discount rate of 5%: 91 €/MWh and 93 €/MWh respectively. By adding these values to the O&M costs, one obtains the LCOE of the Next-CSP and molten salt plants: 103 €/MWh and 102 €/MWh respectively. Considering the uncertainties affecting these estimates, both values can be considered similar and rounded to 100 €/MWh.

2.3. Competitiveness of CSP vs. PV + Batteries

2.3.1. Current benchmark CSP technology vs. utility-scale PV + Batteries

Table 2 below summarizes the 2030 and 2040 LCOE estimates for power generated during a four-hour night-time period by a utility-scale PV farm equipped with batteries. The LCOEs are in US$/MWh.

Table 2 – Future LCOE of PV + 4-hour battery storage

US$/MWh	Pessimistic	Median	Optimistic	If curtailed power
2030	165	125	88	-32
2040	150	105	68	-24

The LCOE of PV + batteries with the median scenario and that of a molten salt tower with a similar dispatch strategy (i.e. nighttime power generation during 4-5 hours per day) are in the same ballpark: US$ 125/MWh and 100 €/MWh respectively. Consequently, CSP technology must improve significantly to remain cheaper than CSP farms equipped with batteries in 2030 and beyond. To this end, disruptive technologies, such as that developed in Next-CSP, are required.

2.3.2. Next-CSP concept vs. current benchmark CSP technology

The high temperature particle receiver must be a cavity receiver to mitigate thermal losses, which limits its size and translates into a multi-tower architecture. Consequently, several kilometres of horizontal conveying of the particles are required. The resulting penalty in terms of thermal losses and costs (Capex and O&M) offsets the cost reduction allowed by the storage system and the downsized solar island. This is why the LCOE of the Next-CSP plant is not lower than that of a molten salt tower.

2.3.3. Future paths to improve the competitiveness of the Next-CSP concept

The main path to economic competitiveness consists in replacing the combined cycle gas turbine by a supercritical steam cycle. Such power cycles are already mature, with decreasing power outputs that will soon be fit with CSP applications.

The combined cycle gas turbine envisioned in this study requires high temperatures (~800°C) to reach efficiencies approaching 50%. Besides, the temperature range of the heat input to the turbine air is narrow, hence a temperature difference between cold and hot particles of only 200 K. All this increases the heat losses and the mass flow of the particles to be conveyed. As for supercritical CO_2 cycles, they provide good efficiencies at lower temperatures but are heavily penalized by dry and hot climates that are the rule in CSP. Besides, they work with an even narrower temperature range of the heat input.

Ultra-supercritical (USC) steam cycles working with main steam at 25-30 MPa and 620°C can achieve efficiencies around 47% in Ouarzazate (Morocco). Regarding the particles, a maximum temperature of ~700°C and a temperature difference of ~400 K can be envisioned. Compared to the combined cycle Next-CSP design, the reduction of the heat losses (in both the particle receiver and the particle handling system) easily compensates for the somewhat lower cycle efficiency; moreover, the cost of the particle handling system is nearly halved.

To summarize, a Next-CSP plant with a USC steam cycle replacing the current combined cycle gas turbine is potentially more competitive than the current CSP benchmark; therefore, it deserves further studies.

2.4. Conclusions – Global potential of CSP

The solar energy that CSP plants use is measured as direct normal irradiance (DNI), which is the energy received on a surface tracked perpendicular to the sun's rays. DNI measures provide only a first approximation of a CSP plant's electrical output potential. In practice, what matters most is the variation in sunlight over the course of a day: below a certain threshold of daily direct sunlight, CSP plants have no net production, due to constant heat losses in the solar field.

Following the analysis we conducted in the framework of WP7, reported in deliverable D7.3, with current electricity prices and cost construction for CSP plants, a large-scale deployment in Europe is considered unlikely, unless significant subsidies are granted. Without subsidy, Sicily is the best area in Europe for CSP due to its high price levels and variability combined with a good DNI (less than 10% lower than the best DNIs in Europe). A larger deployment in the mid/long-term future would require a strong decrease of the LCOE of CSP and/or a significant increase of the electricity prices during peak hours. This is plausible if the operating cost of fossil-fuelled plants is severely affected by rising costs of fuel and carbon. Overall, the global share of CSP plants built in Europe will remain marginal.

Outside Europe, even though the deployment of CSP will remain much more limited than that of Wind or PV due to the very stringent DNI criterion (today, there is about 100 times more PV capacity installed worldwide than CSP, and the same is true for Wind), there is considerable room for deploying peaker CSP plant worldwide. New power plants would be “green peaker power stations”. Green because no hydrocarbons are required and peaker plants because they store up hot sand during the day and convert that heated sand into electrical power for use between 6 pm and 9 pm at night where the electricity rate is at its highest which makes the whole system economic.

At present North Africa is unstable politically, but there is full of potential for CSP technology. Long term the political situation will hopefully change. The USA is a good strong market and there is real interest in CSP, they of course have their own companies and technology which makes it a difficult market to penetrate although a partnership route might be the best way forward.

As a general recommendation, in order to maximize the efficiency of each Euro spent for subsidizing CSP, European stakeholders should accept to subsidize the construction of CSP plant outside Europe (where each kWe of CSP capacity needs little subsidies to be competitive) rather than in Europe (where each Euro will subsidize a lower amount of CSP capacity). CSP can be an exporting European industry, even if few plants are built in Europe.

3. STAKEHOLDERS

3.1. Target groups

Concretely, it is important to stress that at the Next-CSP TRL level, commercial exploitation is not yet possible and further R&D and innovation investments are needed to bring the technology from 3 MWth et 10 and 50 MWth scale. The collaborations foreseen below integrates short and mid-term visions.

The primary target:

Companies - In order to get investments in the technology, the first main stakeholders are the end users and industries that have expressed a market need and on which the Next-CSP impact will be the most beneficial one.

From presentations and discussions, mostly during the SolarPACES conferences and the Next-CSP info days, the following companies expressed a clear interest in further developments and commercialization of the Next-CSP SPT concept.

Table 3 – Companies interested in the project concept

Company	Location	Interest
Hiro Energy-Tech Ltd.	Mumbai (India)	Technology development in renewable energies Consulting and engineering services
SunOyster Systems GmbH	Halstenbek, Germany	Potential addition to the renewable energy portfolio
SolarInsure	Cota Mesa, California (USA)	Commercial insurance brokerage firm with major activities in lrge solar manufacturers and smaller solar/wind

		contractors
Abengoa	Spain	Interested in the technology developed by the project and to participate in a potential follow-up of the project
German Academy for Renewable Energy and Environmental Technology	Berlin, Germany	Only offers a rnge of seminars. Their mission is to train students in teh wide field of renewable (including solar) energy
Lion Alterntive Energy PLC	London, U.K.	Mostly interested in energy storage and solar thermal production
Technicas Reunidas	Madrid, Spain	Engineering and Consulting company with specific interests in heat transfer, heat storage and cogeneration
Solartron Energy Systems	Halifax, Canada	Main interests in the optical systems of a CSP
Tuba Turbine GmbH	Frankfurt, Germany	Main interests in the power block (heat exchangers, turbines)
Sargent a& Lundy	Chicago, USA	Consulting company for the electric power and energy intensive clients

Mithras CSP Beteilungs GmbH	Rossbach-Wied, Germany	Mostly manufacturing parabolic throughs, but interested in particle-driven solar receivers
Thermax Limited	Wakdewadi, India	Builds nd commissions large scale steam and power generation plants. Interested in hybrid solar power plants.
KPV Solar GmbH	Klagenfurt am Wörthersee, Austria	Designs and constructs photovoltaic and solar thermal power plants. Largely interested in the PV-CSP peaker concept.
Franco Tosi Mecanica SpA	Legnano, Italy	Mostly interested in the steam turbine part of the CSP
Ibereólica Group	Madrid, Spain	Consulting company in renewable energy sources, including solar energy
Victory Energy Operations LLC	Collinsville, USA	Only interested in custom-engineered idustrial boilers, hende in the power block of Nect-CSP
EnviroMission Ltd	Melbourne, Australia	General consultant in Solar thermal Power stations

SolarReserve LLC	Santa Monica, USA	Leading developer of utility-scale solar power projects, and hybrid PV-CSP systems
Torresol Engineering	Getxo, Spain	Manufacturer and operator of large CSPs. Partner of the previous CSP2 (FP VII) project.
Soltigua	Gambettola, Italy	Specialized in sun-tracking technologies.
BrightSource Energy	Oakland, USA	Main designer, buider and operator of CSP technology

Additional contacts are continuously made. As an example, a company in Saudi Arabia active in new technology encouraging investment into the Kingdom is interested in the project: they asked to be contacted after the results of the testing in the Next-CSP are known to start a dialogue with them. A project like this will take many years to develop but we need to make sure this technology is developed and realized: this is a good time to be introducing such technology into a country which has vast resources of money and even greater resources of sun power and this is surely a future potential commercial route.

On a second level, **CSP engineering companies** will benefit from the Next-CSP technology by being able to elaborate a strategic vision for the medium to long terms. In particular, apart the power production, the Next-CSP technology offers a reliable solution for producing high temperature and storable solar heat for industrial processes in the temperature range 600-750°C.
Nevertheless, intermediate steps are necessary for the industrial development of the Next-CSP concept. In particular, it is essential to construct and operate during a significant duration a demo-scale system. The estimated power range of this demo-scale plant is 5-10 MW_{th}. It must include a demonstration of particles conveying equipment (horizontal and vertical).

On a third level, **engineering company involved in the supply of components for energy management** in industry can take profit of some component developed in the framework of the project. It is particularly the case for the fluidized particle compartmented heat exchanger, which application domain is much larger than CSP.

The research community – They are also considered as the primary target for the exploitation of the post-project results since without further R&D, the maturity of the technology will not be reached.

The secondary target:

Policy stakeholders and regulators will benefit from the achievements of Next-CSP. These have been targeted at local, regional, national and European level. This will help to strengthen politic engagement into the draft of policy agendas supporting the use of solar energy. Supporting the policy makers in their understanding of the technology and of the economic and environmental gain will be of primary importance to be able to influence their decisions and secure their engagement. In order to raise their attention on the technology, however, we have to stress what most matters at decision makers and government level to guide investment strategies and market developments, for example the decarbonization issue and the low water consumption of this technology.

The **civil society** will also extremely benefit from the Next-CSP project development, which will be impacted on different aspects, like improve living environment, reduce energy consumption and improve employability. This target group has been reached mainly through means of communication actions (visits, social media, articles in the press, popularization events, ...)

Authorities and regulators

- EC Directorate General (DG Climat, DG Environment, DG Energy)
- European organisms (Council of European Municipalities and Regions)
- Regional and national governments in European Countries
- Renewable Energy Policy Network for the 21st Century (REN21)

3.2. The point of view of experts

Following the Next-CSP infoday (July 8, 2021), we have organised a follow-up online meeting with experts in the field of CSP (CENER, ESTELA and one indipendent consultant) on July 21, 2021 to gather their feedback on the project and on the 4 points below:

1. Advantages and disadvantages of the innovation
2. Barriers to the development and necessary steps to be taken before the industrial demonstrator
3. Possibility to valorize one of the components outside the complete system
4. Possible exploitation outside the scope of the CSP

Discussions were led by the project coordinator. Minutes of this meeting are available in Annex 1.

4. EXPLOITABLE RESULTS

4.1. Methodology

In order to raise awareness among partners of the importance of exploitation, a dedicated seminar has been organised by Euronovia in December 2019, led by an external expert on exploitation. The aim was to help the consortium in analysing different routes to exploitation and advise on Intellectual Property Rights.

During this workshop, Next-CSP partners were trained on the importance of KERs and exploitation in general and were presented several templates to be used to collect information about the KERs identified by the consortium: a research and commercialization roadmap, risk analysis, lean canvas. At the end of the meeting, partners were given instructions to fill the templates presented during the meeting to track the project results and to send them for analysis to the expert. These tables were constantly updated during the project duration and were refined until a final list of exploitable results were agreed upon by the Consortium (see Table 4 below).

4.2. Results

Below is presented the final list of exploitable results identified by the consortium, the main exploitable results being the system prototype and the scaled-up solar receiver.

Table 4 – List of Next-CSP Key Exploitable Results (KERs)

Exploitable result	Owner/s; Joint ownership	Project partners who have related background	Form of exploitation protection and its status	Who will exploit it	What will be the product/service exactly	Exploitation intentions	Starting and final TRL level
System prototype	CNRS, EPPT, COMESSA, WEL, SBP,	CNRS, COMESSA, EPPT	Secret know-how	EDF	Solar power plant	Licensing	Initial TRL = 4; Now at TRL 5/6
Scaled-up solar receiver	CNRS, COMESSA, EPPT and WEL	CNRS: general concept, instrumentation, testing; COMESSA: Engineering design and control system; WEL: FEM simulations and construction	Secret know-how of know-how	Whittaker, other solar receiver manufacturers are also a possibility	High temperature solar receiver for particle heating at about 700-800°C	Licensing	Initial TRL = 3-4; Now at TRL 5/6
Heat exchanger	CNRS, EPPT, WEL, COMESSA	CNRS and EPPT: concept, basic design and thermal simulation. WEL: FEM simulation and construction.	This is secret know-how. Fluidized beds are as such not patentable. They have been developed since 1970 and only new process applications can be protected	WEL, or other heat exchanger manufacturers	A fluidized bed heat exchanger technology	Licensing First move towards TRL6-7 level and apply the technology in particle storage systems, solar and not solar.	Initial TRL = 3; Now at TRL 5/6
Heliostat aiming strategy	CNRS and SBP	CNRS and SBP	Exchange of software with users on a case-by-case basis	CNRS	Software	Not directly, tailored services using the knowledge received from this development	Initial TRL = 3; Now at TRL 6

5. INDIVIDUAL EXPLOITATION PLANS

5.1. Methodology

The highest risk a consortium faces is not being able to implement the exploitation and dissemination plan and increase the TRL level or go to market, due to lack of plans or resources. To mitigate that risk all key exploitable results were examined. We used self-developed templates for collecting the exploitation related information, which were filled by the owners of the results. The completion and content of the received documents were checked by the exploitation expert team. They commented on them and sent it back to the partners for clarification/correction. The final form (which can be found under each result) was created after multiple discussions. The final forms of the templates are described in the following chapter ("Commercially exploitable results" and "indirectly" commercial results"). Looking through the results achieved so far, most of the project partners have ideas for further research and commercialization opportunities that could realize the transfer of the technologies into further research, funding, or market opportunities.

5.1.1. Templates used to gather information on KERs

5.1.1.1. Result description

It contains the description of the Result and the exploitation plans including the description of the product/service derived from the result. Basic market and potential customer information are also included as well as the IP protection plans. This is the basis for all the other templates. There were different description templates used in the project, one for the commercially exploitable results and one for the "indirectly" commercial result. The completed descriptions are introduced in the following chapters of this report.

Description of result for licensing **Result name: ………………………… (Result no. …..)**	
Description of the Result and fields of use Please add a description that can be understood by anybody. Also please add the fields of use.	
Intentions to license the result: **Please describe what would you like to license exactly (**a patent, trademark, design or model, any plan, secret formula or process, information concerning industrial, commercial or scientific experience or others**)** **Description of the product/service/process that will be derived from the result.**	
Innovativeness introduced compared to already existing Products/Services	
Whom would you like to offer your license? On which markets (market segment and countries of interest)? If you have company names it is also fine.	
Do you plan to apply for a patent? How would you like to protect your result? (Keeping in secret, patenting?) In case you have a patent application already that is related to the project, please let us know In case you would like to keep in secret, please explain why is this the best option according to your opinion	

Description of result for further research Result name: ………………………… (Result no. …..)	
Description of the Result and fields of use Please add a description that can be understood by anybody. Also please add the fields of use.	
Description of the product/service planned to be developed from the result	
Intentions to exploit the final development: further exploitation plans related to the result (i.e. own production and sales, contract manufacturing and sales, offering services, licensing)	

Whom would you like to offer the development/product/services? On which markets (market segment and countries of interest)? If you can please list companies as examples.	
Innovativeness introduced compared to already existing Products/Services	
How would you like to protect your result? (Keeping in secret, patenting?) In case you would like to keep it secret, please explain why is this the best option according to your opinion. In case you have a patent application already that is related to the project, please let us know.	

5.1.1.2. Research and commercialization roadmap

The research and commercialization roadmap is intended to summarize the further research & development steps necessary to reach the market with the newly developed product, process or service and to introduce the further research opportunities that can be built on the project results and for realising the transfer of the technology to other applications. This creates a basis for planning future research directions that could emerge in order to build on the knowledge generated during the project. The other part of the template is focusing on the commercialization point of view. It is designed to help the consortium to identify and plan activities to be performed after the end of the project.

During the course of the project, individual research and commercialization roadmaps were prepared for commercially important Key Exploitable Results and a research roadmap was prepared for the “indirectly” commercial result that are included in the respecting chapter of this report.

Research and commercialization roadmap for results to be licensed **Result name: ………………………… (Result no. …..)**	
What will be the stage of development by the project end? Technology Readiness Level (TRL) by the project end	
Is there any need for further R&D before licensing? **What are the routes for further research and development if needed?**	
Will the licensee need further development before commercialization of the result? What will be the main steps for the licensee to reach the market with your newly developed product/service or introduction the process into the production lines?	

List stages! (Development of prototype, demo tests, upscaling for mass production, market testing, …)	
If there is need for further R&D before licensing, briefly describe actions planned 3-6-12 months after project end (list milestones, indicate the timeline)	
Financial sources to cover the planned activities (3 months, 6 months, 1 year)	
Do you already have an interest from a potential licensee for this result? (If yes, please add where the negotiation stands)	
What will be the impact in 3-year time? (jobs created, investments mobilized, turnover generated)	
Further research opportunities for building on the project results and for realising transfer of the technology to other applications: The developed technology could be further developed and used in other technological fields?	
Is your result built on another result of the project? Or do other results build on your result? If yes, please explain!	

Research roadmap **Result name: ………………………. (Result no. …..)**	
What Technology Readiness Level (TRL) your result will reach by the end of the project?	
Are you willing to continue the research with the project partners after the project end or you plan to continue on your own?	
How do you plan to finance further research? (in the frame of a new EU project, own financing)	
What are the steps for further research and development to reach a market ready stage? **List stages also (Development of prototype, demo tests, market testing, …)**	
Further research opportunities for building on the project results and for realising transfer of the technology to other applications: The developed technology could be further developed and used in which technological fields?	
Is your result built on another result of the project? Or do other results build on your result? If yes, please explain!	

5.1.1.3. Risk analysis

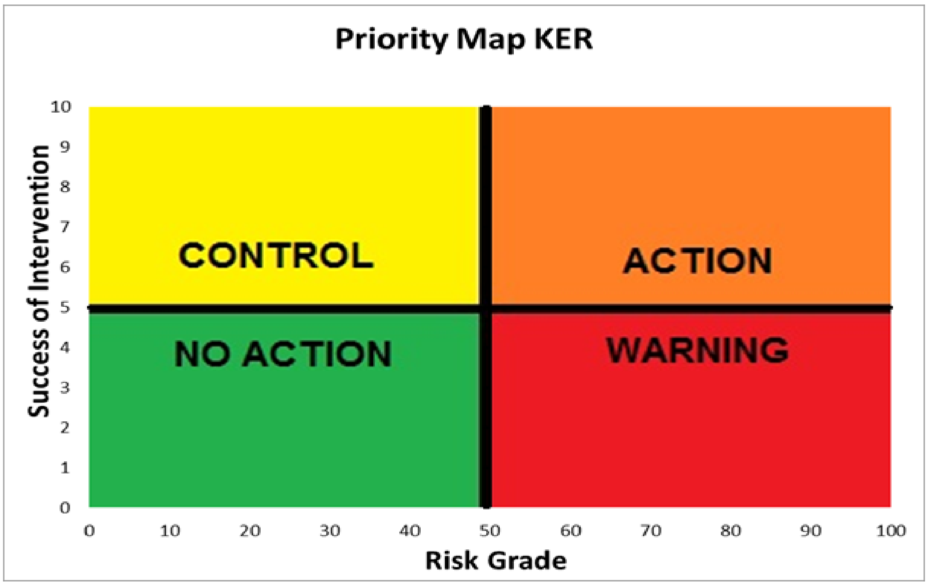
Connected to the exploitation plans risk analysis was performed for each of the commercially important Key Exploitable Result with the help of a Boston matrix grid that analyses the risk grade in relation to the success of the intervention. The 'risk grade' is the product of the impact of any given risk and the probability of that risk occurring. With the grade of the intervention's success, the grid shows whether a risk can be controlled or rather should be taken seriously since it could significantly impact the success of any particular potential exploitable result. The following Table supported by a priority map was sent out to the partners to analyse the risks of their results. In the risk analysis chapters of the results, the most relevant risks are listed that could affect the exploitation of the results. The related chapter summarizes not just the most important risks mentioned by the project partners but also describes the potential solutions found by the partners.

	Key Exploitable Result:	Degree of importance for the risk of not achieving the Key Exploitable Result. (1 low - 10 high)	Probability of risk happening (1 low - 10 high)	Risk Grade	Scope and type of potential intervention	Feasibility of Intervention Please rate from 1 to 10 (1 low- 10 high)	Priority Level
	Partnership Risk Factors						
1				0			0
2				0			0
	Technological Risk Factors						
3				0			0
4				0			0
	Market Risk Factors						
5				0			0
6				0			0
	IPR/legal Risk Factors						
7				0			0
8				0			0
	Financial/management Risk Factors						

9				0			0
10				0			0
	Environmental/regulatory Risk Factors						
11				0			0
12				0			0

The risk grade coupled with the probability of success will position the risk in the Priority Map to lead to focus on areas that need to be strengthened.

- A high-risk grade and a low probability of success of the intervention identifies a situation where we may consider discussing to stop the project (Warning).
- A high-risk grade with a high probability of success for the remedy action defines a situation where there is a need for immediate action to ensure exploitation (Action).
- A low-risk grade coupled with a high probability of success of the planned remedy defines a situation where it would be preferable to keep an eye on what is happening (Control) to be ready to act.
- A low-risk grade and a low probability of success for the remedy is a situation that does not call for immediate action (No action).



5.1.1.4. Licensing canvas

The lean canvas for licensing is a business model template for entities in favour of licensing their result. The lean canvas for licensing model has 12 building blocks: Problem, Your Solution, Competitors' Solution, License Value Proposition, Key Metrics, Unfair Advantage, Licensee Segment, Channels, License Agreement, License Revenue Plan, Cost Structure and Value Chain. Lean canvas for licensing was developed by LC Innoconsult, revamping the Lean business model canvas. The final forms of the lean canvas are listed for each result individually. These templates are not to be viewed as a final business plan for the results, but a guide on what potential each of them have and which segments need to be focused for future exploitation.

<table>
<tr>
<td rowspan="2">1) Problem
What are the problems that the license solves?
(Please list them)</td>
<td>2) Your solutions
How your license solves the problem(s)?</td>
<td rowspan="2">4) License value proposition

Why is your license better than others, different and worth buying?
How will it improve the licensees' position?</td>
<td>5) Key Metrics
What proofs do you have that your license is better than the competitors'?
(Please use appropriate metrics to explain the difference)</td>
<td>7) Licensee segment
Who are the potential licensees?
Who are the potential early adopters?
Do you already have an interest from a potential licensee for this result? (If yes, please name the company and where the negotiation stands.)</td>
</tr>
<tr>
<td>3) Competitors' solution
What are the existing alternatives to address the same problems?</td>
<td>6) Unfair Advantage
Does your license have unique features?
Is it easy to copy?
What is the entry barrier for competitors? (Is it low or high?)
Do you have IP protection?</td>
<td>8) Channels
On what channels are you planning to seek potential licensees? (Technology exhibitions, Technology transfer databases, through TTOs or strategic partners etc.)</td>
</tr>
</table>

<table>
<tr>
<td>9) License agreement

What type of licence will be proposed?

· Geographically

· Time period

· Exclusivity (Exclusive License, Non-Exclusive License, Sole License, Cross License)</td>
<td>10) Licensing revenue plan
What type of licence revenue are you interested in a licence agreement? Please use exact numbers and percentages when describing the licensing revenue plan. There are commonly used royalty standards that can help in defining the licensing revenues.

Lump sum fee (Upfront fee):
1. Complete
2. Partial (For patent licenses partial lump sum payments are common.)

Royalty model:
1. Running royalties
2. Independent royalties</td>
</tr>
<tr>
<td colspan="2">11) Cost structure
What type costs were incurred during the development of this licence?
(Please list the actual numbers.)</td>
</tr>
<tr>
<td colspan="2">12) Value chain

How will the licensee get revenue from the result? (The result generates end products to sell, generates materials or other parts that will be the base for a final product etc.)

Please describe the Return of Investment (ROI) period.

What will be the impact in 3-year time? (jobs created, investments mobilized, turnover generated)</td>
</tr>
</table>

5.2. Commercially exploitable results

The results are mostly around TRL 6 with great future exploitation potential. CSP technologies are developing in the market, they are reaching lower and lower CAPEX/OPEX and with a combination of high-capacity storage and the clear increase of costs of fuel/carbon (increasing operating costs of fossil-fuelled plants), it is getting competitive to other sources of energy. More research is needed at the moment to mature the technologies developed in the project, but there is a need and a will from partners to follow up on the Next-CSP project for high-temperature particle receivers.

5.2.1. System prototype

It is the system for improving current CSPs to be able to work and benefit from a higher temperature and a better conversion cycle. It integrates a multi-tubular fluidized bed solar receiver, a hot storage heat exchanger, a bucket elevator, a cold store and it utilizes solid particles as a heat transfer fluid. CNRS, COMESSA, EPPT, SBP and WEL has contributed to the development of the system. The contribution of each partner is not yet quantified, but as it is a shared result, they are planning on signing a Joint ownership agreement. The system is not yet fully developed, there is still a need for further R&D for data analysis of the prototype system. The partners are planning on applying for Horizon Europe calls as a further funding opportunity. It is not patented as a whole; the system is planned to be commercialized as secret know-how for the CSP industry. The solution can be a great opportunity to level up the current CSP systems.

5.2.1.1. Description of KER #1

Description of system prototype for licensing	
Description of the Result and fields of use	The system is an innovative central receiver (power solar tower) solar thermal power plant using solid particles as heat transfer fluid and storage material. It consists of the integration of a multi-tubular fluidized bed solar receiver, a hot store a heat exchanger, a bucket elevator and a cold store. Except for the bucket elevator, there are no other mechanical parts; the particle circulation is controlled either by pressure or by the gas flow. It produces heat at high temperature (600-800°C) that can be converted into electricity using a turbine (steam or gas turbine)

How will you protect your result? (Keeping in secret, patenting, other forms of protection, i.e. design, trademark, copyright…)	The best option is to keep the know-how secret because there is a lot of tricks to operate the system. Moreover, the principle was already published
Intentions to license the result: What is the subject of the license?	Secret formula or process (secret know-how)
Description of the product/service/process that will be derived from the result	Solar process for producing high-temperature heat and power. The solar heat can be stored to be delivered when needed.
Innovativeness introduced compared to already existing Products/Services	A similar process is not available. In particular, the heat is produced at a higher temperature than molten salt (>560°C) delivered by a commercial power tower.
Whom would you like to offer your license, who is your ideal licensee? On which markets (market segment and countries of interest or companies of interest)?	Market in countries where CSP can be profitable (DNI > 2000 kWh/m2.y) e.g.: EDF

5.2.1.2. Research roadmap of KER #1

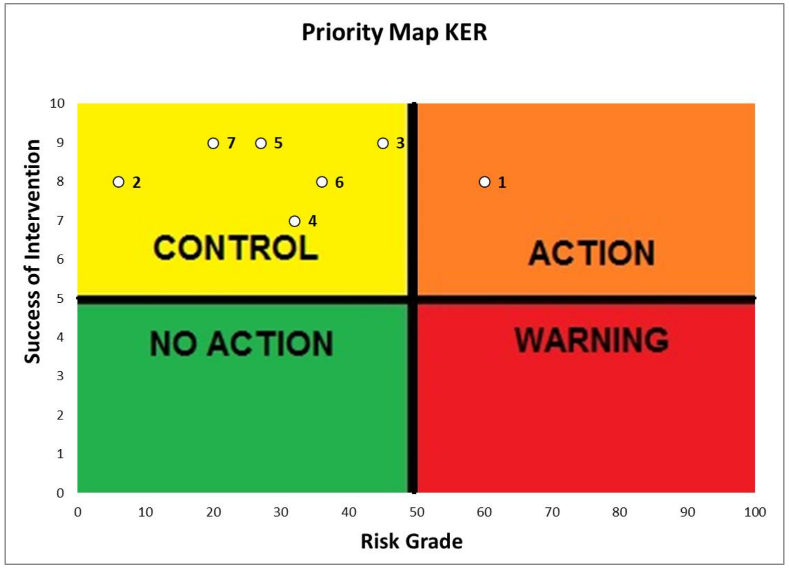
Research and Commercialization Roadmap of the system prototype to be licensed	
Technology Readiness Level (TRL) reached by the project end	TRL6 from the technology viewpoint, but TRL5 from the operation viewpoint due to lack of time.
Is there any need for further R&D before licensing? If yes, please describe actions planned 3-6-12 months after the project end.	Yes, 12 months: On-sun operation of the complete system
If the answer is yes to the previous question: How do you plan to finance further research?	Yes, we are interested in the National R&D grant and International R&D grant (HE, Eureka, other…)
Will the licensee need further development before the commercialization of the result? **What will be the main steps for the licensee to reach the market with the licensed technology?** **List stages! (Development of prototype, demo tests,**	Further development is needed: 1. Prototype operation feedback analysis 2. Hot particle conveying technology testing 3. Long tube (8 m) solar receiver manufacturing and testing 4. Long duration hot particle storage testing 5. Integration of a high-efficiency supercritical cycle in a demo-scale unit

upscaling for mass production, market testing, …)	
Do you already have an interest from a potential licensee for this result?	Yes, EDF
What will be the impact in 3-year time?	In 3 years time, a demo-scale unit can be constructed with the cost of approximately 3000€/kW
Further research opportunities for building on the project results and for realising the transfer of the technology to other applications: The developed technology could be further developed and used in other technological fields?	Yes, production of high-temperature storable heat for industry
How is this result connected to other ones from the project?	The system integrates all the components of the conversion loop, in particular, the solar receiver (Result No.2) and heat exchanger (Result No.3)

5.2.1.3. Risk analysis of KER #1

	Key Exploitable Result N°1: System prototype	Degree of importance for the risk of not achieving the Key Exploitable Result. (1 low - 10 high)	Probability of risk happening (1 low - 10 high)	Risk Grade	Scope and type of potential intervention	Feasibility of Intervention Please rate from 1 to 10 (1 low- 10 high)	Priority Level
	Partnership Risk Factors						
1	Disagreement on further investments: some partners may leave.	*10*	*6*	**60**	*With written agreements or finding potential partners who will replace the ones who leave this can be evaded.*	*8*	**480**
	Technological Risk Factors						
2	Failure of one component of the system such as the particle conveying system	*3*	*2*	**6**	*Deep maintenance*	*8*	**48**
3	Excessive thermal losses of the particle conveying system	*9*	*5*	**45**	Improvement of the existing technology by R&D	*9*	**405**
4	Lack of turbine supplier at commercial scale	*8*	*4*	**32**	Extend the supplier research outside Europe	*7*	**224**
	IPR/legal Risk Factors						
5	Disagreement between partners on IP related to a specific component	*9*	*3*	**27**	*There should be an agreement on which partners and what rights do they have on the specific background related to this result, and what rights do they have*	*9*	**243**

					to the foreground (the result)		
Financial/management Risk Factors							
6	Insufficient system operation feedback to found the next development step Further development is needed to exploit the potential of the system, and for that further funding opportunities are also needed	*9*	*4*	**36**	*Identifying potential calls in HE (related to CSP development IA 2022) or regional funds*	*8*	**288**
Environmental/regulatory Risk Factors							
7	Dust formation	*4*	*5*	**20**	*Dust formation cannot be avoided but the filter can limit dust emission to acceptable values*	*9*	**180**



5.2.1.4. Licensing canvas of KER #1

<table>
<tr>
<td rowspan="2">1) Problem
The main problem with solar power systems is that when there is no sun, there is no energy for that there are conversion cycles to increase the operational time of the systems.

Also, the current systems are high priced and can be further developed for more efficient operation.</td>
<td>2) Your solutions
The system is an innovative central receiver (power solar tower) solar thermal power plant using solid particles as heat transfer fluid and storage material. It produces heat at high temperatures (600-800°C) that can be converted into electricity using a turbine (steam or gas turbine)</td>
<td rowspan="2">4) License value proposition
Cycle: Increase the temperature to be able to operate higher efficiency cycles (supercritical cycle) 48-50% efficiency of the cycle (Molten salt 42%)

Storage:
Particles are much cheaper than molten salt

The cost of the storage is half</td>
<td rowspan="2">5) Unfair Advantage
Part of the system is patented
The operation is not classical, there is a lot of know-how involved which makes reverse engineering and copying harder</td>
<td>6) Licensee segment
Potential licensees:
Energy companies (like EDF, international market)
Construction companies (like EPC)

A potential early adopter can be EDF.</td>
</tr>
<tr>
<td>3) Competitors’ solution
Alternative PV + batteries
Molten salt</td>
<td>7) Channels
Technology transfer through TTOs or strategic partners</td>
</tr>
<tr>
<td colspan="2">8) Cost structure
Cost of the development inside of the project
Cost of the development before the project
Cost of the patent</td>
<td colspan="3">9) License Agreement
Most probably the know-how as the whole system cannot be patented</td>
</tr>
</table>

	10) **Revenue plan** It cannot be calculated as of now. It will depend on the shares of partners involved in the results as well as individual companies interested in licensing the know-how.
11) **Value chain** The current know-how can be used to prototype new types of solar energy towers, but after future development, the system can be integrated into full-sized CSP-s.	

5.2.2. Scaled-up solar receiver

CNRS, COMESSA, EPPT and WEL scaled up the previously patented solar receiver (using solid particles) by CNRS to be utilized in the prototype of the solar system. The knowledge allows a solar receiver to be adapted to a given sized of the solar power plant. They are planning on licensing this know-how for construction or energy companies to manufacture future solar receivers.

5.2.2.1. Description of KER #2

Description of the scaled-up solar receiver for licensing	
Description of the Result and fields of use	The solar receiver is composed of vertical tubes irradiated by concentrated solar energy assembled on the top of a vessel name "dispenser". A fluidized bed is created inside the dispenser. The bottom tip of the tubes is immersed in this fluidized bed. An increase of the pressure in the dispenser results in the fluidized particle moving up inside the tube. Consequently, the solar heat absorbed by the tubes is transferred to the particle. At the receiver outlet, the particles are collected in a hot store. The solar receiver scaling up consists of increasing the tube number and the tube height. Nevertheless, the tube height can be limited by the slugging phenomena appearing in the up flow of fluidized particles circulation inside. Slugging is associated with a dramatic decrease of tube wall-to-fluidized bed heat transfer thus reducing the acceptable solar flux on the receiver tube. Solutions have been proposed to avoid this problem.
How will you protect your result? (Keeping in secret, patenting, other forms of protection, i.e. design, trademark, copyright…)	The principle of the solar receiver has been already patented. The best solution seems to keep secret the know-how
Intentions to license the result: What is the subject of the license?	Design or model Secret formula or process (secret know-how)
Description of the product/service/process that will be derived from the result	The service is a method for solar receiver scaling up. The product is a solar receiver adapted to a given sized (thermal power) of the solar power plant
Innovativeness introduced compared to already existing Products/Services	particles in the receiver tube and not gas or fluid (particles flowing in the tubes)
Whom would you like to offer your license, who is your ideal licensee? On which markets (market segment and countries of interest or companies of interest)?	Manufacturer of solar receiver for a power tower. Market: solar electricity with thermal energy storage capacity.

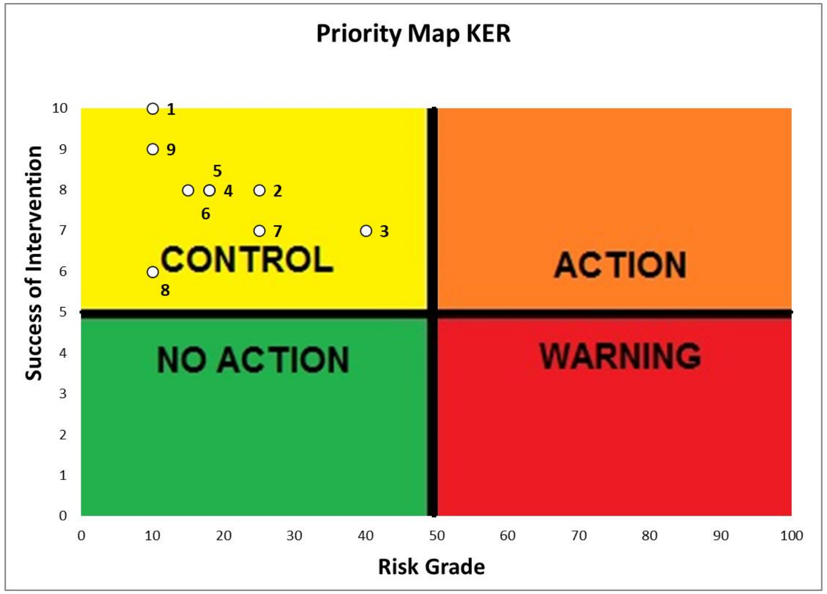
5.2.2.2. Research roadmap of KER #2

Research and Commercialization Roadmap of the scaled-up solar receiver to be licensed	
Technology Readiness Level (TRL) reached by the project end	TRL6 Same remark that for result No.1 (Only TRL5 from the operational viewpoint)
Is there any need for further R&D before licensing? If yes, please describe actions planned 3-6-12 months after the project end.	Yes, 12 months: Long-duration testing
If the answer is yes to the previous question: How do you plan to finance further research?	Yes we are interested in National R&D grants and International R&D grants (HE, Eureka, other…)
Will the licensee need further development before the commercialization of the result? What will be the main steps for the licensee to reach the market with the licensed technology? List stages! (Development of prototype, demo tests, upscaling for mass production, market testing, …)	Further development needed: 1. Manufacturing of a high-temperature alloy solar receiver 2. Upscaling: Thermal-mechanical design and testing of an 8 m-long tube solar receiver
Do you already have an interest from a potential licensee for this result?	EDF
What will be the impact in 3-year time? (jobs created, investments mobilized, turnover generated)	Testing at demo-scale, associated cost ~5M€ for a 50 MWth solar receiver
Further research opportunities for building on the project results and for realising the transfer of the technology to other applications: The developed technology could be further developed and used in other technological fields?	Production of high-temperature solar heat for industry
How is this result connected to other ones from the project?	The solar receiver is the main component of the thermal loop (System, result No.1). It supplies hot particles to the hot store that delivers particles to the heat exchanger (result No.3)

5.2.2.3. Risk analysis of KER #2

	Key Exploitable Result N°2: Solar receiver	Degree of importance for the risk of not achieving the Key Exploitable Result. (1 low - 10 high)	Probability of risk happening (1 low - 10 high)	Risk Grade	Scope and type of potential intervention	Feasibility of Intervention Please rate from 1 to 10 (1 low- 10 high)	Priority Level
Partnership Risk Factors							
1	No manufacturer	*10*	*1*	**10**	*Some potential manufacturers exist in Europe outside the Consortium*	*10*	**100**
Technological Risk Factors							
2	Efficiency lower than expected	*5*	*5*	**25**	*Change of the initial design to limit radiation losses*	*8*	**200**
3	Excessive temperature gradient on the tubes	*8*	*5*	**40**	Modify the receiver design and the aiming strategy of the heliostats	*7*	**280**
4	Non uniform fluidization inside tubes and bad control of particle flow rate	*6*	*3*	**18**	Act on the fluidization gas injection and velocity	*8*	**144**
5	Partial clogging	*6*	*3*	**18**	insert secondary air injection	*8*	**144**
6	Faulty part-load operation	*5*	*3*	**15**	As far as low particle mass flow rate is concerned, decreasing the outlet temperature (larger mass flow rate) can solve	*8*	**120**
Market Risk Factors							

7	No confidence for a new technology	*5*	*5*	**25**	Chemical industry uses it since decades, this can be argued to increase confidence	*7*	**175**
Financial/management Risk Factors							
8	Too expensive component	*5*	*2*	**10**	*reducing the working temperature of the receiver, adapt the cycle to the new temperature, or find other cheaper materials (that needs to be experienced with)*	*6*	**60**
Environmental/regulatory Risk Factors							
9	Dust formation	*5*	*2*	**10**	*Dust formation can not be avoided but the filter can limit dust emission to acceptable values*	*9*	**90**



5.2.2.4. Licensing canvas of KER #2

<table>
<tr>
<td rowspan="2">Problem
1)
Heating of heat transfer fluid (HTF) at a higher temperature than molten salt (>560°C) and using the same medium for thermal energy storage (TES)</td>
<td>Your solutions
2)
The use of particles as HTF and TES medium. The current solution also replaces the high-temperature pump with pressurized air.</td>
<td rowspan="2">License value proposition
4)
Capacity to heat a medium at high temperature (700-800°C) that can be stored and then is used to power a conversion cycle</td>
<td rowspan="2">Unfair Advantage
5)
The basis of the solution is patented and has unique features.

There is development cost and time that can add to the patent as an advantage also.</td>
<td>Licensee segment
6)
Potential licensees are the solar receiver manufacturers and contractors like EPC

No potential licensee identified, maybe EDF in the future.</td>
</tr>
<tr>
<td>Competitors' solution
3)
Using gas as HTF or molten metals
Gas suffer of low heat transfer and molten metal of strong corrosion</td>
<td>Channels
7)
Technology exhibitions and conferences
Strategic partners</td>
</tr>
<tr>
<td colspan="2">Cost structure
8)
Capital costs
Operation costs
R&D costs</td>
<td colspan="3">License Agreement
9)
Construction design, operation protocol, in the future possible a patent can be licensed.</td>
</tr>
</table>

	Revenue plan 10) It cannot be calculated as of now. It will depend on the shares of partners involved in the results as well as individual companies interested in licensing the know-how.
Value chain 11) This solution can be used outside the power system as a chemical reactor to process high-temperature particles. At the market entry, there can be a barrier by the difference between the chemical and power engineer's way of work/seeing/thinking/protocols etc..	

5.2.3. Heat exchanger

CNRS, COMESSA, EPPT and WEL developed the heat exchanger that transfers the heat of the solid particles delivered by the solar receiver and stored in the hot bin to a working fluid that powers the turbine. The innovation is the use of a compartmented fluidized bed in a tube-shell heat exchanger concept with fluidized particles in the shell part. This is a key component of a particle solar thermal power plant with storage because it delivers useful heat from the particles but can be used in many industrial heat recovery applications and can supply renewable high-temperature process heat. The partners are interested in licensing the know-how of the design and the manufacturing of the system.

5.2.3.1. Description of KER #3

Description of the heat exchanger for licensing	
Description of the Result and fields of use	The heat exchanger transfers the heat of the particle delivered by the solar receiver and stored in the hot bin to a working fluid that powers the turbine. The working fluid can be air, steam, supercritical CO_2 etc. It is composed of a bundle of tubes immersed in a fluidized bed of hot particles. This fluidized bed is compartmented to create a thermal gradient along with the heat exchanger. This is a key component of a particle solar thermal power plant with storage because it delivers useful heat from the particles.
How will you protect your result? (Keeping in secret, patenting, other forms of protection, i.e. design, trademark, copyright…)	The principle cannot be patented because it is known. Nevertheless, the specific design and the manufacturing process can probably be patented.
Intentions to license the result: What is the subject of the license?	Patent (the construction can be patented? WEL) Design or model
Description of the product/service/process that will be derived from the result	A fluidized particle heat exchanger that allows heat recovery from the particles to a fluid. This fluid can power a conversion cycle or be used in a thermal process.
Innovativeness introduced compared to already existing Products/Services	Design and manufacturing of the system. (the principle is known)
Whom would you like to offer your license, who is your ideal licensee? On which markets (market segment and countries of interest or companies of interest)?	Heat exchanger manufacturers

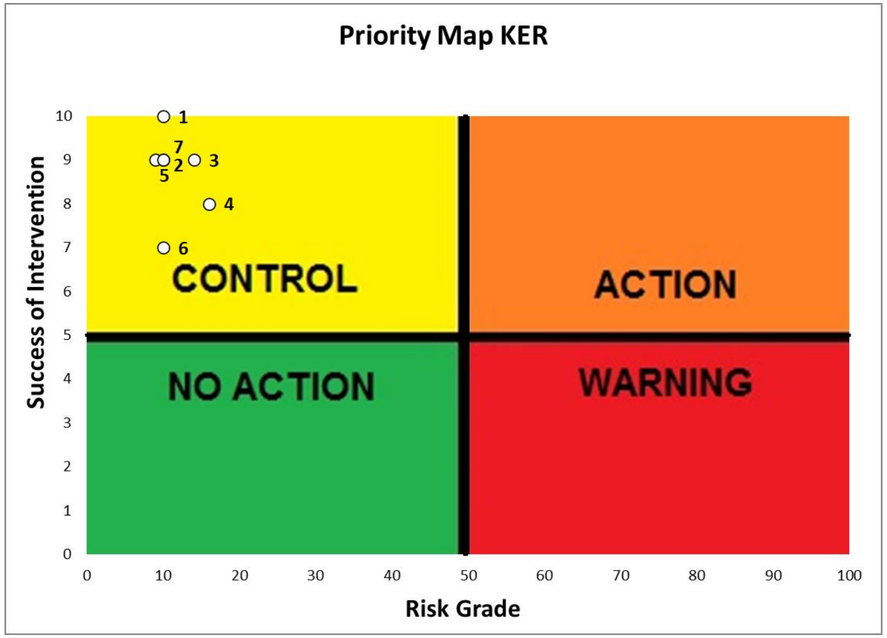
5.2.3.2. Research roadmap of KER #3

Research and Commercialization Roadmap of the heat exchanger to be licensed	
Technology Readiness Level (TRL) reached by the project end	TRL6
Is there any need for further R&D before licensing? If yes, please describe actions planned 3-6-12 months after the project end.	Yes, 6 months: upscaling methodology and technology
If the answer is yes to the previous question: How do you plan to finance further research?	Yes, we are interested in National R&D grants and International R&D grants (HE, Eureka, other…)
Will the licensee need further development before the commercialization of the result? What will be the main steps for the licensee to reach the market with the licensed technology? List stages! (Development of prototype, demo tests, upscaling for mass production, market testing, …)	Further developments 1. Demo tests: Heat exchanger with compartment number larger than 6 (approximately 10) 2. Testing of the heat exchanger with other fluids that air (steam, supercritical steam and CO_2)
Do you already have an interest from a potential licensee for this result?	Yes, if integrated into the solar system (EDF)
What will be the impact in 3-year time? (jobs created, investments mobilized, turnover generated)	Demo-scale test results, 250 k€ for a large-scale prototype
Further research opportunities for building on the project results and for realising the transfer of the technology to other applications: The developed technology could be further developed and used in other technological fields?	In every application of particle technology to the energy domain, the heat exchanger is a key component for delivering stored heat to the industrial processes.
How is this result connected to other ones from the project?	The heat exchanger is the key component for recovering the thermal energy stored in the particles and transferring it to the heat conversion system (the turbine). It is linked to the solar receiver (result N°2) and is a part of the system (result N°1)

5.2.3.3. Risk analysis of KER #3

	Key Exploitable Result No.3: Heat exchanger	Degree of importance for the risk of not achieving the Key Exploitable Result. (1 low - 10 high)	Probability of risk happening (1 low - 10 high)	Risk Grade	Scope and type of potential intervention	Feasibility of Intervention Please rate from 1 to 10 (1 low- 10 high)	Priority Level
Partnership Risk Factors							
1	No manufacturer	*10*	*1*	**10**	*Potential manufacturers in Europe exists*	*10*	**100**
Technological Risk Factors							
2	Excessive abrasion of particles on the heat exchanger tubes	*5*	*2*	**10**	*limit the fluidization gaz velocity and/or use hard coating*	*9*	**90**
3	Dysfunctional control of particle feeding	*7*	*2*	**14**	Modify the feeding system	*9*	**126**
Market Risk Factors							
4	Exploitation disagreement between partners	*8*	*2*	**16**	*Define a market target for each partner*	*8*	**128**
IPR/legal Risk Factors							
5	Insufficient IP protection	*3*	*3*	**9**	*Improve the IP agreement between the partners*	*9*	**81**
Financial/management Risk Factors							
6	Too expensive component	*5*	*2*	**10**	*Modify the design and material to reduce cost*	*7*	**70**
Environmental/regulatory Risk Factors							

7	Dust regulation	*5*	*2*	**10**	*Filtering can reduce dust emission to a regulation level*	*9*	**90**



5.2.3.4. Licensing canvas of KER #3

<table>
<tr>
<td rowspan="2">Problem
1)

The main problem was to transfer the particle heat to a fluid (gas, steam, liquid, supercritical fluid)

Current solutions main problem is the low efficiency:
- high power/ unit volume of the heat exchanger
- or / unit surface area of exchange</td>
<td>Your solutions
2)
Using the compartmented fluidized bed in a tube-shell heat exchanger concept with fluidized particles in the shell part</td>
<td rowspan="2" colspan="2">License value proposition
4)

The solution offers much higher particle bed-to-tube heat transfer than moving packed bed</td>
<td rowspan="2">Unfair Advantage
5)

The principle is known but the manufacturing solution is difficult to copy.
No IP protection</td>
<td>Licensee segment
6)

Heat exchanger manufacturers
No potential licensee contacted yet

WEL can be a potential licensee, but not yet discussed as they are mostly adapted to medium scale, not high scale</td>
</tr>
<tr>
<td>Competitors’ solution
3)

The general solution is with moving packed beds</td>
<td>Channels
7)
Technology exhibition and conferences
Contact with manufacturers</td>
</tr>
<tr>
<td colspan="3">Cost structure
8)
Design costs
Manufacturing cost
Testing costs</td>
<td colspan="3">License Agreement
9)
They are interested in licensing the engineering design, manufacturing solution and operation guide</td>
</tr>
</table>

<table>
<tr><td></td><td>Revenue plan
10)
It cannot be calculated as of now. It will depend on the shares of partners involved in the results as well as individual companies interested in licensing the know-how.</td></tr>
<tr><td colspan="2">Value chain
11)
The technology can be used in many industrial heat recovery applications and can supply renewable high-temperature process heat</td></tr>
</table>

5.3. Indirectly commercial results

5.3.1. Heliostat aiming strategy

SBP with the help of CNRS had been developing a software solution to aim the heliostats in the system to achieve the maximum consistent power to the solar receiver. The software was developed for the project and is not generalized as of now. In the future, there is a possibility to generalize the software to work with more, or all heliostat fields, but not foreseen. Currently they are interested in offering tailored services to energy companies in the future using their expertise learnt from the project.

5.3.1.1. Description of KER #4

Description of the heliostat aiming strategy for further research	
Description of the Result and fields of use	A heliostat field delivers power (kW) and power density (kW/m2) on the solar receiver wall. The maximum acceptable power density depends on the heat transfer fluid (heat transfer coefficient at the receiver wall). A heliostat aiming strategy is needed to maintain the power density below a threshold value given by the maximum acceptable power density. It results in a flattening of the power density distribution.
Description of the product/service planned to be developed from the result	It is a software that uses a database of individual heliostat or group of heliostats' optical performances and manages the tracking position of the heliostats to achieve the chosen power density distribution.
Intentions to exploit the final development: further exploitation plans related to the result (i.e. own production and sales, contract manufacturing and sales, offering services, licensing)	Offering services
Whom would you like to offer the development/product/services? On which markets (market segment and countries of interest)? If you can please list companies as examples.	Central receiver solar power plant operators such as Abengoa, Acwa.

Innovativeness introduced compared to already existing Products/Services	Not clearly establish. No commercial products but case by case development by operators
How would you like to protect your result? (Keeping in secret, patenting?)	Keeping in secret

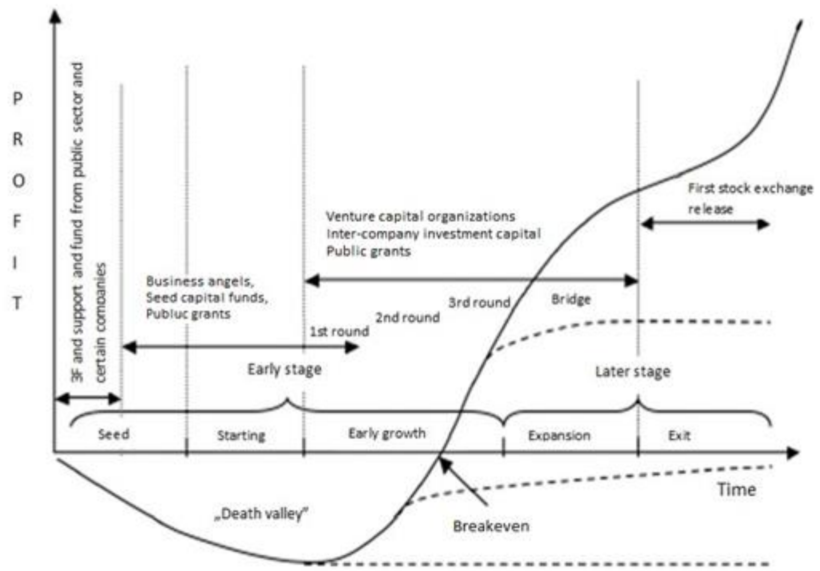
5.3.1.2. Research roadmap ok KER #4

Research roadmap of the Heliostat aiming strategy	
What Technology Readiness Level (TRL) your result will reach by the end of the project?	TRL6
Are you willing to continue the research with the project partners after the project end or you plan to continue on your own?	On our own
How do you plan to finance further research? (in the frame of a new EU project, own financing)	National and European projects
What are the steps for further research and development to reach a market-ready stage? List stages also (Development of prototype, demo tests, market testing, …)	Generalization of the software to all heliostat fields. The software was developed and validated only for the Themis tower. Stages: validation at demo-scale and testing in a commercial plant
Further research opportunities for building on the project results and for realising the transfer of the technology to other applications: The developed technology could be further developed and used in which technological fields?	Control of heliostat field of central receiver solar thermal power plants.
Is your result built on another result of the project? Or do other results build on your result? If yes, please explain!	The solar receiver design, modelling and operation strategy are built on the result.

6. FUNDING OPPORTUNITIES

The aim of this chapter is to introduce and summarize the further funding opportunities both in private and public sector to secure the post-project future of the Next-CSP initiative. It summarizes the further funding opportunities for the project partners who would like to further develop their results or need financial help for commercialization or would like to start a new R&D project in other fields based on their results reached in this project.

There are various possible alternatives to financing innovation projects from public and private sources. As it can be seen from the next picture the choice of the proper source depends on the development phase of the project and also a good combination of them can be used throughout the life of the project.



Within public funding both regional and national funding schemes were monitored, as well as funding opportunities for spin-out research, further industrialisation and commercialisation support. Further investments will be needed for a wider implementation post project as it can be seen from the result descriptions and from the research roadmaps related to each result. In the following we introduce and present the most common types of public and private sources for investment to be taken into consideration by the partners of the project.

6.1. Public grants

Public grants are set into motion by legislative bodies, greatly increasing the resources and accountability of the grant project. The amount of available money for public grants is usually greater than that of private grants, leading to overall larger awards. Additionally, a public grant is more likely to cover all of the expenses of your project due to its size.

6.1.1. Horizon Europe

Horizon Europe is the EU's key funding programme for research and innovation with a budget of €95.5 billion. The programme facilitates collaboration and strengthens the impact of research and innovation in developing, supporting and implementing EU policies while tackling global challenges. It supports creating and better dispersing of excellent knowledge and technologies.

The main opportunities in Horizon Europe calls could be found in the Cluster 5 - Climate, energy and mobility. This clusters aims to fight climate change by better understanding its causes, evolution, risks, impacts and opportunities, and by making the energy and transport sectors more climate and environment-friendly, more efficient and competitive, smarter, safer and more resilient.

As Next-CSP was a Research and Innovation Action project (RIA) the next step would be to apply for Innovation Action calls. The technology readiness levels of the results supports this suggestion.

6.2. Private investment

If a partner is about establishing a new company or wants to receive external funding in an existing company to finance product development, then private investment could be an option. Depending on the project phase and amount of money different types of equity investors can be considered. Here we list the most common equity investment forms starting with earlier stage investors, which also means smaller amount of investment.

6.2.1. Business angel

They are usually wealthy individuals with business experience who invest financial, intellectual and social capital in innovative technology-oriented start-up companies. Ideal source in case of small capital need and personal relation with the angel.

Advantages

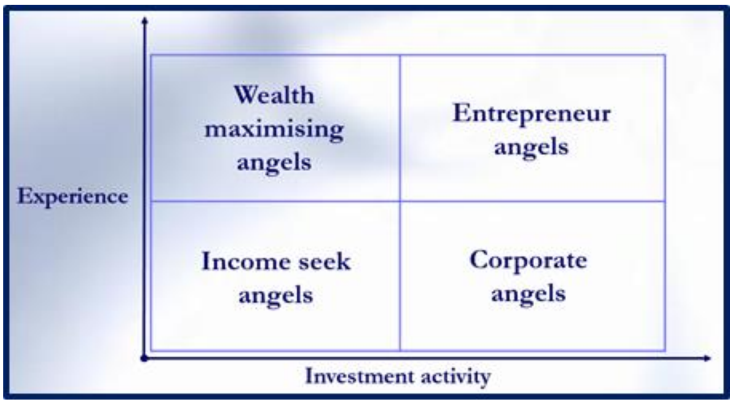
- Relatively cheap source
- The control stays with the management

Disadvantages

- Angels have less experience than VCs
- Angels do not want to invest as much as VCs

Features:

- Local/regional investors
- They receive information from business partners and relatives
- Investors share their knowledge, experience, know-how with the company and even participates in the management
- In case of investment or loan: advantages of financing from the same resources



Entrepreneur angel: ideal investors for innovative companies. The most active and experienced angel with high risk tolerance.

Corporate angel: company leaders who do angel investments for financial or social reasons taking the interests of own company into consideration.

Income seek angel: smaller investors with one or more investments, considers his share as an additional source of income and work.

Wealth maximising angel: invests in few projects. High expectations towards return, high risk-taking ability, searching for full-time job.

6.2.2. Venture capital funding

Venture capital is a capital investment from external source for companies with high-risk activities. It aims to secure that the company reaches the next stage of development. Venture capital firms and funds make investment decisions through fixed, regulated investment processes. VC firms invest the capital of the owners (their own money). VC funds invest money collected from other companies and individuals.

What do investors expect beside ownership?

- Capital increase/rights to sell shares
- Participation in the company's board of directors/supervisory board
- Participation in strategic decisions
- Participation in the decision-making process
- Optimal capital structure (credit - equity ratio)
- In exceptional cases participation in the company's management

What do investors provide besides money?

<u>Business relations</u>

- Extensive local and international business relations

<u>Business and management experience</u>

- Significant business expertise gained during former investments
- Knowledge about international industrial trends

<u>Credibility</u>

- Reputable, internationally acknowledged investors
- Towards customers, suppliers, banks

<u>Exit</u>

- The goal of venture capital investors is to sell their shares, which provides an opportunity for owners to realize their investments

6.3. Established companies – bank loan

For more established companies bank loan could be a straightforward solution as they have various loan instruments already established with their bank. These loan instruments and loan products vary from country to country and even from bank to bank. In some countries there are special loan instruments to finance the last phases of R&D. Therefore, companies should check with their bank what loan schemes are available.

6.4. Opportunities to guide post project exploitation

6.4.1. Horizon Results Booster and Horizon Results Platform

The above mentioned Key Exploitable Results have commercial potential on the market, this is why we have planned to follow up on the exploitation opportunities using the Horizon Results Booster services. Horizon Results Booster is a package of specialized services to maximise the impact of R&I public investment and further amplify the added value of the Framework Programmes (FPs). It helps to bring a continual stream of innovation to the market and beyond. It will help to speed up the journey towards creating an impact, providing support to remove bottlenecks.

HORIZON RESULTS BOOSTER

An initiative of the European Commission

https://www.horizonresultsbooster.eu/

We are also planning to upload our results on the Horizon Results Platform for the project's results to be more visible. The Horizon Results Platform is a Platform created by the European Commission where EU-funded project consortia can present their results for search, contact owners, and hopefully form fruitful partnerships that will eventually generate the desired value. This way we hope to find additional funding, loans and investments, get help to reach the market, receive additional technical help, or join any kind of cooperation.

https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform

7. KNOWLEDGE MANAGEMENT AND IPR

To help partners with this Knowledge Management and IPR issues, an internal event on exploitation and IPR was organized by Euronovia for the partners of the project in collaboration with the IPR Helpdesk from the European Commission, who provides training for EU funded projects.

As part of the project, a Consortium Agreement has been signed to address all relevant issues related to IPRs and the results generated during the project (access rights to background and foreground necessary for the execution of the Project, rules for dissemination and use of own knowledge etc). The Consortium Agreement (CA) complements the rules of the Grant Agreement. In the Consortium Agreement, information on the following items has been detailed:

- Which knowledge the consortium will exchange?
- Under which conditions?
- Who will be the owner of the results?
- What happens in cases of joint ownership?
- Who (and how) will exploit the results?
- Who (and how) will disseminate the results?
- How is the consortium protecting confidential information?

As a general rule, IPR is the property of those partners who have contributed to get the knowledge. The degree of ownership will depend on the degree of contribution to the IPR. This applies as long as it does not violate national legislation, specific agreements for scientific publication, and specific agreements among partners regarding ownership of IPR. Partners, that have jointly carried out work generating foreground and where their respective share of work cannot be ascertained, shall have joint ownership of that foreground and may establish appropriate joint ownership agreements or license agreements.

A joint ownership among different partners has been agreed upon for each of the 4 KERs identified, as indicated in Table 4.

8. CONCLUSIONS

The consortium has identified a list of Key Exploitable Results and most of the project partners have ideas for further research and commercialization opportunities that could realize the transfer of the technologies into further research, funding, or market opportunities.

It is important to stress that at the Next-CSP TRL level, commercial exploitation is not yet possible and further R&D and innovation investments are needed to bring the technology from a power of 2.5 MW_{th} at the receiver to commercial scale (50-100 MW_{th} solar receiver). Intermediate steps are necessary for the industrial development of the Next-CSP concept. In particular, it is essential to construct and operate during a significant duration a demo-scale system. The estimated power range of this demo-scale plant is 5-10 MW_{th} and it must include a demonstration of particles conveying equipment (horizontal and vertical). Consequently, we envision the following next steps:

1. Develop and operate during a significant duration (at least one year) a 5 MW_{th} demo-scale system based on the Next-CSP concept in order to fix all the issues identified during the execution of the current H2020 Next-CSP project. An Innovation Action in the framework of the Horizon Europe programme can fund this unit. In particular, the definition of the operation strategy will be a key deliverable of this project. Time: 2023-2026.
2. Construct and operate a First-Of-Its-Kind unit: 50 MW_{th} single tower integrating a long duration storage and a supercritical cycle. Time: 2027-2030
3. Deploy the technology at commercial scale (after 2030).

ANNEX 1 – Minutes of the meeting with experts (July 21, 2021)

Point 1 - Advantages and disadvantages of the innovation

Advantages

- Temperature higher than molten salt. The target 750°C is suggested because it is more adapted to super critical cycle, and it is not necessary to reach 800°C as planned at the start of the project.
- Molten salt plants have possible corrosion problem, while in this technology we have identified no problem in the potential corrosion of the metals.
- No freezing issue as with molten salt.
- Low cost and efficient storage is a key advantage because it is the main service expected from CSP with respect to the electricity network.
- Very low water consumption is another argument to raise interest on the technology

Disadvantages

- It is more difficult to circulate particles than liquids – we (CNRS) discovered that there is a lot of know-how which was never published in this domain.
- The conveying of tons of particles horizontally is an issue. Nevertheless, the conveying of particles is well known in mining, and iron and steel industry, for example. There is a lot of industrial experience on particle conveying but this is a real critical point for the Next-CSP technology.

Comments

- From ESTELA perspective, we have no technical comment on the quality of the innovation, more concerned on bringing the potential of innovation closer to the industry and market. What matters to decision makers and government level to guide investment strategies and market developments?

Point 2 - Barriers to the development and necessary steps to be taken before the industrial demonstrator: the level of what we are making now is a prototype, not a demonstrator. We should agree on what we call industrial demonstrator

and if we agree on the size we can then discuss on what are the steps to reach these demonstrator size.

- When we are looking at the size of single receiver we agreed within the consortium that the max size to have high efficiency (more than 80%) is more or less 50 MWth.
- For an industrial demonstrator a solar receiver power ranging from 5 to 10 MWth is significant.
- Testing the horizontal (and vertical) conveying of the particles is also a necessary step to include in the demonstration unit.
- Starting procedure and transient phases should be also checked.

Point 3 - Possibility to valorize one of the components outside the complete system

- The particle heat exchanger can be used in other applications.

Point 4 - Possible exploitation outside the scope of the CSP

- For commercial application: what is the size/power for this technology to be applied? The trend is high power, typically 100 MWe and more, with big storage capacity. It is the lessons learnt from the recent project (Dubai, Morocco ...).
- High temperature industrial process heat supply.
- In the last 2 years, we see clearly that doors are opening, and people are listening to the opportunities offered by concentrating solar technology in other fields than electricity production because decarbonization is more urgent for industry and renewable fuels for the transportation sector.