

INSHIP

EUROPEAN COMMON
RESEARCH AND INNOVATION AGENDA



Horizon 2020
European Union funding
for Research & Innovation



INSHIP

*Integrating National Research Agendas on
Solar Heat for Industrial Processes*

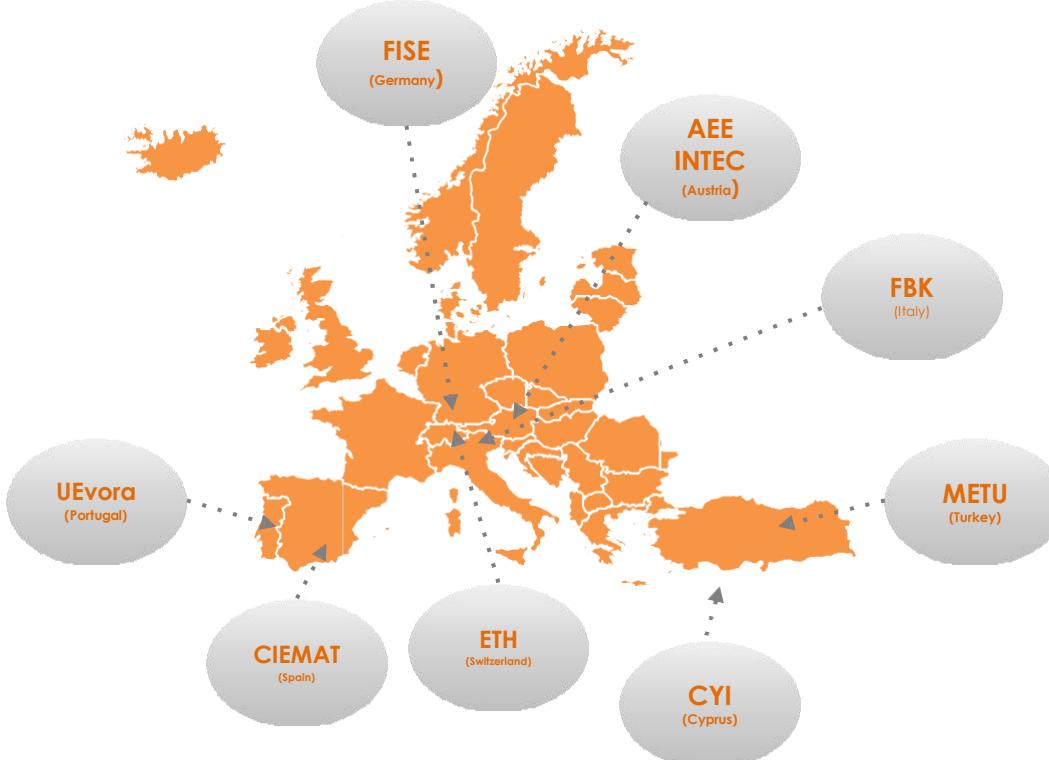
[CIEMAT-PSA]

alfonso.vidal@ciemat.es

Spain national workshop

Who are the main R&D organizations working on this?

WP4 Technology and applications to high temperature SHIP (400°C to 1500°C)



CONTACT

contact@inship.eu

Fraunhofer Institute for Solar
Energy Systems ISE
Heidenhofstraße 2, 79110
Freiburg
GERMANY

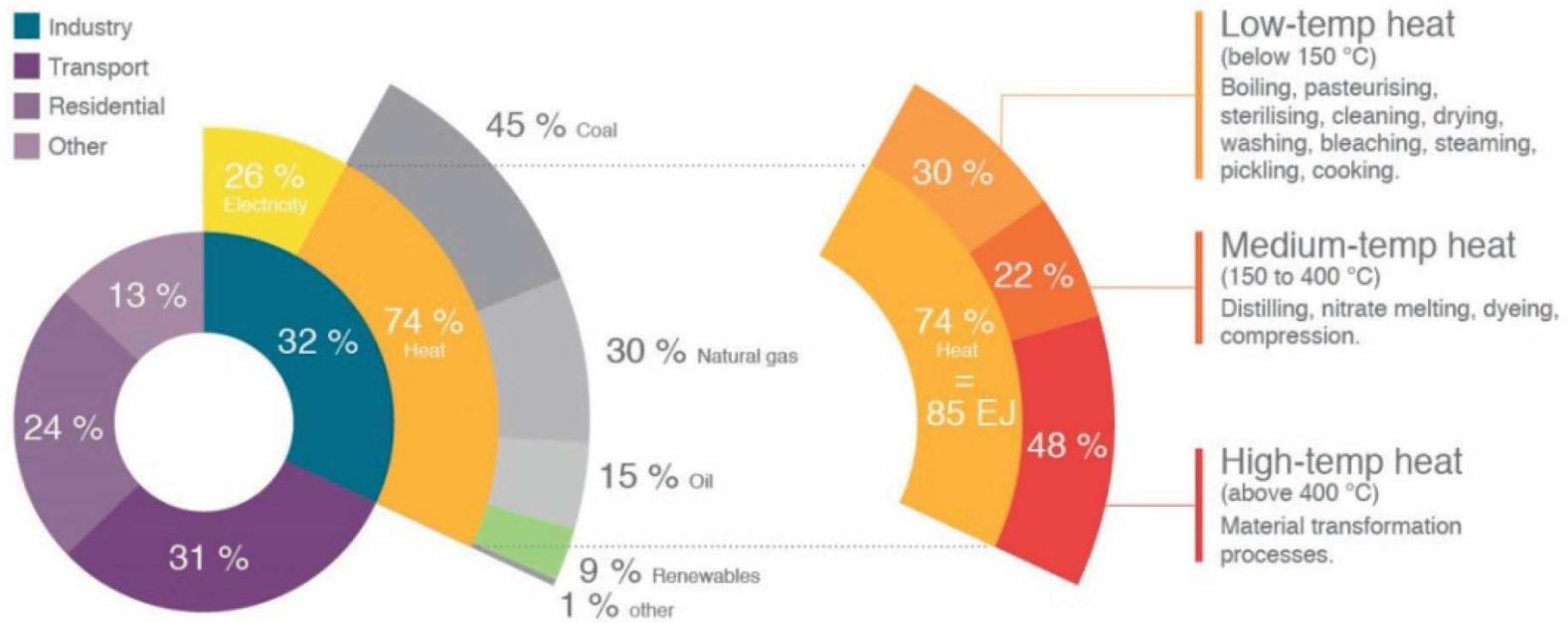
WP4 Technology and applications to high temperature SHIP (400°C to 1500°C)

High temperature 400°C-1500°C

El uso del calor de proceso solar ofrece ventajas potenciales únicas, específicamente:

- Evitar las emisiones de GEI, mediante la sustitución de combustibles fósiles por energía solar concentrada.
- Proporcionar una fuente limpia de calor de proceso a 1500 °C
- Almacenamiento térmico y/o hibridación para un funcionamiento continuo las 24 horas del día.

Technology and applications to high temperature SHIP



Technology and applications to high temperature SHIP

High temperature 400°C-1500°C

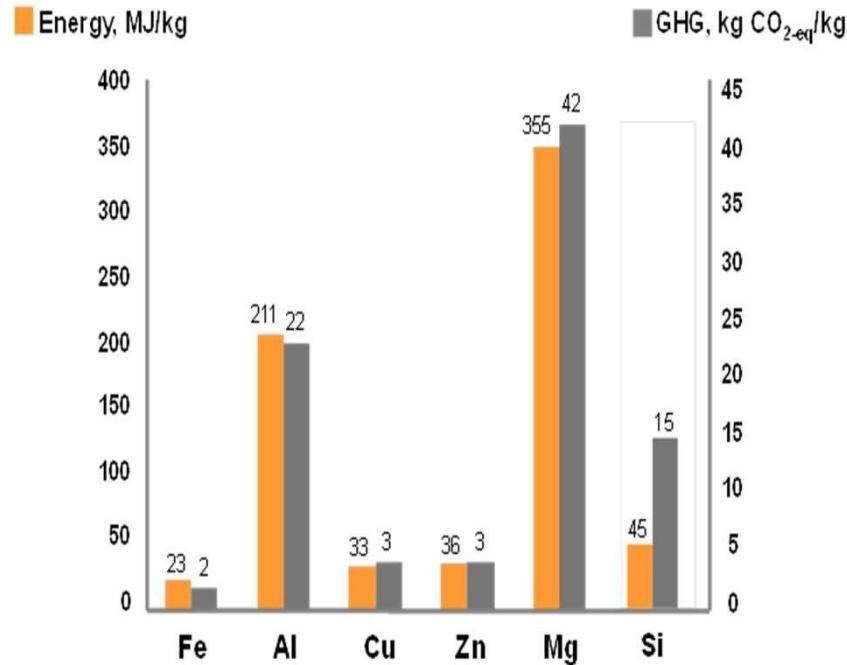
Task 4.1: Solar metals production for the metallurgical industry

Task 4.2: Solar lime production for the cement industry

Task 4.3: Solar fuel production for the transportation sector

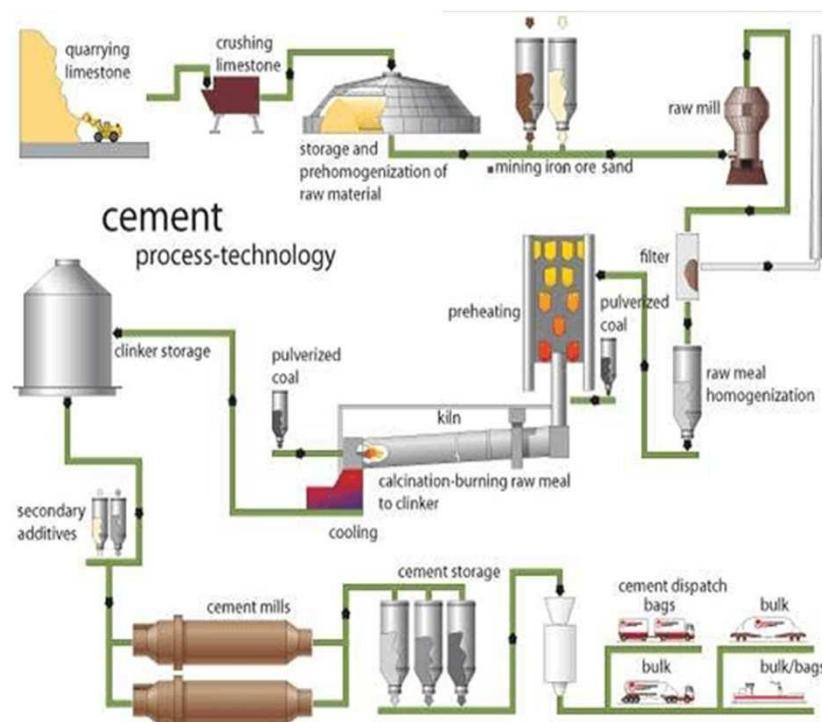
Task 4.4: High-concentration optics for high-temperature solar reactors

Solar metals production for the metallurgical industry



- La industria metalúrgica extractiva es la mayor consumidora de calor de proceso a altas temperaturas.
- El hierro y el acero es el segundo mayor consumidor de energía de la industria, con un **23% de la demanda total de energía final de la industria mundial**.
- El mayor **emisor industrial de CO₂, con el 28% del total de las emisiones directas de CO₂ del sector en 2014**,
- Este porcentaje representa el **7% del total de las emisiones de CO₂** relacionadas con la energía, y se prevé **que aumente hasta el 10% en 2050** en el marco de la 2DS (AIE, 2017a).

Solar lime production for the cement industry



- Tercer consumidor de energía del **sector industrial**, con un 7% del total del consumo final de energía industrial.
- **Segundo mayor emisor de CO₂ de la industria**, con un 27%.
- Según el World Business Council for Sustainable Development, la **industria cimentera es responsable del 5% de las emisiones antropogénicas globales de CO₂**, de las cuales el 50% se deriva del proceso químico y el 40% de la quema de combustible.
- **Previsión de que esta cuota esta cuota se duplique en 2050** bajo el 2DS, situando al subsector del cemento en el primer lugar.

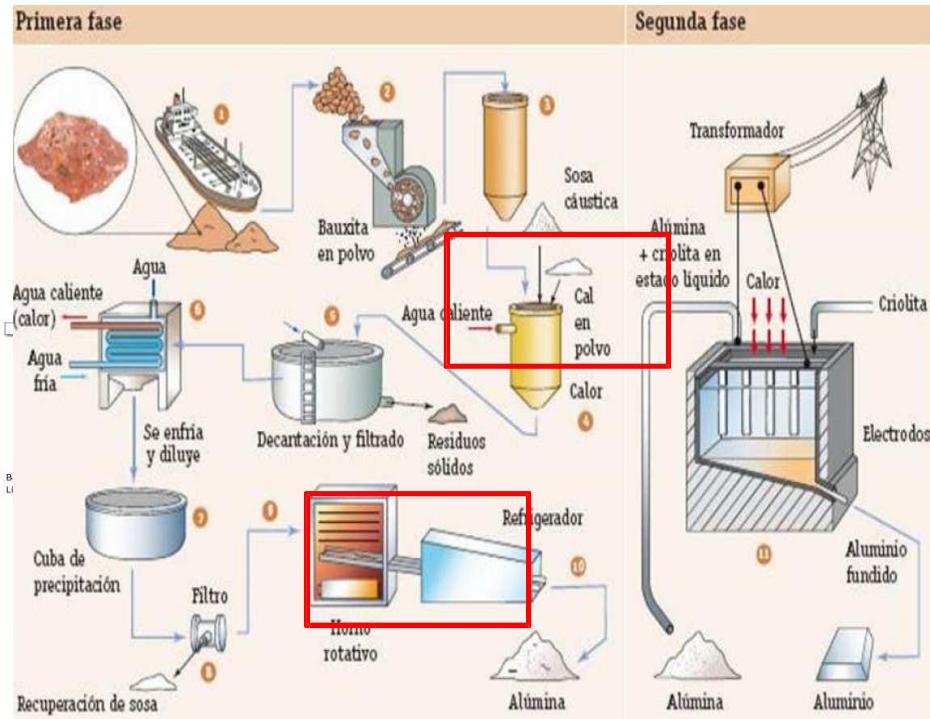


WP4 Technology and applications to high temperature SHIP (400°C to 1500°C)

OBJETIVOS WP4

- **Análisis energético de procesos endotérmicos** de alta temperatura en la industria de procesamiento de minerales y metalúrgica extractiva
- Definición de los requisitos del proceso y del sistema óptico;
- **Evaluación de conceptos y diseños de reactores solares químicos;**
- Integración de almacenamiento de energía térmica y/o hibridación para operación continua 24/7
- Diseño conceptual de la implementación a gran escala, análisis económico y potencial de mitigación de CO₂.

Solar metals production for the metallurgical industry



CHALLENGE

Minimize carbon footprint in energy- & carbon-intensive industries

DEVELOPMENT LINES

Accomplished: Mass and energy balances for the metal industries

Ongoing: Possible paths for solar energy use hybridization and integration with thermal energy storage investigating **solar hybridization and heat recovery options** design improvements via modeling & optimisation

Planned: large scale implementation, economics and CO₂ mitigation potential

Research institute: METU

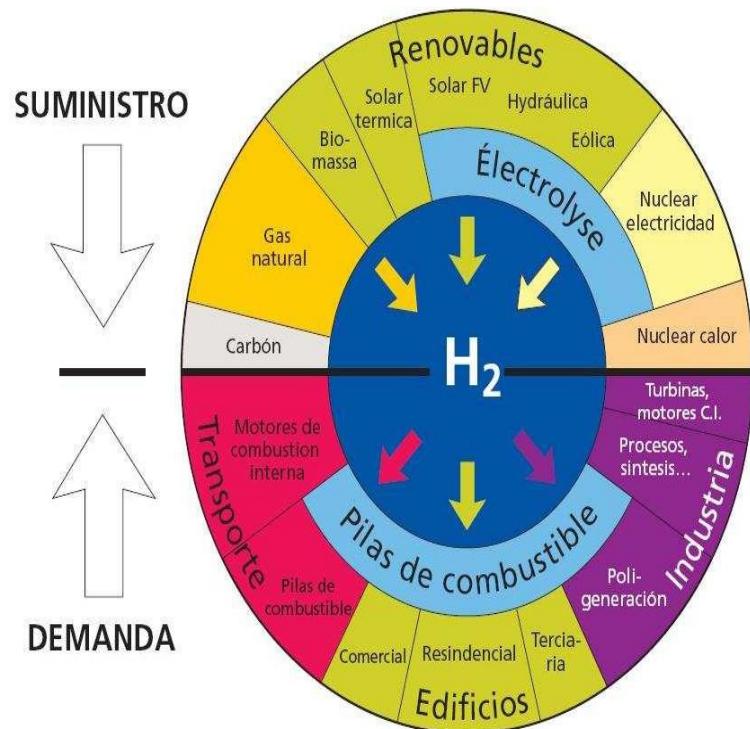
Technology: Solar hybridization of Zn, Al, Mg, Cu and Sn production

Industry sectors: fuels, metals, cement, glass, waste management

EXPECTED BENEFITS

- ✓ Developers: emerging tech, first mover advantage
- ✓ End users: : CO₂-neutral heat source for sustainable production processes

Solar fuel production for the transportation sector

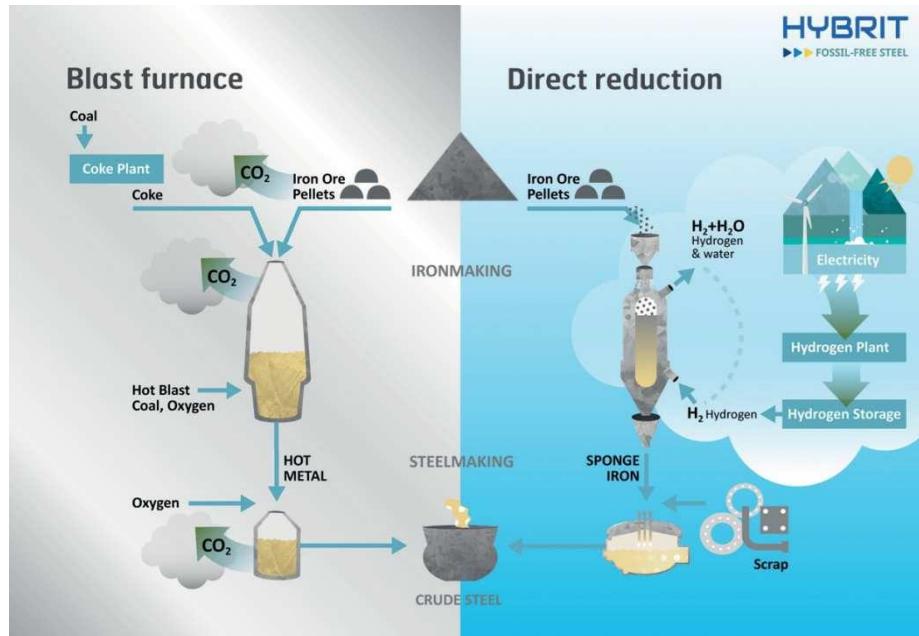


DEVELOPMENT LINES

- Actualmente, más del 95% del hidrógeno, una producción global de alrededor de 60 Mt/año,
- Generados a partir de combustibles fósiles: De gas natural a través del reformado de metano a vapor (SMR), del craqueo de productos petrolíferos en refinerías y de la gasificación de carbón, principalmente en China. El resto por electrólisis, generalmente como subproducto de la producción de cloro.
- La mayor parte del hidrógeno se destina a la fabricación de amoníaco, principalmente para la producción de fertilizantes, y a las refinerías.

Research institute: ETH Zurich, Switzerland

Solar metals production for the metallurgical industry



DEVELOPMENT LINES

- La industria siderúrgica es una de las más altas emisiones de dióxido de carbono de las industrias emisoras, que el **10% de las emisiones de CO₂ de Suecia**.
- Suecia ha establecido un **objetivo nacional de alcanzar un nivel cero de emisiones netas de dióxido de carbono para el año 2045**, definiendo el futuro para la industria siderúrgica del país.
- Aunque el actual sistema de producción de LKAB-SSAB es uno de los más eficientes del mundo (6 millones de toneladas de dióxido de carbono al año).



Private Company: HYBRIT

Technology: Fossil-free steel

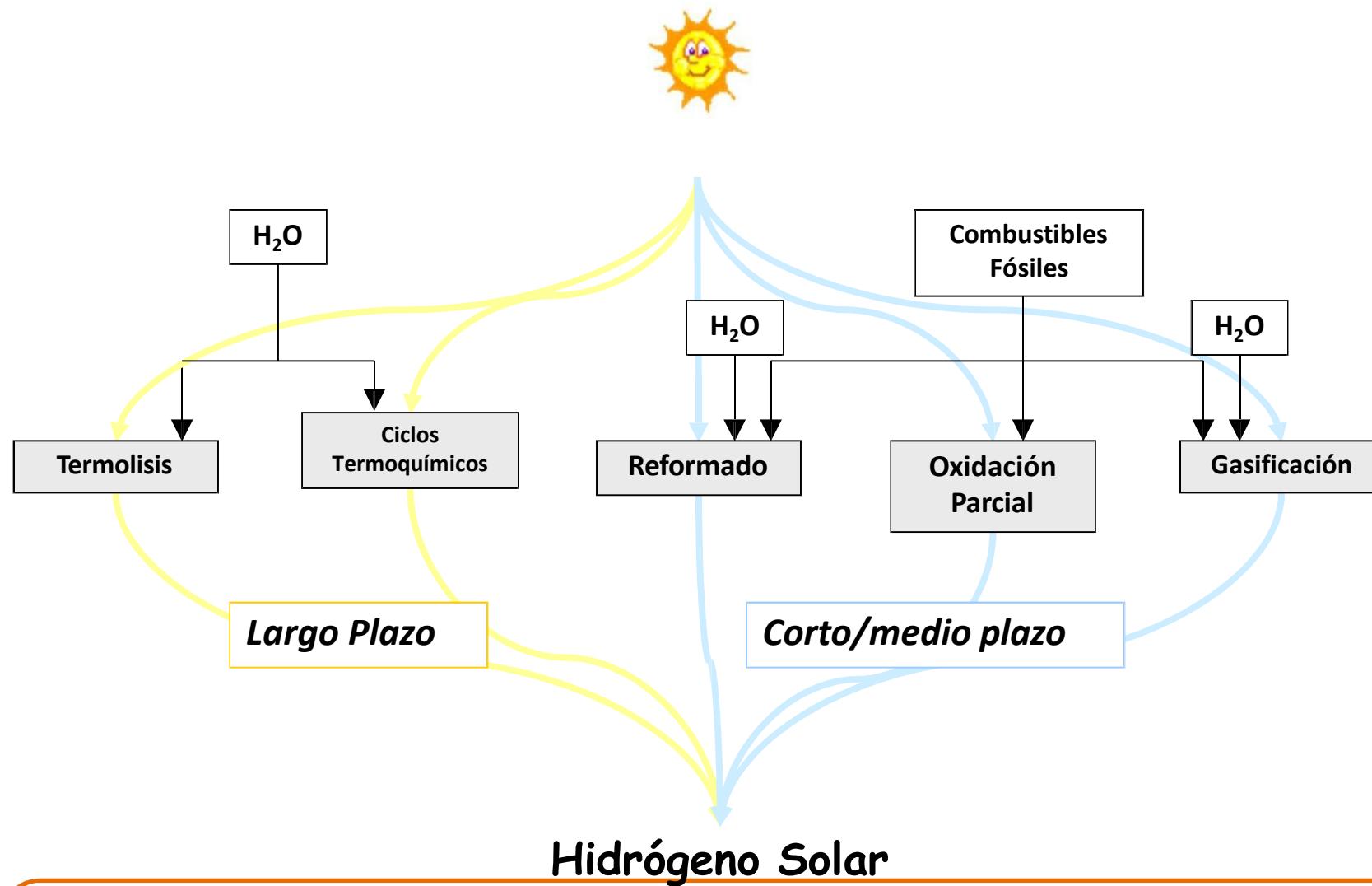
Industry sectors: fuels, metals, cement, glass, waste management



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Solar Process Heat / High Temperature 400°-1500°C

Producción de Hidrógeno solar por vía termoquímica

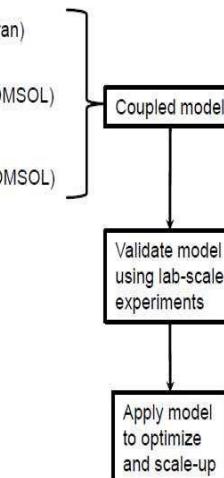
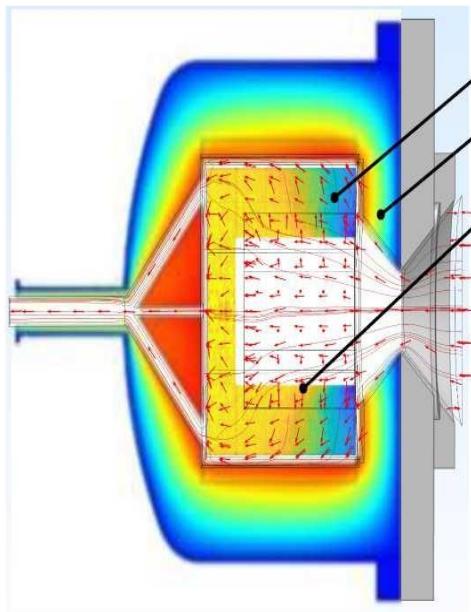


Evaluation of solar chemical reactor concepts and designs

High temperature 400°C-1500°C

- Solar-heated air as a source of clean process heat at temperatures above 1000 °C
- Solar reactors for mineral calcination
- Thermal performance of a solar receiver with solar transients

Solar-heated air as a source of clean process heat at temperatures above 1000 °C



CHALLENGE

Minimize carbon footprint in energy- & carbon-intensive industries

DEVELOPMENT LINES

Accomplished: lab-scale prototype with >50% efficiency at above 1000 °C

Ongoing: design improvements via modeling & optimisation

Planned: Integration with heat storage for 24/7 operation

Planned: scale-up & modular systems

EXPECTED BENEFITS

- ✓ Developers: emerging tech, first mover advantage
- ✓ End users: CO₂-neutral heat source for sustainable production processes

Research institute: ETH Zurich, Switzerland

Technology: Ceramic air receiver

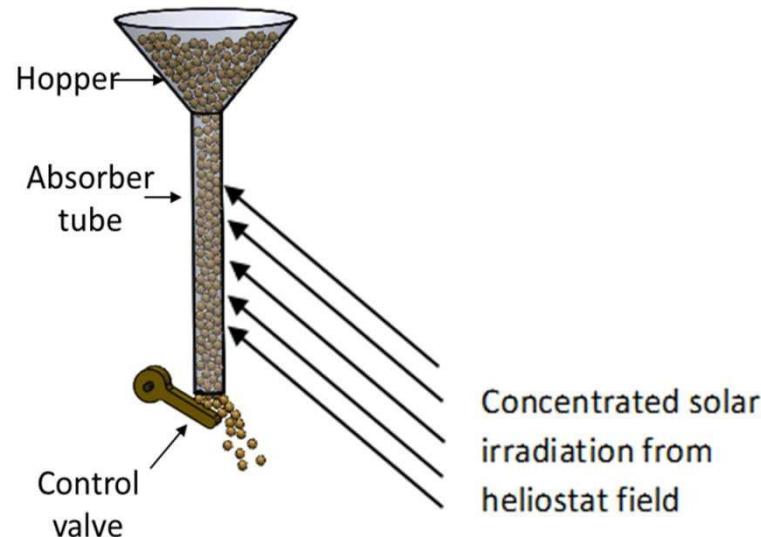
Industry sectors: fuels, metals, cement, glass, waste management



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Solar Process Heat / High Temperature 400°-1500°C

Concentrated solar heating of particles to high-temperatures



Solar-heated particles in industrial processes to temperatures around 1000 °C

Research institute: METU-GUNAM

Technology: Dense Granular Flow Receiver

Industry sectors: metallurgy, cement production

CHALLENGE

Reduction of carbon foot-print of cement industry and metallurgy; integration to existing plants



DEVELOPMENT LINES

Accomplished: detailed multi mode heat transfer particle based model

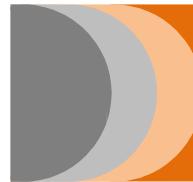
Ongoing: experimental set-up to test the dense granular flow receiver with solar simulator and validation of the model

Planned: Scaled-up prototype proof with simulations using the model



EXPECTED BENEFITS

- ✓ Developers: use of developed model for scaled-up receiver development
- ✓ End users: Low cost heating of particles without fossil fuel use



SOLPART H2020 Project Solar reactor for mineral calcination



Solar reactors for mineral calcination

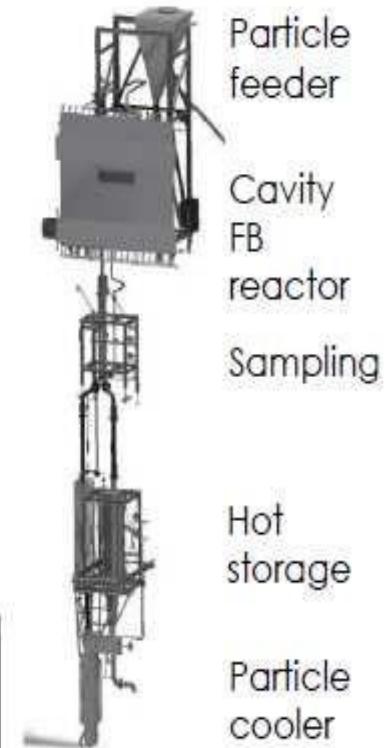
Pilot scale reactor tested at the CNRS 1 MW solar furnace



Research institute: CNRS

Technology: Solar Particle receiver

Industry sectors: fuels, cement, glass, waste management



Particle
feeder

Cavity
FB
reactor

Sampling

Hot
storage

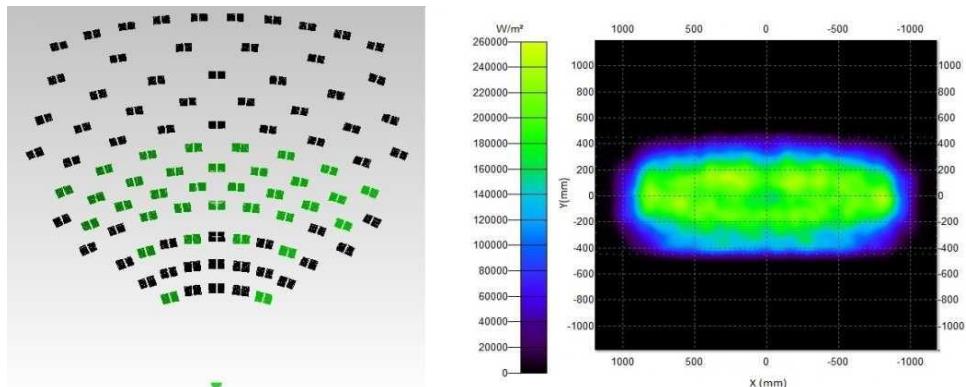
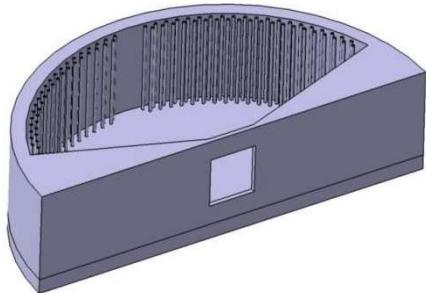
Particle
cooler



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Solar Process Heat / High Temperature 400°-1500°C

Thermal performance of a solar receiver with solar transients



Research institute: CIEMAT-PSA, Spain

Technology: Multi-tubular receiver

Industry sectors: fuels, H₂ production

CHALLENGE



Operation of a solar reactor with solar transients; Uniform flux inside the cavity

DEVELOPMENT LINES



Accomplished: First tests were performed. Temperatures near 1000°C can be reached

Ongoing: Ray tracing simulations to assess which heliostats supply the required power with the optimal flux distribution

Planned: Thermal and transient tests to verify results obtained in simulations

EXPECTED BENEFITS



- ✓ **Developers:** emerging technology
- ✓ **End users:** H₂ production from renewable energy and CO₂-neutral process

Conceptual design of efficient and scalable
high-concentration solar optics.

High temperature 400°C-1500°C

- Solar dish systems with spherical mirrors
- Solar Dish and Solar Tower Systems with non-imaging optics
- Solar tower systems: Computer tools
- Concentrator system providing a vertical beam

Solar dish systems for process heat at high-temperatures



Spherical and non-imaging optics to provide concentration ratios > 1000 suns.

Research institute: FBK, Trento, Italy

Technology: Solar dish systems with spherical and parabolic mirrors

Industry sectors: fuels, metals, cement, glass, waste management

CHALLENGE



High concentration ratio to provide heat at high temperature that can be used to activate high-temperature processes

DEVELOPMENT LINES



Accomplished: Spherical -Parabolic solar dish , temperature reached > 1350 °C

Ongoing: Characterization of solar flux

Planned: Study of the better option for tracking respect using SPA (solar algorithm position) or sun sensor for the estimation of sun position

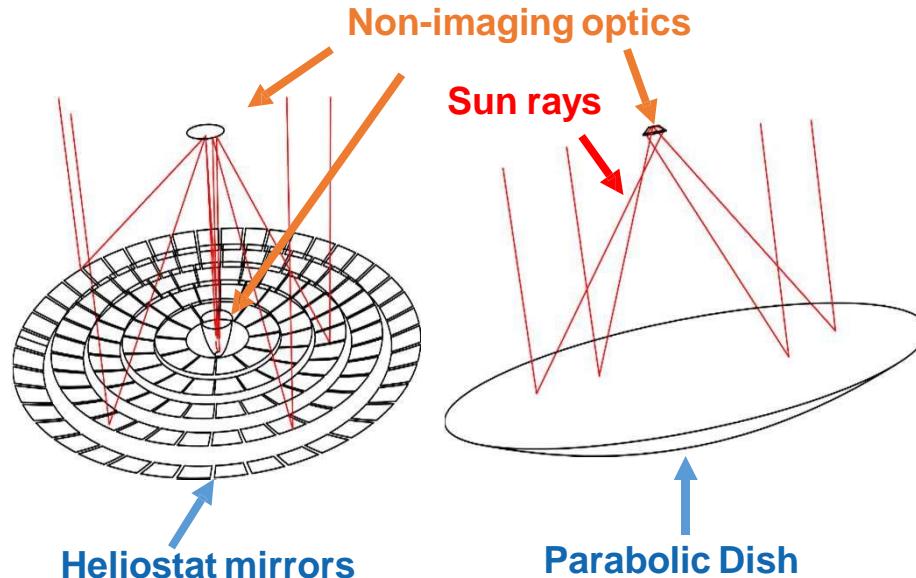
Planned: evaluation of the possibility to install on FBK's facility the volumetric receiver developed

EXPECTED BENEFITS



- ✓ Developers: advanced flexible system to explore high-temperature processes
- ✓ End users: high-temperature heat source for sustainable production processes

Non-imaging optics for solar tower and parabolic dish concentrators



Solar tower/Parabolic Dish systems: non-imaging optics to provide concentration ratios > 1000 suns

Research institute: University of Évora, Portugal

Technology: Concentrated Solar Power systems

Industry sectors: fuels, metals, cement, glass, waste management

CHALLENGE

Increase the concentration factor of current solar tower and parabolic dish concentrator to operate at higher temperatures



DEVELOPMENT LINES

Accomplished: First simulation tests using non-imaging concentrators

Ongoing: Design of practical solutions for solar tower system with beam-down and parabolic dish systems

Planned: Full optical and thermal performance analysis

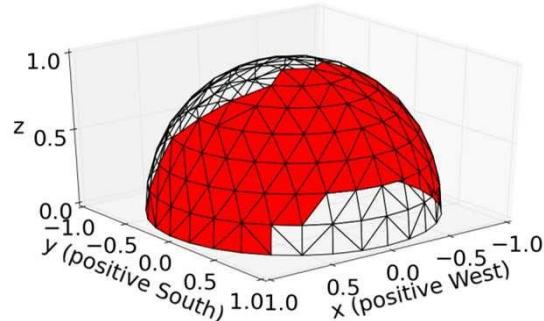
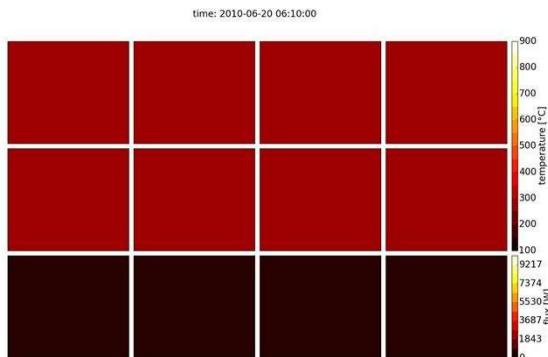


EXPECTED BENEFITS



- ✓ Boost in concentration: Concentration factors close or even above 2000 suns are possible accommodating 2-3 sun widths (optical tolerance)
- ✓ Compactness: Tower heights < 50m

Transient Simulation of High-Concentration Beam-Down Optics



Accurate assessment of high-concentration optical systems with transient simulation tools

Research institute: Fraunhofer ISE, Germany

Technology: Simulation tools

Industry sectors: CSP

CHALLENGE

Solar technologies require transient simulation and annual yield assessment due to fluctuation of efficiencies and DNI



DEVELOPMENT LINES

Accomplished: Sky discretization and flux level interpolation method for fast and accurate annual assessment

Planned: Implementation of beam-down model in the F-ISE software Raytrace3D

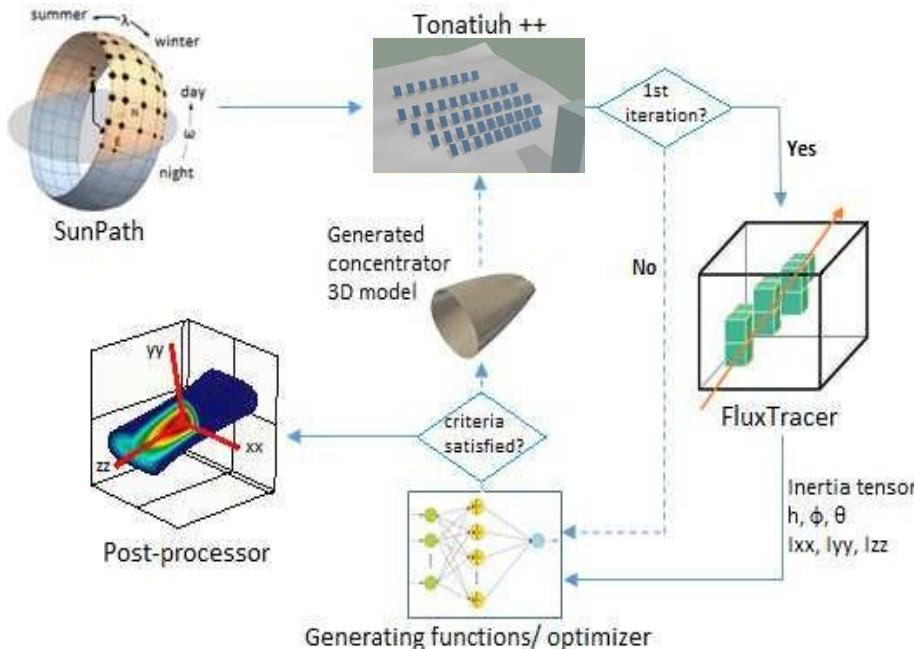
Planned: Annual optical yield assessment of beam-down system



EXPECTED BENEFITS

- ✓ Developers: Evaluation and comparison of competing technologies accelerated by several orders of magnitude

Open Source Ecosystem for Automatizing the Design of High Concentration Optics



Research institute: The Cyprus Institute, Cyprus

Technology: Open Source Software optimized for use in High Performance Computing (HPC) systems

Industry sectors: fuels, metals, cement, glass, waste management, electricity production

CHALLENGE

Develop an ecosystem of advanced open-source tools to assist in the design of solar concentrators

DEVELOPMENT LINES

SunPath sun position sampling to minimize the computational effort needed to evaluate annual system performance accurately

Tonatiuh++ HPC-optimized Monte Carlo ray tracer for the modelling, analysis, design and optimization of almost any type of solar concentrating system.

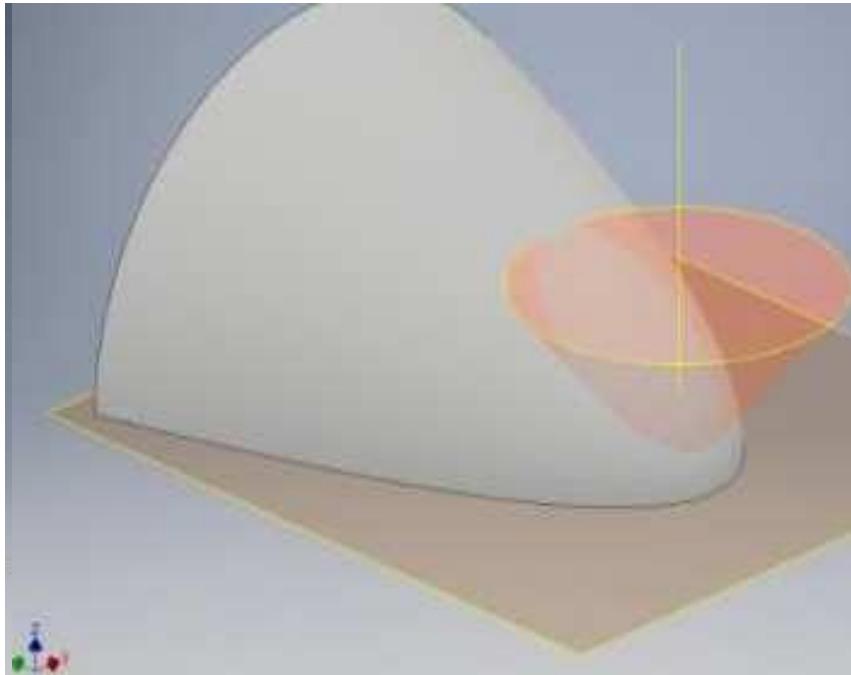
FluxTracer Monte Carlo Ray Tracing post-processor for advance analysis and exploration of ray tracing results

SolarWolf Specialized AI-enhanced and HPC-optimized Scientific Workflow System for the automated optimization of solar concentrators

EXPECTED BENEFITS

- ✓ Capability to automatize the exploration of the optimization space, undertake ambitious optimization problems, and achieve better designs.

Concentrator system providing a vertical beam for gravity-dependent applications



Research institute: CIEMAT-PSA, Spain

Technology: Parabolic concentrator system

Industry sectors: fuels, metals, chemicals, fluidized beds.

CHALLENGE

Provide a vertical beam of radiation to a chemical reactor without need to cool the reflector.

DEVELOPMENT LINES

Accomplished: design of concentrator concept from the intersection of two entities: a paraboloid and a cone called "mussel".

Ongoing: design of a truncated concentrator to improve the focal properties such as size and shape.

Planned: Investigate options for extreme lightweight and foldable design for mobile and low-cost applications.

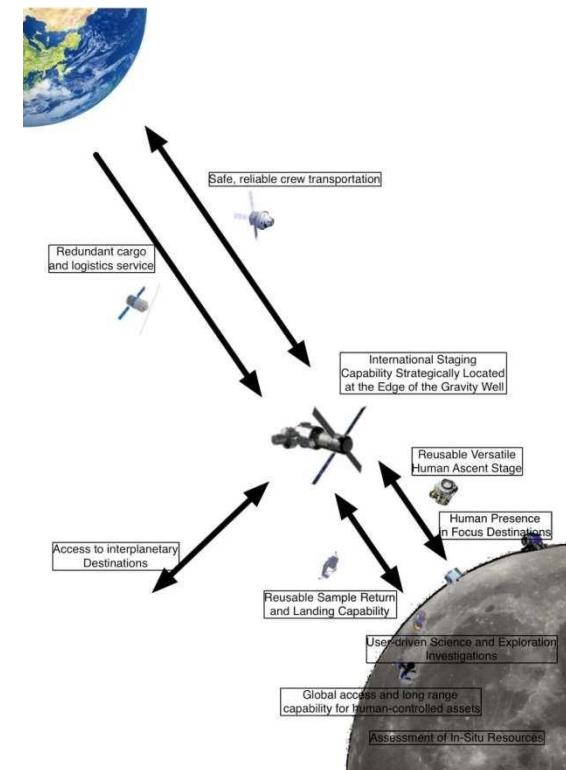
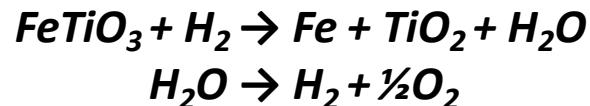
Planned: Build a small prototype as a demonstrator model.

EXPECTED BENEFITS

- ✓ Developers: emerging tech, avoiding the need of a third diagonal mirror, requiring active cooling.

Concentrator system providing a vertical beam for gravity-dependent applications

- **ALCHEMIST: Lunar ISRU Demonstration Mission Definition Study - Segment 1: ISRU-Payload**
- **Period:** February 2018 – November 2019
- **Funding:** European Space Agency (ESA)



SWOT analysis for High T°C SHIP technology



STRENGTHS

- Utilizar todo el espectro de radiación solar incidente.
- Fácilmente hibridable con las vías de combustión existentes y otras tecnologías térmicas renovables
- De calor a calor: sin conversión intermedia de energía



WEAKNESSES

- Requiere energía solar directa
- Sensibilización de los aspectos sociales y medioambientales de los beneficios de la CSP



OPPORTUNITIES

- Potenciar la investigación sobre la tecnología de almacenamiento de alta temperatura y de almacenamiento termoquímico
- Aumentar la concienciación mundial sobre el cambio climático



THREATS

- Posición dominante de los combustibles fósiles
- Discontinuidad de políticas energéticas



Muchas gracias

<https://www.inship.eu/index.php>