Final publishable summary report

1.- Executive Summary.

The overall objective of the proposed project is to develop New Ecological Furnaces Designs addressing the needs of the Energy Intensive Industries such as foundries, glass, ceramics and cement. These designs have been developed with the double aim to increase the furnace's energy efficiency and cost efficiency.

The EDEFU project has proposed an integrated approach to overall optimisation of the furnace operating conditions and process management along with highly innovative breakthrough in heating technologies and insulation designs, significantly contributing to a reduction in the energy waste and the environmental footprint while increasing the competitiveness of such designed systems.

The EDEFU goals are:

- Develop integrated hybrid heating systems.
- 20% energy efficiency increase.
- Set up new insulation designs.
- Develop new energy and waste recovery systems.
- Validate developed concepts on industrial level.
- Reduction of emissions of CO_2 and other greenhouse gases higher than 20%.
- Feedstock savings higher than 20%.
- Operating cost reduction of at least 10% and productivity increase of at least 10%.

As described in present Final Report, all main objectives of the project have been achieved.

2.- Description of main S&T results/foregrounds.

Overview of the progress of the work in line with the structure of Annex I to the Grant Agreement

New Heating Systems.

- Successful development of innovative heating technologies for different sectors.
- Successful hybridizing of heating technologies. Target of EDEFU.

New refractory materials.

- Development of nano-reinforced refractories and of CNT reinforced refractories.
- Conclusions on laser sintering of new refractories.

Recovery Systems.

- Developments in design of new recovery systems integration.
- Developments in new furnace cleaning system based on the laser technology and the use of new storage temperature materials with Phase Change Materials.

Furnace Model and Design.

- Developing and simulating conditions of the melting and holding operations processes.
- Thermal simulation of the holding operation for the aluminium industry.
- Biomass heating systems in cement kilns.

Demonstrator and Prototypes.

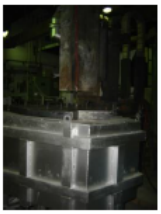
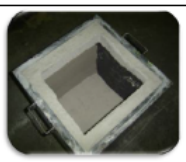
- Construction and set-up of aluminium industrial furnace demonstrator.
- Construction and set-up of glass and ceramic furnace prototypes.
- Theoretical and techno-economic assessment of cement furnace prototype based on biomass gasification using plasma heating.

Furnace Validations (WP8)

- Industrial and scientific validation of the demonstrators and prototypes.

According to the Work Plan accepted in the Dow, following table summarizes the evolution carried out in different technologies in EDEFU project.

SECTOR		LAB-SCALE TESTS		SMALL-SCALE PROTOTYPES	ACHIEVEMENTS OF EDEFU ACCORDING TO DOW (March'14)
GLASS INDUSTRY	WP 3 WP 4 WP 5		WP 6 WP 7		• Energy Efficiency: < 1 kWh/Kg (savings of 25-28% at melting). • Emissions: Reduction (but energy demand increased). • Economics: Only interesting for specific applications. • High commercial potential expresed by end users and furnace manufacturers (production of short series for colour tests, ...e.g.).
START AT TRL 2	EDEFU EVOLUTION → TRL 5 Sairem-Vidrala-Tecnalia				
CERAMIC INDUSTRY	WP 3 WP 4 WP 5		WP 6 WP 7		• Energy Efficiency: 25-35% (up to 50%). • Emissions: Reduced due to minimize energy consumption. • Economics: Interesting ROI for end users (< 4 years). • High commercial potential expresed by end users (possible reduction of cycle time per batch).
START AT TRL 2	EDEFU EVOLUTION → TRL 6 C-Tech/Jiesia				
CEMENT INDUSTRY	WP 3 WP 4 WP 5		WP 6 WP 7		• Energy Efficiency: More efficient process but higher electricity demand. • Emissions: Reduced by 10%. • Economics: Unapproachable at current European situation. • High commercial potential expresed by end users as low cost fuels are used minimizing GHG emissions.
START AT TRL 2	EDEFU EVOLUTION → TRL 5 VDZ-Cemex-Tecnalia				

SECTOR		LAB-SCALE TESTS		SMALL-SCALE PROTOTYPES		INDUSTRIAL DEMONSTRATOR REAL-SCALE PROTOTYPE	ACHIEVEMENTS OF EDEFU ACCORDING TO DOW
ALUMINIUM INDUSTRY	WP 3 WP 4 WP 5	 ***PLASMA TECH.***	WP 6 WP 7		CONFIRMATION OF RESULTS (WP8)		**MELTING FURNACE** VALIDATION AT TECNALIA (MARCH-APRIL 2014) VALIDATION AT FAG (APRIL-MAY 2014) • Energy Efficiency: Yes. 27% energy savings compared to conventional processes. • Emissions: Yes. 27% of reduction of CO_2 emissions related to conventional processes.
		NEW REFRACTORY WITH IMPROVED INSULATION PROP. 		 Semi industrial validation of the new refractory in designed special holding furnace (TECNALIA).		 New refractory in Melting furnace.	**NANO REINFORCED DENSE ALUMINA REFRACTORY CASTABLE / IMPROVED INSULATION PROP.** VALIDATION AT TECNALIA / FAG. • Target-Thermal conductivity <1W/mK: Achieved. -Impact on furnace's energy savings. -Good Corrosion resistance.
		HRR TECH. 					**HOLDING FURNACE** VALIDATION AT IFAM (MARCH-APRIL 2014) VALIDATION AT FAG (APRIL-MAY 2014) Energy Efficiency: >20% Emissions: Reduction >20%
START AT TRL 2-3	EDEFU EVOLUTION → TRL 7 FAG						

Main Conclusions related to Heating Systems.

After full techno-economic assessment of the involved technologies, their high potential applicability at aluminium, glass, ceramic and cement sector's furnaces has been demonstrated. There are influencing benefits related to CO_2 trading system and new production opportunities and improvements for developed processes and furnaces.

Developed heating systems and hybridization of these technologies at furnace demonstrator and prototypes fulfil the objectives of the EDEFU project. In the same way the aim of the project is the substitution of fossil fuels increasing the application of energy efficiency heating technologies and get a reduction of fossil CO_2 emissions. In this way, all heating technologies developed in EDEFU project allow the use of renewable energy sources for selected energy intensive industry sectors.

Main Conclusions related to Insulating Systems and Refractory Developments.

A new refractory castable has been developed that fulfills the WP4 target (Thermal conductivity<1W/mK) and that can be applied in Aluminium furnaces. This refractory has been validated in the final melting prototype (TRL7) confirming its improved insulation properties and heat storage capacity comparing to a commercial grade. The economic viability of the material has also been validated since the extracost of adding nano particles keeps the price of the material still in the market price range. This product will be industrially manufactured by KELSEN to enter the market.

Main Conclusions and Highlights of Most Significant Results related to Recovery Systems.

The analysis covered systems producing heat in the form of saturated steam for processes, or hot water, and systems producing electricity using microturbines (small steam turbines). It also considered PCM systems, mainly heat storage systems for producing continuous saturated steam from a highly variable flue gas flow.

Main Conclusions and Highlights of Most Significant Results Related to Furnace Model Design.

The summary of the results of the model design tasks carried out at EDEFU are described below:

- Developing and simulating conditions of the melting and holding operations processes.
- Thermal simulation of the holding operation for the aluminium industry.
- Biomass heating systems in cement kilns.
- Design and manufacturing prototype for glass industry.
- Design and manufacturing MW-radiant test prototype furnace.
- Design and manufacturing initial prototype of holding furnace for aluminium industry.
- Results analysis between aluminium holding prototype and simulations.
- Design of the melting/holding furnace for aluminium industry.

Main Conclusions and Highlights of Most Significant Results for Prototypes Construction and Validation.

The main output of the project is **a *real scale demonstrator furnace for Aluminium*.** In addition, a small scale glass, ceramic and cement furnace prototypes have been set-up with the aim to be as representative as possible of the thermo-physical phenomena occurring in a real scale one.

So the prototypes validation of developed furnace construction methodology is based on:

- An Aluminum melting and holding demonstrator manufactured by TECNALIA, CERAPRO and KROWN. Two separate units in industrial scale. One unit for melting Aluminum with innovative HPTP (High Power Thermal Plasma) plasma technology and one unit with and revolutionary heating system for warm holding operation. Both units have been installed and tested in FAG aluminium foundry for industrial validation.

- A glass melting prototype using innovative microwave technology for small scale glass melting is built and tested at SAIREM with VIDRALA support.

- A commercial development furnace (CARBOLITE) using innovative microwave technology to support the firing process and shorten the cycle time by shorting the down cooling phase has been tested at C-TECH with JIESIA support.

- Techno-economic feasibility assessment of plasma heating biomass gasification for cement production based on small scale plasma torch prototype site at TECNALIA with CEMEX and VDZ support.

3.- Address of the project public website.

Following address of the EDEFU website were more information about the project and the partners contact details can be looked up:

- www.edefu.eu