SET-P Plan Implementation

The Steering Group of the SET-Plan in its last meeting on October 28th, 2010 agreed to speed-up the execution of activities of the Implementation Plans (IPs) of the European Industrial Initiatives (EIIs). It was decided to collectively identify the possibilities for launching joint actions between Member States and/or Member States and the European Commission.

The mapping exercise carried out through this questionnaire builds upon this decision of the Steering Group. It aims to identify topics for leveraging best ongoing efforts with complementary joint actions, as prioritized by the Implementation Plans. In this phase the mapping will focus on projects and activities with a total budget higher than 1 M€.

We trust that you also consider the success of this exercise important for the immediate implementation of the SET-Plan.

MAPPING OF PROJECTS, ACTIVITIES, RESOURCES AND INVESTMENTS

To which EII(s) is your project, activity, resource or investment relevant? (multiple choices are possible)

<table>
<thead>
<tr>
<th>WIND</th>
<th>SOLAR</th>
<th>GRIDS</th>
<th>CCS</th>
<th>NUCLEAR</th>
<th>BIOENERGY</th>
</tr>
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A. PROJECTS AND ACTIVITIES

GENERAL INFORMATION

Name of project: Development of High-Efficiency CFB Technology to Provide Flexible Air/Oxy Operation for a Power Plant with CCS

Acronym: FLEXI BURN CFB

Location: 0.1MW (VTT, Finland), 30MW (CIUDEN, Spain), 460MWe (PKE, Poland)
SHORT PROJECT DESCRIPTION

FLEXI BURN CFB project aims to develop and demonstrate a power plant concept based on the Circulating Fluidized Bed (CFB) technology combined with Carbon Capture and Storage (CCS). The plant will be based on the super critical once through (SC OTU) technology and oxygen-firing with carbon capture, hence, providing high efficiency, operational flexibility and potential for an almost 100% reduction in CO₂. The fuel flexibility of the CFB technology enables the utilization of indigenous fossil fuels with simultaneous co-firing of biomass. Thus, the technology provides potential for addressing the needs for climate change mitigation, security of supply and reduction of dependence on imported coals.

PROJECT GOALS & OBJECTIVES

Goals:
Indicate main qualitative goals

The goal is to develop a readiness for a commercial-scale demonstration project for a FLEXI BURN CFB power plant concept with CCS. The role of local fuels will be emphasised in order to decrease dependency.
on imported coals and improve power plant economics, especially with CCS operation. The FLEXI BURN CFB technology provides potential for addressing the needs for climate change mitigation, security of supply and reduction of dependence on imported coals.

Objectives:
Indicate quantitative objectives (similar to KPIs of the IPs of the EIIs). Also indicate intermediate milestones where applicable.

<table>
<thead>
<tr>
<th>Develop and demonstrate FLEXI BURN CFB concept step by step from 0.1MW up to 30MW scale. 0.1MW and 1MW steps have been completed and the next step is 30MW demonstration tests at CIUDEN TDP in the beginning of 2012. In addition to that validation tests at the world’s first and largest supercritical once through CFB (460 MWe Lagisza) are an essential element in the project to ensure the design tool’s validity and to emphasize scale-up of the FLEXI BURN concept.</th>
</tr>
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<tbody>
<tr>
<td>• Verify CFB combustion technology in air-oxy-firing mode for various indigenous and imported fuels, including biomass, in order to maintain and further develop the advantages of fluidized bed combustion technology: fuel flexibility, high efficiency and low emissions.</td>
</tr>
<tr>
<td>• Verify CFB performance on a large scale and high efficiency in order to emphasize scalability of the technology under air/oxygen operation.</td>
</tr>
<tr>
<td>• Demonstrate CFB performance in flexible oxy / air mode on the 30 MWth scale with CO₂ capture. Study limestone addition into the furnace under oxygen-firing conditions to control emissions (SO₂ and potentially chlorine) and to ease subsequent separation of CO₂.</td>
</tr>
<tr>
<td>• Develop the overall plant concept for reliable, safe and economical carbon capture with advanced circulating fluidized bed combustion (CFBC) technology that can operate under air- and oxygen-firing mode, enabling CO₂ separation and capture for geological storage.</td>
</tr>
<tr>
<td>• Create the readiness to start engineering of a commercial-scale demonstration of air/oxygen flexible CFB power plant with CCS that is applicable to various local</td>
</tr>
</tbody>
</table>
### PERFORMANCE OF THE PROJECT

| Assumed state-of-the-art: | CFB technology is now proven on the utility-scale. Plant sizes up to 300 MWe are in operation today. The net efficiency of those conventional subcritical designs is approximately 38 to 40%, depending on the fuel and condenser conditions. During recent years, supercritical once-through (SC-OTU) CFB technology has been developed, enabling the next stage in CFB development to proceed to medium-scale (<500 MWe) commercial projects such as Lagisza, with gross efficiencies near 45%. The Lagisza boiler (460 MWe) was started up in June 2009 in Poland and the boiler utilizes local low grade coals and is capable to co-fire biomass in the future. However, scaling up the technology further to ‘real’ utility scale (600-800 MWe) with a net efficiency of 45 to 50% is needed to fulfil the future requirements of utility operators. Some studies have already been undertaken to investigate the process of oxygen-firing, but mostly for pulverized fuel combustion. Experimental oxygen-firing CFB studies have been done by Alstom (USA), CANMET (Canada), Czestochowa University of Technology (Poland), Vienna University Of Technology (Austria) and VTT Technical Research Centre of Finland with Foster Wheeler Energia Oy. These investigations are mainly focused on the basic fundamentals related to combustion in an oxygen-firing atmosphere. |
| Achievements so far: | During the first half of the project a lot of experimental work has been carried out in order to support the development of FLEXI BURN CFB concept. Combustion tests in different scales and field measurements in a commercial scale power plant provide a base for development and validation of the design tools needed in the concept development. The basic design parameters for a FLEXI BURN CFB plant, from a technical and... |
The initial conceptual design of the Flexi-Burn CFB boiler and overall concept including ASU and CPU has been developed.

Difficulties and potential risks:
Indicate briefly problems encountered or to be encountered in the short term (e.g. overall legislative context, public acceptance, permitting, etc.)

Emission limits are expressed as milligrams per normal cubic meter (mg/Nm3) for power plants in Europe. Emission limits based on the concentrations and volumetric units are not applicable for the CCS processes. Emission limits in CCS applications should be expressed in energy basis. For example emissions limits could be expressed as milligrams per megajoule (mg/MJ) or milligrams per megawatt hour (mg/MWh).

FUNDING & BUDGET

<table>
<thead>
<tr>
<th>Funding programme:</th>
<th>FP7-ENERGY-2008-TREN-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funding public entity:</td>
<td>European Union</td>
</tr>
<tr>
<td>Total (public &amp; private) project budget (€):</td>
<td>11 026 943.80€</td>
</tr>
<tr>
<td>Public funding (€):</td>
<td>6 413 869€</td>
</tr>
<tr>
<td>Total effort (person-months)</td>
<td>967.1</td>
</tr>
</tbody>
</table>

DISSEMINATION OF PROJECT RESULTS

Publications, presentations in conferences and workshops, and other dissemination means:

2) 1st Project Workshop in Brussels 24th March 2011
(http://www.vtt.fi/sites/flexiburncfb/reportsandpublications.htm)


TOWARDS COMMERCIALISATION

Indicate (new) products and/or services expected from the project. Are new business models required for commercialisation of the project results?

Highlight expected commercialisation benefits, e.g. patents, spin-offs, new products, business partnerships

The main project result will be the overall plant concept for the reliable, safe and economical carbon capture with advanced circulating fluidized bed combustion (CFB) technology that can operate under air- and oxygen-firing mode, enabling CO₂ separation and capture for geological storage by

a) integrating a FLEXI BURN CFB boiler with an air separation unit (ASU) and CO₂ processing unit (CPU) in order to create an optimized overall power plant concept

b) verifying the feasibility and readiness for the utilization of the technology within different regions of the EU

Learnings will be incorporated into future plant designs and the technology available for full-scale demo plants and future generating plants bringing better overall efficiencies and economies to lower the cost of this clean-coal technology. The final goal for exploitation of the results obtained is the demonstration of the commercial scale FLEXI BURN CFB power plant concept. Utilities will apply the result in planning optimized energy infrastructure in different countries and local conditions.

SYNERGIES WITH THE IMPLEMENTATION PLANS OF THE EUROPEAN
INDUSTRIAL INITIATIVES – NETWORKING – KNOWLEDGE SHARING

Contribution to/Relevance with the IPs: To your opinion, to which activities of the IPs of the EIIIs is this project related to? Indicate contributions / complements.

Please note that reference here is made to the activities of the IPs as published in http://setis.ec.europa.eu/activities/implementation-plans

The project is directly related to CCS EII Implementation Plan 2010-2012. The project develops and demonstrates advanced circulating fluidized bed combustion (CFB) technology that can operate under air- and oxygen-firing mode, enabling CO₂ separation and capture for geological storage. The project creates a base for the Compostilla OXYCFB300 project, which is one in six EEPR projects awarded on 9 December 2009.

Potential synergies with other projects and activities: Can you identify any other project(s) in your country, another MS or at European level that could be synergetic with this project?

Projects related to oxyfuel combustion and CLC e.g. ECLAIR, INNOCUOUS, Oxy-coal UK, Vattenfall (30MW) Germany, Total Lacq France, Vattenfall (Janschwalde, 300MWe), Endesa OXYCFB300 Spain

Networking: Would you be willing to share results with the projects identified above?

Indicate willingness to networking and also potential conditions

Yes, especially oxygen production is the key area in which cooperation could be very effective. As indicated in the CCS EII, the one of the most important CCS R&D objectives related to oxyfuel combustion is the reduction of energy penalty for oxygen production. One potential option to achieve that is Chemical Looping Combustion (CLC) to replace Oxyfuel boiler. It is assumed that fluidized bed technology can be applied to CLC very well.

Knowledge sharing: Would the abovementioned Networking necessitate a formal knowledge sharing agreement? To your view would this be the preferred route?

Typically a formal knowledge sharing agreement is a compulsory element.

Future steps: Are there any follow-up activities considered after the completion of your project? Is there a need to scale up activities in this topic at European level?

There is need to further develop the oxyfuel combustion technology to reduce significantly the efficiency penalty caused by CCS. This will reduce significantly the break even price for the technology. This is in line with the detailed KPIs and target values related to net efficiency of coal fired power plants equipped with CCS.

B. RESOURCES AND INVESTMENTS

RESOURCES AND INVESTMENTS
Describe in short any RD&D infrastructures that your project relies on. Are these available or do they need to be developed?

1) VTT small scale pilot plants in Finland
2) CIUDEN TDP in Spain

These are the main infrastructures in the Europe related to development of oxyfuel CFB technology. The infrastructures must be further developed to support the development of the 2nd generation oxyfuel technology, which will significantly (~ 50%) increase the overall efficiency of oxyfuel CCS power plant.

If these are to be developed, what is the corresponding investment required? What is the allocated budget (€) for this investment in your project?

For the future projects 1-25 M€ is needed depending on the scale of the research and demonstration activities.

OTHER INFORMATION

| Date: when the questionnaire was completed | 26.4.2011 |
| Information provider: | Antti Tourunen |
| Give the name and affiliation of the contact person for the questionnaire. If you are the project coordinator, check the box | |

Please send the completed form to set-plan-secretariat@ec.europa.eu preferably by MAY 15.

Thank you for your cooperation!