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Draft Strategy and Action Plan for the Involvement and Contribution of Stakeholders to National and Multi-National Programmes for the Promotion of Zero Emission Fossil Energy Power Plant

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FENCO-ERA Report	

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Executive Summary

The purpose of this report is to develop a draft strategy and action plan for enhancing cooperation between Member State programmes and for engaging the broad range of stakeholders needed to deliver ZEP technologies. It has done this by:

a. Defining the areas where action is needed to deploy fossil ZEP technologies and types of activity needed (eg. R&D, pilot plant, full-scale demonstration) in each of these action areas.
b. Defining the time line required for taking forward these activities with the aim of having ZEPs available for general deployment from about 2020.
c. Identifying the combination of action areas and activities where transnational cooperation through joint programmes will be most beneficial and cost effective.

Key conclusions to be taken from this interim stage of the work are:

- Joint programmes between Member States on ZEP technologies should focus on R&D and possibly pilot scale demonstration of key processes and devices.
- Full-scale demonstrations of ZEPs including CCS require substantial funding that exceeds the budgets that Member States have for innovation with fossil fuel technologies and will require separate arrangements. This puts them out of the scope of this FENCO initiative although joint programmes might be based on one or more demonstration. For example R&D on safety or geological monitoring of a CO_2 store.
- The most promising areas for joint programmes involving R&D are:
  - Advanced fossil fuel generation
  - CO_2 capture
  - CO_2 use and storage
  - Infrastructure, environment and safety
  - Communication and public acceptance
- The most promising areas for joint programmes involving pilot scale trials are:
  - CO_2 capture
  - CO_2 use and storage
- The most promising areas for joint programmes involving long term R&D are:
  - Advanced fossil fuel generation
  - CO_2 capture
  - CO_2 use and storage

- For joint programmes to be cost effective they need to have an overall value of at least €1M and preferable €10M.
- Less formal methods are needed to facilitate cooperation when the level of activity is less than €1M. An important example is work on "Market regulation and policy", which is important to the implementation of ZEPs but is likely to involve study programmes that are less than €1M at any one time.

It is proposed to take this work forward through two consultations firstly with National Funding Agencies and later with a broader representation of stakeholder groups.

Contents

1. Introduction

Zero emission fossil energy technologies are a group of devices and processes that can considerably reduce (>90%) or even totally eliminate the emissions associated with fossil fuel combustion. Foremost amongst these is carbon capture and storage (CCS), in which the carbon dioxide (CO_2) produced during fossil fuel combustion is first separated and then committed to geological storage. CCS is currently the subject of considerable worldwide interest because it opens up the option of continuing to use fossil fuels while considerably reducing energy related CO_2 emissions, one of the main causes of the increase in atmospheric green house gas concentrations.

Zero emission fossil technologies are most suited for application to large combustion or process plant that offer appreciable economies of scale. This is particularly true for CCS, which in addition to the CO_2 capture process, requires a transport infrastructure to move the CO_2 to suitable geological stores. Consequently most attention has focused on the development of Zero Emission Fossil Fuel Power Plants (ZEPs) since power stations represent a high proportion of large combustion plant, and they are particularly suited for the development of standardised technologies and designs. The European Technology Platform for Zero Emission Fossil Fuel Power Plants (ETP) has drawn together stakeholder groups to formulate and propose integrated strategies for the research and development, and deployment of ZEPs including CCS.

Nonetheless, at present the European Union's (EU) effort to develop ZEPs, although considerable, remains fragmented. Full-scale demonstrations (>1MtCO_2/yr) of the full chain of CCS technologies (ie. capture, transport and storage) have been announced by Norway and the UK, and a similar scale project is being considered by Germany, while The Netherlands and France are supporting pilot scale trials. Additionally several Member States support R&D related to ZEPs and the European Commission's Framework Programmes continues to encourage collaborative projects amongst Member State organisations. However, much of this activity is driven by national or regional strategies, or by the priorities of a limited group of business stakeholders, with little opportunity to gain synergistic benefits through broader collaboration and coordination.

The Fossil Energy Coalition (FENCO-ERA) was established as a Coordination Action under the EU's ERA-NET initiative with the objective of establishing a durable network for the development and promotion of ZEPs across Europe. FENCO-ERA is composed of the national agencies charged with managing Member State programmes for the development of fossil energy technologies, and therefore can have a strong influence in delivering greater cooperation between national programmes.

In this document the FENCO-ERA team present a draft strategy and action plan for enhancing cooperation between Member State programmes and for engaging the broad range of stakeholders needed to deliver ZEP technologies. It is intended that this document will form the basis for a consultation workshop with stakeholders to consider how Member State's should formulate and organise their programmes to encourage and support wider cooperation and the establishment of joint actions.

2. Scope of the strategy and action plan

The scope of the strategy and action plan needs to be sufficiently broad to encompass all the elements needed to achieve the successful delivery of fossil fuel ZEPs. Generally Member State programmes directed at ZEPs have evolved from earlier programmes aimed at the development of cleaner fossil fuel technologies. As a consequence they tend to encompass a wide range of devices and enabling technologies that are mainly concerned with power generation plant. For the purpose of this strategy, these may be grouped under four broad categories:

- **Efficiency improvement** – developments that improve the combustion and conversion efficiency of fossil fuel plant, thereby reducing the amount of fuel burned and emissions associated with the production of a given quantity of electricity.
- **Emission reduction** – processes aimed directly at reducing the emissions of atmospheric pollutants (eg. sulphur and nitrogen oxides, particulates and heavy metals) associated with fossil fuel combustion.
- **Reduced carbon intensity** – co-firing with nominally carbon neutral biomass can reduce the CO_2 emissions from fossil fuel plant, but the affect of their combustion products on advanced boiler systems requires further investigation.
- **Carbon dioxide capture and storage** – CCS is the key to achieving truly zero emission fossil fuel plant, and is the most challenging development because it requires the establishment and linked operation of a novel chain of devices covering capture, transport and storage.

While all four of the above categories are important and can make a useful contribution to reducing the emissions of fossil fuel plant, it needs to be recognised that only CCS gives the radical step change essential for delivering true ZEPs. The other three categories listed above give evolutionary improvements that contribute towards CCS and ZEPs and therefore can be regarded as supporting CCS as well as being worthwhile in their own right. For example efficiency improvement benefits CCS in two ways, firstly the reduction in fuel burn helps to offset some of the energy penalty associated with running the CO_2 capture plant, and secondly it reduces the amount of CO_2 to be captured. Similarly biomass co-firing will be needed to enable a CCS plant to

achieve 100% CO_2 abatement by using carbon neutral fuel to offset the ~10% of CO_2 still released from CO_2 capture plant.

Accordingly this strategy takes the development and deployment of CCS as its central objective, while recognising that the other categories listed above remain important, and can to some extent be pursued separately with their own time schedules.

This focus on CCS brings in the transport and storage of CO_2, which introduces new developments that go well beyond cleaner fossil fuels. The European Technology Platform (ETP) has specified five areas requiring action, namely:

- Advanced fossil plant and CO_2 capture
- CO_2 use and storage
- Infrastructure and environment
- Market and regulatory policy
- Communication and public acceptance.

These groupings recognise that CCS is not simply a new fossil power generation technology, but that it introduces new challenges including transnational networks, safety, regulation and public acceptance, all of which require new knowledge and know-how if they are to be addressed successfully. This strategy and action plan, with two modifications, uses the same areas for action to facilitate continuity and shared dialogue between FENCO-ERA and the ETP. One exception is that the first action area has been separated into two (a) Advanced fossil plant and (b) CO_2 capture. This has been done to simplify consideration of State Aid regulations (see below). The second exception is to include safety as part of the “Infrastructure and environment” activity area.

The acquisition of the knowledge and know-how referred to above will require R&D, pilot trials and full-scale demonstrations that include not only technical work but also economic and social studies. Essentially a matrix of areas for action can be envisaged as illustrated in Figure 1 below. Furthermore, research and development will not stop with the attainment of full-scale deployment; there will be a needed to improve the technology for second and third generation plant. For example technical advances are needed to reduce the energy used for CO_2 capture, and to reduce manufacturing costs.

This strategy and action plan is concerned with identifying the areas within this matrix in which enhanced cooperation and collaboration between Member State programmes will deliver most added value and benefit.

Figure 1 Matrix of areas for action needing to covered for the development of fossil ZEPs

Action Area / Activity	Advanced fossil plants	CO_2 Capture	CO_2 use and storage	Infra-structure, environment and safety	Market regulation and policy	Communication and public acceptance
R&D to support full-scale deployment						
Pilot plant trials to support scale-up						
Full-scale demonstration						
R&D in support of second and third generation systems						

3. Timeline for Zero Emission Plant

It is generally agreed that the combination of technologies and processes needed for the first implementation of fossil ZEP power generation with CCS are all at a mature stage of development. The remaining technical steps to general deployment are the scale up of some processes to power station size (eg amine scrubbers for post combustion capture of CO_2), the build up of experience in the safe and reliable operation of the integrated chain of CCS processes (ie. capture, transport and storage) and strengthening the evidence base for the integrity of long term storage. Even so it is likely that power generators and associated businesses would be prepared to support the necessary development and investment in CCS if they were confident of gaining a reasonable rate of return for the substantial capital investment and risks involved. However, at present there is no mechanism accessible to ZEPs that places a sufficient value on their CO_2 abatement to deliver such a return. The European Commission has recently published a proposed amending Directive that will give ZEPs access to the EU Emission Trading Scheme (ETS)[1], and a separate draft Directive dealing specifically with the permitting, regulation, monitoring and verification of CCS has also been published[2]. However, analysis suggests that with current EU greenhouse gas targets (ie. 20% reduction by 2020) it is unlikely that the ETS will deliver a price for CO_2 emission permits that is sufficient to encourage commercial deployment of CCS before 2020, particularly as the EU's renewable energy target will reduce the level of effort needed from the ETS sectors. Moreover, there remains some uncertainty whether the principal market based instrument that is available to CCS, the EU Emissions Trading Scheme (ETS), will continue over the 15 to 20 year payback period needed for ZEP power plant.

Nonetheless there is a growing consensus that fossil ZEPs have a major role to play in achieving the reductions in greenhouse gas emissions needed to limit climate change to tolerable levels. For example a range of modelling studies both at the national and global level have shown that CCS needs to be deployed in addition to energy efficiency and renewable energy technologies from 2020-25 in order to follow an abatement trajectory that reduces CO_2 emissions to 60% of 2000 levels by 2050[3],[4], [5]. This was recognised by the European Commission in its communication on sustainable power generation

[1] Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emissions allowance trading system of the Community, COM(2008)16, January 2008.
[2] Proposal for a Directiver of the Parliament and of the Council on the geological storage of carbon dioxide, COM(2008)XXX, January 2008.
[3] Scenarios and Sensitivities for long term UK carbon reductions using the UK MSARKAL and MARKAL-MACRO energy systems models, UKERC Report RR/ESM/2008/002. February 2008 (http://www.ukerc.ac.uk/Downloads/PDF/S/Scenariosreport.pdf).
[4] Ref IEA Energy Technology Perspectives
[5] IPCC Special Report on Carbon Dioxide Capture and Storage, IPCC Working Group 3, 2005

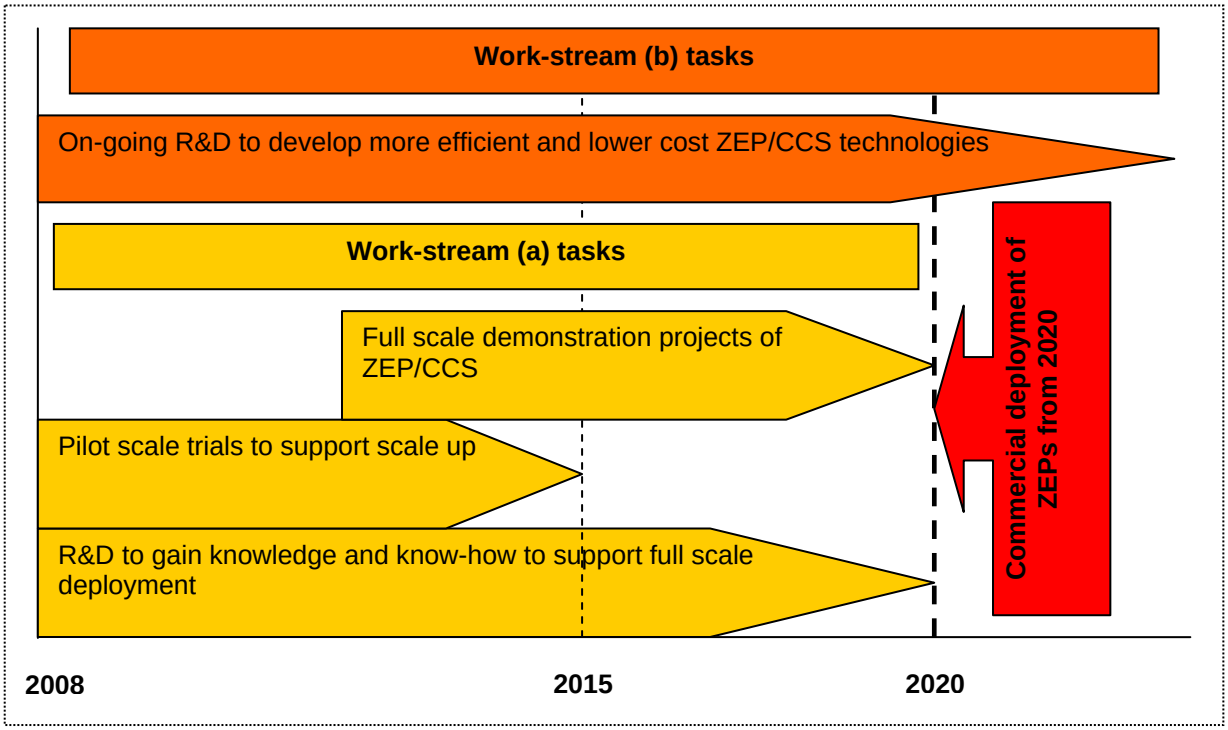
from fossil fuels which proposed that all new fossil power generation should from 2020 be required to have CCS fitted[6].

So the current position is one in which the need for ZEPs is being increasingly recognised but the necessary incentives to encourage their first commercial deployment have yet to be fully established. Against this background to role for innovation is two fold:

a. Firstly to undertake the R&D and demonstration work needed in order to provide the knowledge and know-how to support the deployment of ZEPs when the required policy measures are put in place.
b. Secondly to undertake longer term R&D to develop more efficient and less expensive second and third generation ZEPs.

These two work streams have different timelines. Work-stream (a) should be geared to supporting wider deployment of ZEPs from about 2020 and therefore needs to be compressed into the 2008-2020 period. In contrast Work-stream (b) is concerned with longer-term development and will be a continuing process extending beyond 2020. These timelines are illustrated in Figure 2.

Figure 2 Illustrative timeline for the two innovation work-streams needed to support the implementation of ZEP technologies



[6] Communication from the Commission to the Council and European Parliament – Sustainable power generation from fossil fuels: aiming for near-zero emission from coal after 2020, COM(2006)1723.

The above discussion shows that the FENCO-ERA strategy and action plan need to consider both of the above work-streams with their different timelines. However, with the growing concern to move to full-scale deployment of ZEPs by about 2020 the shorter term work streams needed to support such deployment are likely to demand priority.

4. Status of Member State Programmes

Another important input to the development of a strategy and action plan for cooperation and collaboration between Member State programmes is the current status and objectives of these programmes. As mentioned above most Member State programmes on ZEPs have evolved from earlier programmes on cleaner fossil fuel technology, with increasing priority being given to CCS.

Information on Member State ZEP programmes and initiatives have been gathered from FENCO participants, through the questionnaire process undertaken by Work Package 2, which was designed to gain insights on the rationale and objectives for their national programmes. Additionally more detailed insights into how national programmes are organised and their priorities set has been gained from Deliverable D3.1 of Work Package 3[7]. The information has been grouped under the six activities identified in Section 2 above, namely:

i. Advanced fossil plant
ii. CO_2 capture
iii. CO_2 use and storage
iv. Infrastructure, environment and safety
v. Market regulation and policy
vi. Communication and public acceptance.

The questionnaire has also shown that work on fossil fuel ZEP technologies varies in scope and significance between Member States. This probably reflects a range of national factors such as the relative importance of fossil fuels within different national contexts, differing levels of national resources for advancing the technologies and the role perceived for fossil fuel ZEP technologies within national climate change strategies. The questionnaires have shown that Member State's activities can be placed into one of four categories representing increasing levels of commitment to the development of ZEPs:

- **Watching brief –** mainly concerned with maintaining awareness of developments and establishing a knowledge base to make more informed judgments of the ZEP technologies. This may be combined

[7] "R&D Programmes for Carbon Abatement Technologies – Assessment Report on UK CATs, German COORETEC, Dutch CATO and Norwegian CLIMIT" by W. Kuckshinrichs, Systems Analysis and Technology Development (STE), Forschungszentrum Jülich. 2008.

with some basic research to hold open the option of becoming more actively involved with the development of the technology at a later date. Generally programmes of this type are not stand alone, but are one theme within much broader cross cutting programmes on science and technology or industrial innovation.

- **R&D –** actively supporting R&D on ZEP technologies with the objective of being an "informed buyer" or possibly with a view to moving to larger pilot or demonstration projects at a later stage. Generally programmes of this type are stand alone in nature with separate budgets and defined timescales and objectives.
- **R&D and pilot demonstration –** this activity includes R&D but with a larger budget to support pilot demonstration projects covering either the full CCS chain or key components (e.g. Germany's oxy-fuel 30MW prototype capture plant and the Ketzin CO_2-Store project).
- **R&D, pilot and full-scale demonstration** – this activity goes one step further with support for R&D, pilot demonstration and one or more full-scale demonstrations of CCS. Because of the high cost of a full-scale CCS demonstration the support for such projects tends to be provided by special measures lying outside of national innovation programmes. Norway and the UK are the only countries to have committed to supporting full-scale demonstrations, but others have indicated that it is under consideration (e.g. Germany).

Member State's and their programmes are grouped according to this classification in Table 1.

The table shows that, of the Member States covered by the FENCO-ERA questionnaire, Austria, Greece, Portugal, Poland and Latvia currently have only small activities concerned with zero emission fossil fuel and CCS (i.e. watching brief). However, some, notably Austria, have a growing interest in the subject, which could lead to an extended R&D programme in the future. Other Member States including Germany, Denmark, The Netherlands, Spain and the UK have significant R&D programmes that extend to include support for pilot plant scale demonstration activities. Some members of this group, for example Germany, are giving detailed consideration to supporting a full-scale demonstration of CCS, but only Norway and the UK have formally declared support for such a project.

The table shows some clustering of interest in the development of CO_2 capture technology and in the assessment and monitoring of CO_2 storage options. There is a developing activity on assessing the infrastructure implications and potential environmental impacts of CCS, and on market regulation and public acceptance.

Most Member States are taking a holistic view of CCS and are aiming to be involved in all six areas for development action covered in Table 1.

Table 1 Summary of Member State interests and subjects being considered for action on zero emission fossil fuel technology

Activity	Advanced fossil plants	CO_2 Capture	CO_2 use and storage	Infra-structure, environment and safety	Market regulation and policy	Communication and public acceptance
Watching brief	AT, EL, PT, LV, PO	EL, PT, LV, PO	EL, LV, PT, PO	AT	AT,	AT, PT
R&D		AT	A	(DE). DK, FR, NO, NL, UK	DE, DK, FR, NL, NO, UK	FR, NL, UK, NO, (DE)
R&D and pilot plant demonstration	DE, ES, UK	ES, FR, DK, NL	ES, FR	N/A	N/A	?
R&D, pilot and full-scale demonstration		NO, DE(?), UK	NO, NL(?), DE(?), UK	N/A	N/A	?

( ): activities outside the programme
N/A Not applicable, it is unlikely that demonstration projects will be needed advance these areas, although they may benefit from demonstration projects aimed at the other development areas (e.g. CO_2 capture).
(?) Indicates that there are proposals for full-scale capture and storage projects in these Member States but they have yet to be approved.

5. Gaining maximum benefit from joint programmes

Collaboration and cooperation between countries on research, development and demonstration should not be regarded as an end in itself. The organization of such collaboration incurs significant transaction costs and inefficiencies, both for the providers and recipients of funds, and these need to be more than offset from the synergies and benefits that can be gained from wider stakeholder engagement. These benefits may be gained through a number of mechanisms:

a. **Assembling a critical size team** - In subjects covering a wide range of disciplines, and consequently requiring a substantial team of specialists, it may not be possible to assemble a complete team in one country.
b. **Achieving a critical sized programme** – National resources may not be sufficient to support all the work needed to be done within a limited timeframe.
c. **Accelerating progress** – Similar to (b) above except this is concerned with the required pace of development. Cooperation between rival teams may induce a desire to drive work forward more quickly.
d. **Tackling trans-national issues** – Some issues that need to be resolved using the knowledge and know-how coming from R&D and demonstration are likely to require agreement at an international level (eg regulation, monitoring and verification, safety standards). In such cases there are advantages if the knowledge base is assembled through collaborative work engaging the parties concerned.

Programme options that capture these benefits could merit consideration for some form of joint action. However, determination of the nature of this action must also consider the costs involved. Experience from FENCO's pilot joint call shows that the cost to the national agencies of organizing and administering such an exercise is of the order of 100k€ (GM estimate, needs checking). Therefore a full formal joint call procedure would only be justified for programmes exceeding about 1M€ (ie administrative costs should not exceed 10% of the programme budget). For smaller actions the cost of running a full joint call cannot be justified, and a more informal network for cooperation and information exchange would seem to be a more cost effective approach.

6. Priority work topics and schedules

Previous sections of this report have defined:

i. The general scope of work needed to develop and deploy fossil ZEPs.
ii. The timelines for this work.
iii. Criteria for assessing where transnational joint actions will be most cost effective.

This section uses the above information to identify priority work topics meriting further consideration for transnational joint actions.

Joint actions will be supported with Member State funds that generally are derived from taxation or possibly some form of levy on the consumer. The use of such funding is normally targeted to address some form of "market failure", since otherwise there would be no justification for government intervention. This same requirement also arises through the EU's State Aid regulations that again seek to prevent interventions in normal market mechanisms except where a market failure can be identified. Consequently before identifying priority topic areas for joint action it is essential to consider how this choice may be affected by national and EU State Aid requirements.

Government support for R&D is normally justified on the basis that the work is pre-competitive and that commercial organizations are deterred from investing in such work because it is not possible for them to capture the full benefit of their investment (ie a market failure). For example, much of the knowledge gained from R&D "leaks" from the organization funding the work either through the publication of technical reports or the loss of staff to competitor organizations. Of course companies can take measures to protect the intellectual property rights (IPR) they gain from R&D directed at the specific development of products and devices. However, this only applies to R&D close to commercial exploitation (near market), which would not qualify for national or EU level support.

Government support for pilot and full-scale demonstration projects is more difficult to justify because clearly this is aimed at a specific product or device and therefore could constitute a market intervention. In the case of ZEPs, however, this can be justified because of another market failure, in this case the failure of the market to deliver an adequate financial reward for the CO_2 abated. However, invoking this market failure means that governments should only provide financial support for the parts of the pilot or demonstration plant that are concerned with CO_2 capture and storage. Demonstrations of technologies that improved conversion efficiency or advance biomass co-firing would not be justified because these are not subject to the same market failure. Of course this does not mean that, for example, a full-scale demonstration of a fossil ZEP involving advanced conversion and co-firing could not gain government support. However, this support would need to be confined to the CO_2 capture elements of the project, with the commercial stakeholders carrying the full cost of any aspects of the project that would gain market rewards (eg reduced fuel costs through higher conversion efficiency), and therefore are not subject to a market failure.

Drawing these considerations together a set of criteria can be specified for choosing action areas for developing and implementing ZEPs that would merit and benefit from trans-national joint programmes. These are:

A. Need for larger or wider effort
B. Need for a larger team with a wider range of expertise.

C. Need to accelerate progress
D. Addresses a transnational issue
E. Can be set up cost effectively
F. Conforms with national and EU State Aid requirements.

A preliminary assessment of the matrix of action areas and types of development activity described in Section 2 (Figure 1) has been made using the above criteria. This is shown in Figure 3, in which the symbols A, B, etc are included to show that a particular action area/activity is judged to meet that particular criterion for a transnational initiative. Action areas that are judged not to conform with State Aid regulations have been exclude.

This preliminary assessment shows that the action areas "CO_2 use and storage", "Communication and Public Acceptance" and "Infrastructure, Environment and Safety" meet all the criteria for action areas that would benefit from transnational joint programmes.

Action areas for which programmes should extend beyond R&D to pilot and full scale demonstration are "CO_2 capture" and "CO_2 use and storage". "Infrastructure environment and safety" could also benefit from R&D projects based on pilot and full-scale CCS demonstration projects, although large projects may not be essential to this action area.

Work on "Market and Regulatory Policy" also is a priority area for transnational actions, but it is likely that programmes will be small (ie. less that 1M€) and therefore it would not be cost effective to set up a formal process for joint programmes. Instead, this area should be covered through a more informal network and cooperation system.

Longer term transnational collaborative R&D is also justified principally to improve the performance and reduce the cost of CCS for second and third generation ZEPs. These actions should cover R&D on CO_2 capture and CO_2 use and storage. These joint programmes should not extend beyond R&D because second and third generation ZEPs should not be subject to the market failures that currently impact on ZEP CCS technologies. A market based system to fully reward CO_2 abatement should be in place by the time second generation ZEPs are ready for deployment. Longer term cooperation is unlikely to be required on "Market regulation and policy" or "Communication and public acceptance" since these issues will have been addressed through the deployment of first generation ZEPs.

Figure 3 Preliminary assessment of ZEP action areas and activities that would most benefit from transnational joint actions

Action Area / Activity	Advanced fossil plants	CO_2 Capture	CO_2 use and storage	Infra-structure environment and safety	Market regulation and policy	Communication and public acceptance
Activities aimed at supporting first generation deployment						
R&D to support first full-scale deployment	A, B, C,E	A, B, C , E	A, B, C, D, E	A, B, C, D, E	B, C, D	A, B, C, D, E
Pilot plant trials to support scale-up	N/A	A, B, C, E	A, B, C, D, E	N/A	N/A	N/A
Full-scale demonstration	N/A	A, B, C, E	A, B, C, D, E	N/A	N/A	N/A
Activities aimed at developing improved devices and processes						
R&D to improve ZEP efficiency and reduce costs	A, B, E	A, B, C, E	A, B, C, D, E	N/A	N/A	N/A

Notes
1. N/A indicates either that there is no requirement for action in this area or that action would be precluded by State Aid regulations.
2. Action areas in which a formal transnational programme is judged not to be cost effective are shaded red.
3. Areas where a formal transnational programme is judged to be cost effective are shaded green

The schedule for initiating these joint actions can be derived from the discuss of ZEP timelines in Section 3:

- R&D in support of the deployment of first generation ZEPs needs to initiated as soon as possible.
- Pilot scale projects to aid the scale up of ZEPs should also start as soon as possible.

Realistically full-scale demonstration of ZEPs cannot commence before about 2012, although design and planning will need to start soon to meet such a start up schedule. Such projects are likely to each require several hundred million Euros of financial support, even when support is confined to the CCS elements. Because of the cost, and also the complexity of organizing, managing and regulating such projects, it seems likely that the first few demonstrations at least will be initiated by individual Member States, possibly with the European Commission and ETP providing a coordinating role. It is therefore uncertain if any additional transnational action of the type considered by FENCO-ERA is needed. However, there may be a role for separate transnational actions that utilize one or more full-scale demonstration projects as hosts for additional work (eg R&D to develop advance methods for monitoring CO_2 stores).

7. Interim conclusion and outstanding issues

The purpose of this report is to develop a draft strategy and action plan for enhancing cooperation between Member State programmes and for engaging the broad range of stakeholders needed to deliver ZEP technologies. It has done this by:

d. Defining the areas where action is needed to deploy fossil ZEP technologies and types of activity needed (eg. R&D, pilot plant, full-scale demonstration) in each of these action areas.
e. Defining the time line required for taking forward these activities with the aim of having ZEPs available for general deployment from about 2020.
f. Identifying the combination of action areas and activities where transnational cooperation through joint programmes will be most beneficial and cost effective.

Key conclusions to be taken from this interim stage of the work are:

- Joint programmes between Member States on ZEP technologies should focus on R&D and possibly pilot scale demonstration of key processes and devices.
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demonstration. For example R&D on safety or geological monitoring of a CO_2 store.

- The most promising areas for joint programmes involving R&D are:
  - Advanced fossil fuel generation
  - CO_2 capture
  - CO_2 use and storage
  - Infrastructure, environment and safety
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- The most promising areas for joint programmes involving pilot scale trials are:
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  - CO_2 use and storage
- For joint programmes to be cost effective they need to have an overall value of at least €1M and preferable €10M.
- Less formal methods are needed to facilitate cooperation when the level of activity is less than €1M. An important example is work on "Market regulation and policy", which is important to the implementation of ZEPs but is likely to involve study programmes that are less than €1M at any one time.

So far this strategy and action plan has not considered some more detailed issues:

- Firstly more detailed consideration is needed of work to be done in each of the priority action area/activity combinations listed above. For example it makes no judgment on what types of CO_2 capture technology to focus R&D (ie. post combustion, pre-combustion, oxy-firing) or what the key R&D topics are to advance CO_2 use or storage (eg. development of advanced geological survey methods, geophysical or geochemical modeling, leak remediation methods, etc.)
- Secondly it does not specify the mechanism by which joint programmes should be organized, funded and managed.

The second of these points will be covered by FENCO-ERA Work Packages 4 and 5. However, the first point raises important questions that merit further consideration before inclusion in the final version of this strategy. They are:

i. Should any joint call be prescriptive on the types of work required, or be limited to a general specification, that enables bidders/stakeholders to determine priorities? This decision may need to accommodate different national approaches to programme strategy with some Member States

favouring a stakeholder led approach (eg. UK) while others may prefer to be more prescriptive on what they are prepared to fund.

ii. The issue of prescriptive versus open calls differ between action areas. For example with "Infrastructure Environment and safety" and also "Market and regulatory policy" national government's and their agencies will be the leading customer and therefore they will be in a position to be prescriptive of their needs. In contrast work on "CO_2 capture" and "CO_2 use and storage" are more business focused and loosly defined calls may be more appropriate to enable business organizations to have a greater say over priorities.

iii. Would national programmes be prepared to support joint actions that go beyond their national priorities?

iv. How to develop criteria to prioritise between action areas when funds are limited? For example should the areas for joint action be limited at the outset or should funds be allocated according to the quality of the proposals received?

v. Should prioritization be limited to the selection of high level action areas or also define the specific topics to be covered within an action area? To illustrate this Annex 1 to this report possible lists topics, taken from the ETP's Strategic Research Agenda, that might be considered for work in each action area. Should joint calls list the topics and be confined to a general specification of the action area?

Decisions on these issues will need to take account of the need to have joint actions that are cost effective to operate. In other words that the level of funding and activity involved, justifies the additional transaction costs of mounting a transnational programme.

Also more detailed consideration is needed on how such joint actions should fit in with existing and future actions that are part funded by the EU's framework programmes.

8. Next Steps

It is proposed to take this work forward through two consultations firstly with National Funding Agencies and later with a broader representation of stakeholder groups.

The first consultation will review this draft strategy and in particular test:

- If stakeholders endorse the priority areas for action/activities proposed and the timelines proposed for their execution.
- What type of prioritisation approach do stakeholders consider most appropriate for inviting bids in each action area/activity combination (ie. open versus prescriptive).
- Who should take the lead with the "Communication and public acceptance" action area? To what extent is this a generic action suitable

for a transnational approach and to what extent does the process need to be tailored to particular national positions and preferences?
- Do stakeholders agree that a formal joint call approach to cooperation is only cost effective for large programmes and actions?
- How could a more informal system be arranged for smaller programme actions (eg market and regulatory policy).

The second consultation will examine more detailed prioritization down to specific development actions. This would draw on the detailed lists of development priorities presented in the ZEP Technology Platform's Strategic Research Agenda. Once again the emphasis would be on identifying the topics that would benefit from transnational joint actions, and for which programmes could be big enough to make this a cost effective approach.

9. Annex 1

Possible subjects for projects in each of the action areas identified in the strategy

Action Area 1 – Advanced Fossil Fuel Plant
Activity – R&D

Increase the efficiency of steam power plant to over 50%
Develop new high temperature materials
Develop new protective coatings
Improve fabrication methods for increased integrity and cost reduction
Develop novel steam turbine designs
Advanced design codes and tools
Improved NDT and defect detection
New seals
Increase the efficiency of gas combined cycle plant to over 63%
Improved optimization of gas turbines, boilers and steam turbines
Improved high temperature materials for gas turbines
Advanced high temperature coatings
Improved aerodynamic design for gas turbines
Improved seals
Advanced low emission technologies and processes
Life time extension with modeling and condition monitoring
Increased fuel flexibility
Cross cutting themes for gas and steam plant
Improved instrument and control systems
Gasification development for IGCC
Improve part load efficiency
Advanced fuel processing and multi-fuel capability

Action Area 2 – Carbon dioxide capture
Activity – R&D

Post Combustion
New and less energy intensive solvents
Solvent degradation mechanisms
Process optimization and integration (heat and gas path)
Retrofit concepts
Adsorbents and membranes for separation
Methods to reduce the impact of flue gas contaminants
Advanced process and equipment models
Pre-combustion
Up scaling gasifiers to 1200-1500MWth
Improved gas clean up
Conversion technologies with oxygen membranes
Improved shift catalysts
Improved solvents for separation
Membranes for separation
Develop larger turbines capable of burning hydrogen
Hybrid cycles involving fuel cells
Process integration and optimization
Membranes for oxygen separation
Oxyfuel combustion
R&D into oxy-combustion, heat transfer, slagging, fouling and corrosion
Develop design tools for scale up
R&D of oxy-fuel gas turbines and combined cycles
Chemical looping
Flue gas cleaning technologies
R&D of the degradation of materials for handling oxy-fuel flue gases
Materials for high efficiency boilers operating with oxy-fuel environments

Action Area 2 – Carbon dioxide capture
Activity – Pilot Plant

Post Combustion
Solvent trials
Pre-combustion
Hybrid cycle trials
Oxygen membrane separation
Hydrogen gas turbine trials
Oxyfuel combustion
Pulverised coal burner trials
CO_2 clean up trials
Circulating fluidized bed with oxy-fuel trial

Action Area 3 – Carbon dioxide use and storage
Activity – R&D

Physical, chemical and biological behaviour of CO_2 in the subsurface
Fluid – rock interactions
Development of dynamic models of storage behaviour
Rock cap integrity and seal characterisation
Tools for reservoir design (well location, monitoring systems)
Modelling the long term evolution of CO_2 stores
CO_2 thermodynamics
New monitoring tools
R&D of well bore integrity
Leak detection and tracking
Leak mitigation techniques

Action Area 3 – Carbon dioxide use and storage
Activity – Pilot Trials

Field investigations of rock-fluid interactions
Pilot tests of seal integrity
Field trials of monitoring equipment
Well seal monitoring trials
Field laboratory for studying CO_2 migration in the over burden

Action Area 4 – Infrastructure, environment and safety
Activity – R&D

Corrosion properties of CO_2
Seals and valves for CO_2
Develop subsea dispersion models
Impact of CO_2 on terrestrial and marine ecosystems
Methods for mitigating leaks in the transport system
Safety implication of different sized leaks of gaseous and supercritical CO_2
Other potential environmental impacts of CCS (solvent leakage)

Action Area 3 – Infrastructure, environment and safety
Activity – Pilot Trials

Leakage impact tests with pressurized gaseous and supercritical CO_2

Action Area 6 – Communication and public acceptance
Activity – R&D

Research the perception of different stakeholder groups
How to build public trust
Develop risk communication strategies
Use full-scale demonstration projects to engage with the public and better understand their concerns