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Comparison of R&D Programmes for Carbon Abatement Technologies Assessment Report on UK CATs, German COORETEC, Dutch CATO/CAPTECH and Norwegian CLIMIT

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Executive Summary[1]

The study examines the UK CATs, the German COORETEC and GEOTECHNOLOGIEN, the Dutch CATO and CAPTECH and the Norwegian CLIMIT R&D programmes for carbon abatement technologies. It comes up with an indicator set, which characterises the R&D programmes either to be of high degree of conformity, of low degree of conformity or to non-conform. With *storage analysis and assessment* and *regulatory, social and market aspects* it identifies two indicators where the programmes are to be characterised as partial conform, but where collaboration and joint actions are regarded to easily increase the benefit of national programmes.

The carbon lock-in problem characterises the programmes to be non-conform. Collaboration and joint actions with respect to economic modelling of the potential of different technology routes keeping in mind country-specific framework conditions and regulation approaches are necessary to indentify technology areas where R&D synergies result to maximum benefit.

Keywords

Carbon abatement technologies, zero emission electricity plants, fossil fuel technologies, clean coal technologies, carbon capture and storage, fossil fuel technologies R&D, CATs, COORETEC, GEOTECHNOLOGIEN, EOS, CATO, CAPTECH, CLIMIT

Contribution to

Work Package 3, D. 3.1, of FENCO-ERA project

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1. Introduction

To a large extent, the increase in atmospheric concentration of CO_2 is the result of anthropogenic use of fossil fuels for energy supply for electricity, space heating and transport. The *World Energy Outlook 2006* shows a further increase of energy demand up to 60% in the coming 30 years [International Energy Agency, 2006]. However, using fossil fuels for energy supply will add to the problem of global warming, unless their GHG emissions can be abated.

Generally, end-use efficiency, combustion efficiency, fuel switch to less carbon-intensive fuels, deployment of renewable energies, and in the longer term CO_2 neutralization with carbon capture and storage have the potential to considerably reduce anthropogenic GHG emissions. But, for a wide range of technologies further R&D is necessary to improve its performances as carbon abatement technologies. The role of energy technology innovations for carbon mitigation is widely analyzed (see e.g. [Grubb, 2004], [Egenhofer et al., 2007]), as is the role of international agreements on low-carbon technologies (see e.g. [Philibert, 2004], [de Coninck et al., 2008].

For several EU member countries governments set up national R&D programmes to encourage further R&D activities for fossil fuel technologies and carbon abatement technologies, i.e. the United Kingdom, Germany and the Netherlands. Norway as a further European country runs a carbon abatement technology R&D programme. Worldwide, the USA, Australia and Japan set up further important R&D programmes for fossil fuel technologies and carbon abatement technologies [Figueroa et al., 2008], [Klara et al., 2003], [COAL21, 2003] [COAL21, 2004]. For FENCO-ERA, the European programmes are very important, as on the one hand, they represent R&D programmes of EU countries, whose electricity production will depend on a high share of fossil fuels or whose energy industry acts as an international or global player. On the other hand, the programmes in part or even totally, may be regarded as exemplary for further programmes.

As the programmes are by nature national programmes, this results to fragmentation of European R&D activities. On the one hand there is significant thematic overlap between the national programmes, on the other hand there is lack of critical mass of the individual programmes. Consequently, inefficiencies arise, which can be removed through coordinating research expenditures on a bilateral or multilateral level.

To improve the situation in line with the FENCO-ERA objectives this study aims at a comparative analysis of European R&D programmes on fossil fuel technologies for carbon abatement focusing on the United Kingdom, Germany, the Netherlands and

Norway. Therefore, a comparative survey is done for CATs (The United Kingdom), COORETEC and GEOTECHNOLOGIES (Germany), CATO and CAPTECH (The Netherlands) and CLIMIT (Norway) to improve the mutual understanding and to identify programme-specific foci and potential areas of thematic collaboration. To be useful in this sense, the comparison gives a brief overview of selected programmes (section II), analyses the policy context for carbon abatement in the selected countries (section III), identifies main criteria for programme comparison and assessment (section IV), and it works out the important aspects and components of each programme (section V). Section V formulates areas of mutual interest which might be applicable for first thematic collaborations and indicates national experiences in handling approval and selection of proposals.

Methodologically, the study is based on a systems analysis approach, which identifies important energy system aspects and typical barriers for technology uptake. For R&D characterisation, a set of indicators is compiled to describe each individual programme. The study is conducted as literature analysis where different programmes are assessed based on publicly available programme documents from governments or programme management teams. Additionally, the results of a questionnaire for national experts on R&D programmes are used to come up with an overview on national experiences on approval and selection procedures.

2. General Review on Selected Programmes

There is no uniform understanding of R&D programmes for the development of carbon abatement technologies across European countries. Nevertheless, a programme may be defined "… an in some way strategically planned and executed constellation of projects" [The Association For Technology Implementation In Europe, 2005]. In some countries, a programme is characterized by a set of items like expression of thematic interest and topics, call and evaluation procedures and the need for proposals. Nevertheless, such R&D programmes for carbon abatement technologies are embedded into broader national energy research programmes. This procedure can be described by a three-step approach: National energy research programme – Carbon abatement technology R&D programme – Projects. The German COORETEC follows this approach. Other countries use a two-step approach, where national energy research programmes are directly converted into projects on carbon abatement technologies, and where from a national viewpoint the two steps together are regarded to characterise a programme on carbon abatement technologies. The Dutch energy research programme EOS (Long Term Energy Strategy) with CATO and CAPTECH can be interpreted in that sense.

The four selected cases are briefly described as follows:

- The United Kingdom: *A Strategy for Developing Carbon Abatement Technologies for Fossil Fuel Use – Carbon Abatement Technologies Programme (CATs)*

  CAT is the abbreviation for fossil-fuel based carbon abatement technologies and stands for a group of innovative technologies that enables fossil fuel to be used with substantially reduced CO_2 emissions, and therefore can be part of the solution to climate change. It covers a range of options including higher efficiency conversion processes, fuel switching to lower carbon alternatives and CO_2 capture and storage (CCS). The CAT programme [dti, 2005] [Department of Trade and Industry & Affairs, 2004] is intended to be industry-led, and therefore not prescriptive about the work it will support. It defines broad areas for work and looks to industry and research institutions to come forward with innovative projects. It is run by the Department for Business, Enterprise and Regulatory Reform (BERR), formerly the Department of Trade and Industry (dti).

- Germany: *Research and Development Concept for Zero-Emission Fossil-Fuelled Power Plants (COORETEC)* and *A Geo-scientific R&D Programme (GEOTECHNOLOGIEN)*

  In Germany there are two programmes dealing with R&D for carbon abatement technologies. COORETEC [Federal Ministry of Economics and Labour, 2005] stands for CO_2 Reduction Technologies, a programme on research and development concepts for zero-emission fossil-fuelled power plants run by the Federal Ministry of Economics and Labour. It has its basis with the 5th Energy Research Programme of the Federal Government Innovation and New Energy Technologies [Federal Ministry of Economics and Labour, 2005] covers areas of work for power plant technologies, decentralised supply and CO_2 capture, utilization and storage, for which industry and research institutions can provide innovative research proposals. By initiative of the ministry industry and research institutions established four working groups on socio-economic and political framework conditions, power plant technologies, future technologies and CO_2 capture and storage.

  GEOTECHNOLOGIEN [GEOTECHNOLOGIE, 2006] is a geo-scientific R&D programme funded by the Federal Ministry of Education and Research and the German Research Foundation. It covers 13 main research themes of which *investigation, use and protection of the underground* raises opportunities for R&D on CO_2 storage.

- The Netherlands: *Long Term Energy Strategy (EOS) with CO_2 Capture, Transport and Storage (CATO)* and *CO_2 Capture Technology Development (CAPTECH)*

  CATO [CATO, 2004] is regarded as the national research programme on CCS in the Netherlands and its aim is to identify whether and how CCS can contribute to a sustainable energy system in the Netherlands. It is implemented by a consortium of Dutch companies, research institutions, universities and environmental organisations led by the Utrecht Centre for Energy Research. The CAPTECH programme [CAPTECH, 2006] concentrates on CO_2 capture technologies and is coordinated by ECN. The research portfolio covers the entire field of CO_2 capture technologies including a variety of projects such as the CATO programme and some European projects such as CASTOR and others. The consortium works in close cooperation with these projects and programmes. Both are run by the Ministry of Economic Affairs and have its basis in the long-term national energy research strategy [SenterNovem, 2004].

- Norway: *Norwegian Gas Power Technology R, D&D Programme (CLIMIT)*

  CLIMIT [CLIMIT, 2005] is a Norwegian programme aiming at supporting sustainable natural gas power technologies and solutions for capture and storage of CO_2. Its vision is to develop profitable gas power technology with CO_2 management in Norway. CLIMIT is a joint programme between Gassnova (administrative agency) and the Research Council of Norway.

3. Country-specific Carbon Abatement Policy Context

R&D programmes for fossil fuel technologies are embedded into a country's carbon abatement policy context. To interpret a country's strategy for technology R&D it's necessary to know the country-specific characteristics. The country profiles give a survey for the four selected countries (Tab. 1, Tab. 2).

According to different population sizes, economies, and carbon intensities of energy supply the four countries show a wide range of CO_2 emissions from 43 Mt for Norway to 865 Mt for Germany. The energy intensities (kg oe/1000 €1995 GDP) range from 159 (Germany) to 207 (UK) resulting from different economic production structures and efforts to produce energy-efficient.

Due to the Kyoto process and the EU burden sharing for EU member countries Germany and the UK show the strongest reduction targets. Due to the EU development process there are further announcements to commit on more ambitious climate protection measures which indicate the share of renewable energy and the target for end-use efficiency increase.

The countries are involved in the main international technology-oriented agreements (TOAs) for development of fossil fuel-based technology and for addressing climate change, which are governmental-driven like the Carbon Sequestration Leadership Forum (CSLF), or industry-driven like the European Technology Platform on Zero Emission Fossil Fuel Power Plants (ETP ZEP).

	CO_2 emissions 2003 Mt*	Energy intensity 2004 kg oe/ 1000 €$_{1995}$ GDP*	Kyoto/ EU burden sharing %**	International initiatives with regards to carbon-based energy technology	Energy-economic instru-ments
United Kingdom	557	207	-12.5	CSLF IEA WPFF IEA CCC IEA GHG R&D IEA CTI ETP ZEP	ETR, ETS, tax incentives
Germany	865	159	-21.0	CSLF IEA WPFF IEA CCC IEA GHG R&D IEA CCS IEA CTI ETP ZEP	ETR, ETS, FIT, subsidies
The Netherlands	177	203	- 6.0	CSLF IEA WPFF IEA CCC IEA GHG R&D IEA CCS ETP ZEP	ETR, ETS, FIT, subsidies
Norway	43	189	+ 1.0	CSLF IEA WPFF IEA GHG R&D IEA CTI ETP ZEP	CO_2 tax, ETS, subsidies

CSLF: Carbon Sequestration Leadership Forum
IEA WPFF: IEA Working Party Fossil Fuels
IEA CCC: IEA Implementing Agreement Clean Coal Centre
IEA GHG R&D: IEA Implementing Agreement Greenhouse Gas R&D Programme
IEA CCS: IEA Implementing Agreement Clean Coal Science
IEA CTI: IEA Implementing Agreement Climate Technology Initiative
ETP ZEP: European Technology Platform on Zero Emission Fossil Fuel Power Plants
ETR: Environmental Tax Reform
ETS: Emission Trading System
FIT: Feed-in Tariff for Renewable Energy and Bio-energy

Sources: *: EUROSTAT, **: EC

Tab. 1: Country profiles I

The International Energy Agency runs a Working Party on Fossil Fuels (IEA WPFF) and a couple of Implementing Agreements (Clean Coal Centre (IEA CCC), Greenhouse Gas R&D (IEA GHG R&D), Clean Coal Science (IEA CCS), Climate Technology Initiative (IEA CTI)), with contracting parties (governmental membership) and industrial sponsors. The Carbon Sequestration Leadership Forum and the task sharing IEA Implementing Agreements focus on knowledge sharing and coordination, whereas the cost sharing IEA Implementing Agreements concentrate on RD&D [de Coninck et al., 2008]. Germany is involved in all of the 7 initiatives, whereas UK and the Netherlands are each involved in 6 of the 7 initiatives. As coal is irrelevant for the Norwegian energy supply, Norway is the only country which is involved neither in the IEA CCC not in the IEA CCS.

To promote the deployment of climate protecting energy technologies the countries rely on energy-economic instruments like ETR and ETS. According to the general macroeconomic policy approach some countries additionally use tax incentives and subsidies. Norway mainly relies on a CO_2 tax, but will gradually change to ETS and other measures.

The countries' domestic fossil energy resources are very unequally distributed. Whereas the United Kingdom, the Netherlands and especially Norway own significant amounts of natural gas and mineral oil, Germany only has minor own resources of natural gas and mineral oil. The UK and Germany own domestic stocks of coal. Whereas for the UK after a long period of continuous decline of coal extraction from deep mining and surface mining the present production of around 15 Mt/a is not expected to further be reduced over the next few years, the situation is different in Germany. Presently, domestic coal reserves are economically unattractive to extract and subsidies for coal mining will be phased out during the next years. But lignite presently plays a significant role in Germany's domestic primary energy supply and will presumably preserve its importance.

Consequently, the UK, the Netherlands and Norway are regional or global suppliers of mineral oil and natural gas, whereas Germany is one of the major importers for mineral oil, natural gas and coal, too. As a further result, the UK and Norway are very much interested in offshore activities for enhanced oil or gas recovery (EOR, EGR).

Looking at all life cycle stages of technologies from production to operation (including financing), a large number of business sectors is involved in carbon abatement technologies. This includes project developers, geological services, petroleum engineering, offshore engineering, fossil fuel supply, process engineering, power engineering and electricity generation. Power generation and power engineering are key sectors for the development of carbon abatement technologies although other sectors should have a strong interest in their development. For example, with cofiring the producers of crops, while with coal gasification most current experience lies with the process engineering and petroleum refining industries. According to their activities as fossil fuel suppliers the UK, the Netherlands and Norway have own industries focusing on petrol and gas engineering including offshore engineering. The UK and Germany are main European suppliers of equipment for coal and gas power plants. All the four countries are involved in R&D activities.

	Domestic fossil energy resources	Global/ regional PE supplier	Offshore activities (EOR, EGR)	Involved domestic industries
United Kingdom	Natural gas Mineral oil Coal	X	X	R&D, power & process engineering, plant construction, petrol & gas engineering, fuel suppliers, utilities
Germany	Natural gas Mineral oil Coal	-	-	R&D, power & process engineering, plant construction, utilities
The Nether-lands	Natural gas	X	-	R&D, power & process engineering, petrol & gas engineering, fuel suppliers, utilities
Norway	Natural gas Mineral oil	X	X	R&D, petrol & gas engineering, fuel suppliers, utilities

Source: IEF-STE

Tab. 2: Country profiles II

Summarizing, the following clusters can be characterised:

- Germany: Poor domestic mineral oil and natural gas resources, large domestic coal resources, but extraction presently economically unattractive, large economically attractive lignite resources, fossil-based electricity supply dependent on imports of natural gas and coal, as well as on own lignite resources

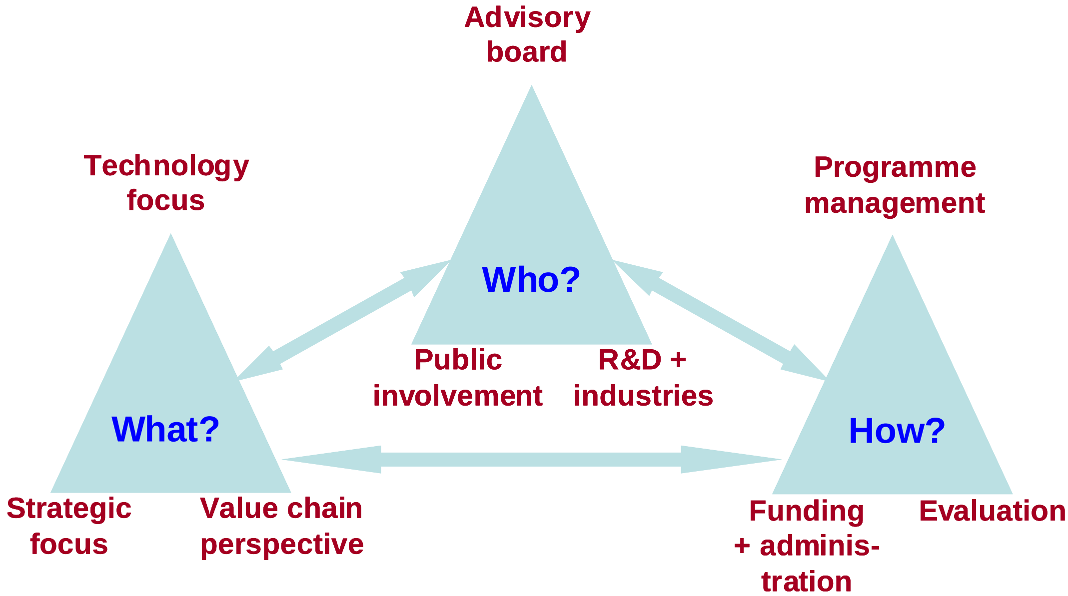
- UK and the Netherlands: Offshore activities, regional supplier of natural gas and mineral oil, but potential future importer; fossil fuel mix including coal for electricity supply
- Norway: Offshore activities, regional and global supplier of natural gas and mineral oil, high share of hydropower but increasing share of natural gas based electricity generation

4. Indicators for Comparative Programme Analysis

Successful deployment of technology depends on a range of factors which have to be fulfilled and which can be regarded as obstacles or barriers. This range covers technical factors, cost aspects and other factors like the existence of appropriate legal arrangements and regulations as well as public acceptance [IEA, 2006]. To overcome technical and cost barriers, technology R&D is one appropriate measure for further improvements. Thus, R&D programmes should include not only basic R&D, but should give the opportunity to pilot plant operations as well as large scale demonstration plants. Additionally, further incentives may be necessary, e.g. to overcome the “valley of death”, where mature technologies are not taken up by the market quickly enough. For this and other aspects like legal arrangements and public acceptance R&D programmes should focus on non-technical factors, too, for successful deployment.

The literature evaluating climate regimes has identified a wide variety of evaluation criteria specifically oriented towards the assessment of alternative climate policy approaches (e.g. [Philibert & Pershing, 2001], [Aldi et al., 2003], [Den Elzen, 2002]). Adapting these criteria de Conick et al. consider five criteria for the evaluation of TOAs: (1) environmental effectiveness, (2) technological effectiveness, (3) economic efficiency and cost-effectiveness, (4) incentives for participation and compliance, and (5) administrative feasibility [de Coninck et al., 2008].

For a comparative assessment of R&D programmes a set of indicators is necessary, which works out the specific characteristics of the individual programmes, and which gives support for development of further programmes. For a full analysis these indicators should cover three cornerstones (Fig. 1).



Source: IEF-STE

Fig. 1: Cornerstones for programme assessment

Firstly, there are indicators concentrating on the “what” aspects, i.e. technology-related important aspects. This includes the aim of the programme, the technology perspective as well as non-technical perspectives. Secondly, there are indicators focusing on the “who” aspects, i.e. stakeholder perspectives, and indicating who is involved in the process of programme development and operation. Thirdly, the “how” indicators cover funding, administrative and further management aspects of the programmes. For the “who” and “how” aspects there are similar approaches focusing on programme-technical aspects.

For the interpretation of results it has to be kept in mind that the three cornerstones are not necessarily independent from each other. E.g., if there is an advisory board (“who” aspect), this must be in line with the evaluation procedure to identify successful proposals and the evaluation of projects (“how” aspect).

This study’s focus is on all three categories. The chosen set of indicators for the “what” aspects does comply with the main programme aspects:

1. Strategic focus: What is the strategic focus of the programme? Does it include efficiency improvements, fuel switch and CCS to reduce CO_2 emissions?
2. Industrial policy approach: Is there any governmental regulation, activity or support, that encourages the ongoing operation of a particular industry or this industry’s investment, either domestic or globally?

3. Research, pilot plant, demonstration plant: Does the programme cover all stages from basic research to demonstration?
4. Value chain perspective: Does the programme cover all technology options, even if they do not primarily focus on CO_2 reduction?
5. Non-technical aspects: Does the programme relate to regulatory, social and market aspects, which are important for successful deployment?
6. Technology preference: Are there technology preferences for electricity generation and for capture and storage in case of CCS?
7. Carbon lock-in: The longevity of power plants prolongs the operation of technologies, not optimally designed for carbon mitigation, and thereby hindering rapid and large-scale absorption of low-carbon technologies. This effect is interpreted as carbon-lock-in [Brown et al., 2008, Foxon, 2006]. Retrofitting existing sites is regarded to be an option to partially escape carbon lock-in. Does the programme include R&D for capture-ready options as a means to retrofit existing plants?
8. Time-line: Does the programme-specific time-line fit to long-term development of technologies to reduce CO_2?

For the “who” and “how” aspects the following criteria are taken into consideration:

9. Form of calls
10. Frequency of calls
11. Application procedure
12. Methods of evaluation
13. Evaluation criteria

For each of these indicators the programme analysis and comparison assess the degree of conformity of the programmes. The degree of conformity can be high, partial or low, indicating whether the programmes are consistent with each other. The assumption is, that the higher the degree of conformity is the easier it is to collaborate and to harmonise the programmes. Otherwise, the lower the degree of conformity, the easier it is to gain benefits from joint programmes. FENCO-ERA therefore can use the outcome of this assessment as one criterion for the identification of topics for first calls.

5. Results

5.1 Indicators for "what" aspects

Strategic focus

With respect to general measures to reduce CO_2 the programmes show a high degree of conformity (Tab. 3). They support the three pillars efficiency improvement, fuel switch and CCS, except CATO which does not explicitly mention fuel switch. Although COORETEC regards fuel switch to be an important option to mitigate CO_2 emissions, it is not in the focus of R&D activities.

Industrial policy approach

All four programmes are aware of the direct and indirect economic opportunities of developing, producing and exporting CCS equipment and services. The direct opportunities of production and exports comprise job and income creation, whereas technology development gives the opportunity to be a technology driver. Concerning industrial policy there is only partial conformity of the programmes. The Dutch CATO and the Norwegian CLIMIT follow a weak industrial policy approach ("… opportunity for industry…", "… economic development of Norway…"), although industry sponsors the CATO programme for about 25-50% (depending on the subject). As a R&D programme the German COORETEC points to a moderate policy approach generally taking into consideration export markets. The UK CATs programme strongly supports industrial policy approaches clearly expressing "… to take the lead…". The UK CATs gives moderate programme support to an industrial policy approach clearly expressing "…to take the lead…", but this is given less priority then the need for international leadership on CO_2 abatement.

Research, pilot plant, demonstration

Regarding development stages of a technology from basic research to demonstration the programmes show partial conformity. Two programmes, CATs and CLIMIT, clearly support all three stages from research and piloting to demonstration of energy technologies whereas in the Netherlands project demonstration is by and large not within CATO and in Germany COORETEC does not clearly refer to demonstration. This comes along with the commitment of German companies to invest in CCS demonstration without financial support of the government.

	Strategic focus	**Industrial policy approach**	**Research, pilot plant, demon-stration**	**Value chain perspec-tive**	**Regulatory, social and market aspects**
CATs	Efficiency improve-ment, fuel switch, CCS	"… take the lead…"	R,D&D	EOR/EGR	Task 8, 9: "regulatory, market framework", "public awareness and information"
COORE-TEC GEOTECH-NOLOGIEN	Efficiency improve-ment, fuel switch, CCS	"… export markets…"	R&D	Awareness	Awareness
EOS CATO	Efficiency improve-ment, CCS	"… opportunity for industry…" sponsoring	R,D&D	EGR ECBM	CATO: "Communicati on"
CLIMIT	Efficiency improve-ment, CCS	"… economic developme nt of Norway…"	R,D&D	EOR/EGR	Awareness
Programme Conformity	+	o	o	o	o

+: high degree of conformity, o: partial conformity, -: low conformity

Source: IEF-STE

Tab. 3: Indicator results I

Regulatory, social and market aspects

Concerning these factors the programmes are partially homogeneous. The Norwegian CLIMIT and the German COORETEC are aware of these factors without explicitly demanding corresponding activities. In Norway, these topics are covered by another programme. But in case of Germany, funds for studies on public acceptance are available. CATO refers to communication activities involving research on public acceptance. In comparison, the UK CATs strongly supports in its tasks 8 and 9 regulatory and market framework activities as well as public awareness and information. Although regulatory approaches are national on the basis of the corresponding European Union directives, there is a need to analyse social and market aspects from a European perspective, as on the one hand market integration goes forward and on the other hand problems which may arise due to social acceptance of technologies in one country may have impacts on acceptance of the same technology in another country.

Value chain perspective

For CCS three of the four programmes clearly engage in technologies to enhance extraction of hydrocarbons. CATs, CATO and CLIMIT support development of advanced technologies for enhanced recovery of oil, gas and in case of the Netherlands coal-bed methane (EOR, EGR, ECBM). The German COORETEC is aware of the use of CO_2 as a production factor but does not explicitly support corresponding R&D. A reason is that Germany has only few opportunities to use EOR and EGR technologies. There is only partial degree of conformity concerning the value chain perspective.

Technology preference

Generally, the four programmes comprise a range of energy conversion technologies as well as CCS technologies (Tab. 4).

With respect to energy conversion there is only partial conformity of the programmes. The Norwegian CLIMIT focus is on gas power technology including different energy conversion technologies. The Dutch CATO concentrates on coal and gas conversion and fuel cells as well and on hydrogen but with major efforts on fuel cells and hydrogen taking place in other programmes. The UK CATs and the German COORETEC focus on steam cycle plants, gas turbines and coal IGCC, although the UK integrates development of CATs with hydrogen and fuel cells through HFCAT fund which provides support for prototype scale demonstration projects. In Germany, fuel cell activities are supported by its own programme which comprises R,D&D.

	Technology preference			**Carbon lock-in**	**Time-line**
	Conversion	Capture	Storage		
CATs	Steam cycle plants (boilers and turbines), gas turbines, gasification	Post-comb., pre-comb., oxy-fuel	Offshore gas fields	Capture-ready option	10 y
COORE-TEC GEOTECH-NOLOGIEN	Steam cycle plants (coal and gas) + GCC, IGCC coal	Post-comb., pre-comb. (IGCC + capture), oxy-fuel	Saline aquifers, onshore gas fields	not explicitly mentioned	long-term
EOS CATO	Advanced coal and gas conversion	Post-comb., pre-comb., oxy-fuel	Onshore gas fields, ECBM, minerali-sation	Post-comb.	EOS: long-term CATO: 4 y (2008) CAPTEC H 4 y (2009)
CLIMIT	Gas power technology, fuel cell	Post-comb., pre-comb. with H_2 production, membranes	Geological storage, EOR	Post-comb.	long-term
Programme Conformity	o	o	o	-	-

+: high degree of conformity, o: partial conformity, -: low conformity
Source: IEF-STE

Tab. 4: Indicator results II

Concerning CO_2 capture technologies, again there is only partial conformity of the programmes as they comprise all three pillars (post-combustion, pre-combustion, oxyfuel). In case of CATs, CATO and COORETEC there is no favourite technology, as they support post-combustion, pre-combustion and oxyfuel technologies as well, whereas the focus of CLIMIT is on post-combustion and pre-combustion (incl. hydrogen production). CLIMIT also points out membrane development. In Germany, R&D on membrane for all three pillars is supported by the Helmholtz-Gemeinschaft, which is the umbrella organization of national labs.

Referring to CO_2 storage again there is only partial conformity of the programmes. For storage offshore oil and gas fields, onshore oil and gas fields, onshore saline aquifers, coal seams and mineral storage are pointed out. Whereas CATs clearly favours offshore gas field storage, COORETEC and CATO focus on onshore gas fields. Additionally, CATO also studies mineralisation. But for Germany, the main pillar is storage in saline aquifers. The Norwegian CLIMIT put priority on storage of CO_2 in geological formations. Although there is only partial conformity with respect to kind of geological storage collaboration or joint programmes could be very useful. E.g. seismic studies, analysis of the diffusion of CO_2 in the underground formations or safety studies can be of interest for all countries irrespective of the different storage opportunities in the countries as this kind of studies can be regarded as basic R&D.

Carbon lock-in

The longevity of power plants prolongs the operation of technologies, not optimally designed for carbon mitigation, and thereby hindering rapid and large-scale absorption of low-carbon technologies. This effect is interpreted as carbon-lock-in [Brown et al., 2008, Foxon, 2006]. Retrofitting existing sites is regarded a technological option to partially escape carbon lock-in. For CCS technologies capture-readiness is a technological concept adjusting new coal power plants for future retrofit measures [Bohm et al., 2006, Bohm et al., 2007].

For this aspect, the programmes clearly demonstrate low degree of conformity. CATO and CLIMIT focus on post-combustion technologies which can be relatively easy used to retrofit existing fossil fuel power stations compared to pre-combustion and oxy-fuel technologies. COORETEC does not explicitly make reference to future handling of fossil fuel power stations operating without integrated carbon separation. Although it is not without controversy to define capture-ready plants the UK CATs actively promotes the development of these options. Although still no generally agreed definition of a power plant being capture-ready is available, the option of capture-readiness of fossil power plants is not primarily a technical question, which can't be solved. Reflecting the uncertainties with respect to basic framework parameters as e.g. primary fuel price assumptions, demand, residual technical lifetime of power plants, and carbon prices, but technological developments as well, it is an economic consideration to decide on new capture-ready power plants and power plant retrofit. Even in case that not all requirements of capture-readiness are fulfilled, it is basically an economic question to invest in retrofit.

Presently, the discussion may be summarized as follows: On the one hand capture-readiness is fulfilled if the power plant assigns adequate area for retrofitting existing power plants but without adjusting any technical components. Therefore, the power plant design enables to produce with maximum efficiency until retrofitting takes place. Retrofitting then results to a design with less efficiency than maximum efficiency of an integrated power plant with carbon capture. On the other hand capture-readiness is fulfilled if plant components are adjusted for later retrofitting. This results to less efficiency for both the pre-retrofit phase and the after-retrofit case as well, but total investment cost may be less also.

Time-line

Finally, concerning the time-line the programmes again demonstrate low degree of conformity. Whereas COORETEC and CLIMIT cover long-term R&D, CATO and CAPTECH are limited to 5 years, but a successor programme is being prepared (2009-2013). The short-term nature of CATO and CAPTECH refer to its project character, but the basic Dutch energy programme is long-term. CATs is limited to 10 years.

5.2 Resulting thematic priorities for FENCO-ERA initiatives

The analysis adds up to one indicator with high degree of conformity, which is the strategic focus that allows using a broad range of measures to reduce CO_2. For the majority of indicators the programmes are characterised by partial conformity. Two indicators characterise the programmes as being non-conform.

Out of the indicators with partial conformity collaboration and joint programmes on two aspects are regarded to easily increase the benefit of national programmes. Firstly, for storage analysis and assessment, i.e. seismic studies, diffusion studies and safety analysis, it is very useful to collaborate irrespective of the special storage opportunities of the countries as these studies might be regarded as basic R&D, producing general results necessary for any kind of geological storage. Secondly, for regulatory, social and market aspects, due to market integration and cross-national social attitudes a European perspective is necessary.

The carbon lock-in problem characterises the programmes to be non-conform. Collaboration on economic modelling of potential of different technology routes, depending on country-specific basic conditions and regulations are necessary to indentify technology areas where R&D synergies result to maximum benefit.

5.3 Approval and selection procedures on national levels[2]

This paper provides an overview of current practices in the selection procedures adopted by the four programmes chosen for the study. The selection procedures will cover two steps: (i) the call for proposals and (ii) the evaluation process of the proposals.

The input of this paper is based on the answers gathered in the database developed by FENCO-ERA, Work Package 2 “Information exchange on national R&D fossil fuel programmes” (http://www.fenco-era.net).

The specific features and important stages of each national selection procedure will be incorporated in this paper. This mapping aims to identify the common characteristics and different approaches in order to facilitate the design of a common selection procedure for joint and future trans-national R&D activities in the field of European Fossil ERA.

Form and frequency of calls

The programmes involved in this study apply competitive approaches to the selection of projects with a clear structure, timetable and end-dates, once or twice a year (Table 5). In general, competition favours quality, and diversity in applications and project execution as well as offers transparent and fair decision making. But the rigidity of procedures may exclude the weaker consortium in terms of capabilities or resources, which may need special attention. In Germany, there is a possibility to submit applications throughout the whole year without a fixed closing date. The remaining three programmes (UK, NL and N) define topics for research and then put out restricted periodic invitations to tenders.

It appears that the majority of the programmes use one type of call for proposals rather than several, so as to ensure simplicity and consistency of administration. Only NL and UK adopt a mixture of types of call for proposals, according to the different needs of funding. For example, a biannual, fixed-term call for proposals is employed for R&D projects while a continuously open call is used for demonstration projects.

[2] The following section takes into account the work of Work Package 4 on deliverable 4.2.1 „Evaluation procedure with common criteria“.

Programme	Selection method	Frequency of calls	Application process	Evaluation methods	Programme monitoring
CATs	Call for proposals	1/y call for demonstrat ion plants, 2/y for R&D	Two stages	Assessors drawn from a panel of experts	ACCAT APGTF
COORETEC	Continuous open call	Open call for R&D	Single stage*	Evaluation of proposals by Project Manage-ment Team	COOERETE C Advisory Council
CATO/ CAPTECH	Call for tender	3/y	na	Pro-gramme Secretariat and external experts	na
CLIMIT	Call for proposals	Open call for demonstrat ion plants, 2/y for R&D	Single stage	Pro-gramme Secretariat and external experts	na

*Discussion starts with proposers on the basis of outlines before submission of full proposals
na: not available
ACCAT: CATs Advisory Council
APGTF: Advanced power Generation Technology Forum

Source: Questionnaire, FENCO-ERA Work Package 2

Tab. 5: Form of the call and frequency

The choice between open and fixed-term calls for proposals should be considered. Open calls permit programmes to respond immediately to emerging research needs and secondly, they avoid a work overload at the call deadline. However, open calls may weak competition at undesirable levels and also reduce volumes of applications to the point that the programme management can not support a suitable spread of projects.

On the other hand, fixed-term calls for proposals increase competition among applicants and assure consistent and efficient processing of proposals but may not correspond well to research opportunities.

Application procedure

The large majority of fossil fuel R&D programmes apply the single-step procedure and only UK uses a two-stage approach. A two-step procedure has a double advantage. It gives applicants more time to prepare high quality proposals in terms of partnership and content. It also allows the programme manager to assist consortia through the preparation process, offering them targeted assistance and guidance. The success rate is thus usually higher. Conversely, because this procedure entails greater effort, it is more advisable for more complex collective research programmes where grants are substantial.

A single-step procedure has the advantage of being simpler to administer by the programme manager (shortening the selection time and the overall management). It is more suitable for simpler and smaller collective research programmes and when grants are lower.

Methods of evaluation

The project evaluation is based on the selection of the evaluators as well as the evaluation procedures and criteria applied. In most programmes each proposal is considered by at least two evaluators but it is also possible that three or more individual evaluators are involved. Typically, evaluators are selected from an established database of experts.

Different roles are performed by:

- The programme management agency; which usually assists the applicants over the submission phase providing only general information about the call or administrative support (completing forms, providing legal statements etc.). In addition, the management agency may be responsible for carrying out the eligibility check, assessing proposal content and budget up to the technical evaluation. For COORETEC, the Project Management Team itself is also responsible for the evaluation of the proposals.

- The programme owner; which is responsible for the proposal selection and takes the final funding decision but often implementing the recommendations of the programme managers / external experts.
- The external evaluators; which are usually selected jointly by the programme manager and programme owner. The independent evaluators are selected based on their backgrounds/ experience - technological, scientific and economic - to contribute particularly to the technical assessment of proposals. In-house experts are chosen within the programme owner and management staff and are involved in all evaluation phases including the technical element, like in Germany.

Evaluation criteria

In general, criteria used for the selection of projects are often the same from programme to programme. The main proposal evaluation criteria are:

- relevance to the programme objectives
- scientific quality of the proposal
- innovation potential;
- quality & experience of consortium
- quality of approach / work plan
- quality of dissemination activities
- socio-economic impacts and, finally;
- project management quality

5.4 Resulting procedural approaches

Each programme has its specific practices and practices how the programs calls are defined and organized, in more specifically, the form of the calls, the evaluation process of proposals and the recruitment of evaluators.

The timescales of each national evaluation procedure should also be considered as a critical factor for the implementation of a joint call since the timing should be in line with the national schedules.

The co-operation model that will be adopted by the partners concerning the level of integration will define the required changes to the national administrative routines. However the existing differences among the FENCO-ERA fossil fuel R&D

programmes appear not to be major barriers to develop an evaluation procedure with common criteria. This has already been demonstrated by the adaptation of most of the funding organisations' rules to comply with the procedure of the 1st FENCO-ERA Joint Call which is based on common evaluation criteria and evaluation of proposals both at national and FENCO-ERA level.

6. Summary and Conclusion

The United Kingdom, Germany, the Netherlands and Norway run important European R&D programmes for the development of carbon abatement technologies. For other European countries there exist further national programmes, as for the United States, Canada, Australia and Japan. On the one hand there is significant thematic overlap between the national European programmes and on the other hand there is lack of critical mass of individual programmes. Consequently, inefficiencies arise, which can be removed through coordinating European research expenditures on a bilateral or multilateral level.

The study examines the UK CATs, the German COORETEC and GEOTECHNOLOGIEN, the Dutch CATO and CAPTECH and the Norwegian CLIMIT programme. It comes up with an indicator set, which characterises the R&D programmes either to be of high degree of conformity, of low degree of conformity or of nonconformity. With *storage analysis and assessment* and *regulatory, social and market aspects* it identifies two indicators where the programmes are to be characterised as partial conform, but where collaboration and joint actions are regarded to easily increase the benefit of national programmes.

The carbon lock-in problem characterises the programmes to be non-conform. Collaboration and joint actions with respect to economic modelling of the potential of different technology routes keeping in mind country-specific framework conditions and regulation approaches are necessary to indentify technology areas where R&D synergies result to maximum benefit.

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