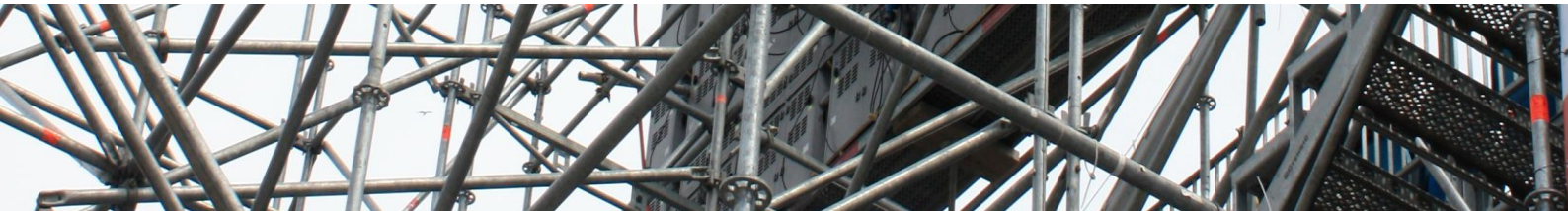
OXFORD RESEARCH

THEMA CONSULTING GROUP

elementenergy

Evaluation of the CLIMIT Programme



Oxford Research was established in 1995 and is part of the Oxford Group. The company is a full service research company offering research and management consultancy services within the areas of international development, science & innovation, business development and welfare issues.

Oxford Research also carries out evaluations (especially management evaluations of programmes and organizations) and analyzes, and offers consultancy on strategy. The research company combines academic depth, excellence in communication and strategic understanding. Currently Oxford Research has branches in Denmark, Norway and Sweden, and has wide experience in conducting European research projects.

Oxford Research is also research partner of the European Network for Social and Economic Research (ENSR). Our staff experience in coordination of multi-country projects was confirmed by other partners as Oxford Research holds the position as president of the Network. Covering 32 countries, the network works with international policy studies.

See our website for more information: http://www.oxford.no/

Element Energy Ltd Element Energy is a dynamic and growing strategic energy consultancy. We specialize in the intelligent analysis of low-carbon energy, and help our clients (in the sectors of transport, power generation and buildings) to understand low-carbon energy.

Over the past eight years we have gathered a team of experts based in London and Cambridge, who provide robust technical insights into low-carbon energy markets.

See our website for more information: http://www.element-energy.co.uk/

THEMA Consulting Group is a consultancy with expert competence within advice and analyses for the energy and electricity industry. Our business idea is that deep insight into energy and climate policies combined with in-depth understanding of market dynamics is crucial in order to provide excellent business and strategy advice to energy market agents, authorities and industry associations.

See our website for more information: http://www.t-cg.no/?L=E

Oxford Research:

NORWAY

Oxford Research AS
Kjøita 42
4630 Kristiansand
Norge
Telefon: (+47) 40 00 57 93
post@oxford.no

DENMARK

Oxford Research A/S
Falkoner Allé 20, 4. sal
2000 Frederiksberg C
Danmark
Telefon: (+45) 33 69 13 69
Fax: (+45) 33 69 13 33
office@oxfordresearch.dk

SWEDEN

Oxford Research AB
Box 7578
Norrlandsgatan 12
103 93 Stockholm
Telefon: (+46) 702965449
office@oxfordresearch.se

BELGIUM

Oxford Research
c/o ENSR
5, Rue Archimède, Box 4
1000 Brussels
Phone +32 2 5100884
Fax +32 2 5100885
secretariat@ensr.eu

Title:	Evaluation of the CLIMIT programme
Contractor:	Gassnova SF
Project period:	April – september 2011
Project leader:	Tor Borgar Hansen
Authors:	From Oxford Research AS: Tor Borgar Hansen, Bjørn Brastad, Aase Marthe J. Horrigmo and André Flatnes From Element Energy Ltd: Harsh Pershad From Thema Consulting Group: Eivind Magnus
Short summary:	Our main conclusions are that the CLIMIT Programme has been very important in stimulating relevant R&D-activities and that there have been important achievements, both among the Gassnova- and RCN-funded CLIMIT-projects. Many interesting ideas and prospects for further R&D activities have been developed. Some of the research activities are within areas which could turn out to be next generation technologies with applications also outside the CCS value chain. CLIMIT-funded research has 'narrowed', rather than closed the knowledge gaps and has provided options for improved performance of CCS systems. Whilst causality is difficult to prove, the steady progress made by Norwegian stakeholders working with international partners may have reassured policymakers and businesses on the likely viability of CCS, and this has helped support the case for financing CCS demonstration. Therefore, the CLIMIT Programme can be said to have made the prospects of global CCS deployment more likely than would have been the case without, and maintained Norway's position in many aspects of CCS.

Foreword

The unprecedented challenges of climate change demand unprecedented solutions. In the 1990s, Norwegian industry led the world through initiating the Sleipner project to capture and permanently store CO2 from the atmosphere. Norway has since maintained the lead in developing carbon capture and storage technology, active in research, development and demonstration. The CLIMIT Programme, administered by Gassnova and the Research Council of Norway, is arguably the most concentrated and systematic endeavour worldwide to close CCS knowledge gaps, reduce risks and costs, and improve the performance of CCS.

With such a pioneering programme, it is useful to reflect on the achievements over the first phase.

In March 2011 the task of evaluating the CLIMIT Programme was assigned to Oxford Research AS, Thema Consulting Group AS and Element Energy Ltd by Gassnova SF.

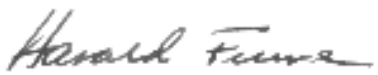
The purpose of the evaluation has been to make a systematic review of the achieved results from the CLIMIT Programme and assess these against the programme's objectives.

In the first phase of the CLIMIT Programme, 199 projects have been funded across all aspects of CO2 capture, transport and storage. Whilst considerable further work is still required, the analysis in this report demonstrates considerable progress has been made. Norway has brought eventual commercial CCS deployment worldwide closer to reality. The detailed analysis described in this report provides valuable understanding on where the achievements have been most significant. The results are potentially of relevance globally as countries seek to support technology development

We would like to thank all those who contributed to this evaluation – both in the interviews, in the survey and in the technical audit. These include managers of projects financed under the CLIMIT Programme as well as representatives from the authorities, agencies, NGOs, programme managers and members of the programme's Board.

A special thank you to our main contact persons from the CLIMIT secretariat: Mr. Aage Stangeland from the Research Council of Norway and Mr. Ståle Aakenes from Gassnova SF. We are grateful for their provision of huge amounts of information and for the smooth co-operation. We sincerely hope that our reports and the tailor-made indicator system for forthcoming evaluations and monitoring may be of use to the CLIMIT Programme when its future course is being shaped.

Kristiansand, October 2011



Harald Furre

CEO

Oxford Research AS

Index

List of tables

List of figures

Chapter 1. Executive summary

1.1 Conclusions

1.1.1 Effort and activities

To what extent have the projects portfolio (effort and activities) been relevant for achieving the overall objectives of the Program?

The project portfolio is relevant in terms of achieving the objectives of CLIMIT. The projects have targeted the entire range of activities from scientific outputs to commercialization. Although the majority of projects have focused on scientific activities, around half of them have ambitions of launching new commercial products and services and new processes. These have a focus on international CCS activity as well as Norway-specific issues.

The CLIMIT Programme is still in an early phase. This is reflected in our results. Except for scientific publications, no differences in targeted deliverables are found when comparing projects funded by the Research Council of Norway (RCN) or Gassnova.

In terms of balance within the CLIMIT project portfolio, there seems to be issues regarding the balance between, on the one hand research- and demonstration projects, and on the other hand technology areas. First, the question arises whether there should be a clearer divide between research and demonstration activities in the CLIMIT Programme. As the technology develops, it must be discussed whether the RCN-funded projects should become more oriented towards (basic) research activities and whether Gassnova should strive to focus more on pre-commercial projects which aim at prototyping, piloting and demonstration as well as more pure commercial activities. Although Gassnova and the RCN have established a secretariat for the programme staffed with personnel from both organizations, this would allow for further specialization of skills within the organizations. Second, there are also few basic research projects, which are often spurred by findings of other projects. This must also be discussed in the light of the fact that HSE-related topics seem to be underrepresented in the project portfolio. Third, perhaps too little emphasis has been placed on the transportation area. This is an area where Norwegian industry should have a competitive advantage.

There is much cooperation in the projects; however they have not opened up for very many new partners entering the programme. This may indicate that most of the relevant Norwegian partners are already participating in the programme. Another reflection is that the programme may have contributed to strengthening already existing relations. The recognition of the importance of international cooperation seems to have increased over time, not least because of the perception of increased complexity in the CCS-area.

In sum, CLIMIT projects address all of the gaps discussed in chapter 3 to varying degrees, consistent with the opportunity to make an impact given the evolving priorities of Norwegian and wider stakeholders.

1.1.2 Results and effects

To what extent can results be documented in terms of scientific publications and commercialization of technologies?

Have the projects contributed to filling any technology gaps?

The CLIMIT project portfolio has yielded results that contribute to the programme's objectives in various areas. Most notably, we find that approximately half of the projects which have had ambitions to do so, have already submitted patent applications, obtained patents and developed prototypes. New processes have already been developed by 1/3 of the projects which set out to do so.

While some projects already have started, or will start shortly, the process of commercialization, others have developed new knowledge or technology and have yet to start the process of commercializing their technology. Others again are in a very early stage and have not developed new knowledge or technology yet. Thus, it is highly uncertain whether

or not these projects have a commercial potential at this stage.

The CLIMIT Programme has so far only to a very limited degree contributed to new company start-ups, new product lines or businesses or definition of new standards. Moreover, among those that originally had the ambition to commercialize their technology, the success rate is low when compared to the success rate in knowledge and technology development. However, the development of new processes has both been targeted in many projects and has a higher success rate. Except for scientific publications, no differences in achieved deliverables are found when comparing the RCN-funded projects with those funded by Gassnova.

Another important finding of this study is that partners are regarded as very important for achieving results, both in the scientific and commercial area.

1.1.3 Additionality

Would the activities have been carried out without the program?

The CLIMIT Programme has not only been a precondition for financing projects, but has also stimulated the research institutions and the industry to develop new ideas, which would not have been developed without the programme.

In general the CLIMIT Programme has very high additionality, as confirmed by interviews and surveys. Almost ¾ of the respondents claimed that the financial resources offered by CLIMIT had a high influence on their ability to carry out the project. This view was further strengthened by the very low number of respondents that said that finding alternative sources of finance would have been easy. The picture is somewhat more nuanced when the results are broken down on project type. In general, the project leaders from the Gassnova-funded projects state that it is harder to find alternative sources of financing than what the project leaders from the RCN-funded projects state.

While the program overall has had a high influence on project deliverables, the patent area does not fit into this picture. Here the projects that have targeted this, state that CLIMIT-support only has had a medium to no influence on the outcome.

1.1.4 Main conclusions

Our main conclusions are that the CLIMIT Programme has been very important in stimulating relevant R&D activities and that there have been important achievements, both in the projects funded by Gassnova and those funded by RCN. Many interesting ideas and prospects for further R&D activities have been developed. Some of the research activities are within areas which could turn out to be next generation technologies with applications also outside the CCS value chain.

CLIMIT-funded research has narrowed the knowledge gaps and provided options for improved performance of CCS systems. Whilst causality is difficult to prove, the steady progress made by Norwegian stakeholders working with international partners may have reassured policymakers and businesses on the likely viability of CCS, and this has helped support the case for financing CCS demonstration projects.

Therefore, the CLIMIT Programme can be said to have made the prospects of global CCS deployment more likely than would have been the case without, and maintained Norway's position in many aspects of CCS.

1.2 Reflections

Based on the main conclusions of this evaluation, two dimensions are recommended for further discussion among CLIMIT stakeholders.

1.2.1 Potential for commercialization?

Even the most ardent CCS enthusiasts would agree that despite significant progress in every area identified on the technology gaps slide in Norway through CLIMIT, it is difficult to escape the conclusions that (i) nearly all the same knowledge gaps exist today, albeit these are much better constrained, (ii) the challenges of deploying CCS technology remain substantial; and (iii) a sustained research, development and demonstration activity is still required to realize the benefits that CCS deployment could bring. This evaluation contains findings indicating that the Norwegian industry, though better positioned than previously is by and large not positioned to follow up every new CCS technology development identified in under CLIMIT. There are many factors supporting

such a hypothesis. One is that there are giant international actors already in the market place which would be hard to compete with for smaller companies, in particular in the carbon capture part of the value chain. Another could be that the commercial risks involved in CCS technology ventures are generally too high for many Norwegian actors, since they expect that there is a long way to go before CCS is likely to be commercial. The possibility remains that it never would. A third factor could be that demonstration projects generally are capital intensive and the commercial actors cannot afford the financial risk involved. However there are exceptions. The most frequently mentioned in the interviews are Aker Clean Carbon, Statoil and Veritas which have good positions for participating in various market segments in a future CCS industry. Aker Clean Carbon is for example a participant in the proposed post-combustion capture project at Scottish Power's Longannet Power Station, which is expected to be operational starting between 2015 and 2020.

There is no doubt that Norwegian research institutions are at the research forefront in many technologies within the CCS value chain, which partly is the merit of the CLIMIT Programme. That is a significant achievement. However, since CCS is far from being commercial and because the uncertainties regarding the future of CCS as a main technology option in the transition to a sustainable energy future, the question for Norwegian Authorities would be how to keep and develop the competence built up so far. The commercial drivers needed to bring the activity further without significant public support are to a large degree not there yet. This, combined with the lack of Norwegian companies able or willing to involve own resources in technology projects will be, as we see it, one of the main challenges for the future. Therefore, CLIMIT stakeholders should discuss the possibility of opening up the programme for international participation.

Even though the technology gaps have been reduced, CCS technology is still immature and there are several areas where the need for more research is significant. There are also areas where the industry could be reluctant to participate. For projects where industry financing is a precondition, industry hesitation could in some cases be an obstacle for developing new ideas and concepts developed in the research institutions. The Program should therefore consider if it is possible, within the framework of the ESA-rules, to support some development and demonstration projects with lower and even without industry financing.

Research, Development and Demonstration activity in CCS is occurring in many countries and in the EU bloc as a whole. Other countries and institutions are joining the CCS community, eager to share in any benefits from being early developers or adopters of CCS technology. In some cases this has led to duplication, so that the case for additionality from CLIMIT will become harder to substantiate in the future with increasing competition. However rather than being viewed as wasteful, it is possible that this approach encourages innovation.

IEA and other estimates suggest that very large take up of CCS technology would occur by the 2030s. Given this long lead time, it is not clear whether the early leads developed by Norway's academic and commercial institutes will be sustained into the 2030s and beyond when the growth of CCS could take off.

1.2.2 Risk profile of CLIMIT project portfolio

In general, it is necessary to find sound balance between the projects' additionality and the results obtained. High additionality is of no value if the projects fail, i.e. a reasonable level of risk must be identified. In regard of CLIMIT, it is only one of the surveyed projects that state that the project has proven that the technological path is not promising. This result can be interpreted in several ways:

- The CLIMIT Programme has worked actively to raise the quality of the projects, resulting in a very high success rate. This is achieved through an active dialogue with applicants in the application process.
- The CLIMIT Programme is too risk-averse. This is related to two points. First, even if the level of risk is higher, the expected rate of return might be higher. Second, to enhance future development, it may be important to clarify that the path doesn't work to a larger degree. This is related to a discussion of the scope of the project portfolio. Is the scope wide enough? As pointed out above, the technology gaps are bigger than anticipated, making it hard to "pick the winners". This might call for a broader portfolio of projects.
- Given the fact that many projects are still ongoing and the programme may be labeled as being in an early phase, it could also be argued that it is premature to judge the risk profile of the programme.

It is not difficult to find some merit in all three perspectives. However, given the fact that both the CLIMIT Programme and technology development in CCS in general is still in an early phase, we believe that the project portfolio should be wider, rather than narrower. Regardless of which perspective is chosen, we believe this is a key question in the development of CLIMIT.

1.2.3 Projections for CCS

Through the CLIMIT Programme, a large amount of Norwegian RD&D activity is concentrated on CCS. It is worth a final remark that stakeholders should be aware that technology growth is always difficult to predict and impossible to guarantee. Whilst there are grounds for some optimism from this evaluation, 'optimism bias' must be avoided.

There are a number of long term outcomes (e.g. 2050) for the CCS industry:

- CCS and the related technologies funded by CLIMIT contribute a major role to meeting climate objective, partly through Norwegian activity, and Norway industry shares in the multi-trillion dollar market that ensues.
- CCS contributes a major role to meeting climate objectives, but Norwegian industry is unable to profit from CCS, perhaps because 'winning' technologies or supply chains are developed elsewhere. In this case mankind in general still benefits, but Norwegians may have paid a disproportionate price to help move CCS along.
- CCS contributes only a minor role in reducing world CO_2 emissions, perhaps because world CO_2 emissions are not controlled or because other approaches prove more viable. In this scenario, and even if Norwegian industry plays a major role in the CCS market that does exist, it may have been more profitable for Norway to invest resources elsewhere.

It will probably not be apparent for at least another decade which of these outcomes is most likely for CCS and Norway's contribution to CCS.

Chapter 2. Norsk sammendrag

2.1 Konklusjoner

Vår hovedkonklusjon er at CLIMIT-programmet har vært svært viktig i stimuleringen av relevante FoU-aktiviteter og at det har vært oppnådd viktige resultater, både blant Gassnova-finansierte prosjekter og prosjekter finansiert av Norges Forskningsråd (NFR). Det har blitt utviklet mange interessante ideer og framtidsutsikter for videre FoU-aktiviteter. Noen av forskningsaktivitetene er innenfor områder som kan vise seg å være neste generasjons teknologier med mulighet for anvendelser også utenfor verdikjeden for CO_2-håndtering.

CLIMIT finansiert forskning har både innsnevret kunnskapsgapet og frembrakt alternativer for bedre ytelse i CO_2-håndteringssystemer. Til tross for at det er vanskelig å påvise klare årsakssammenhenger, så kan den stabile fremgangen hos norske interessenter som jobber med internasjonale partnere ha gitt politikere og bedrifter rundt om i verden ny tiltro til levedyktigheten til CO_2-håndtering. Dette har styrket oppslutningen rundt finansiering av CO_2-håndtering-demonstrasjonsaktiviteter.

På denne bakgrunn kan CLIMIT-programmet sies å ha gjort utsiktene for global utbredelse av CO_2-håndteringsteknologi mer sannsynlig enn det som hadde vært tilfellet uten programmet. Programmet har også bidratt til å opprettholde Norges posisjon i mange områder innenfor CO_2-håndtering.

I det følgende vil vi presentere og reflektere over de viktigste funnene i denne evalueringen med utgangspunkt i hovedproblemstillingene i evalueringen.

2.1.1 Innsats og aktiviteter

Prosjektporteføljen er relevant i forhold til å oppnå målene i CLIMIT. Prosjektene er rettet mot hele spekteret av aktiviteter; fra vitenskapelige resultater til kommersialisering. Selv om de fleste prosjektene har fokusert på vitenskapelige aktiviteter, har rundt halvparten av dem ambisjoner om å lansere nye kommersielle produkter og tjenester samt nye prosesser. Disse har også fokus på både internasjonalt rettede CO_2-håndteringsaktiviteter så vel som mer særnorske spørsmål.

CLIMIT-programmet er fortsatt i en tidlig fase. Dette gjenspeiles i våre resultater. Med unntak for vitenskapelige publikasjoner, er det ikke funnet forskjeller i målrettede leveranser mellom prosjekter finansiert av NFR og Gassnova.

Når det gjelder balansen innad i CLIMITs prosjektportefølje, synes det å være et avklaringsbehov mellom forsknings -og demonstrasjonsprosjekter på den ene siden og teknologiområder på den andre siden.

For det første kan det stilles spørsmålstegn ved om det bør være et klarere skille mellom forsknings- og demonstrasjonsaktiviteter i CLIMIT-programmet. Etter hvert som teknologien utvikler seg, må man diskutere om prosjekter finansiert av NFR bør bli mer orientert mot (grunnleggende) forskningsaktiviteter og hvorvidt Gassnova bør tilstrebe seg på å fokusere mer på pre-kommersielle prosjekter som tar sike på prototyper, pilotering og demonstrasjonsaktiviteter samt mer rene kommersielle aktiviteter. Selv om Gassnova og Forskningsrådet har etablert et sekretariat for programmet bemannet med personell fra begge organisasjonene, vil dette gi rom for ytterligere spesialisering innenfor organisasjonene. Oppgaver som prosjektutvalg, håndtering av pågående prosjekter og evaluering krever ulike sett av kompetanse og erfaring avhengig av hvilken type prosjekter det gjelder.

For det andre så er det et kun et fåtalls grunnforskningsprosjekter, som ofte har sitt utspring i funn fra andre prosjekter. Dette er også noe som må diskuteres sett i lys av at HMS- relaterte temaer synes å være underrepresentert i prosjektporteføljen.

For det tredje er det muligens for blitt lagt for lite vekt på transportområdet. Dette er et område der norsk industri burde ha konkurransefortrinn.

Det er mye samarbeid i prosjektene, men de har likevel ikke ført til mange nye samarbeidspartnere i programmet. Dette kan tyde på at de fleste av de aktuelle norske partnerne allerede deltar i programmet. En annen refleksjon er at programmet kan ha bidratt til å styrke allerede eksisterende relasjoner. Erkjennelsen av betydningen av internasjonalt samarbeid synes å ha økt over tid, ikke minst på grunn av erkjennelsen av økt kompleksitet innenfor CO_2-håndteringsområdet.

Oppsummert kan man si at CLIMIT prosjekter i større eller mindre grad adresserer teknologigapene som er diskutert i kapittel 4 i denne rapporten. Dette er i samsvar med de mulighetene til å gjøre en forskjell sett ut fra hvordan prioriteringer gjort av norske og andre interessenter er i ferd med å utvikle seg.

2.1.2 Resultater og effekter

CLIMITs prosjektportefølje har gitt resultater som bidrar til programmets mål på ulike områder. Vi finner at omtrent halvparten av prosjektene som har hatt ambisjoner å sende inn patentsøknader, ta patenter og utvikle prototyper allerede har oppnådd dette. Nye prosesser har allerede blitt utviklet i en tredjedel av prosjektene som har hatt dette som mål.

Mens noen prosjekter allerede har startet eller vil starte om kort tid med kommersialiseringsprosesser, har andre utviklet ny kunnskap eller teknologi, og har ennå til gode å starte med kommersialiseringsprosessen for deres teknologi. En tredje gruppe av prosjekter er i en veldig tidlig fase og har ikke utviklet ny kunnskap eller teknologi ennå. Dermed er det høyst usikkert hvorvidt disse prosjektene har et kommersielt potensiale på dette stadiet.

CLIMIT-programmet har så langt bare i svært begrenset grad bidratt til nye bedriftsetableringer, nye produktlinjer eller bedrifter eller definisjon av nye standarder. Dessuten er det slik at blant prosjekter som opprinnelig hadde ambisjoner om å kommersialisere sin teknologi, så er suksessraten – ikke uventet - lav i forhold til suksessraten for prosjekter som kun har som målsetning å utvikle ny kunnskap og teknologi. Imidlertid har prosjekter som har hatt som målsetning å utvikle nye prosesser en høy grad av suksess.

Med unntak for vitenskapelige publikasjoner, er det ingen forskjeller i oppnådde resultater mellom prosjekter finansiert av NFR og Gassnova.

Når vi ser på konkrete resultater innen teknologiutvikling, har det blitt oppnådd svært positive resultater innen viktige områder som:

- Aminteknologi; det er blitt dokumentert en vesentlig reduksjon i energiforbruk
- CO_2 lagring; flere prosjekter har sørget for bedre kunnskap når det gjelder CO_2-oppførselen i reservoarer og det er utviklet metoder for overvåking av CO_2
- Miljøspørsmål; CLIMIT prosjekter har gitt en bedre forståelse av luftforurensning fra aminprosesser
- Retningslinjer for bedre praksis som også gir et bedre grunnlag for sertifisering av CO_2-håndteringsteknologi

Dessuten er det blitt identifisert lovende resultater innenfor områder som:

- Overvåkningen av CO_2 i reservoarer
- Kjemisk "looping"
- Forbrenningsteknologi
- Membranteknologi

Et annet viktig funn i denne evalueringen er at partnere synes å være svært viktige for å oppnå resultater. Dette gjelder både innenfor det vitenskapelige og det kommersielle området.

CLIMIT-programmet har også gitt resultater i forhold til universitetenes utdanningsportefølje. For det første har programmet ført til mer enn 50 doktorgrader(PhD) og Post-doc stillinger. For det andre har det blitt utviklet nye bachelorkurs som resultat av CLIMIT-prosjekter både ved Universitetet i Bergen og Høgskolen i Telemark. For det tredje tilbyr universitetene i Oslo og Bergen samt Norsk teknisk-naturvitenskapelige universitet (NTNU) CO_2-håndteringsrelevante kurs på masternivå og PhD-nivå.

Samlet sett er det vår oppfatning at CLIMIT-programmet har bidratt til en akselerasjon av CO_2-håndteringsteknologi. Dette er oppnådd gjennom utvikling av kunnskap på viktige områder og ved å redusere teknologigap. Selv om gapene har vist seg å være større enn opprinnelig antatt, det vil si at det tidshorisonten før CO_2-håndteringsteknologi blir kommersielt attraktiv har økt siden CLIMIT-programmet startet, betyr ikke dette at programmet i seg selv er mindre relevant. Tvert imot, vi ser ingen grunn til at CLIMIT ikke bør videreføres.

2.1.3 Addisjonalitet

CLIMIT-programmet har ikke bare vært en forutsetning for finansiering av prosjekter, men det har også stimulert forskningsinstitusjonene og industrien til å

utvikle nye ideer som ikke ville ha blitt utviklet uten programmet.

Generelt sett oppviser CLIMIT-programmet svært høy addisjonalitet, noe som bekreftes gjennom intervjuer og spørreundersøkelsen. Nærmere ¾ av respondentene hevder at de økonomiske ressursene som tilbys av CLIMIT har hatt stor betydning for deres evne til å gjennomføre prosjektet. Dette funnet styrkes ytterligere gjennom et svært lavt antall respondenter som mener at det ville ha vært enkelt å finne alternative finansieringskilder. Imidlertid ser det ut til at respondentene som har mottatt støtte fra NFR er av den oppfatning at det er noe lettere å finne alternative finansieringskilder enn respondentene som representerer Gassnova-finansierte prosjekter. Dette skyldes sannsynligvis størrelsen i prosjektene.

Programmet har generelt hatt stor betydning for prosjektenes resultater på de aller fleste områder. Et unntak er patenter. Representanter for prosjektene som har hatt patentering som målsetning rapporterer at CLIMIT-støtten kun har hatt middels eller ingen innflytelse på deres oppnådde resultater.

2.2 Resultater fra teknisk revisjon

Omfanget av vitenskapelige publikasjoner og PhD/post-doc-kvalifiserte personer som har sitt utspring i CLIMIT-programmet, har gitt en viss kvantitativ innsikt i fremdriften av de CLIMIT- finansierte prosjektene. Selv en overflatisk vurdering av prosjektlisten som er finansiert av CLIMIT i løpet av de siste årene, avdekker en betydelig bredde av utforskede temaer. Prosjektene adresserer nesten samtlige problemstillinger som er relevante for utbredelsen av CO_2-håndtering, både i Norge og internasjonalt. Det store flertallet har vært rettet mot fangst og lagring. I tråd med de forventede høye kostnadene og de respektive utfordringer i forhold til fangst og lagring, synes dette fornuftig.

Historisk sett har forsknings- og utviklingsinvesteringer (FoU) i lavkarbon teknologier vært uforutsigbare. Da CLIMIT-programmet ble etablert var det usikkerhet knyttet til hvorvidt andre land ville etablere egne FoU programmer innenfor CO_2-håndtering. I praksis har det vist seg at andre land har arbeidet med CO_2-håndtering, og at internasjonalt forskningssamarbeid innen CO_2-håndtering er svært utbredt.

Mange sider ved de norske prosjektene som er undersøkt i detalj i denne tekniske revisjonen kan hevdes å være i verdensklasse, spesielt når vi ser på områder der det finnes internasjonale forskere som også arbeider med lignede problemstillinger. En god indikasjon på dette er også den høye norske deltagelsen på internasjonale fagkonferanser.

Når man tar i betraktning de tre prosjektene som ble undersøkt nærmere i den tekniske revisjonen, har disse gjennomført mesteparten av sin aktivitet i tråd med deres opprinnelige planer. I de tilfeller der det foreligger avvik fra opprinnelige planer, har arbeidet allikevel vært i samsvar med CLIMTs målsetninger og behov i den gryende CO_2-håndterings- industrien har blitt ivaretatt. I mange tilfeller indikerer publikasjoner og interne rapporter at viktige milepæler er nådd, til tross for at to av prosjektene ikke var fullført på evalueringstidspunktet. I disse tilfellene er våre vurderinger basert på framdriftsrapporter.

Forskningen som er gjennomført i SOLVit- og BIGCO2 prosjektene har påvist at ulike fangstkonfigurasjoner er teknisk gjennomførbare. Det er imidlertid fremdeles en lang vei å gå før disse er kommersialiserbare da kostnadene fortsatt er for høye. Delvis er dette, slik som utfordringene assosiert med karbonfangst, nå langt bedre forstått. Det samme gjelder utfordringene knyttet til skalerbarhet. De etablerte metodene og utstyret for membranproduksjon, simulering og kostnadsanalyse, samt testing av løsemidler, bør være nyttige i en stund fremover, og vil sannsynligvis fortsette å være tiltrekkende i forhold til internasjonalt samarbeid. Det foreligger så langt ingen bevis på at det endelige målet for BIGCO2, som er en kombinasjon av 50 % kostnadsreduksjon, 90 % fangstrate og 7 % energistraff, er nådd. Prosjektets tidsrammer åpner imidlertid for at disse målsetningene kan oppnås på et senere tidspunkt. Den tekniske revisjonen har ikke lykkes i bringe på det rene hvorvidt det å samle såpass forskjellige delprosjekter eller arbeidspakker under "BIG"-paraplyen vil forbedre forskningskvaliteten. Imidlertid har dette grepet ført til økt frihet for prosjektlederne til å (re)allokere ressurser for å kunne imøtekomme endring i prioriteringer, kapasitet og finansiering. Prosjektlederen for BIGCO2 har bekreftet at en rekke endringer i prosjektets målsettinger og leveranser ble bestemt gjennom diskusjoner i komiteer.

I forbindelse med SSC-RAMORE fremkommer det et liknende mønster, dvs. mye fremgang i prosjektene, leveranser i tråd med forventede mål, og større innsikt i konkrete problemstillinger, men med en erkjennelse av at utfordringene rundt lagring er betydelige, og at det vil ta lang tid å adressere dem på en god måte.

Vi vil trekke frem noen generelle problemstillinger som det kan være verdt å undersøke videre dersom de oppdages i flere andre prosjekter i CLIMIT-porteføljen:

- Prosjektoverlapping: Overlappingen mellom SOLVit, BIGH2, BIGCLC and BIGCO2 gjør det vanskelig å knytte til oppnådde resultatene til spesifikke prosjekter. De to prosjektene ble videreført med noen justeringer i arrangementet mellom partnerne, noe som førte til at BIGCO2 endret sitt fokus mot grunnleggende forskning. Innen grunnforskning kan en muligens oppnå bedre resultater ved en slik paraplyorganisering. Det kan blant annet føre til at det blir lettere å omfordele ressurser, at det oppnås bedre samspill mellom institusjoner, at kapasiteten utnyttes bedre samt at det kan fremme tverrfaglig kommunikasjon.
- Fleksibilitet: Det er tydelig at partnerne i SOLVit prosjektet har tilpasset seg utsettelsen av pilottest anlegget. Dette har de gjort ved å konsentrere seg om resultater ved Mobile Test Unit, som er direkte relevant for Aker Clean Carbons tilbudte løsningsforslag om å forsyne Longannetanlegget med fangstteknologi.
- Publiseringskvalitet: Norske forskere synes å være godt representert på internasjonale konferanser og workshops, til tross for at produksjonen i fagfellevurderte tidsskrifter var lavere enn opprinnelig antatt.
- Målformulering: SOLVit prosjektet synes å ha nådd sitt energimål, likevel kunne dette ha blitt definert på en mer hensiktsmessig måte ved starten av prosjektet for å kunne knytte det mer opp mot arbeidsflyten.

2.3 Refleksjoner

Med basis i hovedkonklusjonene i denne evalueringen vil vi trekke frem to forhold som bør tas opp til nærmere diskusjon og avklaring blant CLIMITs interessenter.

2.3.1 Potensiale for kommersialisering?

CLIMIT har gitt vesentlige til å redusere teknologigapene på alle områder som er blitt identifisert gjennom denne evalueringen. Selv de ivrigste CO_2-håndteringsentusiastene vil imidlertid si seg enige i at til tross for de betydelige fremskrittene som er gjort i Norge, er det vanskelig å ikke konkludere med at:

- Nesten alle de samme kunnskapsgapene eksisterer også i dag, selv om disse ville vært mye større dersom CLIMIT-programmet ikke hadde eksistert
- Det fremdeles er betydelige utfordringer med å ta i bruk CO_2-håndteringsteknologi
- En vedvarende forsknings-, utviklings- og demonstrasjonsaktivitet fortsatt er nødvendig for å virkeliggjøre de fordelene som en utrulling av CO_2-håndtering kan bringe med seg.

Denne evalueringen indikerer at norsk industri, til tross for å være bedre posisjonert enn tidligere, i det store og hele ikke er rustet til å følge opp alle de nye teknologiske mulighetene som er identifisert gjennom CLIMIT. Det er mange faktorer som støtter en slik hypotese. En av dem er at det finnes allerede betydelig store internasjonale aktører på markedet. Disse vil det være vanskelig å konkurrere med for mindre bedrifter, særlig i karbonfangst-delen av verdikjeden. En annen kan være at den kommersielle risikoen forbundet med utvikling av CO_2-håndteringsteknologi generelt er for høy. Mange norske aktører forventer at det er en lang vei å gå før CO_2-håndtering vil være kommersielt interessant, og det er fremdeles mulig for at den aldri vil bli kommersiell. En tredje faktor kan være at demonstrasjonsprosjekter generelt er kapitalintensive og kommersielle aktører ikke er villige til å ta den økonomiske risikoen som følger med. Det finnes likevel unntak. De som er hyppigst nevnt i intervjuer er Aker Clean Carbon, Statoil og Veritas. Disse aktørene er godt posisjonert for å delta i ulike markedssegmenter i en fremtidig CO_2-håndteringsindustri. Aker Clean Carbon er for eksempel deltaker i det foreslåtte etterbrennings fangst- prosjektet på Scottish Powers Longannet kraftstasjonen, som forventes å være klar for driftsstart mellom 2015 og 2020.

Det er ingen tvil om at norske forskningsinstitusjoner er i forskningsfronten innenfor mange teknologier i verdikjeden for CO_2-håndtering. Dette kan delvis tilskrives CLIMIT-programmet og må sies å være en betydelig prestasjon. Men ettersom CO_2-håndteringsteknologi er langt fra å være kommersialiserbar og fordi det er usikkerhet knyttet til mulighetene for CO_2-håndtering som et viktig teknologialternativ i overgangen til en bærekraftig energifremtid, er et viktig spørsmål for norske myndigheter hvordan en kan beholde og videreutvikle den kompetansen som er bygd opp så langt.

De kommersielle insentivene som trengs for å bringe CO_2-håndteringsutviklingen videre uten betydelig offentlig støtte er i all hovedsak enda ikke tilstede. I tillegg er det en mangel på norske selskaper som er i stand til eller villig til å bruke egne ressurser i teknologiprosjekter. Dette vil være de viktigste utfordringene i fremtiden. Derfor bør CLIMITs interessenter diskutere muligheten for å åpne opp programmet for internasjonal deltakelse.

Til tross for at teknologigapene har blitt redusert, er CO_2-håndteringsteknologien i det store og det hele fortsatt umoden og det er flere områder der behovet for mer forskning er betydelig. Det finnes også områder der industrien kan være lite tvillige til å delta og hvor det muligens hadde vært bedre å utvikle demonstrasjonsprosjekter uten krav om industrifinansiering.

Forsknings-, utviklings- og demonstrasjonsaktivitet innen CO_2-håndtering foregår i mange land og i EU. Andre land og institusjoner har blitt en del av CCS-samfunnet. De fleste har ambisjoner om å høste fordeler knyttet til det å være i forkant, både når det gjelder utvikling og bruk av CO_2-håndteringsteknologi. I noen tilfeller har dette ført til dobbeltarbeid, slik at addisjonaliteten eller merverdien som kan tilskrives CLIMIT vil være vanskeligere å påvise i fremtiden. Selv om addisjonaliteten reduseres, er det mulig at den økte konkurransen vil føre til høyere innovasjon.

Utredninger fra IEA og andre tyder på at utrulling av CO_2-håndteringsteknologi i stor skala vil finne sted rundt 2030. Gitt denne lange tidshorisonten, er det uklart om de satsinger som hittil har blitt utviklet av norske akademiske og kommersielle aktører vil bli videreført inn i 2030- årene og fremover, altså i den perioden der veksten av CO_2-håndtering i IEAs CCS Roadmap anslås å bli sterkest.

2.3.2 Risikoprofil i CLIMITs prosjektportefølje

Generelt sett er det nødvendig å finne en fornuftig balanse mellom prosjektenes addisjonalitet og de resultatene som oppnås. Høy addisjonalitet gir ingen verdi dersom prosjektene mislykkes. Det er med andre ord nødvendig å finne et rimelig risikonivå. I forbindelse med spørreskjemaundersøkelsen blant prosjektledere for CLIMIT-finansierte prosjekter finner vi bare ett som sier at teknologien ikke er verd å jobbe videre med. Dette resultatet kan tolkes på flere måter:

- CLIMIT-programmet har arbeidet aktivt for å heve kvaliteten på prosjektene, noe som resulterer i en svært høy suksessrate. Dette kan oppnås gjennom en aktiv dialog med søkerne i søknadsprosessen.
- CLIMIT-programmet er for lite risikovillig. Dette er forbundet med to forhold. Til tross for at risikoen er høyere, kan det hende at forventet avkastning ville blitt høyere dersom en hadde tatt enda høyere risiko. For det andre, for å forbedre fremtidig teknologiutvikling er det også viktig å klargjøre hvilke teknologier som ikke fungerer i større grad enn i dag. Dette er knyttet til en diskusjon av den teknologiske bredden i prosjektporteføljen. Er bredden stort nok? Som påpekt ovenfor, teknologigapene er større enn forventet, noe som gjør det vanskelig å "peke ut vinnerne". Dette kan peke i retning av en bredere prosjektportefølje.
- Gitt det faktum at mange prosjekter er fortsatt pågående, og at programmet er i en tidlig fase, kan det også argumenteres for at det er for tidlig å vurdere risikoprofilen til programmet.

Det er ikke vanskelig å finne argumenter for alle tre perspektivene. Likevel, gitt det faktum at både CLIMIT-programmet og teknologiutviklingen innenfor CO_2-håndtering generelt fortsatt er i en tidlig fase, mener vi at prosjektporteføljen heller bør være bredere istedenfor smalere. Uavhengig av hvilket perspektiv som velges, mener vi dette er et sentralt spørsmål som må drøftes i forbindelse med den videre utviklingen av CLIMIT programmet. Uavhengig av hvilken tolkning er valgt, tror vi fortsatt at dette er et sentralt spørsmål i utviklingen av CLIMIT.

2.3.3 Fremtidsutsikter for CO2-håndtering

CLIMIT programmet har bidratt til konsentrasjon av en stor mengde norsk forsknings-, utviklings- og demonstrasjonsaktivitet aktivitet innenfor CO_2-håndtering. Det er viktig å være klar over at teknologisk utvikling og vekst alltid er vanskelig å forutsi og umulig å garantere for. Mens denne evalueringen gir grunnlag for en viss optimisme, må overoptimisme likevel unngås.

Det er utviklet flere scenarier for utviklingen av CO_2-håndteringsindustrien på lang sikt (f.eks 2050). De mest fremtredende er:

- CO_2-håndtering og relaterte teknologier finansiert av CLIMIT spiller en viktig rolle for å imøte-

komme klimamålene, dels gjennom norsk aktivitet, og norsk industri lykkes i tillegg med å ta sin andel av det enorme markedet som åpner seg opp. Dette vil gi nordmenn store velferdsmessige gevinster i tillegg til de globale klimagevinstene som oppstår.

- CO_2-håndtering bidrar til å imøtekomme klimamålene ved å spille en viktig rolle, men norsk industri er ikke i stand til å ta en del av CO_2-håndteringsmarkedet. Dette kan skyldes at «vinner» teknologier eller forsyningskjeder er utviklet andre steder. I dette tilfellet vil menneskeheten generelt sett fremdeles høste fordeler, men vi nordmenn kan ha betalt en uforholdsmessig høy pris i forhold til andre land gjennom vårt bidrag til å videreutvikle CO_2-håndtering.
- CO_2-håndtering spiller bare en mindre rolle i reduksjonen verdens CO_2-utslipp, muligens fordi CO_2-utslipp ikke blir kontrollert eller fordi andre teknologier viser seg å være bedre. Selv om norsk industri spiller en viktig rolle i CO_2-håndteringsmarkedet som eksisterer, kan det vise seg at det ville ha vært mer lønnsomt for Norge å investere ressurser i andre alternativer.

Det vil trolig ikke være mulig å påvise hvilke av disse scenariene som vil inntreffe før om tidligst ti år.

Chapter 3. The CLIMIT Programme

3.1 CLIMIT - Background

As a result of Norway's innovative offshore CO_2 taxation, Norway-based Statoil pioneered the world's first true carbon dioxide capture and storage project in the 1990s. This project has resulted in the separation of CO_2 from natural gas at the Sleipner gas field and re-injection of approximately one million tonnes of CO_2 each year for long term storage in the Utsira aquifer.

With this project, Norway emerged as a leading developer of CCS technology, and Norwegian-based research institutes and companies have been active across the world in advancing CCS technology. CCS is suited to large point sources of CO_2 emissions to atmosphere, for example from fossil fuel use at power stations and heavy industry.

In 2002 the Bondevik Government appointed a committee (Gassteknologiutvalget) for assessing the organizational framework for promoting climate friendly technologies for natural gas utilization. In its report, the committee underlined the need for having a consistent toolbox of measures along the whole innovation process from research, via development, demonstration to commercialization. The committee did also propose that the Government should establish a new state owned Innovation Company for gas technology development. The Government followed up by establishing Gassnova SF January 1st 2005.

The CLIMIT Research Programme was also established January 1st 2005, partly based on the committee's proposal. The objective was to support development of Carbon Capture and Storage (CCS) technology for power generation based on natural gas in Norway. At that point of time, gas power had been a political headache for years, and CCS was launched as a way out of the political backwater that domestic use of natural gas for power generation had been. The programme was a continuation of the Research Council of Norway's programme KLIMATEK which was part of the RENERGI-programme. In 2008, the mandate was extended to cover all power generation technologies based on fossil fuels. Two years after, in 2010, the mandate was further extended to also include emissions from industrial activities.

Table 1: Important events in the CLIMIT Programme

Year	Event
2002	Gassteknologiutvalget's report presented
2004	Government White Paper - St.meld. 47 (2003-2004) on Innovation of gas friendly technology
2004	First mandate for the CLIMIT Programme formulated by the Ministry of Petroleum and Energy
2005	The CLIMIT Programme launched
2008	The climate change agreement (Klimaforliket) reinforces CCS as an important tool for achieving Norwegian climate change goals
2008	The CLIMIT Programme includes CCS for coal
2010	The CLIMIT Programme includes industry emissions

3.2 The mandate of CLIMIT

In the first mandate formulated by the Ministry of Oil and Energy dated June 25 2004, it was underlined that one important objective was to ensure that the R&D activities in Norway was coordinated across important institutions and actors. CLIMIT should be a national research programme involving actors from academia as well from the industry.

The revision and broadening of the mandate in 2008 and 2010 was clearly a recognition that the deployment of CCS is relevant for all kinds of CO_2 emissions from fossil combustion processes, and that the commercialization of CCS related technologies is dependent on their relevance for the international market, and that an international deployment of CCS technology is essential for its contribution to curb global emissions. So instead of having a national focus, the focus has gradually become more international, where the stated motivation was to contribute to the international struggle to reduce CO_2-emissions.

The main objective of the programme has been formulated somewhat differently over time. In 1995 the vision was to "Establish profitable gas power stations with CCS in Norway". In the short term more specifically to:

- Qualify and reduce costs of CCS
- Establish methods for safe geological storage of CCS

and in the long term to:

- Improve and develop technologies which have the potential to significantly improve the energy efficiency in carbon capture processes
- To develop robust methods for CO_2 storage which fulfils international obligations and agreements

The main objective restated in 2008 to; "*Commercialize power generation with CCS through research, development and demonstration projects*". The reference to gas power was removed and replaced with power generation in general, indicating that all kinds of fossil fuels involved in power generation should be included in the CLIMIT Programme.

In 2010 the mandate was extended to include emissions from the industry as well. The main objective was again restated to: "*Accelerate the commercialization of CCS through economic stimulation of Research, Development and Demonstration*."

The motivation for Norway to engage in CCS technology development through a national R&D programme has been refined and extended, including elements such as:

- Develop competitive Norwegian CCS technology to serve a future international market
- To make fossil fuels utilization acceptable also within the framework of a low carbon economy
- Make gas power plants with CCS an option for Norwegian security of supply considerations
- Reduce emissions from Norwegian industry and to ensure the same industry's competitiveness in a low carbon society
- Capitalize on the storage capacity on the Norwegian Continental Shelf (NCS)

With reference to the main objective and the motivation of the Programme, its focus areas should be where Norway could "*make a difference*", by:

- Extensively supporting R&D activities to foster new concepts to bring costs for CCS down
- Building on the competence and experience in Norwegian industry clusters and companies with ability to develop geological storage, including the prospects of utilizing storage capacity in geological structures on the NCS
- Building on the experience, infrastructure and commercial basis which flue gas capturing have in Norway, and by utilizing synergies between power generation and industries

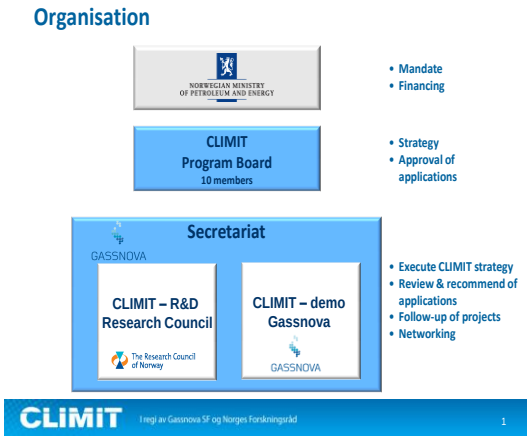
The main measures are:

- Long term support to R&D activities (2010-2014)
- Support to pilot and demonstration projects of proven technologies (2010-2014)
- Support to pilot and demonstration of new technologies (2015-2019)
- Contributions to the commercialization of new technologies (2020-)

3.3 Organisation of CLIMIT

The organization of the program is showed in figure 1 below. Under supervision of the Ministry of Petroleum and Energy, the program is a common undertaking by the Research Council of Norway (RCN) and Gassnova, in which RCN takes care of the research projects, while Gassnova has the responsibility for projects in the development and demonstration phases. The MPE has the responsibility for the formulating the mandate and the financing. A common programme board formulates the strategy and considers project applications. Gassnova coordinates the activities through a separate secretariat.

Figure 1: Organizational overview of CLIMIT



Source: Gassnova

3.4 CLIMIT budgets and grant size

During the 6 years period from 2005 to 2010, NOK 897 millions have been granted, of which NOK 638 million (71 percent) to research projects and NOK 259 million (29 %) to Demo projects. 25 percent has been allocated to Universities, 46 percent to institutions and 30 percent to companies. The 5 largest receivers have been allocated 75 percent of the funds, while the 10 largest 81 percent. The 5 largest beneficiaries as of April 2011 are:

Table 2: CLIMIT budget by beneficiaries, 2005-2010

Institution	Support in MNOK
SINTEF	281
Statoil	115
NTNU	81
IFE	60
Universitetet i Bergen	53
Source: Oxford Research AS	

If the budget is split between RCN and Gassnova-funded projects, the following emerges:

Table 3: CLIMIT budget by funding source, 2005-2010

Funding source	MNOK
RCN	**102**
Researcher projects (Forskeprosjekt)	22
User-driven Innovation Projects (BIP)	10
Competence-building Projects with User Involvement (KMB)	70
Gassnova	**257**
Technological Feasibility Projects	82
Main Projects	174
Conference Support	1
Source: Oxford Research AS	

The allocation of funds between the different phases in the value chain is as follows:

Table 4: CLIMIT budget allocation by technology area, 2005-2010

Technology area	Share
Carbon Capture	49 %
Storage	34 %
Transport	12 %
Other	5 %
Source: Oxford Research AS	

When allocating grants, the determination of maximum grant rates is based on ESA's rules for state aid. The maximum grant that can be allocated is generally 50 % for development projects and 25 % for demonstration projects. However, it is underlined that the maximum grant shall not be more than what is needed to have an incentive effect on the activity being applied for. Although the programme is open to non-Norwegian partners, an important requirement is that the project contributes to technology development and capacity building in Norway within the field of CO2 capture and storage. In effect, this implies that the main applicant must be a Norwegian legal entity.

3.5 RCN evaluations

In their annual reports, the RCN assesses the results and the challenges in the Programme.

Over time, RCN has concluded that it has turned out to be more difficult than anticipated to mobilize commercial actors in the programme. One reason is the uncertainty regarding the future potential of CCS and the economic risk involved. Even though CCS is regarded by important institutions such as IEA as a part of the solution to the climate change problem, it is still controversial both internationally and domestically. Therefore it has taken longer time than expected to establish demonstration projects with participation from the industry. It has also been more difficult to get a general acceptance that the priority which have been given to CCS in Norway is more than political indulgence.

The technological challenges to get the costs down have been revealed to be demanding, and even though there has been technological achievements, it is still a long way to go before CCS is close to be commercial.

Chapter 4. CCS – value chain: Technological challenges and gaps

The guiding philosophy associated with geological CCS technologies is the prevention of significant emissions of CO_2 to the atmosphere. This is achieved by the addition of processes that separate CO_2 from other products in the process and re-directing this to a geological storage that can be expected to hold the CO_2 securely for thousands of years (potentially longer). For technical, environmental, logistical and economic reasons, the CO_2 must typically be purified and transported by pipeline or ship from the site where the CO_2 is produced to where it can be stored. Ideally the fate of the buried CO_2 is then monitored to ensure that there are no long-term dangers. Some analysts expect that large-scale deployment CCS could contribute up to 19% of global decarbonisation potential by 2050, reducing the costs mitigating climate change relative to other options by 70%, and increasing the probability that global climate objectives could be met.

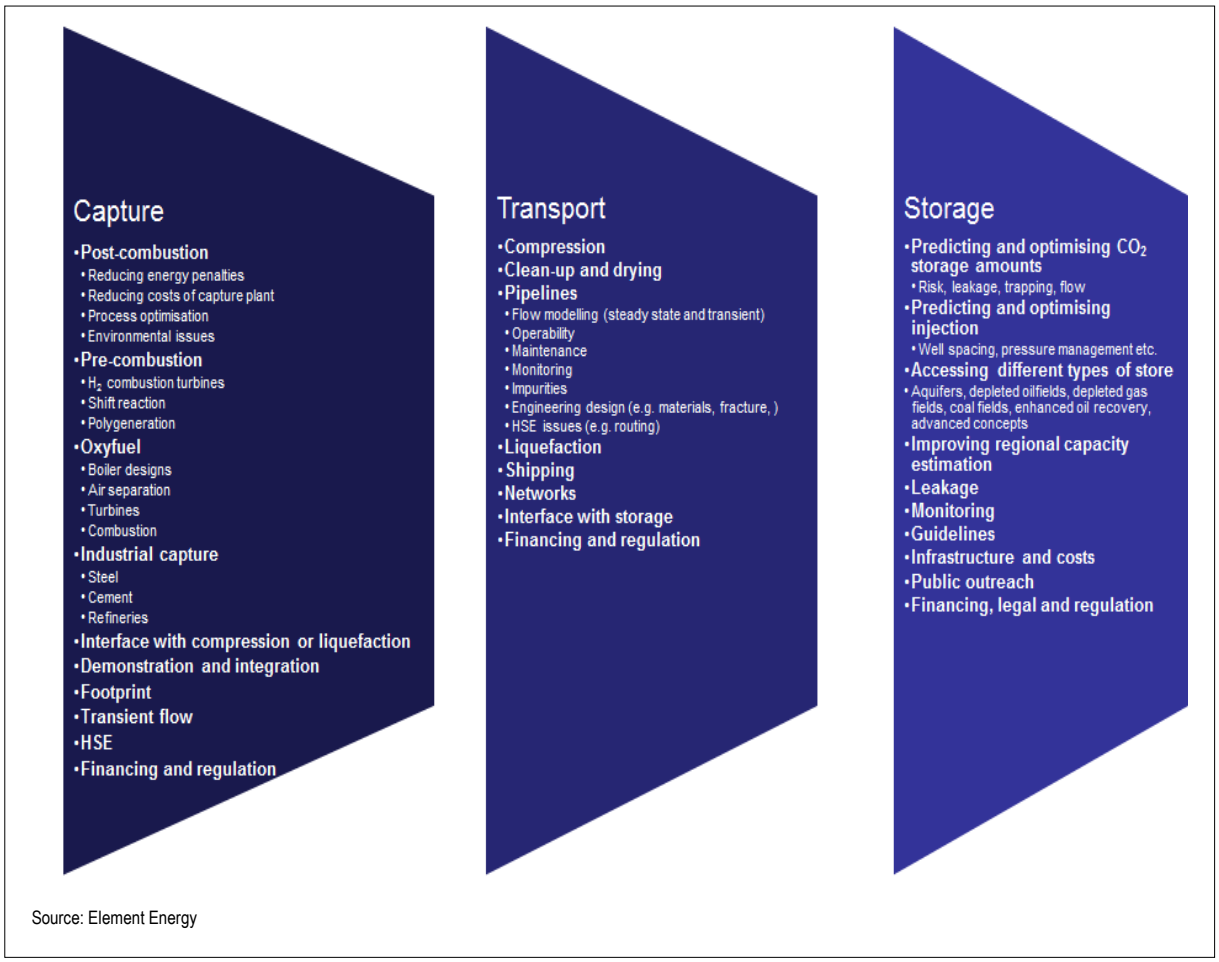
Confidence in the potential for CCS comes from a recognition that the individual steps of CO_2 separation, CO_2 transport, geological CO_2 injection and monitoring fluid movement underground have been used for many years by different industries, most notably the oil and gas industry. Confidence has also come from preliminary estimates of storage potential that showed this to be both abundant and widely distributed geographically, in many areas within reasonable distances of existing CO_2 emitters.

However the application to CO_2 from power and industrial sources, the transport requirements from sources to stores, the requirement for injected CO_2 to remain secure for long timescales, the much larger scale of a CCS project and or integrated system compared to existing practice, and the need to integrate diverse supply chains pose a multitude of new and unique challenges.

These challenges are diverse. Some barriers ought to be solved through improved scientific understanding and engineering. These have been the major focus of CLIMIT investment. However, as with other carbon abatement measures, CCS also faces political, economic, legal, commercial, and regulatory challenges.

The focus of CLIMIT, and the international CCS community at large, has been primarily directed at (i) demonstration activity which broadly seeks to ensure engineering viability, integration, and scalability of existing technologies whilst containing costs and risks, and (ii) research and development activity which seeks to close knowledge gaps and improve the performance of CCS.

Figure 2: Knowledge gaps in CCS technology



Source: Element Energy

The figure above delineates key technology gaps associated with CCS in terms of CO_2 capture, CO_2 transport and CO_2 storage. The majority of issues in the Figure were highlighted to the international community already by 2005, for example in the Carbon Sequestration Leadership Forum. They are relevant in Norway directly for its own CCS activities, and to Norwegian researchers and industry that wish to develop and participate in any future global CCS industry.

It is useful to describe some of the gaps as these form the context around which CLIMIT projects can be evaluated.

There are at least three basic philosophies for CO_2 capture from fossil fuel power stations, post-combustion, pre-combustion and oxyfuel capture.

Post-combustion technology can use chemicals and processes that have been successfully applied to the clean-up of CO_2 from, for example, natural gas streams. However these processes involve large equipment and energy input, which raises costs. Furthermore, when used with the oxygen rich flue gas these chemicals degrade, leading to by-products that could have adverse environmental impacts. CLIMIT projects such as SOLVit and BIGCO2 have work packages dedicated to improving post-combustion capture technology to reduce costs and environmental impacts.

Pre-combustion capture involves drastic plant redesign so that power is generated from hydrogen combustion in air, with the hydrogen generated from the fossil fuel followed by separation of the CO_2. Projects such as BIGCO2 seek to provide fundamental understanding of hydrogen combustion and improved membranes for hydrogen separation.

Oxyfuel capture involves moderate plant redesign so that combustion happens in oxygen instead of air. BIGCO2 seeks to provide fundamental understanding

of combustion in pure oxygen and improved membranes for oxygen separation (Task A).

For post-, pre-, and oxyfuel combustion capture, there will be a requirement to understand transient behaviour (i.e. as plant ramps up and down, during start-up and shut down but more importantly in response to varying demand over time).

Compared to capture from coal or gas power sources, less research worldwide has occurred in CO_2 capture from industrial sources. The different physical and chemical characteristics of CO_2 streams imply different capture conditions when industrial sources are considered.

Other challenges to capture include the large physical area (footprint) associated with capture equipment. If the additional footprint of capture plant is too large, it may not be possible at some sites, especially retrofit at existing sites.

The boundary of capture is typically its interface with transport. In general the CO_2 will be compressed (for pipeline transport under ambient conditions) or liquefied (for ship transport at low temperatures).

Following compression or liquefaction, for CO_2 transport, the focus is largely on the incremental challenges relative to the numerous CO_2 pipelines and ships already in use. With CO_2 transport networks potentially linking many sources and diverse geological sites (including enhanced oil recovery), at the forefront has been research into the impacts of CO_2 purity on network performance (e.g. resistance to corrosion).

Some of the greatest challenges to specific CCS projects and systems may be developing appropriate CO_2 storage. Every potential site will have unique characteristics. Fundamental scientific and reservoir engineering questions on storage include questions on how much capacity is available, where, how this can be accessed, and on the fate of CO_2 injected (migration, dissolution, and chemical reaction). Equally important are socio-political and economic concerns, i.e. addressing real and perceived hazards, minimising costs, and developing appropriate financing systems.

Chapter 5. Objectives of the evaluation

The main purpose of the evaluation is to make a systematic review of the achieved results from the CLIMIT Programme and assess these against the programme's objectives. In order to evaluate the effectiveness of CLIMIT, we will address whether the projects individually have sufficient quality and ambition, and whether the project portfolio as a whole has adequate technological and industry breadth and relevance in relation to the objectives of the scheme.

The evaluation consists of three deliverables:

- An indicator system for evaluating the performance of the programme
- An assessment of the results and impacts of the programme so far as well as goal achievement
- An assessment of additionality, international research cooperation and Norwegian competitiveness

Below, we give a more detailed description of the three deliverables. We present the detailed issues we will look into in connection with the deliverables and discuss our understanding of the issues in more detail.

5.1 Indicator system

To address both the current and future performance of the programme, we will design an indicator system for CLIMIT. This means that we will develop a system for measuring inputs, processes, results and effects of CLIMT. This system will be used as a guideline for what kind of data that must be collected to address the different evaluation questions in a proper manner as well as creating a platform for a system that can also be used for an overall evaluation system for the programme.

5.2 Results, impacts and goal achievement

The evaluation should make an assessment of the results and impacts of the programme so far and whether the programme has contributed to accelerating the commercialization of CO_2-handling. To do that, we will first evaluate the results and the impacts of CLIMIT. What kind of results has been created so far in the programme period, and what are the effects of the programme. To address the last issue, it will be critical to look into the additionality of CLIMT. This is the assessment of the effects or added value that can be attributed to the programme, and will not be achieved without it.

To understand the impact of a research and demonstration programmes, it is important to understand the innovation processes in general and specifically for a given technology. The various stakeholders in and framework for innovation is often described as an innovation system, see for example Breeders, etc. (2007) and Fagerberg and Verspagen (2009). Innovation systems represents the whole picture of the actors, institutions and networks involved in the innovation process (Freeman and Lundvall, 1988; Lundvall, 1992 and Nelson, 1993), or the combination of "hardware, software and orgware" (Negro e. al., 2008). These are dynamic processes with cumulative causal relations that can be difficult to trace back to individual decisions or actions. Technology Innovation Systems (TIS) refers to technology specific innovation systems ¬ (Negro et al, 2008) and these systems will vary between different technologies. Some cross-cutting features are however comparable, like entrepreneurs, knowledge and learning, policy direction and goals, market mechanisms, resource mobilization, and coalitions and interests.

5.2.1 Goal achievement

In order to evaluate the effectiveness of CLIMIT, we will address whether the projects individually have sufficient quality and ambition, and whether the project portfolio as a whole has adequate technological and industry breadth and relevance for accelerating the commercialization of CO_2-handling. Our assessment will be based upon the following questions:

1. Has the programme contributed to development of new concepts for handling CO_2 that can lead to reduced costs?
2. Does the programme, to a reasonable extent, support projects that can contribute to piloting

and demonstration of known technology towards 2015?

3. Has the programme stimulated to development of new and more radical technologies that can be supported in pilot- and demonstration-projects after 2015?
4. Does the programme, sufficiently, support projects that can contribute to commercialization of new and radical technology in the period after 2015?
5. Does the programme contribute to establishing knowledge, technology, methods and standards for safe transport and storage of CO_2?
6. Has the programme contributed to developing or strengthening companies which provide services within CO_2-handling?
7. Has the programme contributed to advancement of knowledge through scientific articles, patent rights etc.?
8. Are the projects conducted in accordance to the set schedule, to ensure that they contribute to force the development of technology for CO_2-handling, in accordance with the goal of the programme?
9. Do the projects hold a sufficient professional and quality level, with regards to technology and the potential of commercialization?

5.3 Further issues

5.3.1 Additionality

The concept of additionality is very relevant and important when one looks at the impacts of CLIMIT. By looking at additionality, we will be able to map the effects that are caused and can be attributed to the programme, i.e. which projects would have been realized (to a greater or lesser degree) without support.

5.3.2 International research cooperation

We will make an assessment of whether the programme has contributed to strengthening the international orientation and impact within the field of research (both in terms of cooperation within the EU and other international cooperation). We will also investigate whether the projects sufficiently have used experiences and knowledge from other international areas.

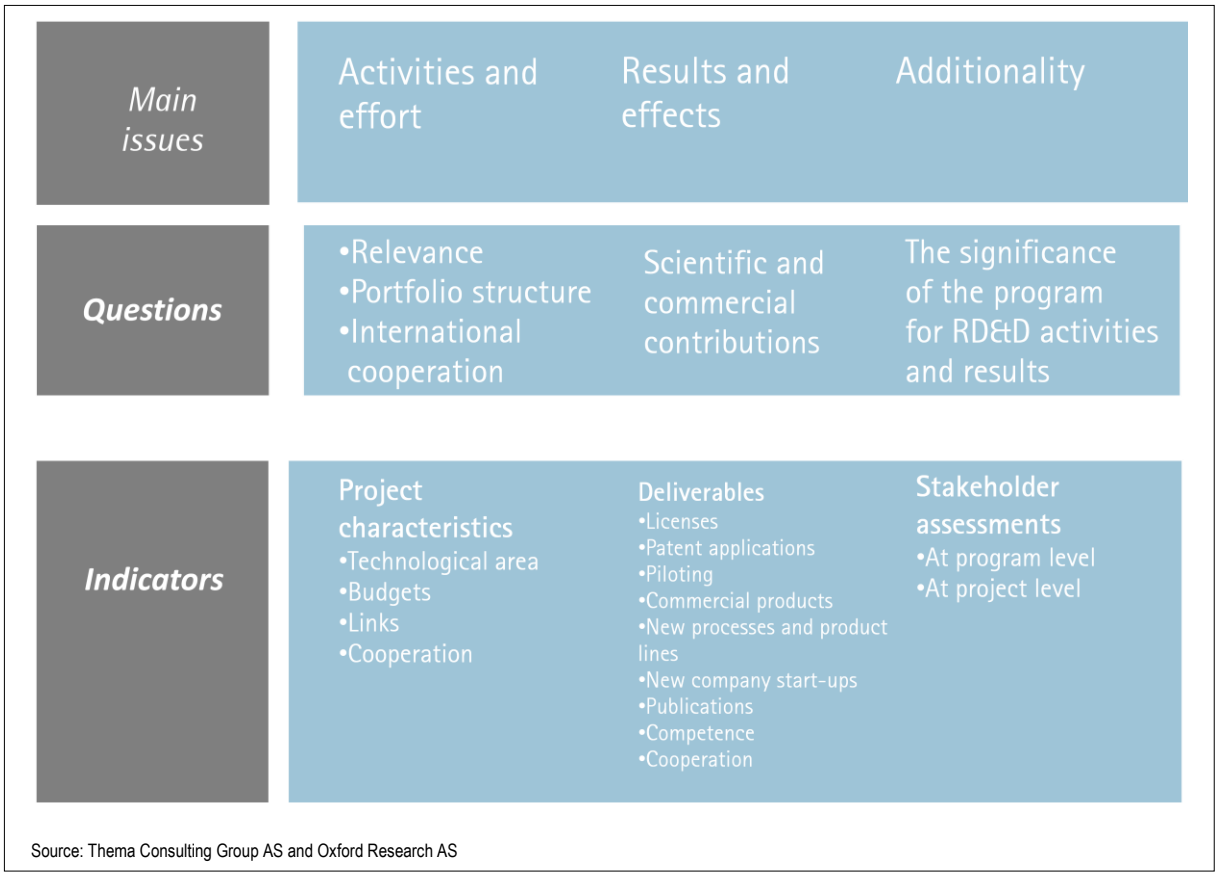
5.3.3 Norwegian competitiveness

As a part the evaluation, we will assess whether the programme has contributed to improve Norwegian competitiveness in the international market within CO_2-handling.

5.4 Operationalization of evaluation questions

To be able to conduct the evaluation in an effective way, we have interpreted and operationalized the evaluation questions. Our approach is presented in the figure below. For each main issue we will go into, more detailed questions are specified. In addition, we also present the main indicators that will be used to address the different questions.

Figure 3: Operationalization of evaluation questions



Source: Thema Consulting Group AS and Oxford Research AS

Chapter 6. Methodological approach and data sources

In this chapter we will describe our methodological approach, and the data sources applied.

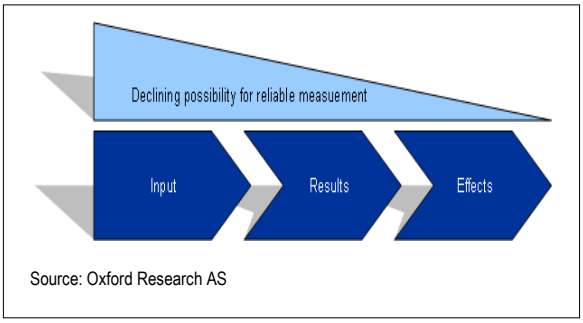
Our evaluation approach has two foundations. First, the indicator system is based on established, general models for measuring activities, results and effects. In order to apply it to the context of CCS, we also need a thematic point of departure. We combine the gap perspective described in chapter 3 with a model for measuring activities, results and effects of long-term RD&D initiatives in the energy area.

6.1 Measuring results and effects

It is a challenging task documenting the result and effects of the projects financed by the CLIMIT Programme. When assessing the effects of actions one often differentiates between input, results and effects. In general this means that inputs are expected to generate both short-terms effects and long-term effects. In most cases there are certain results and effects that are expected and predicted. One often used example of this is a pill, where the action of taking the pill is regarded the input, the following dizziness the result and the final recovery the effect.

There are two important implications of the approach to evaluations that have been described here. Firstly, the possibility to measure the implications of the CLIMIT projects will deteriorate the further out in the chain one attempts to measure the effects. This is illustrated in the following model:

Figure 4: The possibility for measuring effects



Source: Oxford Research AS

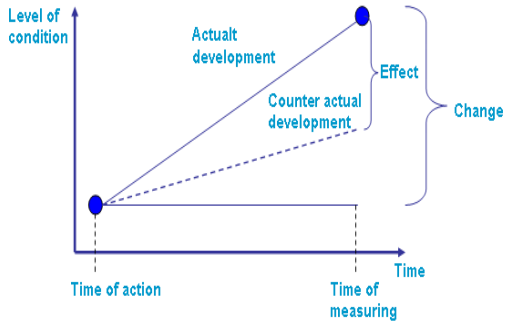
The reason for this is that it takes longer before the effects appear. And when they do, a range of factors could have influenced the process and make it difficult to see the correlation.

Secondly, it could be the case that the inputs generate other effects than those predicted. These are called side effects. If the evaluation does not measure side effects it could appear that the inputs do not have any results or effects at all.

When assessing outputs, the basis will always be the actual change of a condition. The next and crucial question is then; “To what extent has the input caused the changes?” If this question is not answered, or no attempt is made to answer it, the whole change will be ascribed to the input. Often this is a serious mistake, giving actions a lot more credit than they are responsible for, or worse in a situation of negative change, giving no credit to a functioning action - the point being to isolate the effects from the change.

An often used approach to answer this question is the use of control groups. However, this is not possible in this project due to the fact that there is no relevant business that can be used as a foundation for the comparison. The most realistic solution is found in relation to the term “additionality”. This term is based on the more commonly known term “added value”, or in other words how much of the output that can be ascribed to specific actions carried out. It is based on the question of “What would have happened if not….?”, hence a clear counter factual dimension. From the answers to these types of questions one can estimate a change in condition in cases where the input or actions have *not* been carried out. The difference between the actual change and the estimate based on the counter factual questions represents effects of an action, as illustrated in the following figure.

Figure 5: Effect and additionality



Source : "Evaluation of public support measures", The Norwegian Government Agency for Financial Management

The evaluation of the CLIMIT Programme will be able to give a comprehensive picture of all the results and effects created on the basis of the programme. To assess the results and effect, our main tool will be a survey to all the project managers. The survey will also be supplemented by personal interviews with project managers and key stakeholders.

6.2 A conceptual model for measuring effects of long-term RD&D initiatives in the energy area

The US Department of Energy has developed a framework for analyzing effects from RD&D (research, development and demonstration) projects in large-scale energy research programmes. This approach distinguishes between economic benefits and costs, environmental benefits and costs as well as security benefits and costs. The project effects are categorized as either realized benefits, options benefits or as knowledge benefits based on the degree to which these effects can be commercially exploited and stages of the technology development process. This model was used in the evaluation of the DEMO 2000-programme and is summarized in figure 6.

Figure 6: Model for measuring activities, results and effects of long-term RD&D initiatives in the energy area

Technology Development / Economic/ policy conditions	Technology Developed	Technology Development in Progress	Technology Development Failed
Already materialized	Realized benefits	N.A.	N.A.
Will be favorable for commercialization	Realized benefits	Knowledge benefits	Knowledge benefits
Might become favorable for commercialization	Options benefits	Knowledge benefits	Knowledge benefits
Will not become favorable for commercialization	Knowledge benefits	Knowledge benefits	Knowledge benefits

Source: NIFU STEP, 2005

This evaluation framework is applicable to the CLIMIT programmes due to the similarities between the cases presented in the Department of Energy's study, DEMO 2000 and the CLIMIT projects. The CLIMIT projects may be categorized across all three categories of technology development, although the two latter categories are likely to be more populated than the first, as the programme is still running; hence many CLIMIT projects are still in an early phase.

Most likely, some projects will be tested with positive results, and thus be a step closer to commercialization or even reach the commercial stage in immediate succession to test/demonstration/pilot-activities. In other cases the result may be that further testing is needed. Finally, some projects may prove to have no commercial potential due to failed tests and further development may thus be aborted.

6.3 Data sources

This evaluation has been carried out by drawing on four different sources of information. We have chosen a mixed method approach which combines the strengths of both qualitative and quantitative methods. This enhances both the reliability and validity of the result. Each of the applied data sources will be described in the following.

6.3.1 Register data

The registry data provide an important basis for the interviews, survey and technology assessment. The data has been provided by the CLIMIT-secretariat in

the form of Excel spreadsheets. The status of the information is per March 31 2011. These sheets have been reconstructed by Oxford Research into an evaluation database. The database contains basic information on all projects which have received support from the CLIMIT Programme.

According to the registry data, the portfolio of CLIMIT projects consists of 199 completed and ongoing projects.[1] The distribution of these projects between RCN- and Gassnova-funded projects is shown in the following table:

Table 5: CLIMIT project portfolio as per April 2011, by project status

Type	Completed	Ongoing	Total
Gassnova	49	38	87
RCN	63	49	112
Total	112	87	199
Source: Oxford Research AS			

In the following table, the projects in the CLIMIT portfolio have been broken down into their respective technology areas.

Table 6: CLIMIT project portfolio as per April 2011, by programme type and technology area

Technology area	Gassnova	RCN	Total
Capture	44	47	91
Storage	25	34	59
Transport	3	9	12
Capture and storage		6	6
Capture, transport and storage		1	1
Other/hybrid	15	15	30
Totalt	87	112	199
Source: Oxford Research AS			

As evident from the above table, information on the technology area is incomplete or missing for some 30 projects.

As respondents for the survey, the project leaders according to the evaluation database were chosen due to their intimate knowledge of the projects in terms of ambitions, achieved results and potential effects. However, some ¼ of the project leaders were in charge of multiple projects, as shown in the table below.

Table 7: CLIMIT projects and project leaders

Number of CLIMIT projects	Project leaders
1	94
2	17
3	7
4	6
5	2
6	1
10	1
Total	128
Source: Oxford Research AS	

A pre-survey quality check of the projects and the organizations which had received CLIMIT support revealed that some private companies had gone bankrupt or for other reasons were not active anymore. This led to exclusion of six projects, managed by five different project leaders. As a basis for the survey, 193 projects managed by 123 different project leaders were included in the sample.

To keep the burden on the respondents as low as possible, each project leader only received the questionnaire once. This was achieved by either selecting the largest project managed by the project leader as a basis for the survey, or by asking them to answer on a portfolio of projects which clearly are linked.

6.3.2 Interviews

In the period June-August 2011 we carried out 15 interviews in 13 organizations.[2] The purpose was to get stakeholder's views on our evaluation questions. Informant candidates were selected to cover the main stakeholder groups of CLIMIT. The selected organizations which participated in the interviews were:

[1] The notion of a completed project refers to the fact that the projects do not receive funds from the CLIMIT Programme anymore. This does not necessarily imply that the project is completed from the beneficiaries' side. Consequently, further results may also be expected from projects which in this evaluation are labeled completed.

[2] See Appendix 10.2 for a detailed list of informants

Table 8: Interviewees in the evaluation

Authorities
Ministry of Oil and Energy
KLIF
Representatives from the CLIMIT Secretariat and Steering Committee
Gassnova
Research Council of Norway (RCN)
2 interviews with individual members of the CLIMIT Steering committee
Research Institutions which have received support from the CLIMIT Programme
SINTEF
NTNU
UiB
UiO
Tel-Tek
IFE
Commercial companies which have received support from the CLIMIT Programme
Aker Clean Carbon AS
Statoil AS
NGOs
Bellona
Source: Thema Consulting AS

The interviews were organized as semi-structured group interviews normally with 2-4 participants from each organization. The purpose was to discuss and qualify the results from the survey and the information we have extracted from other sources such as the register data. The interviews have also given the informants the possibility to present their views on various aspects of the CLIMIT Programme not directly addressed in the survey.

Throughout the interviews we have focused on the three different evaluation questions discussed in chapter 3:

- **Effort and activities:**
  - To what extent have the projects portfolio (effort and activities) been relevant for achieving the overall objectives of the Programme?
- **Results and effects**
  - To what extent can results be documented in terms of scientific publications and commercialization of technologies?
  - Have the projects contributed to filling any technology gaps?
- **Additionality**
  - Would the activities have been carried out without the programme?

The interview guide is enclosed in appendix 10.1.

6.3.3 Survey

As described in section 4.3.1., the survey included 123 project leaders, responsible for 193 projects supported by CLIMIT. The survey was conducted as a web-based survey, using the Confirmit platform. It was active in July and August 2011, with a few late responses collected in the beginning of September.

During the survey, feedback from some of the respondents revealed that there have been changes in the staffing and responsibilities for a limited number of the projects. This is of course quite normal, and the practical consequence was that – in most cases - the survey invitation was redirected to the relevant respondent. In one case, the responsibility for five different projects had been transferred from one person who had left the organization to two new project leaders. As a consequence, the number of project leaders increased to 124. In some cases, however, it was not possible to establish who is in charge of the project today, especially in the case of projects completed some years ago, i.e. the early CLIMIT projects.

The survey had a response rate of 76 %, as shown in the next table.

Table 9: Survey response status and response rate

Survey response status	RCN	Gassnova	Total
Complete	51	34	85
Incomplete	4	6	10
Declined	1		1
No answer	12	10	23
Irrelevant	2	4	6
N	70	54	124
Response rate	79 %	72 %	76 %

Source: Oxford Research AS

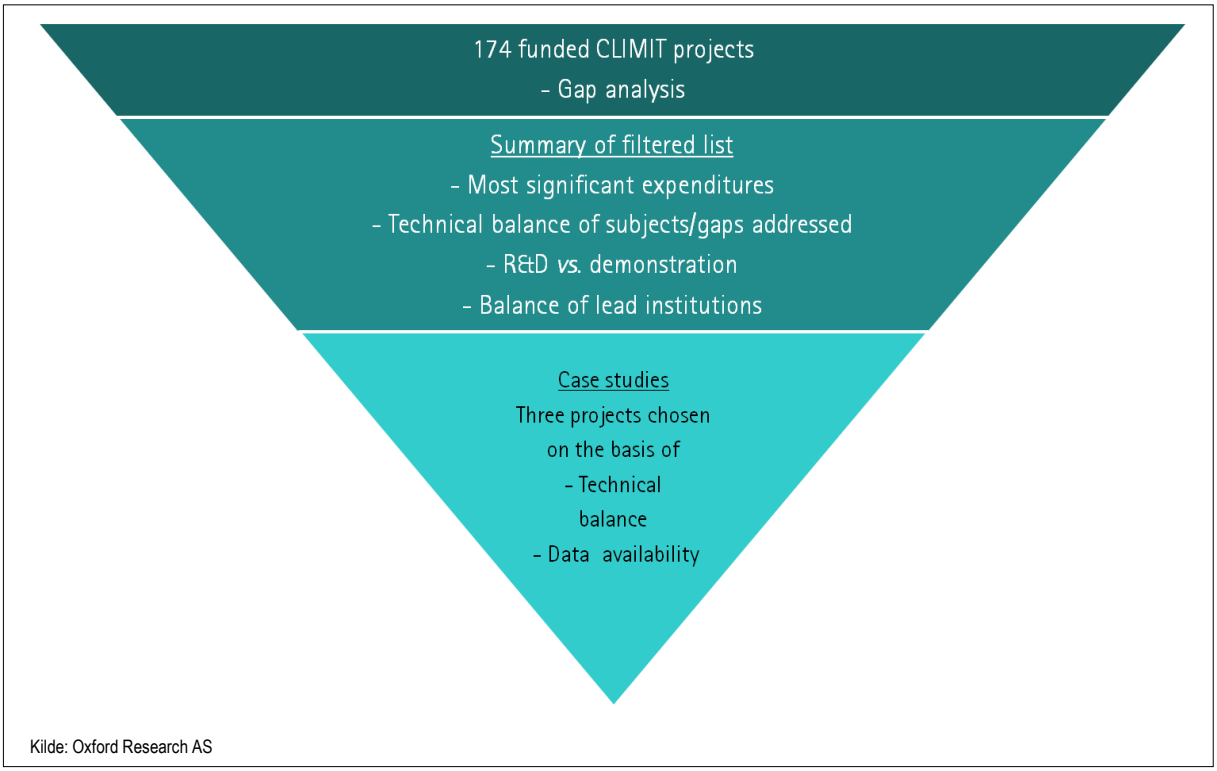
It could be argued at the response rate is rather low, taking into account that the beneficiaries are obliged to take part in evaluations. This has been a condition for receiving funds from the programme, and the respondents were reminded of this by the CLIMIT-secretariat prior to the survey. Nonetheless, taking into account that there have been changes in responsibility for a number of CLIMIT projects in several organizations due to normal personnel turnover, we regard the accomplished response rate for the web-based survey as satisfactory.

Regarding the interpretation of the results from the survey, there are some important points to be made. First, the portfolio contains relatively few projects. This fact makes it difficult to conduct analyses related to different subgroups of the portfolio, e.g. technological areas (Capture, Storage and Transport). This limits the possibilities of conducting statistically sophisticated analyses with the aim of comparing projects by technology area. Secondly, a potential minor bias may occur in projects that received funding, but for various reasons were not completed, these may be underrepresented in our survey.

6.3.4 Technology assessment

As shown in section 5.3.1, 199 projects have been funded through CLIMIT to date, involving virtually all Norwegian organisations/institutions connected to CCS, in many cases with international partners. These projects span all aspects of CCS, with the majority in capture or storage. Within the resource constraints of the project, it is not feasible to examine even a significant fraction of these CLIMIT projects. It was therefore agreed with the client that 3-4 CLIMIT projects would be taken forward for technical audit.

Figure 7: Technical audit process



Kilde: Oxford Research AS

The audit is based on balance of technical objectives (research, development, demonstration, capture, transport, storage), balance of lead institutions, (large) budget, and suitable information[3] provided to the consultants by the end of June 2011 to permit a technical audit to take place.

A shortlist of ca. 20 projects was identified and presented to the client. This list is shown in the next table.

[3] English language proposals, final reports etc

Table 10: Shortlist of CLIMIT candidate projects for technical analysis

Project acronym	Partner	Total budget in kNOK
SOLVIT fase 1	Aker Clean Carbon	33 826
BIGH2 SP2 F2 (Innovation, phase II)	SINTEF	13 600
Compact desorber	Statoil	12 855
CO_2 fangst med nye aminer på Kårstø (NAM)	Statoil	10 280
ZENG - Zero Emission Norwegian Gas R&D Project Activities for period 2004 - 2005	CO_2-Norway	64 073
SOLVit SP4 Educational Programme	NTNU-Fakultet for naturviten-skap og teknologi	37 327
Development of large scale zero emission fuel cell for offshore application	AS Norske Shell	32 730
Power Generation with CO_2 Capture - Extension	SINTEF-Klima og kuldetek-nikk	29 030
CO_2 Capture Project Extension (CCPe)	BP NORGE AS	21 670
CO_2 field laboratory for monitoring and safety assessement	SINTEF	49 122
Microseismic monitoring insalah	NGI	15 076
Subsurface storage of CO_2 - Risk assessment, monitoring and remediation (SSC - Ramore)	UiO - Institutt for geofag	31 874
Subsurface storage of CO_2 - Injection well management during the operational phase	IFE - Kjeller	21 367
Geological Storage of CO_2: Mathematical Modelling and Risk Assessment	UiB	21 017
In-situ imaging of CO_2 flow, storage and entrapment in subsurface aquifers and hydrocarbon reservoirs	UiB - Institutt for fysikk og teknologi	19 507
Sorption and Migration of CO_2 in Porous Media	NTNU - Fakultet for naturvi-tenskap og teknologi	19 236
Experimental investigation of selected thermophysical properties of CO_2 mixtures relevant for CCS	SINTEF Energi AS	46 050
CO_2 Interface Transport Interface Storage	Statoil ASA - Trondheim	34 400
Large-Scale Demonstration of pressurized Chemical Looping Technology (CLC) in Natural Gas Power Generation with CO_2 Capture	SINTEF Energi AS	27 600
BIGCO2 Phase II. CO_2 Management Technologies for Future Power Generation.	SINTEF Energi AS	104 310

Following feedback from the Client, three projects were chosen for technical audit and review:

- SOLVit Phase I
- SSC-RAMORE
- BigCO2

The technical audit seeks to answer four key questions:

1) Has the project met its originally approved technical objectives?

2) Did individual project participants carry out their work packages using the methodologies originally proposed?

3) Where there are deviations to (1) or (2), are these appropriate and agreed?

4) How well did the original objectives and final outputs align with the overall CLIMIT objectives?

In the course of the audit, additional commentary/insight will be provided on issues that may be of more general relevance to CLIMIT stakeholders beyond the specific project.

However, it is important to note that the technical audit is not an exhaustive evaluation of either an individual project or the CLIMIT Programme. Furthermore, the technical audit is not a substitute for individual project evaluations. In particular, the following are outside of scope:

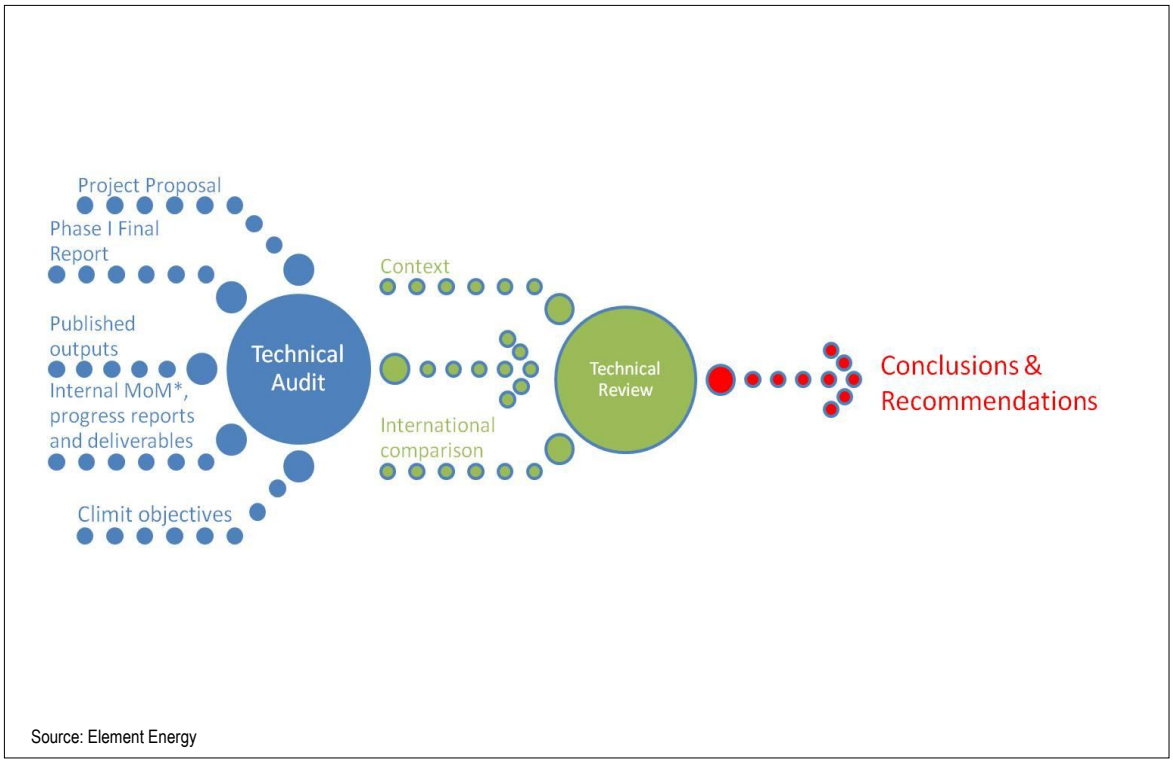
- Quality of project administration and management for the project as a whole or individual work packages.
- Budgets and value-for-money for the project as a whole or individual work packages
- Appropriateness of methods chosen
- Reproducibility of outcomes (i.e. results are accepted at face value, with no examination of

the potential for accidental or deliberate misleading).

- Detailed comparison of methods, results, and conclusions with other Norwegian or international research in this area.
- Explanations or critique concerning deviations for a project from original proposals.
- Overlap with other CLIMIT- or non-CLIMIT funded research by the same or other institutions.

Given these limitations, the technology assessment was conducted as a technical audit. The technical audit and review involved desk research using project data supplied by Gassnova, supplemented within information disclosed at the TCCS6 and similar conferences. In addition, managers and researchers of the projects selected for the technology assessment have been very helpful in providing documentation such as internal reports and scientific articles. Given the nature of the content of the technology assessment report, this is delivered to the client as a confidential appendix. A short summary of the overall results from the technical evaluation is provided in chapter 8.

Figure 8: Methodology of the technical audit



Source: Element Energy

Chapter 7. Results from interviews

7.1 Introduction

In the beginning of each interview we discussed the main objectives and the mandate of the Programme with the informants, as described in section 2.2. This made it possible to establish a common platform and reference for the main parts of the interviews. This approach turned out to be fruitful, as many of the informants had only vague knowledge of the detailed objectives and the mandate of the CLIMIT Programme.

7.2 The informant's views on the mandate and the main objectives

CLIMIT is a technology programme. According the Ministry of Oil and Energy, the main objective is to contribute to the development of new concepts and technologies within CCS. The Norwegian Authorities have gradually become more focused on promoting value creation in Norway than in the first phases of the Programme. The objective is to develop CCS technology within Norwegian institution and companies. The Authorities see it as important to build-up Norwegian competence.

The majority of the informants are satisfied with the fact that the mandate of the Programme has been adjusted over time from only focusing on emission from gas power in the first years, then to include emissions from coal power generation from 2008 and to also include emissions from industrial sources from 2010. Some of the informants said that the narrow focus on gas power made it difficult to attract interest for the Programme among potential international partners, indicating that the broader scope should have been in place from the outset. But most informants are aware of the political background for the whole programme and suggest that the mandate formulations should be regarded in that perspective.

Some informants stated that the Programme could have included use of CO_2, not only storage. One main argument for that view was that knowledge about other CO_2 value chains would also gain the CCS value chain. Furthermore, technologies closer to commercialization can more easily attract industry participation. Some informants argued that the Programme should include project beyond purely technological issues, such as social science projects addressing public acceptance of CCS, with reference to the growing skepticism in Germany and other European countries. Basically, there is no future for CCS if the technology is not accepted. CO_2 capture for other applications than storage would perhaps contribute to the general acceptance of CO_2 in relation to CCS. In that respect including other value chains than CCS could reduce barriers stemming from the lack of public acceptance.

Some informants feel that the objective of the CLIMIT Programme has been politically motivated and too narrowly tied to solving domestic problems. They claim that the research funding in the long term would yield a higher return if the research activities to a lesser extent were tied to these political objectives. Others were critical to the Norwegian value creation perspective, because it could reduce the willingness to support projects were the main effects were deployment of CCS outside Norway, indicating that Norwegian industry would not be able to compete for supplies to such international projects.

Finally, some also principally questioned the neutrality of Gassnova, due to its two roles as being responsible for both the Norwegian State's interest in the Mongstad TCM/CCM and the demonstration part of CLIMIT Programme.

7.3 Efforts and activities

7.3.1 Relevance of the activities and the structure of the project portfolio

A common view among the informants was that the projects receiving support from the programme have been relevant for achieving the overall objective of the programme. But many had comments regarding the structure of the project portfolio. The main comments are summarized below:

- Many informants stated that transportation was not sufficiently represented in the project portfolio so far. Transport of CO_2 is an important part of the CCS value chain, and Norway has, due to its positions as a large offshore transpor-

ter of natural gas, companies and institution with relevant knowledge for participating in international research to develop the CO_2 transportation technology further. It was also mentioned that Norway would be a significant receiver of CO_2 in the future and a large infrastructure for offshore transportation of CO_2 would likely be established offshore Norway if the CCS option takes off in Europe. However, the transportation area has received increased attention lately.

- A frequently mentioned issue was the balance between demonstration and research projects. Some meant that there have been too few demonstration projects relative to research projects. They argued that Norway doesn't have an industry capable of bringing many of the good ideas and concepts developed in the research institutions closer to the commercialization phase. Another related explanation was that the technology is still immature and that the uncertainties remain regarding when the technology is to be commercial. The commercial risk is therefore considered to be too large for most potential industry actors in Norway. Some other informants underlined on the other hand that the technology gaps were larger and probably underestimated when the programme started. The need for basic research is still great, indicating that the research projects should have had a higher priority relative to demonstration projects.
- Among the demonstration projects too few are sufficiently large. Statoil is the only player with a big enough capital base to enter large demonstration projects.
- Some informants are critical to the number of projects and institutions involved in the programme. One argument is that the programme should have been brave enough to concentrate the activity among few research institutions. But other welcomes the pluralism, and thinks it is a good thing that many institution and companies have had the possibility to participate in the programme.

7.3.2 International cooperation and participation in the Programme

"Many applications come from companies and institutions without international network. On the other hand, there are quite a few examples of projects with extensive international co-operation and involvement. One good example is the ADA project (Claus Nielsen of UiO). Also within storage you will find projects with extensive international co-operation. More international co-operation would have been positive. According to the Programme's guidelines, CLIMIT can only finance projects with Norwegian applicants and with significant development in Norway." From the interview with Gassnova.

- Some of the informants state that international cooperation is important and that the Programme has been too weak in stimulating international participation in the project.
- Some others have an opposite view, namely that the Programme has underlined the importance of international cooperation and has been fairly good at marketing Norwegian institutions and competence abroad.
- It is difficult to establish international cooperation before the institutions have established an international network. Some of the institutions suggest that the Programme should have the possibility to support development of institutional cooperation.

The Programme is not entitled to support research activities of potential international partners. According to some of the informants, this could be an obstacle for an increase in international cooperation.

7.3.3 Link between the CLIMIT Programme and the Mongstad Technology Senter

"To support Mongstad is not an explicit objective of the CLIMIT Programme. But the existence of the Mongstad project (TCM and CCM) has certainly influenced which technological questions have been developed and supported. In that respect the existence of the Mongstad Project has attracted attention" From the interview with the Ministry of Oil and Energy

- The common view among the informants is that the TCM and CCM have been very important for the CLIMIT Programme, even though there is no formal link between the two. The whole Programme, the applications and the issues in focus have to a large extent been influenced by the Challenges of the TCM and CCM (the full scale project)

- But there are also critical voices from some of the informants; TCM is not an adequate demonstration site for CLIMIT projects. This is a great disadvantage since access to demonstration sites is an important precondition for promoting new demonstration projects.

7.3.4 Transparency

Several of the informants raised the question of transparency of research results. One recommendation was to look to USA when it comes to transparency. The dilemma is of course that research results have a commercial value, and in projects with private co-funding, the access to research results is restricted for commercial reasons. As some of the informants argued, this could however be an obstacle for the migration of competence and the development of new ideas.

7.4 Results and effects

7.4.1 Has the CLIMIT Programme contributed to accelerating the commercialization of CCS technology?

"Many projects financed by the CLIMIT Programme have given results that definitely have contributed to reducing the technology gaps. We underestimated the challenges when we started, but the research has not revealed any new show stoppers." From the interview with Gassnova

"The results have been more indirect. We have developed knowledge which has given the industry ideas on how to revise, adjust or develop the technology further." From the Interview with project leaders from the University of Oslo

The informants were generally very positive regarding the role the CLIMIT Programme plays as a facilitator for reducing technology gaps. A common view, however, was that the expected number of years before CCS is likely to become commercial has increased since the CLIMIT Programme started. The reason is that the challenges related to the CCS value chain, including the technology gaps, have turned out to be greater than anybody predicted five years ago. Nevertheless, even though the estimated time for commercialization has been postponed, it is still valid to say that the CLIMIT Programme has contributed to an acceleration of CCS technology by improving the knowledge in important areas and by reducing the technology gaps, even though the gaps turned out to be larger than anticipated.

7.4.2 In which areas have the programme given the most important contributions?

The views differ when it comes to identifying the most successful areas of the Programme. But some technological areas are frequently mentioned. Many of informants were for obvious reasons not neutral when commenting the main areas for success. Therefore we only refer the views of the representatives from Gassnova and RCN, respectively.

Representatives from the Research Council summarize the most significant results as follows:

- Amine technology, significant reduction in energy consumption is documented
- Better knowledge regarding CO_2 behavior in reservoirs
- Better understanding of air pollution from amine processes
- Certification of CCS technology
- Monitoring of CO_2 in reservoirs
- Chemical looping
- Combustion technology
- Membrane technology

Representatives from Gassnova mentioned the following areas to be most successful:

- 3 C project
- Environmental issues
- Measure leakage from geological storage
- Guidelines for best practice. Certification of capture technology

7.4.3 Cooperation between Norwegian and International research institution and commercial actors

"CLIMIT has made Norwegian institutions interesting in international co-operations, for instance in EU-projects." From the interview with project leaders from SINTEF

International cooperation could have been more extensive for the projects supported by the CLIMIT Programme. Even so, the Programme has stimulated participants to establish cooperation with international institutions. Many of the projects have international partners or sub-contractors. And the competence build-up, which has come as a result of the Programme, has made Norwegian research institutions interesting partners in projects abroad, not the least in relation to EU projects.

One challenge, though, is that the institutions need a network before international cooperation is possible. According to some of the informants, there should have been time and money in the projects supported by the CLIMIT Programme for networking activities.

7.4.4 International attention?

"Our general competence has made the industry interested" From the Interview with project leaders from the University of Oslo

The international CCS community is very much aware of the CCS activities in Norway. The Sleipner project and Mongstad projects (TCM and CCM) have received substantial international attention. Also CLIMIT projects and the competence which the Programme has fostered have attracted international attention. In general, both SINTEF and NTNU have established a strong foothold as Centers of Excellences within research relevant for CCS technology.

7.4.5 Implication for education programmes in Norway

The universities interviewed (UiO, UiB, NTNU) have established courses in CCS-relevant subjects both at Master and PhD levels. There are several PhD students and post docs working in the CCS field, in particular at NTNU, but also at other universities.

Tel-Tek has, as a result of the Programme, entered into close cooperation with Høgskolen i Telemark. One rig for testing amine processes is built and used for educational purposes. Here CCS related subjects are also included at Bachelor level as well.

The University of Bergen has established courses at Bachelor level together with Gassnova.

A list of Post docs and PhDs received from RCN is enclosed in appendix 10.4.

7.4.6 Application of the knowledge outside of pure CCS

When it comes to application of the knowledge outside of pure CCS, the following areas were mentioned:

- Separating CO_2 from the natural gas flow.
- Degradation of biological materiel in the air is of general interest.
- Shale gas production
- Geothermal production
- Hydrology
- Water supply
- Biotechnology
- Waste Management
- Water Supply
- Sustainable energy production
- Other flue gas capturing

7.4.7 New technology companies

Not many new technology companies have been established as a result of the research activities in the research institutions. In the institutions interviewed, there were just a couple incorporations which partly could be linked to the research activity spurred by the CLIMIT Programme.

One of the informants said that generally Norwegian research institutions do not have the tradition to support the researchers in commercialization of new ideas and prospects. More competence and systematic support to researchers with ambitions to form new technology companies would have been helpful according to the informant.

7.5 Additionality

"Additionality has definitively been the case." From the Interview with Research Council of Norway

All informants express that a large part of the research activity supported by the CLIMIT Programme would not have been undertaken without the Programme. One informant put it this way: The CLIMIT Programme has not only been a precondition for financing projects, but has also stimulated the research institutions and the industry to develop new ideas, which would not have been developed without the Programme.

Based on comments from informants, additionality is definitely the case for the capture end of the value chain, since this technology is immature and contains considerable commercial risk. Commercial actors, and in particular Norwegian companies, would not have financed significant projects without support from the CLIMIT Programme.

In the storage end of the value chain, additionality is by and large also the case, but some issues addressed could be of commercial interest for the oil and gas industry regardless of CCS. Nevertheless, the activity level would have been much lower without the Programme.

Several informants also stressed the fact that the CLIMIT programme also yields value beyond the financial support. The views can be summarized to the following:

- The Programme has spurred more cooperation between institutions and companies. This increased interaction has been positive for technology diffusion
- Many of the informants had the view that the CLIMIT secretariat is very competent and has deep understanding of the challenges related to CCS technology. A professional secretariat is a pre for the Programme in many ways. It means for instance fruitful dialogues between the institutions and the secretariat in various processes. Some informants said that they have received valuable support in connection with the application processes
- The CLIMIT program has given synergies by making the Norwegian CCS activities and technological competence known outside Norway. Some informants remarked that the CLIMIT secretariat has been good at marketing Norwegian CCS competence internationally, by being present in international CCS venues and by arranging conferences in Norway with broad international participation

Chapter 8. Results from survey

In this chapter, we will present the results from the web-based survey which was carried out among project leaders of CLIMIT-funded projects (see section 5.3 for a presentation of the population and sample of respondents). We start out by reporting findings describing the background information which completes the registry data. This background information is a descriptive in nature as it seeks to describe the variety of activities and efforts in the CLIMIT project portfolio. In the second part of this chapter, we present results and effects of the projects. Throughout this part of the chapter, we test for differences between the Gassnova- and RCN-funded projects as well as for differences between Capture-, Storage- and Transportation projects, i.e. the main characteristics (background information) of the CLIMIT projects.

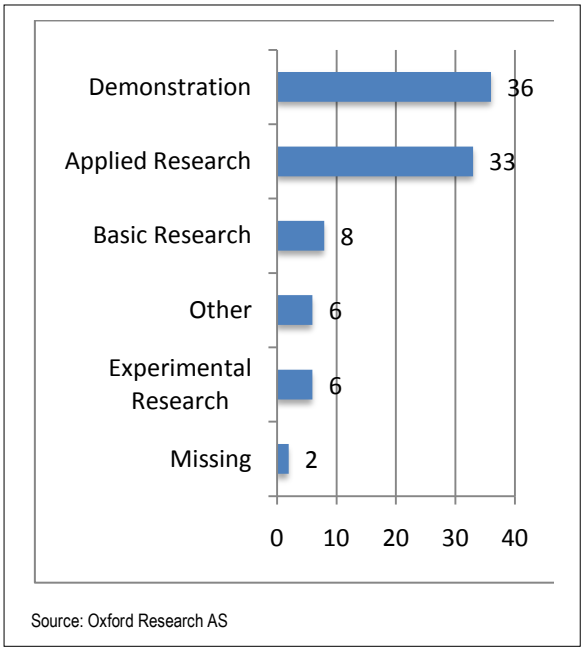
8.1 Background information on projects (refinement of registry data)

In this section we present the results from the first part of the survey. The intention of this part was to complete the dataset of the registry data as there was information missing for several projects with respect to which technology area they belong.

8.1.1 Project portfolio composition: RCN- and Gassnova-funded projects

The evaluation database contains information on whether the projects are funded by the Research Council or Gassnova. The projects leaders of the RCN-funded projects where asked whether their projects focused on basic, applied or experimental research.[4] The distribution of the project portfolio in this dimension is displayed in the next figure.

Figure 9: Main purpose of the project, frequencies, N=91



Source: Oxford Research AS

The demonstration projects are those funded by Gassnova.[5] Of the other projects, figure 9 shows that applied research was the most frequent type of research. Only a small proportion of the projects were categorized as basic research or experimental research projects. This indicates that the portfolio of CLIMIT-funded projects is mainly oriented towards applied research.

Of the respondents that stated "other" as their purpose, the networking, preparing for cooperation, administrative work and general input on the R&D agenda were mentioned, together with one project that combined applied and basic research.

8.1.2 Specific technological areas for CLIMIT projects

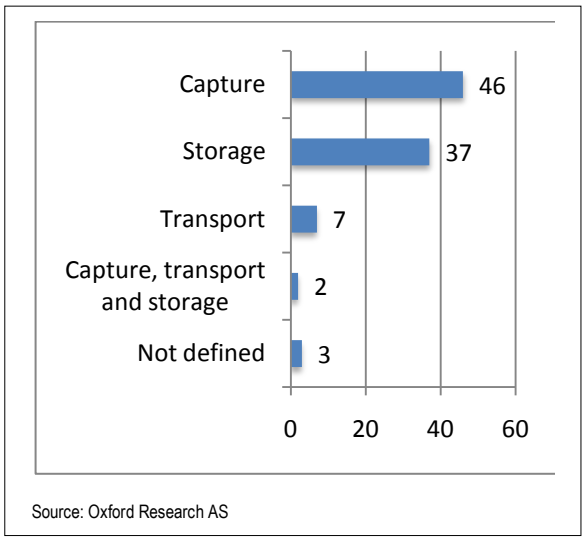
In 20 cases, the registry data did not show which technology area the projects belonged to. To fill in this information gap, the project leaders of these projects were asked to submit that information. The figure below shows the distribution of the projects on technology areas. Capture and storage projects

[4] The categorization is based on the Frascati manual, see: OECD (2003): Frascati Manual 2002. Proposed Standard Practice for Surveys on Research and Experimental Development. OECD Publishing, Paris.

[5] It should be noted that Gassnova refers to their demonstration projects also as Industrial research projects.

represent the two largest categories of the evaluated projects, with only seven projects concentrating on the transport area. In general, the projects are focused on one technology area however two projects look at all three areas (capture, storage and transportation).

Figure 10: CLIMIT projects by technology area, N=95

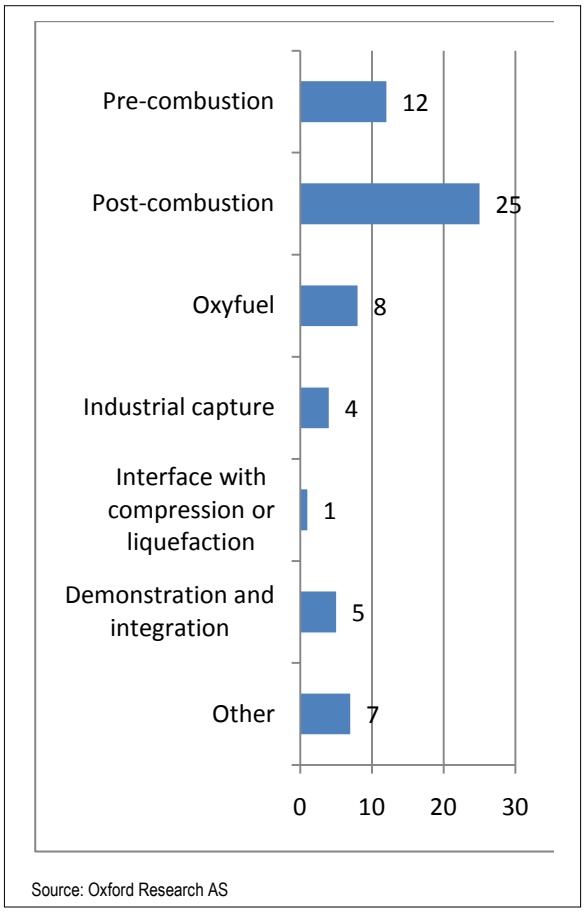


As a further refinement of the focus of the projects, the project leaders were asked to categorize their project(s) by choosing from a predefined list of possible subareas within each of the technology areas (multiple answers were possible). These subareas correspond to the identified technological gaps in the CCS-value chain, as described in chapter 3.

The results are shown in the following three figures.

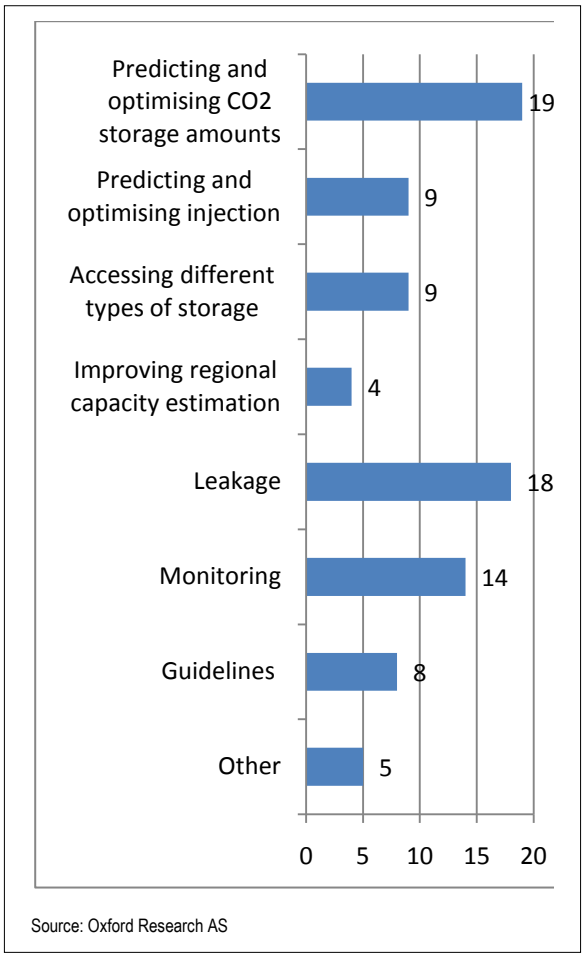
Figure 11 shows that the capture projects surveyed are mainly focused on combustion technologies, with a lion's share falling into Post-combustion technologies with pre-combustion and oxyfuel technology as the second and third most popular areas. In the "other"-category, non-combustion technology, surface hydrogen, general environment focus as well as public acceptance were mentioned. One project also stated that they were looking at the whole value chain.

Figure 11: CLIMIT capture projects by subarea, frequencies, N=45



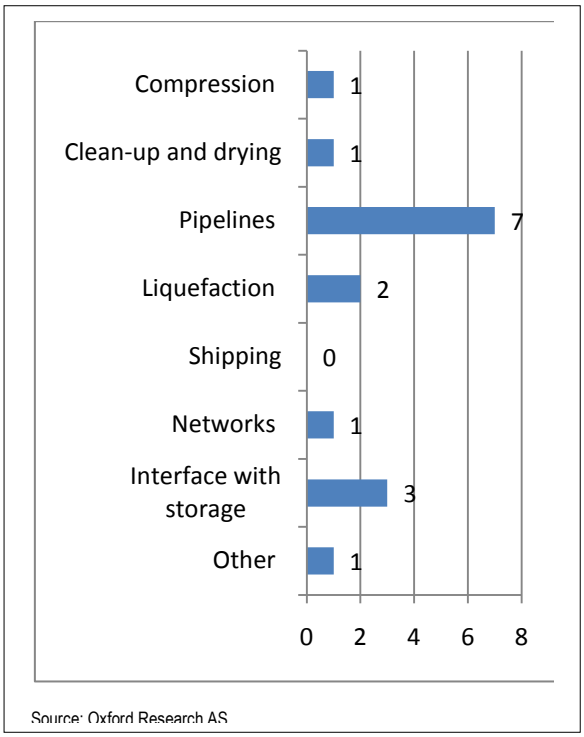
The portfolio of storage projects is more diverse than the capture projects in terms of number of subareas covered. As figure 12 shows most storage projects focus on prediction and optimizing of CO_2-storage amounts, leakage challenges as well as monitoring. The "other"-category included basic research on the behaviour of CO_2 in various media, carbon utilization in the industry and efficient utilization, preparation of research cooperation and well integrity.

Figure 12: CLIMIT storage projects by subarea, frequencies, N=37



The portfolio of transport projects is less diverse as all projects surveyed dealt with challenges related to pipelines. Most projects also involved other technological areas, with interface with storage as the second most popular field. No projects were concerned with challenges related to shipping. The "other"-category included one project that dealt with risk assessments.

Figure 13: CLIMIT transport projects by subarea, frequencies, N=7



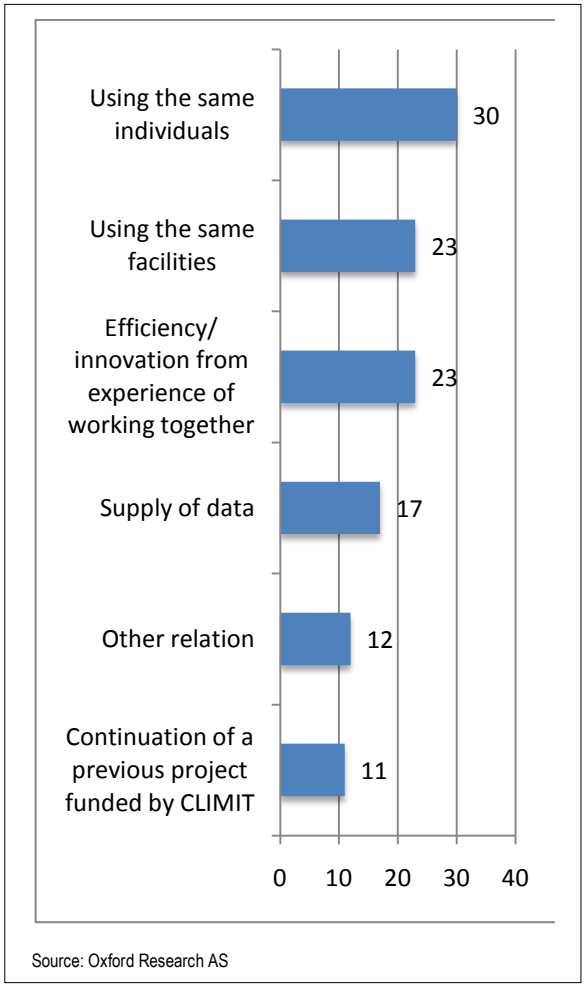
8.1.3 Link to other CLIMIT projects and Mongstad CCS projects

Out of the 91 projects which answered the question of whether their CLIMIT-project(s) are/were linked to other CLIMIT-projects, 37 (41 percent) gave a positive answer. This implies that the CLIMIT project portfolio is made up of a fairly high degree of connected and interlinked projects. Together with the fact that some 25 percent of the project leaders are in charge of more than one project, this could also indicate that there is a high degree of cooperation in the programme. In the next figure the content of the linkages are displayed.

As is evident from figure 14 there is a multitude of relations between projects, both in terms of personnel and infrastructure. Moreover, the answers reveal that cooperation yield important rewards in terms of increased efficiency and innovation. The "other"-category included continuation of previous Research Council projects, cooperation with EU FP6 projects and implementation of methods developed in other programmes, synergies with ADA projects and cooperation with SOLVit, integration with SUCCESS, and

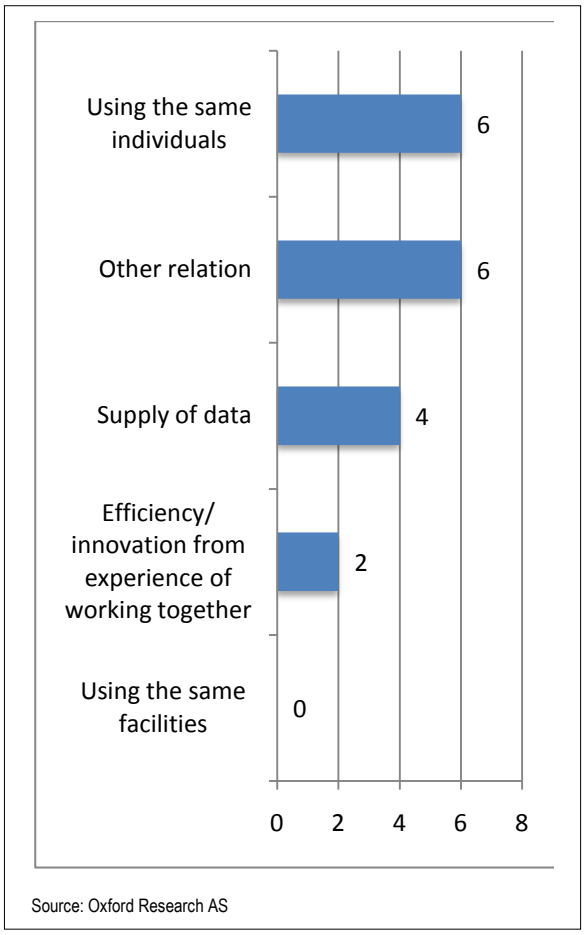
other projects funded by GASSNOVA and Basic Research funded by the Research Council.

Figure 14: Content of CLIMIT project linkages, frequencies, N=37



The respondents were further asked whether their CLIMIT-project(s) are/were linked to the Mongstad CCS project. 15 out of 91 respondents answered this question with yes, i.e. some 16 percent of the CLIMIT-funded projects are related to the Mongstad CCS project. In the next figure the nature of the reported linkages are displayed.

Figure 15: Link to Mongstad CCS projects, frequencies, N=15



As the figure shows, of the specified linkages, the sharing of personnel is the most frequent linkage, but also supply of data is a common link to the Mongstad project. The "Other relation"-category included competence building, internal network synergies in Statoil, using same suppliers, assessing a prospective storage site for Mongstad, as well as environmental aspects of PCCC where Mongstad has similar projects, but where there is no scientific overlap. One respondent stated that their project might be linked to Mongstad.

8.2 Additionality and project deliverables

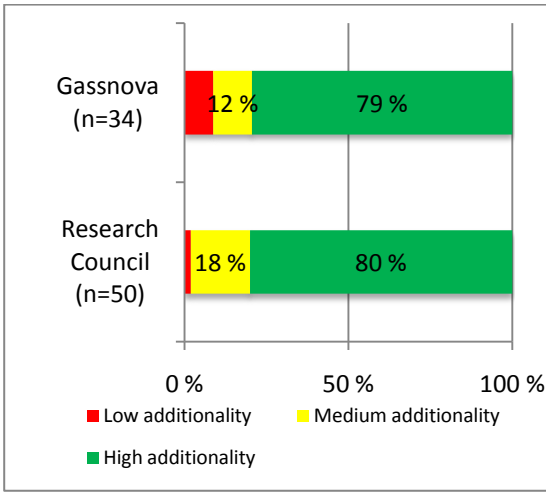
In this section we will present the results from the survey's second part. The purpose is to reveal how the respondents evaluate the additionality of the CLIMIT project. Moreover, we will show if there are any differences between the technology areas and programme types.

8.2.1 Input additionality

Two questions in the survey measures the input additionality of the programme. These concern the importance of CLIMIT funding for the importance of financial support from CLIMIT for the respondents' ability to carry out the project. The answers have then been broken down on project type and technological area to assess if there are any differences in the additionality between these sub-groups.

The input additionality is generally seen as high by the respondents. As figure 18 shows, for 18 % of the Gassnova-funded projects and 10% of the RCN-funded projects the financial support from CLIMIT has had little to say for the ability to carry out the project. On the other hand, a majority of the respondents state that the without the CLIMIT support the project would either not have been carried out, or carried out on a smaller scale at a later time. In other words, the financial support is perceived as very important by those that have received CLIMIT-funding.

Figure 16: Additionality of CLIMIT projects by funding-source

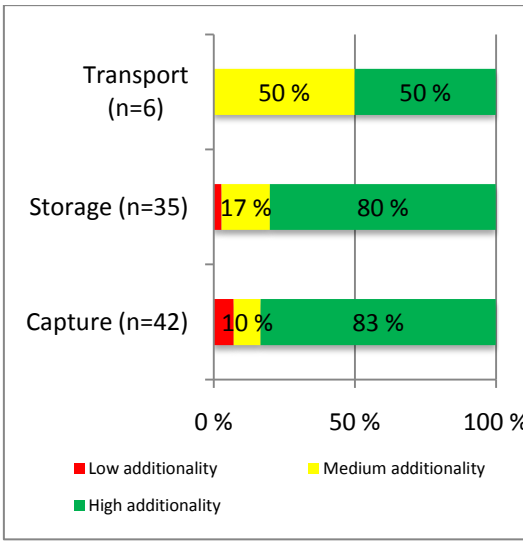


Source: Oxford Research AS

When looking at the answers for the Gassnova- and RCN-funded projects separately there we find no significant differences between the two groups on how they value the CLIMIT financial support. This confirms the findings in the interviews on input additionality.

The next figure illustrates the importance of CLIMIT funding for the projects broken down by technological area. Again, there are no significant differences between the areas.

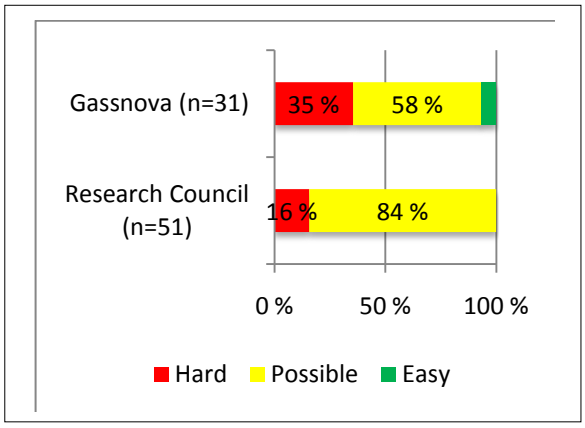
Figure 17: Additionality of CLIMIT projects by technology area



Source: Oxford Research AS

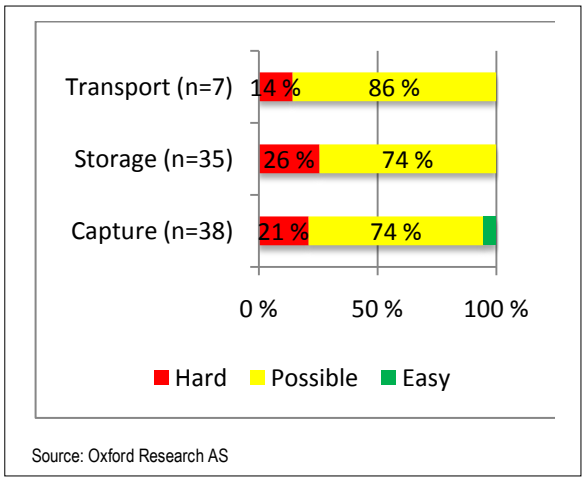
When moving on to alternative finance sources, the previous finding that CLIMIT plays an important role as a financier of projects is confirmed. As shown in figure 19, only 7 % of the Gassnova-funded projects report that alternative financing would have been easy to obtain and the percentage is 0 for RCN-funded projects. However, the as many as 35 % of Gassnova-projects stated that is would have been hard to find other sources of financing, while 16 % of the RCN-projects claimed the same. In other words, it is more difficult those that have received funding from Gassnova to find alternative support than it is for RCN-funded projects, and this difference is statistically significant.

Figure 18: Respondent assessment of alternative sources of project finance if no CLIMIT support, by funding source



When looking at the numbers based on technology area, we find no significant differences between the three areas surveyed.

Figure 19: Respondent assessment of alternative sources of project finance if no CLIMIT support, by technology area



Source: Oxford Research AS

To sum up, the overall finding for input additionality is that CLIMIT is both seen as an important finance source and that this source makes it possible to get financial support that otherwise would have been hard to find.

8.2.2 Deliverables in CLIMIT projects

In this section we study how the project leaders of CLIMIT-funded projects assess the performance of their projects in terms of actual results or deliverables. In this evaluation, a number of possible project deliverables were pre-defined by the evaluation team[6] and the respondents were asked to indicate which deliverables have already been obtained, are planned to be obtained or are not targeted at all in the project.

In the subsequent analysis, we have divided the project deliverables into two groups, based on:

- Whether a certain objective has been targeted or not and
- If the targeted objective has been reached, and if not, in which timeframe it is planned to be reached.

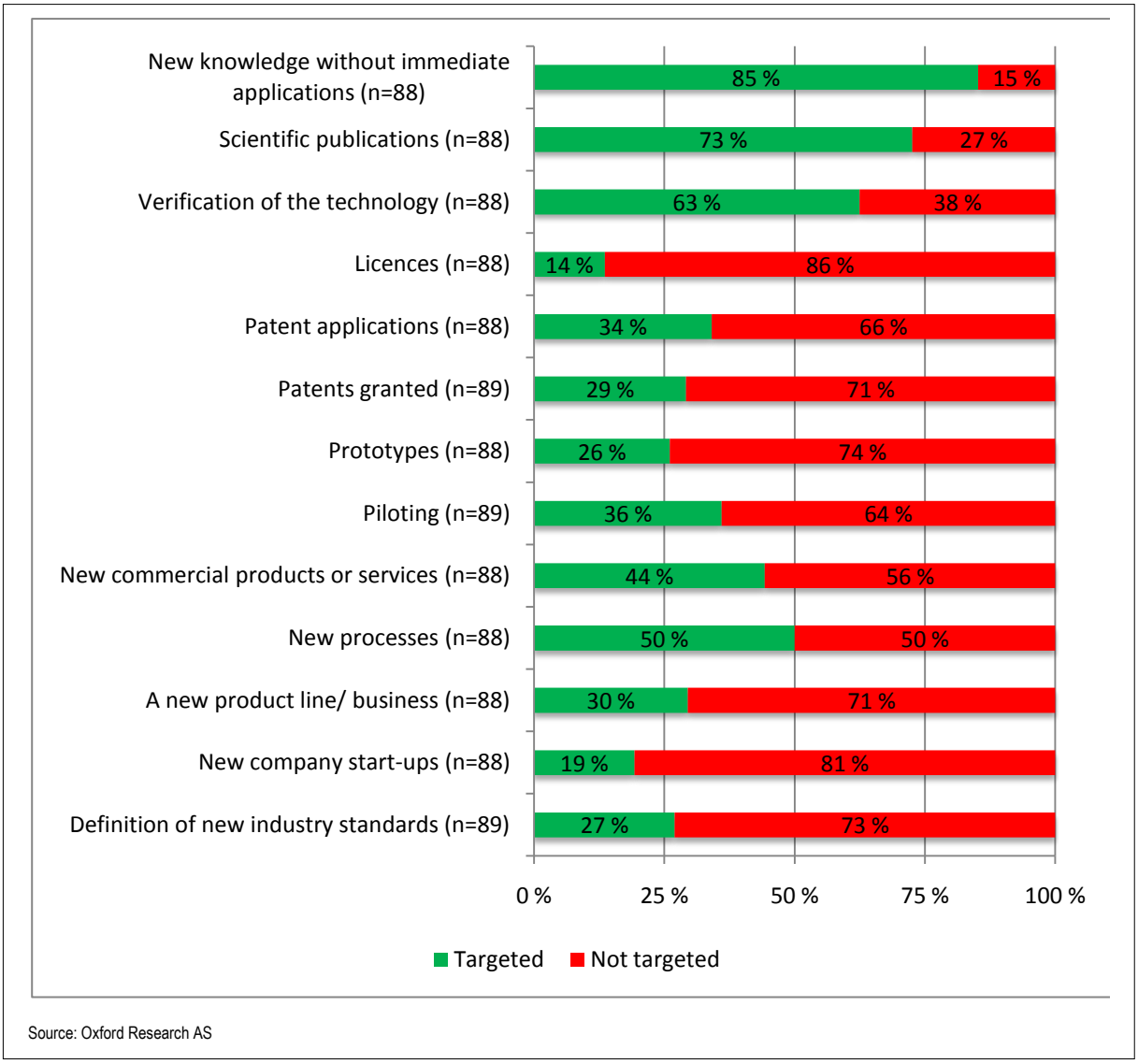
Consequently, the results displayed in Figure 20 is not directly based on the questions the respondents were asked, but is derived from their answers on the question battery concerning which deliverables they have targeted and within which timeframe. Thus, the not-targeted category is based on the respondents that answered that they did not target a specific deliverable, while the targeted category consists of the respondents that answered that they either had obtained, or planned to obtain a certain deliverable.

The survey shows that the CLIMIT projects have targeted a wide range of goals, varying from knowledge and technology development to commercialization of technology and new companies. As the figure below shows, there are some differences between the areas targeted by the various projects. A difference between knowledge development and commercialization is visible from the figure. Most projects aim at generating new knowledge, scientific publications and verification of technology. But when looking at the commercialization related deliverables, the frequency is much lower. At the low end of the scale, only 14 % of the projects have attempted to license new technology, and 19 % had company start-ups as an objective compared to 73 % for scientific publications.

[6] The list of deliverables is a CCS-adjusted extension of the list used in the evaluation of the DEMO 2000 program, see Hansen, T.B. et. al. (2005).

When interpreting these number it is however important to bear in mind that as we move down the figure, from knowledge development to industry standards, we also move further down the timeline. While publications and knowledge development can be attained in most technology projects, new commercial products or services demand that the project already has generated important and necessary technology.

Figure 20: Intended deliverables in CLIMIT projects



Source: Oxford Research AS

We continue by looking more closely at the targeted deliverables and analyse the time frame for their accomplishment, i.e. those which are already obtained and those which are planned to be achieved in the future. As figure 21 shows, there is a great variety in success rate among the different deliverables. Where the green areas represent the targeted deliverables that have already been accomplished, the yellow area represent those that are expected to be obtained shortly, and the orange those are planned to be obtained in four years or more. When moving from left to right in the figure, in addition to moving along a time dimension, the level of uncertainty also increases. Thus, whether or not the outcomes that are expected in ten years time will be realized is uncertain at this stage.

Another factor that influences how this figure should be interpreted is that the survey includes both ongoing projects as well as projects that were finished some years ago.

Despite these caveats, overall those areas that have been targeted by the projects seem to yield a fairly high success rate. However, as was evident in the latter figure, scientific objectives generally have a higher accomplishment rate than those related to commercialization. Generally, the commercialization deliverables receive low scores, but there are some notable exceptions. The projects that intended to start new companies or develop new processes have a relatively high success rate. In other words, the projects that aimed at starting up new businesses have succeeded in doing so. However, only 17 projects stated that they had the intention of doing so. The deliverables have not been quantified and, hence these may be seen as conservative estimates of achieved and expected deliverables.

A positive finding here is that the projects that attempted to patent their technology have a high success rate. The same is also true for prototyping. However, the last leg of the commercialization process yields fewer results than the earlier steps.

When looking at differences in outcomes between RCN- and Gassnova-funded projects we find few examples of variation. The only significant difference between the two is found for scientific publications, where there is a significant higher production among the RCN-projects than among the Gassnova-projects.

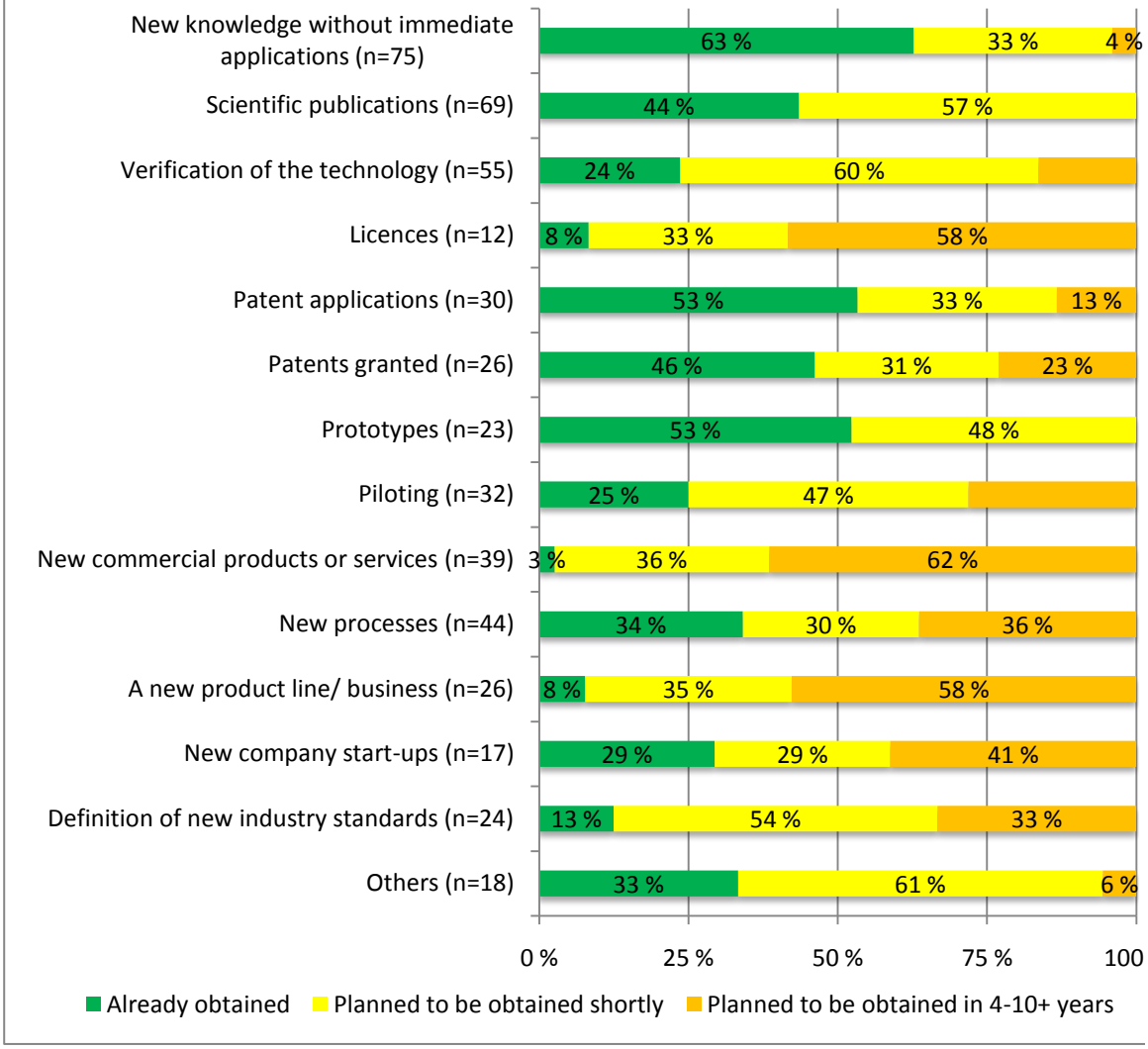
When moving on to commercialization, there are no differences, which mean that RCN-projects result in the same level of commercialization as the Gassnova-funded projects.

However, when the projects are grouped into ongoing or completed projects, we see significant differences for most activities. But for the categories “Verification of new technology”, “Piloting”, “New commercial products or services” and “New company start-ups” we find no significant differences between the two groups. To sum up, the difference between ongoing and completed projects revealed here, suggests that the success rate is likely to increase in the coming years, as more projects are finished and obtain their targeted objectives.

Overall, our impression is that, despite the lower success rate of the activities related to commercialization of knowledge and technology, the picture of already obtained results is very positive. When taking into account that most of these activities are of a long-term nature where results takes time to materialize, combined with the fact that many projects are still active, our impression is that the CLIMIT projects deliver on most accounts.

When compared with corresponding results from the evaluation of the DEMO 2000 programme, which included a comparable number of projects, we may conclude that the CLIMIT-projects in some areas score higher than those of DEMO 2000. This is especially true for patents and new processes.

Figure 21: Deliverables of CLIMIT projects, by timeframe of accomplishment



Source: Oxford Research AS

Not all the achieved or planned deliverables can be attributed to the CLIMIT Programme. The programme only co-finances the projects. To assess the impact the respondents think that the CLIMIT programme has had on the deliverables, the respondents were asked to consider CLIMITs impact, i.e. the effect of the programme.

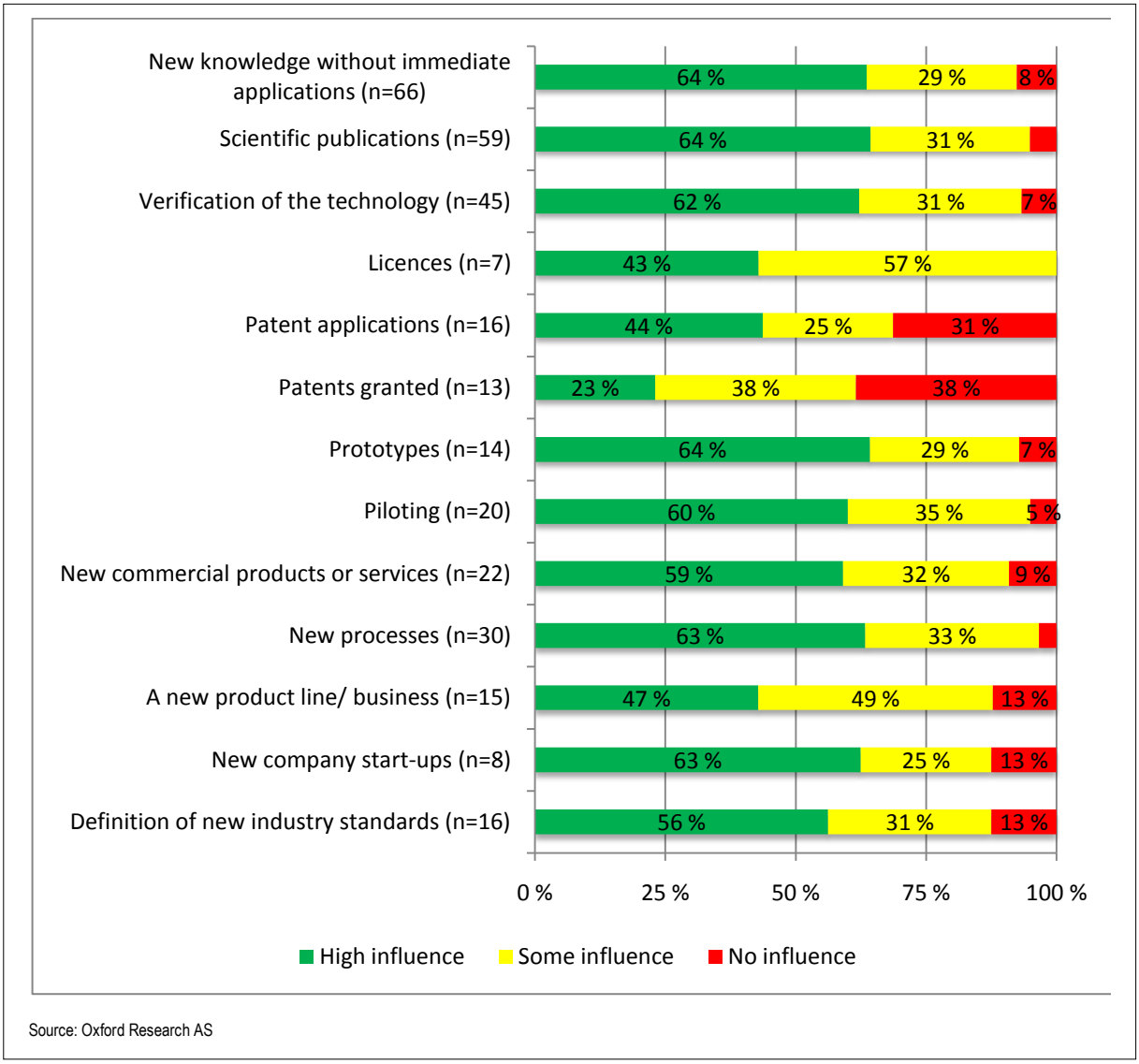
Figure 22 reveals that CLIMIT is viewed as very important for the achieved and expected results. In a majority of activities, the respondents state that CLIMIT has had a high influence on the deliverables in the projects. The most obvious break with the pattern is related to patent applications and patents granted. For patents granted only 23 % say that CLIMIT has had a high influence, and close to 40 % say that the programme has had no influence on the result. This may indicate that the programme has not placed special emphasis on IPR-related matters.

When we compare the scores on the different deliverables between RCN- and Gassnova-funded projects, the general impression is that the respondents from the RCN-funded projects value the CLIMIT-support more than the respondents from the Gassnova-funded projects. In four areas we see significant differences in answers. The project leaders from the RCN-funded projects report more often that CLIMIT had a high influence on the deliverables than the respondents from the Gassnova-funded projects for scientific publications, verification of technology, prototypes and new commercial products or services. In other words, the CLIMIT programme has mattered more for the RCN-projects for knowledge

and technology development, but also for some of the more commercial deliverables.

When the answers are analyzed along the lines of technology area, there are few differences between capture, storage and transport. The only area where we see significant differences is on scientific publications, where the CLIMIT programme is reported as having played a larger role in the capture field than in storage and especially transportation.

Figure 22: Programme influence on deliverables



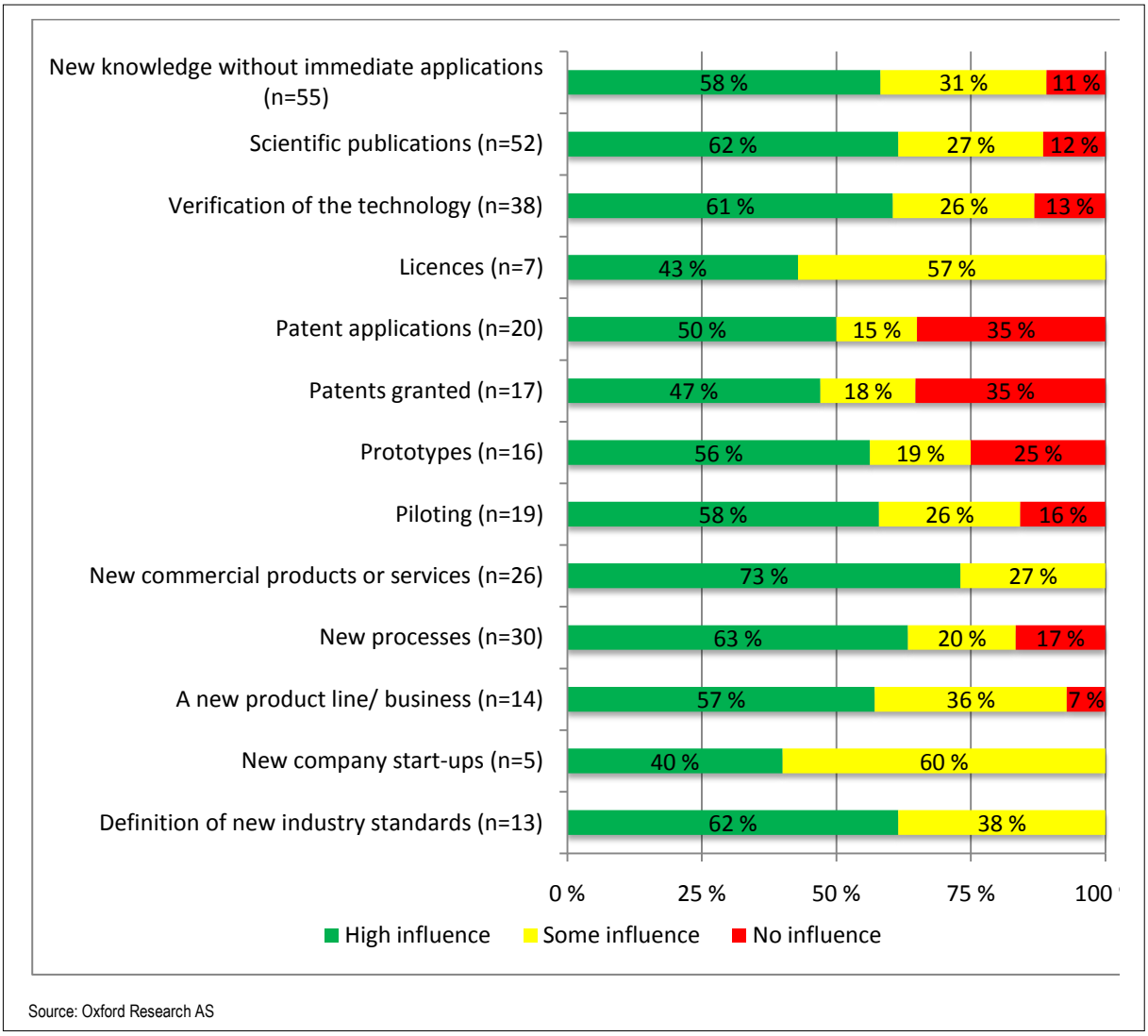
Source: Oxford Research AS

The next figure shows how the respondents view the partners influence on the deliverables from the project. As the figure illustrates, partners have had a high influence for most deliverables. That partners are important for scientific publication and knowledge development is not unexpected, but the high scores for commercial activities are. For the projects that had the development of new commercial products or services as an objective, as many as 73 % have found partners to be central for the outcome.

This shows that cooperation and partnership is important to develop both knowledge and new technology as well as to be able to commercialize these findings.

When broken down on Gassnova and RCN-funded projects, we see some differences. The partners are seen to be more important by the RCN –projects than the Gassnova-projects in two areas, piloting and definition of industry standards. When broken down on capture, storage and transportation, we find very little difference.

Figure 23: Partner influence on deliverables



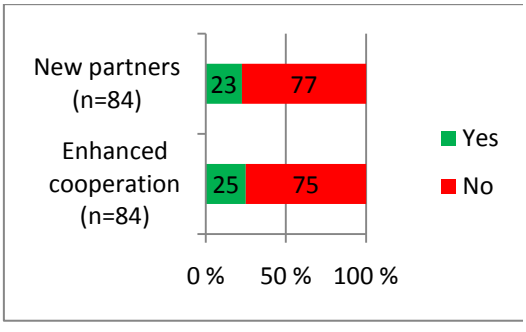
Source: Oxford Research AS

8.2.3 Enhanced cooperation and new partners

We have already established above that the CLIMIT projects to a quite high extent are linked together through personnel and facilities. As an extension of this observation, the respondents were asked whether the project has lead to enhanced cooperation between the partners in the project outside the scope of the CLIMIT-funded project. Furthermore, the project leaders gave their judgement of whether their project has lead to cooperation with new partners. The results of these questions are shown in the next figure.

As figure 24 shows, we find a quite low degree of both new partners and enhanced cooperation. This may imply that most of the important players are already participating in the programme. We have also learned that cooperation works well and that partners are important for achieving results. There are no differences between the RCN- and the Gassnova funded projects on these variables.

Figure 24: Enhanced cooperation and new partners in CLIMIT projects

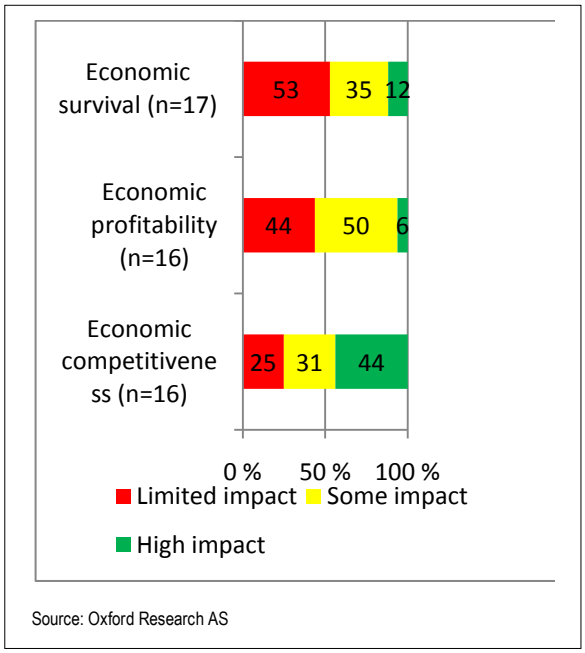


Source: Oxford Research AS

8.2.4 Economic performance

The privately-owned beneficiaries in the CLIMIT Programme were asked to assess the impact of CLIMIT regarding their company's competitiveness, profitability and survival. The results are shown in the next figure.

Figure 25: CLIMIT influence on economic performance



Source: Oxford Research AS

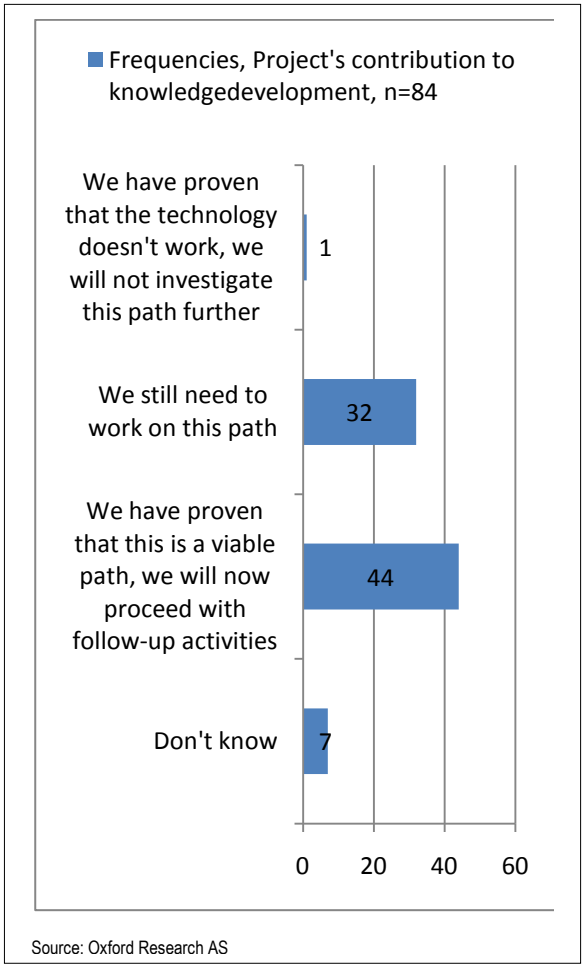
CLIMIT has the largest influence on the companies' competitiveness, and is far more important than for their economic profitability and survival. This may imply that it is regarded as strategically important to be part of the Programme in order to be involved in such long-term projects.

8.2.5 Knowledge development and project continuation

We now return to the technology gaps described in chapter 3. An important question in this evaluation is whether these gaps have been bridged or not. Obviously, knowledge of which technological paths turn out to be promising and which lead in less promising directions is of both scientific and economic interest to those involved. In order to approach this question in an indirect way, the respondents were asked to evaluate their projects' contribution to knowledge development in the technology area in which they are embedded or supporting. The results are shown in the next figure.

As the figure shows, only one project has been what could be labelled an apparent failure, and more than half are encouraged to move on. We find no difference in success rate between the projects funded by RCN and the projects funded by Gassnova or between the technology areas capture, storage and transport.

Figure 26: CLIMIT projects contribution to knowledge development



Source: Oxford Research AS

There are two points that should be taken into consideration when interpreting these results. First, while these numbers show a high success rate for knowledge development that is consistent with the previous findings linked to deliverables, the high success rate could also be interpreted as a sign that the programme is choosing low-risk projects.

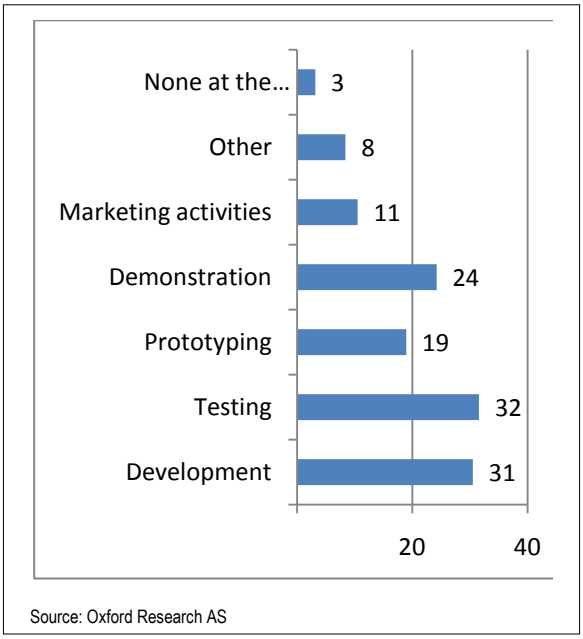
The second point is related to selection bias. There may be a weak tendency among the unsuccessful projects not to respond to the survey. We do not have any information that suggests that this is a major problem. However, some of the respondents

representing projects that had failed and been disbanded have not participated in the web survey.

To sum up, the general picture is that the CLIMIT-sponsored projects have been very successful in generating new knowledge within the CCS-field.

In the next figure we show which follow-up activities are planned for the projects which have proven that the path they have been working on seems promising.

Figure 27: CLIMIT project follow-up activities, in percentage



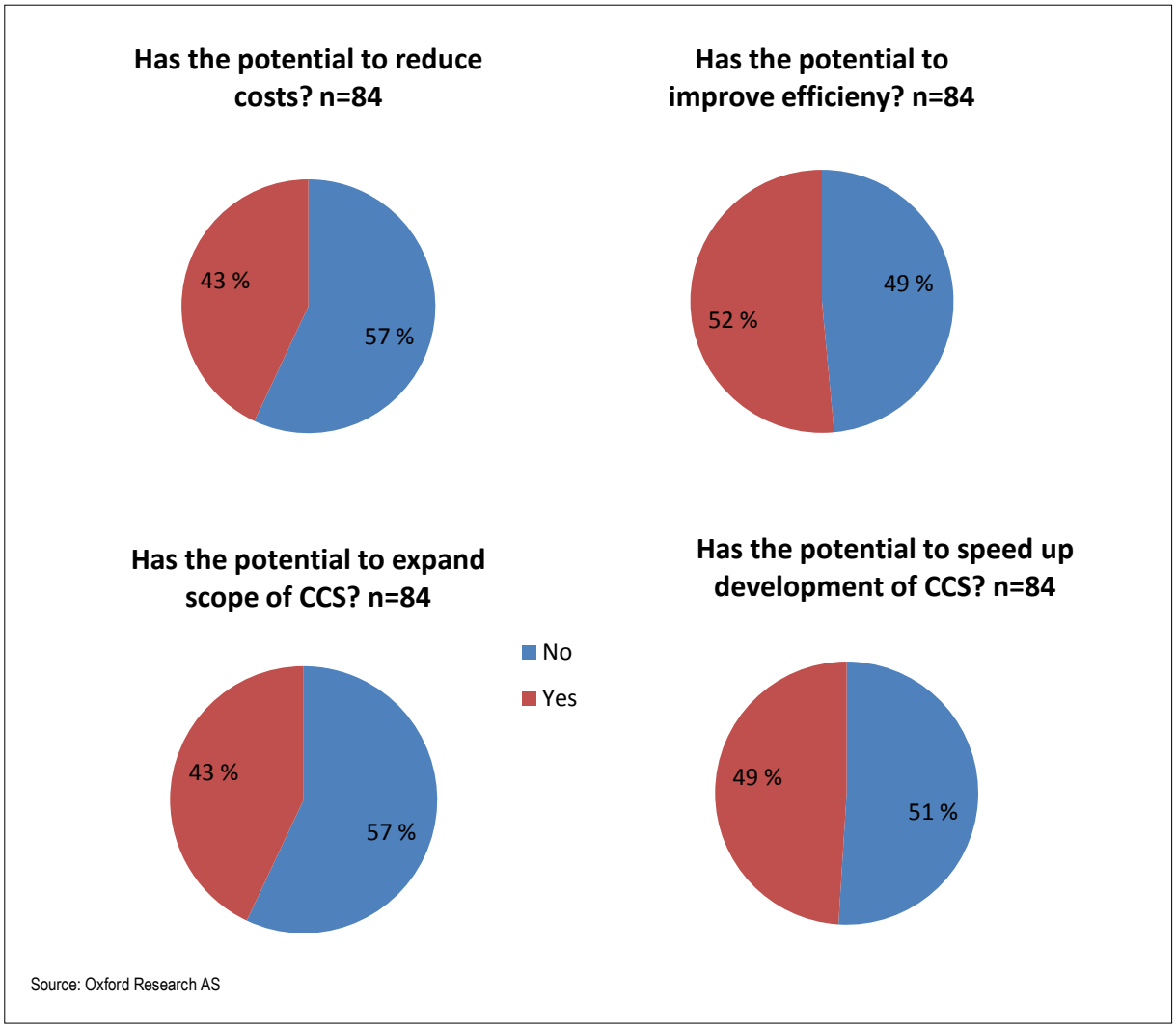
Source: Oxford Research AS

As is evident from the figure, there are a large number of follow-up activities either carried out or planned. This means that the results from the CLIMIT project are further developed after the CLIMIT project period is over. When seen in relation to the smaller success rate of commercialization deliverables seen in the previous sections, this finding suggests that we will see an increase in commercialization of the technology in the coming years. This will be further discussed in the next section.

8.2.6 The commercial potential of CLIMIT projects

We now move on to focus on how the respondents evaluate the commercial potential of the CLIMIT projects. Figure 28 shows how the respondents value their own project's commercial potential. The average yes-score across the four questions showed in figure 28 is 46 % and there is little variance between the four questions. Thus, the general conclusion is quite optimistic as almost half the respondents see some commercial value in their projects.

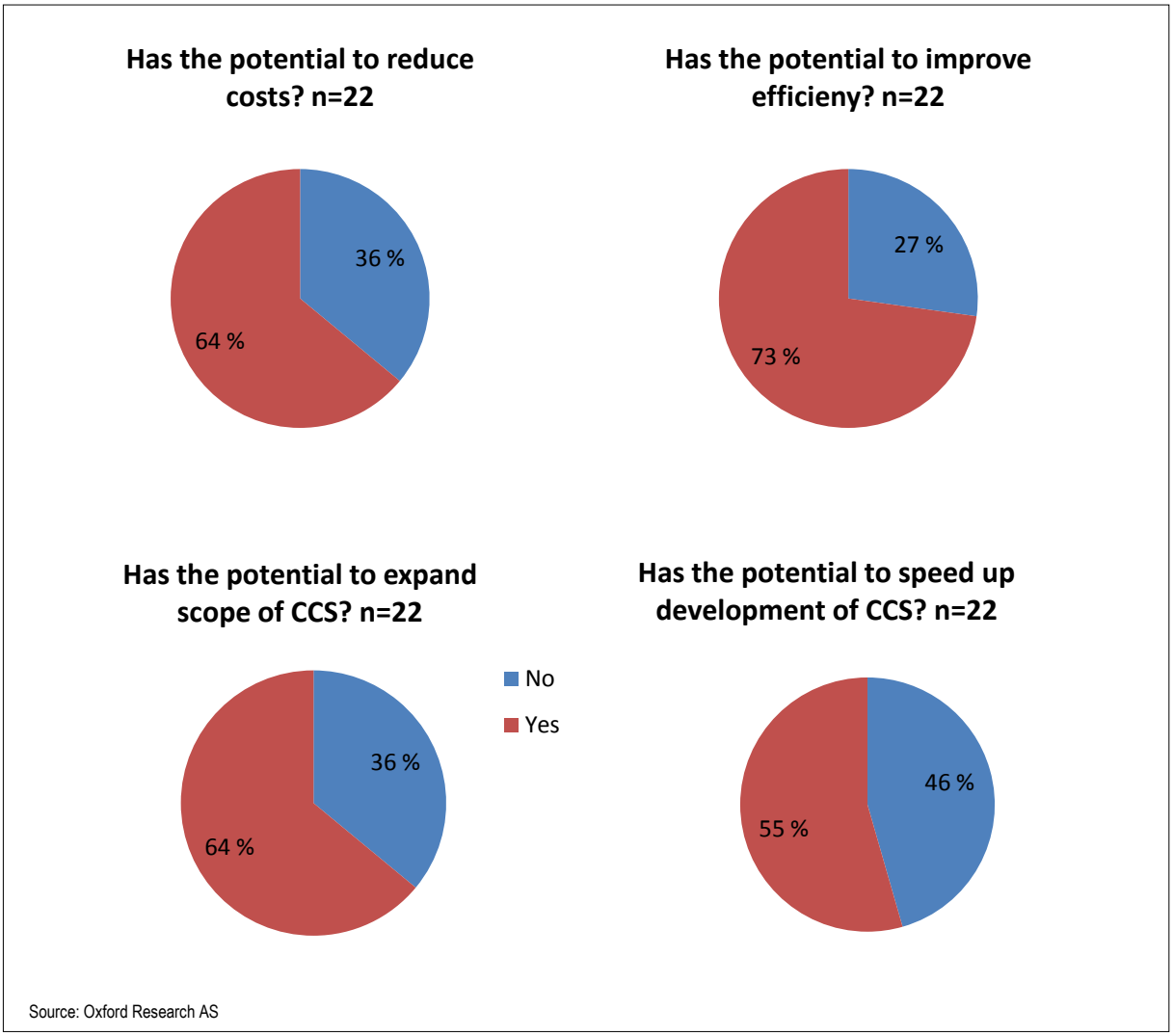
Figure 28: How would you evaluate your project's commercial potential, in percent? N=84



Source: Oxford Research AS

When we zoom in on the respondents that have a CCS-portfolio and asks them to evaluate their entire CCS-project portfolio's commercial potential, the view is even more optimistic. Among the respondents that have a portfolio (n=22), a clear majority state that their portfolio (which may include non-CLIMIT-funded projects as well) has a commercial potential. The commercial potential is regarded as higher for improving efficiency, whereas the potential to speed up the development of CCS is thought to be smaller at this stage. However, an important factor here is that there is a significant correlation among the respondents that see a commercial potential in their own project and those that have a portfolio and see a commercial potential in this portfolio. Hence, it is not surprising that the respondents with a portfolio generally are more positive than those with no portfolio. The result is expected. Those that are involved in more than one project must be assumed to generate more knowledge in the field and technological expertise than those with only one project. Moreover, it can be assumed that those that have access to technology with a commercial potential will involve themselves in more project, and hence, we must assume that the causal links go both ways.

Figure 29: CCS-project portfolio's commercial potential, in percent, N=22

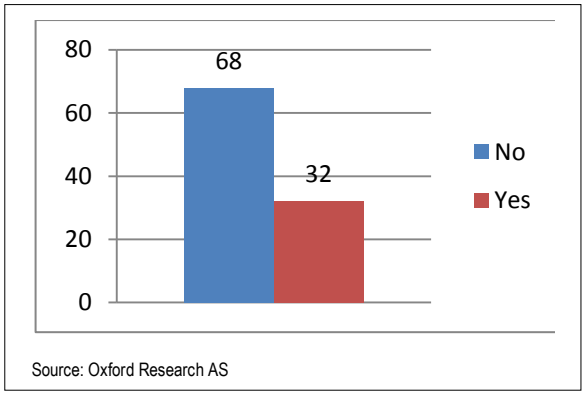


Source: Oxford Research AS

8.2.7 CLIMIT in comparison with international programmes

The figure below shows the percentage of respondents that are aware of international programmes with a similar profile to CLIMIT. A clear majority are not aware of such a programme. Of the 32 % that are aware of comparable programmes, EU's framework programme 7 is the most mentioned programme, by 10 respondents. Four respondents reported the US Department of Energy CCS Programmes as a benchmark.

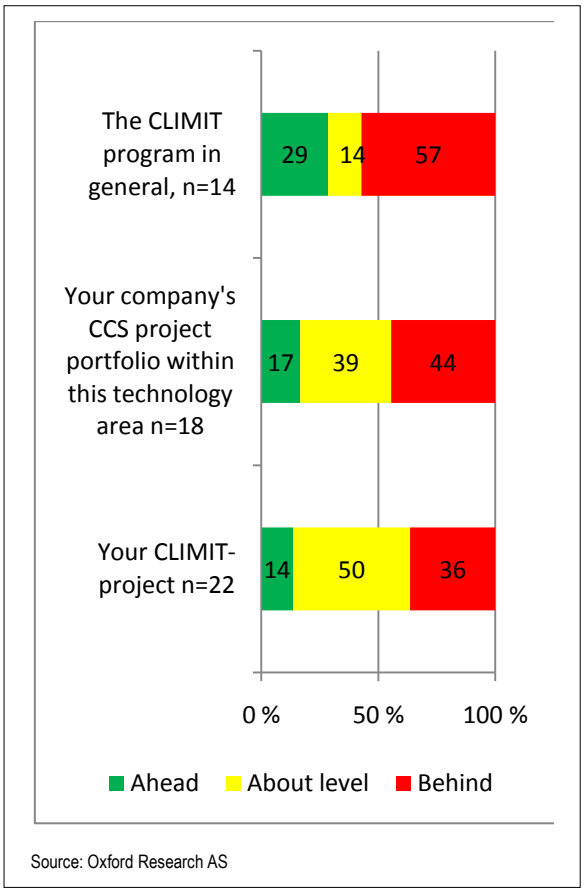
Figure 30: Are you aware of any comparable international programmes which support projects similar to your own, in percent (n=84)?



The respondents that were aware of comparable programmes were further asked how they would evaluate the CLIMIT programme, their company's portfolio and their own project compared to the programmes they had knowledge about. The results can be viewed in figure 31.

The general impression across the three dimensions is that these activities are about level or slightly behind the international programmes. However, there are some minor differences in score between the three areas. The CLIMIT programme is seen as lagging behind the international programmes, whereas the respondents are more optimistic on behalf of their own projects. It is however worth noting that the respondents disagree more on how they evaluate the CLIMIT programme than how they evaluate their own programme. Hence, CLIMIT is viewed as either being ahead or behind other programmes. The number of respondents here is however low, and no strong inferences can be drawn based on this figure.

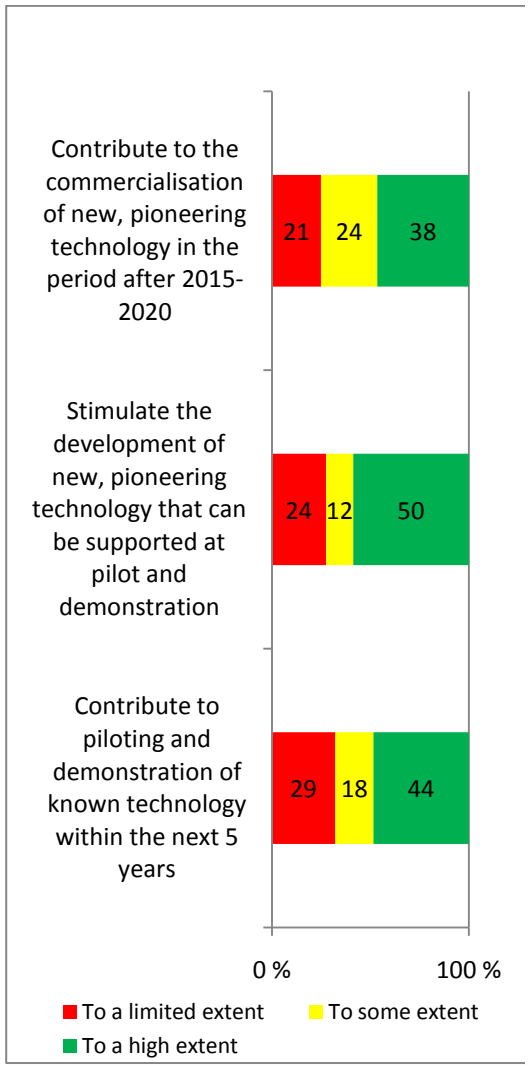
Figure 31: Comparison with international programme, in percent



8.2.8 Project contribution to CLIMIT goals

The Gassnova-funded projects have been evaluated on their ability to contribute to development, piloting and demonstration and commercialization of new technology. As figure 32 shows, the respondents generally state that their projects have contributed to a high extent to the CLIMIT programme's goals. This finding is consistent with the findings from the interviews that also show that there is a high degree of contribution to the programme's objectives.

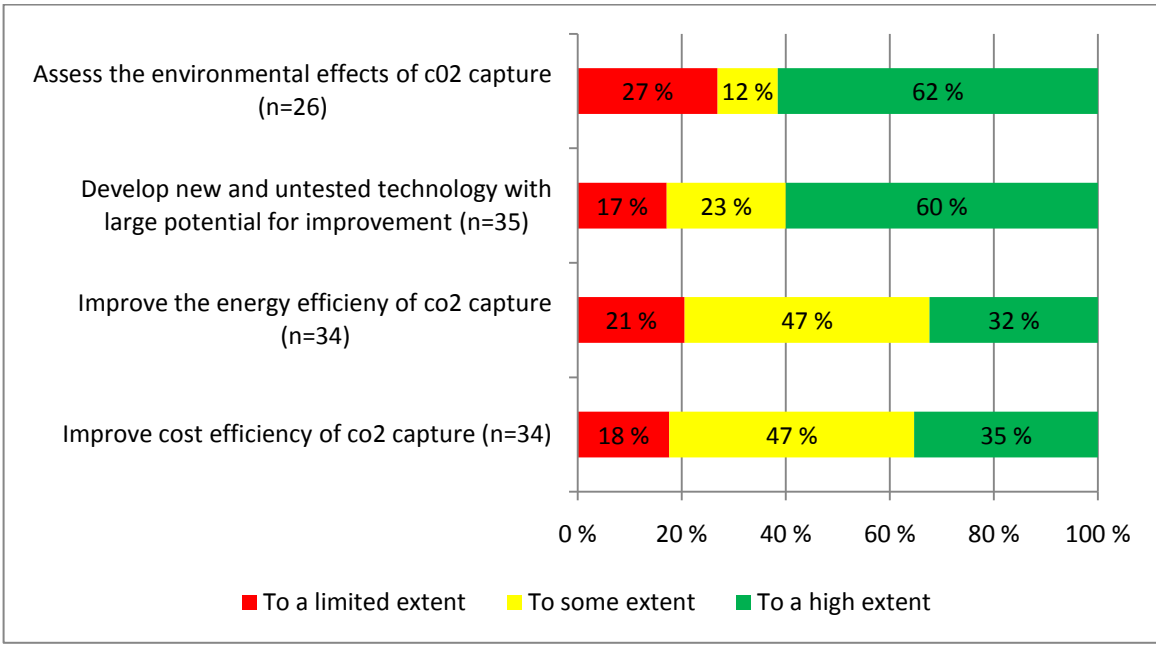
Figure 32: Gassnova-funded projects, in percent (n=34)



Source: Oxford Research AS

The respondents were asked to assess their projects contribution to the CLIMIT programme's specific goals for each technological area. Figure 33 shows the answers from the capture area. Overall, the capture projects are seen as contributing extensively to the CLIMIT goals. However, the contribution seems to be greater for assessing the environmental effects of CO_2 capture and knowledge and technology development than for increased efficiency. Interestingly, the interviews have showed another pattern. The interviewees report that their contribution to improve the energy efficiency is higher than the survey respondents. In the interviews projects like 3C and SOLVit were mentioned as contributing to this goal. This inconsistency could however indicate that the survey respondents have a more realistic view of their own projects' ability to contribute to these goals. Moreover, these results support the previous findings that the deliverables from the projects are centred on knowledge and technology development, and could indicate that many of the CLIMIT projects are in early stages.

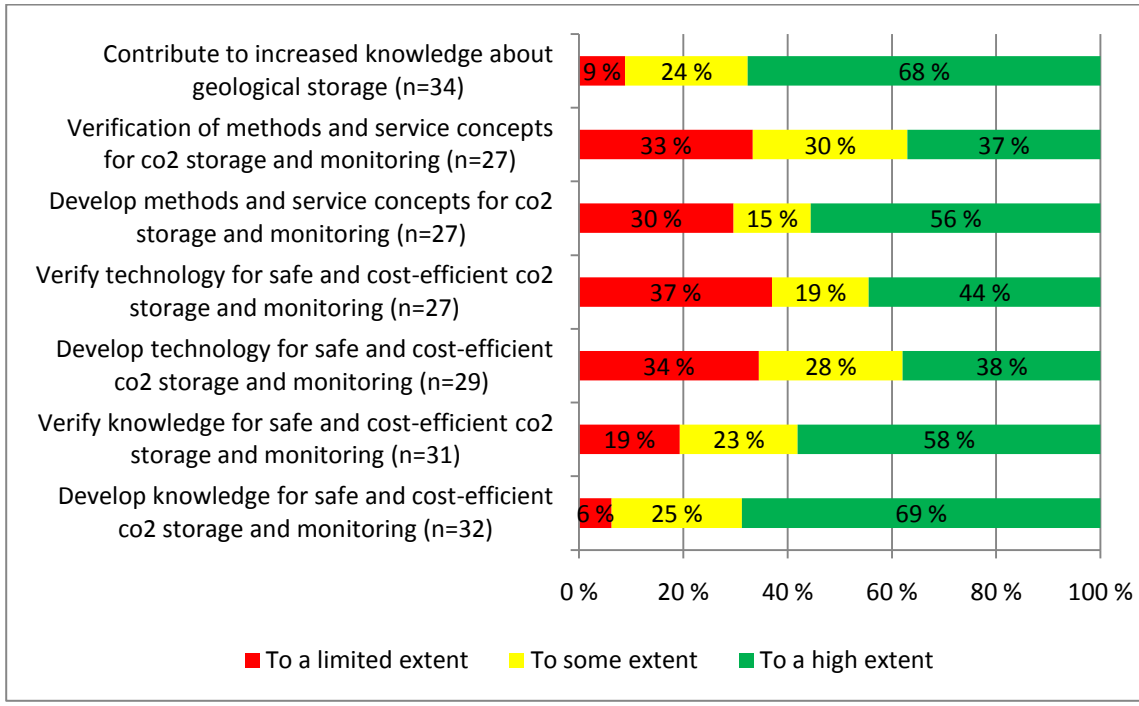
Figure 33: Project contribution to CLIMIT goals – Capture projects



Source: Oxford Research AS

Figure 34 shows the results from the storage projects. The findings here are similar to the overall picture from the capture projects. The projects contribute highly to the CLIMIT goals. Again, the figure shows that there are some differences in score on the seven indicators. The same pattern as seen before is evident here. The contribution to knowledge development is reported as being higher than in the other areas. And as for the capture area, cost-efficiency is also a challenge for storage projects.

Figure 34: Project contribution to CLIMIT goals – Storage projects

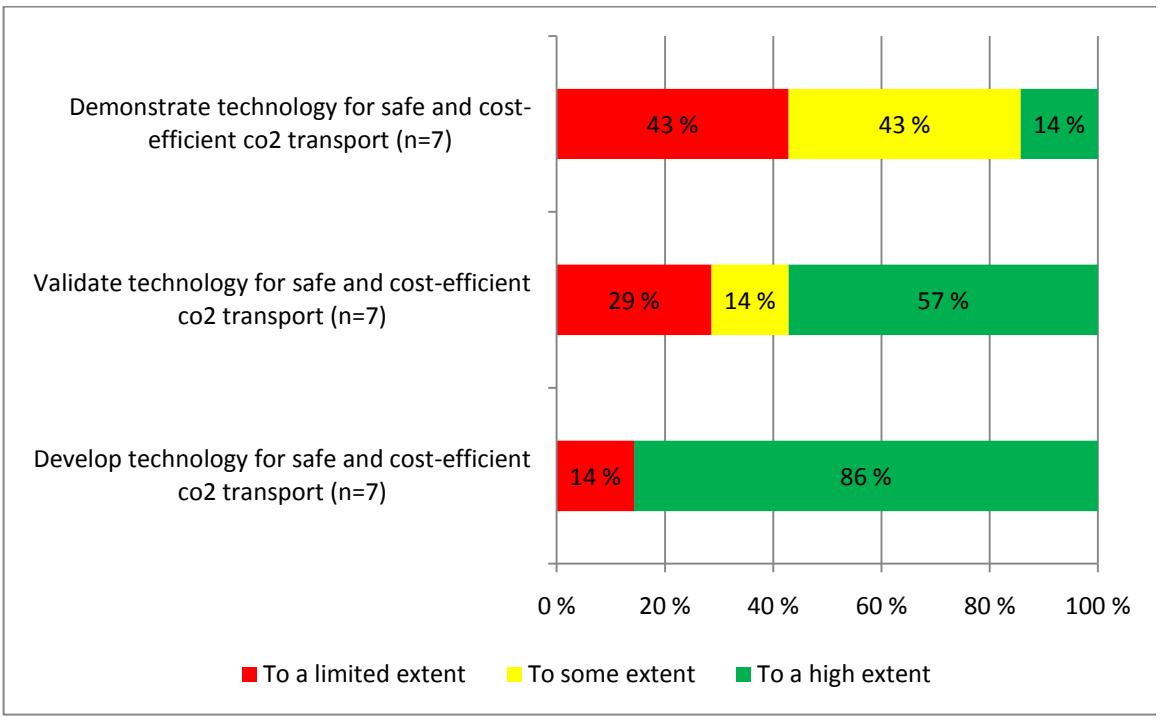


Source: Oxford Research AS

Figure 35 shows the results for the transport area. The number of respondents within this area is however very low and the results must therefore be interpreted with caution. But again, the respondents are more pleased with their projects contribution on the development side compared to verification and demonstration of new technology.

When comparing the respondents' mean scores across the three areas, one difference is obvious, the scores are higher for capture and storage than for transportation. It is not possible to differentiate between capture and storage. However, in addition to the low number of respondents for the transportation area, there is also another caveat, the questions the respondents have been asked, are related to specific challenges in each technology area, and the mean scores are hence not based on exactly the same material.

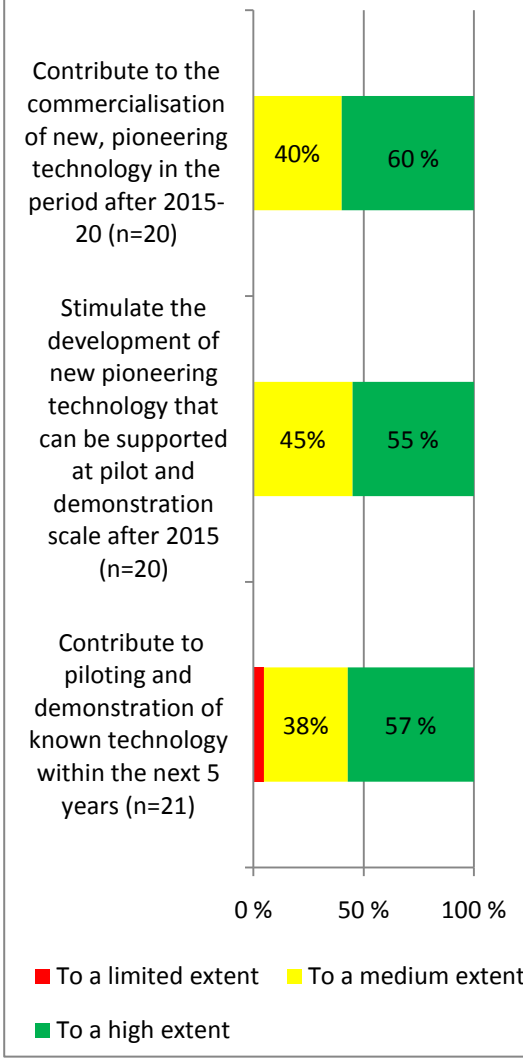
Figure 35: Project contribution to CLIMIT goals – Transport projects



Source: Oxford Research AS

Figure 36 illustrates how the respondents see their CCS project portfolio's ability to contribute to the goals of the CLIMIT programme. Overall, the respondents have an optimistic view on their portfolio's contribution, with a majority stating that their portfolio contributes to a high extent. Interestingly, the commercialization potential of the portfolio is valued quite high here, also compared to both development of new technology and piloting of new technology. Hence, the differences seen earlier between development and commercialization potential are not evident here.

Figure 36: CCS-project portfolio's contribution to CLIMIT goals

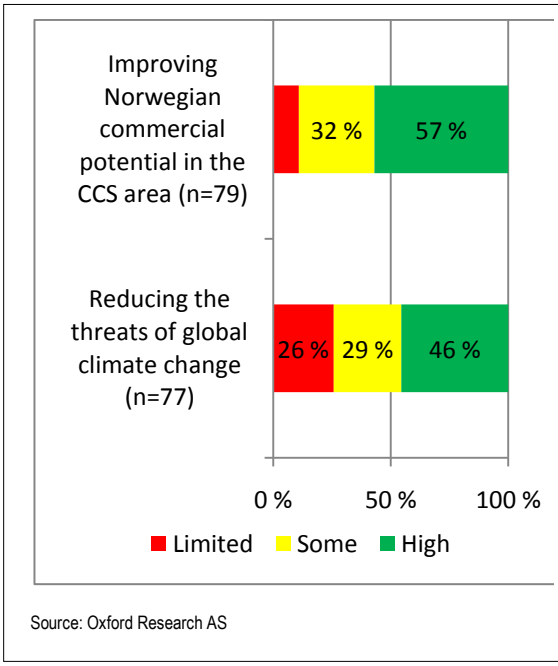


Source: Oxford Research AS

8.2.9 Project impact on overall CLIMIT goals

In the final part of the survey asked the project leaders to evaluate how their regarded their projects' impact on the overall goals of the CLIMIT project. The first goal is to improve the Norwegian commercial potential in the CCS area, and the second is to reduce the threats of global climate change. As the figure below shows, the respondents were positive regarding their project's ability to contribute to reach both these goals. Unsurprisingly, the respondents were however more optimistic for Norway's commercial potential than for the more overall goal of reducing threats of climate change.

Figure 37: Project impact on overall CLIMIT goals



Source: Oxford Research AS

Chapter 9. Overall results from technical audit

The wealth of academic publications and PhD/post-doc qualified individuals emerging from the CLIMIT programme provides some quantitative insight into the progress of the projects funded under CLIMIT. Even the most cursory examination of the list of projects funded by CLIMIT over the last few years reveals an enormous breadth of issues explored, touching on or directly targeting nearly every issue pertinent to CCS deployment in Norway and internationally. Appropriately, the majority of these have been in capture and storage given their anticipated high costs and storage site challenges respectively.

The nature of RD&D investment in low carbon technologies has historically been unpredictable. At the time that the CLIMIT programme was conceived there was no certainty that other countries would develop their own substantive RD&D programmes. In practice other countries have worked on CCS, and there are a plethora of international collaborations for CCS RD&D.

Where there are other international researchers working on similar questions, many aspects of the Norwegian projects examined appear world class. Direct proof of this comes from high Norwegian participation in international conferences.

Considering the three projects examined in more detail in the technical audit, the auditor's opinion is that these have carried out the majority of their activity in line with their original intentions. Where actual deliverables in some cases did deviate from the intended deliverables the work remains in alignment with CLIMIT objectives and needs of the nascent CCS industry. In many cases publications and internal deliverables indicate that major anticipated milestones have been achieved, even though two of the projects were not complete at the time of the evaluation and judgement is therefore based on progress reports.

The research carried out in SOLVit and BIGCO2 demonstrates the technical viability of different configurations for capture, although a commercially implementable low cost, low environmental impact capture technology from power or industry still appears a long way off. Partly this is as the challenges associated with capture technologies are now much better understood and recognised to be sizeable. The equipment and methodologies established for membrane production, simulation and cost analysis, and solvent testing should continue to be useful for some time, and are likely to continue to invite international partnerships. There is no evidence yet that the final target for BIGCO2 of a combination of 50% cost reduction, 90% capture and 7% energy penalty has been met so far, but the project timescales allow for this to be achieved later. The audit does not identify whether bringing disparate work packages together via the "BIG" moniker necessarily improves the quality of research, but it has led to increased freedom for the project managers to (re)-allocate resources to respond to changing priorities, capabilities and funding streams. The BIGCO2 project manager has confirmed that a number of changes in objectives and deliverables were agreed through appropriate committee discussions.

In the case of SSC-RAMORE, a similar pattern emerges, i.e. again much progress over the projects, deliverables in line with anticipated objectives, and greater insight in specific issues, but with a realisation that the challenges around storage also remain substantial, and may take a long time to address.

Some issues may be worthy of further examination if replicated in multiple projects:

- Project overlap: The overlap between SOLVit, BIGH2, BIGCLC and BIGCO2 makes attribution of progress/credit to specific projects challenging. The two projects proceeded with slightly different partner arrangements, leading to a re-focus of BIGCO2 towards fundamental research. In this context, the epithet "BIG" should perhaps be seen as offering more potential to reallocate resources and build up institutional coherence, capacity and foster interdisciplinary communication
- Flexibility: It is clear that SOLVit partners have responded flexibly to the delay in construction of the pilot test facility by concentrating on results at the Mobile Test Unit, which is of direct relevance to the ACC's bid to provide capture technology at the Longannet plant.
- Publication quality: Norwegian researchers seem well represented at international con-

ferences and workshops, although the output in peer-reviewed journals appeared less than originally anticipated.

- Appropriateness of target: The SOLVit project appears to have met its energy target, however, this could have been defined more appropriately at the start of the project to link into the workflow.

Chapter 10. Conclusion and reflections

10.1 Conclusions

Our main conclusions are that the CLIMIT Programme has been very important in stimulating relevant R&D-activities and that there have been important achievements, both among the Gassnova- and RCN-funded CLIMIT-projects. Many interesting ideas and prospects for further R&D activities have been developed. Some of the research activities are within areas which could turn out to be next generation technologies with applications also outside the CCS value chain.

CLIMIT-funded research has narrowed the knowledge gaps and provided options for improved performance of CCS systems. Whilst causality is difficult to prove, the steady progress made by Norwegian stakeholders working with international partners may have reassured policymakers and businesses globally on the likely viability of CCS, and this has helped support the case for financing CCS demonstration.

Therefore, the CLIMIT programme can be said to have made the prospects of global CCS deployment more likely than would have been the case without, and maintained Norway's position in many aspects of CCS.

In the following, we report and reflect over the most important findings of this evaluation seen against the main evaluation questions.

10.1.1 Effort and activities

To what extent have the projects portfolio (effort and activities) been relevant for achieving the overall objectives of the Program?

The project portfolio is relevant in terms of achieving the objectives of CLIMIT. The projects have targeted the entire range of activities from scientific outputs to commercialization. Although the majority of projects have focused on scientific activities, around half of them have ambitions of launching new commercial products and services and new processes. These have a focus on international CCS activity as well as Norway-specific issues.

The CLIMIT Programme is still in an early phase. This is reflected in our results. Except for scientific publications, no differences in targeted deliverables are found between the RCN- and Gassnova-funded projects.

In terms of balance within the CLIMIT project portfolio, there seems to be issues regarding the balance between, on the one hand research- and demonstration projects, and on the other hand technology areas.

First, the question arises whether there should be a clearer divide between research and demonstration activities in the CLIMIT Programme. As the technology develops, it must be discussed whether the RCN-funded projects should become more oriented towards (basic) research activities and whether Gassnova should strive to focus more on pre-commercial projects which aim at prototyping, piloting and demonstration as well as more pure commercial activities. Although Gassnova and the RCN have established a secretariat for the programme staffed with personnel from both organizations, this would allow for further specialization of skills within the organizations. Tasks like project selection, management of ongoing projects and evaluation require different sets of competencies, expertise and experience dependent on the nature of the projects.

Second, there are also few basic research projects, which are often spurred by findings of other projects. This must also be discussed in the light of the fact that HSE-related topics seem to be underrepresented in the project portfolio.

Third, perhaps too little emphasis may have been placed on the transportation area. This is an area where Norwegian industry should have a competitive advantage.

There is much cooperation in the projects; however they have not opened up for very many new partners entering the programme. This may indicate that most of the relevant Norwegian partners are already participating in the programme. Another reflection is that the programme may

have contributed to strengthening already existing relations. The recognition of the importance of international cooperation seems to have increased over time, not least because of the perception of increased complexity in the CCS-area.

In sum, CLIMIT projects address all of the gaps discussed in chapter 3 to varying degrees, consistent with the opportunity to make an impact given the evolving priorities of Norwegian and wider stakeholders.

10.1.2 Results and effects

To what extent can results be documented in terms of scientific publications and commercialization of technologies?

Have the projects contributed to filling any technology gaps?

The CLIMIT project portfolio has yielded results that contribute to the programme's objectives in various areas. Most notably, we find that approximately half of the projects which have had ambitions to do so, have already submitted patent applications, obtained patents and developed prototypes. New processes have already been developed by 1/3 of the projects which set out to do so.

While some projects already have started, or will start shortly, the process of commercialization, others have developed new know-ledge or technology and have yet to start the process of commercializing their technology. Others again are in a very early stage and have not developed new knowledge or technology yet. Thus, it is highly uncertain whether or not these projects have a commercial potential at this stage.

The CLIMIT Programme has so far only to a very limited degree contributed to new company start-ups, new product-lines or businesses or definition of new standards. Moreover, among those that originally had the ambition to commercialize their technology, the success rate is low when compared to the success rate in knowledge and technology development. However, the development of new processes has both been targeted in many projects and has a higher success rate.

Again, except for scientific publications, no differences in achieved deliverables are found between the projects funded by RCN and those funded by Gassnova.

Looking at specific achievements within technology development, notable results have been achieved in important areas such as:

- Amine technology, where significant reduction in energy consumption is documented
- CO_2 storage, where several projects have given better knowledge regarding CO_2 behaviour in reservoirs and developed methods for monitoring CO_2.
- Environmental issues, where CLIMIT projects have given better understanding of air pollution from amine processes
- Guidelines for best practice which give a better basis for certification of CCS technology

Furthermore, promising results have also been identified within areas such as:

- Monitoring of CO_2 in reservoirs
- Chemical looping
- Combustion technology
- Membrane technology

Another important finding of this study is that partners are regarded as very important for achieving results, both in the scientific and commercial area.

Finally, the CLIMIT Programme has also yielded results for the Universities' educational portfolio as revealed through the interview conducted in this evaluation. First, the programme has led to more than 50 PhDs degrees and Post doc positions. Second, new bachelor courses have emerged as a result of CLIMIT projects at both the University of Bergen and Telemark University College. Third, the University of Oslo, the University of Bergen and the Norwegian University of Science and Technology all offer CCS-relevant courses at the Master and PhD-levels.

We believe that it is valid to say that the CLIMIT Programme has contributed to an acceleration of CCS technology by improving the knowledge in important areas and by reducing the technology gaps, even though the gaps have turned out to be

larger than originally anticipated. In other words, the expected number of years before CCS is likely to become commercial has increased since the CLIMIT Programme started. However, this does not make the Programme itself less relevant; on the contrary, we see no reason why it should not be continued.

10.1.3 Additionality

Would the activities have been carried out without the program?

The CLIMIT Programme has not only been a precondition for financing projects, but has also stimulated the research institutions and the industry to develop new ideas, which would not have been developed without the Programme.

In general the CLIMIT Programme has very high additionality, as confirmed by interviews and surveys. Almost ¾ of the respondents claimed that the financial resources offered by CLIMIT had a high influence on their ability to carry out the project. This view was further strengthened by the very low number of respondents that said that finding alternative sources of finance would have been easy. However, it seems like the respondents that have received funding from NCR say that it is somewhat easier to find alternative sources of financing than the respondents representing Gassnova-funded projects.

While the programme overall has had a high influence on project deliverables, the patent area does not fit into this picture. Here the projects that have targeted this, state that CLIMIT-support only has had a medium to no influence on the outcome.

10.2 Reflections

Based on the main conclusions of this evaluation, two dimensions are recommended for further discussion among CLIMIT stakeholders.

10.2.1 Potential for commercialization?

Even the most ardent CCS enthusiasts would agree that despite significant progress in every area identified in the technology gaps figure (ref. figure 2) in Norway through CLIMIT, it is difficult to escape the conclusions that (i) nearly all the same knowledge gaps exist today, albeit these are much better constrained than would have been the case before the CLIMIT Programme commenced, (ii) the challenges of deploying CCS technology remain substantial; and (iii) a sustained research, development and demonstration activity is still required to realize the benefits that CCS deployment could bring. This evaluation contains findings indicating that the Norwegian industry, though better positioned than previously, is by and large not positioned to follow up every new CCS technology development identified in under CLIMIT. There are many factors supporting such a hypothesis. One is that there are giant international actors already in the market place which would be hard to compete with for smaller companies, in particular in the carbon capture part of the value chain. Another could be that the commercial risks involved in CCS technology ventures are generally too high for many Norwegian actors, since they expect that there is a long way to go before CCS is likely to be commercial. The possibility remains that it never would. A third factor could be that demonstration projects generally are capital intensive and the commercial actors cannot afford the financial risk involved. However there are exceptions. The most frequently mentioned in the interviews are Aker Clean Carbon, Statoil and Veritas which have good positions for participating in various market segments in a future CCS industry. Aker Clean Carbon is for example a participant in the proposed post-combustion capture project at Scottish Power's Longannet Power Station, which is expected to be operational starting between 2015 and 2020.

There is no doubt that Norwegian research institutions are at the research forefront in many technologies within the CCS value chain, which partly is the merit of the CLIMIT Programme. That is a significant achievement. However, since CCS is far from being commercial and because the uncertainties regarding the future of CCS as a main technology option in the transition to a sustainable energy future, the question for Norwegian Authorities would be how to keep and develop the competence built up so far. The commercial drivers needed to bring the activity further without significant public support are to a large degree not there yet. This, combined with the lack of Norwegian companies able or willing to involve own resources in technology projects will be, as we see it, one of the main challenges for the future. Therefore,

CLIMIT stakeholders should discuss the possibility of opening up the programme for international participation.

Even though the technology gaps have been reduced, CCS technology is still immature and there are several areas where the need for more research is significant. There are also areas where the industry could be reluctant to participate and where it perhaps would have been better to develop demonstration projects without industry financing.

Research, Development and demonstration activity in CCS is occurring in many countries and in the EU bloc as a whole. Other countries and institutions are joining the CCS community, eager to share in any benefits from being early developers or adopters of CCS technology. In some cases this has led to duplication, so that the case for additionality from CLIMIT will become harder to substantiate in the future with increasing competition. However rather than being viewed as wasteful, it is possible that this approach encourages innovation.

IEA and other estimates suggest that very large take up of CCS technology would occur by the 2030s. Given this long lead time, it is not clear whether the early leads developed by Norway's academic and commercial institutes will be sustained into the 2030s and beyond when the growth of CCS is predicted by the IEA CCS roadmap to grow rapidly.

10.2.2 Risk profile of CLIMIT project portfolio

In general, it is necessary to find sound balance between the projects' additionality and the results obtained. High additionality is of no value if the projects fail, i.e. a reasonable level of risk must be identified. In regard of CLIMIT, it is only one of the surveyed projects that state that the project has proven that the technological path is not promising. This result can be interpreted in several ways:

- The CLIMIT-programme has worked actively to raise the quality of the projects, resulting in a very high success rate. This is achieved through an active dialogue with applicants in the application process.
- The CLIMIT-programme is too risk-averse. This is related to two points. First, even if the level of risk is higher, the expected rate of return might be higher. Second, to enhance future development, it may be important to clarify that the path doesn't work to a larger degree. This is related to a discussion of the scope of the project portfolio. Is the scope wide enough? As pointed out above, the technology gaps are bigger than anticipated, making it hard to "pick the winners". This might call for a broader portfolio of projects.
- Given the fact that many projects are still ongoing and the programme may be labeled as being in an early phase, it could also be argued that it is premature to judge the risk profile of the programme.

It is not difficult to find some merit in all three perspectives. However, given the fact that both the CLIMIT Programme and technology development in CCS in general is still in an early phase, we believe that the project portfolio should be wider, rather than narrower. Regardless of which perspective is chosen, we believe this is a key question in the development of CLIMIT.

10.2.3 Projections for CCS

Through the CLIMIT programme, a large amount of Norwegian RD&D activity is concentrated on CCS. It is worth a final remark that stakeholders should be aware that technology growth is always difficult to predict and impossible to guarantee. Whilst there are grounds for some optimism from this evaluation, 'optimism bias' must be avoided.

There are a number of long term outcomes (e.g. 2050) for the CCS industry:

- CCS and the related technologies funded by CLIMIT contribute a major role to meeting climate objective, partly through Norwegian activity, and Norway industry shares in the multi-trillion dollar market that ensues. Clearly Norwegians would share in any climate benefit that arises.
- CCS contributes a major role to meeting climate objectives, but Norwegian industry is unable to profit from CCS, perhaps because 'winning' technologies or supply chains are developed elsewhere. In this case mankind in general still benefits, but Norwegians may have paid a disproportionate price relative to other countries to help move CCS along. Clear-

ly Norwegians would share in any climate benefit that arises.

- CCS contributes only a minor role in reducing world CO_2 emissions, perhaps because world CO_2 emissions are not controlled or because other approaches prove more viable. In this scenario, and even if Norwegian industry plays a major role in the CCS market that does exist, it may have been more profitable for Norway to invest resources elsewhere.

It will probably not be apparent for at least another decade which of these outcomes is most likely for CCS and Norway's contribution to CCS.

Chapter 11. Appendices

11.1 Interview guide

Objective: Support the register data and survey through conversations

Issues to be covered

1. Objective of the program
2. Effort and activities
3. Results and effects
4. Additionality

Objective

1. Do you have any comments to the overall objective?
2. The main objectives have been revised over time. Have these changes had any implications for the program, including your projects and your CCS strategies?
3. Is there a need for further changes in the main objectives of the programme?
4. Is there a specific Norwegian CCS agenda, and if so, could you describe it
5. If yes under 4 , how has the Norwegian agenda influenced the effort and activities of the CLIMIT program?

Effort and activities

6. To what extent have the CLIMIT-projects been relevant for achieving the overall goals of the program?
7. Has the portfolio of CLIMIT-projects had a good balance between a) R&D and demonstration projects, and b) Capture, Transportation and Storage?
8. Have you other comments to the CLIMIT project portfolio, i the structure of the portfolio.
9. Have international research institutions had any roles in the projects financed by the CLIMIT program?
10. To what extend is there a link between the CLIMIT Research Program and the Mongstad CCS project (Test Center and Full Scale).

Results and effects

11. Has the CLIMIT program contributed to accelerating the commercialization of CCS technology?
12. In which areas have the programme given the most important contributions?
13. In your words, what are the biggest successes and challenges encountered in your project so far.
14. As regards the CLIMIT financed projects your institutions have done, have any of them given documented results?

15. Have any of your institution's CLIMIT financed projects contributed to commercialisation of technologies or concepts?
16. Has your institution published any articles in scientific journals based CLIMIT financed projects?
17. Have your institution entered into cooperation with institutions in Norway or abroad as a result of the projects financed by the CLIMIT program?
18. Has the CLIMIT program had implications for education programmes in Norway?
19. Have your company or institution registered any patents?
20. Please describe the patenting or other intellectual property issues that have emerged, and to what extent Norway's interests have been protected in this respect?
21. Please describe the level of external interest (especially international and especially from commercial organisations) in this work? (i.e. is it just passive or is there a clear push to solve the problems and take to market)
22. To what extent has the application of the knowledge outside of pure CCS been considered? (Better membranes are relevant for separation generally, better CO_2 reservoir interaction is useful for EOR management, etc.)
23. Have your institution participated in other CCS research programs outside Norway?
24. Have the projects contributed to establishing new companies?
25. Are you now aware of new issues/ technological changes/challenges as a result of activities undertaken under the CLIMIT program?
26. How does the work funded by CLIMIT compare with other international activity in this area:

- Far ahead of known international activity
- Ahead of known international activity
- About level with the best international activity
- Close to catching up with the best international activity
- Significantly behind the best international activity

27. Outside Norway, which individuals and organisations do you believe have done the most significant work in this area (please name up to three).

Additionality

28. Why did your institution apply for financial support under the CLIMIT program?
29. Has the CLIMIT-program had any implications on your institution's activities within CCS technology?
30. Do you have examples of projects which would not have been carried out without the financial support from CLIMIT?
31. To what extent would it have been possible to find alternative financial sources if CLIMIT rejected your application?
32. Has the CLIMIT program been essential for your company's activities aiming at developing CCS technology?

11.2 Interview informants

Name of informant	Informant's organization
Aage Stangeland	Research Council of Norway
Alv-Arne Grimstad	SINTEF
Anders Malthe-Sørensen	University of Oslo
Ann Ingeborg Hjetland	Ministry of Petroleum and Energy
Anne Grethe Kolstad	Climate and Pollution Agency (KLIF)
Arne .M Bredesen	NTNU
Arne Dugstad	Institute for Energy Technology (IFE)
Bjørg Andresen	Institute for Energy Technology (IFE)
Bjørn Kvamme	University of Bergen
Claus Nielsen	University of Oslo
De Chen	NTNU
Fredric Weideman	Climate and Pollution Agency (KLIF)
Guttorm Alendal	University of Bergen
Hallvard Svendsen	NTNU
Hans Axel Haugen	Tel-Tek
Harald Johansen	Institute for Energy Technology (IFE)
Helge K. Dahle	University of Bergen
Henrik Andersen	Statoil
Jan Martin Nordbotten	University of Bergen
Jens Bragdø Smith	Statoil
Jon Hovland	Tel-Tek
Knut Koren	Gassnova
Knut Sanden	Aker Clean Carbon
Magnus Wangen	Institute for Energy Technology (IFE)
Maria Barrio	SINTEF
Marie Bysveen	SINTEF
May-Britt Hägg	NTNU
Mona Mølnvik	SINTEF
Nils Røkke	SINTEF
Per Aagaard	University of Oslo
Reidar Müller	Ministry of Petroleum and Energy
Steinar Pedersen	Statoil
Ståle Aakenes	Gassnova
Torbjørn Fiveland	Statoil
Torgeir Knutsen	Ministry of Petroleum and Energy
Trygve Riis	Research Council of Norway
Vibeke Andersson	Aker Clean Carbon

Source: Thema Consulting

11.3 Survey questionnaire

EVALUATION OF CLIMIT

i29 - Welcome to the survey

Some of the participants in this survey have received financial support from the CLIMIT Programmeme for multiple projects. We kindly ask you to provide answers on the basis of "^f('Projecttitle')^" when filling out the questionnaire. Please use the ">" buttons at the bottom of each page when navigating in this questionnaire. Your answers will then be stored. Please don't use the navigation buttons in your browser.

q1 - Main purpose of the project

To which of the categories below does your project mainly belong?

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products or devices, installing new processes, systems and services, or improving substantially those already produced or installed.

- ❍ Basic research
- ❍ Applied research
- ❍ Experimental development
- ❍ Other (please specify)_____ [*Other*]

q2 - Main technological area of the project

To which of the categories below does your project mainly belong?

- ❍ Capture
- ❍ Storage
- ❍ Transport

q21 - Specific technological areas CCS capturing

To which of the following categories does your project belong?

- ❑ Pre-combustion
- ❑ Post-combustion
- ❑ Oxyfuel
- ❑ Industrial capture
- ❑ Interface with compression or liquefaction
- ❑ Demonstration and integration
- ❑ Other_____ [*Other*]
- ❑ Don't know

q23 - Specific technological areas CCS storage

To which of the following categories does your project belong?

- ❑ Predicting and optimising CO2 storage amounts
- ❑ Predicting and optimising injection
- ❑ Accessing different types of storage
- ❑ Improving regional capacity estimation
- ❑ Leakage
- ❑ Monitoring
- ❑ Guidelines
- ❑ Other_____ [*Other*]
- ❑ Don't know

q22 - Specific technological areas CCS transportation

To which of the following categories does your project belong?

- ❑ Compression
- ❑ Clean-up and drying
- ❑ Pipelines
- ❑ Liquefaction
- ❑ Shipping
- ❑ Networks
- ❑ Interface with storage
- ❑ Other_____ [*Other*]
- ❑ Don't know

q6 - Link to other CLIMIT projects

Is the actual project related to other CLIMIT projects, e.g. ...

- ❑ using the same facilities
- ❑ using the same individuals
- ❑ supply of data
- ❑ efficiency/innovation from experience of working together
- ❑ continuation of a previous project funded by CLIMIT (please provide project number(s))_____ [*Other*]
- ❑ other relation (please specify)_____ [*Other*]
- ❑ not related to other CLIMIT projects

q65 - Link to Mongstad CCS project

Is the actual project related to the Mongstad CCS project, e.g. ...

- ❑ using the same facilities
- ❑ using the same individuals
- ❑ supply of data
- ❑ efficiency/innovation from experience of working together
- ❑ other relation (please specify)_____ [*Other*]
- ❑ not related to the Mongstad CCS project

q11 - What if no financial support from CLIMIT

What would have happened to the project if there had been no financial support from CLIMIT?

- ❍ Would have been/will be carried out anyway
- ❍ Would have been/will be carried out, but on a smaller scale
- ❍ Would have been/will be carried out, but at a later time
- ❍ Would have been/will be carried out, but on a smaller scale and at a later time
- ❍ Would not have been/will not be carried out
- ❍ Don't know

q12 - Alternative financial sources

To what extent would it have been possible to find alternative financial sources if CLIMIT had rejected your application?

- ❍ Impossible
- ❍ Possible, but with huge effort
- ❍ Possible, but with some effort
- ❍ Possible, with little effort
- ❍ Possible, with no effort
- ❍ Don't know

q48 - Deliverables

Which deliverables have actually been obtained or are planned to be obtained in the project?

	Already obtained	In 0-1 years time	In 2-3 years time	In 4-6 years time	In 7-10 years time	More than 10 years time	Not targeted in this project
New knowledge without immediate applications	❍	❍	❍	❍	❍	❍	❍
Scientific publications	❍	❍	❍	❍	❍	❍	❍
Verification of technology	❍	❍	❍	❍	❍	❍	❍
Licences	❍	❍	❍	❍	❍	❍	❍
Patent applications	❍	❍	❍	❍	❍	❍	❍
Patents granted	❍	❍	❍	❍	❍	❍	❍
Prototypes	❍	❍	❍	❍	❍	❍	❍
Piloting	❍	❍	❍	❍	❍	❍	❍
New commercial products or services	❍	❍	❍	❍	❍	❍	❍
New processes	❍	❍	❍	❍	❍	❍	❍
A new product line/ business	❍	❍	❍	❍	❍	❍	❍
New company start-ups	❍	❍	❍	❍	❍	❍	❍
Definition of new industry standards	❍	❍	❍	❍	❍	❍	❍
Other (please specify, if not targeted in this project, please write x)_____	❍	❍	❍	❍	❍	❍	❍

q146 - CLIMIT influence on deliverables

How would you evaluate the influence of the CLIMIT Programmeme on the (planned) deliverables of this project?

	.. would have been obtained anyway	.. would have been obtained, but on a smaller scale	.. would have been obtained, but at a later time	.. would have been obtained, but on a smaller scale and at a later time	.. would not have been obtained	Don't know
New knowledge without immediate applications	❍	❍	❍	❍	❍	❍
Scientific publications	❍	❍	❍	❍	❍	❍
Verification of the technology	❍	❍	❍	❍	❍	❍
Licences	❍	❍	❍	❍	❍	❍
Patent applications	❍	❍	❍	❍	❍	❍
Patents granted	❍	❍	❍	❍	❍	❍
Prototypes	❍	❍	❍	❍	❍	❍
Piloting	❍	❍	❍	❍	❍	❍
New commercial products or services	❍	❍	❍	❍	❍	❍
New processes	❍	❍	❍	❍	❍	❍
A new product line/ business	❍	❍	❍	❍	❍	❍
New company start-ups	❍	❍	❍	❍	❍	❍
Definition of new industry standards	❍	❍	❍	❍	❍	❍
^f('q48_14_other')^	❍	❍	❍	❍	❍	❍

q147 - Partner influence on deliverables

On a scale from 1 (lowest) to 5 (highest), how would you evaluate the contribution of your project partners on the (planned) deliverables of this project?

	.. would have been obtained anyway	.. would have been obtained, but on a smaller scale	.. would have been obtained, but at a later time	.. would have been obtained, but on a smaller scale and at a later time	.. would not have been obtained	No partners in this project
New knowledge without immediate applications	❍	❍	❍	❍	❍	❍
Scientific publications	❍	❍	❍	❍	❍	❍
Verification of the technology	❍	❍	❍	❍	❍	❍
Licences	❍	❍	❍	❍	❍	❍
Patent applications	❍	❍	❍	❍	❍	❍
Patents granted	❍	❍	❍	❍	❍	❍
Prototypes	❍	❍	❍	❍	❍	❍
Piloting	❍	❍	❍	❍	❍	❍
New commercial products or services	❍	❍	❍	❍	❍	❍
New processes	❍	❍	❍	❍	❍	❍
A new product line/ business	❍	❍	❍	❍	❍	❍
New company start-ups	❍	❍	❍	❍	❍	❍
Definition of new industry standards	❍	❍	❍	❍	❍	❍
^f('q48_14_other')^	❍	❍	❍	❍	❍	❍

q16 - Enhanced cooperation

Has the project lead to enhanced cooperation between the partners in the project outside the scope of the CLIMIT-funded project?

❍ No
❍ Yes

q17 - New partners

Has the project lead to cooperation with new partners?

❍ No
❍ Yes

q61 - Economic performance

How would you evaluate the impact of CLIMIT regarding your company's...

	Very limited	Limited	Some	High	Very high	Not relevant/don't know
Competitiveness	❍	❍	❍	❍	❍	❍
Profitability	❍	❍	❍	❍	❍	❍
Survival	❍	❍	❍	❍	❍	❍

q49 - Knowledge development

How would you evaluate your project's contribution to knowledge development in the technology area in which it is embedded/supporting?

❍ We have proven that the technology doesn't work, we will not investigate this path further
❍ We still need to work on this path
❍ We have proven that this is a viable path, we will now proceed with follow-up activities
❍ Don't know

q54 - Project continuation

What kind of follow-up activities are planned?

Please choose all relevant alternatives

❑ Development
❑ Testing
❑ Prototyping
❑ Demonstration
❑ Marketing activities
❑ Other (please specify)_____ [*Other*]
❑ None at the moment

q18 - Commercial potential project

How would you evaluate your project's commercial potential?

Please choose all relevant alternatives

- ❑ Has the potential to reduce costs
- ❑ Has the potential to improve efficiency
- ❑ Has the potential to expand the scope of CCS
- ❑ Has the potential to speed up development of CCS
- ❑ Too early to evaluate
- ❑ Not relevant

q26 - Comparable international program

Are you aware of any comparable international programmes which support projects similar to your own?

- ❍ No
- ❍ Yes

q43 - Name of comparable program

Could you please provide the name of the programme?

Please choose the most appropriate programme

q44 - Country of comparable program

Could you please provide the country in which the program is conducted?

q52 - Comparison with international program

How would you evaluate CLIMIT compared to ^f('q43')^ with respect to performance within your technology area?

	Far ahead	Ahead	About level	Close to catching up	Significantly behind	Not relevant/don't know
Your CLIMIT-funded project	❍	❍	❍	❍	❍	❍
Your company's CCS project portfolio within this technology area	❍	❍	❍	❍	❍	❍
The CLIMIT programme in general	❍	❍	❍	❍	❍	❍

q50 - Project contribution to CLIMIT goals - capture

How would you evaluate the extent to which your project contributes to achieving the following goals of the CLIMIT programme?

	To a very limited extent	To a limited extent	To some extent	To a high extent	To a very high extent	Not relevant/don't know
Improve the cost efficiency of CO2 capture	❍	❍	❍	❍	❍	❍
Improve the energy efficiency of CO2 capture	❍	❍	❍	❍	❍	❍
Develop new and untested technology with large potential for improvement	❍	❍	❍	❍	❍	❍
Assess the environmental effects of CO2 capture	❍	❍	❍	❍	❍	❍

q58 - Project contribution to CLIMIT goals - storage

How would you evaluate the extent to which your project contributes to achieving the following goals of the CLIMIT programme?

	To a very limited extent	To a limited extent	To some extent	To a high extent	To a very high extent	Not relevant/don't know
Develop knowledge for safe and cost-efficient CO2 storage and monitoring	❍	❍	❍	❍	❍	❍
Verify knowledge for safe and cost-efficient CO2 storage and monitoring	❍	❍	❍	❍	❍	❍
Develop technology for safe and cost-efficient CO2 storage and monitoring	❍	❍	❍	❍	❍	❍
Verify technology for safe and cost-efficient CO2 storage and monitoring	❍	❍	❍	❍	❍	❍
Developing methods and service concepts for CO2 storage and monitoring	❍	❍	❍	❍	❍	❍
Verification of methods and service concepts for CO2 storage and monitoring	❍	❍	❍	❍	❍	❍
Contribute to increased knowledge about geological storage	❍	❍	❍	❍	❍	❍

q57 - Project contribution to CLIMIT goals - transport

How would you evaluate the extent to which your project contributes to achieving the following goals of the CLIMIT programme?

	To a very limited extent	To a limited extent	To some extent	To a high extent	To a very high extent	Not relevant/don't know
Develop technology for safe and cost-efficient CO2 transport	❍	❍	❍	❍	❍	❍
Validate technology for safe and cost-efficient CO2 transport	❍	❍	❍	❍	❍	❍
Demonstrate technology for safe and cost-efficient CO2 transport	❍	❍	❍	❍	❍	❍

q56 - Project contribution to CLIMIT goals

How would you evaluate the extent to which your project contributes to achieving the following goals of the CLIMIT programme?

	To a very limited extent	To a limited extent	To some extent	To a high extent	To a very high extent	Not relevant/don't know
Contribute to piloting and demonstration of known technology within the next 5 years	❍	❍	❍	❍	❍	❍
Stimulate the development of new, pioneering technology that can be supported at pilot and demonstration scale after 2015	❍	❍	❍	❍	❍	❍
Contribute to the commercialisation of new, pioneering technology in the period after 2015-20	❍	❍	❍	❍	❍	❍

i70 - Multiple projects

If you now could please consider all your projects which have received funding from the CLIMIT programme, we have a few final questions. The projects you have received funding for are: ^f('Multipleprojects')^

q66 - Match

How would you describe the match of your CLIMIT-funded projects relative to your organization's total CCS project portfolio?

- ❍ Very limited
- ❍ Limited
- ❍ Some
- ❍ High
- ❍ Very high
- ❍ We have no other CCS projects
- ❍ Don't know

q85 - CCS-portfolio's commercial potential

How would you evaluate your CCS-portfolio's commercial potential?

Please choose all relevant alternatives

- ❑ Has the potential to reduce costs
- ❑ Has the potential to improve efficiency
- ❑ Has the potential to expand the scope of CCS
- ❑ Has the potential to speed up development of CCS
- ❑ Too early to evaluate
- ❑ Not relevant

q83 - CCS-portfolio's contribution to CLIMIT goals

How would you evaluate the extent to which your CCS project portfolio contributes to achieving the following goals of the CLIMIT programme?

	To a very limited extent	To a limited extent	To some extent	To a high extent	To a very high extent	Not relevant/don't know
Contribute to piloting and demonstration of known technology within the next 5 years	❍	❍	❍	❍	❍	❍
Stimulate the development of new, pioneering technology that can be supported at pilot and demonstration scale after 2015	❍	❍	❍	❍	❍	❍
Contribute to the commercialisation of new, pioneering technology in the period after 2015-20	❍	❍	❍	❍	❍	❍

q67 - The bigger picture

How would you evaluate the impact of your project(s) regarding ...

	Very limited	Limited	Some	High	Very high	Not relevant/don't know
reducing the threats of global climate change	❍	❍	❍	❍	❍	❍
improving Norwegian commercial potential in the CCS area	❍	❍	❍	❍	❍	❍

q69 - Further comments

[*Not required*]

If you have any comments regarding this survey or other information which may be relevant for this evaluation, please feel free to provide it below.

11.4 PhDs and PostDocs in the CLIMIT Programme

The following table is a list of PhDs and Post-Docs in the CLIMIT-programme. The list includes both ongoing and finished PhD and Post Doc-projects.

Name	Organization	Status	Start date	End date	Gender	Program	Project number	Project title	Project leader
Aldo Bischi	NTNU	PhD	01.09.2007	30.09.2011	M	CLIMIT	176059	Novel CO2 Capture Scheme for Power Generation- BIGCLC	Røkke, Nils A.
Xiao Luo	NTNU	PhD	01.09.2007	31.12.2011	M	CLIMIT	182607	CCERT	Svendsen, Hallvard
Leonid Vasiljev	UiB	PhD	01.11.2007	?	M	CLIMIT	178013	Matmora	Helge Dahle
S. Georgescu	NTNU	PhD	01.01.2008	01.07.2011		CLIMIT	178004	BIGCO2	Mølnvik, Mona Jacobsen
Szczepan Polak	SINTEF	PhD	01.01.2008	01.07.2011	M	CLIMIT	178004	BIGCO2	Mølnvik, Mona Jacobsen
Maria Elenius	UiB	PhD	01.03.2008	28.02.2011	K	CLIMIT	178013	Matmora	Helge Dahle
Mehdi Karimi	NTNU	PhD	01.06.2008	31.12.2011		CLIMIT	182607	CCERT	Svendsen, Hallvard
Binyam Lema Alemu	UiO	PhD	01.09.2008	31.08.2011	M	CLIMIT	178008	RAMORE	Aagaard, Per
Lei Zhao	NTNU	PhD	01.09.2008	?	M	CLIMIT	182607	CCERT	Svendsen, Hallvard
Meisam Ashraf	UiB	PhD	01.11.2008	31.10.2011	M	CLIMIT	178013	Matmora	Helge Dahle
Jingyi Han	Tel-Tek	PhD	01.11.2008	31.10.2011	K	CLIMIT	188936	Channel Integrated Treatment - Fundamental	Fiveland, Torbjørn
Jiru Ying	Tel-Tek	PhD	01.11.2008	31.10.2011	M	CLIMIT	188936	Channel Integrated Treatment - Fundamental	Fiveland, Torbjørn
Van Thi Hai Pham	UiO	PhD	17.11.2008	16.11.2011	K	CLIMIT	178008	RAMORE	Aagaard, Per
Alexis Sevault	NTNU	PhD	01.01.2009	31.12.2011	M	CLIMIT	178004	BIGCO2	Mølnvik, Mona Jacobsen
Solrun Johanne Vevelstad	NTNU	PhD	11.05.2009	10.05.2012	K	CLIMIT	189998	SOLVit SP4	Svendsen, Hallvard
Ashok Chejara	UiO	PhD	15.05.2009	14.05.2012	M	CLIMIT	178008	RAMORE	Aagaard, Per
Cuong Van Phan	UiO	PhD	29.05.2009	28.05.2012	M	CLIMIT	178008	RAMORE	Aagaard, Per
Raheleh Farokpohor	NTNU	PhD	01.06.2009	01.06.2012	K	CLIMIT	178004	BIGCO2	Mølnvik, Mona Jacobsen
Xing When	NTNU	PhD	01.06.2009	01.06.2012	M	CLIMIT	178004	BIGCO2	Mølnvik, Mona Jacobsen
Ardi Hartono	NTNU	PhD	16.06.2009	30.06.2012	M	CLIMIT	182607	CCERT	Svendsen, Hallvard

Hamid Mehdiza-deh	NTNU	PhD	02.07.2009	01.07.2012	M	CLIMIT	189998	SOLVit SP4	Svendsen, Hallvard
Anastasia Trollebø	NTNU	PhD	15.08.2009	14.08.2012	K	CLIMIT	189998	SOLVit SP4	Svendsen, Hallvard
Henrik Jilvero	Tel-Tek	PhD	01.01.2010	31.12.2013	M	CLIMIT	199905	CO2 capture from industrial point sources	Hans Aksel Haugen
Geir Ers-land	UiB	Post-Doc	01.01.2010	31.12.2013	M	CLIMIT	200032	In-situ imaging of CO2 flow, storage and entrapment in subsurface aquifers and hydrocarbon reservoirs	Arne Graue
Mayuri Gupta	NTNU	PhD	04.01.2010	03.01.2013	M	CLIMIT	189998	SOLVit SP4	Svendsen, Hallvard
Prashant Salimath	NTNU	PhD	10.02.2010	09.02.2013	M	CLIMIT	182607	CCERT	Svendsen, Hallvard
Jamil Ahmad	NTNU	PhD	01.03.2010	30.06.2011	M	CLIMIT	182607	CCERT	Svendsen, Hallvard
Davi Fon-seca	NTNU	Post-Doc	01.04.2010	31.03.2013	M	CLIMIT	200041	Sorption and Migration of CO2 in Porous Media	Jon Otto Fossum
Knut Arne Birkedal	UiB	PhD	15.04.2010	14.04.2014	M	CLIMIT	200032	In-situ imaging of CO2 flow, storage and entrapment in subsurface aquifers and hydrocarbon reservoirs	Arne Graue
Bjørnar Jensen	IFE	PhD	15.06.2010	14.06.2013	M	CLIMIT	190002	Inject	Magnus Wangen
Johan Olav Helland	IRIS	Post-Doc	01.07.2010	30.06.2011	M	CLIMIT	200038	Pore-Scale Mechanism	Dimitrios G. Hatzigna-tiou
Ole Ivar Ulven	UiO	PhD	01.07.2010	30.06.2013	M	CLIMIT	200044	Permanent CO2 storage by in situ injection in ultramafic rocks	Anders Malthe-Sørenssen
Yingfang Zhou	IRIS	PhD	02.08.2010	01.08.2013	M	CLIMIT	200038	Pore-Scale Mechanism	Dimitrios G. Hatzigna-tiou
Yifei Zhu	HiT	PhD	16.08.2010	15.08.2013	K	CLIMIT	199890	Better and more intelli-gently formu-lated CO2 absorbents	Klaus-Joacim Jens
Nuria Tavera Valero	NTNU	PhD	20.08.2010	19.08.2013	K	CLIMIT	189998	SOLVit SP4	Svendsen, Hallvard
Halvor Lund	NTNU	PhD	01.09.2010	31.08.2013	M	CLIMIT	189978	CO2 Dyna-mics	Munkejord, Svend Tollak
Gamunu L.S.P. Arachchige	HiT	PhD	01.09.2010	31.08.2013	M	CLIMIT	199890	Better and more intelli-gently formu-lated CO2 absorbents	Klaus-Joacim Jens

Shuai Wang	Tel-Tek	PhD	01.09.2010	31.08.2013	M	CLIMIT	199905	CO2 capture from industrial point sources	Hans Aksel Haugen
Fredrik Moltu Johnsen	Østfoldforsk-ning	PhD	01.09.2010	01.09.2011	M	CLIMIT	199991	Environmental Decision Support for Innovative EcoDesign for CCS	Andreas Brekke
Marc Enssle	NTNU	Post-Doc	06.09.2010	05.09.2012	M	CLIMIT	190340	Carbon dio-xide capture by metal-organic frameworks	Dietzel, Pascal D.C.
Peng Zhao	Norsar	Post-Doc	01.10.2010	30.09.2012	M	CLIMIT	189994	Safe CO2	Volker Oye
Elsa Du Plessis	UiB	PhD	01.10.2010	30.09.2013	K	CLIMIT	199926	VAMP	Helge Dahle
Viktorija Tomkutė	UMB	PhD	01.10.2010	30.09.2013	K	CLIMIT	199990	Carbon Cap-ture in Molten Salts	Espen Olsen
Robin Wegge	NTNU	PhD	01.10.2010	30.09.2014	M	CLIMIT	200005	MixProp	Mølnvik, Mona Jacobsen
Kim Seng-er	UNIS	PhD	01.10.2010	30.09.2013	M	CLIMIT	200006	Outcrop	Alvar Braathen
Kei Ogata	UNIS	Post-Doc	01.10.2010	30.09.2013	M	CLIMIT	200006	Outcrop	Alvar Braathen
Sigmund Mongstad Hope	NTNU	PhD	01.11.2010	31.10.2014	M	CLIMIT	199970	Efficient CO2 Absorption in Water-Saturated Porous Media through Hy-draulic Frac-turing	Alex Han-sen
Deshai Botheju	Tel-Tek	Post-Doc	05.11.2010	31.12.2012	M	CLIMIT	199905	CO2 capture from industrial point sources	Hans Aksel Haugen
Mohamed Ibrahim	NTNU	PhD	01.01.2011	31.12.2013	M	CLIMIT	189978	CO2 Dyna-mics	Munkejord, Svend Tollak
Asuncion Maria Sanchez Aranda	IFE	Post-Doc	03.01.2011	31.12.2012	K	CLIMIT	207791	Innovation in high-temperature CO2-capture Development of novel solid sorbents	Johann Mastin
Kjell-Arne Solli		Post-Doc	01.02.2011	28.01.2013	M	CLIMIT	208508	CO2/H2OPLU S	Antonie Ooster-kamp
Reza Alikarami	UNI	PhD	21.02.2011	21.02.2014	M	CLIMIT	207806	Impact	Anita Torabi
Elin Skur-tveit	UNI	PhD	01.05.2011	01.05.2014	K	CLIMIT	207806	Impact	Anita Torabi
NN	UiB	PhD	?	?		CLIMIT	200040	Safety and Environmental Conse-quences of Unintended Releases from Offshore CO2 Pipelines	Guttorm Alendal

NN	NR	Post-Doc	?	?		CLIMIT	207097	Monitoring Geological CO2 Storage: Quantitative CO2 Predic-tion with Uncertainty from Physical Modeling and Multiple Time-Lapse Data Types	Heidi Kjønsberg
NN	UiO	Post-Doc	?	?		CLIMIT	207841	Dual phase membranes for CO2 sepa-ration in power generation	Truls Norby
Source: Oxford Research AS									

11.5 References

Hansen, T. B., Karlsson, T. and Godø, H. (2005): Evaluation of the DEMO 2000 program, NIFU STEP rapport 7/2005, Oslo, Norway

OECD (2003): Frascati Manual 2002. Proposed Standard Practice for Surveys on Research and Experimental Development. OECD Publishing, Paris

Program plan 2005,

Programplan 2006

Program plan 2006-2010, revised nov 2008

Programplan 2010-2012

NFR, årsrapporter for CLIMIT 2005-2009

Gassteknologiutvalgets rapport "Gass, teknologi og utvikling"

St. meld 47 (2003-2004)

Spread sheet with economic project data from Gassnova and Research Council of Norway

OXFORD RESEARCH

Forskning
Strategi
Kommunikasjon

Oxford Research AS, Kjøita 42, 4630 Kristiansand, Norge, Tlf. 40 00 57 93, www.oxford.no