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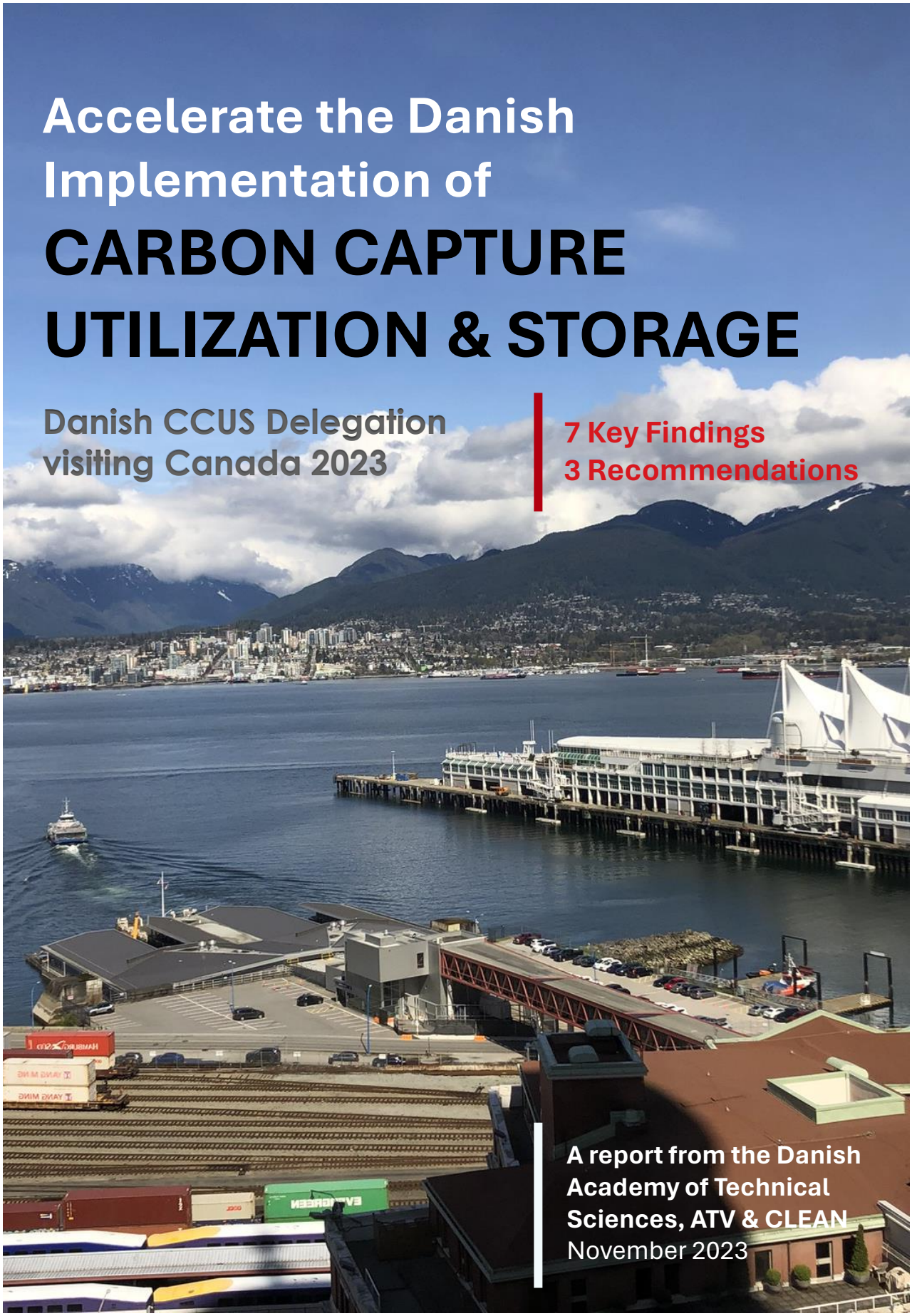
ATV

Accelerate the Danish Implementation of CARBON CAPTURE UTILIZATION & STORAGE

Danish CCUS Delegation visiting Canada 2023

7 Key Findings
3 Recommendations



A report from the Danish Academy of Technical Sciences, ATV & CLEAN
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Disclaimer: This report has been prepared and authored by CLEAN and ATV. Delegation members have provided their input and reflections but may not necessarily agree with all of the learnings and recommendations. This is solely the editorial team's summary. The Study Tour program was developed in close and fruitful collaboration with the teams at the Canadian Trade Commissioner Service and Green Hub Denmark/CO2 Vision

Preface

Denmark can learn from the Canadian approach “Fast Forward - Can Do Attitude”

The Danish CCUS delegation returned from Canada with the important insight that CCUS is happening right now at scale.

A Danish delegation of 24 top managers and experts within CO2 capture, utilization, and storage (CCUS) visited Canada in the spring of 2023 and returned with a network, common insights and key findings regarding challenges and potentials within Danish development of CCUS solutions.

This report encapsulates the experiences through seven key learnings and tree recommendations. The Canadian experience provides insights that, if applied smartly, can accelerate the achievement of Denmark's climate objectives. The aim is to align Denmark with its ambitious climate objectives, which encompass a 70% reduction in CO2 emissions by 2030, achieving net-zero emissions by 2045, becoming carbon-negative by 2050, and implementing a circular economy within the carbon value chain.

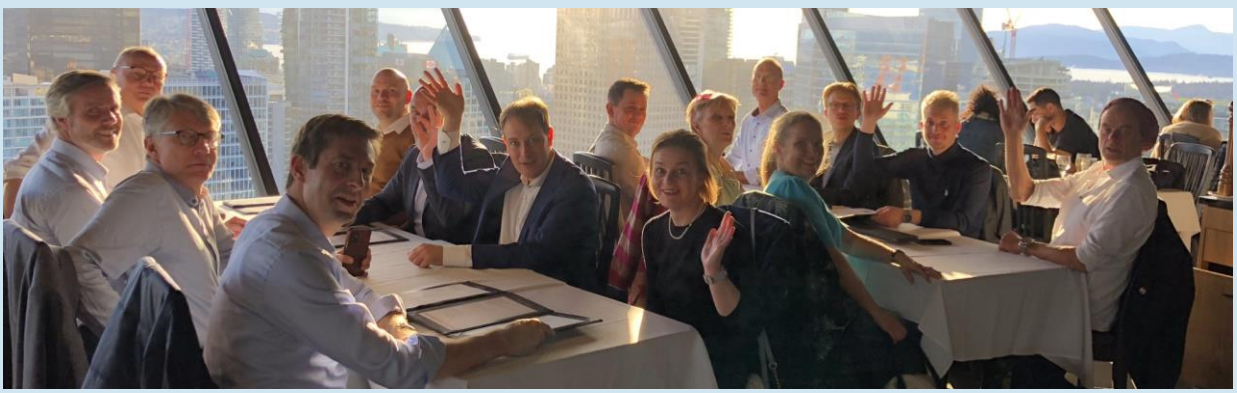
The Danish ATV CLEAN CCUS Delegation included representatives from the Ministry of Foreign Affairs, the Ministry of Climate, Energy and Supply, the Danish Council on Climate Change, the Novo Nordisk Foundation,

The program was developed by ATV and CLEAN in collaboration with the Canadian Trade Commissioner Service and Green Hub Denmark. It involved all types of stakeholders in the Canadian CCUS Ecosystem, i.e. government, businesses, ventures, universities, and knowledge partners from among others the Universities of Alberta, British Columbia, Simon Fraser, and Victoria.

We hope that you will find the learnings and associated recommendations inspiring and should you wish to contact any of the stakeholders mentioned in this publication, we will gladly facilitate the dialogue.

Kind regards

The Danish Academy of Technical Sciences & CLEAN



Summary

Denmark must speed up CCUS implementation - Closer collaboration, best practices, and new technologies

The study trip illuminated areas where Canada is ahead of Denmark in the establishment of CO2 capture, storage, and related infrastructure. Canada's conducive developmental ecosystem facilitates the swift progression of new technologies toward market integration, notably through robust university/private sector collaborations. Furthermore, the historical association of CO2 capture with the fossil industry in Canada has attracted substantial private financing, which has enabled tangible CCUS projects on a substantial scale.

"Canada has shown that shared public and private leadership leads to fast implementation of carbon capture technologies.

Mikkel Krogsgaard Niss, Carbon Capture Cluster Copenhagen (C4)

Nonetheless, there are several indications pointing towards that Denmark could close this gap. Our mission-driven approach, underscored by aligned national ambitions, and initiatives like INNO-CCUS, regional lighthouses, and an agile legislative framework, is moving Denmark toward parity with global CCUS leaders.

This trajectory is profoundly encouraging and emphasizes Denmark's promising ascent within the CCUS landscape.

Despite the substantial differences between Canada and Denmark, including Canada's vast land areas, lighter regulation, and technology rooted in Enhanced Oil Recovery practices, there are valuable lessons to be learned about implementation. Canada has already successfully executed large-scale projects, which stands in contrast to Denmark, where we are only embarking on the construction of our first full-scale CCUS facilities, a collaboration involving Ørsted, Aker Carbon Capture, and Microsoft.
One significant revelation during our visit was Canada's proactive approach to the development and substantial investment in cutting-edge CO2 capture technologies, such as Direct Air Capture (DAC).

Equally impressive was how close to market-ready these technologies seem to be. This presents a good opportunity for knowledge exchange and potential implementation in Denmark's CCUS journey.

Photo: ATV: Visiting Carbon Engineering in Vancouver

Photo: ATV: Visiting Carbon Engineering in Vancouver

This report is structured around seven key learnings and three recommendations that emphasize the significance of a market-driven innovative approach, simultaneous pursuit of multiple paths and technologies, well-established infrastructure for CO2 transportation and storage, a national strategy coupled with a regional approach, and collaborative investments from both the government and major industrial players. These factors have collectively put Canada in a prominent global leadership role in CCUS development and implementation.

Drawing from these insights, there is substantial potential for Denmark to accelerate the development of our own CCUS infrastructure and innovation projects by adopting some of these successful strategies and approaches.

Denmark's role in speeding up CCUS implementation in a global setting will rely on the alliances we build. The study trip highlighted the substantial potential for enhanced dialogue and collaboration between Denmark and Canada. This cooperation holds promise for both countries in terms of integrating CCUS technologies and infrastructure, thus encouraging the continued development of the CCUS eco-system.

> ***The composition of institutions and companies in Canada gives them strong financial backing. This means that they are currently half a step ahead in terms of having some facilities on the ground. And that might be something we're missing in Denmark***
>
> David Egede Fich, Ørsted

Problem Analysis

Why CCUS is a Key Technology for Denmark?

Technology and infrastructure

Research and education

Business development and capacity

Energy and resource consumption + environmental impacts

Citizen involvement and social impacts

Market, regulation, and framework conditions

Cooperation mechanisms and partnerships

Figur: ATV / TI

Four years after the adoption of the ambitious Climate Act, Denmark has not made significant progress in the actual use of CCUS (Carbon Capture, Utilization, and Storage) technology compared to other countries, such as Canada, which has operational commercial facilities. The latest status report (February 2023), of the Danish Council on Climate Change states that Denmark's outlined path to reach its reduction targets contains significant risk elements, especially concerning the heavy reliance on CCS, which is still not a proven technology in Denmark.

The government's planned goal achievement relies heavily on CCS, estimated to contribute 3.2 million tons per year by 2030. However, the technology is only just beginning to be implemented in Denmark, and a completely new value chain for the capture, transport, and storage of CO2 needs to be established. This is a significant task that requires collaboration and contributions from many actors in a complex ecosystem, and there is therefore s a considerable risk that a central element in the government's plan may not deliver on time and to the required extent. Furthermore, efforts must be made to secure various adjacent activities essential for a successful CCUS implementation, including expanding the necessary electricity production and infrastructure.

Additionally, CCUS involves several trade-offs that need to be addressed. The amine-based capture technology, currently the most widespread,

Photo: ATV: Visiting Alberta Innovates

involves the risk of releasing environmentally harmful substances such as nitrosamines and nitramines. CO2 capture from biogenic sources, such as Danish combined heat and power plants, risks extending the lifespan of these facilities, which could be a climate challenge as biomass is a limited resource. Therefore, increasing or maintaining consumption can be problematic, as noted by organizations like Concito and the Danish Council on Climate Change. But we also need negative emissions to achieve national and international climate targets. According to the IPCC, up to 20 billion tons of biogenic CO2 need to be captured and stored underground through bioenergy with carbon capture and storage (BECCS) in 2060.

It is crucial to be proactive, to think broader, and to prepare for a scale-up that encompasses point sources from hard-to-decarbonize sectors and industries, as well as SMEs, storage solutions that leverage Denmark's storage potential, and a transport infrastructure based on common standards and economies of scale. There should also be continued development and maturation of CCUS technologies, including biological solutions, atmospheric CO2 capture, and flexible/modular solutions that can be used on a smaller scale, as well as CCU technology.

Furthermore, it is necessary to consider carbon as another component of public/critical infrastructure, like electricity, gas, and water. This includes considerations about public engagement and what is required regarding framework conditions, regulation, and incentive structures. Finally, it is essential to address CCUS as one piece of a larger puzzle that must be weighed against other elements such as land use and biomass. CCUS cannot substitute the reduction agenda, and ultimately, there is a need for rigorous prioritization.

Facts about Canada

Photo: ATV

Citizens:
Canada: 38.3 million (2021)
British Columbia: 5.4 million (2023)
Alberta: 4.6 million (2022)

Area:
Canada: 9,985 km2
British Columbia: 945 km2
Alberta areal: 662 km2

GDP:
Canada: 1,988 trillion CAD
British Columbia: 272 billion CAD
Alberta: 338.2 billion CAD

Economic Growth:
Canada: 4.5% (2021)
British Columbia: 2.9% (2022)
Alberta: 5% (2021)

CO2 Emission:
Canada: 670 Megatons (2021)
British Columbia: 64.6 Megatons (2021)
Alberta: 256 Megatons (2021)

CCUS Strategy:
Canada: Canada aims to reduce CO2 emissions by 40-45% by 2030, compared to 2005 levels. By 2050, Canada aims to achieve carbon neutrality.

CCUS R&D Budget
Canada: 319 million CAD

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Why & What Canada

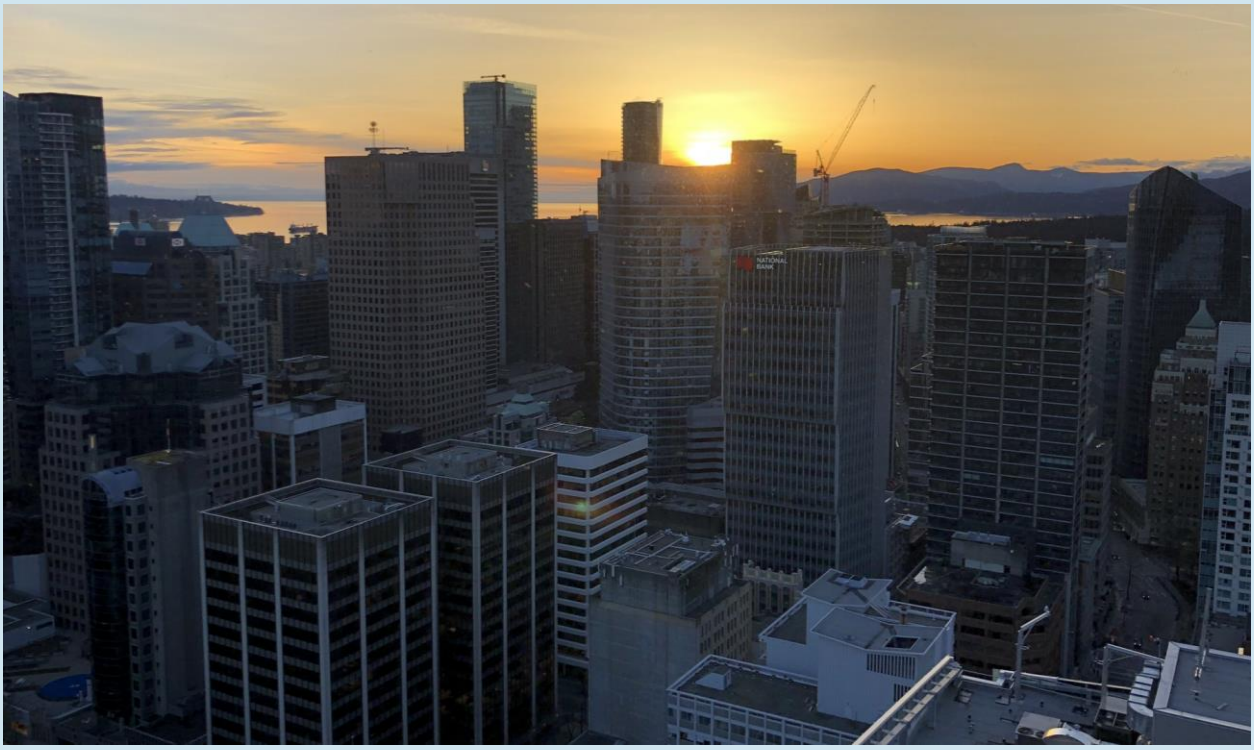

Photo: ATV: Vancouver skyline

Canada is a CCUS technology leader with large scale cutting-edge projects in Saskatchewan, Alberta and British Columbia. Current major projects include SaskPower's Boundary Dam thermal unit, with a carbon capture capacity of almost one million tons per year, plus the Shell Quest plant in Alberta, capturing more than one million tons of carbon annually. Also, the Alberta Carbon Trunk Line project, now in full operation, has the capacity to transport 14.6 million tons of carbon per year, currently drawn from an oil refinery, fertilizer plant, and other industrial sources, and injected into depleted oil fields deep underground.

With 62% of Canadians aged 25–64 having graduated from tertiary education institutions, Canada ranks as the most highly educated country in the world. Of those graduates, 2.8+ million hold a STEM degree, making Canada a prime destination for tech and science related industries. The availability of top-caliber engineers and scientists here, has been evidenced by Canada ranking 4th globally for scientific publications. The Clean Growth Hub is a whole-of-government focal point for clean technology focused on supporting companies and projects across Canada, coordinating federal programs and tracking results of federal investments in clean technology. Its team of experts provide advice to clean technology producers and users by helping them identify and understand the programs and services most relevant to their needs. The Accelerated Capital Cost Allowance (ACCA) allows businesses to immediately write off the cost of specified clean energy equipment as well as machinery and equipment used for the manufacturing and processing of goods.

The Scientific Research and Experimental Development (SR&ED) Program provides income tax credits and refunds for expenditures on eligible R&D activity in Canada. The Strategic Innovation Fund (SIF) provides funding to support innovation in Canada's leading industries. Svante recently secured $25M in funding from SIF to develop technologies that extract carbon dioxide from the atmosphere and use it to produce clean synthetic fuels. Part of the Strategic Innovation Fund, the Net Zero Accelerator allocates $8 billion over 7 years to expedite decarbonization projects with large emitters, scale-up clean technology, and accelerate Canada's industrial transformation. Additional support for innovative projects across all sectors includes $1 billion, on a cash basis, to support private sector investment in cleantech projects.

Vancouver, **British Columbia's** Roadmap to 2030 commits the province to the decarbonization of British Columbia 's industry in line with provincial and sectoral greenhouse gas reduction targets. It includes a commitment to develop a coordinated provincial approach to establishing an appropriate enabling environment for promoting the deployment of CCUS across a wide range of industrial sectors.

Natural Resources Canada (NRCan) has identified British Columbia as a priority province with respect to the use and refinement of its National CCUS Modelling Framework (NCMF) to guide industrial emitters toward viable carbon capture technologies and optimal transportation and sequestration solutions.

British Columbia (B.C.) companies are some of world leaders in Clean Technology, due in large part to our world-class utility programs, access to multiple forms of renewable energy, and strong ties to world markets. With the highest technology sector growth rates in Canada, B.C. is home to Canadian clean technology companies

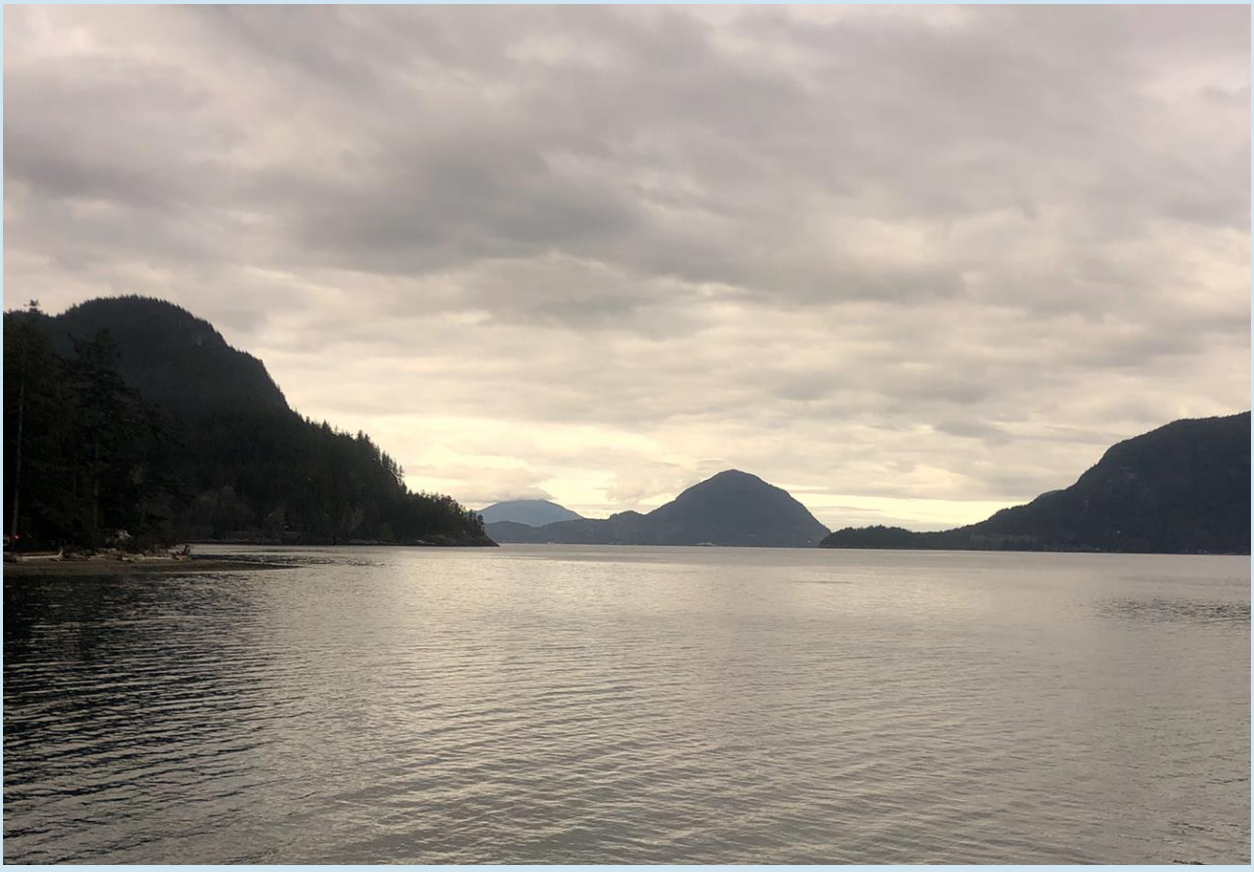

Photo: ATV: Vancouver in British Columbia

Photo: ATV: Edmonton in Alberta

Edmonton, Alberta is a leader in energy decarbonization, having made strides in reducing the carbon intensity of its electricity grid as well as its oil and gas sector. This is being achieved through a series of targeted reductions, a transition away from coal, the development of world-scale renewable energy projects, and investment in a growing carbon capture, focused in the areas of water and waste management, carbon capture, use and sequestration, clean transportation, energy management, efficiency and storage, fuel cells, and hydrogen. Leadership in clean, sustainable energy, with 98% generated from renewable resources, demonstrates that sustainability is a major focus for the people and Government of British Columbia. The Edmonton region is leading in Canada in clean energy technologies because of its strong innovation ecosystem, a commitment to sustainability, and a large pool of highly skilled talent. Alberta is home to more than 900 cleantech companies that serve a wide variety of industries, including traditional energy, power and utilities, manufacturing, agriculture, hydrogen, digitalization, carbon capture, utilization and storage, and more. A pioneer in CCUS, Alberta is leveraging its expertise and existing facilities and infrastructure to expand into low-carbon petrochemical products, such as blue methanol and blue hydrogen.

Alberta is home to two of the world's 18 large-scale projects. The newest, the Alberta Carbon Trunk Line, can sequester 14.6 million tons of CO2 per year. The captured carbon is used to produce blue hydrogen and for enhanced oil recovery.

Delegation Program

Connecting Canada & Denmark in CCUS

DELEGATION: In week 17 of 2023, ATV CLEAN headed 24 delegates from the Danish CCUS eco-system who spent 5 days in Vancouver and Edmonton, seeking inspiration on how CO2 reduction can happen faster, better and cheaper in collaboration with Canada. The delegation included industry, ministries, researchers, and organizations as a perfect sample of the Danish CCUS ecosystem.

Parallel with the ATV CLEAN delegation, Green Hub Denmark - CO2VISION headed a delegation with 16 participants in Edmonton. The last days we ran a joint program in Edmonton, gathering 50 Danish CCUS executives in joint learning, knowledge-sharing, networking, and international collaboration with Canadian counterparts.

PROGRAM: The program involved meetings with more than 300 contacts in 20 encounters/ sessions, in 2 locations in 5 days.

The program was developed in close collaboration with The Canadian Trade Commissioner Service and team, the Danish Ministry of Foreign Affairs and Green Hub Denmark - CO2VISION

This short video sums up the experience and key takeaways: link to video:

7 Key Findings for Denmark to take into consideration

1. "Can do" attitude and a market-driven innovative approach
2. “Exploring the possibilities” multiple paths and technologies simultaneously
3. Environmental and cost-effective Carbon Capture alternatives to amine technology (DAC and MOF)
4. Infrastructure for CO2 transportation and storage is up and running
5. Multiple long-term governmental incentives facilitate large-scale private investments in CCS
6. Joint government and major industrial players’ investments accelerate progress
7. System Thinking and Collaboration: (Market-driven approach vs. holistic planning)

Key Findings

1. 2 3 4 5 6 7

Photo: ATV: Visiting Svante

"Can do" attitude and/ because of market-driven innovation approach

CCUS implementation is not only about technology, but also about business models, financial incentives, regulation and trust among the actors to establish a full value chain.

The Canadian approach to climate solutions appears to be a more market-driven can-do-attitude. Solutions are built around financial incentives, i.e. the industry in Canada can actually earn money from storing carbon.

The industry gets up to 60% financing of investments. The Canadian government has introduced an Investment Tax Credit (ITC) for carbon capture, use, and storage (CCS/CCUS). The state funding provides companies with a tax deduction of 37.5-60% of the capital costs for CCUS projects if they are operational by the end of 2030. Further to this, there is a progressive carbon emission price of 60 CAD per ton in 2023 rising to 170 CAD in 2030. The combination of funding for investments and a tax on emissions incentivises the reduction of carbon emissions from all industries.

> ***We need a market for CCUS in Denmark. We are almost ready to capture and store, not yet ready to transport the CO2, but it is difficult to develop a business case when there is no market.***
>
> Ulla Röttger, London Energy Ltd.

Photo: ATV: Edmonton

The Canadian can-co-attitude is heavily tied to the old business case for CC(U)S regarding enhanced oil recovery, collaborative partnerships, and test facilities. The market-driven approach is based on access to large land areas, limited legislation, available capital, extensive science and knowledge.

The Canadian CCUS ecosystem benefits from strong collaborative partnerships and test facilities. A notable facet is the integration of legacy assets from the oil and gas industry, which have proven valuable in shaping the contemporary CCUS landscape. The collaborative efforts extend to large-scale testing facilities dedicated to materials properties, and well properties related to CO2, hydrogen, and other essential substances for upcoming CCUS infrastructure. This collaborative synergy not only enhances technological advancements but also fosters knowledge exchange among universities, research organizations, and industry stakeholders. We, however, also observed limitations to this approach such as many stand-alone solutions in terms of infrastructure that could benefit from a closer coupling between multiple stakeholders.

In Denmark, we have a strong can-do-ambition. In Canada they have strong a can-do approach. If we can combine the two, interesting results may appear.

> ***First and foremost, there's this "go and do" attitude, so it's about initiating some things and seeing if they actually yield results. We can learn a lot from that. Additionally, Canada can also be something for us, so I think it's the classic win-win situation***
>
> Morten Stage, Total Energy

Key Findings

1 **2.** 3 4 5 6 7

Photo: ATV: Alberta Heartland

“Exploring the possibilities” multiple paths and technologies simultaneously

By diversifying technological approaches, Canada is positioned to harness the strengths of various methods and technologies, increasing the likelihood of successful emission reduction and carbon capture - while creating new companies based on university research.

The ecosystem stands out due to its comprehensive exploration of various technologies towards capture of CO2. An example of this is the development of Metallic Organic Frameworks (MOFs) in carbon capture from point sources. These MOFs show promising results in terms of capturing carbon emissions more effectively. This multi-faceted approach demonstrates Canada's commitment to fostering innovation and diversification within the CCUS sector.

Additionally, the delegation gained insights into the innovative research carried out at universities throughout Canada.

Universities have been instrumental in advancing direct air capture technologies to the brink of large-scale deployment while pioneering research into novel capture technologies, such as photovoltaic capture, is also being researched at the universities.

> ***CCS is at a maturity level ready for implementation. The U, however, seems to needs further developments before solutions are scalable and climate friendly (U=Utilization in the CCUS)***
>
> Charlotte N. Larsen, DTU Offshore – Danish Offshore Technology Center

Photo: ATV: Visiting C-FER Technologies

Looking at the Canadian CCUS ecosystem, it also seems that there is a more ingrained culture of starting independent companies based on state-of-the-art university research. This culture was evident in both British Columbia and Alberta.

Considering Provincial Autonomy, it is worth acknowledging that Canada's decentralized governance structure, characterized by a high degree of provincial autonomy, has contributed to varying approaches in the pursuit of the carbon capture goal, e.i. Alberta is known for its heavy industry, particularly in the energy sector. It is essential to recognize that each region has its unique circumstances, and what works for Alberta may not be directly applicable elsewhere. Still, studying Alberta's experience in managing heavy industry and balancing economic growth with environmental and social concerns can provide valuable insights for other areas facing similar challenges. This element of regional regulatory diversity and circumstances has led to diverse strategies and priorities, highlighting the importance of understanding the nuances within each province's journey towards carbon capture and storage. While British Columbia is particularly focusing on R&D activities, Alberta is largely concentrating on implementation.

Utilization is a future frontier - but there's still some way to go:
However, it is noticeable that the case for the U (Utilization) is still to be further developed in Canada if we look past the possibility of upgrading natural gas to blue hydrogen. Blue hydrogen is produced from natural gas in Alberta, where as green hydrogen is produced from renewable energy.

> ***Both CCU and CCS are going to play a role. Things like plastic recycling, for example, is something that's going to play an enormously significant role. So, I believe a lot in what is described in the reports of the UN's climate panel, where they state that we need all the technologies, and we need all the sources of carbon for an extended period now. Unfortunately, I don't think we can expect to shut down the fossil industry in the next decade or the next two decades. We need to develop green solutions and let them grow organically into the global economy.***
> David Fich, Ørsted

Key Findings

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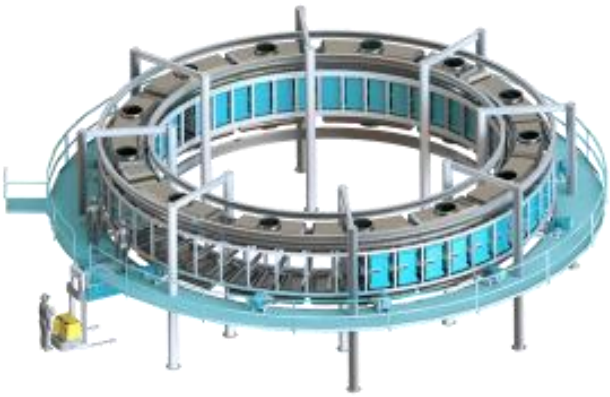

Photo: Svante

Environmental and cost-effective Carbon Capture alternatives to amine technology (DAC and MOF)

Carbon Engineering with DAC and Svante with MOF technology demonstrated pilot to large scale implementation. The exploration of these technologies could present a dual advantage of carbon capture and enhancing energy efficiency

At the visit to **Carbon Engineering,** the delegation was presented with estimates of a 500,000 tons per year DAC facility within a relatively modest 30 acres (120,000 m^2) of space suggesting that DAC's spatial requirements may be more adaptable than previously thought - further plans to scale up to 1Mt were also presented. The delegation was surprised to learn that Direct Air Capture technology (DAC) aimed at capturing CO2 directly from the atmosphere, which has traditionally been perceived as resource intensive in terms of both the cost of the technology and space, seemed so close to actual implementation. Carbon Engineering is in the process of establishing the first full-scale project in Texas. Here, they anticipate capturing CO2 at a cost of 400-500 USD/ton, including expenses for transportation and underground storage. (This is funded by the Inflation Reduction Act (180 USD/ton) in combination with the voluntary market (CDR - Carbon Dioxide Removal).

> ***In Canada, we have seen a great willingness to invest in technology. Carbon Engineering's project in Texas is a major financial risk. But it is exciting to see that some are willing to take that risk so that the technologies can work in the real world.***
>
> Jacob Hjerrild Zeuthen, Maersk.

Photo: ATV: Visiting Svante

The delegation also visited **Svante and got to see the MOF Technology Advancements'** prototype which is being built to capture around 180,000 tons of CO2 pr. year. Svante is actively working towards the commercialization of MOF technology, a technology which in Denmark is currently at a low developmental stage. Looking ahead, Svante aims to scale up significantly, with the capacity to deliver two capture units per week by the year 2030. The absence of amines further contributes to limited environmental challenges associated with operating the technology - as there are apparently no harmful byproducts, which is a typical issue for conventional amines technologies.

Comparison with Danish CCUS focus: In stark contrast, the Danish CCUS landscape has predominantly centred around amine-based technologies for carbon capture. While these methods have shown promise, the Canadian example highlights the potential limitations of solely relying on a single technology.

> ***It was very interesting to see that they are not just relying on one technology; they are exploring the utilization of MOFs in carbon capture for point sources. They are also working on developing, and actually implementing, facilities with capacities up to 1 Mt. It is fascinating, especially when compared to Denmark, where we are currently heavily focused on amine-based solutions. However, many other technologies are emerging. I believe we should consider exploring some of these alternatives within the Danish context and further develop these technologies as well.***
>
> Jakob Ask Hansen, Danish Technological Institute

Key Findings

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Photo: Shutterstuck

Infrastructure for CO2 transportation and storage is up and running

Technology suppliers in the Canadian CCUS infrastructure are far ahead in terms of CO2 pipelines, CO2 capture, storage, and Direct Air Capture.

The Canadian CCUS ecosystem has demonstrated impressive progress in terms of infrastructure development and storage. Additionally, Canada has several large-scale facilities that are already up and running - and dimensioned for the future - some of them mentioned here.

WOLF Midstream Pipeline project: The Alberta Carbon Trunk Line (operated by WOLF Midstream) is a pipeline project that demonstrates Canada's commitment to establishing functional CCUS infrastructure. This operational pipeline spans 240 kilometres and has been designed to meet both current and future needs.

With an annual transportation capacity of up to 14 million tons (Mt) of CO2, the pipeline addresses Canada's carbon management strategy. Since its commencement in 2020, it has effectively transported approximately 1,5 Mt of CO2 per year, showcasing its practicality and capacity. The surplus capacity has been funded by the local government.

Shell Quest project: A megaton facility: The Shell Quest project stands as a milestone in operational CCS infrastructure. It has successfully stored around 10 Mt of CO2 in the Alberta region, highlighting Canada's progress in sustainable carbon management.

Photo: ATV: Visiting C-FER Technologies

Transitioning from EOR to Pure Storage: The development of CCS infrastructure, particularly in Alberta, has evolved from CO2 use for Enhanced Oil Recovery (EOR) to a focus on sustainable carbon management practices. The years of experience from EOR is what has given Canadian stakeholders knowledge on how to safely transport and sequester CO2. In general, Canada is moving away from EOR to pure storage of CO2 due to financial incentives.

Prominent Examples of CO2 Infrastructure: The Quest Operated by Shell, Alberta Carbon Trunk Line. Further that several new mega projects are currently in the pipeline.

> ***My key takeaway from this delegation trip is that we must recognize that, with respect to CCS, in some areas, the Canadians are way ahead of us. This is the case when looking at pipeline infrastructure and the transportation of CO2. They already have experience in transporting large amounts of CO2 in pipelines with a capacity of several million tons. We will be able to benefit from their knowledge and experience when we develop the future Danish infrastructure for CO2 transportation.***
> Morten Poulsen, Evida

Key Findings

1 2 3 4 **5.** 6 7

Photo: ATV: Alberta Heartland

Multiple long-term governmental incentives facilitate large-scale private investments in CCS

The Canadian approach to carbon capture technology implementation demonstrates the power of combined public and private sector leadership

This report delves into the Canadian model, where the synergy of progressive carbon taxation, financial incentives, and accessible pipelines have paved the way for significant private investments in carbon capture and storage (CCS). Moreover, a competitive landscape has emerged within the domain of CCS, fostering innovation and advancement in both capture and storage of CO2. These insights raise the question of whether Denmark could leverage similar strategies to potentially yield even greater climate impact, considering its advantageous position with renewable energy and biogenic point sources.

Canada's Paradigm: *Aligning Incentives for Climate Investments***:** The Canadian case underscores the crucial role of incentives in driving climate investments. Canada's trajectory towards carbon capture leadership has been significantly shaped by a conducive environment for investments. The favourable financial structures have acted as a catalyst, attracting significant funding towards CCS initiatives. This, in turn, is anticipated to position Canada as a global frontrunner in carbon capture within a few years. However, it was also worth noting that Canadian stakeholders across the different provinces all mentioned the impact that the US Inflation Reduction Act (IRA) will have on the industry,

Public Funding of CCS in Canada

In Canada, CCS receives subsidies for project development, financing of construction costs, and for saved CO2 taxes in the operational phase. Thus, there are significant financial incentives that support the implementation and operation of CCS.

Project development: up to 50% public funding to FEED studies (Front End Engineering Design) of CCS project. Funding is based on a pool, where the most viable projects get funding.

Construction costs: The Canadian government has introduced an Investment Tax Credit (ITC) for carbon, capture, use and storage (CCS/CCUS). The funding from the state gives companies a deduction in the tax payment of 37.5-60% of the construction costs for CCUS projects if they are operational before the end of 2030. Most funding is given to Direct Air Capture (60%), while transport, storage and use of CO2 are reimbursed 37.5% of the construction costs. Capturing and other relevant parts of CCUS projects are reimbursed 50% of the construction costs.

Saved CO2 taxes: All large emitters (>2,000 tons per year) pay CO2 tax for every ton of CO2 they emit. The CO2 tax increases by 15 CAD each year and will reach 170 CAD in 2030 (1,000 DKK). Companies are not paying CO2 tax if they capture and store their CO2.

Tabel:1

acting as a catalyst while also presenting a significant challenge in terms of avoiding that companies relocate.

Private investments: The public incentives lead to impressive private investments in CCS. Pipeline infrastructures, storage facilities, direct air capture pilots, technology development, and implementation of large-scale carbon capture facilities at point sources throughout Alberta; are obvious results of the public incentives. The local stakeholders are very clear that the long-term governmental incentives facilitate large-scale private investments in CCS. Private equity is used for the CAPEX (capital expenditure) investments resulting in lower OPEX (operational expenditure) and a positive business case due to the governmental incentives.

A progressive carbon tax, financial subsidies and shared open access pipelines lead to very large-scale private investments in capture and storage, and to competition between companies within capture and storage of CO2. If we follow the same path in Denmark, we can deliver even greater climate impact than Canada because we have better prerequisites from renewable energy and biogenic point sources.

Mikkel Krogsgaard Niss, Carbon Capture Cluster Copenhagen (C4)

Key Findings

1 2 3 4 5 **6.** 7

Photo: ATV

Joint government and major industrial player investments accelerate progress

The Quest - Shell Carbon Capture Project showcases a full CCS value chain that works. Each well can store 150 tons of CO2 per hour at full operation, ensuring that the system remains operational even in the case of a well's downtime.

Funding and Financial Support: The Quest - Shell Carbon Capture Project is a collaborative initiative supported by funding from both federal and provincial governments. These entities co-finance the project's construction costs, contributing approximately 575 million CAD (3 billion DKK) in subsidies. Additionally, operational subsidies are tied to the project's CO2 reduction outcomes. Shell anticipates that public funding will cover more than 60% of the total project costs. Furthermore, the project benefits from reduced CO2 taxation, providing additional financial support.

Project Overview and Operational Setup: The Quest - Shell Carbon Capture Project is centred around capturing CO2 emissions from three units engaged in methane-to-hydrogen conversion (blue hydrogen). The carbon capture process employs a traditional amine-based approach, featuring three absorbers (one for each unit) and a collective desorber. Unlike combined heat and power plants, the captured CO2 is intercepted prior to combustion. This unique setup underscores the project's distinct focus on carbon capture from specific processes.

Photo: Shutterstock

> ***It was a surprise to me that the technologies are so far advanced in Canada, and it has made me look at them in new ways. The maturity of Direct Air Capture (DAC) surprised me the most, and it became clear to me that DAC will also play a big role in the transition on an equal footing with other CCUS technologies and methods***
>
> Karina Søgaard, INNO-CCUS

Project Timeline and Performance: The project's inception can be traced back to the initiation of the FEED study in 2009, culminating in the completion of the facility in 2016. Remarkably, the construction process exhibited efficiency, cost-effectiveness, and enhanced performance beyond initial expectations. Notably, the reliability of the facility has reached an impressive rate of 99%, with the plant operational for 99% of the time and experiencing minimal downtime.

Carbon Capture and Emission Reduction: During operation, the facility captures approximately 80% of CO2 emissions, surpassing initial expectations. The annual capture amounts to approximately 1.1 million tons of CO_2. However, considering the fossil energy used for capture and transportation, the net reduction effect is approximately 0.8 million tons of CO2 per year. According to the Global Carbon Capture and Storage Institute, Quest accomplishes the highest annual CO2 sequestration volume worldwide among onshore facilities equipped with specialized geological storage, and this achievement is transparent and verifiable. You can access the annual performance reports on the Alberta government website. It is important to note that the captured CO2 is not utilized for Enhanced Oil Recovery (EOR) purposes.

> ***CCS plays a crucial role in this context, as stated by the IPCC and the EU. This importance is also evident when looking at our capabilities, both from what we have been presented with here, and what we see in the Danish environment back home. It is a key component in achieving Denmark's climate goals for both 2030 and 2050, as well as the global climate goals.***
>
> Morten Stage, Head of Technical Services DK & Chairman INNO-CCUS, Total Energies

Key Findings

1 2 3 4 5 6 **7.**

Photo: ATV: Vancouver by night

System Thinking and Collaboration:

Market-Driven Approach vs. Holistic Planning

Canada appears to focus more on individual factories and technologies in isolation, possibly hindering the development of integrated solutions.

A notable distinction between Denmark and the Canadian provinces the delegation visited, relates to the approach to system thinking and collaboration. In Denmark, we have a strong emphasis on holistic thinking and collaboration across sectors and technological levels. This collaborative spirit extends to research, industry, and governmental cooperation, enabling the creation of comprehensive solutions. In contrast, Canada appears to focus more on individual factories and technologies in isolation, potentially hindering the development of integrated solutions.

Regulatory Framework and Implementation: Denmark has made considerable progress in establishing a regulatory framework for Carbon Capture and Storage (CCS), with effective methods for inspection, control, and verification. The Danish model showcases a successful collaboration between industry and authorities. This harmonious relationship contributes to the efficient implementation of CCS technologies. Conversely, Canada seems to have a less developed regulatory framework in this regard.

> ***Politicians need to acknowledge that the green transition must be accelerated and will come at a significant cost. We can only succeed if politicians have the courage to admit that securing the green transition will be expensive for each individual Dane. Excessive CO2 in the atmosphere comes at a price, and we need to pay it back, including interest! Politicians must make these green initiatives, such as CO2 capture, more accessible for Danish companies, giving them a better chance of success. And this needs to happen now.***
>
> Emil Damkjær Herløv Hasen, Kredsløb A/S

Photo: ATV: Katrine Thomsen, Ministry of Climate, Energy and Utilities

Key Facts

Canada aims to reduce CO2 emissions with 40-45% by 2030 compared to 2005 levels.

Canada aims to achieve carbon neutrality by 2050

Danish efforts are guided by a long-term roadmap, designed to achieve climate goals by 2050. This methodical planning aligns research, industry, and policy, ensuring a coordinated push towards solutions. Canada could potentially benefit from incorporating elements of Denmark's approach, thereby strengthening both ambition and cooperation.

Lessons for Canada: A key lesson Canada can learn from Denmark is the importance of having high-level government commitment to climate objectives. Denmark's combined top-down and bottom-up approach ensures that ambition is shared across all levels, fostering a united effort to create solutions.

> ***I find it exciting and important for the Danish efforts in the roadmaps we have created, as well as our entire approach, to be aware that climate solutions, including CCUS, are not just a technological challenge. It is just as well a societal challenge because we simply need to address the solutions, also ensuring the right economic conditions and that we have the population on board. It doesn't make sense to create possibly important and technologically correct solutions that the population does not support or understand.***
> Claus Beier, University of Copenhagen

3 recommendations

Accelerate the Implementation of Danish CCUS

1.

Intelligent package of long-term incentives and predictability encourages a market driven approach to CCS

The long-term incentives with direct funding for project development and construction and carbon taxes that increase over time, foster private investments in the entire CCS value chain. The most important part is the known future carbon tax price, making it possible to reduce risks in the development of CCS projects. Furthermore, it makes it possible for competitors to cooperate on transport and storage of CO2. We recommend that similar long-term incentives are implemented in Denmark and Europe.

2.

Build pipelines with sufficient capacity

Pipelines are the infrastructure that foster competition in the areas of capture, storage and utilization of CO2 and drive economies of scale. Without pipelines, we will only see stand-alone projects and no real competition for the CO2. Canada has shown that pipelines are the only way to transport large amounts of CO2.
It is important to build pipelines with sufficient capacity from the onset, as it will be very expensive to expand the capacity later. In Alberta they have built trunk lines with large capacity that are future fit. We recommend that when we build pipelines in Denmark, we should make sure that we have enough capacity for future Danish and European developments.

3.

Science to business faster

Canada has shown that the close cooperation between academia and business makes it possible to take new technologies fast to business. Technologies like DAC and MOFs were very far from business a few years ago, but through close cooperation between business and academia, and with a regulative mindset where such cooperation is possible, these technologies now appear very close to market and with very reduced costs.

Results so far (October 2023)

Presented below are some of the early results.

Enhanced Bilateral Collaboration Between Denmark and Canadian Provinces on CCUS

The Alberta Ministry of Energy and the Danish Ministry of Climate, Energy, and Utilities have committed to signing a Memorandum of Understanding (MoU) to strengthen their cooperation in the domains of CCUS, alternative fuels, and general energy policy

Increased Recognition of Denmark as a Prominent CCUS Partner and Potential

Denmark's emphasis on CCUS has gained considerable international attention. The head of partnerships at the Danish INNO-CCUS was invited as a keynote speaker at the "Carbon Capture Canada" conference. Furthermore, several visits to Denmark, notably by representatives from Svante, have taken place to explore potential partnerships and collaborative solutions.

Boosted Academic Collaboration

Aalborg University and Canadian universities have initiated research collaborations. The first PhD student from Aalborg University will embark on an academic exchange to Canada in Q1 2024.

Applications Submitted for New Projects in Canada and Denmark

Multiple funding applications have been submitted to various agencies by consortia comprising Danish and Canadian partners who had not previously collaborated, and the applications reflect the growing interest in joint ventures.

Business-to-Business Collaborations Underway

While the specifics remain confidential due to non-disclosure agreements, several business-to-business collaborations are currently in progress, indicating the fruitful connections made during the delegation's visit.

Strengthening the Danish CCUS Ecosystem

One strong outcome extends beyond international connections. A post-trip survey shows that the visit has played a pivotal role in cultivating a more tightly integrated Danish CCUS ecosystem. Networks, collaboration, and interpersonal relationships among academic, public, and private institutions, have strengthened significantly due to the visit.

Initiative to Establish Clear Links between CCUS and the Danish Climate Targets

A large number of key actors from the Danish CCUS ecosystem participate in a Mission Lab "Carbon 110%" as part of ATV's "Guide to a Resilient Denmark" project. The Mission Lab will address connections, interdependencies, what a sustainable and environmentally friendly use of CCUS demands, and what is required for CCUS to contribute optimally to the 2050 110% CO2 reduction target.

Anticipating More Developments

A survey conducted by the organizing team revealed that several MoUs and new collaborations between Denmark and Canada are underway – too many to list here. We eagerly await announcements over the coming year.

The ATV & CLEANs Danish CCUS delegation

A delegation of 25 high-level decision-makers in the Danish CCUS environmental eco-system from technology companies, universities, knowledge institutions, organizations, clusters, government, and grant providers

MINISTRY OF FOREIGN AFFAIRS OF DENMARK
Invest in Denmark

ROYAL DANISH EMBASSY
Ottawa

Technical University of Denmark

Klimarådet.

LondonEnergy
Powering the Circular Economy

MAERSK

Klima-, Energi- og Forsyningsministeriet

CO2VISION

Government of Canada

Gouvernement du Canada

novo nordisk foundation

Ørsted

TotalEnergies

evida

TEKNOLOGISK INSTITUT

Trade Commissioner Service

GREEN HUB DENMARK

INNO-CCUS
Carbon capture, utilisation and storage

AALBORG UNIVERSITET

Carbon Capture Cluster Copenhagen

CarbonCuts
CARBON CAPTURE UTILISATION TRANSPORT STORAGE

Kredsløb

UNIVERSITY OF COPENHAGEN

INEOS Energy

FORCE TECHNOLOGY

clean
DANMARKS MILJØKLYNGE

ATV

The ATV & CLEAN team in charge of the study tour

Henrik Bjørnager Jensen, CLEAN Denmark's Environmental Cluster
CCO - Strategic Project Development
Managing complex innovation and business development projects. Involved in CLEANs international projects with the C40 cities and CLEANs Nordic Collaboration as well as supporting the International Cleantech Network (ICN), the leading global network of cleantech.

Contact: HBJ@cleancluster.dk or visit www.cleancluster.dk

Kasper Havemann
Project Manager - Head of Air Solutions, CLEAN Denmark's Environmental Cluster
Responsible for developing activities within the CCUS thematic area at CLEAN. Has experience from working with sustainability and innovation from previous positions at Sustainia and Green Innovation Group. Holds a degree from University of Copenhagen.

Contact: kah@cleancluster.dk

Frederikke Kroon
Program Director, The Danish Academy of Technical Sciences (ATV)
Responsible for developing and managing delegation trips at ATV. Experienced facilitator of fast-track innovation processes. Industry background as business developer driving innovations to commercial breakthroughs. Holds a degree from Copenhagen Business School.

Contact: fk@atv.dk or visit www.atv.dk

Anna Høybye
Senior Advisor, The Danish Academy of Technical Sciences (ATV)
Responsible for managing ATV's new signature project "Guide to a Resilient Denmark", which aims to harness science and technology to accelerate Denmark's sustainable transition. Background from the humanitarian sector. Holds an MA-degree in political science from the University of Aarhus.

Contact: aho@atv.dk

The Delegation members

Title	Name	Organisation
Senior Advisor	Anna Høybye	The Danish Academy of Technical Sciences
Programme Manager, Danish Offshore Technology Center, Offshore	Charlotte Nørgaard Larsen	Technical University of Denmark - DTU
Professor of Ecosystems and Sustainability, Head of Department	Claus Beier	University of Copenhagen
Senior Lead Business Developer	David Egede Fich	Ørsted Bioenergy & Thermal Power
Project Manager	Emil Damkjær Herløv Hansen	Kredsløb A/S
Specialist in air emissions from industries	Frantz Bræstrup	FORCE Technology
Program Director	Frederikke Kroon	The Danish Academy of Technical Sciences
CCO - Strategic Project Development	Henrik Bjørnager Jensen	CLEAN
Center director, Air and Sensor Technology, PhD	Jacob Ask Hansen	Danish Technological Institute
Senior Future Fuels Manager	Jacob Hjerrild Zeuthen	Maersk Decarbonisation
Special Advisor	Jasmin Sharzad	Ministry of Climate, Energy and Utilities
Partnership Director – INNO-CCUS	Karina M. Søgaard	Inno-CCUS (1) DTU
Project Manager	Kasper Havemann	CLEAN
Deputy, Head of Department	Katrine Thomsen	Ministry of Climate, Energy and Utilities
CEO	Ken Wesnæs	CarbonCuts A/S
Investment Manager, Cleantech	Lukas Tanzer	Ministry of Foreign Affairs of Denmark, Invest in Denmark
Manager	Mikkel Krogsgaard Niss	Carbon Capture Cluster Copenhagen (C4)
Head of INNO-CCUS & Technical Services and Support, DK	Morten Gjetting Stage	Totalenergies
Head of PtX and Pilot Projects	Morten Poulsen	Evida
Analyst, MSc., PhD	Nis Bertelsen	Danish Council on Climate Change
Head of CCS and Producing Assets	Søren Reinhold Poulsen	INEOS Energy Denmark
Research Group Leader, Associate Professor	Thomas Helmer Pedersen	AAU Energy, Aalborg University
Scientific Director	Torben Vedel Borchert	Novo Nordisk Foundation
Non-Executive Director	Ulla Röttger	LondonEnergy Ltd.

Charlotte Nørgaard Larsen

CO2 Storage Programme Manager Danish Offshore Technology Center – DTU Offshore

Technical University of Denmark (DTU)

My background:
I have been working 4 years at DTU Offshore as programme manager for our CO2 storage program and our Abandonment program. Prior to joining DTU I have been working in the O&G industry for 20 years, with roles spanning from Lead Drilling Engineer to Well Project Manager and Project Manager and working in locations like the North Sea, the Persian Gulf and the Caspian Sea. (Education: Msc Civil Engineering - DTU & Imperial College).

My company:
Danish Offshore Technology Center – DTU Offshore, is Denmark's national R&D center for offshore technologies. We hold a central position in the energy transition by developing research-based technology solutions for the offshore industry in the North Sea. One of the center's focus areas is CO2 storage in Denmark.

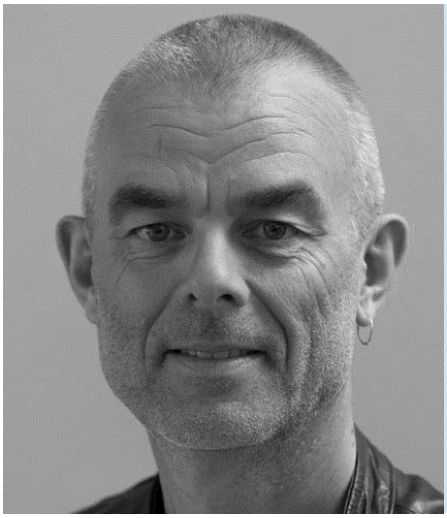
The current CCUS challenge:
In collaboration with our industry partners the center has a significant CO2 storage research portfolio with focus on the challenges around: re-use of O&G wells for CO2 injection, behavior of well barriers in CO2 environment, subsea CO2 leak detection, CO2 plume movement, utilization of chalk reservoirs for CO2 storage, environmental impact of CO2 storage, social acceptance of CO2 storage, and CO2 value chain optimization. The CO2 research program includes more than 50 researchers from DTU (Technical University of Denmark), AU (Aarhus University), and GEUS (Geological Survey of Denmark and Greenland).

This is what I especially contribute with:
My contribution will be a wide knowledge of CO2 storage R&D vs challenges and at the same time being a link between the industry and the research.

Attending to the program, my workplace hopes to gain:
As the CCS industry in Canada is more mature than what we see in Denmark, I hope that the program will give me an understanding of the challenges that Denmark will face in the next CCS phases. Such knowledge will be important to make sure our R&D addresses the right challenges moving forward. In addition, I hope to create a network both within research and industry along the CCS value chain.

Attending to the program, I personally wish to gain:
I would like to get inspiration for future CO2 research challenges and understand the upscaling challenges we in Denmark are likely to face in the near future.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by: I hope that in 5-10 years we have a working CCUS value chain which takes advantage of a variety of technologies and is based on collaboration between industries. In 5-10 years, there will likely still be a need for optimizations and efficiency improvements, however, if we can have a working value chain with both storage and utilization, we have a good starting point for optimizations and upscaling.



Claus Beier

Professor of Ecosystems and Sustainability,
Head of Department
University of Copenhagen

My background:
Cand. Polyt., PhD (Chemistry and Environmental Sciences)

My university:
University of Copenhagen
Department for Geosciences and Natural Resource Management

The current CCUS challenge:
The obvious challenge of course is to:

- implement and scale the CCS technology and the associated infrastructure
- develop technologies to replace black carbon used in chemicals and substances with green alternatives
- secure enough "green" carbon to offset non-stoppable black CO2 emissions, including land planning to make it happen
- scale up biological storage of carbon
- establish sufficient renewable electricity and non carbon energy
- assure citizen support and acceptance

This is what I especially contribute with:
Links to researchers in geological storage and in green carbon production and storage in soils and biomass, as well as researchers in landscape and land use planning.
I am scientific lead for the biological CCUS activities within the Danish InnoMission activities under Mission 1 (CCUS) and also have links to students in the same area.

Attending to the program, my workplace hopes to gain:
Better understanding of the current state of the art in various CCUS technologies.
To strengthen the national network and contacts.

Attending to the program, I personally wish to gain:
Knowledge and understanding of State of the Art - and personal contacts to Danish and Canadian actors.
Understanding of the potentials and state of the DAC technology.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
I hope that CCUS in 5-10 years will provide upscaled biogenic removal of CO2 by increased and improved forest, nature and soil storage and that 1st generation of Danish CCS plants have been established for short term removal and naturalization of fossil CO2 and for long term removal of biogenic CO2 to create negative emissions. Also, my hope is that the CCUS effort will have led to the development of a coherent Danish and international land-use plan to ensure long term provision and prioritization of biogenic carbon production ensuring balanced provision of green carbon, food, biodiversity and other land-based ecosystem services.

David Egede Fich

Senior Lead Business Developer

Ørsted Bioenergy & Thermal Power

My background:
MSc Engineering, HD(o)

My company:
https://orsted.com/en/about-us

The current CCUS challenge:
Creating financial viability within CCX.

This is what I especially contribute with:
Through participation in Ørsted's Carbon Capture and P2X program, I have achieved some End-to-End carbon value chain insight and technological Carbon Capture insight. Furthermore, we have specific experience with marketing and contracting of Carbon Capture-related products. Our general experiences from these processes could potentially be of interest.

Attending to the program, my workplace hopes to gain:
Further data on international CCX project development, perhaps some new info on competitive technologies within the sector and a wider outlook on agents and activities within the Carbon Capture sector. Specifically, also an opportunity to have dialogue with participating partners and stakeholders on this trip.

Attending to the program, I personally wish to gain:
Improved network within the CCX area as well as further insight into emerging international developments within carbon capture, both commercially and technologically.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
Having established the first fully circular carbon economies and value chains based upon biogenic CO2 capture and an integrated approach to the Voluntary Carbon Market and the e-fuels market.

Emil Damkjær Herløv Hansen

Project Manager
Kredsløb A/S

My background
I have a Master's Degree in political science from University of Southern Denmark.

My company
Kredsløb is a private company owned by the Municipality of Aarhus, is the utility company of Aarhus, the second largest city of Denmark. Kredsløb delivers district heating to more than 330, 000 people, and we reuse waste for 178, 000 households in Aarhus.
www.kredslob.dk

The current CCUS challenge
At Kredsløb's power plant, Energy Park Lisbjerg, we have a waste to energy and a biomass power plant. These two plants have a combined stack, with a total emission of 0.45 mio. t. CO_2 /year. Here we plan to capture CO2 as early as possible, and by 2030 at the latest.

This is what I especially contribute with
Due to my background in CCS policy making, I focus my time on CCUS regulation in Denmark. I specialize in the cross field between regulation and CC(U)S projects.

Attending to the program, my workplace hopes to gain
An opportunity to test assumptions in our own project and investigate whether there are new angles/topics we need to uncover.

Attending the program, I personally wish to gain:
To hear and learn something new CCUS-related. And to test assumptions in our own CC-project and to investigate whether there are new angles/subjects/areas we need to uncover.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
Hopefully CCUS will account for reductions in gigatons. But at least equally important, that large-scale reductions will be taking place in other sectors as agriculture and transport, and that society as a whole has a much bigger focus on environment and biodiversity.

Frantz Bræstrup

Specialist in air emissions from industries

FORCE Technology

My background:
I have a background from the University of Copenhagen within material chemistry and mineralogy. Later I continued my studies at Risoe National Laboratory where I acquired a PhD within electrochemical reduction of NOx gases. The last 10 years I have worked with emission monitoring of gases and particles from various sources at FORCE Technology.

My company:
The department of Clean Air Technologies at FORCE Technology delivers services for the industry within emission monitoring of gases and particles from power plants to process industry. The department also performs emission measurements in work environment and ambient air monitoring. I am located within the team that works with projects and advanced commercial tasks within emissions from e.g. CCUS and green fuels.

The current CCUS challenge:
The main CCUS challenge as we see it, is the cost of implementation and maintenance of it in the industry. Large investments also require solid knowledge of the maturity level of the technology needed, including which rules and regulations are expected to be applied in the future. Lack of regulation can also slow down the transition to a zero-carbon emission society.

This is what I especially contribute with:
My key competencies are flue gas analysis and particle measurements from stationary and mobile sources. Flue gas legislations and emission data assessment from various types of emission sources.

Attending to the program, my workplace hopes to gain:
FORCE Technology hopes to increase our knowledge and gain a deeper understanding of how other countries, Canada in particular, manage and incorporate CCUS in their green transition toward zero carbon emission. FORCE Technology would like to learn more of which rules and regulations that drives the implementation of CCUS in Canada.

Attending to the program, I personally wish to gain:
Personally, I wish to broaden my knowledge of how CCUS can play a significant role in the energy infrastructure of the world today.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
We hope that CCUS will become a significant part and backbone in the energy infrastructure, not only in Denmark, but globally.

Jacob Ask Hansen

Center Director
Danish Technological Institute

My background:

My company:
Danish Technological Institute, Center for Air & Sensor Technology

The current CCUS challenge:
Development of monitoring systems for CCUS; CO2 fugitive emissions and unwanted emissions from capture systems.

This is what I especially contribute with:
Understanding of the value chain, development of new solutions, monitoring and characterization of emissions, emission reduction technologies.

Attending to the program, my workplace hopes to gain:
Further understanding of the development needs for ensuring implementation of the CCUS value chain.

Attending to the program, I personally wish to gain:
Stronger network within the CCUS value chain. Better understanding of technologies needed to ensure safe and feasible implementation of CCUS throughout the value chain.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
Helping Danish companies (and particularly SMVs) to gain a strong position in the global CCUS value chains, by supporting the development of the necessary technologies ensuring feasible implementation of CCUS, also on smaller emitters.

Jacob Hjerrild Zeuthen

Senior Future Fuels Manager
A.P. Moller–Maersk. Maersk Energy Transition

My background:
I have a technical background and have been working with development of chemical processes and products most of my career. I have worked for the companies Haldor Topsoe, Amminex Emissions Technologies, and Ørsted. Before I joined Maersk I also worked 3 years and Chief Technology Advisor under the Danish Ministry of Climate and Energy, with a focus on CCUS technologies. I am experienced in development of technologies related to high temperature processes, catalysis, emissions, energy, and climate. My education is as a chemical engineer from The Technical University of Denmark and I hold a PhD from the same university. My research focused on combustion and formation of submicron particles in flames.

My company (www.maersk.com)
Maersk is a large shipping and end-to-end logistics company. The company has a large consumption of fossil fuels and a target of becoming net-zero by 2040. This obviously will require replacement of the existing fuels with other alternatives. In Maersk Energy Transition we focus on development and deployment of technologies for decarbonization. My focus is specifically on alternative fuels.

The current CCUS challenge:
Carbon capture is well-known technology that in some cases makes perfect sense. Sequestration of carbon is possible in some parts of the world and will lead to direct carbon reductions. This will need infrastructure to be developed and supported. Using the carbon for constructive purposes is an option but will set further requirements to the origination of the carbon. How to convert the carbon to products and fuels is an added challenge and will also depend on the availability of low-carbon hydrogen. The hydrogen and the carbon for fuel production will in most places not be co-located and infrastructure is also needed to the CCU-version of CCUS. Direct Air Capture is a potential way to reduce the need for co-location of power and carbon sourcing and a long-term needed option to sourcing of carbon.

This is what I especially contribute with:
Maersk wants to contribute to technology development that push the availability of green fuels. I can contribute to sharing the Maersk view on relevant technologies and in the discussion of how to develop a shared infrastructure.

Attending to the program, my workplace hopes to gain:
In Maersk we would like to understand how to build an effective infrastructure for CCUS.

Attending to the program, I personally wish to gain:
A broader network. A non-Danish perspective on CCUS and on CCS vs CCU. An improved understanding of the cost and regulatory aspects of CCUS.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
Reducing fossil point source emissions by storage, create needed negative emissions by storage of these and allow usage of carbon for fuel production that can decarbonize hard-to-abate sectors.

Jasmin Sharzad

Special Advisor

Ministry of Climate, Energy and Utilities

My background:
MSc in International Business and Politics, work experience from startup, as well as University Innovation Hub (DTU Skylab), past 4 years in the Ministry of Climate Energy and Utilities

My company / university / department is:
In charge of major CCUS relevant regulation, framework, aiding political decisions etc.

The current CCUS challenge:
Enabling cross border transportation of CO2 with the purpose of permanent storage, as well as establishing the full value chain in a timely manner.

This is what I especially contribute with:
Ensuring the right regulatory framework is in place both on a national and international level.

Attending to the program, my workplace hopes to gain:
A better understanding of how other countries overcame the regulatory barriers, established the right framework, ensured a timely value chain, etc.

Attending to the program, I personally wish to gain:
Besides the above, an understanding of how the value chain works in practice, how it physically looks, etc.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
Contributing to the national climate targets, targets of the EU, and overall be a positive contribution to the green transition to the benefit of the climate.

Karina M. Søgaard

Partnership Director. INNO-CCUS

DTU, The Technical University of Denmark

My background:
BEng Chemistry, MEng Biotechnology, PhD Biosustainability.

University:
INNO-CCUS at DTU Chemistry

The current CCUS challenge:
Research funding, network building, collaboration, value chain building

This is what I especially contribute with:
INNO-CCUS is one of the government's four green missions partnerships, with 57 partners across research and companies. We support research and innovation and promote technologies that capture, store, and use CO2 so that we can reach Denmark's climate goals. We want close contact to the CCUS stakeholders in Denmark and abroad, and help achieve the full overview and build the Danish CCUS roadmap.

Attending to the program, my workplace hopes to gain:
New collaborations, new ideas, and more knowledge.

Attending to the program, I personally wish to gain:
Expanded network of CCUS-professionals, interesting conversations about the future for CCUS and how we get there, new knowledge and an experience I will remember.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
my hope is that CCUS in 5-10 years will play a major role by: full-scale capture at major point sources in Denmark, followed by off-shore and on-shore storage of the captured CO2. A dream is to over-achieve the Danish climate goals with CCUS, and that it is broadly acknowledged in the public as a necessary mitigation effort.

Katrine Thomsen

Deputy Head of Department
Ministry of Climate, Energy and Utilities

My background:
MSc in public administration. Has been with the Ministry of Climate, Energy and Utilities for the past 6 years working with regulation of the utility sector, energy infrastructure and now CCS. I am the head of the Ministry's CCS office.

Department:
In charge of CCUS regulation, supporting political decisions and creating the framework for the CCUS subsidy schemes.

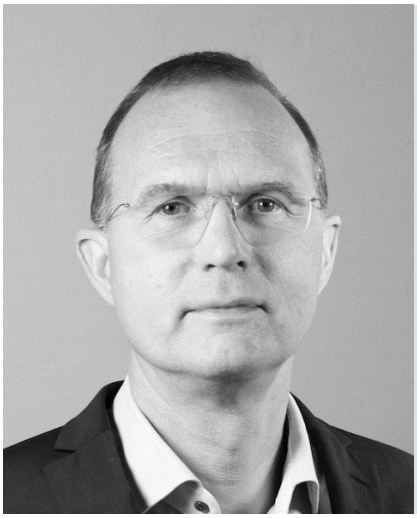
The current CCUS challenge:
Establishing the full value chain in a timely manner and creating the framework for financing CCS with and without national subsidies as well as enabling cross-border transportation of CO2 with the purpose of permanent storage.

This is what I especially contribute with:
Ensuring the right regulatory framework is in place both on a national and international level.

Attending to the program, my workplace hopes to gain:
A better understanding of how other countries overcame the regulatory barriers, established the right framework, ensured a timely value chain, etc.

Attending to the program, I personally wish to gain:
Besides the above, an understanding of how the value chain works in practice, and what it physically looks like.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by: Enabling full value chains for CCS in Denmark and cross-boarder to ensure that CCS can contribute to Denmark's and EU's climate targets.



Ken Wesnæs

CEO

CarbonCuts A/S

My background:
Chemical engineer with 30+ years experience in project development primarily in the oil and gas sector

My company:
CarbonCuts' main activity is in CO2 storage development and operation

The current CCUS challenge:
The main challenge to progress and speed is commercial. The CCUS business model is challenged by the requirement of high CAPEX and OPEX investments combined with significant uncertainty on the value of the service.

This is what I especially contribute with:
Project development and subsurface expertise.

Attending to the program, my workplace hopes to gain:
Technical and economical insight to the entire CCS value chain. Meeting people with practical experience.

Attending to the program, I personally wish to gain:
Meeting people and industry in the field of CCUS.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
my hope is that CCUS in 5-10 years will play a major role by: The overarching goal is to see a reduction in the risk and global warming.

Lukas Tanzer

Investment Manager – Cleantech

Danish Ministry of Foreign Affairs,
Invest in Denmark, Silicon Valley

My background:
Academic background in electrical and industrial engineering. Professional experience in business development, project management in the climate tech industry.

My company /department is:
Invest in Denmark, Cleantech

The current CCUS challenge:

This is what I especially contribute with:
Enhancing the Danish industry ecosystem by attracting innovative North American CCUS companies to expand their business or research operations to Denmark.

Attending to the program, my workplace hopes to gain:
Meet with key stakeholders of the Canadian and Danish CCUS ecosystem. In addition, I am very much looking forward to a lot of insightful conversations and follow-ups with other attending participants.

Attending to the program, I personally wish to gain:
Educating myself on the latest developments in the carbon removal and utilization sector.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
Finding economically viable ways to remove the excess carbon from the air that we cannot prevent or was emitted in the past. Furthermore, I see great opportunities for captured carbon to be used as a feedstock for the production of carbon-neutral products such as e-fuels or polymers.

Mikkel Krogsgaard Niss

Manager
Carbon Capture Cluster Copenhagen (C4)

My background:
Mikkel Krogsgaard Niss is the manager of C4 – Carbon Capture Cluster Copenhagen. Mikkel is appointed chair of the governmental cluster for CO2 infrastructure and transport in Greater Copenhagen Region.

During the last 15 years, Mikkel have worked with environmental and climate issues in highly political settings within City of Copenhagen and the Danish government. Mikkel holds a master degree in environmental planning from Roskilde University

My company:
Carbon Capture Cluster Copenhagen (C4) is a cluster cooperation with nine members from the energy sector in Copenhagen. C4 represents 2 biomass-combined heat and power plants, 3 waste-to-energy plants, a wastewater treatment plant, 2 district heating distribution companies, and the commercial port of Copenhagen. The members of C4 have a shared vision to reduce CO2 emissions by up to 3 million tons annually through CO2 capture.

The current CCUS challenge:
Regulation, financing and transport of CO2

This is what I especially contribute with:
Knowledge about the CO2 value chain in Denmark, direct access to the main emitters in Copenhagen, and a good political overview of the Danish CO2-ecosystem.

Attending to the program, my workplace hopes to gain:
I would like to get inspiration for future CO_2 research challenges and understand the upscaling challenges we in Denmark are likely to face in the near future.

Attending to the program, I personally wish to gain:
The same as my workplace.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
In 5-10 years, we will start to see CCUS as a major contributor in reaching the 1,5 degree target from the Paris accord. I expect that most large emitters In Denmark will have implemented CO2 capture before 2035. CO2 storage and PtX production will be the new normal in the energy sector.

Morten Gjetting Stage

Head of INNO-CCUS & Technical Services and Support, DK

Totalenergies

My background:
PhD in physics, worked in technical and executive positions within the energy business for more than 25 years. Have worked with CCUS since 2008.

My company:
Totalenergies, a global energy company focusing on delivering clean and affordable energy to the world

The current CCUS challenge:
How do we establish the full value chain while adopting the newest and most efficient technologies.

This is what I especially contribute with:
Experience in multi-disciplinary collaboration, unlocking new technologies and I bring experience and perspective from an Energy Major.

Attending to the program, my workplace hopes to gain:
Learn more about the collaboration between governments, academia, and industry. Learn more on CCUS development and operations.

Attending to the program, I personally wish to gain:
Build a global network, potentially find collaboration partners and bring new knowledge home building success for INNO-CCUS.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
CCS will be a cornerstone in our global CO2 emission reductions, and upscaling of the utilization of CO2 has accelerated.

Morten Poulsen

Head of PtX and Pilot Projects
Evida

My background:
PhD Biology, professionally I've been working as a technology provider and advisor to the oil and gas industry for seven years before taking part in the exciting journey of Evida for approx. 1,5 years.

My company:
Evida - Business Development

The current CCUS challenge:
Developing and maturing a full value chain from carbon capture, transportation to storage, including technology development and supplier landscape.

This is what I especially contribute with:
In-depth knowledge concerning pipeline-based transportation of gases, particularly methane, but to an increasing extent also hydrogen and carbon dioxide.

Attending to the program, my workplace hopes to gain:
I hope to gain further insight into challenges and opportunities across the value chain, potential future business areas and how Evida can best support the development of this new industry.

Attending to the program, I personally wish to gain:
I wish to expand my network to other professionals with a passion for the green transition, hereunder CCUS.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
I hope that we, in few years' time, will see the first full scale CCS projects developing in Denmark, and in 10-15 years' time see Denmark as a hub for import and storage of European CO2, thus both developing a future successful industry while playing a significant role in decarbonising Europe.

Nis Bertelsen

Analyst, MSc, PhD
Danish Council on Climate Change (DCCC)

My background:
PhD in Energy Planning and Governance from Aalborg University Copenhagen, with a focus on sector integration. Have worked with developing and coordination of infrastructure as well as regulation and governance models that promotes long term solutions.
At the DCCC I track and analyze technology development, monitor the overall development of the energy sector and evaluate technology potentials across sectors.

Organisation:
Danish Council on Climate Change (DCCC)

The current CCUS challenge:
CCS is one technology among many, which holds a large potential but also some challenges.

This is what I especially contribute with:
I contribute with a broad perspective on the climate challenge and the need to decarbonize our energy system and society in general.

Attending to the program, my workplace hopes to gain:
We hope to learn more about the current status of CCUS and which challenges the technology faces. Since CCS is set to be a cornerstone in Danish climate policy, it is important for the DCCC to be able to assess risks, potentials, and development of the technology.

Attending to the program, I personally wish to gain:
In addition to learn about CCUS as a technology, I hope to expand my network with both Danish and Canadian contacts. The DCCC has a rather small secretariat and we have to follow the development of the entire energy sector. Therefore, we rely on good contact with technology specialists and regulators, who can provide inputs to our work.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
Capturing emissions in hard-to-abate sectors, thereby outlining a way to decarbonize industry, waste incineration and others.

Soeren Reinhold Poulsen

Head of CCS and Producing Assets
INEOS Energy Denmark

My background:
MSc Chemical Engineering

Company:
INEOS Energy

The current CCUS challenge:
Building a technically and commercially attractive CCS project involving using depleted oil reservoirs offshore in the North Sea and in general building a CCUS portfolio in Europe.

This is what I especially contribute with:
Early mover on what it takes to build a CO2 transport and storage project in The North Sea and in general good insight in the development of the European CCUS landscape, especially in Scandinavia and North Europe.

Attending to the program, my workplace hopes to gain:
Further experience within CCUS and specifically how Canada, as first movers within CCUS globally, has handled the challenges technically, regulatory, and commercially.

Attending to the program, I personally wish to gain:
Network expansion across the Atlantic and further CCUS-related insights.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
Replacing the use of fossils fuels, see a measurable effect of the climate net zero goals, and create a new SDG business area, attracting generations to come.

Thomas Helmer Pedersen

Research group Leader, Associate Professor
AAU Energy, Aalborg University

My background:
Trained process engineer with a PhD in experimental hydrothermal liquefaction. I have a solid theoretical and practical background in production of renewable liquid fuels. Currently, I am research group leader of approximately 20 researchers, including an analytical lab, an experimental lab with several unique experimental setups, and a pilot HTL unit. Within carbon capture I have researched in BECCS technologies, point source carbon capture, and direct air capture, mainly for utilization applications.

University:
Aalborg University contributes to the knowledge building of the global society as well as the development of prosperity, welfare and culture of Danish society. This is accomplished through research, research-based education, public sector services and knowledge collaboration. Aalborg University educates students for the future and activities are based on a dynamic and transformative collaboration with the surrounding community.

The current CCUS challenge:
Develop the next generation capture technology which integrates well with the CO2 emitting process, the utilization process, and the existing energy system. This, in order to move away from the “capture-transport-use” paradigm that does not benefit from obvious integration potentials.

This is what I especially contribute with:
Broad technical knowledge within the entire carbon capture and utilization value chain, covering process and chemical engineering fundamentals, practical knowledge and experience, economic and life cycle considerations.

Attending to the program, my workplace hopes to gain:
AAU hopes to expand the professional network and to team up with new collaboration partners, which can bring about new significant scientific results. Furthermore, AAU hopes to expose the unique research carried out.

Attending to the program, I personally wish to gain:
I wish to gain more information about the CCUS agenda in Canada in general, and specifically know more about current research focuses.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
Carbon capture being successfully demonstrated at commercial levels across various industrial processes.

Torben Vedel Borchert

Scientific Director
Novo Nordisk Foundation

My background:
I have an educational background in chemical engineering and I have worked predominantly with leading new product discovery/development of biosolutions at industrial biotechnology companies like Novozymes, Novo Nordisk, and Dupont. The last two years I have been working on the sustainability mission of the Danish Novo Nordisk Foundation: The Novo Nordisk Foundation is committed to improving people's health and the sustainability of society and the planet.

Company:
Biotech section of the Novo Nordisk Foundation

The current CCUS challenge:
With the current and rapid escalation of global warming, we must identify many parallel solutions with large potential for GHG reductions through implementation within the next decade. Many technical solutions are available but few of these show sufficient potential for scaling to Mton impact within affordable costs. This picture must change.

This is what I especially contribute with:
A sound interest in impactful climate change mitigation solutions and influence on funding for research programs related to this. The Novo Nordisk Foundation funds predominantly science related grants amounting annually to 1,3 billion US$, i.e., it is one of the most influential foundations operating in the sustainability space.

Attending to the program, my workplace hopes to gain:
inspiration to how a philanthropic foundation optimally helps society to accelerate the green transition towards carbon neutrality.

Attending to the program, I personally wish to gain:
I hope to identify opportunities where gaps in understanding can be addressed by scientific research to contribute to Mtons savings of CO2 equivalents of Green House Gas emissions globally.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
a significant step towards a circular Carbon economy.

Ulla Röttger

Non-Executive Director
LondonEnergy Ltd

My background:
Ulla Röttger has 35 years of experience in top management and leadership at board level for companies within energy production and distribution, waste management, climate and environment, and sustainability. She has had several positions at public bodies, boards and committees. She was responsible for establishing Copenhill at USD 600 million, an innovative, iconic and world-famous building in Copenhagen - not only as the world's most energy- and environmentally efficient waste-to-energy plant, but also a ski-slope, a hiking trail, a climbing wall and a café on the top. She is also chair of the Danish Academy of Technical Sciences' (ATV) theme group Technology for Sustainability.

My company / university / department is:
London Energy LtD: Waste management in London on behalf of 7 boroughs and North London Waste Authority.

The current CCUS challenge:
London Energy wants to capture the carbon from our new waste to energy plant. The plant will incinerate 700,000 tons of waste each year. The plant will be in commercial operation from 2026.
What investment is needed and what will the operating cost be? Can we prepare for the installation of CC while constructing the plant? What technology is best? What is important to investigate before making a decision? Impact on the environment?

This is what I especially contribute with:
My knowledge and experience from construction and operation of power stations. Work experience as a CEO with politicians and the decision process in parliament and municipal councils. Many years of cooperation with civil servants and government officials. My experience from the Danish Academy of Technical Sciences (ATV) theme group Technology for Sustainability.

Attending to the program, my workplace hopes to gain:
Knowledge about technology and the challenges. Insight in the business case. Knowledge about storage and utilisation and how it will affect the capture process. Knowledge of the experiences other companies have about this technology.

Attending to the program, I personally wish to gain:
Answers to the questions mentioned above. Learn a lot about technology CCUS. Getting contacts in the sector. And having a good time and a lot of exciting discussions with the other participants.

Dreaming about a future: my hope is that CCUS in 5-10 years will play a major role by:
I consider CCUS as a must, if we want to avoid (or repair on) the impact of our activity on the climate. We should not incinerate but instead recycle waste, but it is not possible. I believe there will always be waste for incineration, also when we have obtained a high degree of recycling (paper can only be recycled 6 times, plastic only a few times etc.).

ATV – the Danish Academy of Technical Sciences is Denmark's leading network for high profiled technology leaders and decision makers.

ATV combines the prestige of being a national academy with the ambition of making Denmark one of the five leading Science and Engineering regions in the world. Hence, ATV is an independent think tank that utilizes the combined knowledge of our more than 800 fellows and partner members – for the benefit of future generations.

Half of the members work in private businesses; the other half are employed at universities and other knowledge institutions. ATV provides the meeting place for all. More information about the members: https://atv.dk/partnere-medlemmer

As a member-driven think tank, with fellows and technology leaders in universities, industry and the public sector, ATV is uniquely positioned to qualify, disseminate, and implement our conclusions and recommendations.

ATV was founded in 1937. Then and now, our reliability is based on our independence and the strong professional competences of our fellows and partner members.

ATV works on a non-profit basis, is a private organization, and does not receive any direct public funding. Our fellows and partner members work pro bono for ATV, supported by our secretariat of 18 employees.

ATV is a member of CAETS – International Council of Academies of Engineering and Technological Sciences.

More information:
atv.dk

CLEAN

CLEAN mediates and runs projects and partnerships between public actors, knowledge institutions and private cleantech companies. It creates innovative solutions to challenges that concern us all. The companies and their bottom line are the mainstay and innovative promise to our surroundings. They are motivated not only by thoughts of what can pay off at some point, but what can pay off now.

Photo: CLEAN

CLEAN is a world-leading cleantech cluster based in Denmark with an international focus. Our mission is to accelerate the green and sustainable transition while realizing growth for the Danish cleantech sector. CLEAN is a Gold Award Cluster Management Excellence and the national Danish triple-helix cleantech cluster with 280+ members across 5 offices in the five regions of Denmark. CLEAN works to strengthen the productivity and competitiveness of Danish environmental technology companies, especially by strengthening growth, employment, and internationalization in Danish SMEs - through collaboration on research-based and business-driven innovation and transfer of knowledge between companies, knowledge institutions, public entities and other actors with relevant business and technology expertise.

CLEAN has strong national activities focused on driving intersectoral collaboration between SMEs, academia, municipalities, and large enterprises to develop and implement novel green solutions and services within society. The specific activities are within business matchmaking, public procurement, facilitation of co-creation workshops, hosting of international conferences, provision of cascade funding for specific circularity and sustainable related activities of companies and much more.

CLEAN has a strong international presence and drives numerous EU and international projects. By hosting the Secretariat for the International Cleantech Network (ICN), CLEAN has a direct line to 20 other international cleantech clusters around the world with reach to 16,000 SMEs in 5 continents. CLEAN has been working closely with the C40 cities network to deliver innovation in cities around the world where innovative solutions can be co-created to solve city challenges, including waste management projects in Rio de Janeiro and São Paulo.

More information:
cleancluster.dk

The Study Tour program was developed in close and fruitful collaboration with the Canadian Trade Commissioner Service and Green Hub Denmark

Green Hub Denmark

Part of the program in Edmonton, Thursday and Friday, was prepared in close collaboration with Green Hub Denmark who has a delegation from the project CO2VISION, which focuses on turning the North Denmark Region into a national and international CCUS hub.
There were good opportunities for networking between the two delegations during these days.

For more information, please contact:

Thilde Møller Larsen
Project Manager - Energy, Internationalisation & Sustainable Behaviour

tml@aalborg.dk

The Canadian Trade Commissioner Service

Richard Higginson and team has been involved in planning the entire program and will be partly participating in the delegations during the week.

For more information, please contact:

Richard Higginson
Trade Commissioner- Global Affairs Canada

Richard.Higginson2@international.gc.ca

ATV – THE DANISH ACADEMY OF TECHNICAL SCIENCES – IS AN INDEPENDENT, MEMBER-DRIVEN THINK THANK

We are working to make Denmark one of the five leading science and engineering regions in the world –to benefit the future generations

Our members contribute to the implementation of recommendations from projects.

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