Volume 90
Number 62
March 2022

SOCIETY OF PETROLEUM ENGINEERS

# SPE NEWS

COPENHAGEN SECTION

# FROM THE SECTION CHAIRPERSON

## Dear SPE Copenhagen Members,

After a start to the year impacted by new restrictions, we are glad to be back. Indeed, December 2021 to January 2022 was a challenging period with the latest COVID wave having a huge impact on our events schedule. Three events were either cancelled or postponed but I am glad that the SPE CPH board has been agile and adaptive to the situation. Danish society opened again in February and we now have a full program of events scheduled for the rest of the 2021/22 season.

On 20th of January, the SPE CPH board met to plot a future for our section. Some of the action points from the meeting include:

1. Conduct most of our upcoming events as physical face-to-face meetings
2. More interaction with sister sections within Europe especially for virtual events
3. Development of a second member questionnaire
4. Utilize and consult our members more - we are over reliant on the Board members to work hard for the section
5. Explore the possibility of involving other sections in newsletter content

### Activities

Virtual Officers Meeting Europe
We participated in the Europe section officers regional meeting on the 9th of February. The main agenda had to do with the proposed merger between SPE and AAPG, which we now know has been terminated. The new Geothermal Technical Section was introduced, and Hans Horikx and I took the opportunity to interact with other section officers and share ideas.

### Rig Visit for Student Chapter

In furtherance of our commitment to the SPE Copenhagen Student Chapter, on 21st February we arranged a visit to the Maersk Resolve jackup rig currently at the quayside at Esbjerg. 19 students accompanied by the Section Chairman were taken on a tour of the rig and its various systems and sections. Our gratitude goes out to Maersk Drilling and to Allan Ramsing, the rig manager, Arlo the OIM and the rest of the crew of the Maersk Resolve. For photographs of the visit and feedback from the excited students, a dedicated article can be found in this newsletter.

### Student Sponsorship

A student has been selected for the opportunity to physically attend the SPE Norway Subsurface Conference next month after submitting a motivational letter. The board will sponsor transportation, accommodation and feeding costs. Congratulations to Natalia Pereyra. ⏩

## Virtual Event

On the 24th of February, the first event of the year took place. It was organized as a virtual event hosted by the DHRTC.

There were 3 topics of discussion:

1. Unlocking the potential for $CO_2$ storage in existing oil and gas fields in the Danish North Sea.
2. Project Bifrost: an innovative $CO_2$ storage project
3. Chalk for $CO_2$ storage

We had a record attendance of 152 participants at the event with a significant number of participants from outside the Copenhagen section. This is a very good development and we are encouraged.

## New Board Member

I am pleased to welcome back Jose Antonio Acero to the SPE Copenhagen Board. He is a familiar face. Jose was previously a board member but left Denmark 2 years ago to work in Spain. He has now returned to Denmark recently to work for WellPerform. His energy will be a great addition to this Board.

## SPE Copenhagen Student Chapter Board

I am pleased to announce that our student chapter has new board members with the following officers elected:

- Jakub Drochomirecki, Vice president
- Saud shaheen, Treasurer
- Vasileois Tsiftsis

With Isaac Applequist Løge at the helm as Student Chapter President, I look at this board and can only be confident about the future. I wish them a rewarding tenure and the skill to help the chapter grow from strength to strength.

## Membership Renewal

We look forward to you continuing your SPE membership. There is no doubt that in the last year, we have all faced many new challenges but through it all, we have continued to inspire and support each other. We as a board will continuously work towards bringing greater value to your membership.

To renew your membership, visit SPE.org or click on the link: http://go.spe.org/sectionrenew

On a final note, I would like to thank members for their continued engagement and participation in activities of the section.

## Yours Sincerely,

Adebowale Solarin

*SPE Copenhagen Section Chairman 2021/22*

Please remember to pay your SPE dues. If you are in work transit, please check the link https://www.spe.org/en/members/transition/

Please follow us on LinkedIn to be up to date on SPE Cph events and other great stories:

**https://www.linkedin.com/company/spe-copenhagen-section**

Graphic design & production: nectarcph.dk

SPE
COPENHAGEN SECTION

# THE BOARD

## 2021-2022 SEASON

**SECTION CHAIRMAN**
**Adebowale Solarin, Maersk Drilling**
Lyngby Hovedgade 85, 2800 Kgs Lyngby
Tel.: +45 6336 3472
E-mail: adebowale.solarin@maerskdrilling.com

**PROGRAM CHAIRMAN**
**Jaime Casasus-Bribian, Maersk Drilling**
Lyngby Hovedgade 85, 2800 Kgs Lyngby
Tel: +45 2999 9654
E-mail: jaime.casasus@maerskdrilling.com

**SECRETARY**
**Hans Horikx, DTU – Centre for Oil and Gas**
Elektrovej Building 375, 2800 Kgs. Lyngby
Tel: +45 6114 1852 · E-mail: horikx@dtu.dk

**MEMBERSHIP CHAIRMAN**
**Jonathan Hastings, TotalEnergies**
Amerika Plads 29, 2100 Copenhagen Ø
Tel.: + 45 5164 0531
E-mail: jonathan.hastings@totalenergies.com

**TREASURER**
**Mette Juncker Brædstrup, Schlumberger**
Dampfærgevej 27-29 3rd floor, 2100 Copenhagen Ø
Tel.: +45 6035 0711 · E-mail: mhansen4@slb.com

**PROGRAM CHAIRMAN 2**
**Mette Lind Fürstnow, Welltec**
Gydevang 25, 3450 Allerød
Tel.: +45 6114 1849 · E-mail: mfurstnow@welltec.com

**MEMBERSHIP CHAIRMAN 2:**
**Peter Tybjerg, CALSEP A/S**
Tel.: +45 4597 0817 · E-mail: pt@calsep.com

**DIGITAL WEB MASTER**
**Solvejg Kolbye Jensen, Ørsted**
Nesa Alle 1, 2800 Gentofte
Tel.: +45 9955 4722 - E-mail: solje@orsted.com

**Pernille Silberg, AFRY**
Lyskær 3EF, DK-2730 Herlev
Mobile: +45 2342 8637 · Office: +45 4343 1400
E-mail: pernille.silberg@afry.com

**NEWSLETTER AND SOCIAL MEDIA OFFICER**
**Nikolai Andrianov, GEUS**
Øster Voldgade 10, 1350 Copenhagen K
Tel.: +45 9133 3488 · E-mail: nia@geus.dk

**SPE YOUNG PROFESSIONALS REP**
**Darya Shingaiter, Schlumberger**
Dampfærgevej 27-29, 3rd floor, 2100 Copenhagen Ø
Tel.: +45 6035 0141· E-mail: dshingaiter@slb.com

**STUDENT LIASON OFFICER**
**Jedrzej Bryla, Maersk Decom**
Lyngby Hovedgade 85, 2800 Kgs Lyngby
Tel: +45 2023 5614 · E-mail: jedrzej.bryla@maerskdecom.com

**SPE STUDENT REP**
**Isaac Appelquist Løge, DTU**
Chemical Engineering
Søltofts Plads, 2800 Kgs. Lyngby
Tel.: +45 5313 1399 · E-mail: isacl@kt.dtu.dk

**FACULTY ADVISOR**
**Alexander Shapiro, DTU CERE**
Department of Chemical and Biochemical Engineering
DTU b. 229 Søltofts plads, 2800 Kgs. Lyngby
Tel.: +45 4525 2881 · E-mail: ash@kt.dtu.dk

**OUTREACH CHAIRMAN**
**Jose Antonio Acero, WellPerform**
Tel: +45 4422 8180
E-mail: jap@wellperform.com

# IMPURE VS. PURE $CO_2$

## Abstract

**Peter J. Herslund**
**Senior Consultant**
**Calsep**

This presentation will give an overview of the many fascinating aspects of $CO_2$ and place them in the context $CO_2$ transport and carbon capture and storage (CCS). What makes $CO_2$ special, and what are the requirements to software tools for simulating the phase behavior and bulk phase properties of $CO_2$ in relation to CCS?

$CO_2$ is one of the most studied components from an experimental point of view. Yet, it still causes headaches for engineers around the world. In a CCS context, this is often because the $CO_2$ streams to be dealt with are not pure. Identification and proper handling of impurities, including water, is the key to success, when it comes to obtaining accurate predictions of phase behavior and bulk phase properties of impure $CO_2$.

The qualitative and quantitative influence of a selected number of impurities will be illustrated. The presentation discusses how this translates into practical challenges in real applications, and it will be discussed whether existing thermodynamic models are sufficient to handle the challenges facing the industry in relation to transport and storage of impure $CO_2$.

## Biography

Peter J. Herslund is a Senior Consultant at Calsep. He joined Calsep in 2013 and has since then worked mainly with thermodynamic modeling of reservoir fluids and calculation of fluid properties. Peter holds a Ph.D. degree in Chemical Engineering from the Technical University of Denmark and a Graduate Diploma in Business Administration from Copenhagen Business School.

SPE International

calsep

# Meeting Thursday
# MARCH 31

**PROGRAMME**
**17:00 – 17:30**
Networking with drinks and snacks in the Café

**17:30 – 18:15**
Presentation in the Event Space

**18:15**
More networking and goodbye

**LOCATION**
REBEL WORK SPACE,
DAMPFÆRGEVEJ 27-29,
2100 COPENHAGEN Ø.

**TOPIC**
"Impure vs. Pure $CO_2$"

**SPEAKER**
Peter J. Herslund, Ph.D., Calsep A/S

**ENTRANCE FEE**
None

**REGISTRATION**
Please indicate your attendance by Friday March 25 by signing up on the internet www.spe-cph.dk.

Register HERE

# GEOTHERMAL ENERGY CAN BECOME FOR HEATING WHAT WIND AND SOLAR IS FOR POWER

This is the mantra that has kept the Innargi team going for the past 4 years. And now we have achieved a breakthrough with our first heat delivery contract for district heating in Aarhus.

There are three main reasons why the breakthrough for geothermal as an energy source for district heating is now:

1. In the future, power will be produced by wind and solar which does not generate waste heat to heat our houses. This opens a demand for new heat production technologies.

2. Historically many projects have failed due to either poor planning and executing in the exploration phase or poor production management in the operating phase. With experience and competencies from the oil and gas industry and taking full project responsibility from 'cradle to grave', Innargi removes the risk from the district heating company and consumers, making geothermal energy an attractive product.

3. The price has reduced when talking large scale geothermal heat production because the process can be industrialized.

As you know, Geothermal energy is about utilizing the energy that radiates from the core of the earth. And using geothermal energy is not a new thing. In Iceland the district heating system based on geothermal energy was established almost 100 years ago and long before that the Romans had thermal baths. So geothermal projects can take many shapes and forms. Targeting everything from hard dry rock to sedimentary reservoirs as the resource for energy use in thermal baths, power generation, district heating, green houses and more.

Our focus is using geothermal energy from brine in sedimentary reservoir for district heating. And doing it in large scale – that means a focus on the large cities which presents an additional challenge to normal oil and gas projects – drilling wells and building facilities in an urban environment.

We have developed and patented a modularized surface facility solution that has a very small physical footprint. The small footprint makes it easier to integrate in an urban environment. The modularization and standardization help us drive down costs and reduces the time on-site in the construction phase. It also reduces downtime if a major repair is to be made - then the module can be lifted out through the roof of the building and repaired off site.

The geothermal brine is produced and injected via a standard pair of wells and what is going on in the reservoir is basically a large waterflood - there is just no oil involved. That is why using experience and competencies from the oil and gas industry is an essential part of unlocking geothermal as a renewable energy source for district heating.

With the current events in Ukraine the need to replace coal and gas in Europe has become even more acute. District heating is one of the cheapest ways of achieving the transition to green energy in large cities. But district heating is only green when the energy sources are green and only reliable when the energy sources are available as baseload 24/7 – 365. Geothermal energy can fulfil both criteria. So why wait. Geothermal energy is a large renewable energy source waiting to be tapped.

INNARGI

## Biographies

**Martin Kaster,**
**Head of Facilities and operations**

Engineer with 22 year of experience in well servicing, completions, intervention technology and concept development. Martin has for the past 5 years been part of the Innargi team that has matured a large-scale geothermal heating project in Aarhus as the lead facilities engineer. In connection with this work, Martin has developed the modularized facility concept for the geothermal facilities planned to be implemented in Aarhus.

**Lars Petersen,**
**Head of Subsurface**

Reservoir engineer with more than 20 years experience in corporate exploration and field development functions within the energy industry.

Lars joined the Innargi team in 2019 and is driving the screening of geothermal opportunities with a focus on integrating the subsurface and commercial aspects.

SPE International

# Meeting Thursday
# APRIL 21

**PROGRAMME**

**17:00 – 18:00**
DRINKS

**18:00 – 19:00**
PRESENTATION

**19:00 – 21:00**
DINNER

**LOCATION**
INNARGI A/S
LYNGBY HOVEDGADE 85
2800 KGS. LYNGBY

**TOPIC**
“Industrialising geothermal for urban heating”

**SPEAKERS**
Martin Kaster,
Head of Facilities
and operations

Lars Petersen,
Head of Subsurface

**ENTRANCE FEE**
None

**REGISTRATION**
Please indicate your attendance by Friday April 8 by signing up on the internet www.spe-cph.dk.

INNARGI

Register HERE

## SPE Meeting schedule

# 2021-2022

| February 24 | MAIN SPEAKER |
|---|---|
| TOPIC | **Carbon Storage in Danish Chalk formation** |
| SPEAKER | Charlotte N. Larsen, Programme manager $CO_2$-storage Research Programme at DTU Offshore / Malene Hein, Project manager, DTU Offshore, Project Bifrost / Hamid Nick, Senior researcher and research team lead at DTU Offshore |
| LOCATION | VIRTUAL MEETING |
| SPONSOR | DTU Offshore |
| **March 31** | **MAIN SPEAKER** |
| TOPIC | **Impure vs. Pure $CO_2$** |
| SPEAKER | Peter J. Herslund, Ph.D., Calsep A/S |
| LOCATION | Rebel Work Space, Dampfærgevej 27-29, 2100 Copenhagen Ø |
| SPONSOR | Calsep |
| **April 21** | **MAIN SPEAKER** |
| TOPIC | **Industrialising geothermal for urban heating** |
| SPEAKER | Martin Kaster, Head of Facilities and operations, Innargi / Lars Petersen, Head of Subsurface, Innargi |
| LOCATION | Innargi A/S, Lyngby Hovedgade 85, 2800 Kgs. Lyngby |
| SPONSOR | Innargi A/S |
| **May TBD** | **MAIN SPEAKER** |
| TOPIC | |
| SPEAKER | |
| LOCATION | |
| SPONSOR | |
| **June TBD** | **MAIN SPEAKER** |
| TOPIC | |
| SPEAKER | |
| LOCATION | |
| SPONSOR | |

# SPE online Meeting 24 February - Recap

***Hans Horikx***
***DTU - Centre for Oil and Gas***

A well received online presentation was made by DHRTC/DTU Offshore Feb 24th on the topic of Carbon Storage in Danish Chalk formation. Some 165 people attended the online meeting, with participants from Denmark, the Netherlands, the UK, Norway, France, Germany and Italy. Three presenters enlightened the visitors on research being carried out at the Technical University of Denmark and associated institutes on behalf of DUC, the Danish Underground Consortium led by TotalEnergies that operates over 90% of oil and gas activities in the Danish sector of the North Sea.

Charlotte Larsen kicked off the presentations by mentioning that DHRTC, the Danish Hydrocarbon Research and Technology Centre, changed its name that very day to the Danish Offshore Technology Centre, or DTU Offshore in short, to reflect the fact that the research portfolio now includes broader offshore activities than just oil and gas. The topic of the SPE presentation is an example of that.

In her presentation 'Unlocking potential for $CO_2$ storage in existing oil and gas fields in the Danish North Sea' Charlotte talked about the reasons why depleted oil and gas reservoirs are good candidates for $CO_2$ storage, mainly that existing fields represent a significant and well described reservoir storage capacity with decades of accumulated knowledge of subsurface behaviour, a proven reservoir seal, and existing infrastructures that can be re-utilized. Then she explained what knowledge and technology gaps need to be closed before $CO_2$ storage can be feasible and cost effective. This is a critical issue in Denmark as most oil and gas fields are comprised of chalk formations, and much less is known about the suitability of chalk reservoirs for $CO_2$ storage than sandstone reservoirs. Research at DTU Offshore will help provide answers on the main perceived challenges.

Malene Hein introduced the audience to the recently started Bifrost project, which is financed by EUDP and led by DUC, Ørsted and DTU. The scope of this project includes the development and selection of a $CO_2$ transport and storage concept at the DUC Harald field in the Danish North Sea. The vision is to unlock the full potential for transport and storage of $CO_2$ in depleted offshore oil and gas fields in Denmark. Initially, the project focuses on depleted sandstone and chalk reservoirs of the Harald field together with re-use of the associated infrastructure. If successful the project can then be scaled up to include Ørsted pipelines and injection into other depleted oil and gas fields. The Bifrost name was chosen as it symbolises the concept of connecting the old and new energy worlds during the energy transition. In Norse mythology Bifrost is the rainbow bridge that connects the material world with Asgard, the 'home of the gods'.

DTU Offshore leads two work packages within Project Bifrost: The first aims to demonstrate the feasibility of $CO_2$ storage in the chalk reservoir of Harald East, with significant upscaling potential to other depleted Danish chalk fields, whilst DUC focuses on the sandstone formation of Harald West. The second work package focuses on advancing novel monitoring technologies which could reduce costs as well as play a role in public and regulatory acceptance of CCS in Denmark.

Hamid Nick described in more detail what the main challenges and enablers are for $CO_2$ storage in chalk in his presentation 'Chalk for $CO_2$ storage'. He gave an overview of existing studies on $CO_2$ injection in chalk that address the suitability of chalk formations as a long-term carbon storage solution, and what the critical parameters are. He explained that the thermo-hydro-mechanical-chemical behaviour of chalk in the presence of $CO_2$ and formation fluids still requires further attention in order to de-risk $CO_2$ storage. He discussed the processes that impact containment, injectivity and storage capacity, and answered many questions by the audience on related topics, such as induced seismicity, repressurisation challenges, caprock effectiveness, possible chemical reactions of $CO_2$ with hydrocarbons and water, and the impact of fractures.

For those who have missed the presentation, or would simply like to see it once again, a recording of the online meeting is available on the new DTU-Offshore youtube channel via this link: **https://youtu.be/kO_bzdNfkYE.**

## Short Bio of presenters:

Charlotte N. Larsen is working as Programme Manager for the $CO_2$-Storage Research Programme at DTU Offshore. Before joining DTU Charlotte worked 20 years with Maersk Oil and Gas as Lead Drilling Engineer and Well Project Manager amongst other roles. Through her career Charlotte has worked in Denmark, Qatar and Turkmenistan and has a Master degree in Civil Engineering from DTU.

Malene Hein is Project Manager at DTU Offshore for Project Bifrost. Before joining DHRTC, Malene worked 18 years with Maersk Oil and Total Energies as a geoscientist and technical project manager in Denmark, Qatar, Turkmenistan and Kazakhstan. Malene has a Masters degree in Geology from Copenhagen University.

Hamid Nick is a senior researcher and research team lead at DTU Offshore, managing various projects on applied research solutions mainly for Danish North Sea hydrocarbon reservoirs. He has a PhD degree from Earth Science & Engineering of Imperial College London, UK.

# Students visit to Maersk Resolve jack-up rig

Students from Petroleum Engineering (DTU – Chemical Engineering) visited the Maersk Resolve jack-up rig at Esbjerg Port in Denmark. The Maersk Resolve is an impressive piece of engineering, capable of drilling in water depths of 106 m and drilling wells up to 10.668 m.

The tour was hosted by the SPE Copenhagen's student chapter and funded by the Department of Chemical Engineering at DTU.

The petroleum engineering students travelled from DTU early in the morning with anticipation to experience what was behind their theoretical background. Upon arrival, all were amazed by the sheer size of the jack-up rig. 150 m tall machinery capable of hosting a crew of 130 personnel, with a galley (kitchen), gym, cinema, a helicopter landing pad. The rig must be self-sustainable during operation, so it has four 2.4 GW generator that delivers electricity for heating, drilling, ventilation, and desalination of 120 ton of water. And that is on a daily basis!

To say the least, it was a great experience!

### Quotes from some of the students:

"I'd like to thank the Maersk's Resolve crew who showed us around the rig and shared their passion for the industry with us. It is quite stunning the level of automation achieved in Maersk's Resolve High-Efficiency Jack Up, its XY cantilever is definitely one of its main features, with a drilling envelope of 21.3 m x 14 m." Natalia Sol.

"I was able to ground my knowledge, this time with a jack-up type rig." Patryk Bijak

"Wow! The food here is great!" - Yao Xu, Bartosz Bula, Michał Stępień, Robin Shibu, Kuba Drochomirecki and many more students.

A big "thank you" goes out to #Maerskdrilling, the Rig Manager, Allan Ramsing, Arlo and Ivo, Brian the TSL, Scottie the Driller and other crew members for making it a memorable experience.
As students, we enjoy trips like this that provide insight into the workings of our industry and we would like to urge companies to provide more opportunities like this!

# TOTALENERGIES SEES DENMARK AS A GOOD OPPORTUNITY FOR CCS DEVELOPMENT

***Interview with Morten Gjetting Stage, Head of CCS & Technical Services, TotalEnergies Upstream Denmark.***

**How does Project Bifrost compare to other TotalEnergies CCS projects worldwide? What are the main challenges and enablers?**

TotalEnergies is building upon the last 20+ years of experience in CCS projects. Since 1996, we have been part of the Sleipner project in Norway, where the naturally occurring $CO_2$ is captured and stored in an aquifer. The Lacq project in Southern France was an opportunity for TotalEnergies to test a complete CO2 capture, transport and storage value chain. In the Northern Lights projects in Norway, we are learning how to build the entire CCS value chain and what the technical specifications for the $CO_2$ transport and storage should be.

When you are building $CO_2$ storage, scale is essential; the more you can store in your reservoirs, the cheaper the storage will be. Looking at some of our current CCS projects, the Northern Lights project aims to store 1.5 million tons per annum, whereas the goal in the Aramis project in the Netherlands is more ambitious with 5 million tons per annum. Likewise, in our recently announced Project Bifrost we will be starting with 3 million tons per annum.

In our EUDP supported Project Bifrost we, our DUC partners, Ørsted and DTU Offshore envision a possibility to accommodate $CO_2$ streams from different customers, which will help reduce both the vulnerability and the storage cost. $CO_2$ will be transported to the injection point in the Harald field located in the Danish North Sea 225 km offshore by ships via an FSIU (Floating Storage Injection Unit). We will also study transport by a pipeline from an onshore terminal as an alternative. The latter option of using the existing pipelines to transport the $CO_2$ is preferable because of its lower $CO_2$ footprint and potentially larger throughput.

Currently, there are numerous CCS activities in the North Sea, supported by the governments in the UK, Norway, Denmark and in the Netherlands. On the one hand, there is a political environment that promotes CCS because of high climate ambitions. For many years, the cost of the ETS (Emissions Trading System) has been so low, so it didn't have any influence on the CCS agenda. But the last couple of years, the price has been climbing steeply, and we are getting to 80 euros per ton. In addition, EU is also funding a lot of projects. On the other hand, TotalEnergies wants to play a role in reducing the $CO_2$ emissions and has a very strong foothold as a company in this region. On that note, Project Bifrost is an important cornerstone for the CCS activities here in Denmark. ⏩

There are technological challenges in the entire CCS chain. In the capture part, the key problem is energy efficiency. For the transport part, the main challenge is standardization; since EU envisions up to 300 million tons per annum of $CO_2$ stored in 2050, and the North Sea is expected to become a storage hub, it is important to agree on the design of transport vessels as soon as possible, in line with all involved countries. Finally, on the storage part, there are normal development challenges just like with an oil and gas reservoir – we need to understand the reservoir dynamics and the seal behavior in relation to the stored $CO_2$.

**What's the level of political support in Denmark for carbon storage, as compared to eliminating the use of fossil fuel altogether? How is that in comparison to other countries?**

In a wider European context, Norway was the first mover, but they did so by selecting one single CCS project and subsidizing it heavily. For example, in the Northern Lights project, 80% of costs are covered by the government, which has also reserved part of the storage capacity. Other European countries prefer to promote a CCS market by making subsidy schemes or by providing financial support. In the Netherlands, a storage site operator and the emitter can apply for the SDE++ subsidy funds to create a CCS value chain Whilst in the UK, a different type of scheme is used to promote a CCS market. In Denmark, a tender will be announced this spring for the emitters, who will then be obliged to make commercial contracts for $CO_2$ transport and storage.  Another topic that the Danish government has been working on for the last year is how the state issues licenses for $CO_2$ storage to private companies, and how the oil and gas licenses should be converted to $CO_2$ storage license.

**CCS is considered an energy transition technology, but what is your view of the endgame? How big will be the role for CCS in the long term?**

It's hard to predict, and right now, there does not seem to be any targets beyond 2050. However, the European countries will need to store 300 million tons of $CO_2$ per year in 2050 to meet the climate ambitions. Therefore, it is likely that CCS will be needed beyond that. This gives a lot of promise to people who have a background in oil and gas. If you have transferable skills, whether you are a geophysicist, geologist or a reservoir engineer, you will have an active role to play in this new technological adventure.

**What are the top aspects of CCS research that you would devote funds to?**

1. Driving down the costs of capturing the $CO_2$ is the key point for any CCS project.
2. Describing the $CO_2$ phase behavior in the pipelines, wellbores, and in the reservoir is done using various software packages which were initially designed for oil and gas. It is important to ensure that these tools give a consistent description.
3. We need to better understand how the organic matter in the caprock is behaving when exposed to $CO_2$.
4. Cheap $CO_2$ storage site monitoring is a very needed enabler in CCS projects.
5. Public acceptance is critical, and the above-mentioned research directions can help in getting it. The earlier involvement with the local communities, the better it is for a project.

**What are your views on the job security and perspectives for oil & gas professionals and the young graduates in the green transition era?**

There seems to be a general concern that if we are reducing oil and gas production, there will be pressure for the young graduates to get into the business. Clearly, CCS and renewables bring new and exciting job opportunities for the petroleum graduates in geology, well engineering, or reservoir engineering. But also, electrical and mechanical engineers could change their paths to CCS or offshore windfarms. Therefore, we can anticipate that shrinking of oil and gas projects will be compensated by expanding project in CCS, wind, and hydrogen. For example, new jobs will be created in project Bifrost.

*Project Bifrost will perform the groundwork necessary for $CO_2$ transportation and storage in the Harald field offshore Denmark.*

# Does it make sense for a Danish environmentalist to date a Petroleum Engineer?

**By: Ali Akbar Eftekhari, DTU - Centre for Oil and Gas**

This is what happened. A colleague of mine met a lady in a Danish bar. He mentioned his career: a researcher, working with scanners and imaging, funded by the oil and gas industry. The lady asked him "do you think it is ethical to work for the fossil fuel industry?"

The lady's name is Mette. She is 30-year-old and works as a science teacher. She lives with her son in a 70 $m^2$ in Helsingør. She drives to work every day; a school in Holte. She is an average consumer: not a vegetarian; eats mostly local products; travels once a year to Fuerte Ventura in the Christmas holidays. More than everything, she cares about the future of her son. She advises her students to be more sustainable and is very proud of Denmark's policy of green transition. These are her values, and she identifies herself as an environmentalist. But her boyfriend, Aidin, works in oil and gas and she does not know if she can accept his proposal to move in with her. She likes Aidin because he is a nice person; most engineers are. She has now shared her concerns with Aidin.

Let's go to an imaginary world, where scientists are not on Twitter, policies follow science, science does not seek public approval, and partners solve their relationship problems with logical discussions. In this imaginary world, everything is possible if the laws of thermodynamics are not violated. In this world, Aidin tries to address an emotional dilemma with what he knows best: physics, chemistry, and math!

This is the story of Aidin making a foundation for those arguments. It will not go into the philosophy of the "ethics of fossil-fuel research" but tries to come up with some numbers that address the real concern: "why, when, and how are we going to be independent of fossil fuels?" This eventually (and hopefully) leads to an answer to the ultimate question for Mette: "is it ethical to date a Petroleum Engineer?"

Aidin begins by looking up the word sustainability: "avoidance of the depletion of natural resources…". OK, it does not help. Depleting natural resources is Aidin's job description and for a good reason; there is a high demand for it. Oil and gas, stored energy of the sun from the age of dinosaurs, is the driver of our society. Does it help to point out that Mette is also heavily addicted to fossil fuels: car, aeroplane, clothes, food, hot showers, and almost everything else still -fully or partially- runs on fossil fuel. Aidin decides not to blame Mette. After all, if oil is a drug, Aidin is a member of the cartel. What else can be done? Aidin thinks about it logically: we can stop consuming natural resources now. How does it work? Everyone can forget about their lifestyle and never use fossil fuel again! No, it is not going to work. The worst strategy is to ask your partner to change. There is another solution. We can reduce the number of consumers! Aidin wisely decides to keep this solution to himself. There is another solution: we can replace the depleting resources. We have mimicked nature before. Oil and gas are made of atmospheric $CO_2$, oceans water, and solar energy. Do we have enough solar energy in Denmark? Thinking about his first winter in Denmark makes Aidin shiver. But solar energy comes in second and third-hand forms: winds and waves. Aidin shivers some more but takes out his calculator and begins: "First, I calculate the amount of energy Mette consumes. Then, the amount of sunshine and wind energy available in Denmark. If there are not enough renewables in Denmark to replace fossil fuels, I'm the hero of the story! If not, I'll have to find a new job."

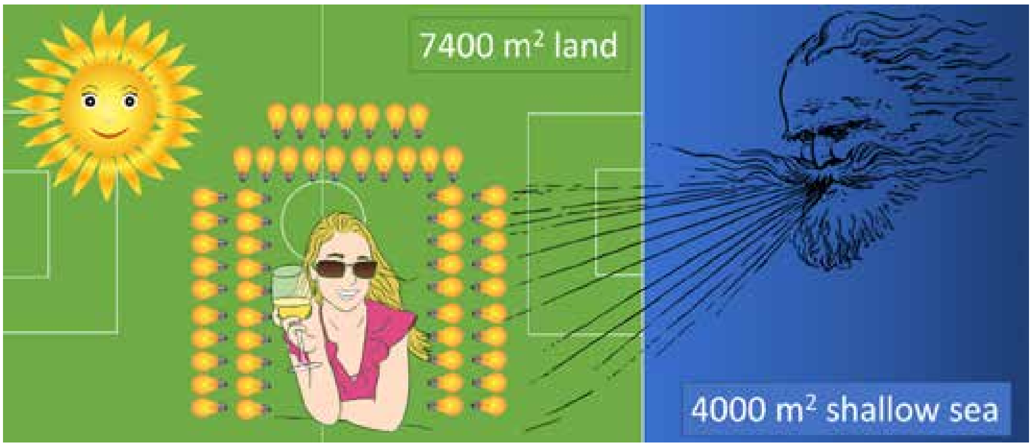



*Figure 1. Available land and shallow sea area for Mette, and her energy demand 57 old 100 W lightbulbs.*

## Energy demand in Denmark

### Heat

Aidin thinks about what he pays directly for energy. The first one is heat. Denmark is mildly cold, so it is necessary to warm the buildings in the winter. There are also hot showers, THE characteristics of modern life. He goes to the Statistics Denmark website and looks up the building regulations and the number of buildings in Denmark. With that and the temperature history of Copenhagen, he calculates the heat loss from the residential buildings and offices: 25 kWh/day per person. He double-checks his calculation from the Danish Energy Agency. He has overestimated the value, but he is lucky because it matches the total heat requirement in buildings and industries. It is roughly equal to keeping 10 old 100W lightbulbs on during the day. He imagines Mette with 10 shining lightbulbs around her head and admires his girlfriend and his imagination.

### Electricity

Aidin looks at his electricity invoice to get an estimation of electricity consumption. It has a lot of numbers on it, mostly explaining the ridiculously high tax! He visits his account with his electricity provider and finds out that he consumes 3-7 kWh/day. It underestimates the electricity demand of the Danish society which is on average between 16 to 22 kWh/day per person. Another 9 lightbulbs turn on around Mette!

### Liquid fuels

Mette and Aidin met in Fuerte Ventura island in Spain where they like to travel every year. The aeroplane consumes a lot of fuel. Aidin follows MacKay's suggestion of dividing the number by the number of days in a year, which gives a number around 30 kWh/day. Mette drives a car, in which she takes her son and a neighbour. So, her fuel demand is for 20 km/day travel by car, which is around 15 kWh/day. A total amount of 45 kWh/day for Mette: another 19 lightbulbs around her head! 45 kWh/day per person is higher than the number reported by the Danish energy agency, but that number only considers the fuel consumption within the Danish border.

### Food

Aidin knows he must be very careful with this one. The wrong word out of his mouth about how much his partner eats and there is no way to fix it! He looks up the amount of energy an adult requires to survive: 3.6 kWh/day. This is the energy that must reach the body. We are way past the food-for-survival times! Now we dine and snack and enjoy a diverse diet. To prepare all those food for a carnivore, 15 kWh/day of energy is consumed. Aidin knows that Denmark has a great dairy and meat industry. This means millions of pigs and cattle. These animals are fat, and they eat a lot. Their energy demand is around 28 kWh/day per person living in Denmark: 18 more lightbulbs in total!

## Renewable resources in Denmark

Extracting renewable energy requires accessible land for installing solar panels and windmills. The land is also required for growing food. Denmark has a population of 5,800,000 living in 42933 $km^2$ land, which gives an average area of 7402 $m^2$ of land per person that is a football pitch. The average solar energy that reaches this football pitch is around 20,000 kWh/day. Assuming an average of 4 km shallow water in the coastal regions, there is also half a football pitch of shallow water available per person. The average speed of wind in the sea is 10 m/s (the speed of a track and field athlete) and 5 m/s in the land. If it was possible to bring this wind to a full stop, one could extract 90,000 kWh/day of energy. These values are orders of magnitude more than what Mette consumes. However, the current state of technology allows Mette to extract only a fraction of this energy. Around 10% of solar energy and less than 59% (Betz efficiency) of wind kinetic energy can be converted to electricity. Only a fraction of land can be covered by these technologies, with an average power density of 3.7 and 1.3 $W/m^2$ for offshore and onshore windmills, and 11 $W/m^2$ for solar panels (in Nordic countries). The manufacturing, transport, installation, and maintenance of windmills and solar panels are entirely driven by fossil fuels. It can be between 5% to 30% of the total energies that can be delivered in their lifetime. Finally, both wind and solar energy are intermittent and can only be considered a reliable steady source of energy if combined with large scale energy storage plans. Biofuels are another source of energy, but it requires arable land that is currently exploited for food unless a simpler diet becomes widespread. Let's assume that we will have enough of it.

The liquid fuel must be synthesized from the atmospheric carbon dioxide and nitrogen and seawater in electricity-driven processes. Mette is a science teacher and knows chemistry. She knows that we can find a lot of carbon dioxide, water, and nitrogen in nature because all of them are stable chemicals. A lot of electrical energy is needed to break these chemicals apart and combine them into new fuels. She knows that old moustached scientists, Sabatier and Haber, have already invented processes for synthesizing methane and ammonia. But is it possible to replace all the fossil fuel demand with these chemicals?

Aidin optimistically estimates the efficiency of 36%, 45%, and 40% for the methane, ammonia, and methanol production from the seawater and air. All these processes require more than electricity: rare and expensive earth metals to catalyze the reactions, and raw material for the equipment. ⏩

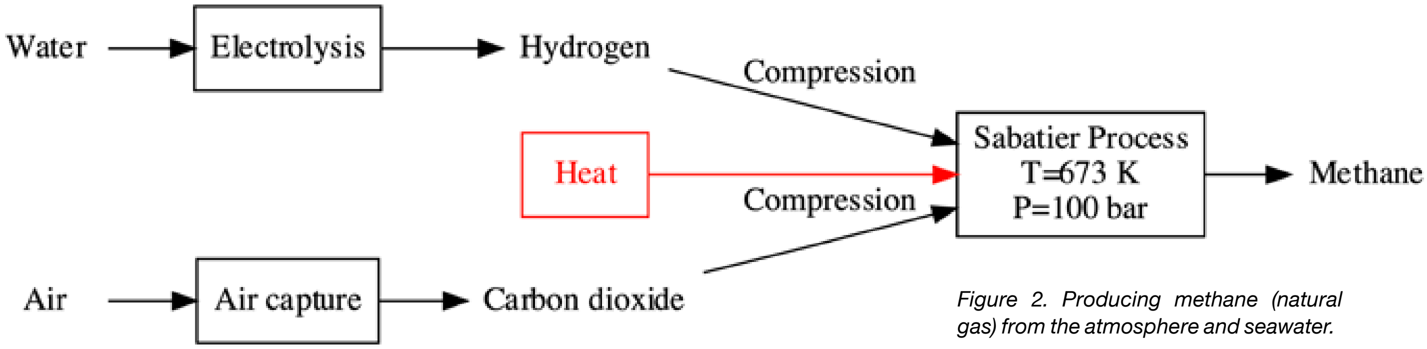



*Figure 2. Producing methane (natural gas) from the atmosphere and seawater.*

## The future

Aidin knows that Mette's concern with sustainability is stemmed from her love and care for her son. He feels a bit jealous at first. Then, when he is over it, he tries to imagine the future for his -hopefully- stepson. He assumes that all the warming systems are converted to electricity-driven heat pumps that consume one unit of electricity and deliver two units of heat. There is no oil and gas extraction because of the synthesized fuels. All food and chemicals are also made of these synthesized fuels in electricity-driven processes. All short distance travel is done in electric cars and public transport is electrified. With these fantasies, he updates the energy demand of Mette in the future. Then he uses the energy density of the renewables and tries to fit enough windmills and solar panels in Mette's one and a half football pith of land and shallow offshore.

| Energy type | Demand, kWh/(day.p) | Updated demand | Renewable resource | Energy density, W/m$^2$ |
|---|---|---|---|---|
| Heat | 25.2 | | Onshore wind | 1.3 |
| Liquid fuel | 15 (cars) | | Offshore wind | 3.7 |
| | 30 (air travel) | 30 | | |
| Electricity | 22 | 22+15+25.2/2 | Solar panel | 10 |
| Food | 15 (human) | | Food | 0.35 (human) |
| | 28 (animal) | | | 0.79-1.63 (animal) |
| | | | Biomass | 0.13 |

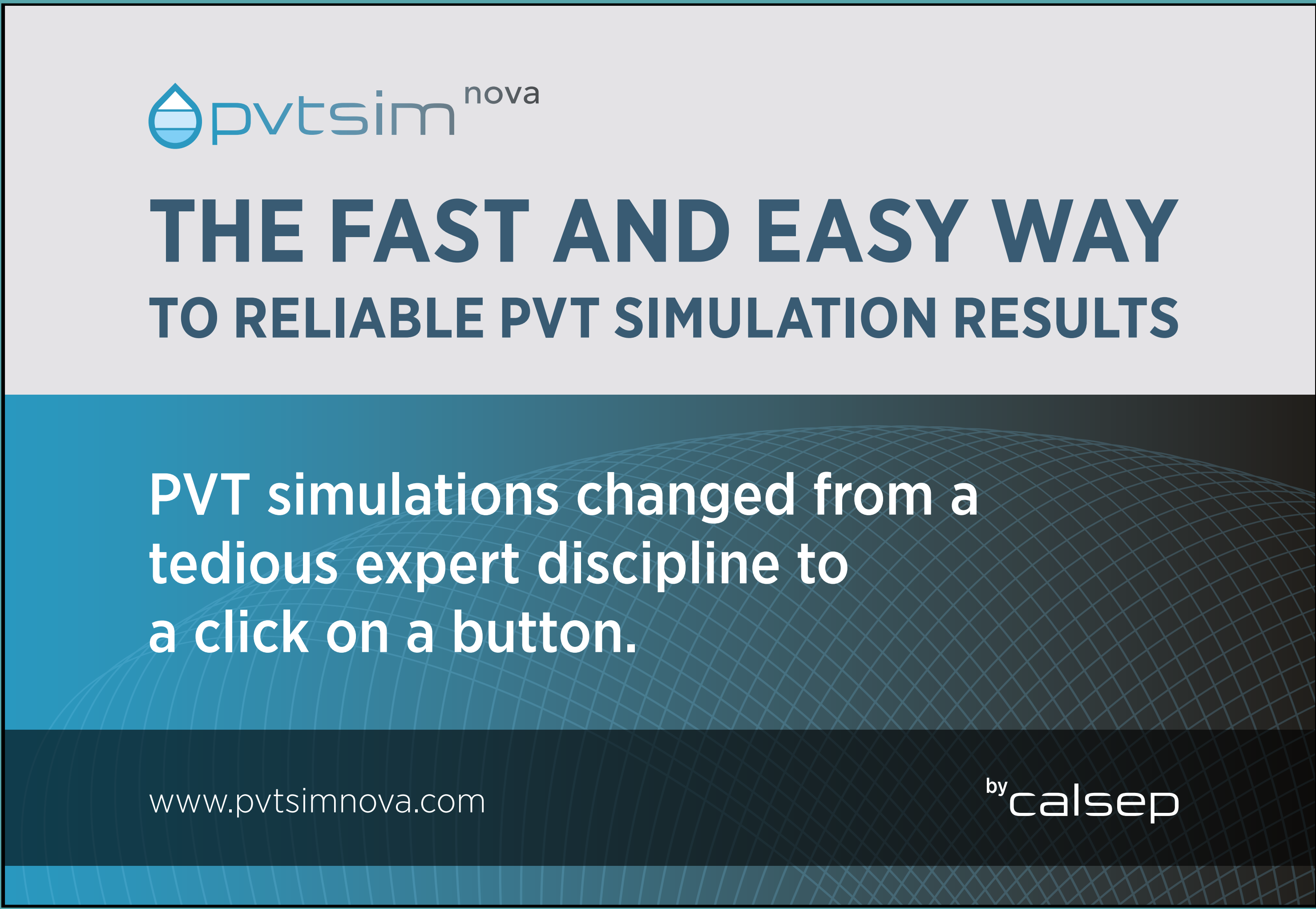
More than half of the land, 4000 to 5000 m$^2$ goes to a European diet. Aidin cannot reproduce this value in his own estimates but trusts agricultural scientists. 61% of Denmark is covered by arable land, which means that Mette needs to use all her share of arable land for food. The byproducts of agriculture can be consumed for electricity or biogas but it can only produce 19% of the future electricity demand even all the energy losses are ignored. Aidin encourages Mette to read more about Danish food import and export, which is both illuminating and scary. The good news is electricity: Mette can produce enough electricity by covering 54% of the land or 35% of shallow seawater with windmills. The bad news is it needs time, huge investment, and a lot of oil and gas to drive the construction. There is another bad news: Aidin never considers the intermittency of wind energy. For the success of his plan, large scale efficient energy storage must be integrated into the electricity network like the hydropower storage in Norway (with no chemical conversion). There are other methods of storing energy by converting electricity to chemicals (P2X), but the energy loss is big and more land must be covered by windmills and solar panels to balance the supply and demand. Aidin decides to end the discussion with Mette with an energy storage joke: those guys must keep it physical until they find the right chemistry.

## Acknowledgement

This story is inspired by the everlasting book of late David MacKay 'sustainable energy without the hot air' (https://www.withouthotair.com/). A more detailed and formal version of this story is available here: https://engrxiv.org/preprint/view/1538/


Making a difference
Noreco is entering the DUC with lots of energy, competence and ambitions
NORECO


Committed to better energy
@TotalEnergiesDenmark
www.totalenergies.dk
TotalEnergies


pvtsim nova
THE FAST AND EASY WAY
TO RELIABLE PVT SIMULATION RESULTS
PVT simulations changed from a tedious expert discipline to a click on a button.
www.pvtsimnova.com
by calsep


Every hour spent on a well counts
- there's a lot to play for
Offshore oil and gas is in a race to produce the most competitive barrel of oil. We provide solutions that plan, orchestrate and integrate the services involved in a drilling campaign.
We call it
Smarter Drilling for Better Value
www.maerskdrilling.com
MAERSK DRILLING