

# US Norway Joint projects

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# NORWAY



## Hilsen til Norge!

Vær hilset du mit fædeland,  
deroppe højt i Nord!  
Jeg lunges mod din kjendte strand,  
den kjæreste paa jord.

Har tak for alt, som du mig gav,  
som du gav frit til hilt og lav,  
som jeg tog med ombord





# US - NORWAY COLLABORATION ON CCUS

## MoU<sub>2004</sub>

- Bilateral meetings
- Internships
- NETL supported test campaigns
  - RTI: Norcem Cement plant and Sintef Research
  - IoN Engineering: TCM plant (2016-2017)
  - 2 of 6 awardees for Phase 1 of Large Pilots aimed at TCM
- CSLF: US and Norway endorse International Test Center Network
- Norway 2013-2015, US 2016–

# «Walk the talk !»

major CCS in Norway for 20 yrs

## Sleipner

- Gas sweetening, saline aquifer
- Operator: Statoil
- CO<sub>2</sub>: 1 MT/year
- Operational: **1996**



## Snøhvit

- LNG: onshore to offshore storage
- Operator: Statoil
- CO<sub>2</sub>: 700 kT/year
- Operational: **2008**



## TCM

- Worlds largest CO<sub>2</sub> Test Center
- Operator: TCM DA
- CO<sub>2</sub>: 100 kT/yr
- Operational: **2012**



**CLIMIT**  
RD&D funding



**GASSNOVA**  
Norwegian Govt. subsidiary

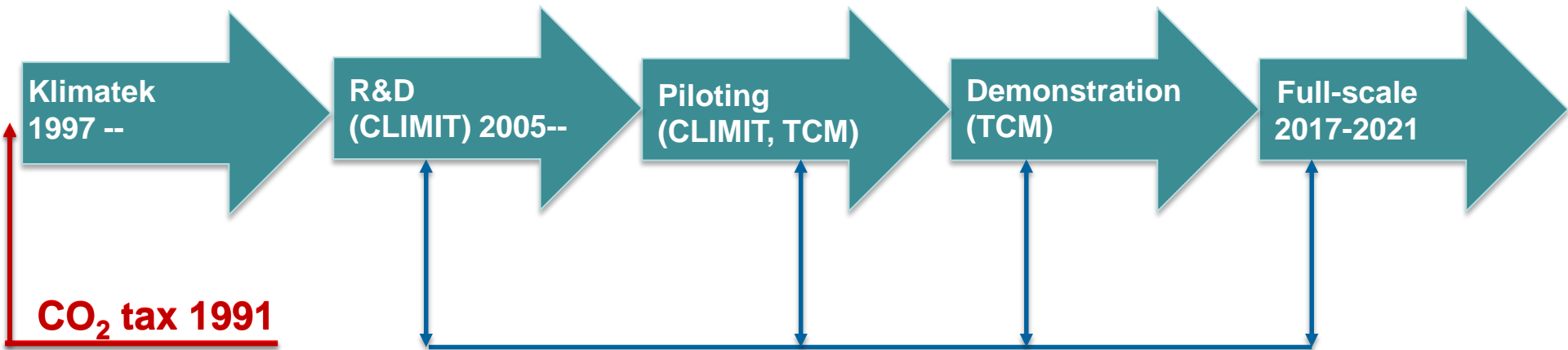


**TCM**  
Testing, verification, and  
improving CO<sub>2</sub> capture

**FULL SCALE CCS**



## 19 YEARS TECHNOLOGY DEVELOPMENT





## **CLIMIT: RD&D funding**

- Annual budget 230 MNOK / 27 MUSD p.y.
- Approx. NOK 1.7 bn / 200 MUSD since 2005
- More than 300 projects

## **Govt. ambition: One full scale CCS chain by 2020**

- Diversity: 3 different industrial CO<sub>2</sub> sources, <500kt/yr
- Intermediate storage/transportation
- Industrial incentives, Business model and funding



**Cement industry: Norcem**



**Fertilizer industry: Yara**



**Waste to Energy: Oslo**





TCM  
2009 – 2017 – 2020





NGCC  
Power Plant

Area for future  
technologies

Amine plant

Chilled  
ammonia plant

Utility systems

Refinery  
catalytic  
cracker

## Two feed streams

- NGCC flue gas (3.5 % CO<sub>2</sub>)
- Refinery cracker gas (13% CO<sub>2</sub>)





# Key features

- Two (13MW) post combustion capture test plants
- Two live flue gas streams: NGCC (3.5% CO<sub>2</sub>), and RFCC (13% CO<sub>2</sub>)
- 24/7 operations, industrial ops mode.
- R&D staff
- Laboratories
- 4000 live sensors
- Infrastructure and utilities for further capture technologies
- Dedicated control rooms



# International customer base

- Aker Solutions, Norway
- Alstom, France (now GE)
- Cansolv Technologies, Canada
- CCSL, UK/India
- IoN Engineering, USA





# MEA baseline campaign at TCM DA

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TCM DA

# BASELINE RESULTS

*Baseline results are of utmost importance!*

- Open dissemination of results
  - 3<sup>rd</sup> party baseline verification
  - Fair comparison to proprietary technologies
- 
- Monoethanolamine (MEA, 30 wt%) is a conventional amine suited for baseline purposes
  - Conducted with U.S. based EPRI







# 2015 MEA CAMPAIGN

## Baseline

- Application of Independent verification protocol developed by EPRI
  - Equipment and instrument accuracies and verifications
- Test execution
- Independent data treatment and reporting

## Additional activities

- Plant capacities
- Testing for modern gas turbine characteristics
- Aerosol and mist born emission testing
- Etc..



# SOME BASELINE RESULTS

## Performance

- Establishing baseline results
- CO<sub>2</sub> capture rates, energy duties, mass balances, etc..
- Emission products

Parameter	Results
Gas turbine flue gas	60.000 Sm <sup>3</sup> /hr
CO <sub>2</sub> capture rate	~85%
CO <sub>2</sub> content in/out (dry)	~3.8 / ~0.5%
Energy penalty	3.5 GJ/t CO <sub>2</sub>
CO <sub>2</sub> produced	3350 kg/hr
MEA degradation rate	~1.4 kg MEA / t CO <sub>2</sub>
CO <sub>2</sub> mass balance	100 ±0.5 %

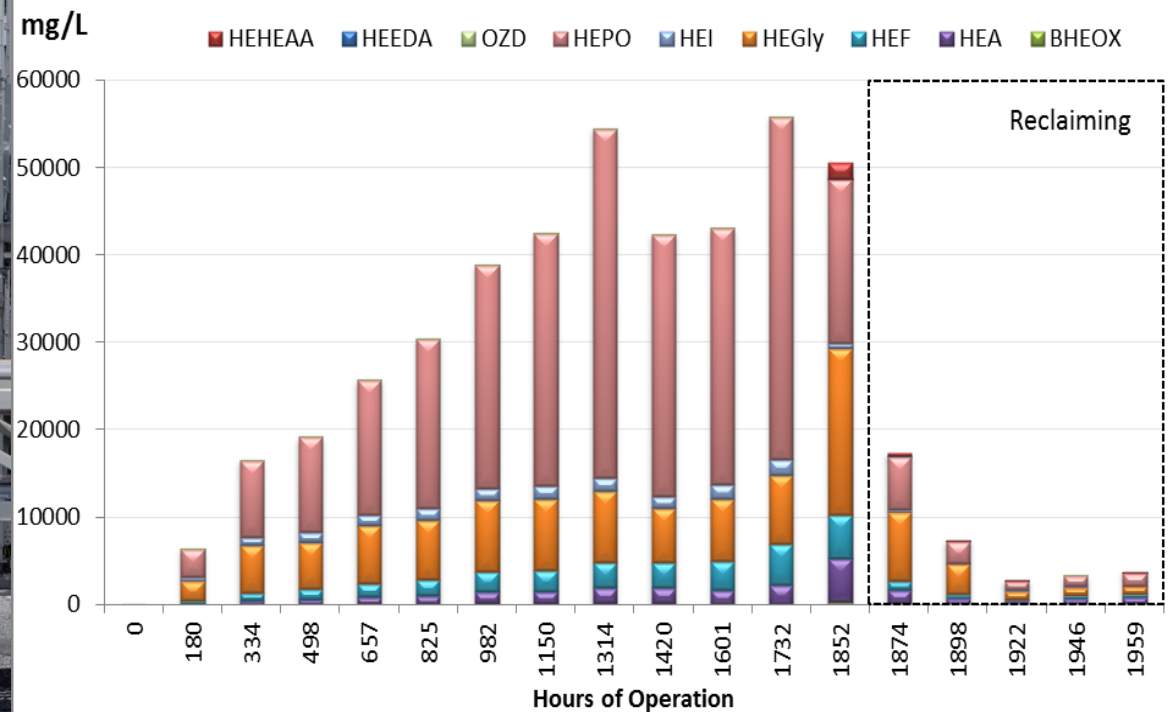
Component	Results
MEA	0.02 ppmv
Ammonia	15 ppmv
Acetaldehyde	0.2 ppmv
Formaldehyde	0.5 ppmv
Total nitrosamines	< 0.00008 mg/m <sup>3</sup>
Total nitramines	< 0.0002 mg/m <sup>3</sup>

# SOME BASELINE RESULTS



## Degradation

- Degradation and reclaiming
- Removal of degradation products
- Long-term operations





# CONCLUDING REMARKS

*Baseline results are  
of utmost importance!*

- Accurate and well established baselines are essential
- Fair comparison to proprietary technologies
- TCM provides baselines, developed with U.S. based EPRI



An aerial photograph of a large industrial facility, likely a refinery or chemical plant, situated along a body of water. The facility is characterized by numerous tall distillation columns, complex piping, and various industrial buildings. In the foreground, there are parking lots filled with cars and a large white building with the slogan "- catching our future" on its side. The background features a wide expanse of water and a range of mountains under a blue sky with scattered white clouds. The text "Thank you !" is overlaid in the center of the image.

Thank you !