

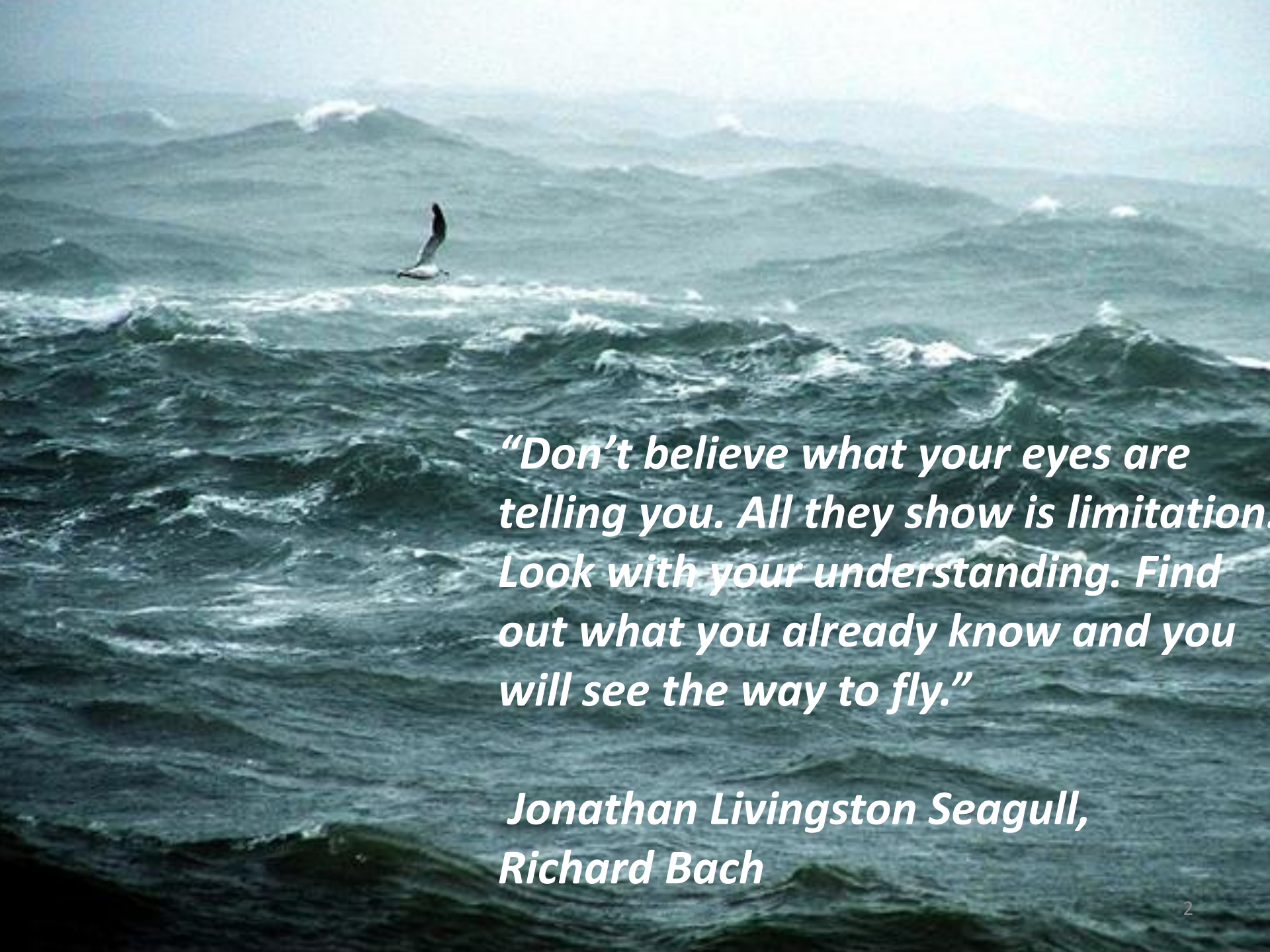


CCS CO-OPERATION OPPORTUNITIES

US-NORWAY



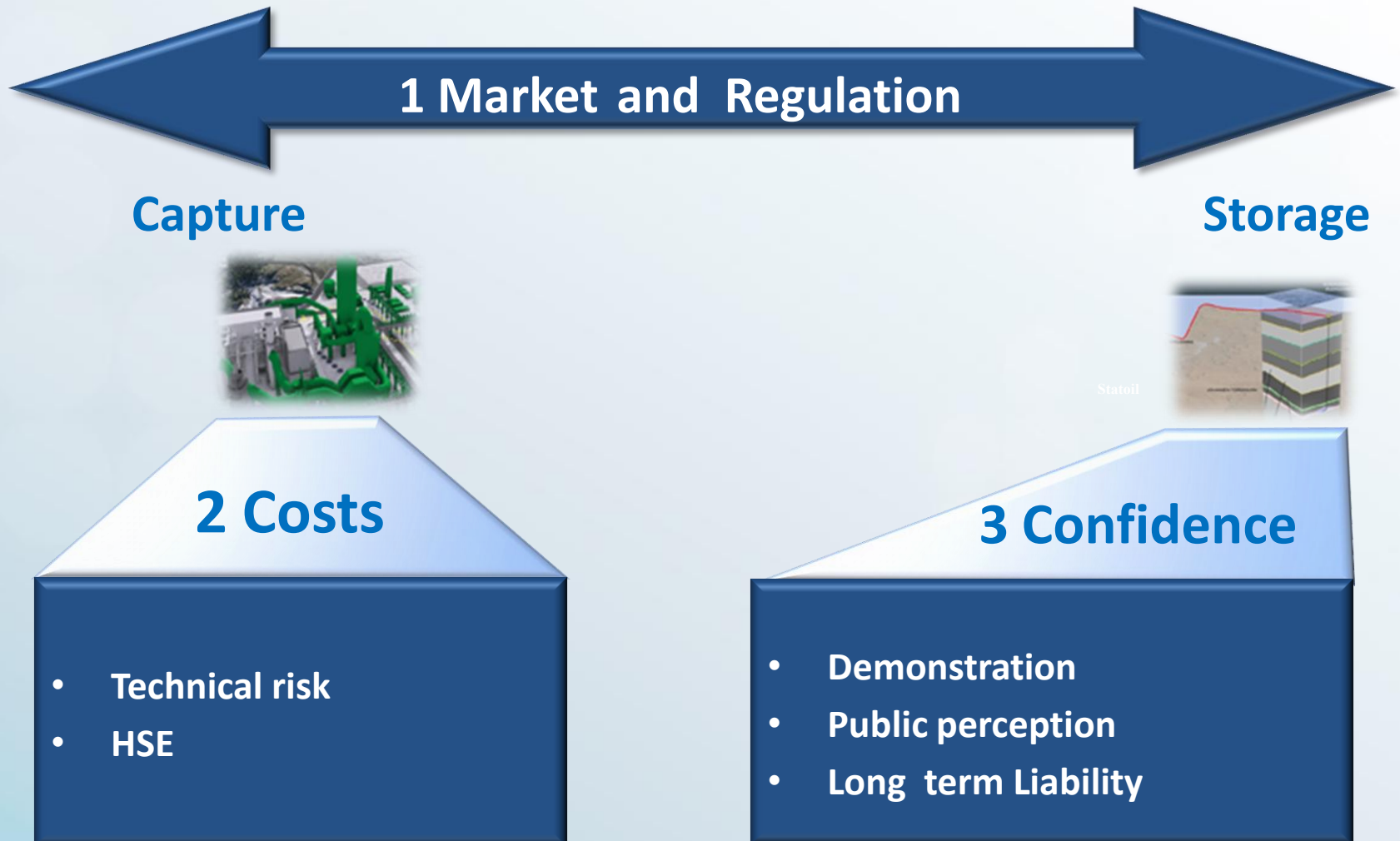
GASSNOVA

A seagull is captured in mid-flight, soaring over a vast, choppy ocean. The water is a deep, dark blue-green, with white foam from the waves. In the distance, a range of mountains or hills is visible under a pale, overcast sky. The overall mood is one of freedom and resilience.

*“Don’t believe what your eyes are
telling you. All they show is limitation.
Look with your understanding. Find
out what you already know and you
will see the way to fly.”*

*Jonathan Livingston Seagull,
Richard Bach*

THREE CHALLENGES FOR CCS



CCS DRIVERS



- **One Price on Carbon?**
- **Legislation**
- **Emission performance standards**
- **Feed in Tariffs, Certificates**
- **CO₂ Tax**
 - Norway, Australia and California
- **Subsidies**
 - Norway, Canada, UK and EU
- **Enhanced oil recovery (EOR)**
 - USA and Canada

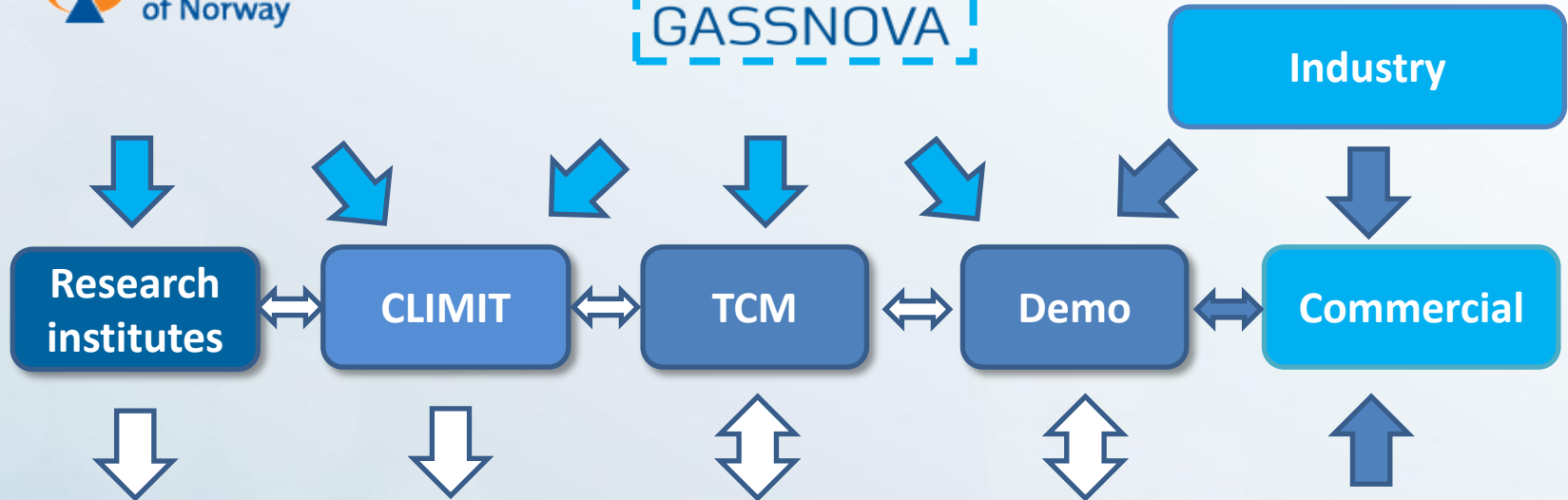
... need market Pull for w.w. CCS deployment ...

NORWAY PUNCHING ABOVE ITS WEIGHT IN CCS



- The climate
- Oil and energy cluster
- R&D based industrial development
- Financial resources
- Making fossil fuels sustainable

POLICY INSTRUMENTS IN NORWAY



Govt.- Industry partnering for CCS

CLIMIT: RD&D:

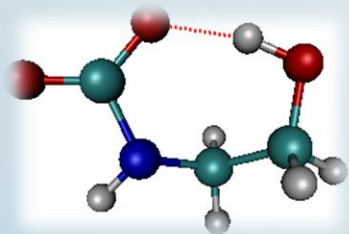
GASSNOVA AND THE RESEARCH COUNCIL OF NORWAY

- **200+ projects, 300M USD for R&D**
- **Improved performance of CCS systems**
- **Reduced power consumption with 35% (Post-combustion)**
- **EHS: Emissions from PCC**



EXAMPLE: SOLVIT

- 20+ years absorption technology research at SINTEF/NTNU
- Aker industrial experience
- Multi-scale and client approach to solvent development
- Tests at appropriate level



Molecular simulations



Lab/pilot tests



New full height pilot plant in Trondheim



Mobile Test Unit



Large demo/full scale

SOLVENT DEGRADATION RIG

- Simulates solvent degradation in CO₂ capture plant
- Qualitative picture of degradation products that are formed
- Components potentially present in the gas exiting the absorber column.







World's first CO₂ capture test facility in cement industry, Brevik, Norway

- Scope
 - Small scale test centre for CO₂ capture from cement flue gases
 - Basis for qualification of CO₂ capture technologies
 - Evaluation of full scale capture
- Budget
 - 9 mill Euro from CLIMIT 2013-2017
- Partners:
 - Norcem
 - HeidelbergCement
 - ECRA (European Cement Research Academy)



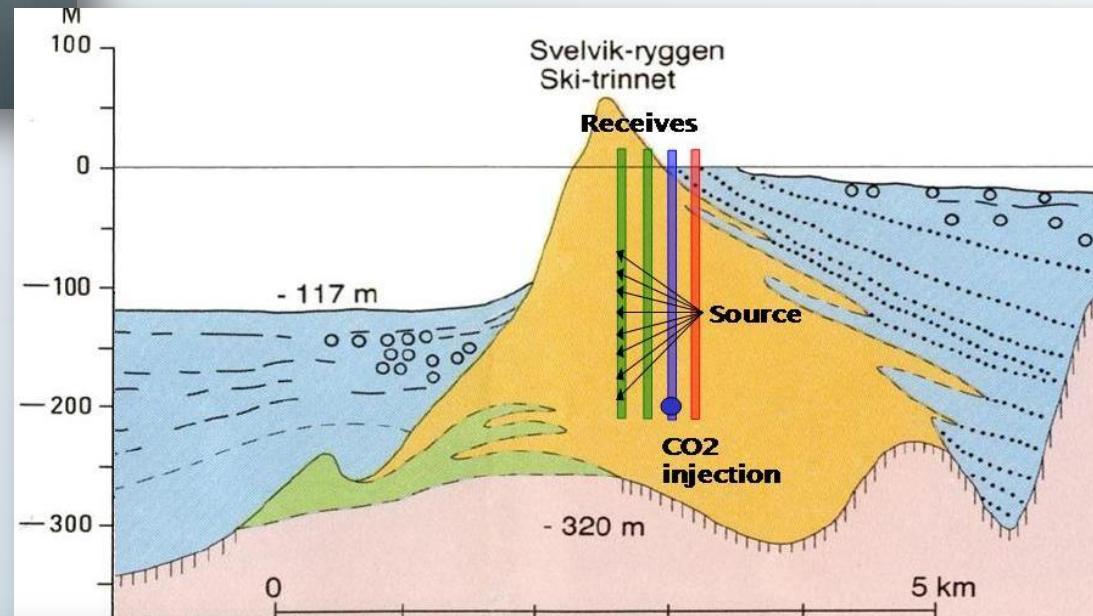
CAPTURE TECHNOLOGIES TO BE TESTED

Technology	Supplier	Comment
Amine technology	 <p>Aker CleanCarbon part of Aker</p>	<ul style="list-style-type: none"> • 1st. Generation technology • Mobile test unit
Membrane Technology	 <p>DNV KEMA NTNU Innovation and Creativity YOOFAT ENGINEERS</p>	<ul style="list-style-type: none"> • Small scale development in early phase of development
Solids adsorption Technology	 <p>RTI INTERNATIONAL</p>	<ul style="list-style-type: none"> • Small scale development in early phase of development
Carbonate looping, RCC	 <p>POWER ALSTOM</p>	<ul style="list-style-type: none"> • Second generation technology • Testing in cooperation with Darmstadt University • Will be evaluated for later testing at Brevik

EXAMPLE: CO₂ FIELD LABORATORY



- Inject CO₂
- Study leakage/migration
- Validate monitoring methods

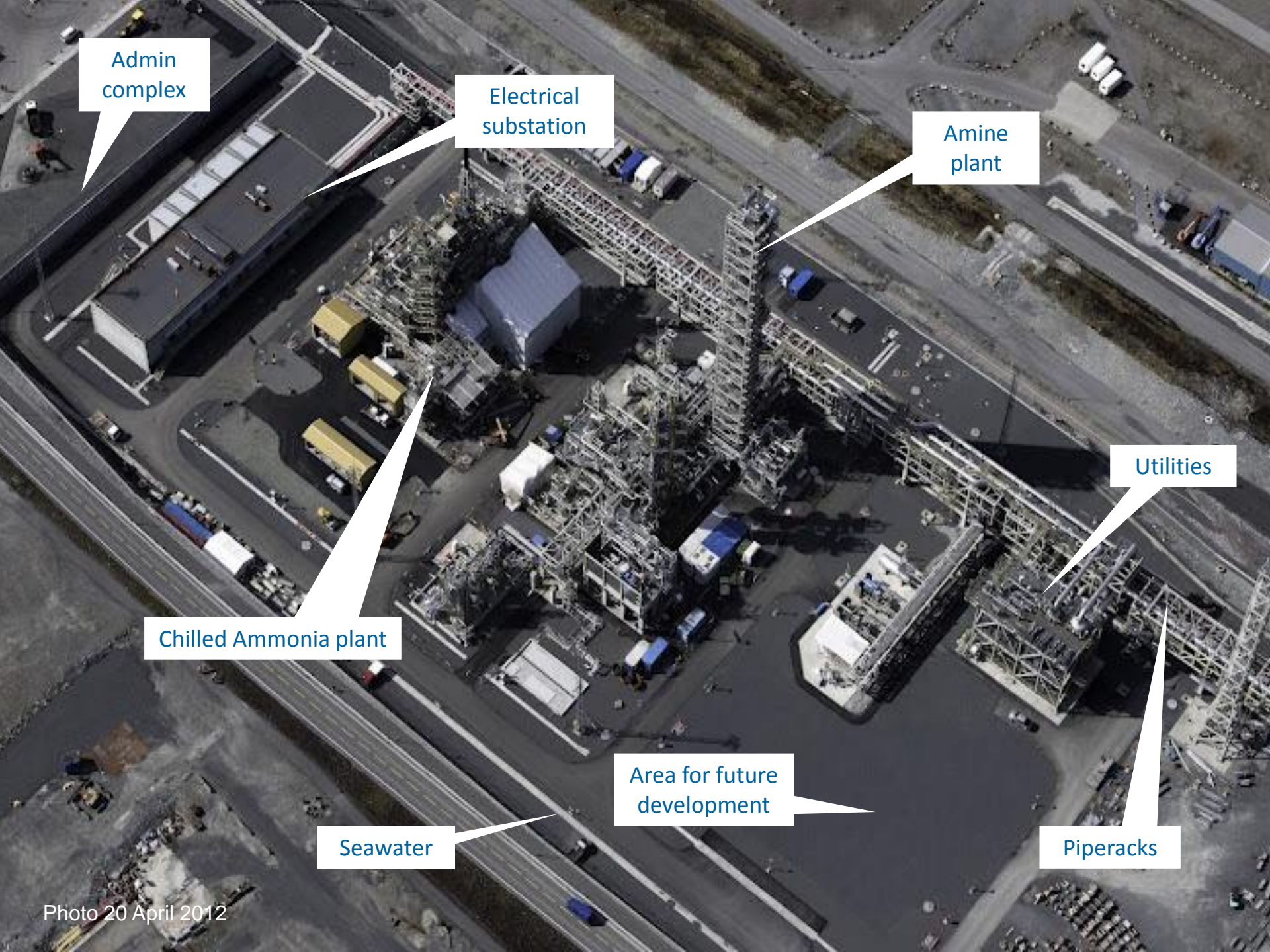




TECHNOLOGY
CENTRE
MONGSTAD

catching our future





Admin complex

Electrical substation

Amine plant

Utilities

Chilled Ammonia plant

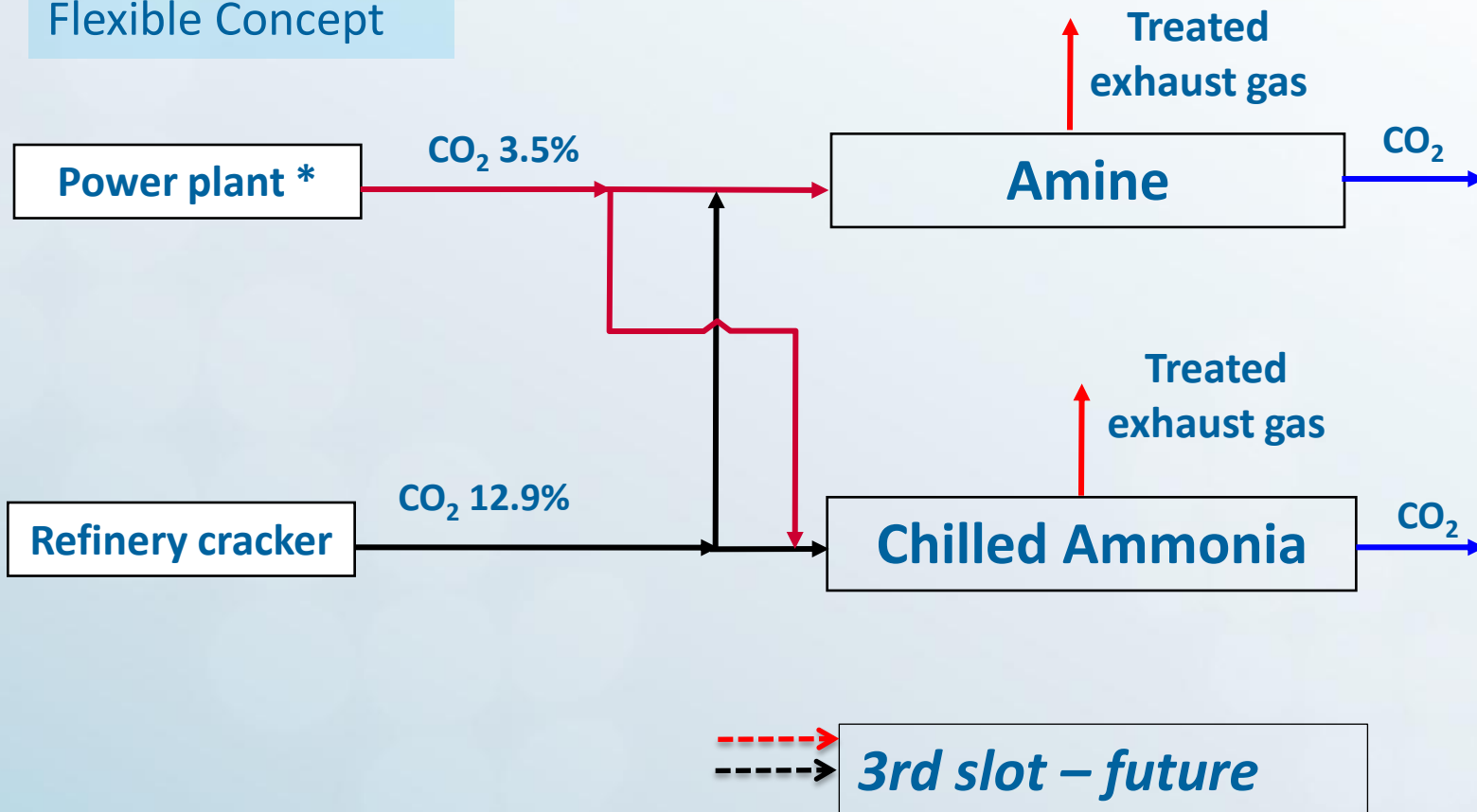
Area for future development

Seawater

Piperacks

CO₂ TECHNOLOGY CENTRE MONGSTAD, TCM

Capacity 100 kt/yr
Flexible Concept



* CHP design capacity of 280MW electricity and 360MW heat



Unique access to flue gas with different CO₂ concentrations.



AMBITIONS

- Test, verify and demonstrate post combustion CO₂ capture
- Reduce costs, technical, environmental and financial risks
- Share knowledge and enable global deployment



TCM – LEARNING

- **Binding contract with leading industry**
- **Industrial methods for project development and technology evaluation**
- **Political persistence**
- **Norwegian Government direct participation through Gassnova**





LESSONS LEARNED – HSE:

- Developed HSE verification toolkit
- Operated well within discharge permit *)
- Solvents demonstrated to be safe

*) Nitrosamines and nitramines shall not exceed
0,3 ng/m³ in air and 4 ng/l in drinking water

TCM GOING FORWARD

- **New tech. suppliers**
- **New solvents**
- **Additional owners**
- **New technologies in smaller scale**
- **International partnering and network**



STAKEHOLDER BACKING

“If CCS fails, we need to find other ways to slash CO₂ emissions, which will be very, very difficult: We must succeed!”

IEA Executive Director Maria van der Hoeven





US – NORWAY COLLABORATION

MoU 2004:

- US Department of Energy and Norwegian Ministry of Petroleum and Energy
- Covers all energy research.
- CCS a key priority
- Testing at TCM
- Cement plant emissions
- Workshop 2012 and 2013 in Washington D.C
- Summer School

«Time and Tide wait for no man»

St. Marher, 1225

– *nor will the CLIMATE...*

