Geological Storage of CO_2

by Paul Freund

Geological Storage of CO_2

- Introduction
  - Options for storing CO_2
  - Requirements for storage
- Monitored injections of CO_2
  - Commercial projects
  - Research projects
- Discussion
  - Progress towards meeting requirements

Options for storing CO_2

- **Main opportunities**
  - **Disused gas fields**
  - **Deep saline aquifers**
- **Early opportunities**
  - **Depleted oil fields**
    - **EOR could help offset the cost**
- **Other storage options**
  - **Coal, Basalt, Carbonation**

Requirements for storage of CO_2

- **Geological formation should have:**
  - **Sufficiently high permeability**
  - **Adequate capacity**
  - **Insignificant internal flow**
  - **Trapping mechanisms**
    - **To contain CO_2 for a very long time**

Requirements for storage of CO_2

- Verifiable quantity of stored CO_2
  - Measured amount injected
  - And either
    - Measured amount of CO_2 in store
  - Or
    - Modelled behaviour of CO_2 in reservoir
    - Detect any leakage
- Report avoided emissions and leakage
  - e.g. under IPCC guidelines

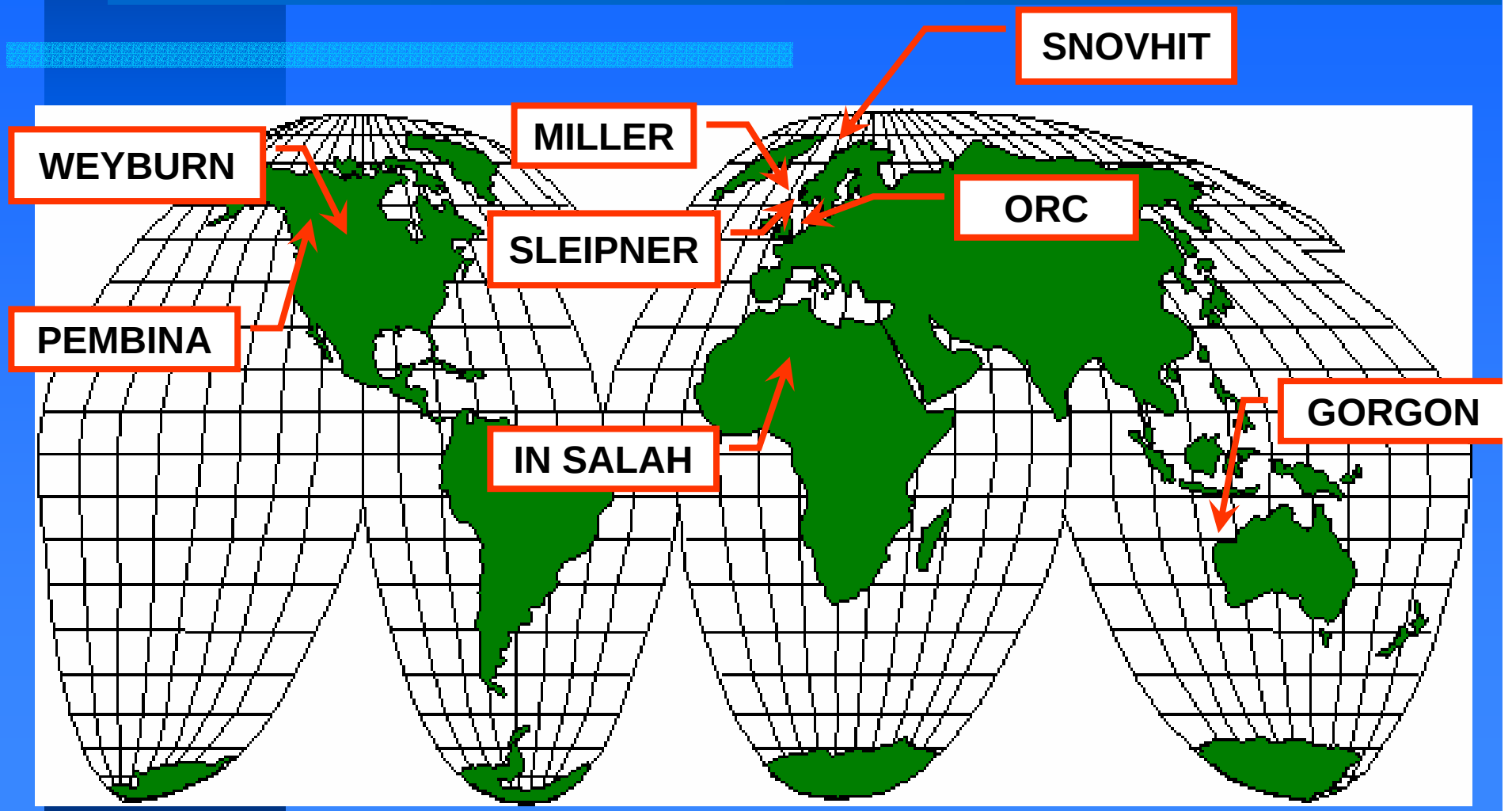
Requirements for storage of CO_2

- **Regulatory framework**
  - **Legal basis**
    - **Onshore – use existing laws**
    - **Offshore – under development**
  - **Responsibility for long-term stewardship**
    - **yet to be defined**

Requirements for storage of CO_2

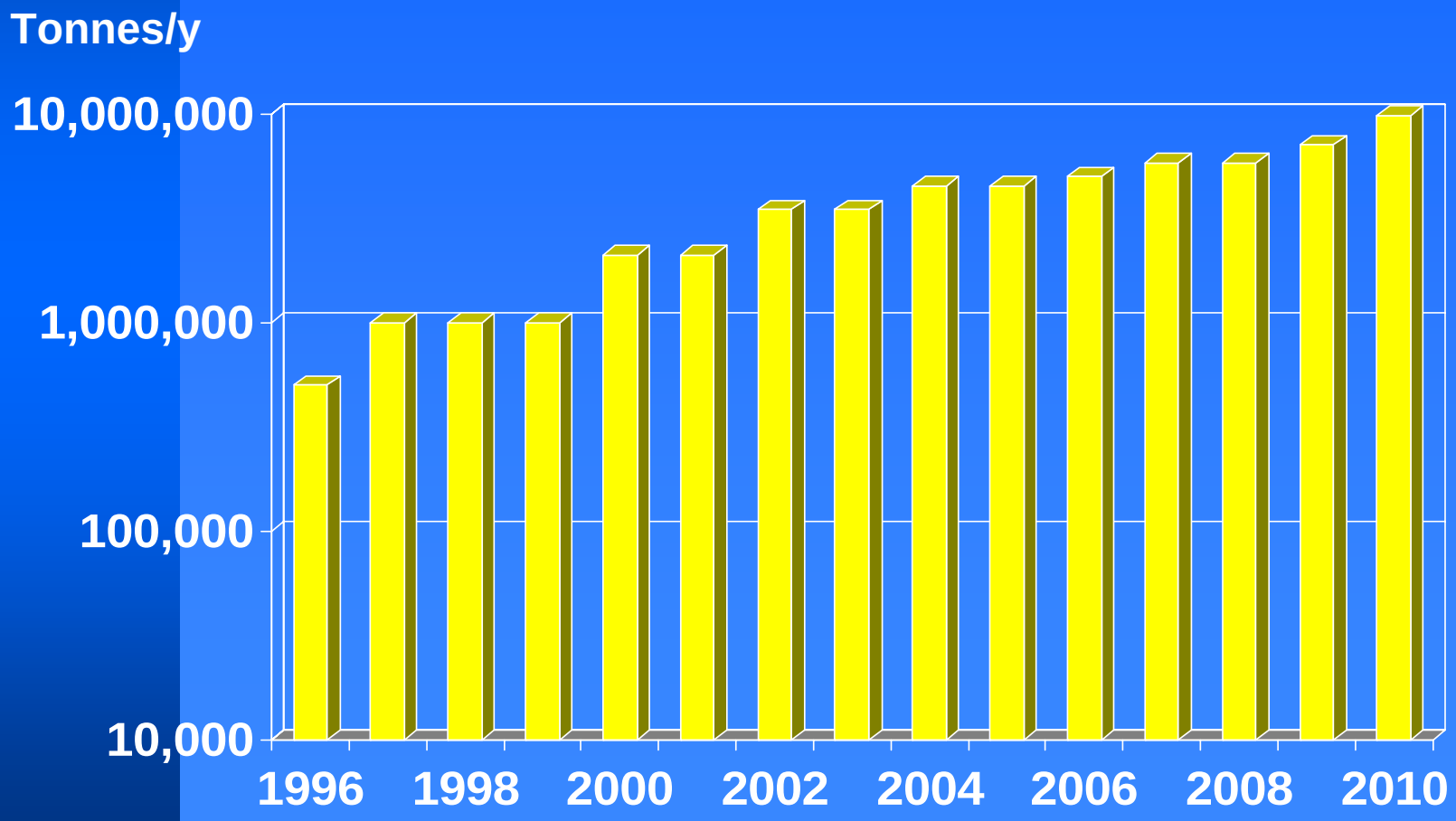
- **Commercial**
  - **There must be a means of paying for it**
    - **Trading of emission rights**
    - **Carbon tax**
- **Public acceptance**
  - **Likely to want evidence of secure storage**

Commercial Projects



Not included: CO_2-EOR without monitoring

Annual Injections of CO_2



Commercial Projects

- Most inject into sandstone formations
  - Sleipner, ORC, Snovhit, Gorgon, Miller
- Other projects involve different formations:
  - Weyburn - carbonate
  - In Salah - carboniferous

Commercial Projects

- Formations contain
  - Brine - Sleipner, Snovhit, Gorgon
  - Oil/Gas - Weyburn, In Salah, Miller

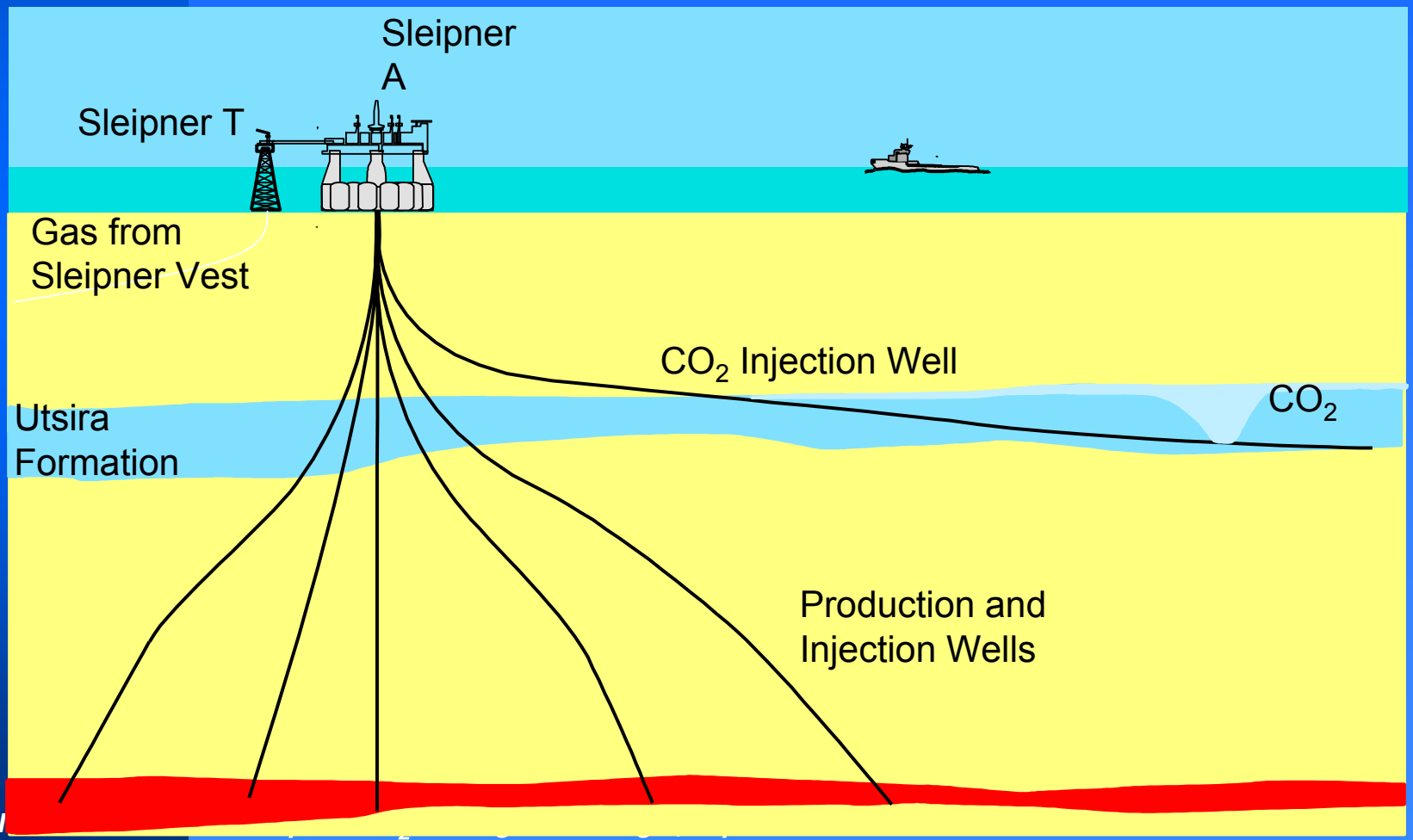
Commercial Projects

- Injecting at a range of depths
  - Sleipner - 1000m
  - Weyburn - 1450m
  - In Salah - 1850m
  - Gorgon - 2000m
  - Snovhit - 2500m
  - ORC - 3800m
  - Miller - c.4000m

Sleipner project

Photo: Statoil

Sleipner CO_2 Injection

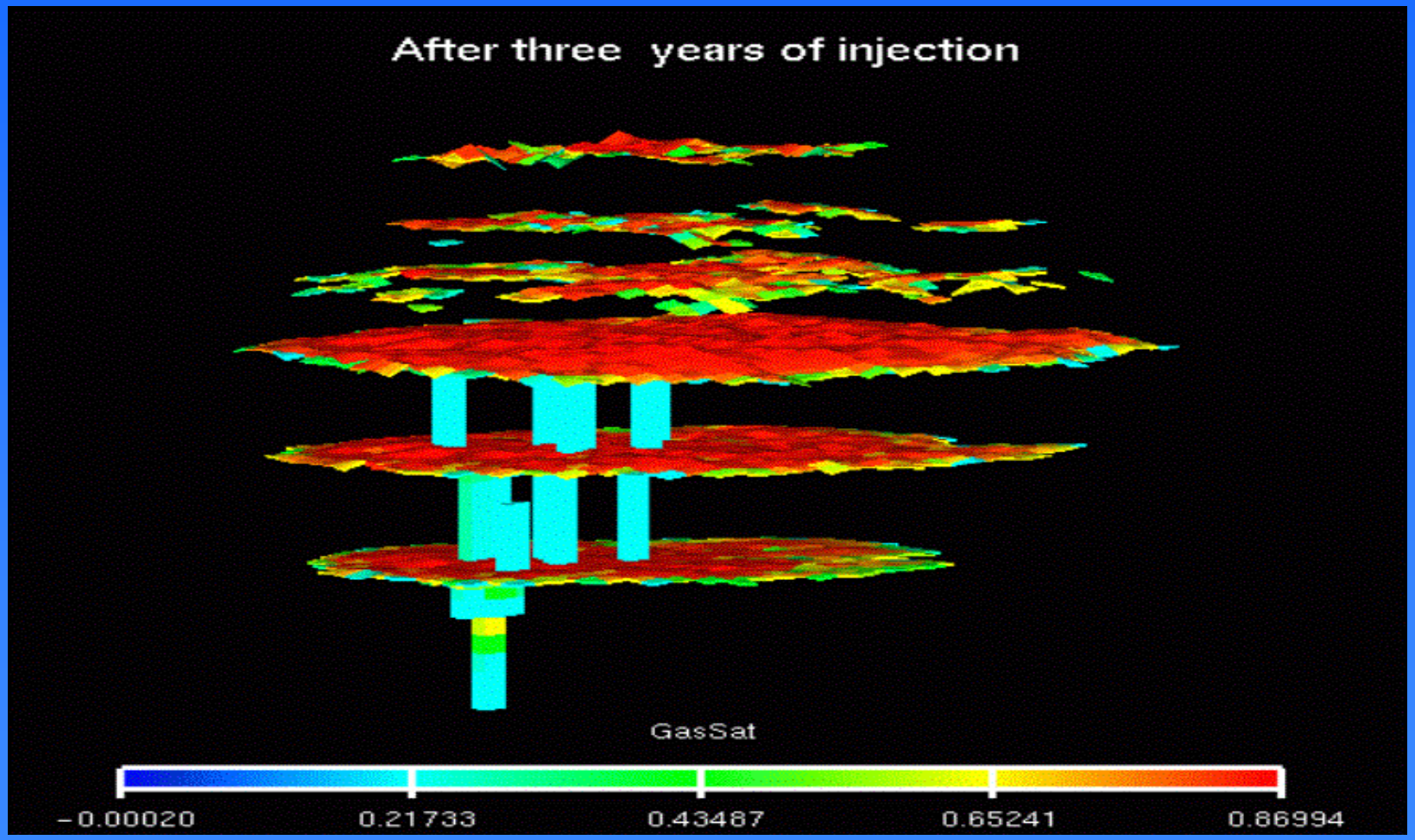


Courtesy of Statoil

Sleipner

- International monitoring programme
  - Established 1997
- Includes:
  - Core study
  - Repeated 3D seismic
  - Micro-seismic; time-lapse gravity
  - Geo-chemistry
- But no observation well

Sleipner: Seismic Analysis

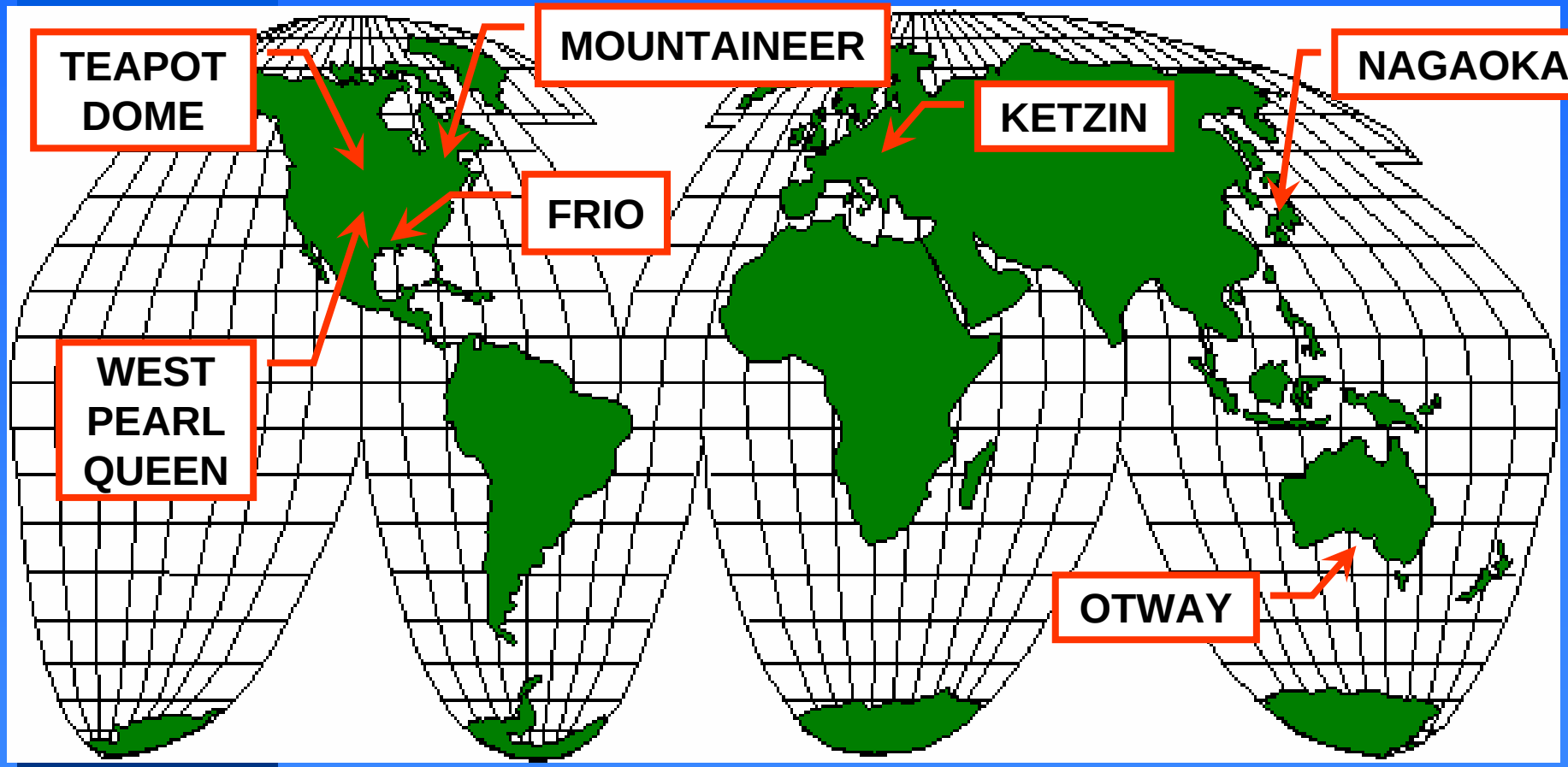


3-year history match courtesy of Sintef Petroleum

Sleipner

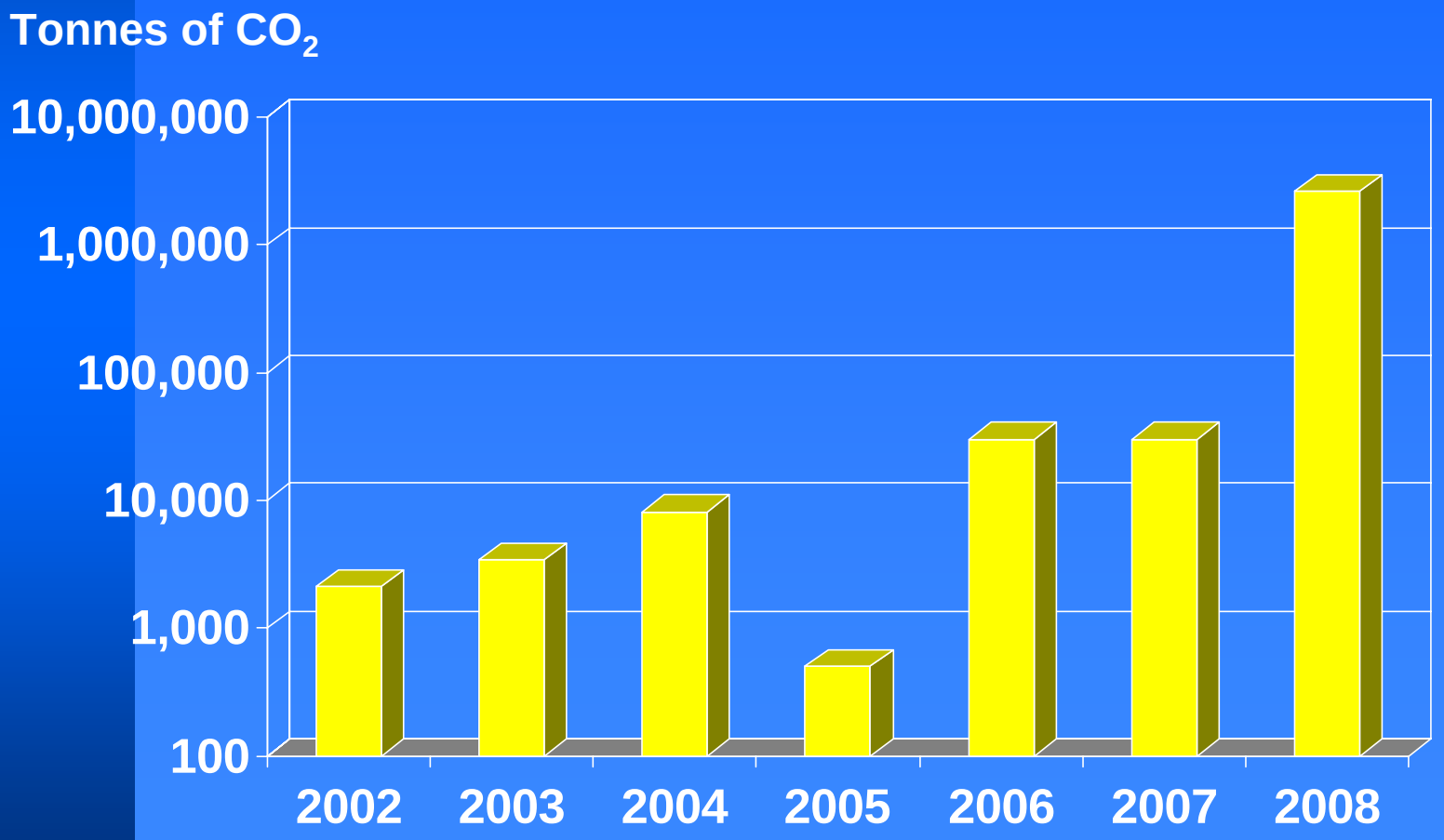
- **What have we learnt?**
  - **Seismic detection of CO_2 bubble**
  - **Minimum volume detectable <4000m^3**
  - **80-85% hydro-dynamically trapped**
  - **No significant geo-chemical reactions**
  - **Verification of CO_2 stored by seismic:**
    - **Depends on assumptions about formation**
    - **Can account for ~85% of injected CO_2**

Research Projects



Not included: recently announced US regional partnership projects

Quantity of CO_2 injected



Research Projects

- All of these projects inject into sandstone formations
- Most contain brine
  - Nagaoka, Frio, Ketzin, Otway
- But some have residual oil
  - West Pearl Queen, Teapot Dome

Research Projects

- Most are at moderate depth
  - West Pearl Queen - 1400m
  - Nagaoka - 1100m
  - Frio - 1500m
  - Otway - c.2000m
  - Teapot Dome - 1700m
- Although
  - Ketzin - 700m

West Pearl Queen

- **Monitoring included:**
  - **Core study**
  - **Observation well**
  - **2 seismic surveys**
  - **Tracers, Micro-seismic**
- **CO_2 not reach observation well (411m)**
- **Free CO_2 then vented from formation**
- **Problem in verifying remaining CO_2**

Nagaoka

- **Monitoring included:**
  - **Core study**
  - **3 observation wells**
  - **Cross-well seismic tomography**
  - **Micro-seismic**
- **Breakthrough of CO_2 (40m) after 8 mo.**
- **Detailed image of 3200t CO_2**
- **No discernible effect of earthquake**

Ketzin

- Measurements planned include
  - Seismic, including cross well
  - Continuous fibre-optic sensor downhole
  - 2 observation wells

Summary of requirements

- Formations suitable for CO_2 storage
- Verifiable amount of CO_2 stored
- National emissions report
- Regulatory and legal framework
- Commercial justification
- Public acceptance

Progress towards requirements

- Formations suitable for CO_2 storage
  - Concept demonstrated
  - Growing recognition in technical and policy communities
- Verifiable amount of CO_2 stored
  - Not fully demonstrated yet

Uncertainties in verification

- Measurement of CO_2 in store
  - Can measure injected CO_2
    - EOR: some CO_2 separated and re-injected
  - Stored CO_2 partitioned between:
    - Supercritical phase
    - Dissolved phase
      - In water
      - In oil
    - Mineralised
- Places limits on verification

Uncertainties in verification

- **Leakage should be low**
  - **How low is low enough?**
  - **To avoid significant reduction in climate benefit, leakage <0.01%/year**
- **How easily can this be detected?**

Detecting CO_2 leakage

- Needs sensitive techniques:
  - Isotopic analysis
  - Tracers in CO_2
- Or monitor sub-surface
  - Standard practice for natural gas storage
- No reports of CO_2 leakage
  - Relatively little work done to detect it

Progress towards requirements

- National reporting of emissions
  - Sleipner included in Norwegian report
- Regulatory and legal framework
  - Discussions started in Europe
- Commercial justification
  - European Emissions Trading Scheme
  - Cost of monitoring will be small

Progress towards requirements

- **Public acceptance**
  - **Little information for general public**

Conclusion - future projects

- **Onshore projects**
  - **More observation wells than offshore projects**
  - **Better data on physical and chemical state of CO_2**
  - **Better seismic resolution**
- **Offshore projects**
  - **Access to supplies of CO_2**
  - **More acceptable location for injection**

Conclusion – twin track approach

- Research projects onshore will develop monitoring and modelling
- Large-scale injections to prove:
  - Injectivity and leakage assumptions
  - Monitoring and verification techniques
  - May be offshore
- International cooperation will be valuable