# Coal-based, CO2-neutral Power Generation

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**ACERC Conference**

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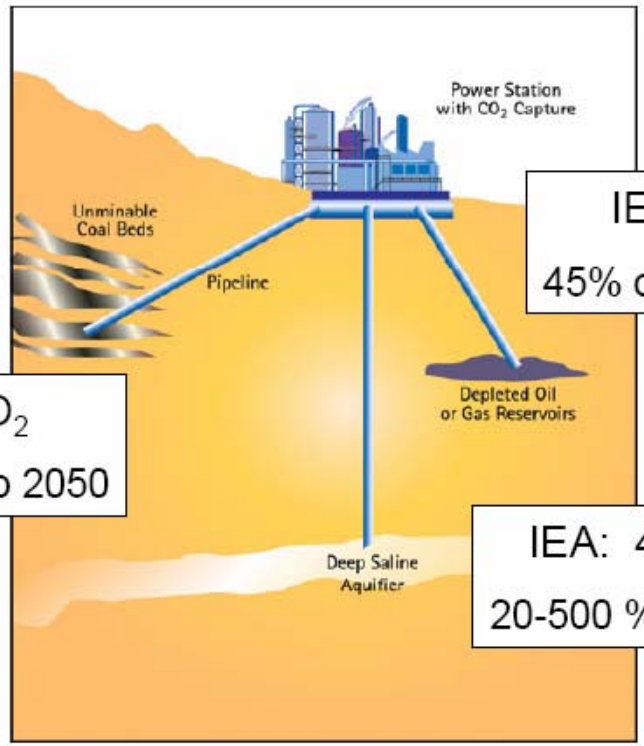
# $CO_2$ Sequestration Options




IEA: 40 Gt $CO_2$

<2% of Emissions to 2050

Parson & Keith:
370-1100 Gt $CO_2$

IEA: 920 Gt $CO_2$

45% of Emissions to 2050

Parson & Keith:
740-1850 Gt $CO_2$

IEA: 400-10 000 Gt $CO_2$

20-500 % of Emissions to 2050

Parson & Keith:
370-3700 Gt $CO_2$

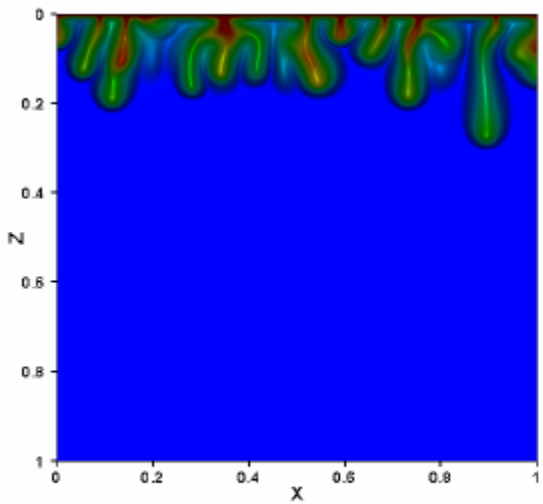
Source: Freund, IEA - Comparative potentials at storage costs of up to \$20/t $CO_2$

Source: Parson & Keith, Science 282, 1053-1054, 1998

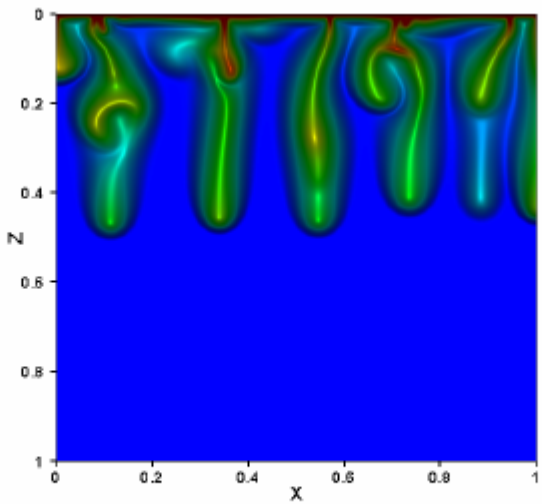
# $CO_2$ Release is Health Hazard


**Lake Nyos, Cameroon, Two Villages Asphyxiated, 1700 Deaths (1986)**

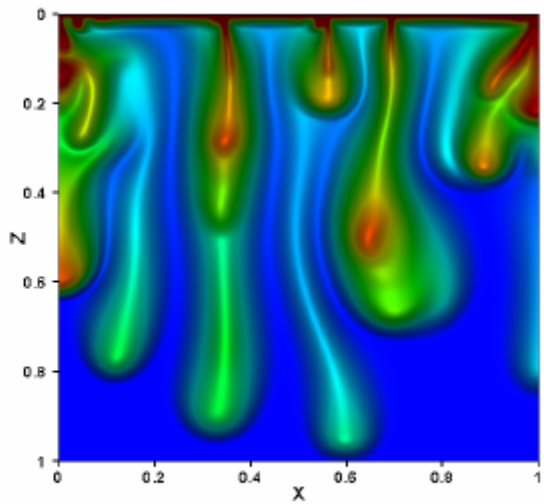
# Aquifer Behavior Over Time




24 years



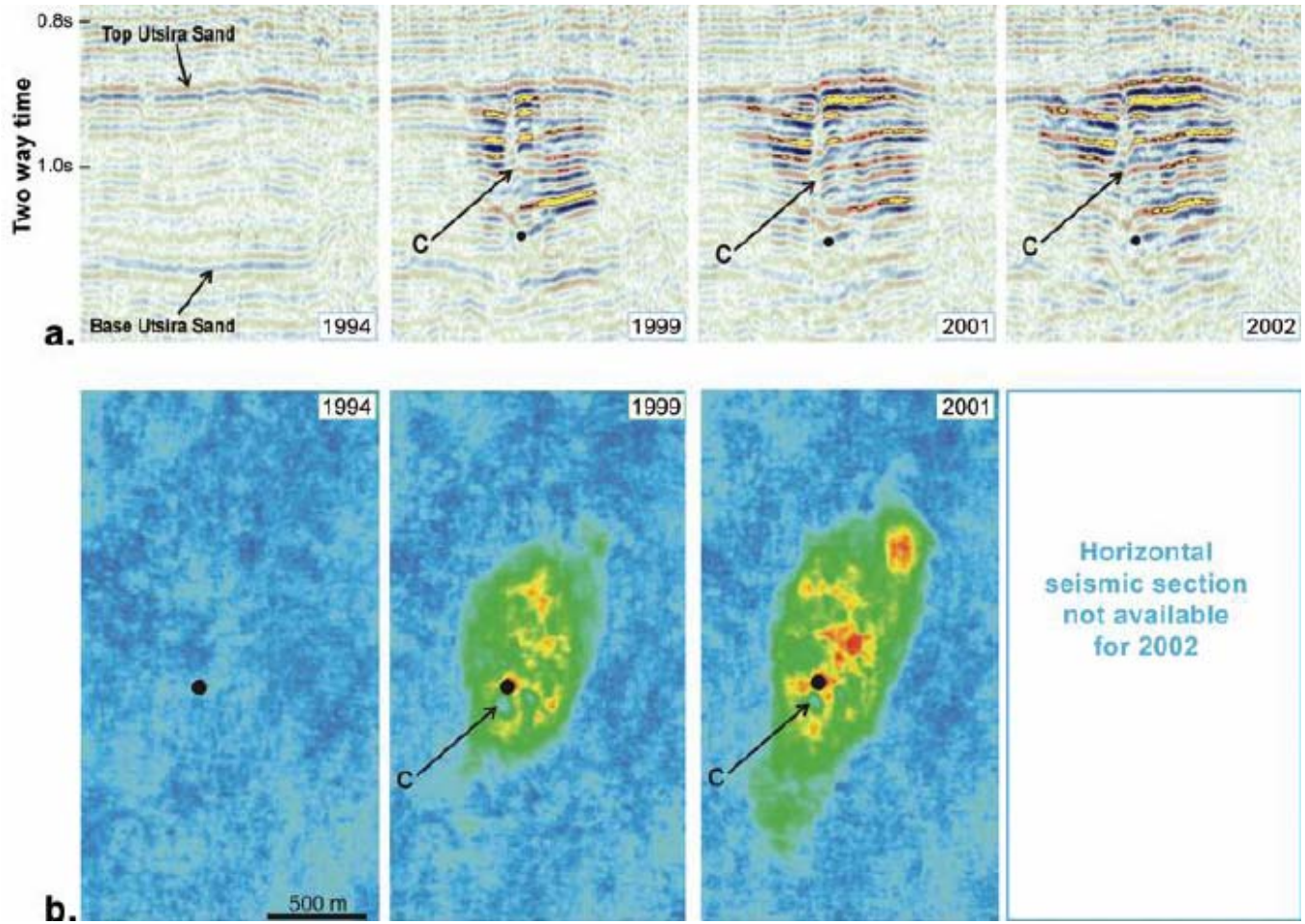

52 years




108 years

Source: A. Riaz, M. Hesse, H. Tchelepi, Stanford University, 2005

# Monitoring Capabilities

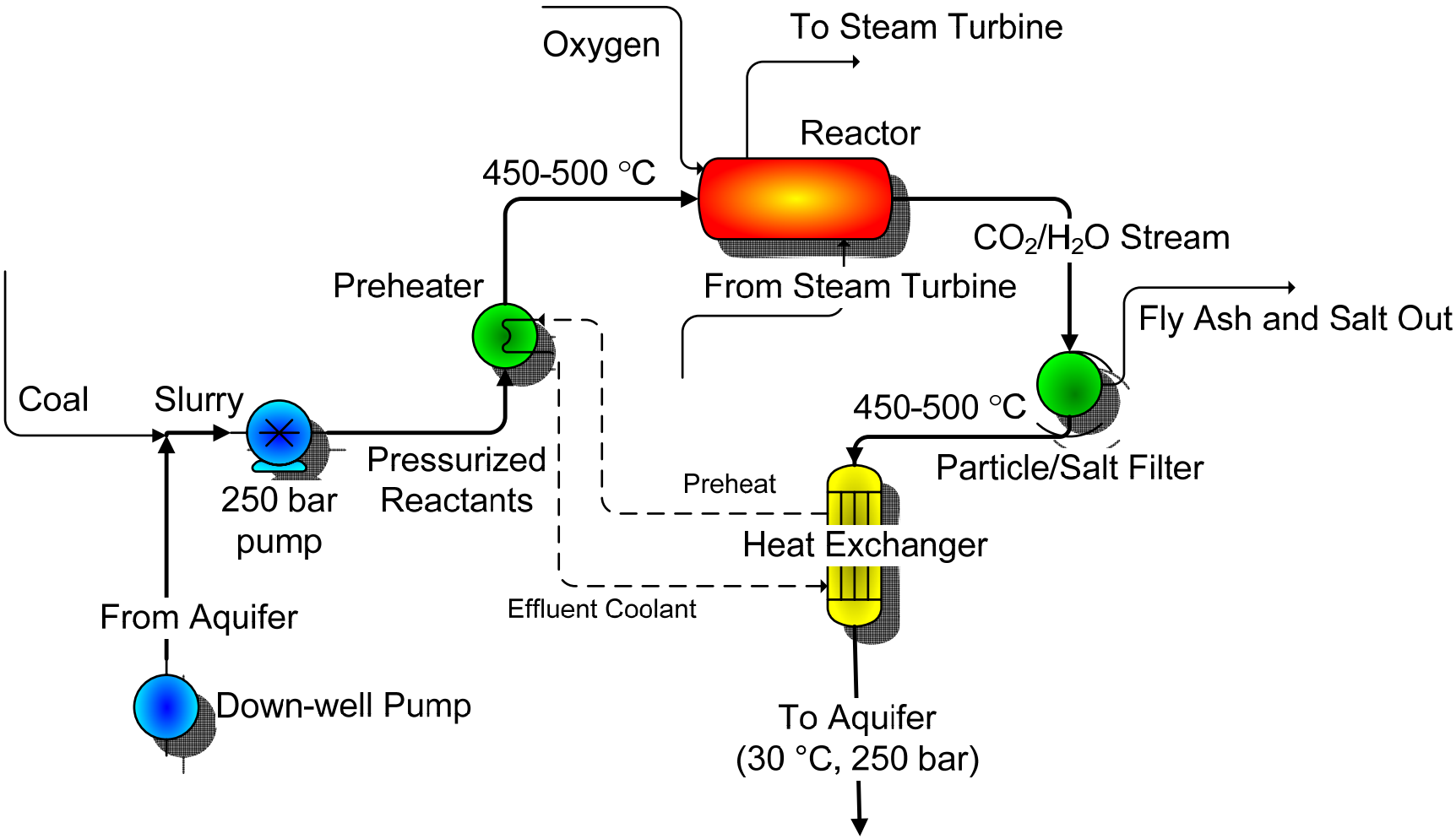



Sleipner Data: Source: S. Benson, GCEP Workshop, Beijing 2006

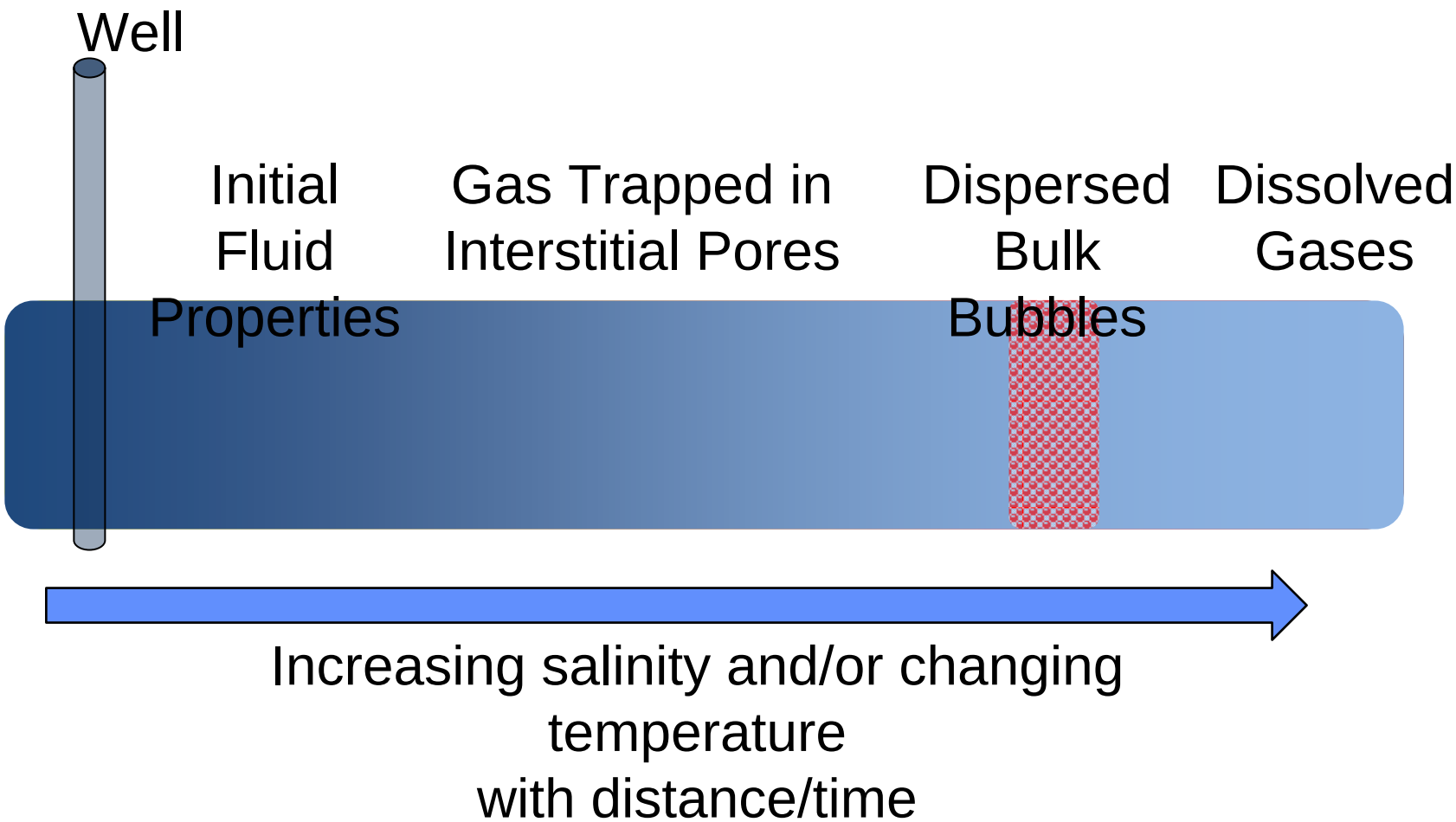
# Project Essentials

- **Awarded (not yet signed) contract from GCEP**
  - **Largest GCEP project to date – only coal-related project to date**
  - **Involves Stanford (Mitchell, Edwards), University of Utah (several), and BYU (many)**
  - **Research and provide conceptual design for supercritical (nominally 250 atm, 2000 °C) coal conversion system for coal slurry**
- **3-year Project Includes**
  - **LCA**
  - **Reactivity**
  - **Fate of Inorganics**
  - **Thermodynamics**
  - **Materials**
  - **Reactor Design**

# Proposed Solution



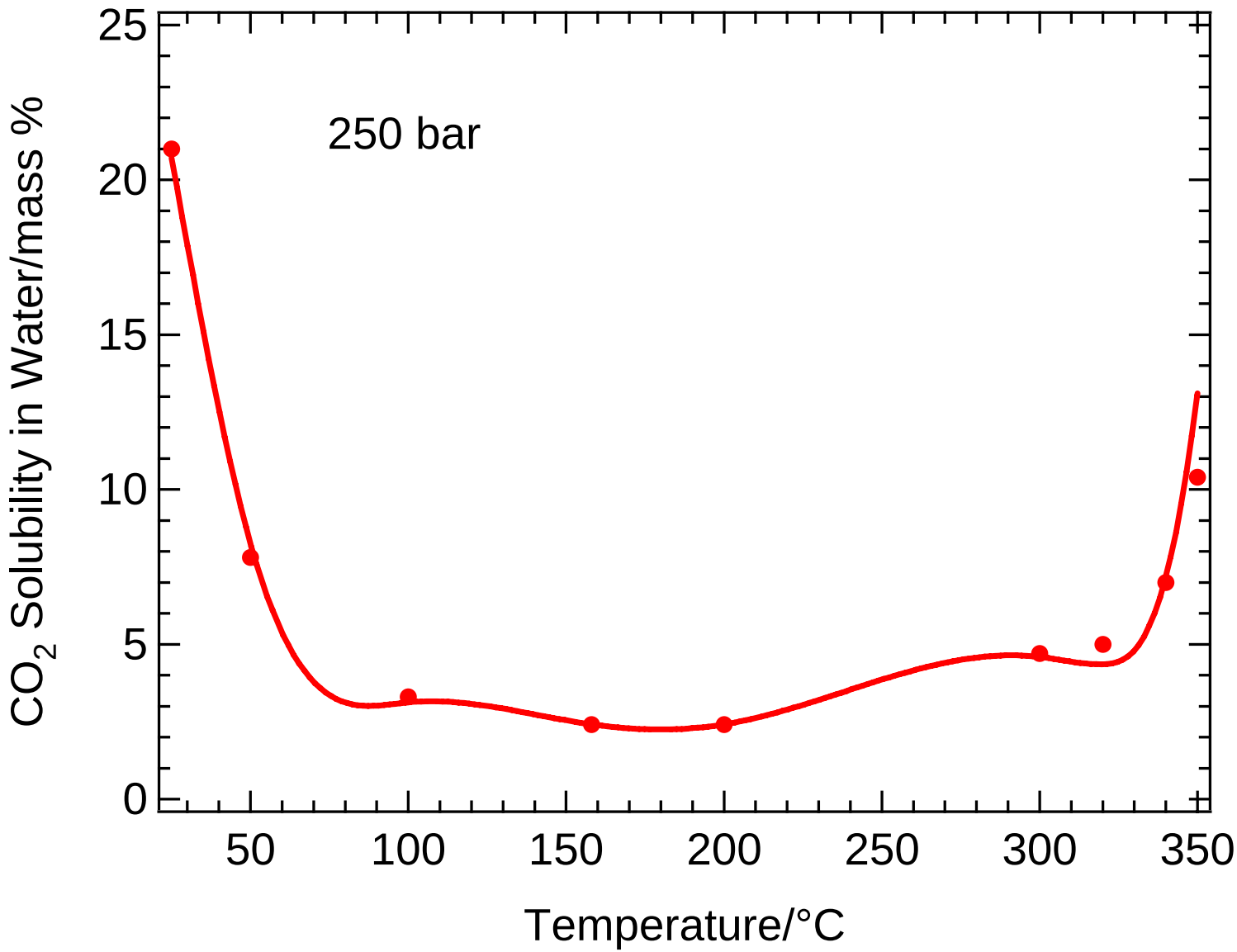
# Aquifer Development



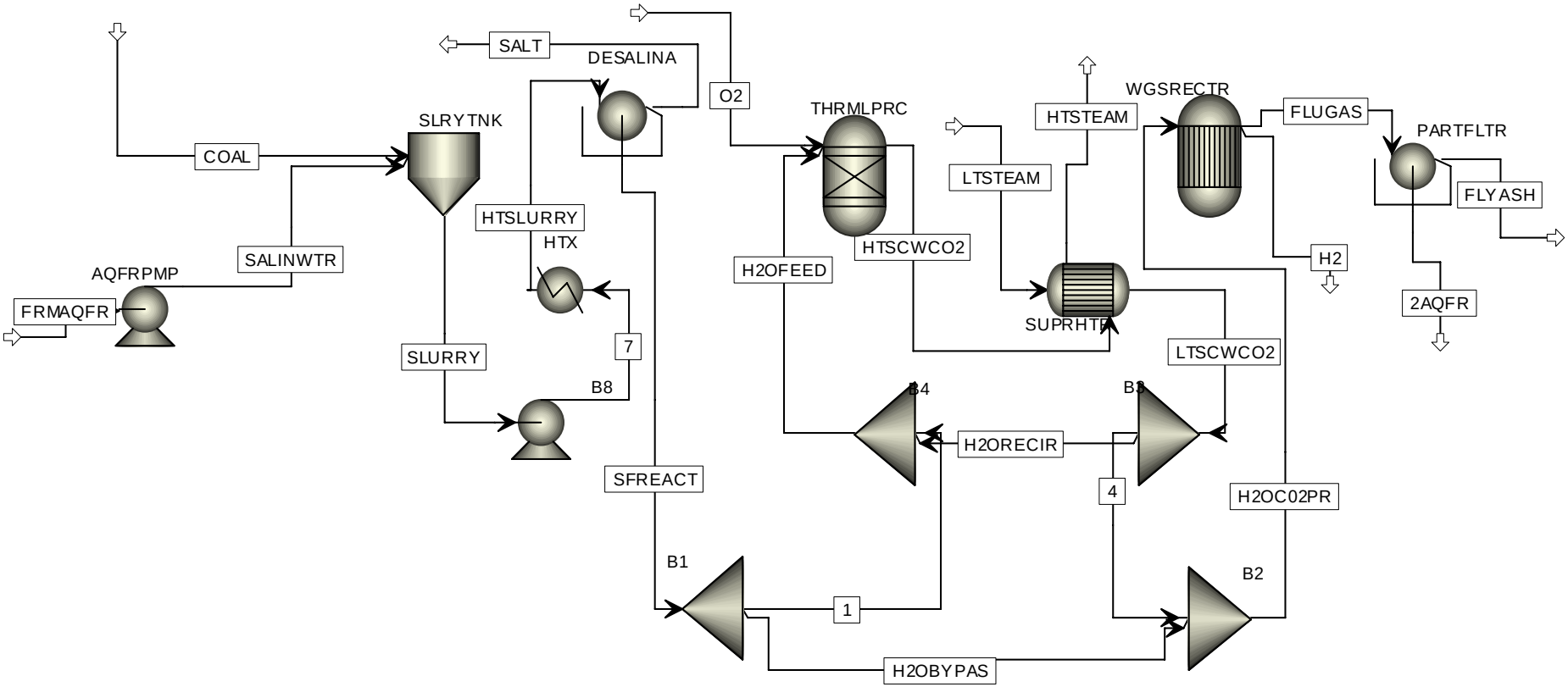
# Supercritical Properties

| | Atmospheric Pressure (0.1 MPa) | | Supercritical Pressure (25 MPa) | |
|---|---|---|---|---|
| | Liquid/Sat Vapor (25 °C) | Gas (374/2000 °C) | Fluid (liquid) (25 °C) | Fluid (374/2000 °C) |
| Density (kg/m$^3$) | 997/0.0231 | 0.335/0.0953 | 1008 | 513/23.6 |
| Comp. Factor | 2.13e-5/0.999 | 0.998/1.000 | 0.182 | 0.163/1.01 |
| Enthalpy (kJ/kg) | 105/2547 | 3225/7377 | 127 | 1836/7371 |
| $C_p$ (kJ/kg K) | 4.14/1.91 | 2.05/2.93 | 4.12 | 12.8/2.96 |
| $CO_2$ Solubility (mass %) | 0.157/NA | miscible | 21 | miscible |
| NaCl Solubility (mass %) | 27 | 2.7e-8/0 | 27 | 45/0 |
| Viscosity (μPa s) | 890/9.87 | 23.4/78.1 | 886 | 59.1/77.6 |
| Thermal Cond. (W/m K) | 0.607/0.0186 | 0.0517/0.292 | 0.618 | 0.415/0.255 |
| Oxygen Diffus. (cm$^2$/s) | 2.1e-5/3.86 | 0.403/14.9 | | 8.1e-4/0.012 |
| Dielectric Constant | 78.4/1.00 | 1.00/1.00 | 79.3 | 10.49/1.05 |
| Isothermal Comp. (1/bar) | 4.53e-5/31.6 | 1.00/1.00 | 4.26e-5 | 0.00292/0.00395 |

# $CO_2$ Solubility



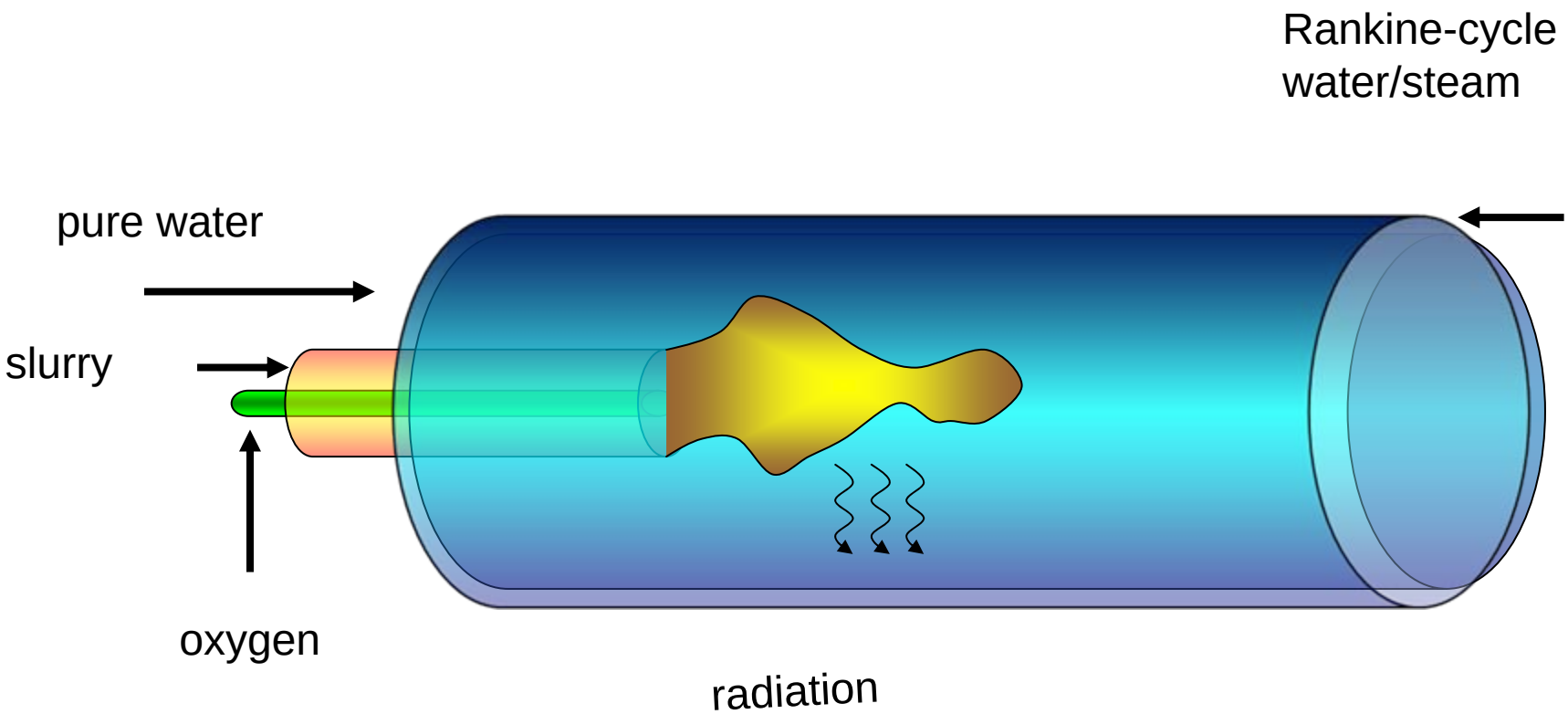
# Process Diagram



# Significant Process Features

- **Advantages**
  - **Inherently stable $CO_2$ storage**
  - **No $CO_2$ compression (coal slurry and liquid $O_2$ pumps), reduces parasitic compression loss by 3 orders of magnitude**
  - **Potentially higher steam temperatures (no pressure gradient across high-temperature heat exchangers)**
  - **Heat recovery from aquifer**
  - **No gaseous emissions of any type**
- **Disadvantages**
  - **Unknown and severe operating regime (materials, reactivities, fluid mechanics)**
  - **Heat/efficiency loss from reinjection, especially if at supercritical conditions**
  - **Potentially large water volumes**

# One Reactor Design



# Status

- **Preliminary LCA indicates possible substantial energy and $CO_2$ advantages compared to IGCC or oxyfuel w/ sequestration, depending primarily on aquifer temperature, water/fuel ratio, and steam temperature.**
- **Materials and reactor design seen as primary barriers**
- **Capital costs highly variable, depending on materials and reactor design decisions**
- **Several detailed scenarios in focus**

# Acknowledgements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