Wrap up

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- General Comments
- Panacea characteristics
- Examples of major accomplishments and implications
- Important issues

General Comments

- Bottlenecks to CCS:
  - Geological storage; beyond EOR to utilize brine formations; regulations
- Risk:
  - definition, reduction, control (monitoring and mitigation), communication
- “Baseline” bottom-line
  - climatic change will have significant impact to society and environment in the not-too-distant future
- “Baseline”
  - current practice of water flooding, groundwater recharge, together with seasonal weather changes are causing major groundwater variation, even without CO2 storage.

Panacea characteristics

- “Essentials”
- Focus on key factors
- Scientific interaction and education of experts
- Publications and conferences (high productivity: 49 papers in peer reviewed journals; participated in 14 conferences just in 2014)
- Education of young PhDs
- Development of communication strategies

Essentials of PANACEA

- Extensive modeling in aspects relevant to the long term fate of the stored CO_2 (trapping, leakage, pressure, chemical interactions etc.).
- Extensive data analysis and interpretation around two new sites (Heletz and Hontomin), analogues and large scale injection sites (Sleipner).
- Prototyping of novel monitoring technologies to be deployed in the field (shallow and deep).

Examples of major accomplishments and implications

- Treatments of heterogeneity
- Simple analytical, quasi-analytical solutions and numerical for many key processes
- Instabilities, fingering and fast paths; effects of residual saturations
- Analog data sets and model evaluation
- Monitoring tools: towards simultaneous THMC data
- Mitigation technologies

Treatments of heterogeneity

- Upscaling the multiphase flow and transport dynamics, and quantification of heterogeneity-induced mixing and dissolution dynamics.
- Upscaling mixing and chemical reaction rates for homogeneous and heterogeneous reactions.
- Quantifying the heterogeneity-induced uncertainty of the predicted large scale flow and transport behavior.
- Key (unconventional) parameters identified for site characterization; for example, those with impact on injectivity and storage capacity (sweep efficiency)

- Simple analytical, quasi-analytical solutions and numerical models for many key processes
  - all these alternative approaches are useful: analytical gives functional forms of parameters; numerical allows inclusion of detailed processes
- Instabilities, fingering and fast paths; effects of residual saturations
  - particularly important for proper interpretation of monitoring data

Analog studies

- Assemble comprehensive datasets for the **calibration, validation and verification** of conceptual and simulation models of the terms CO2 storage in deep seated saline aquifers.
- Construct a **comprehensive database** of pressure, temperature, stress directions and fluid composition **of CO2 contained and failed storage analogues** over geological time scales (St. Johns, Fizzy Field and Baren Borstal).
- Develop **a set of methodological approaches** for the determination of pressure, temperature, and stress history and fluid composition pertinent to long term CO2 storage characteristics of geological reservoirs.
- Evaluate possible **leakage scenarios** based on **analogues.**
- Analyze data and information from **artificial storage** underground facilities of natural gases, as potential analogues of the CO2 storage.

- Monitoring tools: towards simultaneous THMC data
  - To properly understand processes in the CO_2 storage formation, we need simultaneous T, H, M, C data
- Mitigation technologies
  - To include both modeling technologies to interpret the meaning of monitoring data and methods to mitigate potential leakage, both distributed and localized

Important Outstanding Issues
(personal view)

- **Proper site selection and characterization**
  - AOR (determination of Area of Review)
  - Key conventional and unconventional parameters (e.g., S_R, T, P, rock stresses; σ and λ)
  - Measurement techniques (data "support scale")
- **Monitoring, evaluation and mitigation**
  - Improve state of art of monitoring of both localized and distributed leakage
  - Modeling to understand monitoring data
  - Enhance state of art of mitigation technologies

Thank you for your attention