



Science for Energy – A Scientist's Perspective

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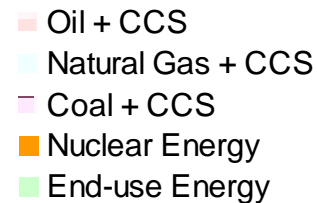
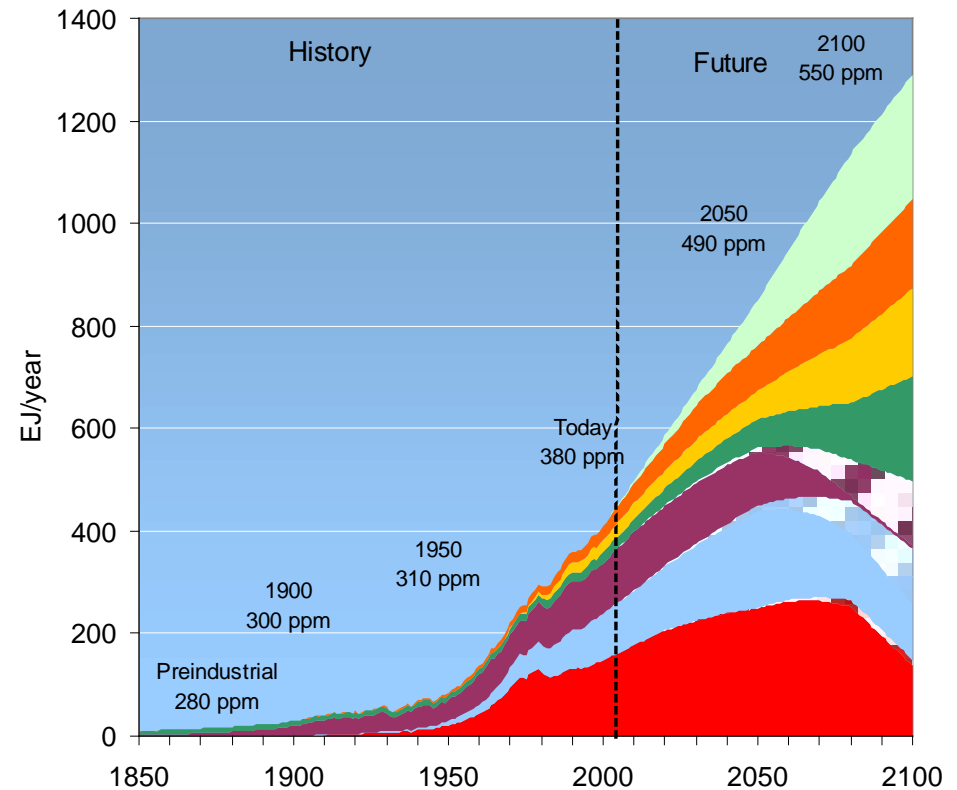
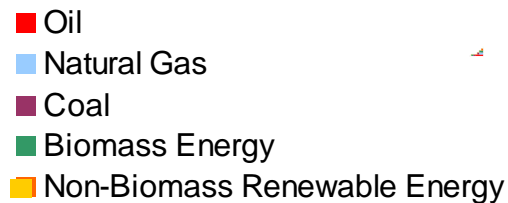
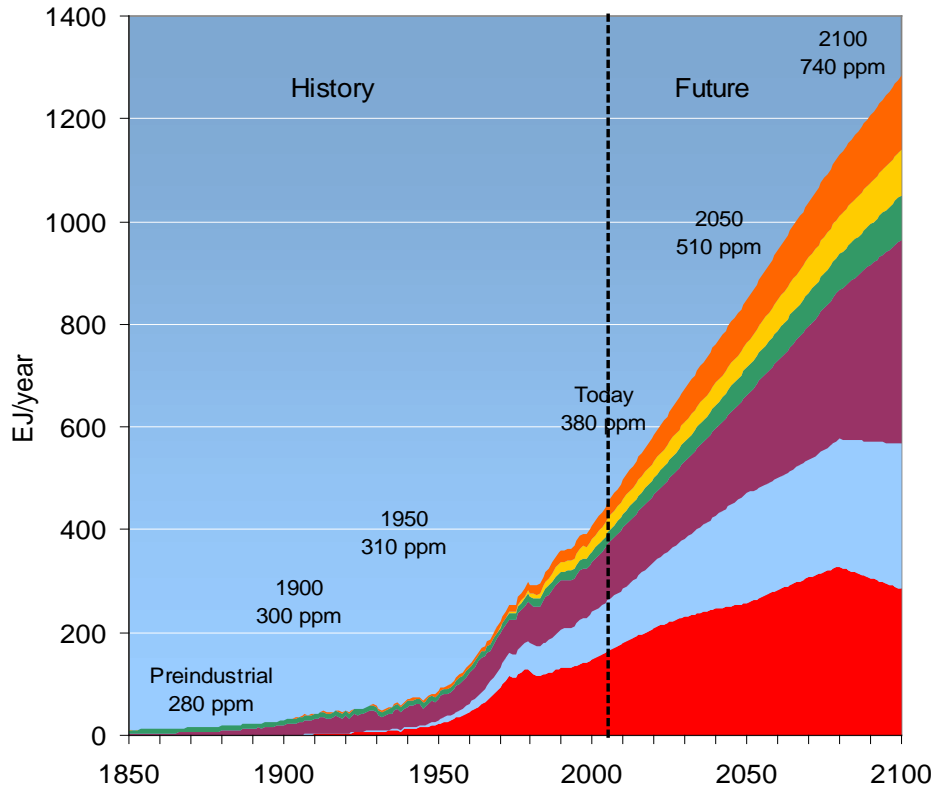
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Stabilization of CO₂ concentration means fundamental change to the global energy system



Required: decarbonize the energy system

- ▶ Efficiency and conservation
- ▶ Nuclear energy: fission and fusion
- ▶ Renewable energy, including large-scale energy storage
- ▶ Geoengineering, including carbon sequestration
- ▶ Science-based policy analysis - largely modeling climate change and impacts, adaptation & vulnerabilities



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The big scientific challenges

- ▶ Understand the dynamics of climate change and its impacts, and implications of technology and policy options for mitigation and adaptation
- ▶ Understand, control and engineer biological systems
- ▶ Develop a scientific understanding of sequestration options
- ▶ Understand and control matter at the quantum, atomic and molecular levels in a wide variety of environments
- ▶ Rapid, scalable, precision synthesis of multicomponent, multifunctional and multiscale materials
- ▶ Demonstrate the scientific and technical feasibility of fusion energy



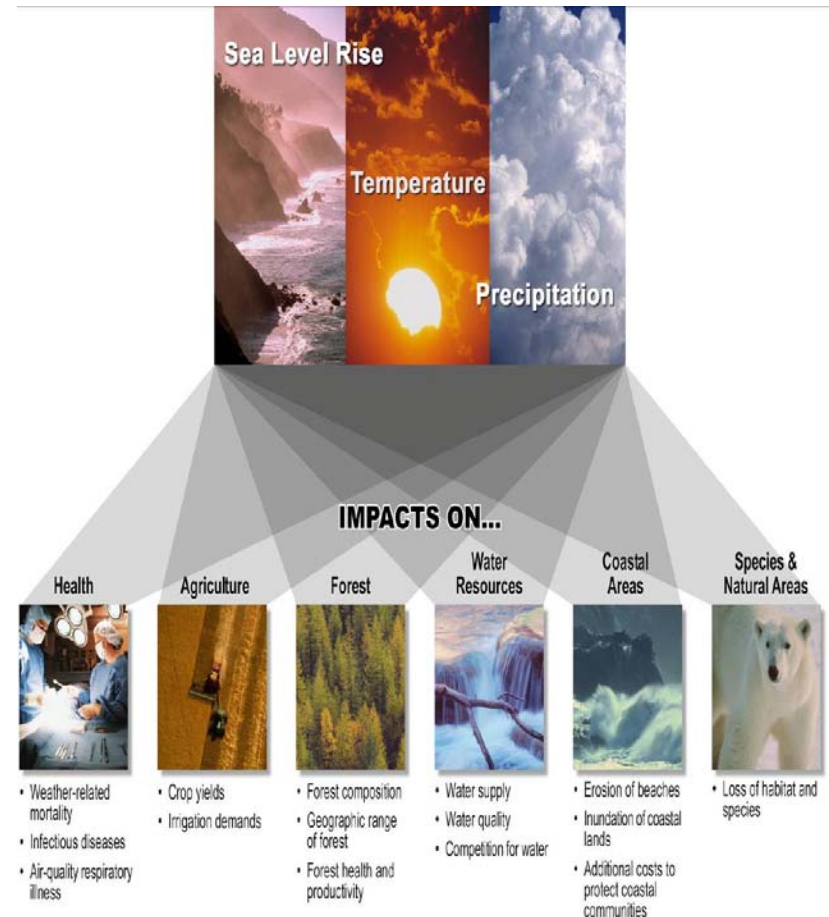
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Understand the dynamics of climate change and its impacts, and implications of technology and policy options for mitigation and adaptation

Needs:

- ▶ Climate models that simulate potential climate change and impacts at regional/local levels, including extreme events
- ▶ Models for evaluating different mitigation options for economic and technological feasibility and impact
- ▶ Modeling and analysis framework for understanding effects of different energy options on food security, economic systems, other sectors, and on climate change
- ▶ System models and analysis tools that enable development and use of regional/local climate change predictions for managing risk, climate change anticipation, planning and adaptation

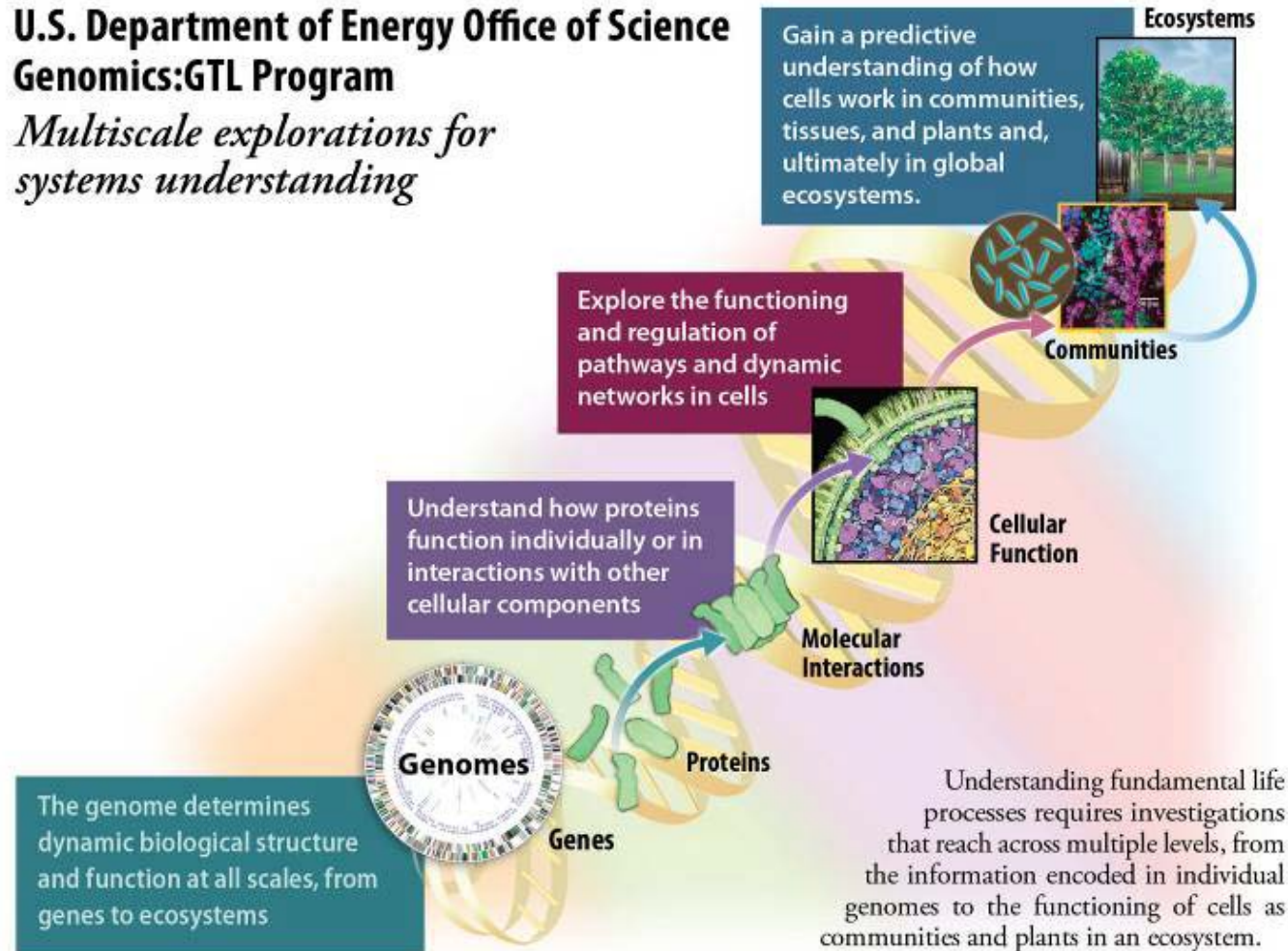


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Understand, engineer and control biological systems

**U.S. Department of Energy Office of Science
Genomics:GTL Program**
*Multiscale explorations for
systems understanding*



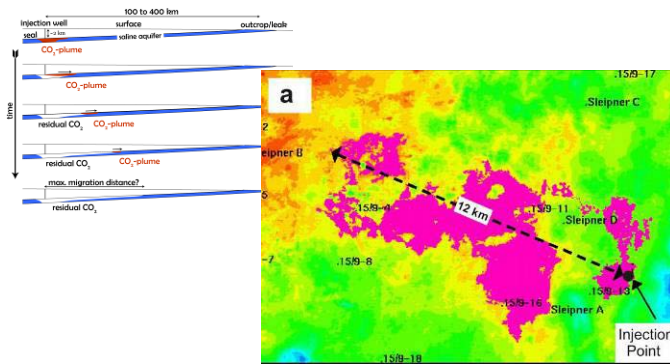
Understanding fundamental life processes requires investigations that reach across multiple levels, from the information encoded in individual genomes to the functioning of cells as communities and plants in an ecosystem.



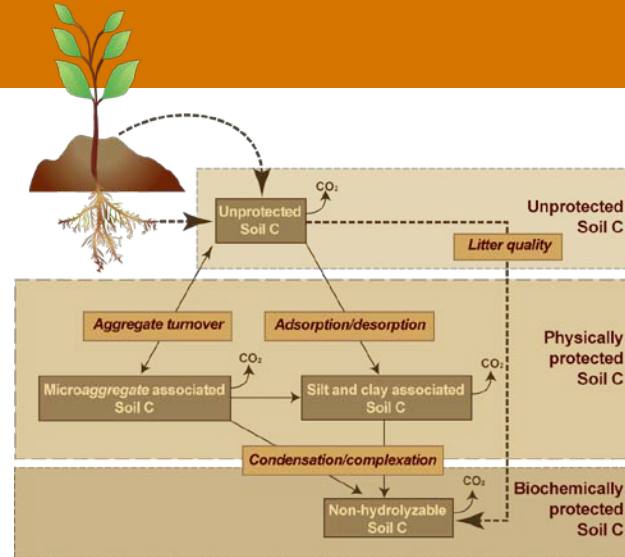
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Understand sequestration options



Mechanistic understanding of deep geologic processes in heterogeneous environments



Fundamental terrestrial control mechanisms



Mechanistic understanding of ocean processes

free air capture
of CO₂?



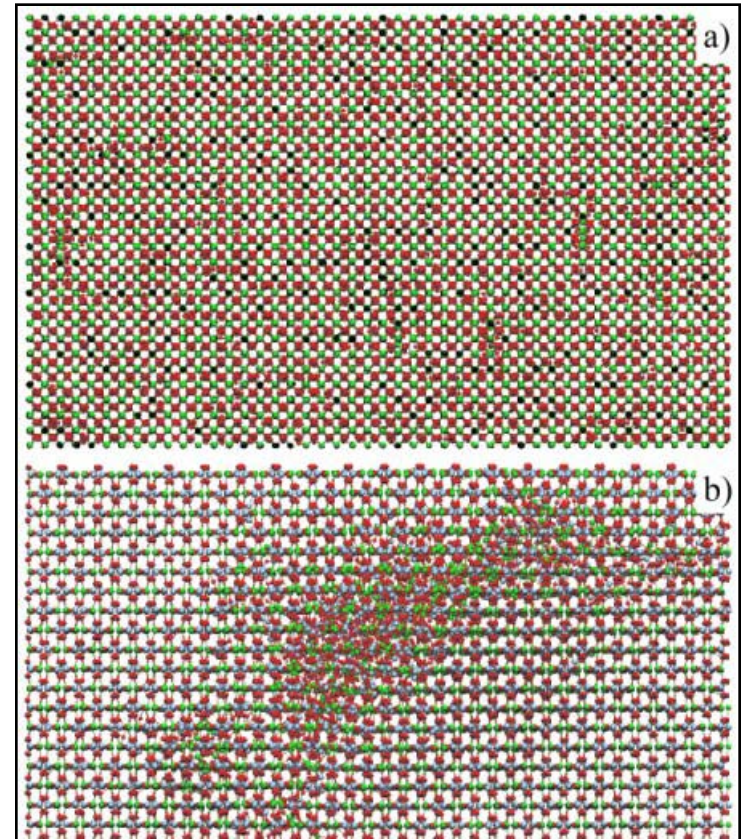
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Understand and control matter at the quantum, atomic and molecular levels in a wide variety of environments

► **Example: a self-healing material**

- Simulation reveals that the movement of oxygen atoms enabled by “designer defects” in a ceramic material heals radiation-induced damage.
- *In yttria-stabilized zirconia (top), the remaining defects are few and far between, having less impact on the properties of the material. In zircon (bottom), the defects are clustered.*

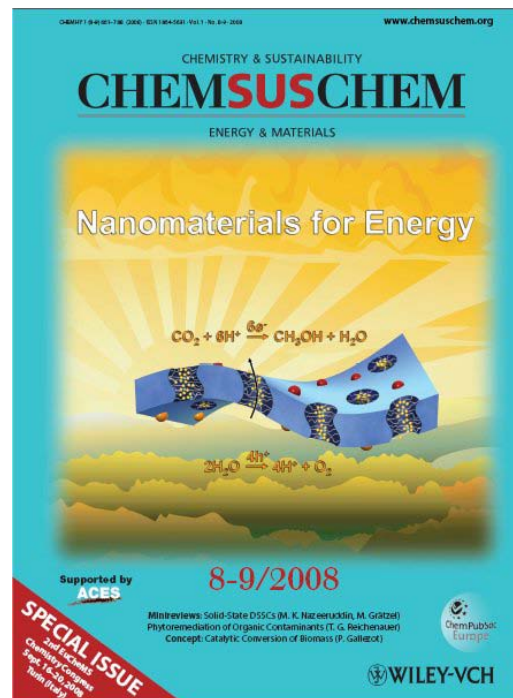


Devanathan, R and WJ Weber. 2008. "Dynamic annealing of defects in irradiated zirconia-based ceramics." *Journal of Materials Research* **23**(3):593-597.

Rapid, scalable, precision synthesis of multicomponent, multifunctional and multiscale materials

Needs

- ▶ Methods to synthesize controlled nanomaterials, including inexpensive solution growth and self-assembly approaches
- ▶ Integration of nano-sized architectures to achieve desired performance
- ▶ Advances in theory and computation to guide synthesis strategies
- ▶ Learning from biological systems



Liu, J, G Cao, Z Yang, D Wang, D DuBois, X Zhou, GL Graff, LR Pederson, and JG Zhang: ChemSusChem. 2008. 1. 676-697. Copyright Wiley-VCH Verlag GmbH & Co. KGaA.

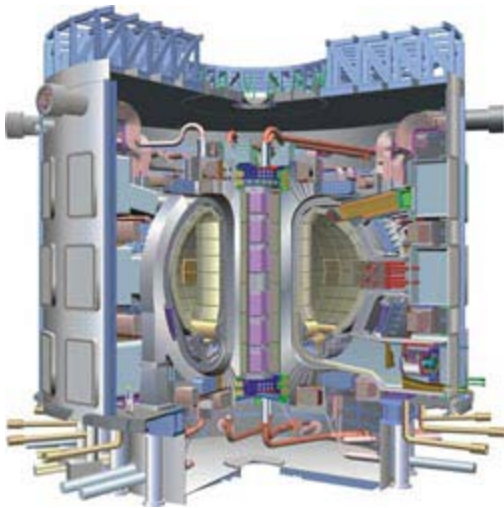


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Demonstrate the scientific and technical feasibility of fusion energy

- ▶ ITER: explore and test expectations for plasma behavior in the fusion burning plasma regime
- ▶ Integrated modeling of magnetically confined plasmas
- ▶ Resolution of materials “challenges”



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Concluding thoughts...

- ▶ Success requires that we focus on outcomes
- ▶ Development of new tools, especially theoretical and computational tools, is crucial
- ▶ Interdisciplinary partnerships are essential - especially between biologists, physical scientists and engineers
- ▶ International partnerships are important – especially for large projects
- ▶ robust STEM education is the foundation



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