“World Energy”
Policy Exercise with En-ROADS

Drew Jones, Climate Interactive
Our Plan Today

• Why we are here
• Who we are
• Your **Mission**
• Interactive intro to En-ROADS simulation
• You form teams, assign roles, confirm software
• End by 3:30
Our cutting-edge tools help people see what works to address the biggest challenges facing our lives on Earth.
Climate Interactive Project Partners

Financial and In-kind Supporters
- Zennström Philanthropies
- ClimateWorks Foundation
- Morgan Family Foundation
- Foundation for Global Community
- Rockefeller Brothers Fund
- Schlumberger Business Consulting

In-kind Supporters
- MIT Sloan Management
- Ventana Systems, Inc.
- Society for Organizational Learning
C-ROADS Scientific Review Panel

“C-ROADS… This very rapid simulation model reproduces the response properties of state-of-the-art three dimensional climate models very well … and with sufficient precision to provide useful information for its intended audience.”

- Dr. Robert Watson - Department for Environment, Food and Rural Affairs (DEFRA) and former chair, IPCC -- Panel Chair
- Dr. Eric Beinhocker - McKinsey Global Institute
- Dr. Klaus Hasselmann - Max-Planck Institut für Meteorologie
- Dr. David Lane - London School of Economics
- Dr. Jorgen Randers - Norwegian School of Management BI
- Dr. Stephen Schneider - Stanford University (deceased)
- Dr. Bert de Vries - Netherlands Environmental Assessment Agency, RIVM
NOTES AND INSIGHTS
Climate interactive: the C-ROADS climate policy model

John Sterman, a,b* Thomas Fiddaman, b,c Travis Franck, b,d Andrew Jones, b Stephanie McCauley, b Philip Rice, b Elizabeth Sawin b and Lori Siegel b


The climate policy challenge

In 1992 the nations of the world created the United Nations Framework Convention on Climate Change (UNFCCC) to negotiate binding agreements to address the risks of climate change. Nearly every nation on Earth committed to limiting global warming...
U.S. State Dept’s Jonathan Pershing Presenting C-ROADS Results to the UN
Intended Use of En-ROADS

• Designed to provide a rapid, broad-brushstroke, rigorous overview of the dynamics of energy supply and demand scenarios and the resulting climate change impacts.

• To support strategic conversations and offer dynamic insights about timing, feedback, and delays in the transformation of the energy system, through interactive simulation experimentation.

• Complement existing, more disaggregated, energy models.
Welcome to the “World Energy” Competition
Your Role

• Your team is a small energy policy think-tank making recommendations on global energy policy and investments to four judges.
  1. Oil company executive
  2. Agricultural laborer from a rural village in India
  3. Angela Merkel
  4. Sally Citizen
Strategies to Explore – One at a Time or Combinations

• **Fuel Mix**: Subsidies/Taxes, R&D breakthroughs, or Early retirement for
  – Natural gas
  – Coal
  – Renewables
  – Nuclear
  – A “New Tech” such as fusion or thorium fission

• **Energy efficiency**

• **GDP growth**
  – Short term
  – Long term

• **Other GHGs**: Land use, Methane, N₂O, and others

• **Policy**
  – Carbon price
  – Carbon emissions performance standard
Rough Schedule

• **Today** – Form teams and learn about your EnROADS simulation

• **Tomorrow** – Run simulations with your team

• **Wednesday** – Semi-finals: Compete against your peer think-tanks by presenting your one PPT slide

• **Friday** – Finals: Present to judges

(Details are in your Mission document)
Let’s explore the simulation

Software Operations and Conducting Experiments
In En-ROADS

• Things take time:
  – Commercialization, permitting, financing, and construction all take time.
  – Non-electrified end uses (e.g., cars and industry) can be electrified, but not instantaneously.

• Success builds success:
  – Costs of energy supplies fall as cumulative experience is gained.
  – Rising market share for the new tech builds familiarity, and broadens the reach of infrastructure, so that success feeds on itself.

• There are constraints:
  – Rising costs and scarcity of materials put limits on the pace of growth in new tech.
  – Coal, oil, and gas resources are limited.

• Demand and supply are linked:
  – Energy demand falls if energy prices rise, and likewise.
Guidelines

• Use the following slide as a template for your slide.
  – Include the same five pieces of content: team name, pithy title, list of proposals, one graph, and 2100 temperature

• You will not be able to include in your slide everything that is interesting about your proposal. Much will need to be handled verbally.

• You will have 9 minutes for your presentation
Rough Schedule

• **Yesterday**—Form teams and learn about your EnROADS simulation

• **Today**—Run simulations with your team

• **Tomorrow, Wednesday**—Semi-finals: Compete against your peer think-tanks by presenting your one PPT slide

• **Friday**—Finals: Present to judges

(Details are in your Mission document)
Your Mission: To Meet Five Goals

1. **Climate**. Make as much progress as possible towards limiting post-industrial temperature increase to two degrees C.

2. **Economy**. Support economic health. Least disrupt the economy and address poverty.

3. **Equity**. Fair for the poor and the rich.

4. **Environment**. Minimize non-climate-related harmful effects on the environment.

5. **Viability**. Could happen if human civilization was working at its best.

(1 is objective. 2-5 are more subjective.)
[Team Name]:[Pithy Version of Strategy]

Our recommendations

• [Specific action #1]
  – Using the name of the exact lever in En-ROADS

• [Specific action #2]

• [Specific action #3]

• [Specific action #4]

• [Specific action #5]

• [Specific action #6]

2100 Temperature Increase = [Your result]
Team Pacific: Nukes, Tax, and GDP

Our recommendations

- **Emissions price** $1.87 starting in 2080
- **Nuclear Subsidy** .2 starting in 2018
- **Other gases** .4
- **GDP Growth** Short term 5.0%/year
- **Renewables** Breakthrough cost reduction .38
- **REDD** .7

2100 Temperature Increase = 2.4 degrees C

(Not intended to be realistic proposals)
Your Resources

- Guide to the Control Panel for En-ROADS
- En-ROADS User Guide
- Mission document
- The A-Team and others
- 100+ page simulation reference guide with equations is online at En-ROADS site
- Your team’s intuition, common sense, and understanding of the energy and climate system
Invitation for feedback

- Focus on doing the exercise and playing your role fully
- And.... If you have feedback about the simulation, we are always open to learning how to improve it
  - Write it down and give it to us
  - Or apjones@climateinteractive.org
En-ROADS Energy System Structure
Framing, Modeling, Data, and Project Team

- Sonia Aggarwal, CWF
- Casey Cronin, CWF
- Tom Fiddaman, Ventana
- Travis Franck, CI
- Hal Harvey
- Drew Jones, CI

- Stephanie McCauley, CI
- Phil Rice, CI
- Beth Sawin, CI
- Lori Siegel, CI
- John Sterman, MIT
- Clara Vondrich, CWF
- Diana Wright

Funded primarily by:
Why? It takes time for New Tech to grow. There are long delays between R&D and displacement of coal, oil, and gas.

- **R&D success year** – 2020
- **Commercialization time** – 12 years
- **Construction time** – 5 yrs
- **Average lifetime** – 30 yrs
En-ROADS Simulation Structure

**Energy Supply**
- **Carbon intensity**
  - 8 types
  - Aging delays
  - R&D success
  - Prices, learning, complementary assets, resource avail

**Energy Demand**
- **Energy intensity**
- Stationary & mobile
- Elec & Non-elec
- Aging, efficiency, & retrofits

**Climate impacts**
- Total emissions
- Concentrations
- Cumulative Emissions
- Temperature Change
- Sea level rise

**Other impacts**
- Materials
- Units built
- Energy poverty

**GHGS from**
- Other gasses
- land use

**CO2 Emissions from Energy Production**

**Economy**
- GDP

**Policy/R&D**
- Carbon price
- Subsidies
- Technical Breakthrough
Energy Demand
- Capital growth
- Embodiment of demand in capital
- Price elasticity
- Energy efficiency
- Electricity/fuel choice

Low C Energy Sources
- Capital accumulation
  - Delays: proposal, permitting, construction, lifetime
- Cost of supply
  - Learning
  - Supply chain congestion
  - Availability

High C Energy Sources
- Capital accumulation
  - Delays: proposal, permitting, construction, lifetime
- Cost of supply
  - Learning
  - Supply chain congestion
  - Depletion

R&D
- Breakthroughs
- Commercialization delays
En-ROADS Energy Sources and Uses

- Petroleum
- Natural Gas
- Coal
  - Conv
  - CCS
- Renewables
  - Solar, Wind
  - Hydro
  - Biofuels
- Nuclear

Fuel Distribution

Stationary (Commercial, Residential, Industrial)
  - Electric
  - Non-Elec

Electricity Production

Transportation
  - Electric
  - Non-Elec
Energy Choice Structure

Total Energy
- Electricity
  - Elec. Coal
  - Elec. Oil
  - Elec. Gas
  - Elec. Biomass
  - Nuclear
  - Hydro
  - Other Renewable
  - New
- Fuels
  - Coal
  - Oil
  - Gas
  - Biomass
# Model Bounds

## What it is
- Energy accounting framework
- Choice of energy sources and carriers
- Energy intensity embodied in capital
- Learning-by-doing
- Depletion & flow supply constraints

## Limitations
- No growth effects from energy costs
- Not a full cost benefit accounting (e.g., neglects opportunity costs of some energy choices)
- No tax accounting or double dividend
- No labor or money, such as in some economic models
Some Prominent IAMs We Seek to Complement

- IGSM – dynamic general equilibrium
- MERGE – intertemporal optimization
- MiniCAM – partial equilibrium, intertemporal optimization
- MESSAGE – energy system optimization
- ASF – hybrid
- AIM – hybrid top-down/bottom-up
- WorldScan – general equilibrium
- DEMETER – top-down optimization
- ENTICE – intertemporal optimization
- MIND – hybrid energy/endogenous growth
- RICE – intertemporal optimization

Source: AR4 WG3 Technical Summary
We Compare our Future Scenarios to Those of Other Simulations

CO2 FF Comparisons to EMF and EIA
We Also Compare our Simulation Output to Historical Data

(in this case, BP analysis and WEO data)
We Also Show Non-Climate Outputs and Impacts
Simulation Interface
Structure

Source attractiveness

Orders → Energy Production Capacity Under Construction

Acquisition → Energy Production Capacity in Use

Retirements → Accelerated retirement
Structure
Structure

Energy Production Capacity Under Construction → Acquisitions → Energy Production Capacity in Use → Retirements

- Orders
- Source attractiveness
- Source cost
- Internal source cost
- Breakthrough cost reduction
- Progress down learning curve
- Progress ratio
- Network effect
- Cumulative production

Purple = assumptions
Blue = Actions or Policies

Learning
Even more troubling, the gas boom starves the reinforcing learning process for Zero – C energy.
Renewables don’t get the chance to build up complementary infrastructure

Relative attractiveness of renewables

Percent of new capacity met by renewables

Installations of renewables

Complementary infrastructure and resources

R2 - Network
Both Reinforcing loops together

- Percent of new capacity met by renewables
- Installations of renewables
- Relative attractiveness of renewables
- Relative price of renewables
- Complementarity infrastructure and resources
- Progress down learning curve

R1 - Learning
R2 - Network
Two Motivations for Our Approach to Simulations

• Policymakers have limited and flawed mental models of the energy and climate system
• People improve mental models well through user-driven interaction with flexible, transparent simulations
Our Questions for En-ROADS

• #1. How much might technological breakthroughs contribute to addressing climate change?
  – Technological breakthroughs might include
    • R&D and scale-up of a new zero-carbon energy supply
    • New approach to nuclear energy
    • Renewables
    • Inexpensive natural gas

  – What would we have to assume – about the technology, the economy, and the world - for a breakthrough to grow with enough speed and scale to deliver climate goals?
Our Questions

• #2 What else, if anything, beyond such breakthroughs might be necessary to achieve climate goals?
  – To what extent are success with energy efficiency, demand reduction, price signals, and other policy also required?
Features of En-ROADS

• Transparent
• Flexible
• Highly aggregated
  – (Complementing, not supplanting, the EMF22 and other models)
• For learning and grounded discussion, not point *predictions*
Counter-intuitive Dynamics of En-ROADS

1. There is no silver bullet
2. To achieve ~2 degrees, it requires “silver buckshot” – success with most everything
3. When low-carbon supply is encouraged and thrives, we still burn fossil fuels
4. New technologies thrive via reinforcing “learning” feedback loops
5. Energy efficiency starves growth in renewables
6. Inexpensive energy (renewables, nuclear, new tech...) increases energy demand via modest “rebound effect”
7. A gas boom absent a C price starves renewables and mitigates little
8. A brand new tech is too delayed to contribute much on its own
9. The transition from hi-carbon to low-carbon takes decades due to long lifetime of fossil fuel capital infrastructure
10. In a hi-mitigation scenario, more nukes/new-tech/renewables just displaces the other low-c sources
11. “Other gases” reduction mitigates a good bit
12. GDP changes are high leverage
13. A carbon price is high leverage because it changes fuel mix and reduces energy demand
14. REDD is lower leverage in long term than most expect
Some Prominent IAMs We Seek to Complement

- IGSM – dynamic general equilibrium
- MERGE – inter-temporal optimization
- MiniCAM – partial equilibrium, inter-temporal optimization
- MESSAGE – energy system optimization
- ASF – hybrid
- AIM – hybrid top-down/bottom-up
- WorldScan – general equilibrium
- DEMETER – top-down optimization
- ENTICE – inter-temporal optimization
- MIND – hybrid energy/endogenous growth
- RICE – inter-temporal optimization

Source: AR4 WG3 Technical Summary
Socialization 1

• Modelers and Scholars
  – **Andrew Ford**, WSU and energy modeling consultant.
  – **Jake Jacoby and John Reilly** of the MIT Joint Program
  – **Jake Jacobson**, Idaho National Lab
  – **Zhao Xiusheng** Tsinghua University
  – **Erling Moxnes**, Univ of Bergen, Norway
  – **Bill Moomaw**, Tufts University
  – **Yanna Antypas**, EIA.
Socialization 2

• Government
  – US DOE: Graham Pugh, Rick Duke, David Sandalow
  – Senate: Climate staff Tom Dower and Ann Zulkosky
  – US State Department: Trigg Talley and Raffi Ballian
    (meeting with Jonathan Pershing in February)
Socialization 3

• Other Organizations
  – Climate Progress, Joe Romm
  – C2ES (formerly Pew): Jay Gulledge and Janet Peace
  – UN Secretary General and SE4ALL project
  – Tracy Terry and Bipartisan Policy Center
  – Schlumberger Business Consulting, Paris
  – World Wildlife Fund, Lou Leonard
  – David Turnbull, Climate Action Network, CAN
The En-ROADS World Is In Many Ways, A Best Case World

• We want to be confident that if the scale up of New Tech appears to be unable to deliver climate goals on its own in our ‘what if world’, then it probably won’t be able to in the real world, either.
Best Case Factors

- Once a breakthrough is discovered, new projects don’t fail.
- The market for the New Tech has no national boundaries or conflicting national interests to slow diffusion.
- The timing and degree of cost reduction of the breakthrough is not constrained.
- There are no cash flow or financing constraints on expansion.
- There are no constraints to the flow of labor between sectors.
- There are no unexpected impacts of the new technology that lead to public resistance, permitting delays or increased costs.
More information

• Model is copyright 2012 by Climate Interactive and Ventana Systems
  – www.ventanasystems.com/
  – www.climateinteractive.org

• Documentation and other materials at:
  – http://www.climateinteractive.org

• Project blog
  – climateinteractive.wordpress.com/

• For an interactive, online demonstration, contact
  – apjones@climateinteractive.org
  – bethsawin@climateinteractive.org