Engineering Solutions to Global Warming - a Mission for Mines

Dag Nummedal

CSM Office of Research (retired)

Golden, CO, December 1st, 2017

NAS 4th National Climate Assessment

3 **November 2017: 4th U.S. National Climate Assessment: Reinforcing the Scientific Consensus**

Volume 1 of the Congressionally mandated 4th U.S. National Climate Assessment (NCA) was released earlier this month. Led by scientists working at NOAA, the Climate Science Special Report (CSSR) is the work of many of the nation's most accomplished climate scientists. A core blueprint used to inform the public and craft public policy decisions to address climate change, the report is a rigorously evaluated document that has gone through several rounds of peer review by NOAA and NASA, as well as review by the National Academy of Sciences.

The report's conclusions are unassailable:

- Carbon pollution is warming the planet at an unprecedented rate producing global changes to the Earth's climate and systems
- These climate shifts are now being seen across every corner of the globe and in every ecosystem
- Extreme weather events are being intensified by climate change and the damages will grow ever more devastating if swift decisive action to address the contributors to that change are not taken
- To meet the goals of the global Paris Agreement on climate change, humanity must rapidly take action to address other factors contributing to the changes in the Earth's climate

- Final report scheduled for release in December 2018

UN COP 23 in Bonn, 2017

- Main finding: climate change is real, it is us, and it is serious

- President Trump's announced intention to pull the US out of this agreement will take, at least ~ 1-2 year to work its way trough the system.

- In the meantime: Actions by US state governors, majors and business leaders have announced that they stay in the agreement. Together, those entities represent the world's 4th largest economy.

The Paris Goals (COP 21, 2015), as amended in Marrakech (2016) and Bonn (2017)

50% chance of limiting warming to below 1.5^{o} C by 2100

Ultimate temperature increase below 2^{o}C and reduce to 1.5^{o} C by 2100

To meet those two goals, <u>global CO_2 emissions must peak by 2020</u>!

And, gross emissions decline trajectory must follow this trajectory:
Now (2017): 36 $GtCO_2$/yr
2020: 40
2030: 24
2040: 14
2050: 5

How do we get there ?
1 – From Drawdown
The Most Comprehensive Plan Ever Proposed to Reverse Global Warming

Paul Hawken, Ed. Penguin © 2017

Ranking of solutions by potential impact	Atmospheric CO_2 reduction, Gt	Primary effects
1. Refrigeration	90	Recover refrig. gases (HFC, CFC)
2. Wind turbines (onshore)	85	2.9c/kwh vs. 3.8 c/kwh for NG
3. Reduced food waste	71	35% food discarded (hi-income)
4. Plant rich diet	66	Reduce cows; they "emit" gas
5. Tropical forests	61	Reforestation
6. Educating girls	60	Edu. women - fewer children
7. Family planning	60	…
8. Solar farms	37	10x increase by 2027

There are 80 solutions categories in total in this evaluation. All are engineering challenges – Mines "responsibilities"

Drawdown Aspen Forum scheduled for Summer 2018

How do we get there – 2

Johan Rockstrom et al.,
Stockholm Resiliency Center

- Eliminate fossil-fuel subsidies (currently at $500 billion/yr) by 2020
- Moratorium on new coal-based energy development (“unabated”)
- Better carbon management on farms and civil society overall
- Improved energy efficiency by 40-50% by 2030
- Implement a carbon price, starting at $50/ton now and rise to $400/ton by mid-century
- By mid-century, expect that coal will have left the energy industry
- Some cities (e.g. Copenhagen and Hamburg, will be fossil fuel free by 2050)
- Expect phase-out internal combustion engines by 2030 in Norway, Sweden, Denmark, Germany and the Netherlands (may take till 2040)

An Excellent Webinar Series

The Energy Security and Sustainability Forum

Edward Saltzberg (Arizona State University)
Managing Director
www.ssfonline.org
esaltzberg@securityandsustainabilityforum.org

Most recent: The 4th National Climate Assessment (National Academy of Sciences, *in review*) and Outcomes from the UN Climate Change Conference in Bonn

Thursday, November 30, 2017
1:15 - 2:45 p.m. Eastern Time

How do we get there
2 – From Carbonbrief

https://www.carbonbrief.org/explainer-10-ways-negative-emissions-could-slow-climate-change

- Negative carbon emissions from re-forestation and future approaches
- Replacement of coal burning power plants with natural gas (US and China, good examples)
- Reduced emissions of natural gas (methane) itself
- Growth in renewables!
- Carbon capture and sequestration (CCS)
- CO_2 EOR
- New carbon (CO_2) based products (materials, chemicals, fuels
- Emerging Industry perspective: oil and gas “too valuable to burn” (Dow/DuPont very explicit on this). “Diamonds from the sky” (USC ‘slogan’)

How do we get there

3 – more from Carbonbrief

Biochar. Biochar is the name given to charcoal that is added to soils rather than burned as a fuel. The charcoal is produced by burning biomass, such as wood, crop wastes and manure, while cutting off the supply of oxygen. E.g. the Terra Preta ("black earth") soils in Brazil,
BECCS. Bio-energy with carbon sequestration (CCUS – below). Biomass, as it grows, draws CO_2 out of the atmosphere, and then the CCUS process captures and stores what CO_2 is produced.
Blue carbon habitat restoration. Restoring salt marshes, mangroves and seagrass beds.
Carbon capture directly from air (rapidly advancing!)
Spraying sulfate aerosols into the atmosphere (? good idea?)
Carbon negative oil (use CO_2 from biofermenters for EOR)
Others: building with biomass, cloud and ocean 'seeding' with alkali, enhance ocean productivity, enhanced weathering
Afforestation and reforestation. Allowing natural regrowth, and planting new forests. This is financially supported by the COP21 UN Clean Development Mechanism

Some Examples of CSM Direct GHG Emissions Reductions Research Projects

Action: develop complete inventory

- Novel CO_2 capture and separation materials
- CO_2 conversion technologies (e.g. to materials, chemicals)
- Policy, legal and financial frameworks for decision making related to CO_2 management
- Use of CO_2 for enhanced oil recovery
- Geomechanical effects of large-scale underground CO_2 storage
- Quantificaton of methane emissions from the natural gas industry and its reduction!
- New joint Mines/CSU test facility: METEC. Purpose: eliminate methane leakage from the natural gas industry.

Satellite and Aircraft Emissions Monitoring

JPL Operated - Orbiting Carbon Observatory – 2. This is not measuring CO_2 directly; but the intensity of the sunlight reflected from the presence of CO_2 in a column of air. The OCO-2 instrument is using a diffraction grating (like the back of a compact disk) to separate the incoming sunlight into a spectrum of multiple component colors.
The instrument measures the intensity of three relatively small wavelength bands (Weak CO_2, Strong CO_2 and Oxygen O_2) from the spectrum. By simultaneously measuring the gases over the same location and over time, OCO-2 will be able to track the changes over the surface over time.

NOAA Boulder + INSTAAR (CU-B). Isotope lab separation of fossil (^{13}C only) versus modern sources of emissions (variable ratios of $^{13}C/^{14}C$)

Partnership under development between
NASA (JPL, Pasadena), NOAA/INSTAAR (Boulder) and Mines

That’s All, Folks!