|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario name** | **Description** | **Degrees of warming/ forcing/ emissions** | **Base carbon tax** | **Timeframe** | **Carbon tax escalation rate** | **With & Without BECCS** | **GCAM** | **GCAM-USA** | **Ref** |
| SSP1 | Sustainability   * Good progress towards sustainable development * Stabilizing population – 6.9 bln in 2100 * Decreasing income inequality ($46,306) * Early MDG achievement * Low resource intensity and fossil fuel dependency; High renewables preference * Strong int’l governance and local institutions * Well managed urbanization * Environmentalism   Technical change on extraction cost (% per year): Coal - 0.5%, Gas - 0.5%, Conv. oil - 0.5%, Unconv. Oil - 0%.  Cost Adder in 2100 ($/GJ): Coal - $1.37, Gas - $0.14, Conv. oil - $0.20, Unconv. Oil - $0.21.  Final energy demand in 2050 is limited to 10–30% above 2010 levels  Bioenergy use is increased by 1–5% per year between 2020 and 2050 in 1.9 W m−2 scenarios | **Radiative forcing n 2100 - 1.9 W m−2**  GHG emissions peak before 2030  Degrees of warming – 1.5C in 2100, Exceedance probability in 2100 (%) – 28 (GCAM4)  Exceedance probability over 21st century (%) – 57 (GCAM4)  Degrees of warming – 2C in 2100, Exceedance probability over 21st century (%) – 11 (GCAM4)  Global non-CO2 emissions in 2100 (GtCO2-eq yr–1):  1) N2O – 1 (GCAM)  2) CH4 – 3 (GCAM)  Mainly from agriculture  Bioenergy is used in large amounts and this can raise concerns for food security or biodiversity. Bioenergy use is increased by 1–5% per year between 2020 and 2050  Cumulative CO2 emission reduction from baseline in the 2020–2100 period for the 1.9 W m–2 scenarios (GtCO2) – 3,400 (GCAM)  **Global CO2 emissions and radiative forcing of SSP scenarios with the selected CMIP6 Scenario MIP subset in 2100:**  1)Radiative forcing n 2100 – 1.9 W m−2  Global CO2 emissions (GtCO2) in 2100 – (-19)  2) Radiative forcing n 2100 – 2.6 W m−2  Global CO2 emissions (GtCO2) in 2100 – (-8) | Prices over the 2020–2100 period discounted to 2010 with a 5% discount rate  **Radiative forcing n 2100 - 1.9 W m−2**  Carbon price - 20-30$/tCO2 (GCAM)  **Radiative forcing n 2100 - 2.6 W m−2**  Carbon price - 5-10$/tCO2 (GCAM)  **Radiative forcing n 2100 - 3.4 W m−2**  Carbon price - 2-5$/tCO2 (GCAM)  **Radiative forcing n 2100 - 4.5 W m−2**  Carbon price - 1-2$/tCO2 (GCAM) | 2020–2100 |  | BECCS deployment over the twenty-first century - 150–700GtCO2  Average annual CO2 storage from BECCS for the 1.9 W m–2 scenarios for the 2020–2100 period (GtCO2 yr–1) – 5.5 (GCAM) | The GCAM SSPs will be released as part of the core in a few months. ! This release will include input and configuration files to generate  reference cases for all 5 SSPs and policy cases for 4 of 5 SSPs.  ! However, the results using this release will not exactly match the official SSPs because the new release will use the most updated version of GCAM. The official SSPs branched from the core in December 2014 and include only limited updates to the model since that point.  ! We do plan to document the differences between the official GCAM SSPs and this release.1 | GCAM4 | 1,2 |
| SSP2 | Middle of the Road   * Current trends continue * Moderate population growth – 9 bln in 2100 * Slowly converging incomes between industrialized and developing countries * Delayed MDG achievement * Reductions in resource and energy intensity at historic rates * Environmental degradation   Technical change on extraction cost (% per year): Coal – 0.5%, Gas – 0.5%, Conv. Oil – 0.5%, Unconv. Oil – 0.5%.  Cost Adder in 2100 ($/GJ): Coal - $0.27, Gas - $0.14, Conv. Oil - $0.20, Unconv. Oil - $0.21.  Final energy demand in 2050 is limited to 10–40% above 2010 levels | **Radiative forcing n 2100 – 1.9 W m−2**  GHG emissions peak before 2030  Degrees of warming – 1.5C in 2100, Exceedance probability in 2100 (%) – 32 (GCAM4)  Exceedance probability over 21st century (%) – 81 (GCAM4)  Degrees of warming – 2C in 2100, Exceedance probability over 21st century (%) – 23 (GCAM4)  Global non-CO2 emissions in 2100 (GtCO2-eq yr–1):  1) N2O – 4 (GCAM)  2) CH4 – 6 (GCAM)  Mainly from agriculture  Bioenergy is used in large amounts and this can raise concerns for food security or biodiversity. Bioenergy use is increased by 1–5% per year between 2020 and 2050  Cumulative CO2 emission reduction from baseline in the 2020–2100 period for the 1.9 W m–2 scenarios (GtCO2) – 5,450 (GCAM)  **Global CO2 emissions and radiative forcing of SSP scenarios with the selected CMIP6** **Scenario MIP subset in 2100:**  1) Radiative forcing n 2100 - 4.5 W m−2  Global CO2 emissions (GtCO2) in 2100 – 10 | **Radiative forcing n 2100 - 1.9 W m−2**  Carbon price - 20-30$/tCO2 (GCAM)  **Radiative forcing n 2100 - 2.6 W m−2**  Carbon price - 10-20$/tCO2 (GCAM)  **Radiative forcing n 2100 - 3.4 W m−2**  Carbon price - 5-10$/tCO2 (GCAM)  **Radiative forcing n 2100 - 4.5 W m−2**  Carbon price - 5-10$/tCO2 (GCAM)  **Radiative forcing n 2100 - 6.0 W m−2**  Carbon price - 1-2$/tCO2 (GCAM) | 2020-2100 |  | BECCS deployment over the twenty-first century - 400–975GtCO2  Average annual CO2 storage from BECCS for the 1.9 W m–2 scenarios for the 2020–2100 period (GtCO2 yr–1) – 12 (GCAM) |  |  | 1 |
| SSP3 | Fragmentation   * Rapid population growth – 12.7 bln in 2100 * Slow economic growth * Failing to achieve MDG * High resource intensity and fossil fuel dependency * Low investments in technology development and education * Unplanned settlements * Weak int’l governance and local institutions   Technical change on extraction cost (% per year): Coal – 1.0%, Gas - 0.5%, Conv. oil - 0.5%, Unconv. Oil – 0.5%.  Cost Adder in 2100 ($/GJ): Coal - $0.0, Gas - $0.14, Conv. oil - $0.20, Unconv. Oil - $0.21. | Radiative forcing n 2100 - 2.6 W m−2 is unachievebale  **Global CO2 emissions and radiative forcing of SSP scenarios with the selected CMIP6 Scenario MIP subset in 2100:**  1) Radiative forcing n 2100 - 7.0 W m−2  Global CO2 emissions (GtCO2) in 2100 – 82 |  |  |  |  |  |  | 1 |
| SSP4 | Inequality   * Increasing income inequality within and across countries: High – 0.9 bln, Medium – 2.0 bln, Low – 6.4 bln. * Effective governance controlled by a small number of rich global elites * Most of populations with limited access to higher education and basic services * Energy tech R&D made by global energy corporations * Low social cohesion   Technical change on extraction cost (% per year): Coal – 0.5%, Gas - 1%, Conv. oil - 1%, Unconv. Oil – 2%.  Cost Adder in 2100 ($/GJ): Coal - $0.27, Gas - $0.71, Conv. oil - $0.98, Unconv. Oil - $1.06. | **Global CO2 emissions and radiative forcing of SSP scenarios with the selected CMIP6 Scenario MIP subset in 2100:**  1) Radiative forcing n 2100 - 3.4 W m−2  Global CO2 emissions (GtCO2) in 2100 – (-18)  2) Radiative forcing n 2100 - 6.0 W m−2  Global CO2 emissions (GtCO2) in 2100 – 20 | **Radiative forcing n 2100 - 1.9 W m−2**  n/a  **Radiative forcing n 2100 - 2.6 W m−2**  Carbon price - 20-30$/tCO2 (GCAM)  **Radiative forcing n 2100 - 3.4 W m−2**  Carbon price - 10-20$/tCO2 (GCAM)  **Radiative forcing n 2100 - 4.5 W m−2**  Carbon price - 5-10$/tCO2 (GCAM)  **Radiative forcing n 2100 - 6.0 W m−2**  Carbon price - 1-2$/tCO2 (GCAM) | 2020-2100 |  |  |  |  | 1 |
| SSP5 | Conventional Development   * Rapid economic development * Stabilizing population * Consumerism * High fossil fuel dependency * Eradication of extreme poverty and universal access to education and basic services * Highly engineered infrastructure and ecosystems   Technical change on extraction cost (% per year): Coal – 2%, Gas - 2%, Conv. oil - 2%, Unconv. Oil – n/a.  Cost Adder in 2100 ($/GJ): Coal - $0, Gas - $0, Conv. oil - $0, Unconv. Oil - $0.  Final energy demand in 2050 is limited to 45–75% above 2010 levels | **Radiative forcing n 2100 - 1.9 W m−2**  GHG emissions peak before 2030  Degrees of warming – 1.5C in 2100, Exceedance probability in 2100 (%) – 34 (GCAM4)  Exceedance probability over 21st century (%) – 75 (GCAM4)  Degrees of warming – 2C in 2100, Exceedance probability over 21st century (%) – 18 (GCAM4)  Global non-CO2 emissions in 2100 (GtCO2-eq yr–1):  1) N2O – 2 (GCAM)  2) CH4 – 4 (GCAM)  Mainly from agriculture  Bioenergy is used in large amounts and this can raise concerns for food security or biodiversity. Bioenergy use is increased by 1–5% per year between 2020 and 2050  Cumulative CO2 emission reduction from baseline in the 2020–2100 period for the 1.9 W m–2 scenarios (GtCO2) – 7,050 (GCAM)  **Global CO2 emissions and radiative forcing of SSP scenarios with the selected CMIP6 Scenario MIP subset in 2100:**  1) Radiative forcing n 2100 - 8.5 W m−2  Global CO2 emissions (GtCO2) in 2100 – 126 | **Radiative forcing n 2100 - 1.9 W m−2**  Carbon price - 30-40$/tCO2 (GCAM)  **Radiative forcing n 2100 - 2.6 W m−2**  Carbon price - 20-30$/tCO2 (GCAM)  **Radiative forcing n 2100 - 3.4 W m−2**  Carbon price - 10-20$/tCO2 (GCAM)  **Radiative forcing n 2100 - 4.5 W m−2**  Carbon price - 5-10$/tCO2 (GCAM)  **Radiative forcing n 2100 - 6.0 W m−2**  Carbon price - 1-2$/tCO2 (GCAM) | 2020-2100 |  | BECCS deployment over the twenty-first century - 950–1,200GtCO2  Average annual CO2 storage from BECCS for the 1.9 W m–2 scenarios for the 2020–2100 period (GtCO2 yr–1) – 11.2 (GCAM) |  |  | 1 |
| Base EMF 32 scenario | EMF 32 focuses on the interactions between carbon tax policies and revenue recycling in the United States3.  CO2 emissions from fossil fuels without climate policy or GHG regulations on stationary sources by the U.S. Environmental Protection Agency (EPA). Eleven modeling groups participated in the carbon tax study: ADAGE-US, CEPE, DIEM, EC-MSMR, FARM, G-Cubed, IGEM-N, NEMS, NewERA, and USREP-ReEDS. | Emissions (2040):  4,650-6,000 MMTCO2 |  | 2010-2040 | no | no |  | exam of the impact of natural gas prices, technology innovation, and CO2 policy on projections of U.S. energy demand and electric sector development.  Three scenarious:  1) Reference – AEO 2016  2) High natural gas price case  3) High Tech – High NG  Yes4  natural gas prices by ex- actly matching AEO natural gas prices in the years 2030–2050, but line- arly interpolating natural gas prices between 2010 and 2030  GCAM-USA uses two exogenously fixed price paths for all of the sensi- tivities in this study.  The CO2 Policy scenarios listed in Table 2 take the reference scenarios (REF, , HighTech, HighTech-HighNG) and add a representative power sector carbon dioxide (CO2) emissions reduction policy. The CO2 policy limits the maximum total quantity of CO2 that can be emitted by the power sector on a national scale—a national mass-based emissions cap. The annual cap imposed in the models is shown in Table 4, and is modeled with national trading allowed across all sub-national regions | 56, 7 |
| EMF 32 25$ with 1% | To compare with base EMF 32 scenario. Cover three types of carbon tax revenue recycling: lump sum to consumers, reduction in labor tax rates, and reduction in capital tax rate.  The core carbon price scenarios lead to significant reductions in CO2 emissions, with the vast majority of the reductions occurring in the electricity sector and disproportionately through reductions in coal 6 | Emissions (2040):  3,250-4,800 MMTCO2  Percentage decrease from reference scenario:  Min – 11%  Max – 18%  Avg – 30%  Reductions in emissions by fuel with household rebates (2040)  1) coal – 30-98%  2) oil – 1-10%  3) gas – (-2)-49%  All of the four core price trajectories appear sufficient to achieve (and often exceed) a 26% economy-wide reduction below 2005 levels by 2025), at least with regard to the fossil-fuel-related CO2 component of the target. This target represents the less stringent end of the U.S. Nationally Determined Contribution to the Paris Agreement (26–28%)  Price trajectory to achieve the 26% reduction target would generally begin between $9 and $40/ton in 2020 and rise to between $11 and $51/ton by 2025. This scenario assumed a real annual escalation rate of 5%, which gives all of the trajectories a similar shape. 8 | 25$/tCO2 | 2015- 2040 | 1%/ year | n/a |  | Callibration of REF to AEO 2016 8 | 6, 7, 8 |
| EMF 32 25$ with 5% | To compare with base EMF 32 scenario. Cover three types of carbon tax revenue recycling: lump sum to consumers, reduction in labor tax rates, and reduction in capital tax rate | Emissions (2040):  2,450-4,250 MMTCO2  Percentage decrease from reference scenario:  Min – 13%  Max – 21%  Avg – 35%  Reductions in emissions by fuel with household rebates (2040)  1) coal – 48-99%  2) oil – 10-20%  3) gas – 1-75% | 25$/tCO2 | 2015-2040 | 5%/ year | n/a |  |  | 6, 7, 8 |
| EMF 32 50$ with 1% | To compare with base EMF 32 scenario. Cover three types of carbon tax revenue recycling: lump sum to consumers, reduction in labor tax rates, and reduction in capital tax rate | Emissions (2040):  2,500-4,300 MMTCO2  Percentage decrease from reference scenario:  Min – 19%  Max – 29%  Avg – 48%  Reductions in emissions by fuel with household rebates (2040)  1) coal – 45-99%  2) oil – 5-20%  3) gas – 5-75% | 50$/tCO2 | 2015-2040 | 1%/ year | n/a |  |  | 6, 7, 8 |
| EMF 32 50$ with 5% | To compare with base EMF 32 scenario. Cover three types of carbon tax revenue recycling: lump sum to consumers, reduction in labor tax rates, and reduction in capital tax rate. | Emissions (2040):  1,900-3,600 MMTCO2  Percentage decrease from reference scenario:  Min – 22%  Max – 30%  Avg – 38%  Reductions in emissions by fuel with household rebates (2040)  1) coal – 65-99%  2) oil – 10-28%  3) gas – 25-65%  Scenario provides the maximum (up to 48%) emissions reductions below 2005 level compare to other exogenous EMF 32 scenarios. | 50$/ tCO2 | 2015-2040 | 5%/ year | n/a |  |  | 6, 7, 8 |
| EMF 32 76% reduction (no BECCS) | To compare with base EMF 32 scenario. 76% reduction of CO2 emissions from 2005 level. Deep de-carbonization scenario.  Scenario implemented only in FARM. 7 |  |  | 2020-2050 |  | CCS is available for fossil fuels but not for bio-electricity |  |  | 6, 7 |
| EMF 32 76% reduction with BECCS | To compare with base EMF 32 scenario .76% reduction of CO2 emissions from 2005 level. Deep de-carbonization scenario.  Scenario implemented only in FARM. 7 |  |  | 2020-2050 |  | CCS is available for all electricity generation technologies, including bio-electricity |  |  | 6, 7 |
| EMF 34, Carbon Policy | Case focuses on the impact of carbon policy as a carbon tax | n/a | 35$/ tonne | 2022 – end of the simulation | 5% / year | n/a |  |  | 6, 7 |
| 450 Scenario | Carbon tax for power and industry sector in the US and Canada | n/a | 2020 – 20$/tCO2;  2030 – 100$/tCO2;  2040 – 140$/tCO2 for $2014 | 2020-2040 | n/a | n/a |  |  |  |

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