DDPP Decarbonization Calculator User’s Guide

The DDPP Decarbonization Calculator is an Excel-based energy system model that allows users to explore different pathways to deep decarbonization. This user’s guide:

• provides a brief overview of the tool;
• walks through key instructions for how to use it; and
• describes necessary data inputs and where these might be found.

1 Overview

Based on user inputs, the Decarbonization Calculator calculates energy metrics and CO₂ emissions for a Mitigation Case and a Reference Case.

The Decarbonization Calculator is separated into six worksheets:

• Instructions — provides a brief overview, basic instructions, recommended steps, and a color key for the controls worksheet;
• Controls — contains all inputs for the Calculator;
• Mitigation Case Calculations — contains all calculations for the Mitigation Case;
• Reference Case Calculations — contains all calculations for the Reference Case;
• Calculator Outputs — shows key outputs from the Calculator;
• Dashboard — show outputs from the Calculator in the DDPP’s standardized format.

2 Instructions

2.1 Recommended Steps

The Instructions worksheet contains five recommended steps for using the Decarbonization Calculator, shown below.

Recommended Steps:
1. Confirm or input new values for Key Overall Parameters, beginning on Row 496 of the Controls worksheet
2. Enter Reference values for Power Sector and Gas & Liquids, from Row 435 to 493
3. Enter Reference values for Buildings, Transportation, and Industry, beginning on Row 35
4. Enter 2050 Mitigation values for all sectors and gauge progress versus sectoral and economy-wide benchmarks in Rows 1 - 29
5. Adjust trajectory (2015 through 2050) for the Mitigation case as needed to meet targets or expected values

Key Overall Parameters, a section in the Controls worksheet, contains a number of generic parameters for conversion efficiencies, plant characteristics, CO₂ emission factors, miscellaneous power sector, and miscellaneous other heating values and conversion factors used throughout the Calculator. This section currently has default values. Users should first check to ensure that these values are consistent with those typically used in their national or local context.

Once key parameter inputs are confirmed, users should then input data for the Reference and Mitigation Cases, as described below. A useful sequence for inputting data is to start with the
energy production sectors (Power Sector and Gas & Liquids) and then work through the end-use sectors (Buildings, Transportation, and Industry). This allows users to gauge whether energy sector inputs need to be adjusted to meet targets or desired values.

2.2 Inputting Data

All user inputs are entered in the Controls worksheet. As described in the Instructions, cells are color coded to allow users to identify which cells require user inputs and which are optional, which cells are purely for calculation, and which cells show intermediate and final outputs.

Within the Controls worksheet, data inputs are organized into seven main sections, organized by end-use sector, energy sector, and key overall parameters. Each section is then broken out into multiple sub-sectors, as shown in the table below. For instance, the passenger transport section includes six transport modes (car, motorcycle, bus, urban rail, inter-urban or long-distance rail, and air). Only the Key Overall Parameters sector has default inputs. Users are required to enter inputs for the remaining sectors.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Sub-sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>End-use Sector</strong></td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td>Residential, Commercial</td>
</tr>
<tr>
<td>Passenger Transport</td>
<td>Car, Motorcycle, Bus, Urban Rail, Inter-urban Rail, Air</td>
</tr>
<tr>
<td>Freight Transport &amp; Pipelines</td>
<td>Freight Trucks, Freight Rail, Domestic Waterway Shipping, Pipelines</td>
</tr>
<tr>
<td>Industry</td>
<td>Mining, Iron and Steel Manufacturing, Non-ferrous Metals Manufacturing, Cement Manufacturing, Other Manufacturing, Other Non-manufacturing</td>
</tr>
<tr>
<td><strong>Energy Sector</strong></td>
<td></td>
</tr>
<tr>
<td>Power Sector</td>
<td>Central CHP, Net Generation Mix</td>
</tr>
<tr>
<td>Gas &amp; Liquids</td>
<td>Pipeline Gas Blend, Liquid Hydrogen Inputs</td>
</tr>
<tr>
<td><strong>Key Overall Parameters</strong></td>
<td></td>
</tr>
<tr>
<td>Key Overall Parameters</td>
<td>Conversion Efficiencies and Plant Characteristics, CO2 Emission Factors, Miscellaneous Power Sector &amp; CHP Inputs, Miscellaneous Other Inputs</td>
</tr>
</tbody>
</table>

2.2.1 End-use Sector Inputs

Inputs and metrics in each end-use sector are organized by activity drivers (Activity), shares of final energy consumption (Energy Shares), shares of different fuels (Fuel Shares), and CO₂ metrics (CO₂). These categories are highlighted in the A column of the Controls worksheet, as shown below.
### Energy and Fuel Shares

All end-use sectors, for 2015, 2025 are entered data for 2010, 2020, 2030, 2040, and 2050, the Calculator will linearly interpolate values.

If traditional biomass is included in this estimate, it should be on a primary energy basis. For both passenger and freight transport, users specify mode shares (e.g., for passenger transport, car, motorcycle, bus, urban rail, inter-urban rail, air) of total energy consumption.

### Activity Drivers

Activity drivers determine total final demand for energy within an end-use sector. For instance, in the residential buildings sub-sector, energy demand is driven by the product of population, residential floor space, and energy consumption per unit floor space ("Unit energy consumption").

Energy shares determine how much total final energy demand is met with different energy sources. In residential buildings, for instance, final energy demand can be met with electricity, central-scale CHP, solar thermal, or "fuels." Fuels are the residual energy source and do not require a user input — if the user inputs 50% under final electricity, for instance, fuel share will fall to 50%. Users then specify the share of different fuels, which in residential buildings includes pipeline gas, liquefied petroleum gas (LPG), kerosene, coal, coal gas, and directly combusted biomass. With the "biomass sustainability factor" users can specify how much direct biomass combustion is CO$_2$-neutral.

### Data Input Sections

Data inputs are separated into a Reference Case section (columns I through Q) and a Mitigation Case section (columns R through Y). The orange cells, shown in the screenshot above, indicate required inputs, for the years 2010 (Reference) and 2050 (Reference and Mitigation). The yellow cells for years 2015, 2020, 2025, 2030, 2040, and 2045 are optional. If users do not specify values, the Calculator assumes a linear trend between data inputs. For instance, if users enter data for 2010, 2020, 2030, 2040, and 2050, the Calculator will linearly interpolate values for 2015, 2025, 2035, and 2045.

All end-use sector inputs follow the same general format, with variations on activity drivers and energy and fuel shares. For both passenger and freight transport, users specify mode shares (e.g., for passenger transport, car, motorcycle, bus, urban rail, inter-urban rail, air) of total energy consumption.
vehicle-kilometers or ton-kilometers traveled. These are converted to final energy demand using vehicle energy efficiencies. In the industrial sector, for heavy industries users specify physical output (million tons per year) and an energy intensity (GJ per ton). Other Manufacturing and Other Non-manufacturing are driven by user-inputted GDP, shares of value added, and economic energy intensity (MJ per $). If users do not have sufficient data to enter inputs for heavy industrial sectors, these can be subsumed within Other Manufacturing.

For cars and freight trucks, the Decarbonization Calculator tracks the stock of vehicles over time, based on user-inputted stock and lifetimes.

2.2.2 Energy Sector Inputs
For the power sector, users must input key parameters, central CHP inputs, and the net generation mix. Average heat rates are in gross terms — they do not include the “own-use” electricity used by generators to power facilities and pollution control equipment. The net generation mix, alternatively, should be net of generator own-use. Whether electricity statistics are in net or gross terms varies by country, and users should ensure that they are using the correct input data. For the gas and liquid fuel sectors, users input the energy mix in pipeline gas, and the energy inputs and processes used in liquid hydrogen production. In all energy sector inputs, users should ensure that the units of data inputs match what is in the Calculator. For instance, a heat rate that is in Btu/kWh must be converted to MJ/kWh to be consistent with units in the Calculator.

2.2.3 Key Overall Parameters
As noted previously, the Decarbonization Calculator requires a number of general inputs, located in the Key Overall Parameters section. These include inputs for energy conversion efficiencies and plant characteristics, CO₂ emission factors, and miscellaneous inputs. Although these parameters have default values, again users should check to make sure these are consistent with national conditions and assumptions. In particular, users should pay attention to CO₂ emission factors, capacity factors, and fuel heating values, which often vary significantly among countries.

2.3 Reviewing Outputs
The Decarbonization Calculator allows users to view outputs in a range of formats. As users work through inputs on the Controls worksheet, they can view how input choices in the Mitigation Case affect CO₂ emissions and key resource indicators.

In this segment, shown above, the figure on the far left shows emission trajectories over time in the Mitigation Case. The middle set of tables shows total CO₂ emissions by sector, per capita CO₂ emissions by sector, and CO₂ emission reductions relative to 2010 for all model years. The
rightmost set of tables shows three key resource indicators: biomass, natural gas, and the amount of CO\textsubscript{2} sequestered through CCS. These indicators provide a means to check whether inputs are realistic.

Users can examine more detailed outputs in the Calculator Outputs worksheet, shown below. This worksheet shows: aggregate results; activity assumptions and energy and CO\textsubscript{2} results by sector; and electricity generation, fuel production, passenger vehicle, and freight vehicle stocks.

Lastly, the Dashboard worksheet shows results in the DDPP’s “mini-dashboard” format, which the DDPP uses to compare results across country studies. A toggle at the top of the worksheet allows users toggle energy units between exajoules and million tons oil equivalent.
3 Sourcing Data Inputs
The Decarbonization Calculator was designed to represent a relatively simple energy-economy system that could be parameterized with a reasonable small number of commonly found data inputs. This section gives an overview of data requirements and possible data sources for the Calculator.

3.1 Activity Drivers
There are seven key activity drivers in the Decarbonization Calculator, shown in the table below. Base year (2010) data for these drivers are likely to be found in national statistical documents. The World DataBank (http://databank.worldbank.org/data/home.aspx), a free World Bank product, is another helpful source for base year data. If users find that base year data does not exist, an alternative approach is to estimate them by benchmarking against other countries. For instance, a medium-sized, medium-income country could estimate ton-kilometers (TKM) by multiplying its GDP by a reference TKM/GDP value in another medium-sized, medium-income country.

<table>
<thead>
<tr>
<th>Activity Drivers</th>
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</thead>
<tbody>
<tr>
<td>Population</td>
</tr>
<tr>
<td>Residential floor space</td>
</tr>
<tr>
<td>Commercial floor space</td>
</tr>
<tr>
<td>Passenger-kilometers</td>
</tr>
<tr>
<td>Ton-kilometers</td>
</tr>
<tr>
<td>Heavy industrial output</td>
</tr>
<tr>
<td>GDP</td>
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</tbody>
</table>

In cases where the effects of simplifying are thought to be small, users are encouraged to focus on important variables and leave less important ones blank. For instance, urban rail travel in a country might be very small, has a negligible impact on the results, and may be usefully ignored.

The Calculator also requires forecasts to 2050. Population projections for most countries can be found in the UN World Population Prospects (http://esa.un.org/unpd/wpp/DVD/). A number of research organizations also publish long-term GDP forecasts, though in general it is better to use real growth rates from these studies rather than using their absolute forecasts, given that most estimates are adjusted for purchasing power parity.

If detailed, long-term forecasts for floor space, travel distance, and industrial output do not exist in the user country, users will likely need to rely on a combination of simplified forecasting and expert judgement. In doing so, it is important to bear in mind that many of these activities (e.g., passenger-kilometers) saturate with continued economic growth. For instance, as the number of cars per household increases, passenger-kilometers increase rapidly, but then begins to slow once car ownership has saturated.

3.2 Energy Inputs
Base year energy sector inputs can most likely be found in government statistics. The IEA also publishes high-level energy balances for most countries in a number of formats (see
http://www.iea.org/countries/non-membercountries/ for energy balances for non-member countries). For conversion efficiencies and other energy parameters, potential references include the IEA *Technology Roadmap* (http://www.iea.org/roadmaps/) series and studies in other country contexts. The DDPP is another reference for these kinds of inputs.

Forecasted energy inputs are, to a large extent, based on user vision and what changes are required to meet CO₂ targets. Users are strongly encouraged to develop multiple scenarios, and to benchmark inputs against existing forecasts or national strategies.