Appendix B. The Climate 2030 Blueprint Cap-and-Trade Program

The Emissions Cap

The cap we modeled in UCS-NEMS starts in 2011. Emissions declined from 7,150 million metric tons of carbon dioxide equivalent emissions ($MMTCO_2eq$) in 2010 to 6,500 $MMTCO_2eq$ in 2011 (9 percent below 2005 levels), and to 3,145 MMTCO2eq in 2030 (56 percent below 2005 levels). This emissions cap will constrain 2000–2030 cumulative emissions to 178,960 $MMTCO_2eq$, of which 78,000 $MMTCO_2eq$ will have been emitted between 2000 and 2010, before the cap-and-trade program begins.

Although the modeling horizon is 2030, we expect that continued steep cuts in emissions will be required beyond that point, reaching at least 80 percent below 2005 levels by 2050.

Figure 2.1 in Chapter 2 shows the modeled cap through 2030, as well as one possible pathway for reductions from 2030-2050 with emissions declining to 1,321 $MMTCO_2eq$ in 2050 (approximately 80 percent below 2005 levels).

Covered Sources and Gases

The cap-and-trade program was designed to cover the six major greenhouse gases and cover all major sources of emissions except for land-use changes and forests. Coverage included electricity generation, transportation, industrial, commercial, and residential sectors. In addition to CO_2, the program included methane emissions from landfills, coal mining, natural gas and oil systems, stationary and mobile combustion, and livestock; nitrous oxides from agriculture, stationary and mobile combustion, industrial sources, and waste management; and fluorinated gases including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). Supply curves for reductions of covered non-CO_2 gases were developed by the Energy Information Administration (EIA 2008).

The Offsets Level

The maximum level of offsets allowed was set at 10 percent of the emissions cap from domestic offsets sources and 5 percent of the emissions cap from international offsets sources. These limits represent the maximum amount of offsets allowed, not the actual amount used by capped entities. Our modeling shows that the domestic offsets cap only becomes binding starting in 2021, while the international offsets cap is binding immediately in 2011.

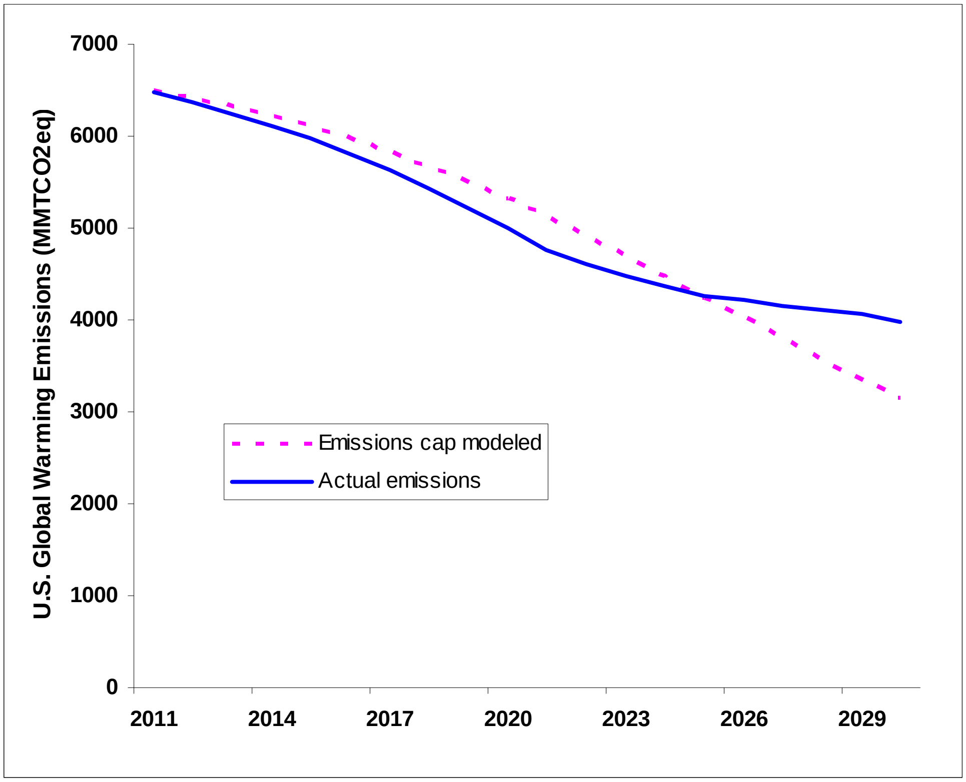
Details about the offsets supply curves we used are available at the end of this appendix.

Banking and Withdrawing

We allowed unrestricted banking and borrowing across the modeling horizon, with a terminal bank balance of zero assumed in 2030. Our results show that borrowing (i.e., maintaining a negative bank balance) does not occur and this is because it is not a costeffective way for firms to meet the emissions cap. Thus we will refer to our results as showing "banking and withdrawing." Other studies have chosen to keep a positive bank balance at the end of the modeling horizon, assuming that the emissions reductions post-2030 may be harder to achieve. We made the simplifying choice of having the model meet our emissions reduction goal, no more and no less, in 2030.

Figure B.1 below shows how banking and withdrawing unfolds in our results. The dashed line shows the emissions cap trajectory. The solid line shows the actual emissions reduction pathway. What we see is that in the early years of the program (until 2024), firms over-comply and bank allowances (the solid line lies below the dashed line). Starting in 2025, firms start to draw down the accumulated bank and the solid line crosses above the dashed line. Over the entire modeling horizon, the total amount of emissions reductions is the same for both pathways (i.e., the area under both lines is the same).

Figure B.1. Emissions Reductions through Blueprint Banking and Withdrawing



Emissions Cap Compliance

Table B.1 below shows how firms comply with the year-by-year emissions cap modeled through a combination of emissions reductions in capped sectors, sequestration offsets, and the use of and banking and withdrawing.

In the table:
Column 1 = Column 2 – Column 3 + Column 4

The last row of the table (TOTAL) summarizes the overall compliance with the cumulative emissions level set by the cap. There is a small discrepancy (82 $MMTCO_2eq$) which is the acceptable level of modeling error in UCS-NEMS. (The model looks iteratively for convergence and we chose to accept the results when it converged within 100 $MMTCO_2eq$ of the cap.)

Table B.1. Blueprint Emissions Cap Compliance

YEAR	EMISSIONS CAP MODELED ($MMTCO_2eq$)	ACTUAL EMISSIONS FROM CAPPED SECTORS ($MMTCO_2eq$)	SEQUEST-RATION OFFSETS* ($MMTCO_2eq$)	BANKING AND WITHDRAWING ($MMTCO_2eq$)
2010	7,150	7,150	0	0
2011	6,501	6,909	433	25
2012	6,418	6,818	444	44
2013	6,325	6,693	462	94
2014	6,221	6,578	480	122
2015	6,103	6,476	498	126
2016	5,973	6,339	531	165
2017	5,830	6,193	571	208
2018	5,672	6,050	616	238
2019	5,501	5,890	668	280
2020	5,317	5,726	727	318
2021	5,121	5,535	767	353
2022	4,914	5,351	738	302
2023	4,699	5,187	704	214
2024	4,476	5,036	671	111
2025	4,249	4,911	640	-21
2026	4,021	4,818	602	-194
2027	3,793	4,729	570	-365
2028	3,570	4,651	535	-546
2029	3,353	4,571	504	-713
2030	3,145	4,460	472	-843
TOTAL	**101,204**	**112,920**	**11,633**	**-82**

* Since these offsets represent sequestration (carbon storage), they will lower the emissions from capped sectors.

Revenue Recycling

The UCS-NEMS model does not have a straightforward way of targeting the auction revenues generated to specific purposes such as efficiency and renewable energy. However, in order for the model to treat these revenues accurately in a macroeconomic sense, in the macro module we chose to send the revenues back to consumers and producers in equal shares (50 percent each).

GDP Effects

As pointed out in Chapter 7 (Section 7.10: Limitations, Uncertainties and Opportunities for Future Research), there are serious limitations in the way the UCS-NEMS model tracks GDP and employment effects.

The cap-and-trade program increases the price of energy; however, we also see consumer energy bills go down due to greater efficiency in energy use. We also see energy demand get reduced due to greater efficiency. In the UCS-NEMS macro module, however, the higher energy prices and lower energy demand are seen as "negative" and this leads to lower economic output, reduced purchasing power, and lower aggregate demand for goods and services. As a result, we see the real GDP fall relative to the Reference case, though these effects are small (1.5 percent or less in any given year).

This result is counterintuitive because the lower energy bills and reduced need for energy should *increase* the purchasing power of consumers and have a positive effect on GDP.

Finally, we were not able to target the recycled auction revenues to specific uses (like efficiency, or to offset the energy price increases) which could have had the effect of further enhancing GDP and offsetting costs to consumers.

Domestic Offsets Supply Curve

Domestic offsets come from domestic biogenic carbon sequestration in the agriculture and forest sectors. The domestic offsets supply curves were developed by the EIA for NEMS and are derived from data developed by the Environmental Protection Agency (EPA).

International Offsets Supply Curve

From 2011 to 2015, we used the international offsets supply curve developed by the EIA for NEMS, which is based on data from the EPA. From 2015 to 2030, we used a supply curve based solely on offsets from avoided tropical deforestation, developed by UCS analysts. Below is a fuller description of the methodology used to develop these curves.

As explained in Chapter 8, Box 8.2 (How it Works: REDD), modeling of the potential of programs to reduce emissions from deforestation in developing countries (REDD) must differentiate between REDD funding that comes from carbon market offsets, and REDD funding from additional sources such as cap-and-trade auction revenues. For offsets, it is the supply curve of REDD credits, which graphs price ($/ton CO_2eq) vs. quantity of REDD reduction (MMTCO_2eq), that is the basis for modeling. For additional funding, on the other hand, it is necessary to use the cost curve, which graphs annual cost ($) vs. quantity of REDD reduction (MMTCO_2eq). The cost curve must be derived from the supply curve based on an assumption concerning how costs will be related to prices. Thus the complete process involved three steps:

1) Derive the REDD supply curves to be used as input in the UCS-NEMS model
2) Choose the most reasonable assumption concerning the relation of costs to prices
3) Calculate the cost curves for additional reductions based on this assumption

The underlying data for the supply curves were provided to us by three modeling groups (based at Ohio State University, Lawrence Berkeley National Laboratory, and the International Institute for Applied Systems Analysis) that have modeled the global economics of REDD. Their models (named GTM, GCOMAP, and DIMA, respectively) are all based on the opportunity costs of forestland in the tropics, but vary in many of their features. However, the three groups have worked together to produce global supply curves for the years 2010, 2020, and 2030 for each model, and have published a joint paper explaining their methods (Kindermann et al. 2008). We took the opportunity-cost-based supply curves for each group and each year as the starting point for our estimates.

Since these supply curves include only the prices for opportunity cost, we added to their prices the best estimates available for additional costs related to REDD:

- *Implementation costs*—the increased planning and land management costs a government undertakes to put REDD into practice (Nepstad et al. 2007)
- *Administrative costs*—the operational costs of administering REDD programs (Grieg-Gran 2006)
- *Transaction costs*—the costs of searching for projects, partners, negotiation, monitoring, and regulatory approval (Antonori and Sathaye 2007)

These per-ton “other costs” amounted to a fraction of a cent less than $1.00 per ton of reductions, so this amount was thus added to the prices of each of the opportunity-cost-based supply curves.

The mean of the supply curves pertaining to the three modeling groups was used as the basis for our price estimates. The 2015 and 2025 supply curves were calculated by interpolation between the 2010 and 2020 curves, and the 2020 and 2030 curves, respectively. Using the 5 percent limit on offsets as the quantity of reductions, interpolation along the mean curve for each year then gave the price at which these offsets would enter into the U.S. carbon market. This was the basic input for the contribution of REDD offsets to the UCS-NEMS model.

A further expense of REDD is *stabilization,* the term for payments to ensure that low-deforesting countries such as those of the Congo Basin do not increase their deforestation as REDD is implemented elsewhere. Stabilization has been estimated to have a cost of around $630 million for the 10 most important stabilization countries (da Fonseca et al. 2007). Since these are payments for maintaining low levels of deforestation, not for reducing emissions from deforestation, they are not proportional to the total amount of emissions reductions, and therefore cannot be included as part of per-ton prices. Therefore, they cannot be included in the supply curve. However, since their overall contribution to costs is small (see below) this does not cause very much of an error.

Step 2 requires making a choice among three possible assumptions concerning the price paid for non-offset (additional) REDD reductions, such as those funded through cap-and-trade auction revenues. The assumptions are:

1) Each country is paid only its own cost (opportunity + implementation + administration + transaction) for the reductions it makes, so that different countries are paid different prices per ton.
2) All countries are paid the marginal cost corresponding to the overall quantity of reductions made by all countries combined, so that each country receives the same price per ton.
3) All countries are paid the price they would receive if they were selling offsets in a global cap-and-trade market, which would be somewhere between the price corresponding to assumption 2 and the global price for allowances if no REDD offsets entered the market.

Of these possibilities, the second is both the most realistic and the fairest. It corresponds to the standard assumption of market dynamics, while the first assumption is what would happen if developed countries acted as monopsonists. Under the third assumption, all tropical countries would be paid a price well above their costs, which does not correspond to normal market dynamics either.

Thus, we chose to use assumption 2. This makes the third step fairly straightforward: given the supply curve (P vs. Q), the cost corresponding to each quantity is simply *C=PxQ*, thus giving the cost curve (C vs. Q).

To complete the process, we added in the cost of stabilization ($630 million globally, irrespective of Q). This added only a few percent to the global cost for almost all quantities except the smallest, thus justifying the use of supply curves without stabilization costs in step 1.

The graphs for these offsets supply curves are below in Figures B.2–B.5.

Figure B.2. 2015 REDD Offsets Supply Curve

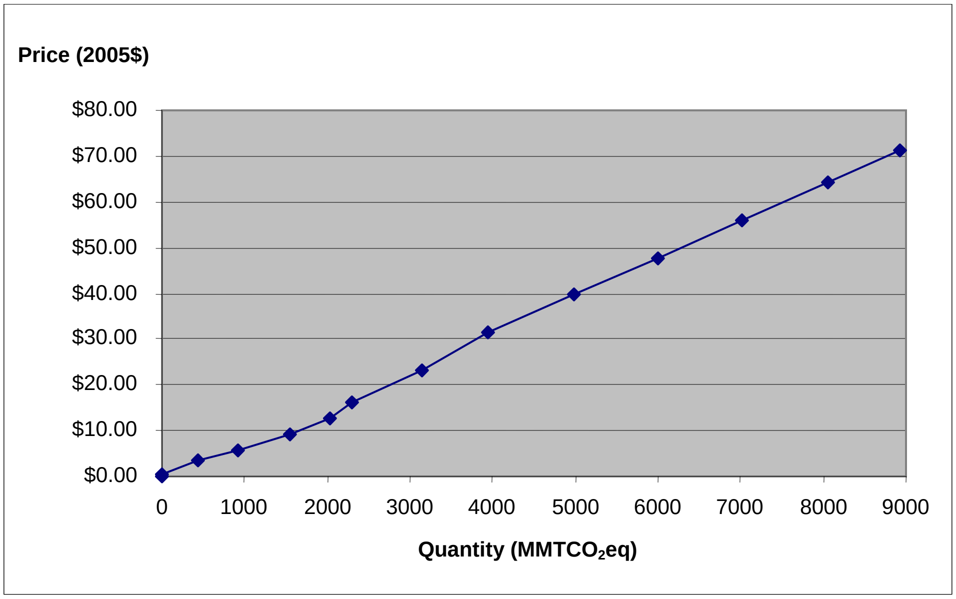


Figure B.3. 2020 REDD Offsets Supply Curve

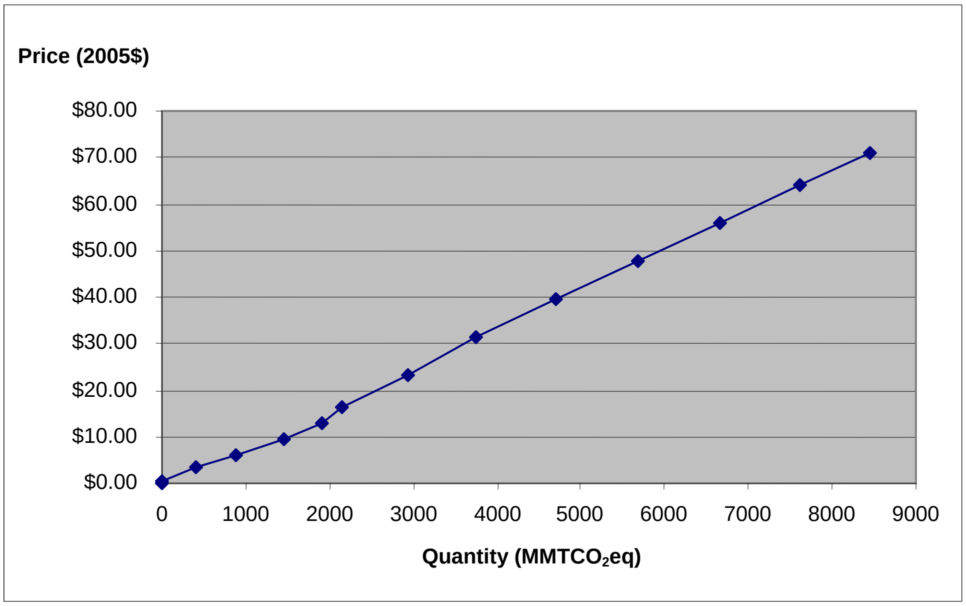


Figure B.4. 2025 REDD Offsets Supply Curve

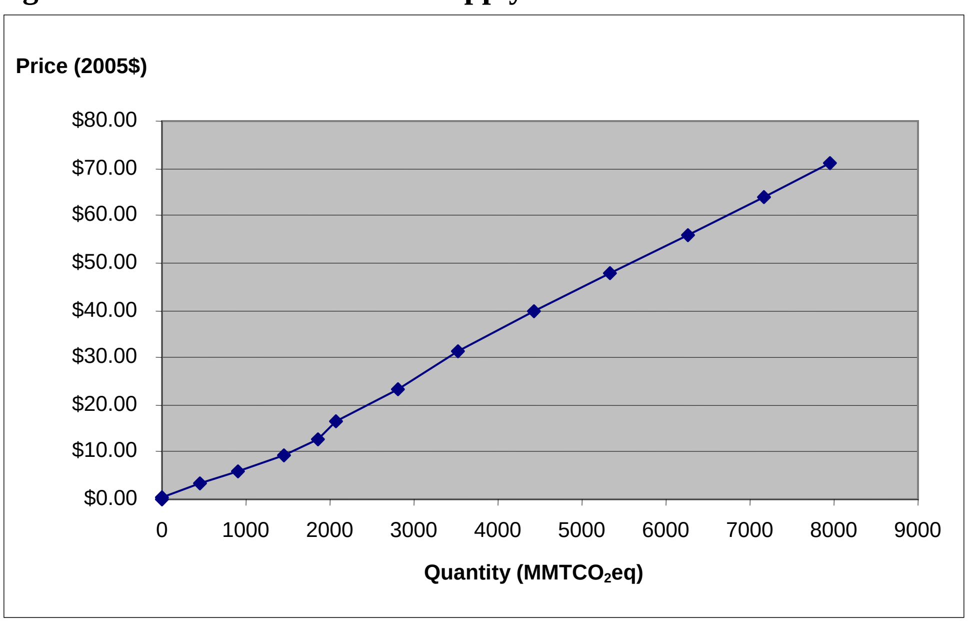
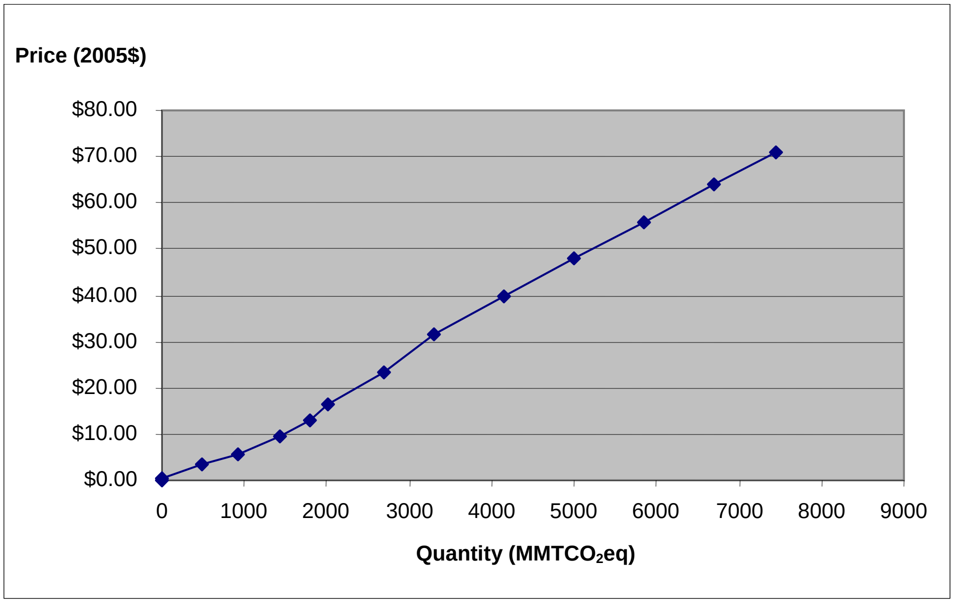


Figure B.5. 2030 REDD Offsets Supply Curve



Further details of the methods for deriving these supply curves, with graphical illustrations, are provided in Boucher 2008.

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