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Using SAS[®] to Model and Forecast Greenhouse Gas Abatement Cost Curves

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ABSTRACT

In the McKinsey paper titled "Pathways to a low-Carbon economy," the authors provide "...a quantitative basis for... what actions would be most effective in delivering emissions reductions, and what they might cost." Many such actions, known as abatement projects, result in a net negative cost, and as such present serious opportunity to those who can determine which ones to do, when, and to what extent. However, when practitioners begin to dig deeper, they find the modeling challenge and tangential constraints too complex for ordinary spreadsheet tools they have been used to using.

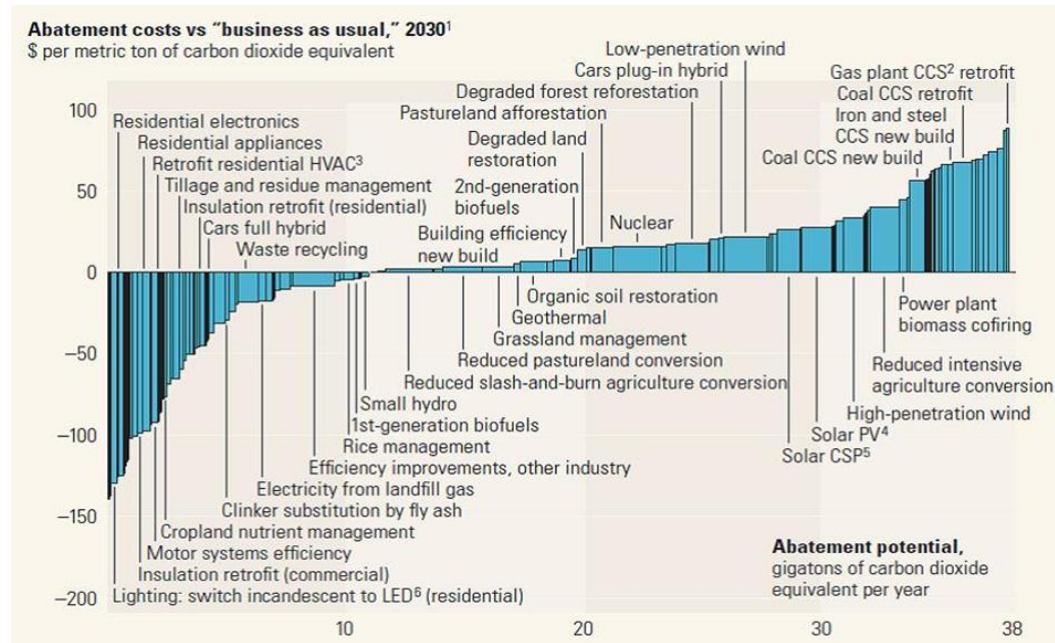
This paper discusses the challenges surrounding greenhouse gas abatement cost curves and provides examples of how a combination of SAS[®] portfolio optimization modeling and energy and emissions forecasting techniques can help make the right decisions, and improve both environmental and economic performance.

INTRODUCTION

As companies move toward a greener future, there are more and more questions that must be addressed by senior management. These questions pertain to the myriad carbon abatement projects that can be undertaken by a given organization. How much carbon is actually reduced? What are the most cost efficient carbon reduction projects? How much will each project impact long-term profitability? These questions and many more cannot be answered arbitrarily or with a gut feeling. The impact on the overall company is far too great to be taken lightly and, in certain situations, the project must be assessed for certification under certain schemes. Only a thorough understanding of the organizational constraints and long-term impacts can give decision makers an appropriate action plan. A marginal abatement cost curve can help in this process by providing a tool to communicate investment required to reach compliance with the carbon reduction commitment (internal or external) and demonstrate that priorities have been investigated.

First, let us consider the McKinsey abatement curve. As you can see in Display 1, this is an overall calculation for the United States. The vertical axis is the actual marginal abatement cost. In other words, the net cost of pursuing a particular carbon reduction project between now and beyond 2030. The horizontal axis is the cumulative abatement potential for CO₂e (carbon dioxide equivalent). If you pick a point anywhere on the x-axis, that location will equate to the total amount you save if all projects to the left are executed and completed. The blocks represent the maximum potential for an individual project. The goal is to take these larger global concepts and apply them to individual organizations.

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Display 1. McKinsey Abatement Curve - US

To generate a more narrow focus, this paper will make use of long-run forecasting and optimization models for dynamic project planning. We use the term "dynamic" because the rate at which carbon is released into the atmosphere can change almost daily in some organizations.

Although forecasting is a great way to gauge where emission rates are trending, we considered that a first step. It is important to narrow the focus for maximum potential reduction returns. This is accomplished by making use of optimization routines. These optimization routines are helpful in weighing the cost and risk implications of each carbon reduction project.

CO₂E DATA

First, let us define the unit CO₂e. A carbon dioxide equivalent (or CO₂e) is the unit used to report greenhouse gas emissions or reductions. Greenhouse gases are converted to CO₂e by multiplying emissions by their respective Global Warming Potential (GWP). It has been shown that not all greenhouse gases have the same potential to trap heat in the atmosphere. A GWP is a measure of the heat-trapping ability relative to CO₂, which is usually reported over a 100-year period. The CO₂e figure allows for reporting of overall greenhouse gas emissions in one standardized value and aids in greenhouse gas emission comparisons.

Normally, most organizations (especially in the Utility space) will have countless CO₂e abatement projects to choose from, and it will be up to the executive team to make the best choice. For this paper, we used a finite set of abatement projects to determine the best course of action for a CO₂e reduction plan. These projects that reduce emissions will either have a limited or perpetual lifecycle. In other words, some projects will not have a termination date (perpetual). Once a perpetual technology is implemented, the carbon will continue to be reduced long after the initial investment is recouped.

If the project in question is new or has not maintained a significant historical data store, we advocate creating or simulating a root type based on a class of projects. SAS can be used to statistically generate project history based on a spread of existing values within a given class. Classes can be things such as wind power, fuel substitution, light efficiency, and so on.

The following chart is an abbreviated set of data for CO₂e abatement projects that we used for our research. Each project will have a range of emission reduction values in tons of CO₂e.

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Project	Durability	ABATEMENT_POTENTIAL_LOW (per tCO ₂ e)	ABATEMENT_POTENTIAL_HIGH (per tCO ₂ e)
HVAC Efficiency	Perpetual	20000	25000
Lighting Upgrades	Perpetual	19200	22300
Solar PV	Limited	34000	58000
Motor Replacement	Perpetual	12500	17650

Table 1. Carbon Reduction Projects

BUSINESS AS USUAL

The first step in any of these types of analyses is to establish a bottom line for current and future emission rates – or the business-as-usual benchmark. The main question here to be answered is the following: What is the expected CO₂e over a given horizon if a company or organization undertakes no specific reduction action? We can get an idea of the future trend (black line) with a simple set of forecasting and graphics code. PROC FORECAST will choose a stepwise autoregressive method by default.

```
proc forecast data=sugi.history_tco2e interval=month lead=10
  out=pred outfull;
  id date;
  var tco2e;
```

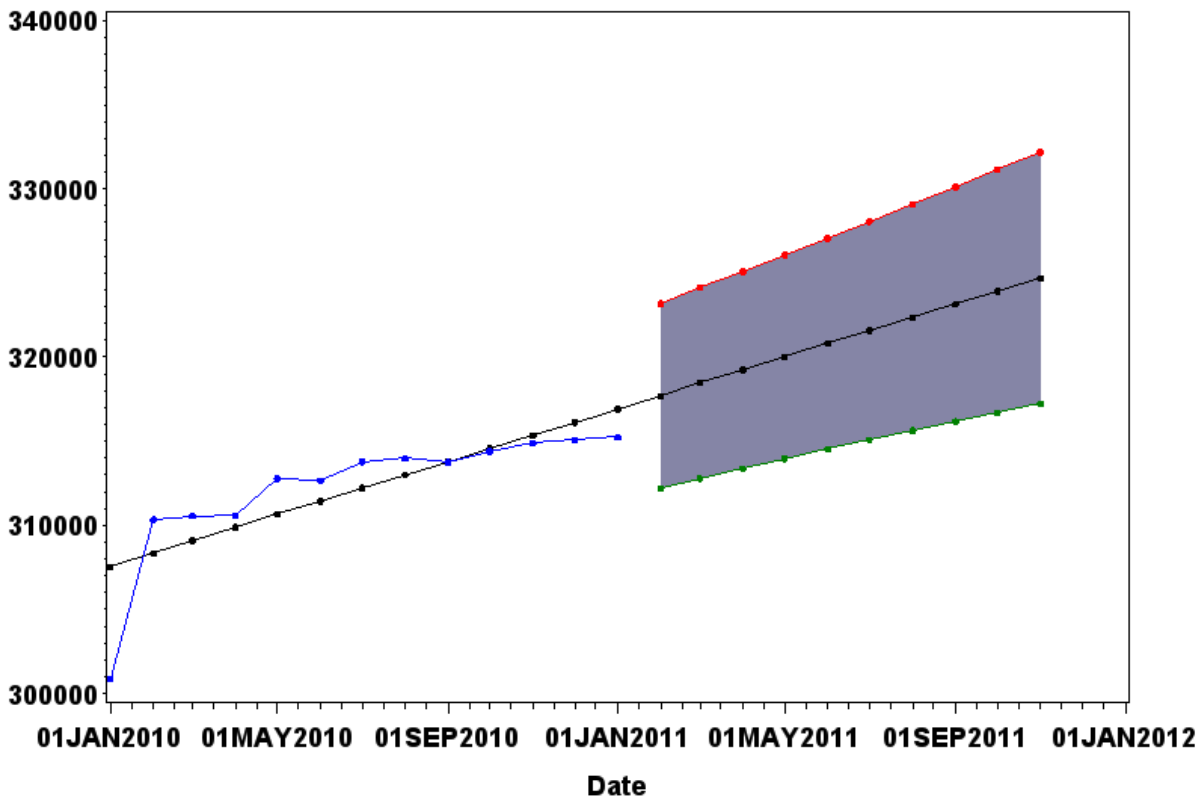


Figure 1. Initial Forecast

From Figure1 and the underlying predicted data, we determined that if this organization continued on its current path, a little over 320,000 tCO₂e would be released into the atmosphere by the 10th month (or a 30% increase). For this particular analysis, our bottom line is an 8% increase in tCO₂e.

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OPTIMIZED

We took a unique approach in analyzing what projects a typical organization should undertake when trying to reduce CO₂e. In the vast amount of projects, it very hard to narrow down what to do first based on the multitude of constraints an organization might have. Everything from budgetary to FTE (full-time equivalent) constraints could impact the cost versus abatement curve. In our research, we have discovered many companies have bits and pieces of CO₂e reduction data – some even contain exhaustive data stores (required for credits, certification, and so on.). We considered this collection of data as a portfolio – or a collection of potential technology investments – a firm could make to reduce the amount of carbon released into the atmosphere. This collection is based on a set of unifying frequencies that can easily be analyzed in a variety of ways. We treated the potential reduction of CO₂e as the most critical element in our analyses. Then, things such as budget and physical constraints can easily be introduced into the problem, if needed.

In MPT (Modern Portfolio Theory) developed by Harry Markowitz, he suggests the risk of a portfolio is not just the weighted sum of the risks of the individual instruments but also a function of the degree of co-movement of the returns of those individual assets (in our case, tCO₂e reduced). With this tool, we have a way of significantly reducing the risk of our overall portfolio without an increased reduction in the expected return of the portfolio.

So as you can see, the only requirement to start our analysis is to access a set of history that maintains carbon reduction figures and to construct a constraint table.

Let' us start taking a look at the SAS code for our optimization problem – we will highlight some of the major components. The first step is to make the code accessible to analytic users to do “what-if” scenarios via SAS stored processes, SAS® BI Dashboard, or other Web-based technologies such as Adobe® Flex® (Display 2, Display 3, and Display 4). These parameters (constraints) to create different scenarios can easily be set up via the %LET statements. Here are some examples of the type of macros we have constructed. TOT_COST is the total amount of funds an organization can invest in carbon reduction technologies. MIN_RETURN is the minimum amount of carbon (in tons) to be reduced by all combined projects. Finally, we wanted to specify what percent of portfolio projects is considered finite (maintained a termination date); represented by MIN_TOTAL_PRCNT.

```
%let tot_cost=100000; /* Change the cost constraint here */
%let min_return=25000; /* Change the amount of carbon abated required here */
%let num_proj=2; /* change how many projects must be limited here */
%let min_total_lim_prct=0.25; /* Minimum percent of portfolio */
/* made up of limited assets.*/
```

Next, let us read the history data set and create a covariance matrix::

```
proc corr data=green.history_tco2e cov nocorr outp=cov_matrix;
var _all_;
run;
```

(We also read in a constraint data set that looks like Table1.)

So now that we have our covariance matrix and our constraint data set specified, we are ready to kick off the PROC OPTMODEL.

```
proc optmodel;
/* Declare sets and parameters */
set <str> assets;
num return{assets};
num tot_cost_final{assets};
str durability{assets};
num covariance{assets,assets};
num min_return = &min_return;
num max_cost = &tot_cost;

/* Read data from sas data sets */
read data work.data1 into assets=[name] return tot_cost_final durability;

read data work.cov_matrix2 into [name]
{j in assets} <covariance[name,j]=col(j)>;
```

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```

/* Define set of limited assets */
set limited_assets = {i in assets: durability[i] = 'limited'};

/* Declare variables */
var x{assets} >=0;

/* Declare constraints */
con portfolio: sum{j in assets} x[j] = 1;

con minimum_return: sum{j in assets}
  return[j] * x[j] >= min_return;

/* Constraint to bound percentage of any single limited asset */
con lim_bound{j in limited_assets}: x[j] <= &max_single_lim_pctnt;

/* Constraint to impose minimum percent of portfolio */
/* represented by limited assets */
con min_lim_asset: sum{j in limited_assets}
  x[j] >= &min_total_lim_pctnt;

con max_tot_cost: sum{j in assets}
  tot_cost_final[j] * x[j] <= max_cost;

/* Declare objective */

min expected_risk = sum{i in assets, j in assets}
  covariance[i,j] * x[i] * x[j];

solve;

```

We created a simple pie chart (Figure 2) using SAS/GRAPH® software to better illustrate what projects our optimization process picked and what “piece of the pie” each project contributes to the total reduction in tCO₂e. Our requirement was that all selected projects will have a combined reduction of at least 25,000 tCO₂e per month. It becomes a simple process to re-build the actual tCO₂e data set. We take the combined reduction of tCO₂e and subtract from the original total tCO₂e history data set. We are now ready to re-run the forecast. Recall that some of our projects have a limited duration (dropping in and out of the project database); therefore, the optimization must be periodically updated to maintain the required level. A cost figure is also produced for the creation of the abatement cost curve.

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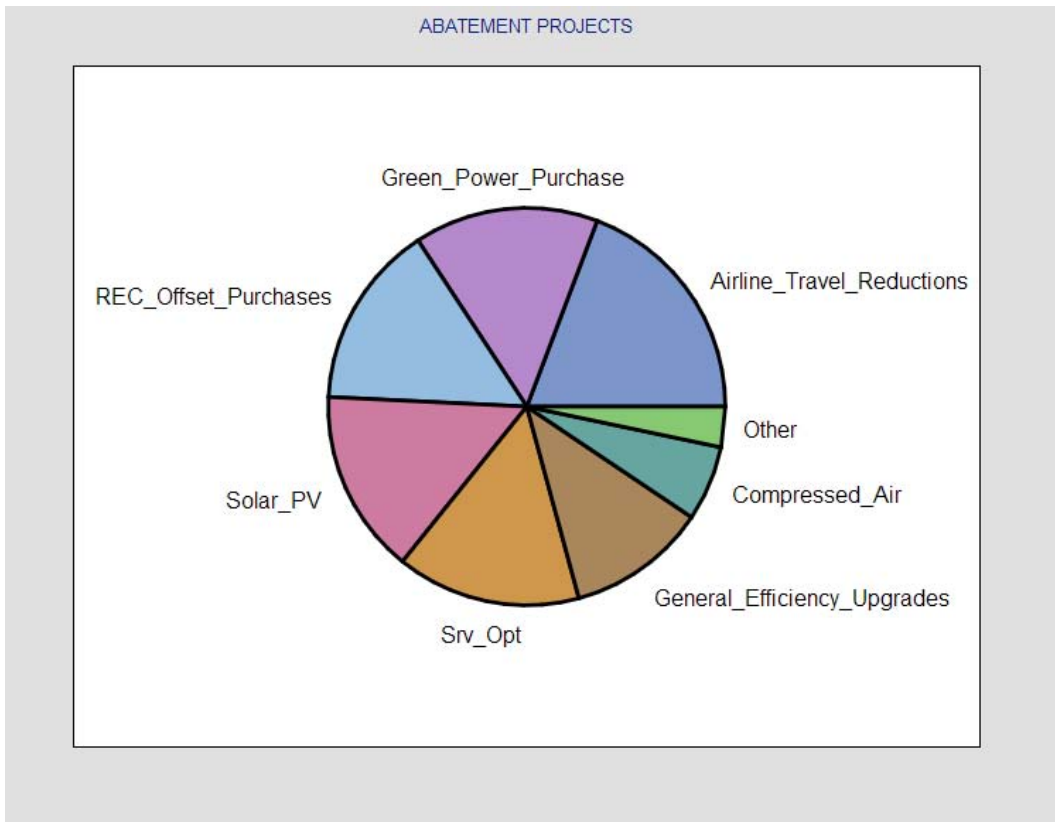


Figure 2. Abatement Projects

Here is the new forecast (Figure 3) for the amount of tCO₂e emitted into the atmosphere. The actual data (blue line) is updated with the tCO₂e reduction values and a new forecast is executed. As you can see, there is still a steady incline, but our new end of period amount of 295,068 tCO₂e is approximately an 8% decrease from the business-as-usual forecast. We can get that percentage even lower by doing some "what-if" scenarios. It is important to note that we are using hypothetical data. In a real world execution, analysts must be very conscious of the potential values each constraint can sustain. This knowledge will help build meaningful future states that lead to accurate decision making for the executive team.

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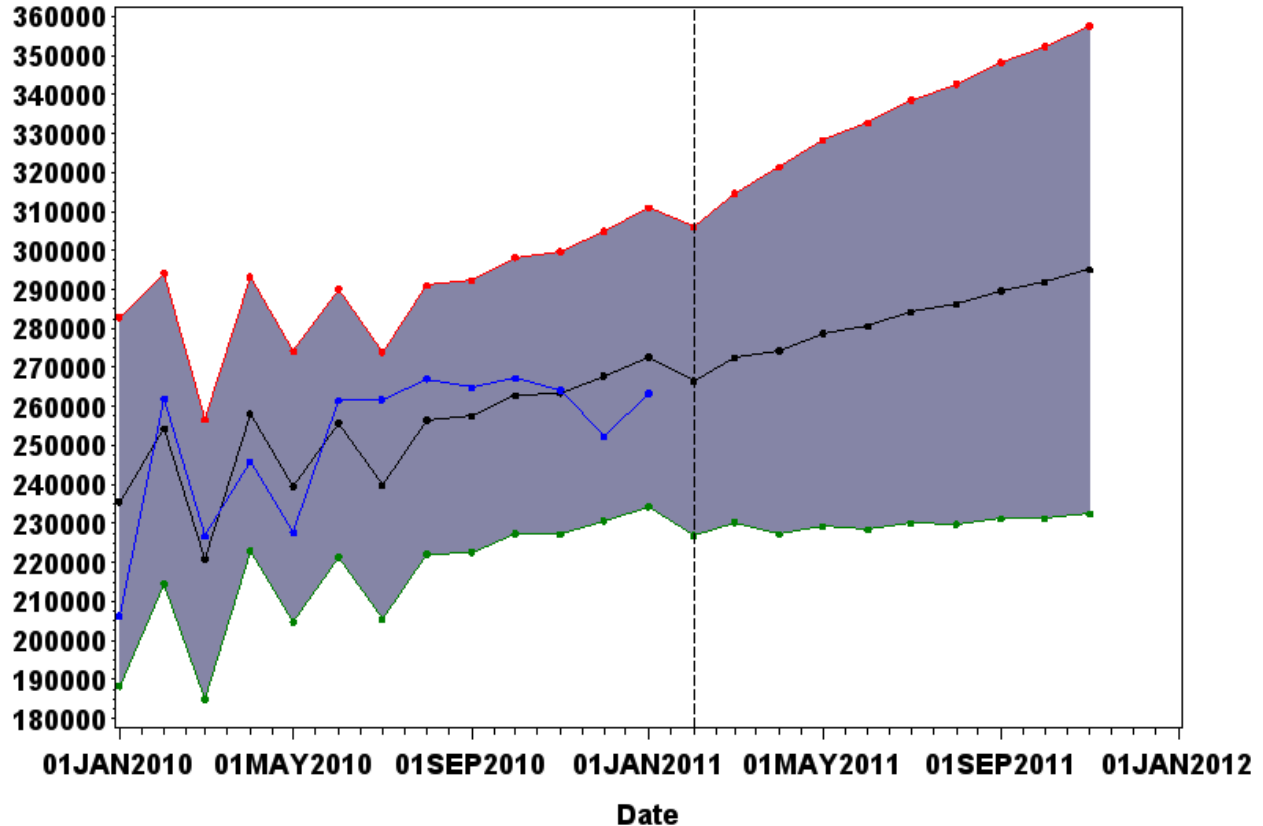


Figure 3. Adjusted Forecast

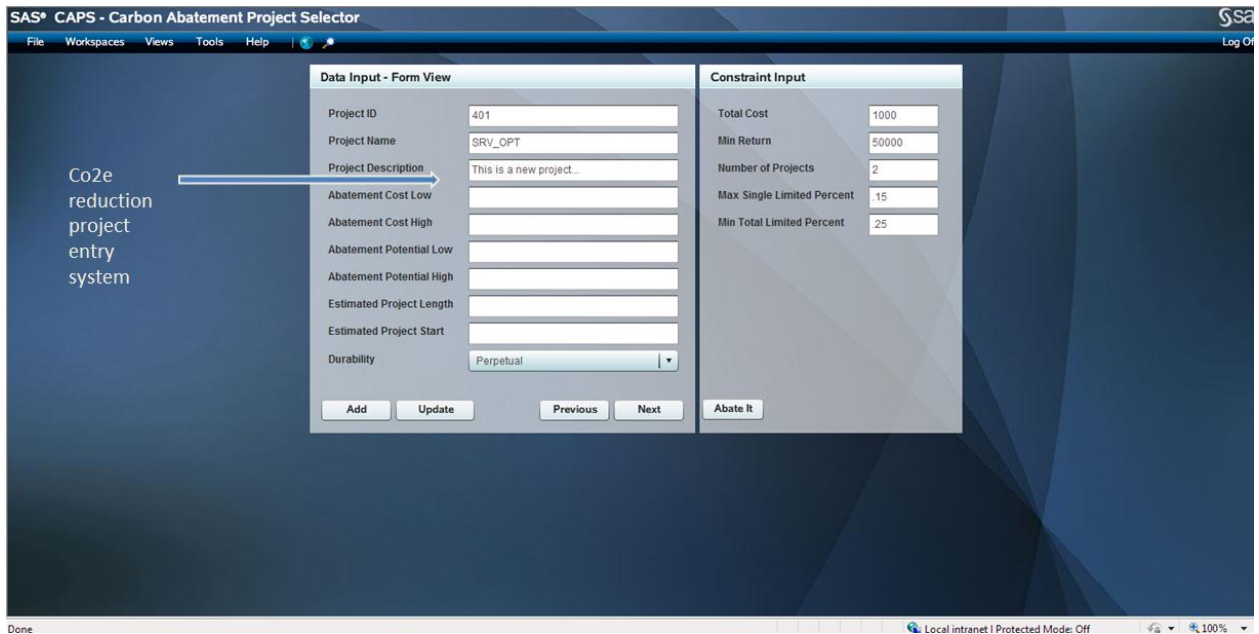
CARBON ABATEMENT VISUALIZATION

In order to better understand the cost of reduction tradeoffs, we developed an interactive visualization tool. The intended purposes of this tool are the replication of the McKinsey marginal abatement curve (Display 1) and assessment of the feasibility of pursuing a given project.

The first screen is the area where we can create parameters that will be loaded back into the SAS data set for conducting the “what if” scenarios described previously in this paper. The data input screen (Display 2) gives the user the ability to update or create new carbon abatement projects. Once all the necessary elements are entered, click the *Update* button, and parameters will be passed back to the constraint data set for the SAS optimization process. The next screen (Display 3) shows the inventory of carbon abatement projects that are available. Every project visible will be used for building the cost versus abatement curve. The user will also notice the flexibility of changing the constraints on the fly. This is another area where future states of the world can be created. Click the *Abate It* button, and the SAS/OR® software takes care of the rest.

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1. Project Entry



Display 2. Entry System

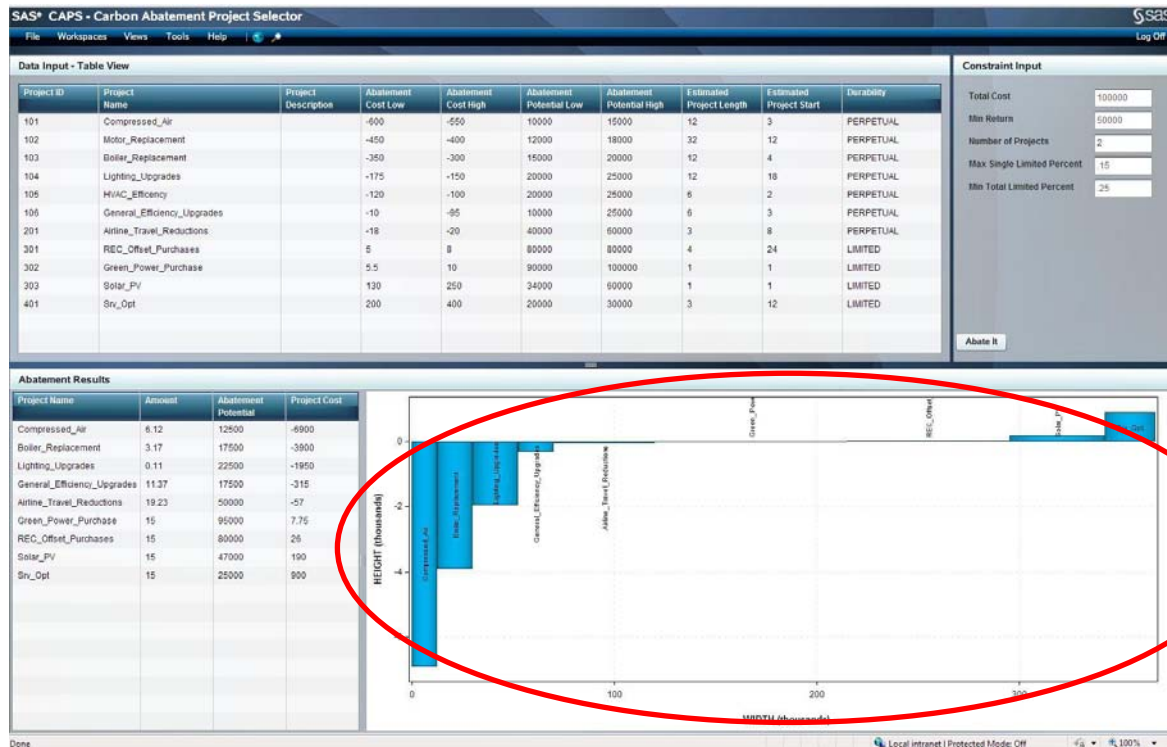
2. What-If Interface



Display 3. Entry System

3. Abatement Curve

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Display 4. Abatement Curve

Let us go over again the cost of a project in relation to its ability to reduce GHG emissions (Display 4), for example, cost per tCO_{2e}. This type of evaluation is important because it shows which projects produce the most carbon reduction per dollar of investment in specific terms – as an example in our case, compressed air.

The bars depict and compare our theoretical carbon abatement projects. The blocks on the left side of the chart -- represented by bars that descend below the zero line -- have negative net present values per ton of carbon dioxide mitigated and thus produce overall dollar savings. The projects on the right side of the graph -- represented by bars that extend over the zero line -- have positive net present values and do not produce savings in amounts greater than their costs. The projects are arrayed from left to right in order of most attractive to least attractive in terms of their carbon reduction efficacy or cost/offset ratio. The width of each measure shows the overall tCO_{2e} reduction that results from the measure.

CONCLUSION

This is just one of the many viable analytic options that companies can pursue that aids in determining environmentally friendly solutions and, at the same time, assesses the impacts on the bottom line.

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Markowitz, H.M. "Portfolio Selection." *The Journal of Finance*, March 1952.

United States EPA. Climate Change. Available at <http://www.epa.gov/climatechange/>. Accessed February 16, 2011.

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ACKNOWLEDGMENTS

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RECOMMENDED READING

- SAS/OR software: <http://support.sas.com/documentation/onlinedoc/or/index.html>
- PROC GPLOT Statement. Available at <http://support.sas.com/documentation/cdl/en/graphref/63022/HTML/default/viewer.htm#gplot-stmt.htm>
- PROC FORECAST Statement. Available at http://support.sas.com/documentation/cdl/en/etsug/60372/HTML/default/viewer.htm#etsug_forecast_sect016.htm
- The AUTOREG Procedure. Available at http://support.sas.com/rnd/app/ets/proc/ets_autoreg.html

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