Greenhouse Gas Mitigation Screening Exercise

For LEAP and Excel

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Contents

1 Introduction

These computer exercises are designed to introduce you to some of the basic techniques used in a GHG Mitigation Assessment.

You will undertake two very simple exercises that will help you to learn some of the skills needed to conduct a GHG Mitigation assessment.

1. **In Exercise One,** you will conduct a simplified static screening of mitigation options. This will consist of two basic parts.

    - In part one, you will complete a simple spreadsheet that calculates some of the main quantitative indicators used in a mitigation screening, including the GHG emissions reductions potential from each mitigation option (in Tons of CO2 equivalent) and the costs (in annualized $ per ton of CO2 equivalent).

    - In part two you will combine these numbers with a qualitative assessment of various different screening criteria in order to develop an overall screening matrix.

2. **In Exercise Two,** you will use LEAP to create a simple GHG mitigation scenario. The scenario will be created by taking some of the data developed in the first simple static screening exercise and using it as input to LEAP's dynamic integrated energy and GHG mitigation analysis. You will use LEAP to create some of the charts and tables that would typically be included in a national communication on mitigation.
3. In **Exercise Three** you will enter additional data to quantify the costs and benefits of the scenario within LEAP.

2 Logistics

Organize yourselves to work in groups of 2 or 3 for the quantitative aspects of these exercises. For the qualitative exercises, form teams of about 5-10 people each, appoint a chair, who will moderate the discussion, and a reporter, who will take notes and prepare a brief (5 minute) presentation to plenary.

The workshop presenters will provide further information about how you will be divided into groups and which rooms will be used by each group.

3 Country Context

While the information presented in these exercises is fictional, it may be useful to imagine a hypothetical country so that you can better assess some of the qualitative criteria.

The country is a rapidly growing developing country. Its urban population is fully electrified and has average income levels close to those in the OECD, while its poorer rural population has very limited access to modern energy services, and is heavily reliant on biomass fuels to meet basic needs.

The country has a warm climate and is only sparsely populated. It has a large potential for forestation, and solar energy and also has good wind resources. It also has good but limited potential for expanding its hydropower system. However, all potential areas for hydropower development are already densely populated and hence any hydropower development will require large numbers of people to be resettled.

4 Exercise One: Mitigation Screening Exercise

4.1 Part One: Constructing a Cost Curve

The goal of this exercise is to conduct a simplified quantitative screening of GHG mitigation options. To complete this exercise you will need to work with Microsoft Excel. We assume basic familiarity with Excel.

Start by opening the Excel spreadsheet "**Screening_partial.xls**".

This spreadsheet is a partly completed GHG mitigation screening calculation developed for a fictitious set of data[1]. The spreadsheet is made up of various worksheets: with one worksheet devoted to each potential mitigation option. You can access the different worksheets by clicking the tabs at the foot of the screen in Excel.

The options included in the spreadsheet are only meant to illustrate the use of the screening techniques: they are NOT intended as recommendations of mitigation options for any particular country and they are specified using entirely fictitious data. Moreover, the options are not intended as a comprehensive list of mitigation options that might be available in a country.

The potential mitigation options included in the spreadsheet are:
- LPG cooking stoves used to substitute for kerosene stoves in urban households.
- Efficient motor drives in the industrial sector.
- Efficient refrigerators in the domestic sector.
- Hybrid cars in the transport sector.

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[1] The spreadsheet is based on a screening tool named "GACMO" developed by UNEP and SEI.

- Electric cars in the transport sector.
- Combined heat and power (CHP) in the industrial sector.
- Hydro power for electric generation.
- New coal power plants with carbon capture and storage (CCS) technologies
- Solar photovoltaics for electric generation.
- Reforestation as a way of enhancing GHG sinks.

The workbook includes three additional tabs (worksheets) labeled "Assumptions," "Screening Matrix" and "Cost Curve".

- **The Assumptions sheet** includes the basic characteristics of the fuels used in the spreadsheets including their emissions factors and prices. It also includes other defaults such as the discount rate used to annualize costs and the Global Warming Potential (GWP) of the three GHGs included in this simplified analysis: CO_2, N_2O and CH_4.

- **The Cost Curve sheet** is used to plot a cost curve for all of the options analyzed in the worksheet. The cost curve plots cumulative GHG reduction from successive mitigation options (Tons of CO_2 avoided) against cost per unit of GHG reduction (e.g. $/Ton). A property of the curve is that the area under the curve yields the total cost of avoided emissions. As you complete the data for the options in each tabbed worksheet the Cost Curve will be plotted.

- **The Screening Matrix** will be used for the qualitative component of the exercise.

This exercise illustrates a simple approach to developing a cost curve, the so-called **"partial approach"**. In this approach:

- Each technology is evaluated separately and compared to a reference technology.
- Overall emission reductions and costs are created by combining options while assuming no interaction between options.

This approach is simple to conduct but does not consider the possible interactions between options. For example, the costs and mitigation potential of demand-side efficiency options will depend on what kind of supply technologies are used to generate electricity. In these simple exercises we ignore these problems and simply assume that electricity is provided by the average baseline electricity mix. In reality, supply-side mitigation options (e.g. more hydro) might affect the carbon intensity of the supply mix, and hence the actual level of emissions that can be avoided by a demand-side efficiency measure.

A second issue is that our spreadsheet analysis will be static: we will only consider the savings that might be achieved in a single year: 2030. Later on, in the second exercise we will use a dynamic modeling tool, LEAP, to create integrated scenarios that examine how both the baseline and the mitigation options might evolve over time from the base

year in 2010 to 2030. In this latter approach we will be able to consider interactions between measures.

In spite of its limitations, the **partial approach** can still be a useful approach for getting a rough first estimate of GHG mitigation costs and potentials and therefore it is the approach we will use here in this first exercise.

<u>**Spreadsheet Exercise**</u>
Use the following descriptive information for each option to complete the worksheet and prepare a cost curve and accompanying data table that describes the GHG emissions reductions potential from each mitigation option (in Tons of CO2 equivalent) and their costs (in annualized $ per ton of CO2 equivalent). Bear in mind that the descriptions and data provided here are simplified for the purpose of this analysis and use fictitious data.

NB: Some cells may be locked or protected to indicate that the calculations have already been completed. You may be interested in viewing the formulas, but we do not recommend editing them.

The options are as follows…

- **LPG Stoves:** By 2030, efficient LPG stoves could replace kerosene stoves in 3 million households. Kerosene stoves annually consume 8 GJ of energy per household and work at an efficiency of 30% while the LPG stoves work at an efficiency of 60%. LPG stoves cost $40 and have an expected lifetime of 8 years. Kerosene stoves cost $15 and last 5 years.

- **Efficient Motor Drives in Industry:** By 2030, the introduction of efficient electric motors throughout the industrial sector is expected to be able to save 10,000 GWhr of electricity at a cost of 10 cents ($0.10) per kWh.

  NB: For this example, try entering an incremental cost and electricity saving.

- **Efficient Refrigerators in the Residential Sector:** By 2030, efficient refrigerators could replace standard refrigerators in 1 million households. Efficient fridges will use 400 kwh/year, while standard fridges consume 700/kwh/year. Efficient fridges cost $500 and have a lifetime of 10 years. Standard fridges cost $300 and last 8 years. Assume one fridge per household.

- **Hybrid Cars in the Transport Sector:** New affordable hybrid vehicles are quickly becoming available in the country, expecting to replace one million conventional ICE vehicles by 2030. This will decrease the fuel consumption in these vehicles from 10 liters/100 km (for conventional vehicles) to 6 liters/100 km by 2030. Each vehicle drives 18,000 km/year. Hybrid vehicles will cost approximately $5,000 more than a conventional car. Assume that vehicles have a lifetime if 15 years. Note that 1 liter of gasoline is equivalent to 0.033152 GJ.

- **Electric Cars in the Transport Sector:** Under a new transportation policy, electric cars are expected to replace 500,000 conventional internal combustion engine (ICE) cars) by 2030. These cars will require an average of 30 kWh/100 km. Each electric vehicle will cost about $10,000 more than a conventional car. Assume the lifetime and mileage from the hybrid example above. Note that for this simplified example we have not included infrastructure costs of the policy, which could include necessary investments in plug-in stations.

- **Combined Heat and Power (CHP) in Industry:** By 2030, 20 million GJ of industrial process heat produced from oil-fired boilers could instead be produced from more efficient natural gas fired CHP plants. The oil-fired boilers operate at 55% efficiency, while the CHP plants would produce heat at 50% efficiency together with electricity at 25% efficiency (for a combined efficiency of 75%). The electricity can be sold back to the grid and is assumed to displace the average baseline mix. To produce this amount of heat, 800 MW of CHP plant will be required at an incremental cost of $1400/kW. CHP plants have a lifetime of 35 years.

- **Coal Power Plants with Carbon Capture and Storage (CCS) Technology:** Carbon capture and storage (CCS) is emerging as an alternative technology that may allow up to 85% of CO2 to be collected and transported for long-term storage when combined with coal power plants. CCS technologies are not yet commercially available, but in this policy scenario it is assumed that by 2030 2000 MW of this new technology could replace existing coal power plants. The existing coal power plants have a 30% thermal efficiency, a capital cost of $1000/kW and have a lifetime of 35 years. CCS capital costs are estimated to be $3000/kW and the technology has a lifetime of 35 years. The new coal power plants are more efficient, but also suffer an energy penalty because of the CCS requirements, which gives them an overall efficiency of 35%. Both power plants have an availability of 80%.

  Note: to make sure emission factors are calculated correctly in the spreadsheet it is important to select "Coal w/CCS" as the fuel used by the CCS plant.
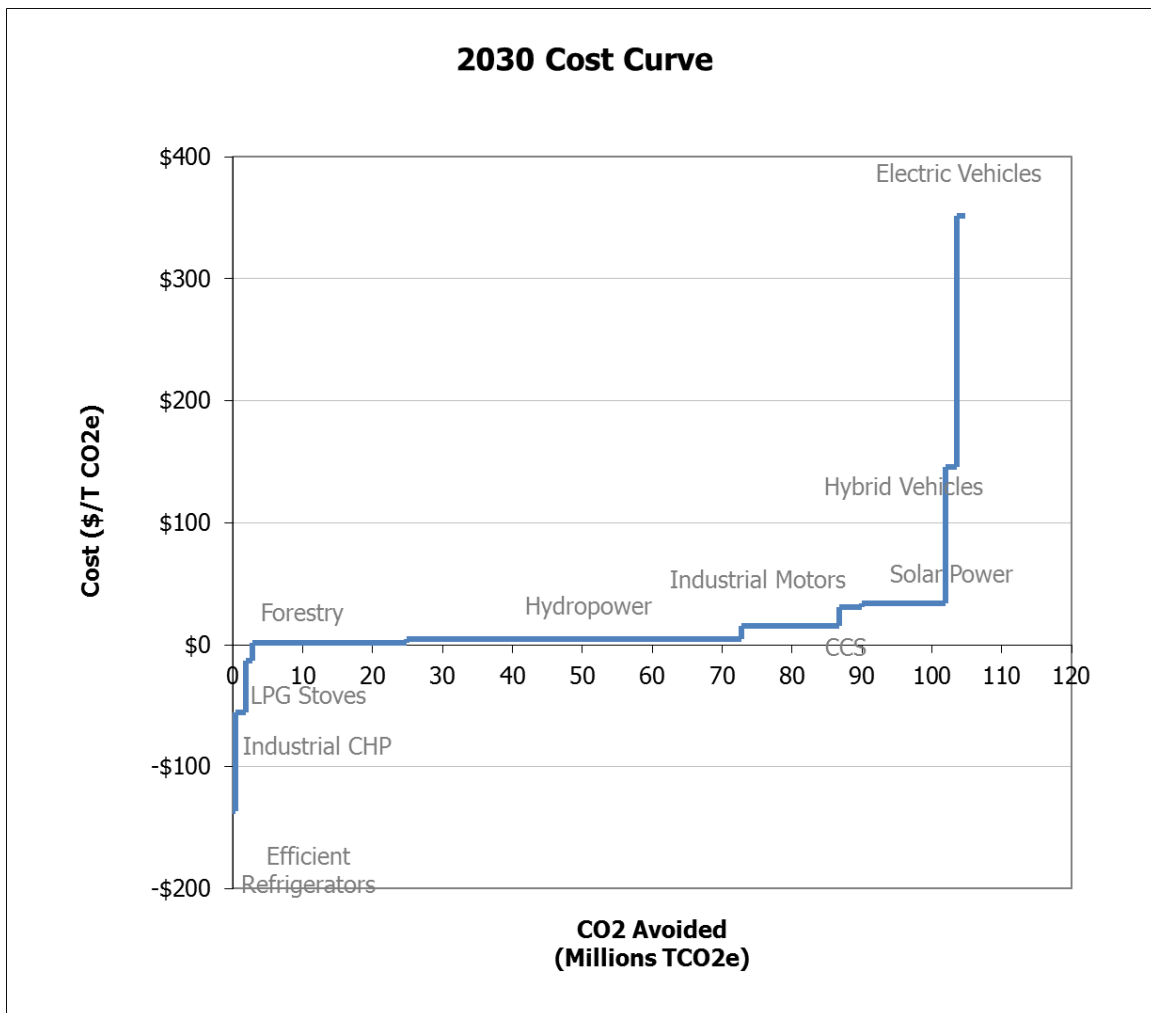
- **Hydro power for electric generation:** Approximately 6000 MW of hydropower could be built by 2030 displacing coal which is expected to be built in the future as the main base load power plant in a baseline scenario. The hydro plants will have an efficiency of 100%, an expected availability of 70% and a plant lifetime of 35 years. Hydropower capital costs are expected to be $4000 per KW. Variable O&M costs are expected to be $1 per MWhr. The hydropower plant would be built and run to replace coal fired plant that would have an expected availability of 80%, a thermal efficiency of 30%, a lifetime of 35 years, a capital cost of $1000 per KW, and variable O&M costs of $3 per MWhr.

- **Solar Photovoltaics for Electric Generation:** 4000 MW of solar power could be built by 2030, again displacing coal-fired base load plant. The solar plants would have an efficiency of 100%, an expected availability of 30% and a lifetime of 30 years. As solar technologies become more competitive, total capital costs are expected to decrease to $2000 per KW in 2030. Variable O&M costs are expected to be $20 per MWhr. Because of solar's low availability; the 4000 MW of solar would only displace about 1500 MW of coal plant. The coal fired plant would have a thermal efficiency of 30%, an expected availability of 80%, a lifetime of 35 years, a capital cost of $1000 per KW, and variable O&M costs of $3 per MWhr.

- **Reforestation (Enhancing GHG sinks):** Reforestation projects are expected to cover 4 million ha by 2030. Each hectare is expected to sequester about 1.5 tonnes of carbon per year at a cost of $5 per tonne of carbon.

Use the above information to complete the spreadsheet. You should end up with a cost curve looking like the one shown on the next page.

Option Name	Million Tons CO2 Opton Mitigation	Million Tons CO2 Cumulative Mitigation	$/Ton CO2 Cost of Saved CO2
Baseline	-	-	
Efficient Refrigerators	0.4	0.4	-$136
Industrial CHP	1.4	1.8	-$55
LPG Stoves	1.0	2.8	-$13
Forestry	22.0	24.8	$1
Hydropower	48.0	72.8	$4
CCS	13.9	86.7	$16
Industrial Motors	3.2	89.9	$31
Solar Power	12.0	101.9	$34
Hybrid Vehicles	1.7	103.6	$146
Electric Vehicles	1.2	104.8	$352

2030 Cost Curve

Notice that the curve shows costs increasing from left to right. The options on the far left actually have negative costs, indicating that for these options GHG mitigation can be achieved with net benefits to the economy. The area under the curve yields the total cost of avoided emissions.

NB: This cost curve will reorder automatically based on the numbers you enter in each worksheet. If your options appear in a different order than above, this likely indicates a problem in your analysis. Use the chart to help troubleshoot your analysis.

4.2 Part Two: Developing a Screening Matrix

In part two of this exercise you will work together as groups to decide on an overall ranking for the mitigation options you began to examine in part one.

To do this, complete the empty screening matrix sheets provided in the screening Excel spreadsheet.

You can develop your screening using either the simple screening sheet (in which you can decide yourself how to score and rank options) or using the detailed screening sheet which has built-in options for conducting a multi criteria attribute (MCA) approach.

Simple Approach
In the simple screening matrix, the first few rows of the matrix show the numbers you developed for the cost curve in exercise one.

The remaining rows can be used to rate the options based on more qualitative criteria, for which numbers are either not available or are uncertain.

As a group, decide on how you want to rate each of the options. Various approaches are possible and equally valid. For example, you may wish to use:

- A score (e.g. 0-5 or 0-10),
- A ranking (1st, 2nd, 3rd, etc.)
- A rating (low/medium/high),
- A comment for each criterion.

You may wish to let each person in the group "vote" on a score or ranking or you may decide to agree a rating more informally.

Detailed (MCA) Approach
The detailed matrix uses a multi criteria attribute (MCA) approach to automatically calculate overall scores and rankings based on the scores you give for each criteria for each individual option. Fill in the cells of the sheet so as to score each option against each criterion from zero (worst) to ten (best). Scores are already provided for the overall mitigation potential and overall cost of each option, again scaled from zero (worst) to ten (best) based on the data you entered earlier.

You should also enter the weightings for each criterion in column C. Each criterion can have a weighting from 0 to 100, but make sure that the total weighting across all criteria is 100.

At the bottom of the matrix, the spreadsheet automatically calculates an overall score for each option, again scaled from zero (worst) to ten (best), and also shows the options ranked from best to worst.

If you have time you may want to make multiple copies of this spreadsheet. Try completing different versions of the matrix to reflect the views of different stakeholders. For example, you may want to try playing the roles of:

- a national government's energy or environmental ministry,
- a local non-governmental environmental or development organization, or
- a national or international donor agency.

Each stakeholder may have different opinions about the scores assigned to each option. They may also have different opinions about the importance of each criterion. How do changes in criteria and scores affect your overall ranking of options?

<u>Presenting Your Results</u>
With either approach, once you have completed at least one screening matrix as a group, you will be asked to present your findings in plenary in a short (3-5 minute max) presentation.

Start by appointing one member of your group as your reporter. That person will be asked to present the cost curve you developed, along with the screening matrix. Try to answer these questions:

- As a group: what process did you use to develop the screening matrix?
- Which options seem the best and worst based on your process?
- In what ways is this analysis too simplified to reflect real-world conditions?
- How might you improve upon it in a real mitigation assessment?
- What finance and support mechanisms could support any of these measures?
- Do you believe that developing a screening matrix will be useful as a step in your own national mitigation assessments?

5 Exercise Two: Creating a Mitigation Scenario in LEAP

In this second exercise you will work with LEAP, the Long range Energy Alternatives Planning System to create a very simple example of a mitigation scenario.

The exercise is not intended to fully train you in the use of LEAP. It is intended only to give you a brief introduction to some parts of the system, to give you a chance to create a simple mitigation scenario and to produce various reports of the type that might be included when reporting on a mitigation assessment in a National Communication.

Exercise 2 builds upon the data and results developed for static screening you undertook in Exercise one. In this second exercise you will take the basic information for selected mitigation options, and enter this into LEAP to create a dynamic mitigation scenario that examines how energy and emissions savings might occur over the period 2010-2030.

You will then use LEAP to create a few charts and tables that report the overall emissions savings in the mitigation scenario compared to the baseline scenario.

To keep things simple, you will work with a partially completed LEAP data set that already has a fully defined Baseline scenario.
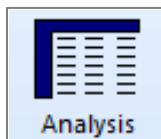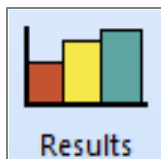
5.1 A Very Brief Introduction to LEAP

Start **LEAP** from the **Start/Programs/LEAP** menu or by double-clicking the LEAP Icon (shown left) on the desktop. Once started, LEAP will display a title screen and then the main screen will appear (shown below).

As much as possible LEAP works like other standard Windows software, so if you are familiar with other Windows tools like Microsoft Excel or Windows Explorer, then you should be able to start using it straight away.
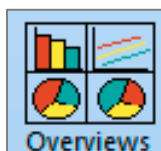
LEAP is structured as a set of different *views* of an energy system. The **View Bar** located on the left of the screen, displays an icon for each view. For this exercise we will only use three views:

The **Analysis View** in which you will enter data and construct your mitigation scenario.
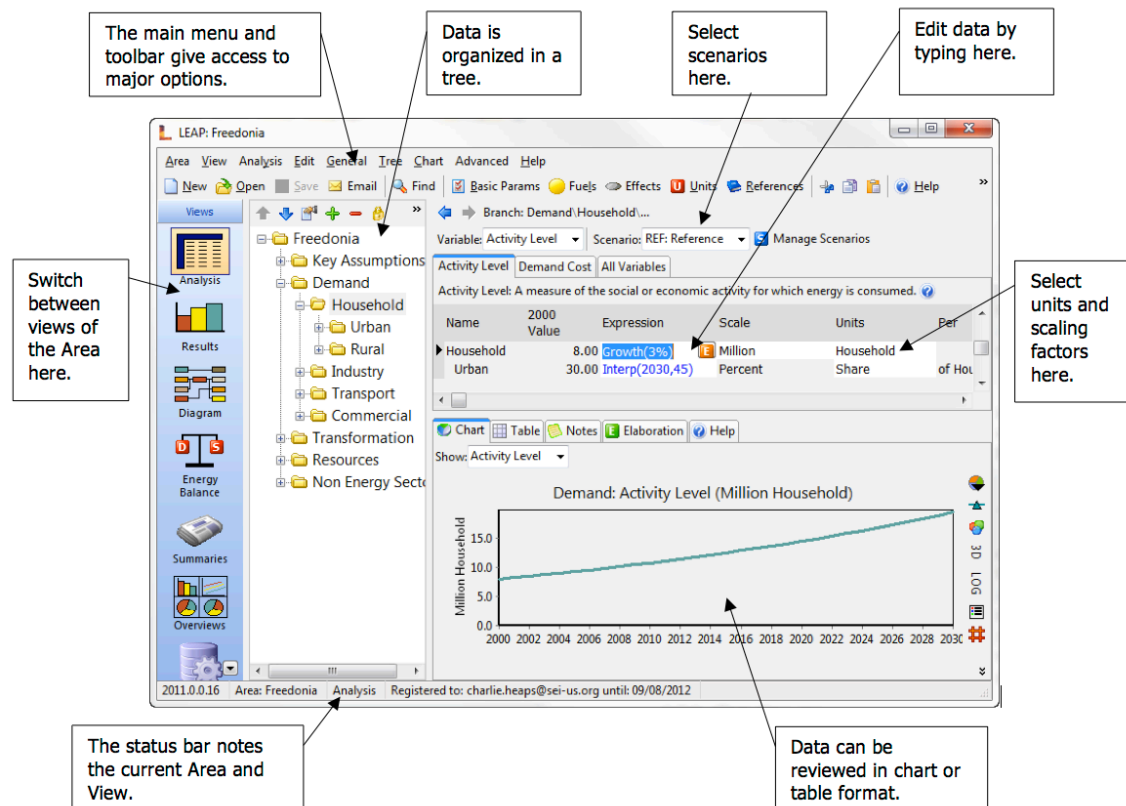
The **Results View** where you will examine the calculated scenarios as graphs and tables.

The **Overviews View** where you view a specific set of pre-defined "favorites" results charts.

The **Analysis View** (shown below) contains a number of controls apart from the view bar. On the left is a tree that is the main organizational tool for the data in LEAP. On the right are two linked panes. At the top is a table in which you view or edit data the data describing your scenarios. Below it is an area containing charts and tables that summarize the data you entered above. Above the data table are toolbars that give access to commonly used commands and a standard menu.

The main parts of the **Analysis View** are described in more detail below:

- **The tree** is the place where you organize your data for both demand and supply (Transformation) analyses. The tree contains different types of branches:

  - **Category branches** are used mainly for the hierarchical organization of data in the tree.

  - **Technology branches** contain data on the actual technologies that consume, produce and convert energy.

  - **Fuel branches** are used to indicate resources as well as the feedstock fuels and outputs of Transformation processes.

  - **Environmental loading branches** represent the various pollutants emitted by energy demand and transformation technologies.

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- **Data Table:** The top-right part of the screen shows a data table where you can view or edit the data associated with the variables at each branch in the tree. As you click on different branches in the tree, the data table shows a series of "tabs". Each tab corresponds to one variable. The variables you see depend on which part of the tree you click on. For each tab, a table presents the data associated with that variable. Each row in the table represents data for a branch in the tree.

- **Chart/Table/Notes:** The lower-right part of the screen summarizes the data entered above as a chart or a table.

- **Scenario Selection Box**: Above the data table is the scenario selection box, which you can use to select between **Current Accounts** and any of the scenarios in an area. Current Accounts are the data for the base year of your study. Different scenarios in LEAP all begin from the base year. In this exercise you will be given a completed **baseline** scenario, and you will then enter the data for a **Mitigation** scenario. Use the scenario selection box to select among the Current Accounts and the scenarios.

5.2 Reviewing Historical Data

In this exercise we will work on a partially completed data set or **Area** named "GHG Screening Exercise". An Area in LEAP is a complete description of a particular energy system, typically a country. Start by opening the area named **GHG Exercise Partial**. To do this select menu option **Area: Open** and then select the area named "GHG Screening Exercise partial". If the exercise cannot be found there, you may have to download it from the COMMEND website. To do this, go to **Area: Install: Install from Internet**.

Let's begin by reviewing the Current Accounts and Baseline scenario that has already been completed for you (to keep this exercise short!)

First, in the **Scenario Selection Box**, choose **Current Accounts.** The Current Accounts scenario includes multiple years of historical data. In this simple exercise we have entered future baseline data into current accounts as well.

Baseline scenarios are not a prediction of the future; instead they are plausible stories of how an area could involve in the absence of mitigation policies. There is also no "right" way to build a baseline scenario. Some baseline scenarios are based on historical trends while others may focus on expected trends for the future. The key thing to understand is that your baseline scenario is what you will be comparing back to; you will not be only looking at your baseline, but instead you will be looking at how your mitigation scenarios relate to the baseline.

Now use the tree to navigate the structure of this data set. First open up the tree branches under the main category "Key Assumptions." This folder contains macroeconomic and

demographic variables that can be used to help model future energy demand. You will see entries for population and gross domestic product (GDP).

Now open up the folders under the Demand branch. You will see that this data set is very simple and aggregate. Demands are broken down by major sector (Residential, Industry, and Transport). Each sector has a simple set of branches listing the final fuels consumed in each sector. Each fuel is shown in the tree as a technology branch ( ). Finally under each fuel, are a set of branches that specify the emissions for each fuel ( ). In this exercise there are emissions specified for CO_2, CO, CH_4, VOCs, NO_x, N20 and SO_2.

Now let's look at the data associated with these branches. Click on one of the sector branches in the tree and then look at the tabs and data pane on the right. You will see that energy consumption data is also specified in a very simple way. Normally in LEAP you would specify separate data describing **activity levels** (e.g. number of households, or pass-km of transport) and **energy intensities** (GJ/households per year or GJ/pass-km). LEAP then multiplies these together to calculate total final energy demand. That is, it uses this relationship:

Total Final Energy Consumption = Activity Level x Final Energy Intensity

But in this exercise the data are specified in an even more simple fashion. The Activity Level variable has simply been set to "No data" and total energy consumption data is specified on the tab marked **Final Energy Intensity**. In other words we have used this relationship:

Total Final Energy Consumption = Final Energy Intensity

Select the **Final Energy Intensity** tab now. You will see the values of the total final energy consumption for each branch specified as data in Millions of Gigajoules. In the lower part of the screen the data is echoed back as a chart.

All the time-series values in this data set are specified using LEAP's built-in ***Interp*** function. The Interp function works by letting you specify values for any years. It then assumes a straight line change between the years calculated by simple linear interpolation. For example, this function…

Interp(2010,28, 2020,60, 2030,80)

…specifies a value of 28 in the year 2010 and a value of 60 in 2020. Thus the interpolated value that LEAP calculates in 2015 is 44.

Now open up the branches below one of the fuels and look at the **Environmental Loading** Tab. You will see a series of expressions that specify the emissions factors for each pollutant per unit of fuel consumption for that fuel. Typically emissions factors are specified in Tonnes/Terajoule or kg/Terajoule. To calculate total emissions of each

pollutant, LEAP simply multiples total energy consumption by each emission factor using this relationship:

Total Emission = Total Final Energy Consumption x Emission Factor

Now let's have a look at how the data is specified for the Energy Supply system. This data is entered under the **Transformation** branches in the LEAP tree. In LEAP, energy supply data is specified by first making a list of *modules* immediately below the Transformation branch. These modules correspond to major energy supply sectors like electricity generation, transmission and distribution, oil refining, charcoal making, ethanol production, coal and oil extraction, etc. Each module can be further divided into different *processes*, each of which can have one or more *feedstock fuels*. A process might be a particular type of power plant or a type of oil refining facility for example. Each module is dispatched to produce one or more *output fuels*.

In our simple example, there are only two modules: one dealing with the **Transmission and Distribution** (T&D) of electricity and a second one below it dealing with **Electricity Generation**. The T&D module is very simple: it simply specifies expected losses during transmission and distribution. The Electricity Generation module has four processes describing the capacity, availability, efficiency and merit order dispatch characteristics of four types of power plants: hydro, coal, oil and solar. The first three exist in the base year, while solar is listed as a potential future type of power plant.

Now, let's switch to the **Results View** to see some results associated with the already complete Baseline scenario. Click on the results view, and if prompted allow LEAP to calculate results. This should only take a few seconds.

Now let's look at some results in Chart form. The Results view has numerous options for selecting results.
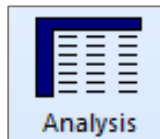
- First use the **tree** to pick the branches for which you wish to see results. For example, you might choose to see demands in the household sector, or GHG emissions for the whole area.
- The **Result** selection box at the top of the screen is used to pick the category of results you are interested in. Different types of results are available at different tree branches. For example, final energy demand results are only available at demand branches while emissions and GHG results are available at both demand and supply branches.
- Two tabs at the top of the view let you switch between **Charts** and **Tables**: both formats contain the same basic information.

Reports can be viewed for one or more scenarios and can be customized in a wide variety of ways. You can also use the "**Favorites**" option to bookmark the most useful charts for your analysis.
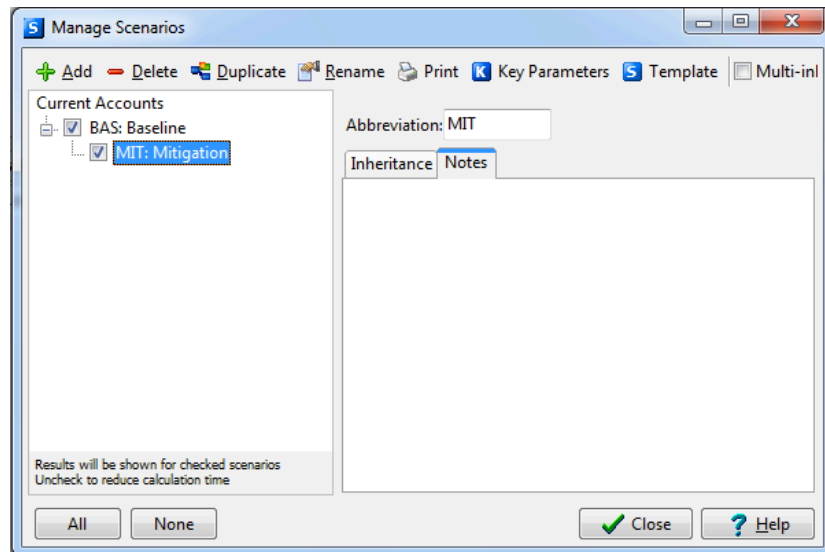
To make things easy, we have preconfigured a set of **Favorite** charts you can use to examine results. Take a look now at the Favorite results for **Total Final Energy Demand in 2030**, **Electric Generation** and **Global Warming Potential** (by sector and by greenhouse gas).

5.3 Entering Mitigation Data into LEAP

Now you are ready to create a mitigation scenario. Switch back to the **Analysis View** and click on the **Manage Scenarios** button (⑤). In the resulting Manage Scenarios screen (shown right), use the Add button (➕) to add a new scenario named Mitigation.

Important: Make sure the mitigation scenario *inherits* from the Baseline scenario. That is, it must appear in the scenario tree indented and below the Baseline scenario as shown above. In this way, all of the data and expressions for the Mitigation scenario will initially be exactly the same as those in the Baseline scenario.

To specify the data for the new scenario you will only need to specify the places where the mitigation scenario is different from the Baseline. Much of the data specified for the Baseline (such as emissions factors) will remain unchanged.

Now close this screen and return to the Analysis View. If necessary, select Mitigation as the active scenario in the **Scenario Selection Box.**

We will now enter data to represent some of the options we studied in Exercise One in our mitigation scenario.

In a real mitigation study it might be desirable to do a thorough end-use oriented analysis in which both the baseline and the mitigation scenario are described in terms of the likely penetration of different technologies. That kind of exercise is data intensive and time consuming and goes beyond what can be done in this simple exercise. Instead, in this exercise we will specify most of our options by simply entering the amount of fuel consumption that is avoided (or increased) relative to the Baseline scenario as a result of implementing the mitigation option.

Let's enter the data for the Household LPG stoves option. If you look at the spreadsheet **screening.xls** you will see that this option is expected to reduce consumption of kerosene by 24 million GJ in 2030 while increasing consumption of LPG in 2030 by 12 million GJ. The changes can be assumed to start from nothing in the base year (2010) and increase linearly to reach these values by 2030.

We can specify this information in LEAP as follows. First, select the Residential branch in the tree then select the **Final Energy Intensity** tab and then enter the following two expressions for the Kerosene and LPG branches. The expressions should override the expressions that were inherited from the Baseline scenario.

For Kerosene:

BaselineValue - Interp(2010, 0, 2030, 24.0)

> This expression specifies that the energy consumption of kerosene in the mitigation scenario gradually decreases versus the baseline scenario, so that by 2030 it is 24 million GJ less.

For LPG:

BaselineValue + Interp(2010, 0, 2030, 12.0)

> This expression specifies that the energy consumption of LPG in the mitigation scenario gradually increases versus the baseline scenario, so that by 2030 it is 12 million GJ more.
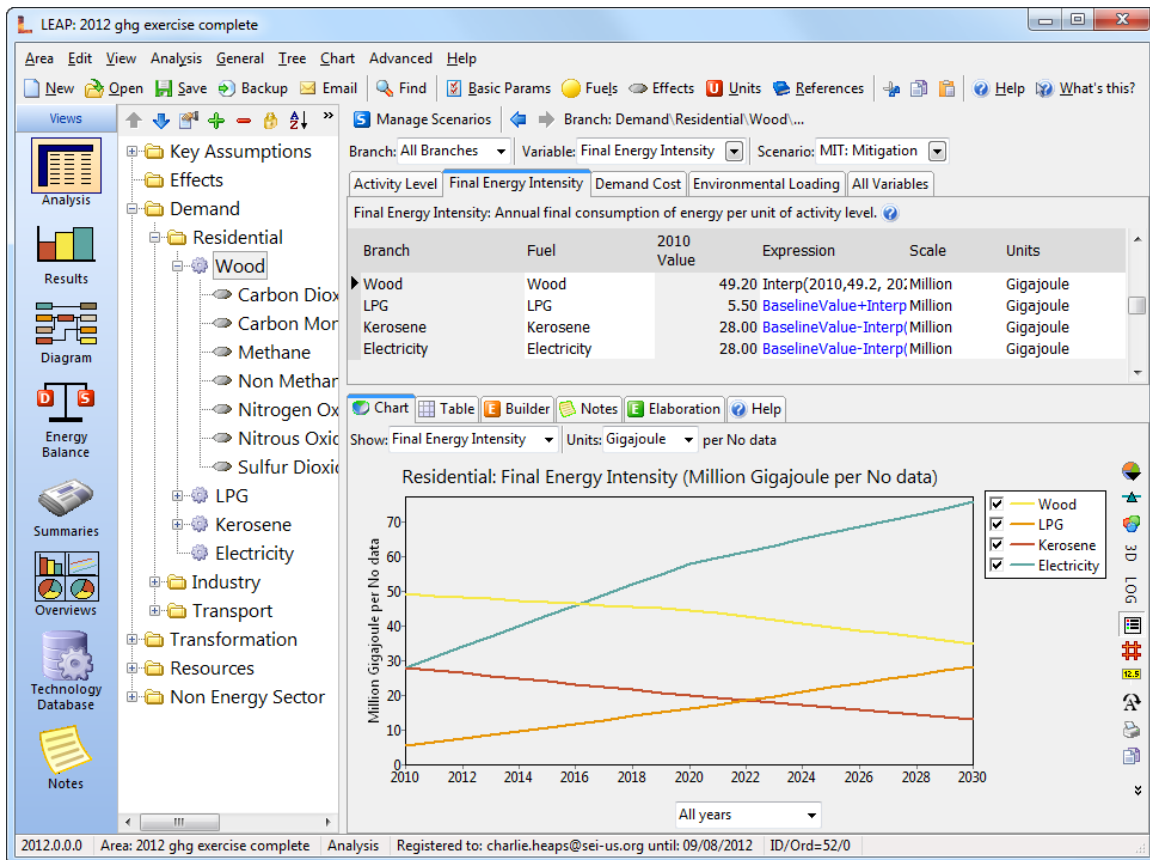
Tips:

1. The screening spreadsheet automatically creates these formulae for each of the demand-side mitigation options, so you may find it easiest to simply copy and paste these formulae from Excel to LEAP.

2. Make sure the formulae you enter are adapted to the local number formatting conventions used on your PC. For example, in Spanish speaking countries the list separator will be the ";" character and the decimal separator will be the "." character. LEAP automatically uses the local number formatting of your PC. So for example, the first equation above would be entered as follows in Spanish speaking countries:

   BaselineValue - Interp(2010; 0; 2030; 24,0)

   Note also that to facilitate easy copying and pasting from Excel to LEAP, you can edit the list separator character used in equations via the Assumptions tab of the spreadsheet.

When entering the data in LEAP's Analysis View, the screen should look something like this:

Use this same approach to continue specifying the data for the other mitigation options that you wish to include in your mitigation scenario. For now only include the following measures (starred items have helpful tips listed below):

- LPG Stoves
- Efficient Refrigerators
- Hybrid and Electric Cars*
- Industrial CHP
- Hydro*
- CCS*
- Forestry*

Most of the other options can be entered into LEAP in a way similar to how you specified the LPG stoves option. However specifying either of the two supply-side options (CCS and hydro), the forestry option or the transport options requires a bit more explanation.

- **Entering data for the transportation measures:** Both of the hybrid and electric measures affect future gasoline usage. In LEAP, this would require entering two

formulas in the same location and so for this simplified example we must combine the fuel usage estimates into one formula.

If you look at the screening spreadsheet you should see that the hybrid mitigation option is expected to decrease gasoline usage by 23.87 Million GJ in 2030 and the electric car mitigation option is expected to decrease gas consumption by 29.84 Million GJ. The two values can be added to give a total saving of 53.71 Million GJ so that the LEAP formula can thus be written as:

BaselineValue - Interp(2010, 0, 2030, 23.87+29.84)

Don't forget to add the additional requirements for electricity in a similar equation for the electric vehicle scenario.

- **Entering data for the Hydro and CCS Measures:** For these options you will need to enter data in the Transformation\Electricity Generation module. Click on the Processes branch and then select the **Endogenous Capacity** tab. This screen lets you specify a set of plants that will be added automatically and as needed as demands grow in order to meet a specified panning reserve margin. You can see that in the baseline LEAP will add Coal and Oil plants in amounts of 500 MW and 300 MW respectively as needed to keep the reserve margin on or above 40%. For the mitigation scenario, you will need to add the Hydro and Coal with CCS processes to the list. Click the Add button (➕) at the right of the table to add two new processes to the **Endogenous Capacity** screen for Coal with CCS and Hydro. You will need to delete (➖) the previous option for Coal and you will need to use the up (⬆) and down (⬇) arrows to make the Addition Order the same as the image below. Now change the **Addition size** values to read (Coal with CCS: 300, Oil: 300, Hydro: 200).

Dispatch Rule	Heat Rate	Process Efficiency	Exogenous Capacity	**Endogenous Capacity**

Endogenous Capacity (Megawatt). Added to maintain planning reserve margin of 40% in 200

Addition Order	Build Order	Process	Addition Size Expression
1	0	Coal with CCS	300
2	0	Oil	300
3	0	Hydro	200

- **Entering data for the Forestry Option:** Unlike all the other options, the Forestry mitigation option is a non-energy sector option. Its implementation has no direct effect on the energy sector with which LEAP is primarily concerned. However, you can still characterize this option in LEAP in very simple terms. Select the **Non-Energy Sector Effects** branch to view the branch for forestry.

There is only one variable for non-energy sector branches, and that is environmental loading.

Now you can specify the emissions sequestered in the Mitigation scenario in 2030 (22 million tonnes of CO_2). Don't forget to set the scaling factor and units to Millions and Tonnes respectively. Enter the emissions sequestered as a negative value because they are a net sink compared to the Baseline scenario. One way to enter this would be to use the following expression:
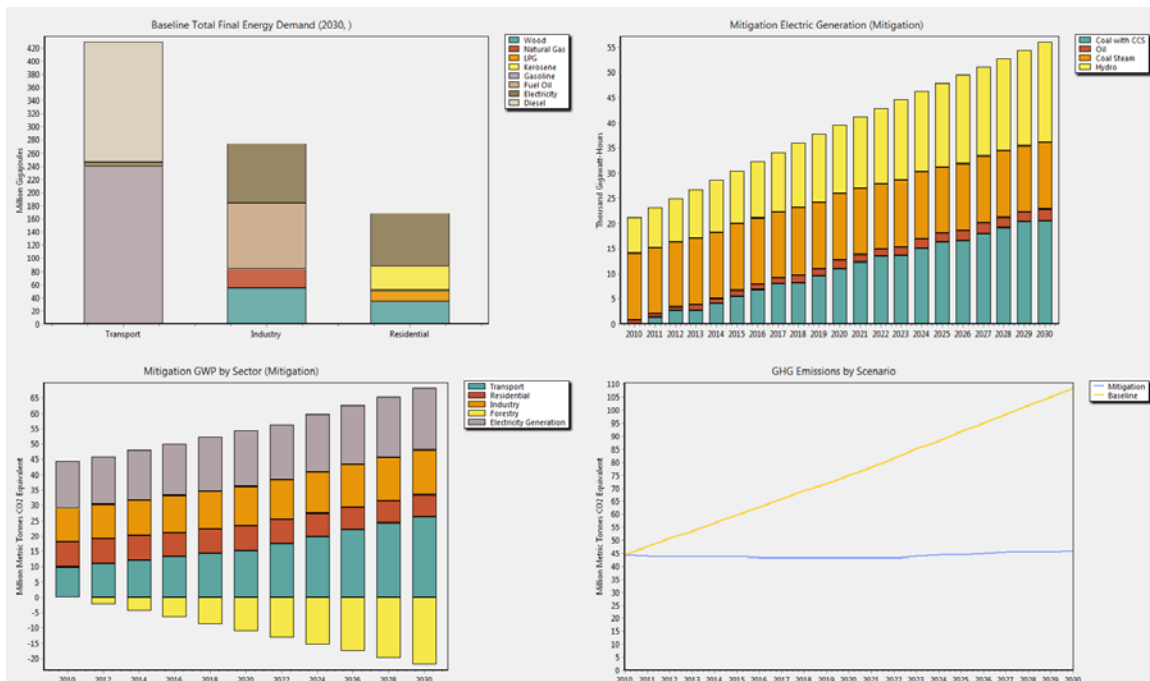
BaselineValue - Interp(2010, 0, 2030, 22)

5.4 Viewing Results in LEAP

Once you have completed specifying the data for the mitigation scenario, switch to the Overviews view. This view allows you to take advantage of favorites charts that you have already created so that you can quickly see changes in results. For the purposes of this exercise we have created an overview with four useful charts.

Compare your results to the ones produced here. These results are based on a scenario that includes all of the mitigation options except for Solar PV and Industrial Motors.
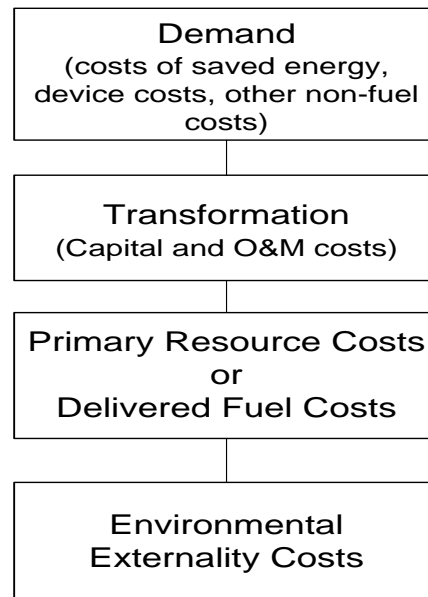
6 Exercise Three: The Costs and Benefits of the Mitigation Scenario.

In this third exercise we will enter data about the costs of the various policies and measures employed in the Mitigation scenario and then use LEAP to look at the overall costs of the scenario versus the "do nothing" baseline scenario.

LEAP performs cost-benefit calculations from a societal perspective by comparing the costs of any two policy scenarios. LEAP can include all of the following cost elements:

- Demand costs capital and operating and maintenance costs expressed as total costs, costs per activity, or costs of saving energy relative to some scenario.
- Transformation capital costs
- Transformation fixed and variable operating and maintenance costs.
- Costs of indigenous resources
- Costs of imported fuels
- Benefits of exported fuels
- Externality costs from emissions of pollutants
- Other miscellaneous user-defined costs such as the costs of administering an efficiency program.

Demand
(costs of saved energy, device costs, other non-fuel costs)

Transformation
(Capital and O&M costs)

Primary Resource Costs
or
Delivered Fuel Costs
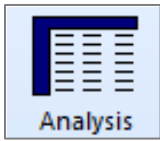
Environmental
Externality Costs

To set-up a costing analysis in LEAP it is first necessary to draw a consistent boundary around your system, so that LEAP will not double-count costs and benefits. For example, if you count the costs of fuels used to generate electricity you should not also count the cost of the electricity in an overall cost-benefit calculation.

Contrast this integrated perspective with the rough project-by-project approach that we used in developing the original screening spreadsheets. Taking this integrated perspective has a number of distinct advantages:

1. It is able to capture interactivity: the effect that one measure has on another. For example: our efficient refrigerators measure was originally judged in terms of the CO_2 saved based on a simple assumption about the baseline electric fuel mix. But in an integrated scenario we may be combining demand-side efficiency measures with supply-side fuel switching measures. Using LEAP we can see the interactive effects.

2. LEAP's analysis is dynamic: thus we can see what happens over time as demand-side measures penetrate the market and the electric supply sector grows accordingly to meet demands.

If you have not already done so, switch-on costing in LEAP by returning to the Analysis View, and going to **General: Basic Parameters; Scope** screen. Now go to the **Costing** tab and select the boundary that will be drawn around the system for the purposes of costing.   For this exercise we will select "Complete Energy System" as the boundary, meaning that fuel costs are accounted for only when they are imported or exported or when indigenously produced fuels are extracted as primary resources.

Now go back to the Analysis View and select the **Current Accounts** scenario. We will first enter data into LEAP that describes the costs (or benefits) of each.

You will need to refer to the spreadsheets you used for evaluating each mitigation measure. Enter the following information:

6.1 Demand-Side Measures

- **LPG Stoves:** From the spreadsheet, calculate the total annualized non-fuel costs per GJ of kerosene saved for this measure ($/GJ). Enter this data in LEAP for the Residential\Kerosene branch on the Demand Cost tab using the "Cost Saved Energy" cost method. Notice that costs of saved energy are always defined relative to some counterfactual. In this case the cost is defined relative to the baseline scenario. Notice also that in LEAP we will assess fuel costs separately from non-fuel costs, so you will need to calculate all of the costs except for the fuel costs.

- **Efficient Refrigerators in the Residential Sector:** Here you will need to use the spreadsheet to calculate the annual electricity savings and the total non-fuel costs of the measure. Again, use the "Cost Saved Energy" method.

- **Hybrid and Electric Cars in the Transport Sector:** Here you will need to use the spreadsheet to calculate the annual gasoline savings and the total non-fuel costs of both transport sector measures ($/GJ).

Tip: Note that in our screening cost curve some of the measures (vehicles, refrigerators, LPG stoves, CHP) had negative overall costs (since fuel savings for these measures outweighed the investment costs).   These are NOT the costs we enter into LEAP's demand analysis. Instead in LEAP we need to specify only the non-fuel costs of each measure. We will deal with the fuel savings later on using LEAP's integrated cost-benefit analysis perspective.

- **Combined Heat and Power (CHP) in Industry:** Here you can specify cost data in terms of the cost per GJ of fuel oil replaced with CHP. Again, you will need to

use the spreadsheet to calculate the annual fuel oil savings and the total non-fuel costs of the measure ($/GJ).

6.2 Transformation Measures

Entering data on the supply-side is more straightforward. We will take the data from the earlier exercises describing the capital, O&M, and lifetime of the four affected power plant types: coal, oil, hydro and coal with CCS and enter it on the various costing tabs under the Transformation: Electric Generation module. That data is repeated here for convenience:

Plant	Capital cost ($/kW)	Variable O&M Cost ($/MWh)	Lifetime (Years)
Coal	$1000	$3	35
Oil	$2000	$5	30
Hydro	$4000	$1	35
Coal with CCS	$3000	$3	35

Remember to use the default discount rate of 5% as the value for the Interest Rate for each plant. This is the value used to annualize the capital costs for each plant.

6.3 Non-energy Measures

LEAP is primarily an energy model. Currently it does not have the capability to include non-energy sector costs. Thus you cannot include the costs of the reforestation measure.

6.4 Resource Costs

Finally, we need to specify the costs of all of the various resources used in both scenarios. This data is entered under the Resource branches in LEAP for both indigenously produced primary fuels and for imported fuels.

Enter into LEAP the fuel prices specified on the **Assumptions** spreadsheet to complete the specification of the costs in your LEAP analysis. Enter costs into both the "Import Cost" variable and the "Indigenous Cost" variable for both primary and secondary fuels.

Finally, you should check that there are sufficient base year reserves of coal and natural gas available so that LEAP does not resort to importing these fuels. You can simply enter a very large number (e.g. 1 trillion GJ for each fuel) under the primary resources branch.
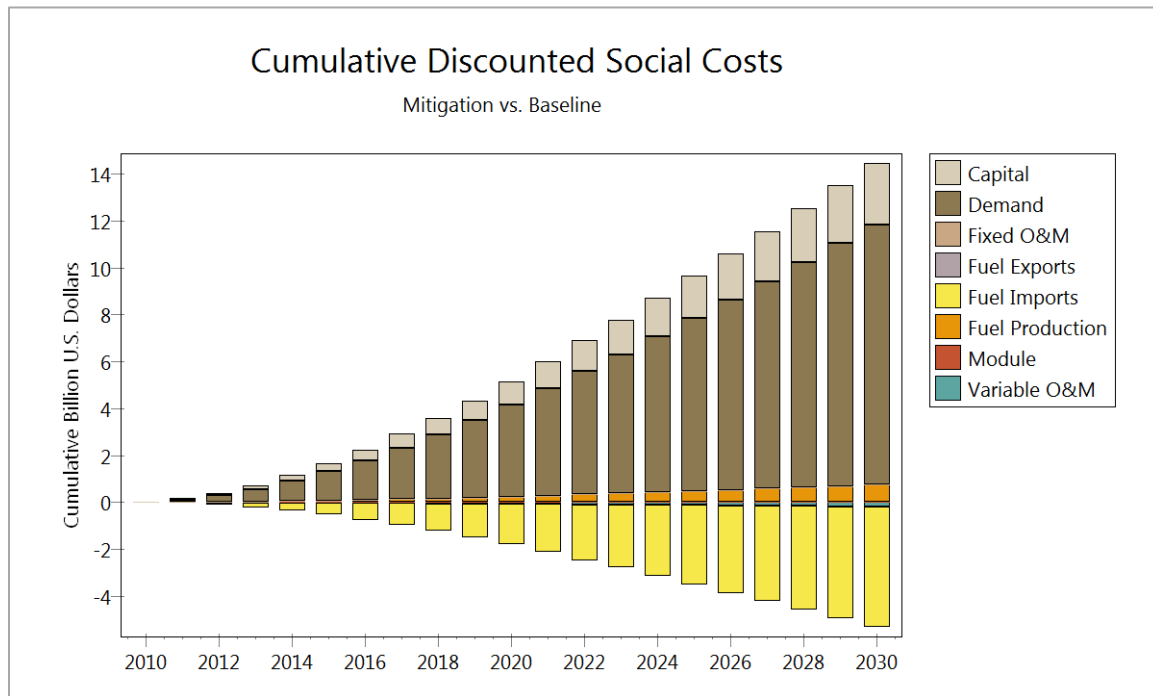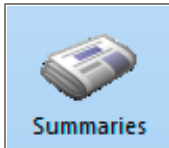
6.5 Viewing Results

You should now be ready to view some results. Click the results view and after LEAP has calculated review the overall cost results for the mitigation scenario minus the baseline scenario.   Select a chart configured to show the following:

- Cost results for the whole area.
- Differences between the mitigation and baseline scenarios.
- Cumulative discounted costs
- X axis showing years, Legend showing cost categories.

You should see a chart like this:

You can also review a cost-benefit **Summaries** summary in the summaries view. It should look like the one shown on the right. Notice that the Net Present Value of the Mitigation scenario vs. the Baseline scenario is a cost of about 6.4 Billion US$.

Cumulative Costs and Benefits: 2010-2030. Compared to Scenario: Baseline. Billion 2005 U.S. Dollar. Discounted at 5.0% to year 2010.	
Costs	Mitigation
Demand	
Residential	0.4
Industry	0.4
Transport	10.3
Transformation	
Transmission and Distribution	0.0
Electricity Generation	7.1
Resources	
Production	0.7
Imports	-5.2
Exports	0.0
Unmet Requirements	0.0
Environmental Externalities	0.0
Net Present Value	13.8
GHG Savings (Mill. Tonnes CO2 Eq.)	664.6
Cost of Avoided CO2 (U.S. Dollar/Tonne CO2 Eq.)	20.8

Why are there positive costs for the demand and Transformation sectors but negative costs for Resources?

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What are the main contributors to the high costs of the mitigation scenario?

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