LINKING GLOBAL SCENARIOS TO NATIONAL ASSESSMENTS: EXPERIENCES FROM THE RESOURCES PLANNING ACT (RPA) ASSESSMENT

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Abstract. The Resources Planning Act (RPA) Assessment provides a nationally consistent analysis of the status and trends of the Nation's renewable forest resources. A global scenario approach was taken for the 2010 RPA Assessment to provide a shared world view of potential futures. The RPA Assessment scenarios were linked to the global scenarios and climate projections used in the Third and Fourth Intergovernmental Panel on Climate Change Assessments to recognize the influence of global forces on domestic resource conditions and trends. This paper reviews the challenges encountered, approaches taken to address these challenges, and the lessons learned.

INTRODUCTION

The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) (P.L. 93-378, 88 Stat. 475, as amended) mandates a periodic assessment of the condition and trends of the Nation's renewable resources on forests and rangelands. Known as the RPA Assessment, it provides a snapshot of current U.S. forest and rangeland conditions and trends on all ownerships, identifies drivers of change, and projects 50 years into the future. A team of U.S. Forest Service (USFS) scientists and their cooperators analyzes trends in outdoor recreation, fish and wildlife, biological diversity, wilderness, forests, range, water, urban forests, landscape patterns, and the potential effects of climate change on these resources.

FRAMEWORK FOR THE 2010 RPA ASSESSMENT

The framing of the RPA Assessment has evolved over time to respond to changes in natural resource issues and management. The original legislation focused primarily on an economic evaluation of whether resource supplies could meet consumer demand. As public expectations about the role of natural resources broadened to include both ecological and socioeconomic values, the RPA Assessment analyses also broadened in recognition of the interrelationships between ecological and socioeconomic conditions in meeting the needs of the American public.

The 2010 RPA Assessment framework was designed to:

- incorporate global interactions that affect domestic resource conditions and trends;
- improve analyses of interactions among resources;
- extend our analytical capability to evaluate the potential effects of climate change across the resources; and
- describe more clearly the complexity and uncertainty associated with projecting future conditions and trends.

Global conditions and trends increasingly affect the conditions and trends in domestic natural resources. The 2010 RPA Assessment is framed around a set of future scenarios tied to a global set of scenarios that provide a coherent interdependent future for global population dynamics, socioeconomic factors, and climate change for more than 50 years into the future. These scenarios provided both quantitative and qualitative connections for the domestic resource analyses that project resource conditions and trends.

Using global scenarios to frame the 2010 analyses provided a coherent framework for evaluating outcomes across resource analyses. Socioeconomic and climate variables were all linked through these global scenarios. Scenarios were not assigned likelihoods, nor were any scenarios intended to be "most accurate" *per se*. Rather, these constructed scenarios provide a means of qualitatively and quantitatively understanding how different socioeconomic processes interacted to create different possible greenhouse gas (GHG) emissions pathways, how these emissions pathways drove global climate models to project different potential future climates, and how natural resources would respond to alternative futures. Each link in this chain of models is subject to uncertainty from a number of sources ranging from deliberate modeling assumptions (e.g., the global population growth rate selected for a given scenario), to stochastic processes in the global climate, economic, and

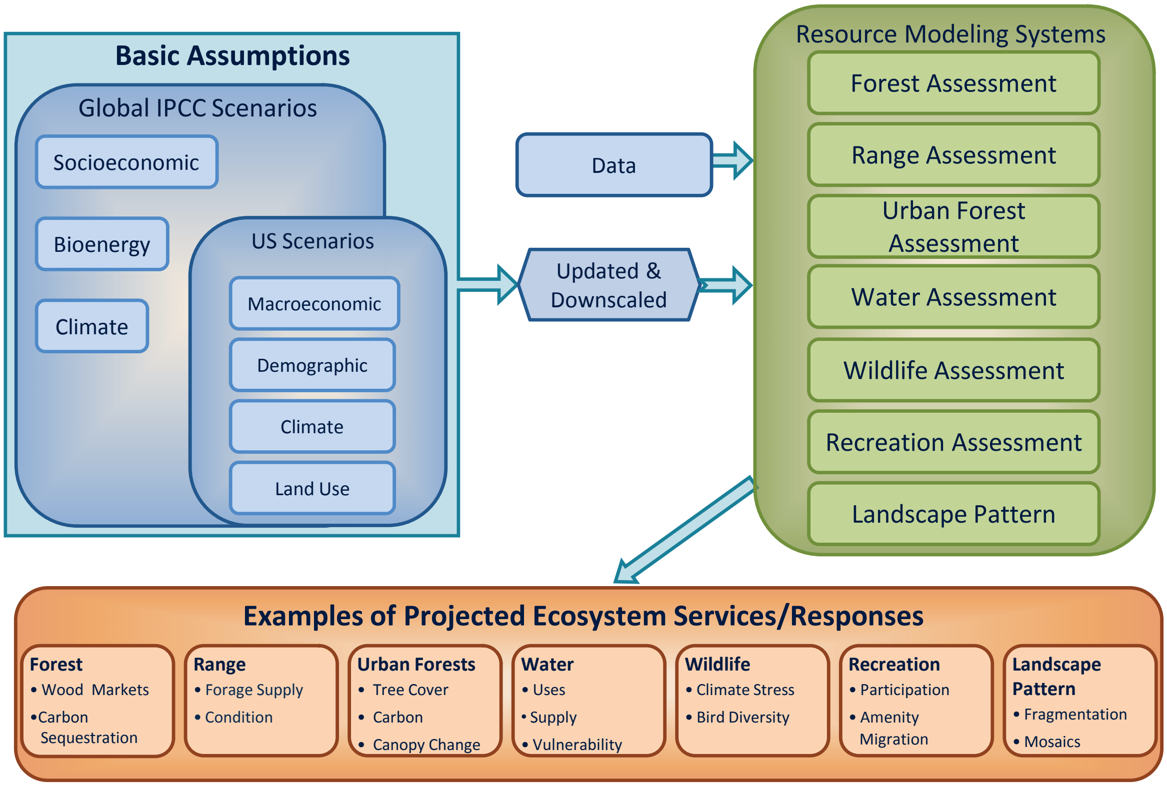

Figure 1.—RPA Assessment scenario analysis and modeling systems.

biological systems themselves. The scenarios help explore a consistent range of possible futures across resource analyses rather than intending to predict future resource conditions. Figure 1 presents a schematic that illustrates how global scenarios were linked to U.S. data that feed the various resource analyses.

SCENARIO APPROACH IN THE 2010 RPA ASSESSMENT

Scenarios are used to explore alternative futures and are intended to serve as a counterfactual framework for objectively evaluating a plausible range of future resource outcomes. This approach is particularly useful when there is considerable uncertainty about the trajectory of the driving forces behind political, economic, social, and ecological changes (Alcamo et al. 2003, Intergovernmental Panel on Climate Change [IPCC] 2007). Scenario methods can use both qualitative and quantitative approaches in visualizing alternative futures using different socioeconomic or institutional assumptions for the United States. Carpenter et al. (2005) and Nakicenovic et al. (2000) reviewed examples and uses of scenarios in other applications.

The challenge of incorporating global interactions into the 2010 RPA Assessment led to the search for a set of comprehensive global scenarios to serve as anchors for the RPA Assessment analyses. These scenarios would provide the global context and quantitative linkages between national and global trends. We identified several criteria for evaluating and selecting global scenarios:

- Scenarios must be globally consistent in their underlying assumptions.
- Scenarios must be from a source that is scientifically credible and well-documented.
- Scenarios must include assumptions about key driving forces of resource change:
    - Population and economic growth
    - Land use change
    - Climate change
    - Energy use
- Globally consistent data must be available to link to U.S.-scale analyses.

A number of scenario-based approaches were reviewed as potential anchors for the 2010 RPA Assessment, including the Millennium Ecosystem Assessment

Table 1.—Key characteristics of IPCC scenarios used to develop the RPA scenarios[a]

Characteristics	Scenario A1B	Scenario A2	Scenario B2
General global description	Globalization, economic convergence	Regionalism, less trade	Slow change, localized solutions
Global real GDP growth (2010-2060)	High (6.2X)	Low (3.2X)	Medium (3.5X)
Global population growth (2010-2060)	Medium (1.3X)	High (1.7X)	Medium (1.4X)
U.S. GDP growth (2006-2060)	High (3.3X)	Low (2.6X)	Low (2.2X)
U.S. population growth (2006-2060)	Medium (1.5X)	High (1.7X)	Low (1.3X)
Global expansion of primary biomass energy production	High	Medium	Medium

[a] Numbers in parentheses (e.g., 6.2X) are the factors of change in the projection period. For example, global GDP increases by a factor of 6.2 times between 2010 and 2060 for scenario A1B.

(Alcamo et al. 2003, Carpenter et al. 2005), the IPCC (Nakicenovic et al. 2000), the "Mapping the Global Future" project (National Intelligence Council 2004), and the United Nations Environmental Program's Global Environmental Outlook (United Nations Environmental Program 2002, 2007). Although these studies exhibited wide variations in approach and objectives, all focused on a similar set of driving forces that shape the global future.

Scenarios used in both the IPCC third and fourth Assessment Reports (known as TAR and AR4, respectively) were selected to provide the global scenarios for the 2010 RPA Assessment. The Special Report on Emissions Scenarios from the TAR (Nakicenovic et al. 2000) provides detailed documentation of these scenarios that were used in both the TAR and AR4. The advantage of using IPCC scenarios as the basis for the 2010 RPA Assessment was the level of scientific rigor and acceptance surrounding their development, the degree of documentation, and the facilitated access to the data. The availability of both socioeconomic and climate data at global, regional, and country scales was also a critical decision factor. The range of scenarios considered in the IPCC Assessments provided a broad spectrum of potential futures from which a subset of the most relevant to evaluating potential U.S. future resource conditions and trends could be selected. In addition to their focus on climate change, the IPCC scenarios also incorporated detailed analyses of global energy trends, featuring alternative levels of growth in renewable energy and biomass energy production in the context of anticipated peaking of global petroleum production in the decades ahead.

None of the IPCC scenarios was considered to be the "most likely" or "business as usual" future. The IPCC deliberately avoided judging the likelihood of future scenarios. Although covering a wide range of alternative futures, the scenarios also deliberately excluded global disaster scenarios. Scenarios simply provide a tool to explore a range of future outcomes without judgment about the desirability of the outcomes (Nakicenovic et al. 2000).

Selecting the Scenarios for the 2010 RPA Assessment

The variation across the IPCC scenarios in projections of world population, U.S. population, world and U.S. GDP, energy futures, and climate was evaluated. There was no pre-determined test of what constitutes "sufficient" variation in any of the variables, so the basic test was whether a subset of the IPCC scenarios would cover the range of possibilities that were likely to drive the greatest variation in resource effects in the United States. Three IPCC scenarios were chosen as the basis for the RPA scenarios. We retained the IPCC labels for continuity: A1B, A2, and B2. Table 1 lists some of the key characteristics of the IPCC scenarios chosen to be the basis for developing national scenarios for the 2010 RPA Assessment.

Table 2.—IPCC U.S. population projections and updated RPA U.S. population projections, 2000-2060 (millions of people)

	2000	2010	2020	2030	2040	2050	2060
IPCC							
A1B	277	300	324	347	367	383	396
A2	278	306	334	363	390	417	447
B2	278	299	322	337	343	348	351
RPA							
A1 B	282	309	336	364	392	420	447
A2	282	315	346	380	416	457	505
B2	282	308	334	353	366	381	397

Each IPCC scenario had multiple associated climate projections. The climate projections vary across scenarios in response to the associated levels of energy production and GHG emissions, but they also vary within a scenario because the general circulation models (GCM) differ in their approaches to modeling climate dynamics. Therefore, we selected three GCMs for each of the three scenarios in order to capture a range of future climates.

Scaling and Updating IPCC Data to U.S. and Sub-national Scales

The IPCC scenarios in combination with the climate projections from the GCMs provided the global demographic, macroeconomic, and climate assumptions for the various component resource analyses in the 2010 RPA Assessment. The next step was to develop national and sub-national projections of population, GDP, income, bioenergy use, and climate for the United States that are linked to the IPCC projections.

The IPCC scenario-based projections provided large-scale data, primarily at the global and macro-region scale. Country-level data for projections of population and GDP were also available. The IPCC projections of U.S. population and GDP were updated with more recent U.S. data. In doing so, the trends and cross-scenario relationships of IPCC scenarios were maintained. The updated estimates were then disaggregated to obtain U.S. county-level income and population data for the RPA scenarios.

Projecting U.S. population and economic information at the county level involved a number of simplifying assumptions. Accounting for all the various state and local events that govern the change and development of towns and counties is impossible. As a result, the RPA county-level projections should not be taken as statistically reliable projections of possible economic or demographic futures for specific counties. Rather, the overall spatial pattern of change in response to alternative scenarios is more important in our analyses, displaying the heterogeneity that would not be evident if projections were made only at the RPA regional or national levels.

U.S. Population Projections

The U.S. population projection for the IPCC A1B scenario was based on the 1990 Census. We updated the RPA A1B population projections to align with the 2004 Census population series for 2000-2050 (U.S. Department of Commerce, Bureau of the Census 2004), with an extrapolation to 2060. The population projections for A2 and B2 were updated to begin at the same starting point in year 2000, and then follow a projection path that maintained the same proportional relationship to A1B as in the IPCC projections. Table 2 shows the IPCC U.S. population projections and the updated U.S. population projections for the 2010 RPA Assessment. Figure 2 illustrates the population projections for the three RPA scenarios relative to historical population trends in the United States. County-level population projections were developed for the three RPA scenarios (Zarnoch et al. 2010).

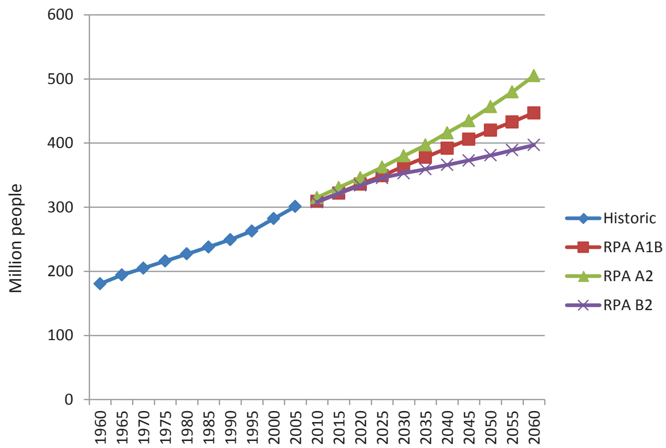

Figure 2.—Historic U.S. population and projected U.S. population to 2060 by RPA scenario.

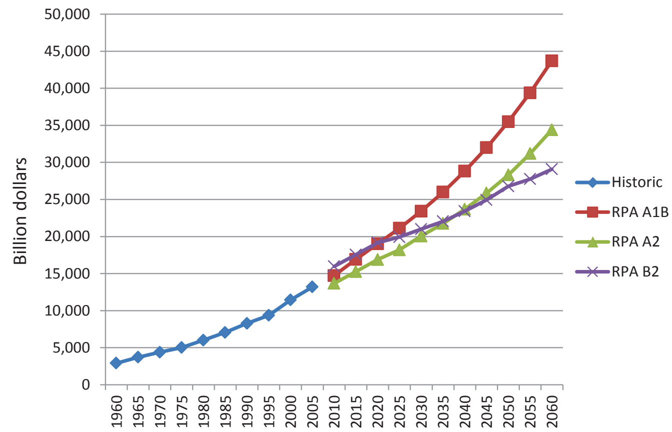

Figure 3.—Historic U.S. GDP and projected U.S. GDP to 2060 by RPA scenario.

U.S. Economic Projections

Macroeconomic trends (e.g., trends in GDP, disposable personal income, and labor productivity) have a critical influence on the supply of and demand for renewable resources. The IPCC data were based on economic data from the early 1990s, so the GDP projections were updated to start with the official U.S. GDP value for 2006 for all three RPA scenarios (U.S. Department of Commerce, Bureau of Economic Analysis 2008a).

We applied GDP growth rates (U.S. Department of Agriculture, Forest Service 2012) to develop an adjusted projection of GDP for the A1B scenario. We revised the A2 and B2 GDP projections to maintain the same proportional relationship between the three RPA scenarios as defined by the IPCC U.S. GDP projections. Table 3 shows the differences between the IPCC projections for U.S. GDP and the updated RPA GDP figures. Figure 3 shows the differences among the three RPA scenario projections for updated GDP in comparison to historical U.S. GDP.

Projections of personal income and disposable personal income were also developed for RPA scenarios. The official U.S. 2006 statistics for personal income (PI) and disposable personal income (DPI) were used to start the updated projection for the A1B scenario (U.S. Department of Commerce, Bureau of Economic Analysis 2008b). We calculated the A2 and B2 projections for PI and DPI to maintain the same proportional relationship across RPA scenarios that were used in calculating the trajectories for U.S. GDP. The national DPI and PI projections were disaggregated to the county level (U.S. Department of Agriculture, Forest Service 2012).

Table 3.—IPCC U.S. GDP projections and updated RPA U.S. GDP projections, 2000-2060 (billion 2006 USD)

	2000	2010	2020	2030	2040	2050	2060
IPCC-U.S GDP							
A1B	10,654	13,456	16,888	21,093	26,112	31,117	38,524
A2	10,282	12,484	14,986	18,061	21,436	24,825	30,330
B2	11,297	14,586	17,017	18,905	21,193	23,466	25,640
RPA – U.S. GDP							
A1B	13,195	14,736	19,029	23,424	28,835	35,496	43,696
A2	13,195	13,679	16,890	20,057	23,683	28,313	34,401
B2	13,195	15,974	19,164	20,990	23,416	26,778	29,084

Population, GDP, and income are important variables in determining GHG emissions levels. Although the U.S. population accounts for a small proportion of the world population, the U.S. contribution to emissions is much higher than its percentage of world population because of relatively high energy consumption. Therefore, updating the U.S. population and GDP projections (raising them modestly as we did) could lead to slightly higher global emissions than projected in the IPCC scenarios, or could lead to higher energy efficiency that would offset emissions. Regardless, we considered re-aligning the IPCC U.S.-level economic and population data with more recent data to be critical for projecting national resource effects within the RPA resource modeling systems. By not adjusting GHG emissions we have implicitly adopted the same variations in climate change across scenarios as projected by IPCC.

It can be noted also that the original IPCC emissions scenarios and the adjusted U.S. projections for the 2010 RPA scenarios were completed before the 2008-2009 global economic downturn. We chose 2006 as the base year for the U.S. economic variables because they were the most recent data available when the RPA scenarios were constructed. The U.S. GDP projection trend line from 2006 to 2010 does not account for the downturn in GDP and other economic variables through 2010, creating some discontinuity in the early years of the projection period. However, RPA long-term projections are not intended to predict temporary ups and downs, meaning that recessions are not part of projected 50-year trends. The recent global recession was quite severe, but the scenarios included in this Assessment have varying rates of economic growth, both for the United States and globally, that provide a robust set of projections across the range of potential futures.[1]

[1] In fact, two of the scenarios (B2 and A2) have lower U.S. GDP growth over the next 50 years than projected by a lognormal regression equation based on historical U.S. GDP growth data through 2010 (taking into account the effects of the recent recession), and the GDP growth of the A1B scenario closely matches the 50-year projection of the lognormal equation, indicating that the RPA GDP growth assumptions are at least as low as or lower than would be expected based on a time series regression analysis of historical GDP growth through 2010.

U.S. Bioenergy Projections

Assumptions about the role of biomass in bioenergy projections were linked to the IPCC scenarios as was done with other RPA Assessment assumptions discussed in this document. The assumptions for bioenergy projections were incorporated into the RPA Forest Assessment Modeling System that includes the Global Forest Products Model (GFPM) and the U.S. Forest Products Module (USFPM). The approach accounted for relevant regional land use projections as well as regional biomass energy projections provided by IPCC scenarios and their supporting database (Nakicenovic et al. 2000). For a detailed explanation of the RPA Assessment bioenergy assumptions, see Ince et al. (2011).

In all three RPA scenarios, expansion of biomass energy plantation area projected in the IPCC macro-regions was directly correlated with projected regional expansion in primary biomass energy production. Comparing across scenarios, A1B had the largest regional expansion in the area of biomass energy plantations and also biomass energy production, while expansions of biomass energy plantation area and biomass energy production were both smaller in the A2 and B2 scenarios.

Because the United States maintains a large share of global GDP in all three scenarios and energy consumption is correlated with GDP, and because biomass energy replaces the declining output of petroleum-based energy, the U.S. projections of expansion in wood energy consumption are prodigious in all RPA scenarios. The expansion is by far the highest in the A1B scenario, followed by the A2 scenario, and lowest in the B2 scenario (Fig. 4). In the A1B scenario, for example, U.S. wood fuel feedstock consumption climbs to levels that dwarf U.S. consumption of wood for all other end uses (about five times higher by 2060 than all other wood uses), while in the B2 scenario U.S. wood fuel feedstock consumption climbs to a level just slightly higher than all other commercial uses.

U.S. Land-Use Projections

Land-use change analyses provide a critical link to other models that analyze resource changes, such as wildlife habitat and timber availability. The IPCC provided

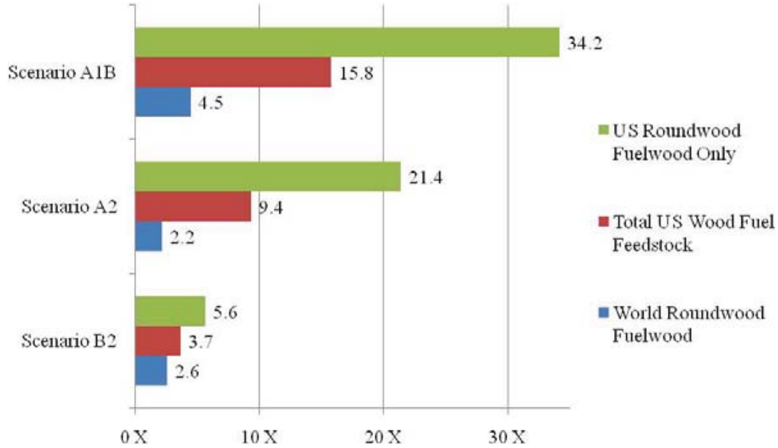

Figure 4.—Projected expansion from 2006 to 2060 in the volumes of wood consumed for energy by RPA scenario, including total U.S. wood fuel feedstock consumption, U.S. roundwood fuelwood consumption, and world roundwood fuelwood consumption.

global land-use projections by macro region that we used to deduce global wood energy consumption by region, but separate RPA land-use area projections were developed that were not tied to the IPCC land-use projections. However, the U.S. land-use projections are indirectly linked to the IPCC projections because the RPA land-use model includes both population and income variables that came from the county-level population and income projections described earlier. The land-use projections are documented in more detail in Wear (2011).

U.S. Climate Projections

We selected AR4 climate model projections for A1B and A2 from the PCMDI Climate Model Intercomparison Project 3 (CMIP3) Web site, and the TAR climate model projections for B2 from the IPCC Date Distribution Centre (DDC). Three GCMs were chosen for each scenario based on the availability of the projections in the CMIP3 database at the time this study started and the variables needed for the RPA Assessment and assessments being done in Canada (Price et al. 2011). For the TAR climate models, a suite of climate models projecting the B2 scenario had been downscaled using the same procedure used for the 2010 RPA Assessment, and had been used to assess the impact of climate effects on vegetation (Price et al. 2004). Hence, these models were selected. The projections from this suite of GCMs capture a range of future climates.

The resolution of GCM projections stored in either the IPCC DDC or at the CMIP3 Web site range from 250 to 600 km on the side of the grid, far coarser than that typically used in many impact assessments, including the RPA Assessments. Many of the resource analyses in the RPA Assessment are conducted at the county level, which in turn necessitated climate projection data at that spatial scale. The IPCC climate projections were first downscaled to the approximately 10-km scale, and then aggregated to the county scale. More detailed documentation of the development of the RPA climate scenario-based projections and downscaling process can be found in Joyce et al. (in prep).

For the 2010 RPA Assessment projection period, the A1B scenario mean represents the warmest and driest scenario at the scale of the United States (Fig. 5). The A2

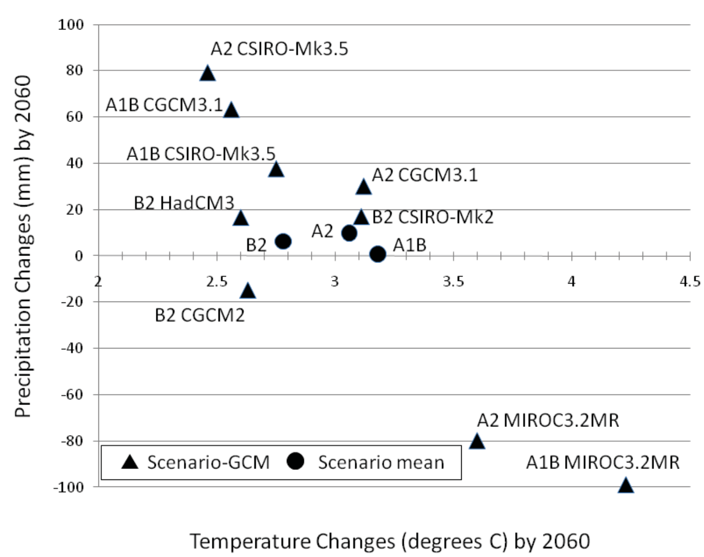

Figure 5.—U.S. temperature and precipitation changes from the historical period (1961-1990) to the decade surrounding the year 2060 (2055-2064) for scenario means and scenario-GCM combinations.

scenario becomes the wettest although the precipitation changes at the scale of the United States are small at 2060. Regional differences in precipitation projections vary greatly (Joyce et al. in prep). The B2 scenario projects the least warming of these three scenarios. The individual model projections vary across the individual scenario. For example, within the A2 scenario, the CGCM model projects the least warming and the MIROC model projects the greatest warming within this scenario. While the IPCC climate projections extend to 2100, the RPA Assessment resource analyses stop at 2060.

LESSONS LEARNED

Developing a global scenario-based approach for the 2010 RPA Assessment was a learning process because previous RPA assessments had not employed global scenarios. Using common scenario assumptions was not new for the RPA process, but using assumptions nested within global scenarios was a departure from the past. It provided a more coherent framework, even though not all resource analyses could use all of the variables in the common assumptions.

The RPA Assessment is not a climate assessment, but rather it is a U.S. renewable resource assessment that takes global change into account. The RPA analyses consider climate as one more variable among many to consider in evaluating future resource conditions. Using the IPCC scenarios as our global anchor raised a concern that we would be seen as climate-focused. But the rationale for selecting the IPCC scenarios was based on the breadth of the variables they used in their analyses as well as the availability of the underlying data. For example, apart from climate projections, the scenarios also incorporate wide variation in wood energy projections linked to the IPCC projections of overall global energy production by source in the context of peaking oil production. As mentioned previously, the driving forces of change tend to be very similar in large-scale assessments, regardless of the objective of the assessment. Other global assessments, for example, point similarly toward anticipated large shifts in energy production toward expanded renewable energy and biomass energy production.

Although the IPCC scenarios provided a good linkage for the RPA scenarios, the major downside was the "freshness" of the IPCC socioeconomic data. Even though considerable work was done to update GCMs between the third and fourth IPCC assessments, no updates were done to the underlying scenario assumptions, so that the population and economic data were somewhat dated. As a result, compromises had to be made between staying true to the IPCC scenarios and updating to more recent data (as we did for U.S. GDP and population projections). For the 2010 RPA Assessment, updating the U.S. population and economic data was considered more important than maintaining strict conformity to the IPCC scenarios because population growth and economic factors are important drivers of resource change.

Developing the data for the United States, especially at the sub-national level, was time consuming and complex and also required a number of compromises. Even at the national level, there are limited sources for 50-year projections of population and income. At the time the projections were developed, the Census Bureau population projections stopped at 2050, ten years short of the RPA projection period. No comparable official U.S. estimate for GDP or other economic variables extends 50 years. Disaggregating the data to smaller scales is even more fraught with difficulties, particularly with limited resources to undertake complex analyses. Climate downscaling also presents myriad challenges—once an approach is decided upon, it is time consuming to conduct the downscaling and subsequently all of the associated data quality checks once the downscaling is completed. As long-term analyses become more common in large-scale assessments, cooperation across agencies to develop sets of U.S. scenarios that could be used in a variety of analyses would be extremely useful.

Assumptions at the scale of broad global regions (such as IPCC "macro" regions) are not always easy to translate to corresponding assumptions for a particular country. The United States is part of an IPCC macro region (OECD90) that includes all of the developed countries of Europe, plus Japan, Canada, Australia, and New Zealand. However, U.S. trends do not always move in concert with the OECD90 regional trend. One of the most obvious examples is in population—population growth is higher in the United States than in most developed countries. Another example of the complexity of translating IPCC scenarios to the United States was the treatment of bioenergy. To be consistent with the role of biomass energy in the IPCC scenarios, it was necessary to require large increases in U.S. consumption of woody biomass that are outside historic patterns of wood energy use, but are consistent with the IPCC view that petroleum-based energy will peak and be displaced in part by renewable energy and biomass energy during the projection period.

Regardless of when scenarios are constructed, some event is likely to create havoc with the assumptions when the project is on a multi-year timeline. The global recession began in 2007, right after the 2010 RPA scenarios and downscaling were completed. By the time the seriousness of the downturn was evident in 2009, it was not feasible to re-create the scenarios because of time and resource constraints. The important role of the housing sector in the economic downturn was also problematic for the RPA Assessment, since dramatic impacts on parts of the forest sector (e.g., reduced demand for lumber and wood panel products) are unlikely to be reversed in the near future.

Communicating the sometimes complex results from scenarios is also challenging. Providing a range of potential future outcomes is realistic given the many uncertainties associated with long-term projections. But there is a danger that users will conclude the information is of little use because of the uncertainty or because the volume of information can be overwhelming. Identifying commonalities and differences across scenario results and the underlying causes of variation across results can help users sort through these complexities. Presenting the results of the 2010 RPA Assessment will be another learning process as we develop communication strategies for various user groups.

SUMMARY

We chose to take a global scenario approach for the 2010 RPA Assessment to provide a shared world view of potential futures. We linked our scenarios to the global scenarios A1B, A2, and B2 developed in the Third and Fourth IPCC Assessments. The use of global scenarios enriched the RPA analyses, but also created many challenges. Large-scale assessments are multi-year projects. Therefore, linking to a set of scenarios for a completed assessment tends to create issues about the timeliness of the source data, which in turn require decisions about updating and otherwise altering the source data, and the potential consequences of those alterations. Global assumptions and data, even at smaller regional scales, are not always easy to translate to national assumptions, especially if the regional trend is not consistent with the individual country trend.

Large-scale assessments such as the RPA Assessment are time- and resource-intensive. Linking to global assessments can actually save some time and resources, as it is unnecessary to develop those assumptions, and provides a starting place for the national assumptions. However, cooperation across agencies for development of national assumptions would be even more effective than individual agencies' developing unique sets of national assumptions. As more large-scale, long-term analyses are undertaken, this type of cooperation will become increasingly important.

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