EXECUTIVE SUMMARY

Center for RESOURCE SOLUTIONS

Review of Renewable Energy in Global Scenarios

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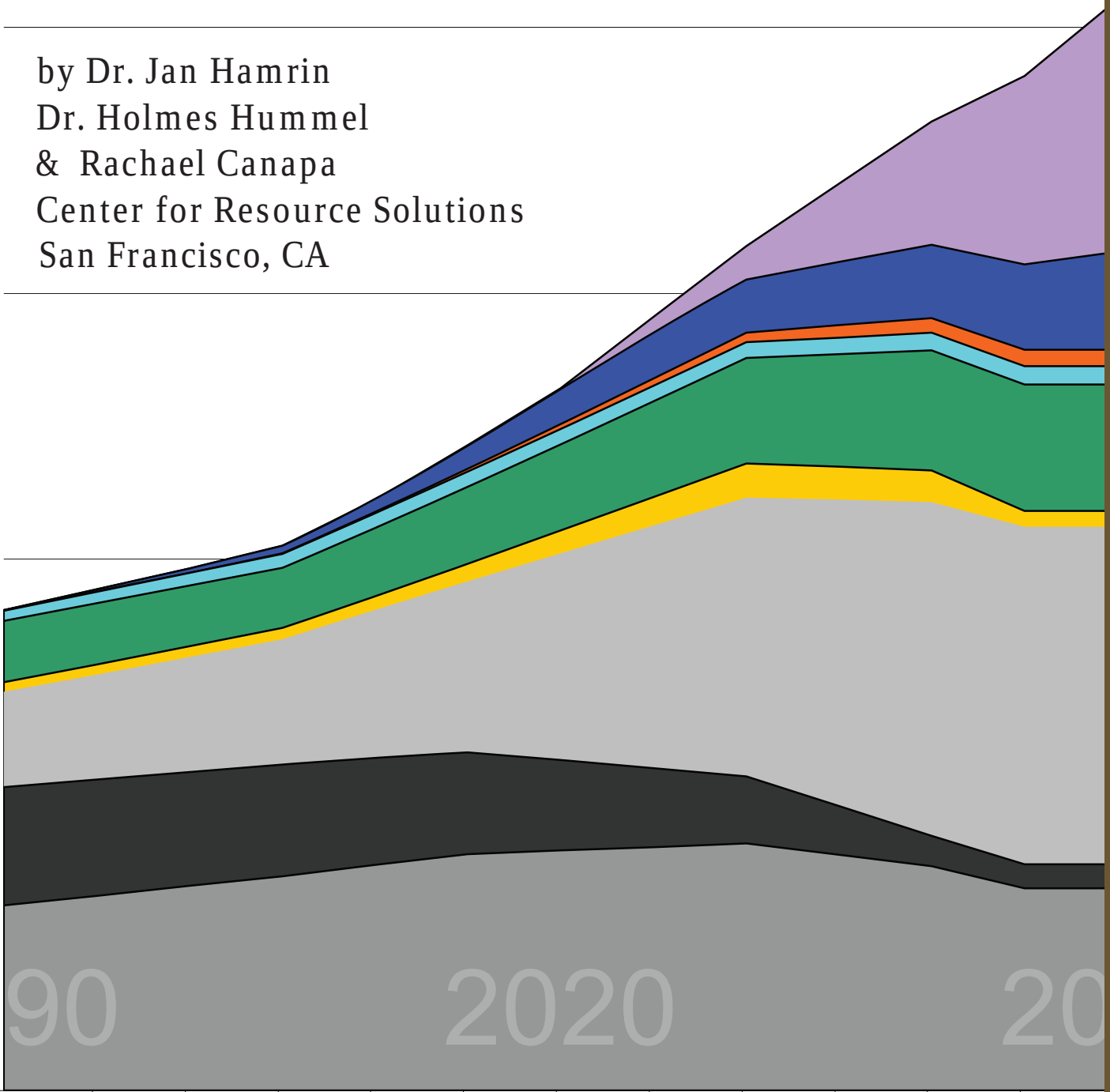

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EXECUTIVE SUMMARY
REVIEW OF THE ROLE OF RENEWABLE ENERGY IN GLOBAL ENERGY SCENARIOS

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What energy future we ultimately experience is the result of choice; it is not fate. Policy makers, investors and consumers do have choices, and every indication in the headlines today is that their decisions are not tracking to the trends of the past. Energy scenarios can help these decision-makers evaluate the available options and the potential implications of their choices. However, to be useful scenarios are needed that provide a broad range of energy options and include explicit data with regard to the assumptions that went into the analysis.

Scenarios are analytical tools that describe our future energy supply. The purpose of this report is to: (1) explain why certain global energy scenarios contain larger shares of renewable energy than others; (2) identify key assumptions; and (3) recommend appropriate settings for assumptions critical to the role of renewable energy that might be used in future global energy scenarios.

As the basis for the discussion of the role of renewable energy technologies in scenarios, the authors undertook a comparison of a group of primarily global energy scenarios. The approach included a comparison of:

- The goals of the scenarios
- The role of renewable energy in terms of shares and growth rates
- The methods used to derive the scenarios
- The key assumptions used in the scenarios
- How costs, benefits and potentials of renewable energy technologies were considered; and
- Major common grounds and differences

The analysis included eleven reports and 35 scenarios but because of constraints on time, resources, and data availability, we were not able to go into depth on all of them. The reports that were analyzed included:

- IEA World Energy Outlook 2006 (WEO 06)
- IEA Energy Technology Perspectives, 2006 (ETP)
- Intergovernmental Panel on Climate Change Fourth Assessment Report Summary for Policy Makers Working Group 1, 2000 (IPCC)[1]

[1] Although these three scenarios are most recently featured in the IPCC's Fourth Assessment Report (2007) because they were selected for use by Working Group 1, the underlying energy scenarios were originally published in the IPCC's Special Report on Emissions Scenarios (2000).

- World Energy Technology Outlook, 2006 (WETO H_2)
- World Energy Council Global Energy Scenarios, 1998 (WEC GES 2050)
- German Advisory Council on Global Change – Climate Protection Strategies for the 21st Century: Kyoto and Beyond, 2003 (WBGU)
- European Renewable Energy Council/Greenpeace Energy [r]evolution, 2007 (EREC/Greenpeace)
- European Energy and Transport Scenarios on Energy Efficiency and Renewables, 2006 (EET/Eff & RE – European scenarios)
- American Solar Energy Society – Tackling Climate Change in the U.S., 2007 (ASES – U.S. Scenario)

For a variety of reasons we reviewed but did not analyze the two reports with detailed "storyline" scenarios:

- Shell Global Scenarios to 2025, 2005 (Shell)
- Pew Center U.S. Energy Scenarios for the 21st Century, 2003 (PEW)

The report discusses the types of scenarios and their uses, the types of models used, and how various technologies are characterized in the different scenario sets. These technologies are shown in the table below, according to the data available.

Table 1: Technology Types Included in Scenario Sets

	Type of Technology	IEA WEO 2006	IEA ETP	IPCC	WETO H2	WEC GES to 2050	EREC/ Green-peace	EET Eff and RE	ASES	WBGU
Renewable Electricity Sources	Hydropower	X	X		X	X	X	X		X
	Biomass	X	X	X	X	X	X	X	X	X
	Geothermal	X	X		X		X	X	X	X
	Solar	X	X		X	X	X	X	X	X
	Solar Photovoltaics	X	X		X		X	X	X	X
	Concentrating Solar Power	X	X		X		X		X	X
	Wind Energy	X	X		X		X	X	X	X
	Ocean Energy	X	X				X	X		
	Other Renewables			X		X				
	Energy Efficiency	X	X	X	X	X	X	X	X	X
	Solar Heating and Cooling		X				X	X		X
	Biofuels	X	X		X		X	X	X	
	Nuclear	X	X	X	X	X		X		X
	Hydrogen	X	X		X			X	X	X
	Carbon Sequestration	X	X	X	X				X	X

The report characterizes the role of renewable energy for each reviewed scenario individually, and these results and key driver metric "dashboard" diagrams are presented in Appendix II. The report also includes a series of comparisons between the scenario results using different indicators, one of which is the share of renewables in the primary energy portfolio. Among the baseline reference scenarios that best reflect "business as usual", there is little variation in the

expectation for the role of renewables in the future, around 11-15% of primary energy production by 2050. Large differences are seen between scenarios that assume specific policy interventions or technological innovations that change the course of the future based on one of the "business as usual" reference cases. For these intervention cases, the EREC/Greenpeace and WBGU B1-400 scenarios are the most ambitious, reaching nearly 50% of the primary energy profile by 2050. Other intervention cases ranged from 19.0 to 42.5% for the share of renewables in primary energy by 2050. Exploratory reference cases involve implicit assumptions about how the future could be very different from the past and are not the result of a single policy. These scenarios showed a variation between 11.6% and 39.4% renewable energy share of primary energy by 2050.

The results for invention cases and exploratory reference cases vary widely for two reasons: (1) the types and combinations of interventions across these scenarios are quite heterogeneous and (2) the modeling tools that characterize the effects of those interventions also vary in nature. Furthermore, the range of renewable technologies characterized for each scenario is different for each scenario, as shown in the Technology Matrix Table above.

Another indicator investigated was the portion of electricity expected to be generated from renewable energy sources for each of the scenarios for which electric power sector data were disclosed. The EREC/Greenpeace [r]evolution scenario is strikingly optimistic, reaching 70% by 2050, while all the other scenarios cluster in the 25-35% range. The lowest two scenarios for share of renewables in electricity generation are the IEA World Energy Outlook Baseline Scenarios that anticipate no change in policy context.

Because global energy scenario models are structured to seek a combination of cost-effective energy supplies to meet a given demand, the cost characteristics assigned to each renewable energy technology are critical determinants. However, the analysis prepared for this report was challenged by lack of data disclosure and transparency about cost assumptions. Only four of the scenario studies reviewed for this report published or provided the input cost assumptions for renewable energy technologies: IEA Energy Technology Perspectives (Map scenario), IEA World Energy Outlook 2006, EREC/Greenpeace Energy [r]evolution, and ASES.

Renewable energy and energy efficiency are categories of mitigation measures that appear in nearly every climate stabilization scenario, and many energy experts would agree that carbon reduction targets are expected in the future. However, among the scenarios selected for review, few explore the impact of explicit climate policies to limit greenhouse gas emissions. Though only four of the future energy scenarios considered the effect of imposing emissions constraints on the energy sector, most of the scenarios published data for carbon emissions from the energy sector, which provide a key basis for comparison among scenarios via a dashboard of key emissions drivers.

Having completed the analysis, the authors suggest seven overarching recommendations to modeling teams constructing future global energy scenarios:

1. Provide **data transparency** for scenario inputs and outputs, including cost and performance assumptions.

2. Clearly articulate the **scenario frame**, describing the question the scenario seeks to answer.
3. Expand the **range of renewable energy technologies** included to explore the range of options available for reducing carbon emissions from the energy sector.
4. Provide detailed **characterization of renewable energy technologies**, similar to the ASES report.
5. Evaluate the impact of policy interventions for the **role of efficiency** by referencing metrics for final energy intensity of economic activity and energy supply loss factor.
6. Clearly **describe model features** and the relationships between the principle factors.
7. Consider the impact of **carbon constraints and climate policies**.

The scenarios reviewed do support some valuable observations for the field of scenario analysts and an audience of scenario users interested in the role of renewable energy. First, the reference scenarios reviewed in this report tend to suggest a relatively modest role for renewable energy technologies four decades in the future. Second, even after applying a number of imagined policy interventions or technology innovations, most of the intervention scenarios indicated 80% of the primary energy portfolio in 2050 would still come from non-renewable sources. The IEA ETP study and the EREC/Greenpeace [r]evolution scenario are notable exceptions, indicating much more aggressive deployment of renewable energy technologies. The two general observations above lead to two different types of interpretations:

1. The models generating the scenarios reviewed accurately describe the energy-economic system as well as the intervention policies. Therefore, the relatively minor role of renewable energy (and the persistent large-scale use of fossil fuels) indicates that the policies presently proposed are inadequate to the task of meeting the climate challenges – <u>something far more bold is required.</u>

Or,

2. The relatively minor potential for renewable energy technologies in the results of an intervention scenario suggests that its modeling assumptions do not accurately capture the changing market conditions, the rate of technological innovation, and the stimulus of multiple policy interventions.

The published reports representing each of the scenarios reviewed did not include a sufficient level of input data or technology characterization to draw either conclusion for each individual scenario. However, this report frames the considerations that would apply to such an evaluation for all of them, a product that is intended to contribute to the development and evaluation of future global energy scenarios.

Those scenarios that do feature the most significant contribution from renewable energy technologies draw heavily on energy efficiency improvements as well. Among the renewable energy sources, biomass was routinely reported to dominate the other options. However, few scenarios include a full range of renewable energy and efficiency options. Exploring the full potential of these options can offer a decision-maker striving to achieve energy security, sustainable development, and climate stabilization a broader range of energy opportunities, many of which are available today. Whereas some technologies only respond to explicit climate

policies (e.g. carbon sequestration or solar-sourced hydrogen), the combination of renewable energy and energy efficient technologies supports all three of those overarching objectives for the 21st century.