Working Paper

Biomass Scenarios, Present and Future: Evaluation of WEC's and Hall's Projections and Comparison to IEW Poll Responses

Susan Swinehart

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IIASA International Institute for Applied Systems Analysis □ A-2361 Laxenburg □ Austria
Telephone: +43 2236 715210 □ Telex: 079 137 iiasa a □ Telefax: +43 2236 71313

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Foreword and Acknowledgments

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Peter de Janosi
Director of IIASA

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1 Introduction

Biomass, renewable plant or animal material used for energy consumption, is currently an important energy source in many countries and may have a more prominent future role globally, especially if greenhouse gas reduction programs are implemented. Quantitative forecasts are difficult because present and past biomass usage is not well documented, mainly because of the difficulty of measuring the amount of non-commercial usage. This document reports current (1990) usage estimates and offers possible scenarios for future usage in 2020 and beyond. The main sources of data are the two World Energy Council (WEC) (1992) reports *1992 Survey of Energy Responses, 16th Edition* and *Energy for Tomorrow's World,* Hall's (1991) "Biomass Energy" in *Energy Policy,* and IEW Poll Responses from the January 1993 overview (Manne and Schrattenholzer, 1993).
When looking at the available biomass literature, there are problems in performing accurate comparisons between different sources. Data for many regions were incomplete, and much of the available data was less useful than it could be due to lack of clarity. Problems and assumptions that were needed for any of the figures are listed, so that the reader can keep these imperfections in mind when viewing the projections.

2 Data Sources

WEC

1990 Usage: The WEC, in *1992 Survey of Energy Responses, 16th Edition,* presents two chapters on biomass usage, categorized by wood and non-wood biomass. The chapter on fuelwood usage gives figures for 1990 fuelwood production for each country. This data is attributed mainly to FAO estimates. Although the data is highly detailed for 1990, no future projections are presented. For this comparison, the WEC data has been converted to Mtoe (million tons oil equivalent) using 1 Mt (million tons) wood to 0.36 Mtoe), as is suggested in *1992 Survey of Energy Responses* although in *Energy for Tomorrow's World* a conversion rate of 0.38 Mtoe to 1 Mt Wood is used. In order to avoid confusing the two different WEC reports, *1992 Survey...* will be referred to as WECs and *Energy for...* will be denoted as WECe. These reports supplement each other as they present data in different formats.
The chapter on non-wood biomass energy in WECs is presented differently than the chapter for fuelwood in the same report. For each country, estimates of various resources potentially available for energy consumption, such as crop stalks and animal wastes, are

listed in millions of tons (Mt). These projections might be appropriate for estimating upper bounds on possible future biomass usage, but are of little help for compiling 1990 estimates. In some of the countries listed, non-wood electrical generation capacity (in kilowatts) and actual fuel production (in terajoules) are listed as well. Actual total biomass figures for 1990 usages may be more reliably be found in either the other WEC report, *Energy for Tomorrow...,* [WECe] or Hall's report, "Biomass Energy."

For the WECs chapters on wood and non-wood biomass, there is no mention of what percentage of the energy is commercially produced. The chapter on non-wood biomass occasionally lists entries for electrical energy production in addition to biomass total energy produced. It can probably be assumed that most of the wood, especially from the developing countries, is being used directly as fuelwood rather than as feedstock for electricity generation, and therefore is more likely to be produced non-commercially.

In WECe, fuelwood, crop residue, and dung biomass usage are categorized as "Traditional" energy and are catagorized as non-commercial. Modern biomass energy, such as electricity generated with biogas, is categorized under "New" along with non-biomass renewables, such as solar, wind, geothermal, ocean and small hydro. It is not stated whether "New" energy is considered to be commercial or not. It will be treated as commercial in this comparison. Actual WECe future biomass usage projections should therefore fall between just "Traditional" and the sum of "New and Traditional" in the WECe report. For this comparison, the figure for "Total Biomass" is the sum of the WECe's "New and Traditional" data, and the figure for "Commercial Biomass" is set to WECe's "New" data. Both of these biomass figures will overstate WECe's biomass projections, as they will include the non-biomass renewable energy sources of WECe's "New" energy.

The regional groupings for the WECe report do not correspond to the divisions used in both the GREEN (OECD) and 12RT (A.S. Manne) energy models, the main source of the projection data from the IEW poll responses and the regional grouping that dominates this comparison. As the WECe report does not provide estimates for individual countries, it is impossible to attempt to regroup data into the desired regional aggregations, as can be done with Hall's "Biomass Energy" report or with the other WEC report, WECs. Hence, the data from WECe are provided only when regions correspond to those used in this comparison, or when an estimate from WECe can be used as an upper bound, as in the case of listing WECe's figures for North America when examining biomass usage in the United States.

Future Projections: While the detailed biomass potentials listed in Chapter 10 of WECs for some of the countries could be useful, WECs has no actual projections for future biomass usage. However, the other WEC report, WECe, makes projections for 2020. WECe provides three future scenarios: Reference, Ecologically Driven and Enhanced Economic Development. Only the data from the WECe Reference case are used, as this scenario should best correspond to the business-as-usual scenario projections from the IEW poll responses. As with the 1990 projections, the regional groupings WECe has chosen are inconvenient for comparison to data organized according to the GREEN and 12RT models.

Hall

1990 Usage: Hall lists two different biomass figures, one calculated from the FAO's estimation of fuelwood and charcoal and the other from BUN's (Biomass Users' Network) estimation of total biomass used. Although these two categories each provide useful information, and can be examined together to get an idea of non-wood biomass usage, it should be remembered that they are from separate sources, and occasionally Hall lists more fuelwood usage than total biomass usage for a country. The wood use numbers are

similar, but not identical to those reported in WECs, although both reports look at FAO data. Hall's labels in his energy usage tables suggests that he categorizes all biomass as non-commercial. However, it seems likely for developed countries that much of this usage would be commercial.

Future Projections: Although no implementation dates are given, Hall has listed possible biomass usage projections based on available crop, forest and pasture land as well as listing potentially recoverable biomass residues. For industrialized countries, he assumes a 10% usage of all forests, woodlands and croplands (but not pastures), and he assigns a production value to this land of 10 tons of biomass per hectare per year (or 150 GJ/ha/yr). For developing countries, he projects a 10% usage of all forests, woodlands, croplands and pastures, and assigns a production value of 5 tons per hectare per year, half that of the industrialized nations. His justification for this difference, according to Swisher, in *Long Term Strategies,* is that "although the biological productivity of land in most tropical climates should be higher than in temperate climates, the lower assumed value is reasonable because of the many biological and economic barriers to successful agriculture in the tropics, and because of the marginal quality of much of the land that might be used for energy feedstock purposes" (Nakićenović *et al.*, 1992). It should again be emphasized that these figures are calculated potentials for, not actual projections of, biomass usage. Although these assumptions allow usage computations to be made quickly, as opposed to performing an evaluation for each nation, they may be simplistic in relation to individual countries' potentials, and may grossly overestimate some nations' potentials, while being more reasonable approximations for others. For instance, Canada and the former Soviet Union both have vast tracts of forests, but given their northerly latitudes, they are less likely to be as productive as those in the USA. Furthermore, much of these forests are remote and may not be efficient to harvest for biomass usage. Consideration should also be made of a nation's food shortage or surplus. In the US, 30 million of its 236 million hectares of cropland are currently surplus (Hall, 1991) but many of the developing countries face acute food shortages and would be less able to devote cropland to non-food usage. Furthermore, much of the forest land listed may be reserved rather than productive land. In WECs, total forest and productive forest areas are listed for each country, the former statistic corresponding closely with Hall's forest area measurements. However, the productive forest area is often much smaller: in Canada, it is 53% of the total forest land. Despite these shortcomings, both projections listed for this report use Hall's 10% land usage figures without modifications.

Energy available from use of potential recoverable biomass residues is listed, and Hall proposes two different residue scenarios, 25% and 50% utilization of this total. Although Hall does not list specific recommendations for future biomass usage, it is clear from his report that he believes that it would be realistic to implement a biomass energy program with a 10% arable land usage, and either a 25% or 50% residual utilization. Therefore, this report will refer to two future scenarios: a conservative projection with 10% land and 25% residuals usage and an aggressive projection with 10% land and 50% residuals usage.

Comparison to IEW Poll Responses

One function of the International Energy Workshop is to gather projections from energy experts worldwide about present and future energy usage. These projections are compiled semi-annually into IEW Poll Overviews. The purpose of this report is to provide the reader with several projections, rather than just one, and also allow the reader to see the degree of agreement among the respondents concerning a projection. This comparison attempts to perform a similar function for biomass usage.

It should be noted that the poll responses do not directly state biomass usage, but rather the usage of"renewables, non-electric." Hence electrical energy generated from biomass would not be included in this figure. Also, other non-electric renewables than biomass may be included, an important consideration, since some of the future projections may include some non-biomass "backstop technologies" in this category. In this way the IEW poll responses should be most comparable to WECe's "New and Traditional" summation, although WECe includes electrical generation as well. Although biomass used for electricity generation may be significant, especially for future projections, it would fall under the category of "renewables, electric" and its contributions would likely be overshadowed by that of hydropower for most regions.

The future projections for IEW poll respondents are based on the last time period reported. In general this is 2020, and exceptions to this will be noted, with the horizon date listed: ie. if the projection period ends at 2010, then [2010] will be appended to the poll respondent. For industrialized countries, where sustainable biomass usage is practiced, it seems reasonable to assume that biomass usage in 2020 will be at least as high as that as in 2010. This may not be a valid assumption for developing regions, as biomass may not be used in a sustainable manner, with the rate of biomass depletion exceeding biomass renewal. Also, increasing industrialization and standards of living may result in a decrease in biomass usage over time, as traditional biomass production and usage is often labor intensive.

Only reference (business-as-usual) scenarios were considered for the comparison. Other scenarios have been excluded because the focus of this report is to examine the projections for future biomass usage assuming a future without extensive carbon taxes or restrictions. Furthermore, other scenarios for the IEW have not yet been standardized. In any class of scenarios with carbon constraints, biomass usage would have likely increased or remained constant with respect to the business-as-usual scenario.

An important point to remember when comparing IEW poll responses to other projections is that the IEW considers only commercial energy usage. Much of biomass usage in many regions, especially in developing nations, is non-commercial, making comparisons between IEW reponses and projections that include non-commercial usage difficult. Some of the IEW projections, however, do include non-commercial usage as well: in specific, the IIASA scenarios II92 (IIASA's "Long Term Strategies for Mitigating Global Warming," 1992) and IIYS[ ] (Y.Sinyak, IIASA,"Global Energy and Climate Change," 1992) and the poll responses from WEI and TERI (Gupta, 1993) mentioned below. All other IEW poll responses will be assumed to measure commercial biomass, as this is the form the IEW requests.

Selected Poll Responses

Although most of the poll responses are from the January 1993 edition of the IEW overview, the following more recent responses were available from some of the respondents and are used instead.

WEI: Dr. Wei Zhihong (1993) of the Tsinghua University in Beijing, the poll respondent representing China, provides present and future projections in "Comparison of Energy Demand Scenarios for China," in a draft dated July 1993. His projections are for non-commercial biomass usage.

TERI: The Tata Energy Research Institute, the respondent from India, in addition to their response to the January 1993 Overview, cites 1987 figures from the Indian Government that include non-commercial biomass usage. It is unclear whether their own estimates encompass non-commercial biomass usage. Although this inclusion seems likely

from the size of the figures, the default assumption for IEW poll responses, unless explicitly contradicted by the respondent, is to assume responses measure commercial energy only.

12RT/G2100: The January 1993 Overview of Poll Responses contain the model results from G2100, A.S. Manne's model with 5 regions solved consecutively. The results from 12RT, which has 12 regions and is a general equilibrium model, are reported in this comparison instead. The 12RT model projections were chosen as they are more explicit, since the regions are further divided, and interactions between these regions in the form of different trade goods are now modeled more accurately. The data used is from one of the "Business as Usual" scenarios, BAU-MD. At present, the model reports zero biomass usage in all regions for 1990. Although the model's time horizon extends to 2050, the biomass usage for each region remains unchanged after 2030.

GREEN: The first model results from OECD's GREEN model were recently submitted to IIASA, and will be presented in the next IEW Overview. The business-as-usual scenarios, however, project negligible present or future usage of biomass.

3 1990 Usage and Future Projections

Explanation of Figures

The regional groupings used in this comparison are based primarily on the political and economic aggregation espoused by the GREEN and 12RT energy models, as well as by the more geographical divisions of the WECs report. Because of these two different influences, some of the regions listed in the comparison are not mutually exclusive, such as WECs's Africa and GREEN/12RT's Energy Exporters (ENX).

For present usage projections, columns for wood usage, total biomass and commercial biomass are provided. For future usage projections, a wood usage column is not included, as none of the respondents provided future wood use projections. Total biomass represents all commercial and non-commercial biomass energy. Commercial biomass generally takes the form of feedstock for electricity generation or biofuels such as ethanol, while non-commericial biomass is usually burned directly on a small scale, such as with fuelwood usage. Traditionally, most biomass has been consumed non-commercially, so it should not be surprising that the commercial biomass column will generally contain much smaller projections than the total biomass column. Also, sometimes a source will specify that the figure represents "non-commercial biomass." In this comparison, such a figure will be recorded as total biomass, under the assumption that since commercial biomass information is more easily obtained than non-commercial energy consumption. Even if this assumption is not valid in all cases, usually the amount of biomass that a country produces commercially is dwarfed by the non-commercial usage, especially for 1990 figures.

A blank in a column for a source indicates that the source did not attempt a projection for this category. A question mark indicates that some data was available, but were incomplete. Many of the WECs total biomass projections fall in this category, as their non-wood biomass projections often only list potential materials available for biomass burning rather than actual usage.

For the comparisons figures presented in terms of Mtoe and are rounded to the nearest integer, except when less than 1. A conversion factor of 23 Mtoe to 1 exajoule is used. The future projections for IEW poll respondents are based on Only reference (business-as-usual) scenarios were considered for the comparison.

WORLD

1990 Usage: The WECs reports that 509 Mtoe of fuelwood was used in 1990, accounting for 5% of world energy consumption. They claim that 14% of the world's energy supply is from biomass, i.e. 1400 Mtoe of biomass. However, in examining the WECs data for the individual countries, this estimate of 1400 Mtoe is too high to be consistent with the rest of the WECs report, especially given the little non-wood biomass usage reported by WECs. Also, this figure is much greater than that reported by WECe.

Hall's estimate for wood and charcoal usage, 437 Mtoe, is similar WECs's estimate of 509 Mtoe. Both reports base their fuelwood estimations on FAO data, although WEC explicitly states that some of the fuelwood projections have been modified. According to WECs, the FAO's global fuelwood falls at 437 Mtoe, although another source (Ahamer *et al.*, 1992) lists it at 391 Mtoe. Different conversion factors and assumptions are most likely responsible for these discrepancies between figures that should be identical.

The WECs estimate for wood falls below the II92 projection, but above all other global IEW projections, although all of these are assumed to be for commercial biomass only. Including all biomass, the WECs figure is almost twice as large as that for II92, and more than the WECe estimate for new and traditional energy sources, an inconsistency if WEC's data is from the same source for both of their reports.

Data Source	Wood	Total Biomass	Commercial Biomass
WECe		930	146
WECs	509	1400	
Hall	437	1765	
IEW: II92		800	
CIES			410
RESPT			190
12RT			0
GREEN			0

Figure 1. *1990 Usage Estimates, Mtoe: World*

Future Projections: One discrepancy with Hall's data is that the total biomass potentials for the world do not equal those for the sum of the developing and developed countries. This difference is negligible in the category of residual potentials: 1991 Mtoe global compared with 2012 Mtoe for the sum of the two regions. However, it is more significant when comparing figures for the other source of biomass: use of 10% of available lands, with 1511 Mtoe global compared to 1765 Mtoe for the sum. For consistency, the latter figures are used, as the figures for the developing and developed regions are summations of their individual component nations, and these national figures are used for this paper. WECe's projections for total biomass usage are less than what Hall's potentials would suggest, especially given that WECe's figure is for "new and traditional" figure contains the usage of non-biomass state-of-the-art energy sources.

Data Source	Total Biomass	Commercial Biomass
WECe	1841	518
Hall: aggr.	2770	
Hall: cons.	2267	
IEW: CIESH		1350
II92	1207	
12RT [2050]		1175
CIESL		1120
RESPT		350
GOSSR [2010]		165
GREEN [2050]		0.43

Projections are for 2020 unless noted

Figure 2. *Future Projections, Mtoe: World*

USA

1990 Usage: The WECs's projection for energy production from other biomass would seem to be incomplete when compared to other projections, as it is 437 TJ, only 0.01 Mtoe. No estimates for quantity of raw material available was given. Hall's estimates seem much more reasonable, and falls in the middle of the wide range of the IEW responses. WECe's figures for North America can be used as a fairly tight upper bound for a hypothetical WECe projection on United States' biomass usage, since from surveying the biomass literature, it is apparent that the USA dominates Canada in terms of biomass usage. However, Hall's figures are larger than the WECe figures, as are many of the IEW poll responses.

Data Source	Region	Wood	Total Biomass	Commercial Biomass
WECe	N. America		67	29
WECs	USA	46	> 47 ?	
Hall	USA	29	80	
IEW: SENOR	USA			104
SEREF	USA			102
EIA	USA			76
GRI	USA			70
BNREF	USA			32
PGE	USA			7
12RT	USA			0
GREEN	USA			0

Figure 3. *1990 Usage Estimates, Mtoe: USA and North America*

Future Projections: Hall's estimates fall in the upper end of the IEW estimates for the USA. There is little difference between the conservative and aggressive scenarios as much of the potential biomass in the United States is from land usage rather than residues. As with their 1990 estimates, WECe's projections are more pessimistic than the other sources listed, especially considering that their figures include Canadian biomass usage as well.

Data Source	Region	Total Biomass	Commercial Biomass
WECe	N. America	196	150
Hall: aggr.	USA	279	
Hall: cons.	USA	223	
IEW: SENOR	USA		280
12RT [2050]	USA		235
SEREF	USA		154
EIA [2010]	USA		134
GRI [2010]	USA		109
GOSSR [2010]	USA		94
PGE [2010]	USA		8
GREEN [2050]	USA		0.1

Projections are for 2020 unless noted

Figure 4. *Future Projections, Mtoe: USA and North America*

European Economic Community (EEC)

1990 Usage: The WECs's estimate for EEC fuelwood production is less than 10 Mtoe, with little use of other biomass (less than 1 Mtoe in total). Although Hall estimates that less fuelwood is used, his estimates of biomass usage is twice that of WECs's, primarily on account of the significant projection of non-wood biomass Hall reports. The WECe region that encompasses the EEC is called Western Europe but also includes nations such as Finland, Sweden, Norway and Turkey, all countries with more biomass usage than the EEC members. This grouping accounts for WECe's fairly large value for the region. The only IEW estimates for EEC usage of biomass, other than GREEN's or 12RT's regional projections, are for some of the individual EEC members, with the only responses greater than 1 Mtoe being for Italy (EN[ ] with 3 Mtoe) and Germany (ER[ ] with 2 Mtoe). Other poll respondents attribute Belgium, Luxemburg, Netherlands and UK each with little to no commercial biomass usage.

Data Source	Region	Wood	Total Biomass	Commercial Biomass
WECe	Western Europe		32	12
WECs	EEC	10	<11	
Hall	EEC	7	21	
IEW: 12RT	EEC			0
GREEN	EEC			0

Figure 5. *1990 Usage Estimations, Mtoe: EEC and Western Europe*

Future Projections: When comparing figures for the entire region, Hall's projections for future biomass usage are similar to those for 12RT and for WECe. However, WECe is less optimistic, as it reports other West European countries that are traditionally heavier users of biomass than EEC countries. But when projections are looked at the level of the constituent nations, the individual IEW projections seem more pessimistic about biomass usage. The example of Italy is shown in the firgure, and it is representative of other individual country projections.

Data Source	Region	Total Biomass	Commercial Biomass
WECe	W. Europe	84	64
Hall: aggr.	EEC	104	
Hall: cons.	EEC	72	
Hall: aggr.	Italy	13	
Hall: cons.	Italy	10	
IEW: 12RT [2050]	EEC		94
GREEN [2050]	EEC		.07
EN[ ]	Italy		2

Projections are for 2020 unless noted

Figure 6. *Future Projections, Mtoe: EEC and Western Europe*

JAPAN

1990 Usage: The WECs's estimate for Japanese non-wood biomass usage is only for electrical generation capacities, not actual direct energy produced. From Hall's report, no data for total biomass usage was available. The IEW figures suggest more biomass usage occurs than do Hall's or WECs's fuelwood figures, although total biomass usage for either of these two reports is not listed. In WECe's report, Japan is grouped into the the "Pacific" region, of which it is likely to provide only a small share of the biomass utilized in the region.

Data Source	Wood	Total Biomass	Commercial Biomass
WECs	0.5	?	
Hall	0.1		
IEW: NEDO			7
ETREF			1
IEE			1
IIYS[ ]		1	
12RT			0
GREEN			0

Figure 7. *1990 Usage Projections, Mtoe: Japan*

Future Projections: With respect to most of the IEW poll responses, Hall's biomass potentials are low, the reverse of the general trend. Even if 100% of the residuals were used, only 24 Mtoe of biomass energy would be available to be produced from Hall's calculations, less than what three of the seven IEW respondents project.

Data Source	Total Biomass	Commercial Biomass
Hall: aggr.	17	
Hall: cons.	14	
IEW: 12RT [2050]		47
NEDO [2010]		34
IIYSL	30	
IIYSB	15	
ETREF		14
IEE [2010]		3
GREEN [2050]		0.1

Projections are for 2020 unless noted

Figure 8. *Future Projections, Mtoe: Japan*

Other OECD Members (OOECD)

1990 Usage: This group, as defined in GREEN and 12RT, excludes Turkey, and consists only of Austria, Canada, Australia, New Zealand, Finland, Norway and Sweden. According to WECs, only Finland and Sweden produce more than 1 Mtoe of fuelwood. (1.7 Mtoe and 1.0 Mtoe, respectively.) Only Sweden is credited with sizable non- wood biomass usage, 2.5 Mtoe, according to WECs figures, although data was not provided for non-wood biomass use in Finland or Australia, and not for all categories of non-wood biomass for the other countries. From the BUN (Biomass User's Network) data provided in Hall, non-wood biomass usage is substantial. The most conservative poll responses for the individual member countries, when summed, (25 Mtoe), suggest higher biomass usage than either WECs or Hall report, although this summation is much closer to the latter's figure. There is no corresponding region to "OOECD" in the WECe report.

Data Source	Region	Wood	Total Biomass	Commercial Biomass
WECs	OOECD	5	<8	
Hall	OOECD	4	22	
IEW: 12RT	OOECD			0
GREEN	OOECD			0
ABARE	Australia			4
EMR	Canada			9
MTIB	Finland			8
MTIE	Finland			7
TRCF	Finland			5
ETREF	Norway			1
CUREF	Sweden			6

Figure 9. *1990 Usage Projections, Mtoe: OOECD and Member Nations*

Future Projections: The Hall potentials are much higher than the projections from the IEW poll respondents, the summation of the individual member's projections lying between 35 to 40 Mtoe, although this does not include any usage from New Zealand. One of the reasons for Hall's high estimates is the region's abundance of forest lands, which is the main contributor to Hall's OOECD estimations. (Although, according to

Hall's report, fuelwood burning accounts for less than 20% of biomass usage in 1990, 245 Mtoe are available from land usage, most of this from forests, where at most half that is available from all potential residues.) It seems unlikely that Canadian forests will supply 150 Mtoe of biomass energy, as suggested from Hall's calculations, since much of this area is isolated or not available as productive forest land, and Boreal forests are generally less productive than temperate ones.

Data Source	Region	Total Biomass	Commercial Biomass
Hall: aggr.	OOECD	307	
Hall: cons.	OOECD	276	
IEW: 12RT [2050]	OOECD		94
GREEN [2050]	OOECD		0.02
ABARE [2000]	Australia		5
EMR	Canada		17
MTIB	Finland		10
MTIE	Finland		9
TRCF	Finland		5
ETREF	Norway		1
CUREF	Sweden		7

Projections are for 2020 unless noted

Figure 10. *Future Projections, Mtoe: OOECD and Member Nations*

Former USSR and Formerly Centrally Planned Economies

1990 Usage: Hall and both WEC reports state data in terms of the USSR and not its constituent countries. WECe defines a region CEE, Central and Eastern Europe, which differs from GREEN/12RT's CEEUR only by the former's exclusion of what was Yugoslavia. All of these reports agree that the rest of the former centrally planned economies produced 4 to 5 Mtoe of fuelwood in aggregate, with no more significant non-wood biomass usage. Although the reports coincide in measurements of the former Soviet Union's fuelwood usage, Hall's data (from BUN) for non-wood biomass differs significantly from the WECs estimate.

Poll responses vary greatly, both in numerical estimates and in usage of regional grouping. Interestingly, the projections for Russia are greater than those for the ex-Soviet Union as a whole, which are in turn greater than the projections for the region which contains both the former USSR and Eastern Europe. Poll responses for individual nations within Eastern Europe agree with the WECs, WECe, and Hall estimations of very little biomass production occurring there, as all responses were below 1 Mtoe.

	ex-Soviet Union				Central Europe			
Data Source	Region	Wood	Total Biomass	Comm. Biomass	Region	Wood	Total Biomass	Comm. Biomass
WECe	ex-USSR		35	9	CEE		7	3
WECs	ex-USSR	21	<22		ex-CEEUR	4	?	
Hall	ex-USSR	21	37		ex-CEEUR	5	9	
IEW: 12RT	ex-USSR			0	ex-CEEUR			0
GREEN	ex-USSR			0	ex-CEEUR			0
SIREF	ex-USSR			1				
WCG	ex-USSR			1				
IIYS[ ]	ex-USSR		1					
EF[ ]	Russia			14				
II92	ex-USSR&CE			0				
MOREF	ex-USSR&CE			0				

Figure 11. *1990 Usage Projections, Mtoe: ex-USSR and ex-CEEUR nations*

Future Projections: Hall's potentials for the ex-USSR may be too aggressive to be realistic. As with Canada, forestland comprises the largest source of potential biomass energy in Hall's report, (about 320 Mtoe) and this land may be too remote to use effectively or too northerly to get the high yields (150 Gj/ha/yr) that Hall assumes feasible for all developed nations. The WECe projections are closer to the poll median for the USSR.
As for the former Eastern Bloc, some of the individual poll projections for member countries, such as
PLAS[ ]'s projection of 4 Mtoe usage for Poland only, conflict with GREEN/12RT projections of zero biomass for the entire region. However, it seems likely this regional forecast should be less than what the Hall data suggests as estimates would be feasible and closer to the WECe projections.

	ex-Soviet Union			Central Europe		
Data Source	Region	Total Biomass	Commercial Biomass	Region	Total Biomass	Commercial Biomass
WECe	ex-USSR	77	46	CEE	16	11
Hall: aggr.	ex-USSR	492		ex-CEEUR	52	
Hall: cons.	ex-USSR	446		ex-CEEUR	42	
IEW: 12RT [2050]	ex-USSR		235	ex-CEEUR		0
GREEN [2050]	ex-USSR		0	ex-CEEUR		0
IIYSL	ex-USSR	100				
GOSSR [2010]	ex-USSR		24			
SIREF [2010]	ex-USSR		18			
IIYSB	ex-USSR	15				
WCG	ex-USSR		10			
EF[ ]	Russia		18			
MOREF	ex-USSR&CE		89			
II92	ex-USSR&CE		68			

Projections are for 2020 unless noted

Figure 12. *Future Projections, Mtoe: ex-USSR and ex-CEEUR Nations*

CHINA

1990 Usage: The WECs projection for wood, 48 Mtoe, is close to Hall's figure, although significantly less than WEI's projection of 90 Mtoe of fuelwood usage. For WECs, no figure for total biomass usage is presented, although it is noted that the installed capacity for electricity generation was 17MW (about the size of Italy's biomass-electric facilities). The WECs report mentions in passing, however, that crop stalk is used as solid fuel and biogas production, and the Chinese possess great quantities of such material, as mentioned by Wei and shown in the large residues usage figure in Hall's report. The WECe report groups China with other Asian centrally planned economies, but, from reports with national figures, it can be seen that China's usage dominates the region. Unlike in many other regions, in China the estimations by WECe and Hall are near agreement.

Data Source	Region	Wood	Total Biomass	Commercial Biomass
WECe	CPA		225	7
WECs	China	48	?	
Hall	China	44	214	
IEW: II92	China		304	
WEI	China	90	195	
12RT	China			0
GREEN	China			0

Figure 13. *1990 Usage Projections, Mtoe: China and Centrally Planned Asian Economies*

Future Projections: Given that China is already an extensive user of residues, the aggressive strategy may be more realistic than the conservative one, especially since it involves maintaining the current level of biomass usage. Hall's data is more conservative in future biomass potential estimation than WECe's. However, Wei projects a decrease in biomass usage in the future, partially resulting from national trends in decreasing population growth and increasing per capita income and industrialization. As traditional biomass usage is often highly labor intensive and not appropriate for industrial consumption, China may experience fuel switching to coal and other fossil fuels.

Data Source	Region	Total Biomass	Commercial Biomass
WECe	CPA	294	37
Hall: aggr.	China	198	
Hall: cons.	China	145	
IEW: II92	China	456	
12RT [2050]	China		118
WEI	China	70	
GOSSR [2010]	China		24
GREEN [2050]	China		0.05

Projections are for 2020 unless noted

Figure 14. *Future Projections, Mtoe: China and Centrally Planned Asian Economies*

INDIA

1990 Usage: For once, the WECs report lists a sizable non-wood biomass energy figure for a country, and this report agrees fairly closely with the Indian Government figures for wood and total biomass. The inclusion of significant non-wood biomass usage raises the WECs projection above the three IEW poll responses. WECe groups India with other South Asian countries, although India's biomass usage should dominate the region. Hall's Biomass Users Network's (BUN) estimation of total biomass usage is twice that of WECs's, but approximately equal to WECe's. However, it seems likely that BUN's estimates are too high, or that the current biomass usage is unsustainable in the long run as even the aggressive scenario for future biomass usage (using Hall's data) is still less than BUN's current usage estimation.

TERI's poll response for the January 1993 Overview estimates biomass usage of 69 Mtoe, but in a preliminary draft of "Comparison of Results from the GREEN Model, 12RT Model, and WECs for India," the 1987 consumption figures from the Indian Government, shown below, are different from TERI's poll response. Also, the government figures specify that the biofuel energy is non-commercial, although it will be assumed that any commercial energy would also be recorded as well.

Data Source	Region	Wood	Total Biomass	Commercial Biomass
WECe	S.Asia		214	10
WECs	India	65	96	
Hall	India	60	196	
Indian Gov't	India	73	113	
IEW: TERI	India			69
12RT	India			0
GREEN	India			0

Figure 15. *1990 Usage Projections, Mtoe: India and Southeast Asia*

Future Projections: As with China, India has extensive potential biomass from residues, which, from the BUN's estimation, is currently utilized. From this fact, the aggressive scenario may be more realistic than the conservative estimation. However, India is planning on implementing an ambitious afforestation program with a goal of forests covering 33% of Indian land. India is currently a net deforester, with fuelwood gathering accounting for much of the deforestation (Gupta and Khanna, 1991), so it would seem that expansion or even maintenance of India's fuelwood usage is not likely under such plans. TERI's projections are lower than Hall's, with biomass usage growing little in the future. Although some of the other countries in the region of South Asia may be contributing a larger share of biomass production in the future, WECe's estimates for 2020 are significantly larger than Hall's potentials suggest possible.

Data Source	Region	Total Biomass	Commercial Biomass
WECe	S.Asia	325	34
Hall: aggr.	India	159	
Hall: cons.	India	101	
IEW: 12RT [2050]	India		118
TERI	India		75
GREEN [2050]	India		0

Projections are for 2020 unless noted

Figure 16. *Future Projections, Mtoe: India and Southeast Asia*

DYNAMIC ASIAN ECONOMIES (DAE)

1990 Usage: This region, according to GREEN and 12RT, consists of the Four Tigers, (Taiwan, South Korea, Singapore and Hong Kong) along with Thailand and the Philippines. There is little data on non-wood biomass usage for any of these countries in the WECs report. Compiling the fuelwood estimates gives a regional figure, dominated mainly by Thailand and the Philippines. The region in WECe which contains the DAE countries had several other countries, many of which are large biomass users, and could not be used for this comparison. There were no other regional IEW responses, aside from those of GREEN and 12RT, and only one estimate for a member country, Taiwan, a minor consumer in the region.

Data Source	Region	Wood	Total Biomass	Commercial Biomass
WECs	DAE	19	?	0
Hall	Thailand & Philippines	17	25	
IEW: 12RT	DAE			0
GREEN	DAE			0
TPC, CPC	Taiwan			0.2

Figure 17. *1990 Usage Projections, Mtoe: Dynamic Asian Economies*

Future Projections: Hall's potentials for Thailand and the Philippines are at the same level or less than his estimates for current biomass usage. However, the question of whether these countries (and other developing countries which are harvesting their rainforests) are using their biomass resources in a sustainable manner is not clear and needs to be examined. In any case, it would seem that the projections for future (and present) usage by GREEN and 12RT are in error.

Data Source	Region	Total Biomass	Commercial Biomass
Hall: aggr.	Thailand & Philippines	26	
Hall: cons.	Thailand & Philippines	18	
IEW: GREEN [2050]	DAE		.03
12RT [2050]	DAE		0
TPC, CPC [2000]	Taiwan		1

Projections are for 2020 unless noted

Figure 18. *Future Projections, Mtoe: Dynamic Asian Economies*

LATIN AMERICA, BRAZIL

1990 Usage: The WECs and Hall figures, although in disagreement, both show that Brazil dominates the rest of the region in terms of fuelwood production. The WECe report has a Latin America group, which includes the relatively small contributions of the Caribbean Islands along with South America. The WECe report estimates much more biomass usage than any of the other reports or polls, even the other WEC report, WECs, assign this region. For Hall's figures, the BUN data for total biomass is smaller than the FAO's estimation for fuelwood usage. This discrepancy is noted in brackets. More recent data from OLADE, an IEW respondent, for both Brazil and Latin America as a whole is obtained from Olade's (1993) *Energy-Economic Statistics and Indicators of Latin America and the Caribbean* which does not distinguish commercial from non-commercial energy.

According to the regional classifications of GREEN and 12RT, Latin America would be part of three different regions: Brazil, Energy Exporters (ENX), and the Rest of World (ROW). Most of the Latin American countries, especially the major biomass users, would be categorized as members of the energy exporter region, which contradicts 12RT and GREEN's assumptions of negligible biomass usage for this region. The major exception to this division is Brazil, the major regional biomass user. The other major biomass user in the region are Mexico (WECs: 6.0/1.8 Mtoe wood/other biomass; Hall: 3.7/9.2 Mtoe wood/total biomass) and Bolivia (WECs: 4.0 Mtoe wood; Hall: 3.9/12.0 Mtoe wood/total), both energy exporters. All the other countries have less than 10 Mtoe biomass energy, according to Hall.

	Latin America			Brazil		
Data Source	Wood	Total Biomass	Commercial Biomass	Wood	Total Biomass	Commercial Biomass
WECe		167	42			
WECs	78	? (>21)		49	70	
Hall	63	78		[45]	[37]	
IEW: OLADE		93		28	45	
MINIS						46
12RT						0
GREEN						0

Figure 19. *1990 Usage Projections, Mtoe: Latin America and Brazil*

Future Projections: The Hall potentials are significantly higher than the IEW poll response projections or the WECe report. The Olade projection is from the IEW poll, and so the biomass projection will be classified as commercial energy.

	Latin America		Brazil	
Data Source	Total Biomass	Commercial Biomass	Total Biomass	Commercial Biomass
WECe	275	96		
Hall: aggr.	467		224	
Hall: cons.	381		181	
IEW: OLADE [2010]		130		
12RT [2050]				118
GREEN [2050]				0.02

Projections are for 2020 unless noted

Figure 20. *Future Projections, Mtoe: Latin America and Brazil*

AFRICA

1990 Usage: The WECs data is extensive for fuelwood, but lists only Ethiopia's use of non-wood biomass. The IEW responses are even less detailed, with only Nigeria's biomass consumption listed, somewhat below the corresponding WECs estimation. This lack of IEW data is partial due to the fact that GREEN and 12RT do not have any region corresponding to Africa and instead divide the African nations between Energy Exporters (ENX) and Rest of World (ROW). Nigeria is one of the most extensive biomass users in Africa, and is classified by GREEN and 12RT as an Energy Exporter, again showing that this region has non-negligible biomass utilization.

By combining the two WECe regions of META (Middle East and North Africa) and Sub-Saharan Africa, a reasonable approximation to Africa can be obtained, since the Middle East is not a large biomass user.

	Africa				Nigeria			
Data Source	Region	Wood	Total Biomass	Comm. Biomass	Region	Wood	Total Biomass	Comm. Biomass
WECe	Africa&M.E.		169	7				
WECs	Africa	123	?		Nigeria	26	?	
Hall	Africa	86	159		Nigeria	24	51	
IEW: CERD					Nigeria			12

Figure 21. *1990 Usage Projections, Mtoe: Africa and Nigeria*

Future Projections: The projections from WECe concur with the conservative estimation from Hall's future potentials. The IEW projections for Nigeria closely match the scenarios from Hall's data as well.

	Africa			Nigeria		
Data Source	Region	Total Biomass	Commercial Biomass	Region	Total Biomass	Commercial Biomass
WECe	Africa&M.E.	367	30			
Hall: aggr.	Africa	400		Nigeria	27	
Hall: cons.	Africa	342		Nigeria	20	
IEW: CERDL				Nigeria		25
CERDR				Nigeria		17

Projections are for 2020 unless noted

Figure 22. *Future Projections: Africa and Nigeria*

Energy Exporters (ENX)
1990 Usage: Although there is negligible biomass usage, especially fuelwood burning, in the Middle East, the grouping of "Energy Exporters" by GREEN/12RT also includes heavy biomass users such as Nigeria and Mexico, as well as other members of Africa and South America. Both Malaysia (> 0.01 Mtoe fuelwood, but 3.5 Mtoe from palm oil burning, according to WECs) and Indonesia (36 Mtoe fuelwood according to WECs) are also members of this group. The only IEW poll responses that are available in whole or in part for this region are those for GREEN and 12RT, both of which estimate zero usage. There is no equivalent region to ENX in the WECe data.
Future Projections: Hall's and the IEW's projections for Nigeria alone (see Figure 21) are in disagreement with the negligible present and future biomass usage projected by 12RT and GREEN, unless all of Hall's biomass is assumed to be produced non-commercially.

Rest of World (ROW)
1990 Usage: By GREEN and 12RT conventions, this area contains biomass users such as Turkey but few consumers of mass quantity. (Although Ethiopia's 10.6 Mtoe of wood and 2.2 Mtoe of energy from crop residue (WECs data) and dung burning constitutes a large percent of their total energy consumption.) No IEW poll responses for nations other than Turkey are available. Although this region includes many countries, the region does not seem to contribute much to the total global biomass usage.

4 Conclusion

Summary
Traditionally, biomass energy statistics have been given very little attention. However, future energy strategies are likely to place more emphasis on biomass, especially as a renewable carbon-free energy source when used in a sustainable fashion. Therefore the need for more knowledge on actual and potential biomass usage is growing.
This report attempts to consolidate and compare existing biomass data and projections. By examining the figures for different regions and nations, as well as the global total, certain observations can be made about the sources. Hall's total biomass projections are generally the most optimistic, especially the future projections based on his formula for biomass resources. The WECs wood use data agrees closely, but not exactly with Hall's

data. The WECs non-wood biomass data was of little use to this report, since few actual usage figures were listed, and most of those seemed suspiciously low, especially when compared to estimations from other sources. For a greater detailed analysis, this information that WECs provides, which lists various non-wood biomass sources for each country, could be used to evaluate potentials for future usage, especially for residue recoverability. Interestingly, the WECe and WECs data, when they can be compared, differ significantly in their projections. The reports also differ in the aggregation of regions and in what biomass statistics were represented, suggesting that there was no attempt to make the two reports consistent. In general, the WECe projections, both present and future, tended to be the most pessimistic of the sources surveyed.

A few interesting points could be seen from the IEW poll responses. Poll responses from organizations that examined only a single country, usually their own nation, tended to report more biomass usage than poll responses from organizations that evaluated an entire region or several countries or regions. One suspicion is that although the IEW poll asks for commercial figures, many of the individual projectors may have included non-commercial biomass as well, as the respondents would likely have the best information on non-commercial biomass consumption. Occasionally, some of the poll responses were larger than Hall's figures.

The future projections of the 12RT model seemed to represent convential wisdom for most regions. 12RT's projections of zero biomass usage for 1990 were echoed only by GREEN and occasional other IEW respondents. The figures from GREEN, the only other poll respondent that offered as many projections, were for neglible present and future usage. Even though these figures may report only commercial biomass, they still seemed unbelievable low by orders of magnitude compared to other sources.

Recommendations

Not only is more raw data on biomass usage needed, but the quality of existing data needs to be improved. In specific, it is important for the researcher to note what fraction of the biomass is produced commercially and what fraction non-commercially. Traditional biomass usage has tended to be non-commercial, but new biomass projects are likely to be medium to large-scale commercial projects. Still, non-commercial biomass will likely always have a place, and it would be inappropriate to omit such sources if one wishes not to underestimate true biomass usage.

Another problem is inconsistencies between data which supposedly comes from the same source. For example, WECs's and Hall's fuelwood estimates differ, even though both reports claim to base their data on FAO's fuelwood data. Although the former report states that some of the data was from different sources, it still appears likely that some of the discrepancies arise from using different assumptions and conversion factors. Still other data were unable to be compared due to the different regional divisions used by the researchers.

Ideally, all researchers would adapt the same conventions with regard to reporting biomass and using conversion factors. This seems unlikely given the differences just between the two WEC reports. But the next best solution would be for researchers to state their assumptions in regard to composition of each region, types of biomass used, fractions of commercial and non-commercial energy, and the conversion factors used. Many of the apparent differences between data from different reports might be able to be traced to different assumptions and could perhaps be resolved.

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