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The role of bioenergy to meet the renewable energy target for New Zealand

Category: Sustainable infrastructure and buildings

Abstract

There is a worldwide push towards using sustainable energy and in particular bioenergy. Environmentally, this is desirable because biomass can substitute fossil fuels for heat and electricity production and thus reduce emission of greenhouse gases. Furthermore, using biomass as an energy source reduces the amount that is disposed of at landfills where it can produce a strong greenhouse gas, methane.

The aim of the present paper is to evaluate the potential benefit from bioenergy to meet the renewable energy target and to evaluate the benefit for the climate. One scenario on how much organic waste is available for energy purposes has been developed. Thereafter, three scenarios have been developed to evaluate the impact different implementation strategies of the bioenergy technologies will have on meeting the renewable energy target and the reducing the emission of greenhouse gases. Bioenergy has a very unique nature in that it has a positive impact on both the waste management strategy, the renewable energy target and climate change. As no other renewable energy source has that ability, its utilisation has impact on many sectors of the economy. Therefore this paper could be seen as an evaluation of the benefits of utilisation of bioenergy to all three policy programmes.

Using the organic waste for bioenergy has a substantial benefit to the reduction of greenhouse gas emissions. The estimates in the present paper suggests that the benefit of using 12 PJ/year of bioenergy for substituting fossil fuels may have as much positive impact on the greenhouse gas emissions as 20 PJ/year of energy from other renewable energy sources. This is due to the benefit of avoided emissions of CH_4, which is almost equal to the avoided emission of CO_2 by replacing fossil fuels. Another way of looking at it is that the benefit for the climate of reducing organic waste going to landfills to 5% of present discharge by 2010, can be as high as the benefit of achieving 40 PJ/year of renewable energy (either bioenergy or other renewable energy sources) for fulfilling the Renewable Energy Target in 2012.

Introduction

In developing a sustainable and renewable energy sector, the use of bioenergy is of key importance. A sustainable and renewable energy sector is desired nationally to reduce the use of non-renewable energy sources, and internationally to reduce the emission of greenhouse gases. The use of bioenergy is a perfect solution to reach these goals mainly because it substitutes fossil fuels in any size of applications especially in meeting low-grade heat demands. Therefore the use of bioenergy is going to play a pivotal role in changing the energy sector in NZ from a fossil fuel based energy sector to an efficient, sustainable and renewable energy sector. By developing an energy efficient energy sector, by designing the conversion technologies optimally, and by capitalising on utilising a growing wood waste stream, bioenergy has the opportunity to be a key renewable energy source in New Zealand in the future.

Why is it not already happening? It is happening. Bioenergy is seen as one of the important energy sources for meeting the national renewable energy target and at the same time the NZ Waste Minimisation Strategy's focus on reducing the organic waste streams including woody biomass, which is landfilled at present. However, energy planning is not very advanced in New Zealand, which means that the energy sector in general is inefficient. The sector is not meeting the energy demand in the most economic way, not for the individual household, not for the individual company and not for the society in general. The energy sector in New Zealand has been set up to use electricity for almost any energy demand whether it is heat or electricity. Therefore to gain the advantage of bioenergy, a different focus has to be taken in the energy sector in general and in the electricity sector in particular. Using electricity to cover low-grade heat demand is only economic in the short term. In the long term it is costly for the users and for the society. It also leaves the energy sector vulnerable in relying on meeting new electricity demand with large scale power generation. Sooner or later an energy sector has to develop into a more efficient setup along with rising prices of fossil fuels, increasing waste disposal costs and more environmental awareness in the society in general. It is an important challenge for bioenergy to be a catalyst for the society to build an efficient energy sector, a path, which sooner or later will have to be taken.

In the following discussion the role of bioenergy will be evaluated for the Waste Minimisation Strategy (Ministry for the Environment, 2002a), the Climate Change Policy (The New Zealand Climate Change Project, 2002) and for the Renewable Energy Target (Ministry for the Environment, 2002b). The climate change policy and the renewable energy target are interdependent so an iterative process has been used to determine illustrative scenarios.

Waste Minimisation Strategy.

We have lots of waste in New Zealand. Not that it is a bigger problem than in other industrialised countries, but its safe and environmentally friendly utilisation still needs to be solved. The government has identified the problem and a strategy has been implemented. The strategy has many targets related to the organic part of the waste stream. One of them is that by 2010 the diversion of commercial organic wastes from landfills to beneficial use will have exceeded 95% (Ministry for the Environment, 2002a)

The total annual organic waste stream has been estimated to be 13.7 Million tons on wet basis as shown in Table 1. In the table cutovers left in the forest and residues left at the skidsites are regarded as being cleanfilled – estimated to be a total of 2.3 Million tons/year. It is also assumed that around 0.4 Mtons of the wood processing residues are cleanfilled per year and 0.2 Mtons landfilled. This despite the organic waste is not allowed to be disposed on cleanfills. This leaves 0.6 Mtons not in use comparable to 0.7 Mtons identified by Nicholas, et al, 2004. By 2010 the residues from wood processing industry will not be allowed to be disposed off at the landfills. The alternative use of the wood waste changes fast but what is important here is that the forest residues are not covered by the waste minimisation strategy. Pulp and paper black liquor is at present all used for energy purposes, and not covered by the waste minimisation strategy.

Table 1: Evaluation of present production and utilisation of organic waste in New Zealand (in Million tonnes (wet) per year).

Organic waste resource M ton per year	Total production	Landfilled today	In use for non-energy purposes	In use for bioenergy	Cleanfilled
Forest residues left in forest	0.8	0.0	0.0	0.0	0.8
Forest residues left at skidsites	1.5	0.0	0.0	0.0	1.5
Wood processing residues	4.0	0.2	1.8	1.6	0.4
Black liquor (Pulp and Paper)	3.0	0.0	0.0	3.0	0.0
Putrescibles	2.0	1.6	0.2	0.2	0.0
Paper and cardboard	0.6	0.3	0.3	0.0	0.0
Demolition waste	0.2	0.2	0.0	0.0	0.0
Biosolids	1.2	0.8	0.2	0.2	0.0
Firewood	0.4	0.0	0.0	0.4	0.0
Total	13.7	3.1	2.5	5.4	2.7
Percentage of total		0.22	0.18	0.40	0.20

Putrescibles, including green garden waste, is targeted in the strategy. On one side it is an ideal source for compost but there is not a big enough market for compost to utilise all the green garden waste for this purpose. For the landfills, which collect gas, putrescibles help methane production, but at the landfills where gas is not collected it will generate methane gas released directly to the atmosphere. Alternatively, it can be either incinerated for waste minimisation purposes for avoidance of methane emissions, or it can be used for bioenergy. It is however, not a desirable fuel for small scale heat plants . It may be an option to separate the green garden waste in an attempt to separate the woody part for bioenergy and the greener part for compost. The number is based on a production of 500 kg of putrescibles per person per year, which is determined by the recent survey by Rotorua District Council (Rotorua District Council, 2004). Garden waste alone is in the strategy estimated to be 1.5 Mtons per year (Ministry for the Environment, 2002).

It is estimated that 0.6 Mtons of paper and cardboard is disposed of per year, of which half is being recycled already. Demolition waste is a controversial waste stream. It covers both clean wood and treated or painted wood. The treated and painted part is at present not desirable for any purpose - neither landfilling, biofuel nor composting. The non-contaminated part is useful, but is difficult to identify. At present it is assumed all of it is landfilled. Biosolids stemming from either municipal sludge or industrial sludge are included in this waste stream. The total amount estimated to be 1.2 Mtons per year, the sludge from the public waste water system contributing between 0.7 and 1.0 Mtons per year (Ministry for the Environment 2002). The use of biosolids for non-energy purposes refers to its use for composting and its use for bioenergy refers to the collection of landfill gas, corresponding to 200,000 tons/year of sludge each. Both figures are estimates of the present treatment of biosolids.

For an evaluation of the organic waste resources it is not important to include firewood, but it is important in a bioenergy perspective, hence it is included in Table 1. This paper assumes that at present 0.4 Mtons of firewood is utilised per year (5 PJ with a calorific value of 12 GJ/tons). It could be regarded as waste, as there would not be any use for it if it was not used for firewood. No attempt has been made here to estimate this number in more detail. In total the numbers in Table 1 indicates that around 40% of the organic waste is at present used for bioenergy.

In Table 2 a large number of assumptions have been made to be able to identify a scenario for how much of the organic waste could be used for bioenergy (assuming there is no competition for the various waste sources). Different scenarios could be made, but in this paper only one scenario is presented. The aim hereafter is to focus on technology scenarios based on various options of how the biomass resource could be utilised in the energy market, which is described later in the paper.

Organic waste resource M ton per year	Removed from Landfills via other uses	Removed from landfill via bioenergy	Total removed from landfill	Available for bioenergy (new)
Forest residues left in forest	0.00	0.00	0.00	0.4
Forest residues left at skidsites	0.00	0.00	0.00	1.5
Wood processing residues	0.00	0.05	0.05	0.6
Black liquor (Pulp and Paper)	0.00	0.00	0.00	0.0
Putrescibles	0.20	0.20	0.40	1.4
Paper and cardboard	0.00	0.00	0.00	0.3
Demolition waste	0.00	0.05	0.05	0.2
Biosolids	0.20	0.20	0.40	0.6
Firewood	0.00	0.00	0.00	0.0
Total	0.40	0.50	0.90	5.4
Percentage of total				0.39
Percentage of landfilled		0.16	0.30	

Table 2: Opportunities to divert the organic waste away from the landfills.

It should be highlighted that bioenergy is not the only solution for treatment or reuse of the organic waste. Sawmill residues are used in the panel board industries, wood wastes are used for landscaping, paper and cardboard are recycled, green garden waste and biosolids are composted. But each of these beneficial uses only takes up a portion of the organic material for many different reasons. For the “other uses” the waste is being composted. Using the surplus for bioenergy is a perfect synergy of the optimal use of the resources, avoiding landfilling of the organic waste and producing a renewable energy at the same time. The scenario presented in Table 2, shows that around 5.4 Million tons of organic waste is available for energy – or 39% of the organic waste stream (and similar to the amount presently used or bioenergy). It is quite obvious that to achieve 95% removal of the total organic waste stream will be a significant contribution to bioenergy in New Zealand. The figure also estimates that around 16% of the organic waste going into landfill are removed as bioenergy (landfill gas utilisation or used as fuel on a bioenergy plant).

Climate change policy

New Zealand has signed the Kyoto Protocol and as part of the agreement obliged to reduce its average greenhouse gas emissions to 1990 levels, between 2008-2012. In 2001 the energy sector contributed 39% of New Zealand's greenhouse gas emissions or a total of 31 Mtons of CO_2-equivalents. The waste sector contributed 5% or 2.3 Mtons of CO_2-equivalents (Ministry for the Environment, 2003).

Table 3: Avoided emissions of CH_4 form landfill, by using part of the organic waste energy and part of it for composting.

	Removed from landfill via bioenergy Mtons/year	Avoided CH4 Mtons/year
Forest residues left in forest	0.0	0.00
Forest residues left at skidsites	0.0	0.00
Wood processing residues	0.1	0.00
Black liquor (Pulp and Paper)	0.0	0.00
Putrescibles	0.4	0.03
Paper and cardboard	0.0	0.00
Demolition waste	0.1	0.00
Biosolids	0.4	0.00
Firewood	0.0	0.00
Total Mtons/year	0.5	0.03
Total Mtons CO2-e/year		0.6

Table 3 shows a first calculation of the amount of CH_4 emission avoided at present for either composting the organic waste going into landfill or using it for bioenergy. It is assumed that the average C content in the putrescibles waste including green garden waste, is 20%. Furthermore, a CH_4 conversion factor of 25% at the landfill is used as a total over the next 50-100 year. No CH_4 emission are expected from the wood biomass waste (Gardner et al, 2004). The continuous addition of waste would, however, make the production of CH_4 a continuous process. Therefore in Table 3 the figure is used directly as an annual emission. It shows that the organic waste available for bioenergy will avoid an emission of 0.03 million tons of CH_4 or 0.6 million tons of CO_2-equivalents per year. It reflects the reduced emissions from landfills in New Zealand in the period 1990-2001 (Ministry for the Environment, 2003)., in which period most compost and landfill gas projects have been implemented.

In Table 4 the amount of substituted natural gas or coal is estimated, first in very simple cases. The figure will be further advanced later in the paper. In this case it has been estimated how much natural gas, coal or electricity is going to be substituted. The figures are determined using the calorific value (CV) listed and in particular for the biosolids the figure is calculate on potential methane production through anaerobic digestion although listed as GJ/tons. It may be surprising that the natural gas figure is only slightly lower than for coal using 26 GJ/tons as CV for coal.

Table 4. The reduced emission of CO_2 by substituting either natural gas or coal is listed in the right columns for each of the organic waste streams.

	Available for bioenergy (new) Mtons/year	CV of biomass source GJ/tons	Substitution of natural gas	Substitution of coal	Substitution of electricity produced by coal
Forest residues left in forest	0.4	12	0.25	0.26	0.68
Forest residues left at skidsites	1.5	12	0.94	0.99	2.55
Wood processing residues	0.6	11	0.34	0.36	0.94
Black liquor (Pulp and Paper)	0.0	8	0.00	0.00	0.00
Putrescibles	1.4	9	0.66	0.69	1.79
Paper and cardboard	0.3	15	0.23	0.25	0.64
Demolition waste	0.2	14	0.11	0.12	0.30
Biosolids	0.6	0.3	0.01	0.01	0.03
Firewood	0.0	12	0.00	0.00	0.00
Total Mtons/year	5.4		2.54	2.68	6.91
Total Mtons CO2-e/year			2.54	2.68	6.91

In the columns to the far right electricity produced by coal with 33% electric efficiency is substituted with heat produced in boilers at 85% efficiency. Although this is just a theoretical number it indicates that it is important how bioenergy is used within the energy system. These two extremes (a range between 2.5 Mtons of CO_2 to 6.9 Mtons of CO_2 per year) are discussed in the next sections and are used to define 3 technology scenarios. It gives us the opportunity to evaluate the bioenergy potential benefit to the renewable energy target as well as to the CO_2 reduction potential. It does, however, assume that it substitutes electricity produced from coal, which in turn assumes that coal is the marginal source for electricity generation.

Renewable Energy Target (RET)

The New Zealand government has in its National Energy Efficiency and Conservation Strategy set a target of 30 PJ/year of additional renewable energy in 2000 (Ministry for the Environment, 2002b). In 2000, renewable energy supplied 133.5 PJ, or 29% of consumer energy. It means that a minimum of 163.5 PJ of consumer energy should be supplied by renewable sources by 2012.

In an attempt to see which role bioenergy can play for the energy sector three scenarios have been developed with a varying degree of bioenergy utilisation taking place. Scenario 1 suggests a total of 25% use of the organic waste as estimated earlier; scenario 2 suggests 60% and scenario 3 suggests 100%. An assumed penetration of bioenergy technologies for the various scenarios is presented in Table 5. It divides the technologies between different energy markets and gives an indication of which fuel is going to be substituted in the various categories.

Table 5: 3 selected technology scenarios for penetration of bioenergy technologies.

Scenario 1	Cogeneration	Indu. boiler	Insti boiler	Residential	Total
Coal		5%	2%		7%
Natural gas		15%		1%	16%
Electricity				2%	2%
Total	0%	20%	2%	3%	25%
Scenario 2	Cogeneration	Indu. boiler	Insti boiler	Residential	Total
Coal	5%	5%	10%	5%	25%
Natural gas	5%	10%	8%	3%	26%
Electricity		5%	2%	2%	9%
Total	10%	20%	20%	10%	60%
Scenario 3	Cogeneration	Indu. boiler	Insti boiler	Residential	Total
Coal	10%	10%	10%	5%	35%
Natural gas	15%	20%	10%	5%	50%
Electricity	5%		5%	5%	15%
Total	30%	30%	25%	15%	100%

Scenario 1: Some use of new bioenergy is taking place in the residential sector, likely to be the use of wood pellets, as the firewood market is unlikely to expand. The substitution is likely to be from natural gas and electricity used for heating. For institutions the substitution of coal is likely to take place either by wood pellets or wood chips. It is also expected that industrial boilers on coal and natural gas will be the first ones to be substituted with biomass, probably wood chips, hogged fuel or “wood waste”.

Scenario 2: In scenario 2 a stronger penetration of wood pellets is expected in the residential market as well as in the institutional market. Still the substitution at the institutional level is likely to take place both by wood pellets and by wood chips. In Scenarios 2 it is furthermore expected that some wood waste boilers will be converted to cogeneration producing both electricity and heat. The scenario expects that a total of 60% of the organic waste is utilised.

Scenario 3: In scenario 3 it is expected that all organic waste available for bioenergy is being utilised. No more expansion is expected at the residential level but still significant expansion at the institutional level. However, the main expansion is in both industrial boilers and industrial cogeneration. It is expected that non-forestry industries will covert to bioenergy and that more wood processing industries upgrade to cogeneration.

In Table 6 the estimated penetration figures from Table 5 are converted into physical amounts of biomass. For this study only the total amount of biomass has been used to determine the figures. It means that it has not been estimated which ones of the biomass resources best suits the various technologies. However, some iterations have been carried out for coming to the figures in Table 6. For instance, for scenario 1 it shows that around 0.16 Mtons of biomass should be used at the residential level, which converted into wood pellets will mean that a total of around 80,000 tons of wood pellets will be utilised in the residential sector per year. If 50% of the biomass used at the institution comes from wood pellets this adds around 25,000 tons of wood pellets (assuming the other 50% is covered by wood chips). It brings the total market of wood pellets up to around 110,000 tons per year. This seems to be a realistic figure. The rest of the biomass sources are not as critical to the quality of biomass source in scenario 1.

Table 6: Use of bioenergy resources for meeting the target for the various technology scenarios.

Scenario 1 (Mt/year)	Cogeneration	Indu. boiler	Insti boiler	Residential	Total
Coal		0.27	0.11		
Natural gas		0.80		0.05	
Electricity				0.11	
Total	0.00	1.07	0.11	0.16	1.34
Scenario 2 (Mt/year)	Cogeneration	Indu. boiler	Insti boiler	Residential	Total
Coal	0.27	0.27	0.54	0.27	
Natural gas	0.27	0.54	0.43	0.16	
Electricity	0.00	0.27	0.11	0.11	
Total	0.54	1.07	1.07	0.54	3.21
Scenario 3 (Mt/year)	Cogeneration	Indu. boiler	Insti boiler	Residential	Total
Coal	0.54	0.54	0.54	0.27	
Natural gas	0.80	1.07	0.54	0.27	
Electricity	0.27	0.00	0.27	0.27	
Total	1.61	1.61	1.34	0.80	5.35

Scenario 2: the pellet market is assumed to be 0.54 Mtons/year of wood waste or around 270,000 tons of wood pellets at the residential level per year. Scenario 2 therefore represents a significant penetration of bioenergy on wood pellet. The total use of biomass being 1.07 Mtons/year in the institutional sector, which with the same split as before of 50/50 between wood pellets and wood chips the demand for wood pellets in this case will be 270,000 tons/year. This means a total consumption of 540,000 of wood pellets per year. That is a very serious penetration of wood pellets into the energy market.

This is assuming that the residential market is the first to respond to increasing gas and electricity prices – followed by institutions. Production of 540,000 tons of wood pellets is not possible with the amount suitable resources available (wood processing residues). Therefore, this will only occur if suitable material is being transferred from use in industrial boilers to manufacturing of wood pellets. This is likely if there is a price signal showing that this is the right thing to do. It is hard to say whether the market by itself can accommodate it. The scenario also assumes 540,000 tons of wood waste going into new cogeneration plants and 1.07 Mtons of wood waste or wood chips used in industrial boilers per year.

For scenario 3, where all available biomass for energy is being utilised, the expansion of the wood pellets market occurs in the institutional sector, adding another demand of 200,000 tons of wood pellets per year to the market assuming same 50/50 split between wood pellets and wood chips as above. The expansion is seen for industrial boilers and for cogeneration. In this case all 5.4 Mtons/year of organic waste not in use is transformed into bioenergy.

Discussion

In Table 7 different types of energy users have been categorised to get an idea of potential heat users. Each of the groups represents significant low-grade energy demand. The biggest heat load demand comes from the residential area where a heat load of the order of 12,000 MW is needed during winter. The load is needed over a relatively few hours, between 500 and 1000 hours a year. Institutions have been categorised as schools and governmental buildings and needing an average of 200 kW heat load. Other categories are non-forestry industries, dairy farmers, dairy industries and the wood processing industries. So how can we use these figures to get a feeling of the use of the biomass evaluated earlier and the technologies scenarios presented above?

Table 7. Potential heat load demand for the various heat users.

Category	Number	Heat load demand	Total heat load demand
Residential	1.2 millions houses	10 kW	12,000 MW
Institutions	1800 schools 300 governmental buildings	200 kW 200 kW	360 MW 60 MW
Non-forestry industries	10,000 large and med. 10,000 small scale	250 kW 25 kW	2500 MW 250 MW
Dairy farmers	40,000 farmers	25 kW	1000 MW
Dairy industries	20 industries (cogen)	10 MW	200 MW
Sawmills	40 large/medium (cogen) 200 small	20 MW 2 MW	800 MW 400 MW
Pulp and paper	4 industries (cogen)	50 MW	200 MW
Reconstituted boards	10 industries (cogen)	30 MW	300 MW

At the moment the residential sector uses 5 PJ/year of bioenergy (firewood), which indicates that either a large part of the 600,000 wood burners installed (Census data 2001) are only used 250 hours a year or a large part of the wood burners are not in real use. To make a significant contribution to the residential market, which assumes 1.2 million houses with an average heat demand of 10 kW (space heating and water heating) 1000 hours a year, the energy demand will be 43 PJ/year. If the industrial sector uses a total of 4000 MW 6000 hours a year, the energy demand will be 86 PJ/year. Unfortunately, there is relatively little data about in particular for the industrial energy use. Wells, C, 2001 estimated the total heat demand to be 36% of the total energy demand in New Zealand, which means a total of around 150 PJ/year, of which around 70 PJ/year is low temperature heat

Bioenergy is presently estimated to cover around 36 PJ/year of primary energy demand (Anderson, C.A, et al, 2003). The result of the resource scenarios in this study shows that around another 48 PJ/ year of bioenergy is available for bioenergy (assuming no competition of the resources). It also indicates that the biomass resources can play a significant role in meeting the renewable energy target. However, the technology scenarios developed indicate that to really achieve – even 12 PJ/year of new bioenergy in the present market (scenario 1) - a significant change to the energy market will have to take place and a significant penetration of bioenergy technologies has to take place to make it happen.

On the other hand, if not only the "easy" resources are targeted, but also the more difficult ones, which generate methane at the landfills, an additional benefit for New Zealand will take place. In this case there are also the benefits of avoiding emission of methane from the landfills, as indicated in Table 8. The figures indicate that the benefit of avoiding the emission of methane from the landfills is significant, assuming that the putrescible organic waste is used to the same degree as the other biomass sources. It means that around 12 PJ/year of bioenergy has the same climate change benefit as 20 PJ/year of other energy resources, including other renewable energy resources. The reduced emissions from substituting fossil fuels are, in this case, based on the fossil fuels substituted in the pattern illustrated in Table 7 and the emission factor for each of the substituted energy sources as in Table 4.

Table 8: Summary of avoided greenhouse gas emissions from landfills using the organic waste for bioenergy energy, and the reduced emission of CO_2 form substituted fossil fuels in the energy sector.

Scenario	Avoided CH4 (MtCO2/year)	Reduced CO2 (MtCO2/year)	Renewable energy (PJ/year)
1	0.6	0.73	12.2
2	1.4	1.95	29.3
3	2.4	3.25	48.8

Conclusions

The aim of the present paper has been to evaluate the potential benefit for the climate of utililsing the organic waste for energy. One biomass resource scenario on how much organic waste is available for energy purposes has been developed. The scenario shows that around 13.7 million tons of wet organic waste is produced in New Zealand annually. Of this at present 40% (5.4 million tons) is used for bioenergy. Another 5.4 millions tons, which at present is either being landfilled or cleanfilled, could be available for bioenergy.

The biomass resource scenario has been used as basis to develop three significantly different technology scenarios with 25% use of the biomass, 60% or 100% use of the organic waste respectively. The result of the resource scenario shows that around another

48 PJ/ year of biomass is available for bioenergy (assuming no competition of the resources), which means that bioenergy can play a significant role in meeting the renewable energy target. However, the technology scenarios developed indicate that to really achieve – even 12 PJ/year of new bioenergy in the present market - a significant change to the energy market will have to take place and a significant penetration of bioenergy technologies has to take place to make it happen. On the other hand, the study indicates that the benefit of avoiding the emission of methane from the landfills is significant assuming that the putrescible organic waste is used to the same degree as the other biomass sources. In this case only 12 PJ of bioenergy has the same climate change benefit as 20 PJ of other renewable energy resources.

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