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# RENEWABLE RESERVES: TESTING THE CONCEPT FOR THE US AND BRAZIL

## A report by Bloomberg New Energy Finance, commissioned by BP

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# EXECUTIVE SUMMARY

With the growing importance of renewable energy in the global energy mix, it is increasingly common to compare renewable and fossil fuel energy sources. Yet many comparisons only consider the capacity and output of renewables today, rather than their potential contribution over future decades. It is also often difficult to compare renewables projects with each other on a clear and transparent basis. As a basis for comparison across energy systems, this report describes the concept of renewable reserves and the result of a simple renewable reserves classification methodology as applied to the wind and bioenergy sectors in the US and Brazil (see Figure 1 and Figure 2, respectively).

In the fossil fuel industries, a well-established methodology has been developed over many decades to assess projects based on agreed criteria. A company's fossil fuel reserves, described using specific terms such as Proved and Probable reserves, are good indicators of its future earnings, and correlate with share prices.

While on a resource level renewable energy sources themselves are infinitely replenished and thus quite different from finite geological energy sources, at a project level it is possible to consider a renewable project as representing a future cumulative energy output. This output is not infinite, but bounded by technological and economic constraints in a way that has significant parallels with fossil energy projects. By considering a project's commercial status within these constraints, it is possible to evaluate the cumulative energy output over its lifetime, and to classify this output as a reserve. In this way, different energy sources can be compared more easily, and renewable energy's contribution can be more directly compared to that of fossil fuels.

Renewable energy from existing projects, when seen through this frame, is perhaps larger than expected. In the US, thanks in part to high rates of wind and biofuels deployment, the 'commercial' renewable reserves of these two sectors are about one seventh the size of the equivalent combined oil and gas reserves (note that bioenergy reserves include biomass and waste-to-energy sources). In Brazil, bioenergy is particularly strong, again because of biofuels, and represents reserves equivalent to over two fifths of the country's Proved oil and gas reserves. The Brazilian wind sector, though small today, is expecting rapid capacity growth in coming years, shown by the large reserves attributed to 'potentially commercial' projects[1].

**Figure 1: US energy reserves**

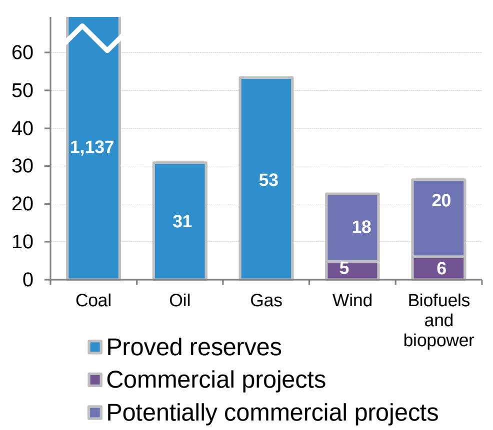
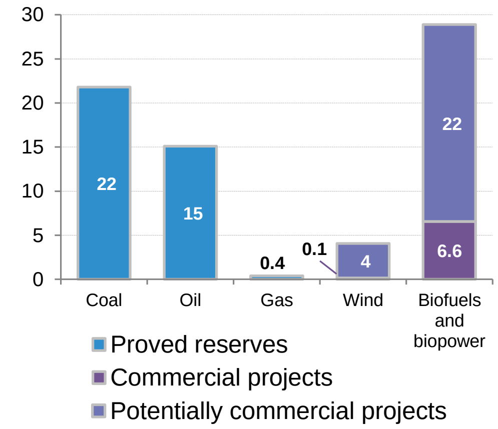



**Figure 2: Brazil energy reserves**




*Source: Bloomberg New Energy Finance, BP Statistical Review 2012. Note that Commercial projects are equivalent to Proved reserves for fossil fuels.*

[1] See Section 1 below for definitions of this and other concepts used in the report.

Many further factors must be included in the analysis under a full reserves accounting methodology. However, the proof-of-principle described here, and the estimates of renewable reserves derived from it, indicate the potential value of agreeing on a renewable reserves convention. This value will be realised by companies, investors and governments, all of which will be able to make investment and policy plans more effectively. This report concludes with a number of suggestions for further action that will be required to realise this ambition.

The Renewable Reserves Initiative, a group formed of industry stakeholders, is currently working to develop a methodology to enable the evaluation of Renewable Reserves using a framework consistent with the UNFC-2009 methodology. This study, commissioned by BP, is intended to complement the work of the RRI by demonstrating the concept for wind and bioenergy resources in the US and Brazil.  Note that the approach used in this study should not be taken as indicative of the final approach that will be used in the Renewables Specification, or necessarily as representative of BP's view of that methodology

# SECTION 1. PURPOSE AND SCOPE

While fossil fuels still supply the majority of the world's energy, an increasing proportion comes from renewable sources. This trend is expected to continue with the renewable share of primary energy projected to increase from about 13% in 2010 to at least 20% in 2035[2], driven by falling equipment costs and concerns about the environmental effects of fossil fuels. For example, one main objective of the United Nations' Sustainable Energy for All initiative is to double the global share of renewable energy between 2012 and 2030.

In spite of this, the world still lacks a widely-agreed methodology for comparing renewable energy projects with each other, and with fossil fuels. The increasing popularity of renewable technologies presents a challenge to companies, governments and investors more used to thinking in terms of finite fuel reserves.

In the coal, oil and gas industries, resources and reserves are measured in terms of volume. As the resource is finite, the quantities exploitable can be estimated, and categorised according to specific levels of certainty. This enables reserves to be listed as a future revenue source, allows projects to be compared on a consistent basis, and allows fair comparisons between countries and companies.

In contrast, renewable energy sources such as biofuels, wind and solar power, are typically expressed in terms of energy per unit time. The useful output of a renewable project is given as a capacity, and depends on the characteristics of the technology and the renewable energy source at a particular location. This tells us nothing about the energy contribution that these projects will make over their lifetime, or, in other words, the total quantities of energy achievable. Further, there is a general lack of consistency between sectors and regions when describing the technical and economic maturity of renewable energy projects and the level of certainty about their energy output.

A reserves methodology for renewables, analogous to that for fossil fuels, would overcome both of these problems, and would provide information to help companies, governments and investors assess and compare energy projects of all types.

At present many energy companies face challenges in assessing the current and future value of their assets. If companies cannot demonstrate the revenue potential of renewable projects as easily as for fossil fuel reserves, they have less incentive to invest in renewables. Being able to assess renewable and fossil fuel energy reserves on a comparable basis will also allow governments to have a clearer view of their options when developing energy policies. At a global level, establishing a convention for estimating reserves and capacity for renewable energy sources also makes it easier to determine the outlook for future energy supply.

In the following sections, this report:

- Sets out the concept of renewable reserves, explaining how the same ideas used to assess fossil fuel reserves can be applied to renewable energy projects
- Presents a first attempt to quantify the potential for renewable reserves, based on a simplified analysis of wind and bioenergy resources in the US and Brazil
- Makes suggestions for future directions and issues for consideration by those drafting a full renewable reserves specification.

[2] Source: Renewable energy accounts for 13% of global primary energy consumption: see p. 212, IEA World Energy Outlook 2012. 2035 projections are based on the New Policies Scenario of the same report (Section 7: Renewable Energy); International Energy Agency, www.iea.org

# SECTION 2. THE CHALLENGE

The objective of developing a renewable reserves methodology is to enhance the comparison of renewable projects with fossil fuel projects while facilitating comparison of renewable energy projects with each other.

The fossil fuel industry uses the word ‘reserve’ to describe a quantity of energy (expressed as barrels or tons of fuel) that can be brought to market under a given set of technical, commercial and socioeconomic conditions. Reserves are assessed on a detailed project-by-project basis.

A number of alternative specifications exist for making this assessment, but the UNFC-2009[3] methodology established by UNECE[4] is the only one that is applied across all reserve types including oil, coal, gas and other minerals. In this process, projects are evaluated on three scales: social and economic viability, technical feasibility, and geological uncertainty. Based on these three dimensions, reserves from a project are placed into one of four categories, from the most to the least certain:

- Commercial projects
- Potentially commercial projects
- Non-commercial projects
- Investigation projects.

These categories are similar to those of Proved, Probable and Possible, used in the oil and gas industry, as defined in the Petroleum Resources Management System.

Renewable energy projects clearly differ from fossil fuel extraction projects in that the renewable resources are not subject to depletion. While a fossil reserve can be considered to be an estimate of energy in place that can be brought to market under a prescribed set of conditions, a renewable project can similarly be considered in terms of cumulative energy production with analogous conditions. Renewable projects can be evaluated and classified into categories depending on their technical, commercial and socio-economic viability, in an analogous way to oil, coal and gas reserves thanks to the parallels between them, namely:

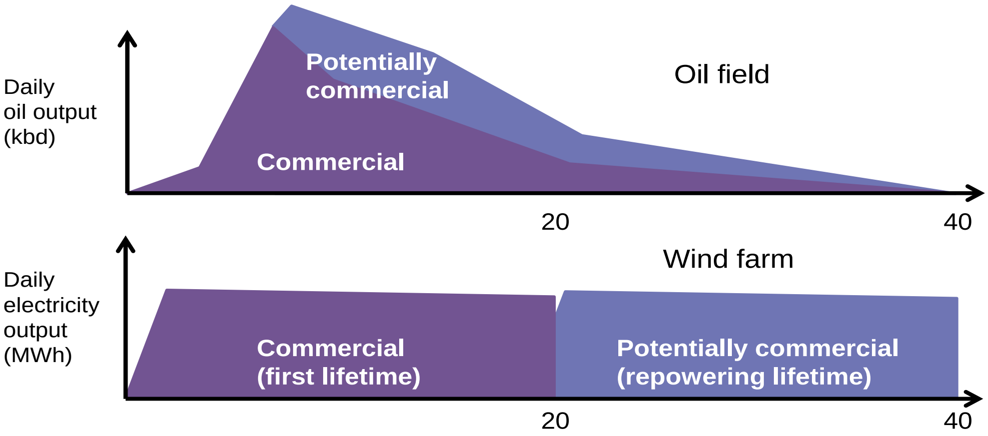
- Projects progress through specific stages, from announcement to the granting of planning permission through to financing, construction, operation and decommissioning.
- Projects have similar prerequisites such as gaining the right to access the resource, the means to sell the product to the market, authorisation for the project to go ahead, and validation of the economic case.
- As the project develops, investment risk declines and certainty of returns improves.

Using the reserves approach, a renewable project’s output can be estimated into the future. Figure 3 illustrates the total energy output of a project, represented by the area under the curve, with the lighter regions showing reserves available with a lower degree of confidence.

[3] United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009: http://www.unece.org/energy/se/unfc_2009.html

[4] The United Nations Economic Commission for Europe

**Figure 3: Representative profiles of energy output from oil and wind projects**




*Source: Bloomberg New Energy Finance*

The Renewable Reserves Initiative (RRI)[5] is a multi-stakeholder initiative set up in 2012 in order to establish a convention for renewable energy reserve assessment. This consortium aims to develop a rigorous methodology for the benefit of companies, investors and governments. A draft specification for a Renewable Resource Classification Framework has been developed as a first step towards a framework comparable to the UNFC-2009.

This study is intended to complement the work of the RRI by demonstrating the concept for wind and bioenergy resources in the US and Brazil, thus building the case for a full-scale renewable reserves assessment methodology. Note that the approach used in this study should not be taken as indicative of the final approach that will be used in the Renewables Specification, nor necessarily as representative of BP's view of that methodology.

[5] Renewable Reserves Initiative: http://www.unece.org/index.php?id=31324

# SECTION 3. METHODOLOGY

This section describes the methodology used in this study to generate an initial estimate of renewable reserves from information readily available in Bloomberg New Energy Finance's (BNEF) renewable energy project database. The methodology is necessarily simple in its approach given the early stage of devising specifications for renewable reserves accounting and the need to present some high level comparisons. Any final specification would include many additional criteria and considerations.

## 3.1. Overview: reserves estimation and classification

This study takes as its starting point the RRI and UNFC-2009 methodology. However instead of assessing the economic and social viability, technical feasibility, and uncertainty of each project in order to classify the reserve quantities, the development stage of the project is used as a proxy (see Table 1). For example, a wind farm where financing has been approved or is under construction is categorised as a "potentially commercial" project. This approach simplifies the analysis as it only requires information on the development stage of each project for the classification, rather than detailed data on the technology, project and market conditions.

Any project not yet operating is classified as 'potentially commercial', regardless of financing or construction progress. The high-level approach taken by this report therefore produces a conservative estimate of 'commercial' reserves, as some of the 'potentially commercial' projects are likely to have full approval for development. Note that the study focuses on the first two reserve categories only: no assessments are made for the "non-commercial" and "exploration project" categories. In addition, the study does not consider unannounced projects that may potentially be built to meet policy targets or to generate profits.

**Table 1: Assigning reserves classifications: renewables in this study vs. oil and gas projects in UNFC-2009**

| | Oil and gas: UNFC-2009 sub-classes | Renewable energy: Development stage in BNEF project database |
|---|---|---|
| 1. Commercial projects | On production;<br>Approved for development;<br>Justified for development. | Commissioned (i.e. in operation) |
| 2. Potentially commercial projects | Development pending;<br>Development on hold. | Announced (less than 8 years ago)<br>Financing approved<br>Under construction<br>Lifetime extensions of commissioned projects |
| 3. Non-commercial projects | Development unclarified<br>Development not viable | Decommissioned<br>Construction cancelled<br>Announced (over 8 years ago) |
| 4. Exploration projects | Unknown quantities | [Not applicable for renewable energy] |

*Source: UNECE UNFC-2009, Renewable Reserves Initiative, Bloomberg New Energy Finance*

## 3.2. Estimating annual production

The first step in the calculation for each renewable energy project is to estimate the annual energy production of the asset including power, heat and biofuel liquid volume. For biofuels, liquid production capacity is given in million litres per year (mLpa). Heat and electrical power output is given in megawatts (MW) which must be converted to average annual units in order to determine total lifetime energy output.

Since power is normally stated as a maximum ('nameplate') capacity, and no power station operates at its maximum capacity 100% of the time, load factors are used to convert between nameplate capacity (MW) and annual production units (MWh per year), as follows:

*Annual production (MWh) = Capacity (MW) x 365 x 24 x Load Factor (%)*

Load factors are estimated using historical data and correlate with different project parameters depending on the sector:

- Biofuel load factors correlate with the feedstock type and technology used to produce the fuel.
- Biomass and waste load factors are determined by operational costs, principally deriving from feedstock.
- Wind load factors (strictly, "capacity factors") are determined for any given asset by the wind speed, which itself is largely a function of siting and location[6].

We assume that there is no variation in load factor over the lifetime of the asset. Note that some biofuel plants, in addition to their liquid output, also produce power and heat. Almost without exception, these are plants that produce ethanol from sugar cane. We also take account of power and heat in estimating the plant's energy output. We assume that for every 1GWh of power output, a plant produces 1.88GWh heat energy in the form of pressurised steam. Energy used both on and offsite is included in the total output. This is consistent with some conventional energy reserve methodologies, where energy derived from the resource itself that is used for the production of that resource may be included in the reserve calculation.

## 3.3. Estimating asset lifetimes

The next step is to estimate the total energy output of the renewable energy project by multiplying the annual production by the remaining project lifetime. It is assumed that annual production is constant over time and that all projects operate until the end of their lifetime.

As previously mentioned, the reserves associated with a project are quantified by the cumulative energy production potential. While in practice a range of factors will determine this assessment, a key factor will be the operating lifetime of the technology. Therefore as a simplifying assumption this study uses the estimated equipment lifetime to place a time-limit on the exploitability of the renewable resource. The lifetime assumptions for the different renewable energy types in Table 2 are based on typical operating lifetimes of the technology.

**Table 2: Renewable project assumptions**

| Sector | Description | Lifetime assumption (yrs) |
|---|---|---|
| Wind | Technology lifetime, land lease terms, ability to extend PPA[7], advances in turbine technology to improve capacity factors | 20 |
| Biomass and waste-to-energy | Technology lifetime, land lease terms, ability to extend PPA, feedstock availability | 30 |
| Biofuel | Technology lifetime, land lease terms, seasonal or multi-year trends in agricultural productivity, water availability, advances in second generation biofuels | 30 |

*Source: Bloomberg New Energy Finance*

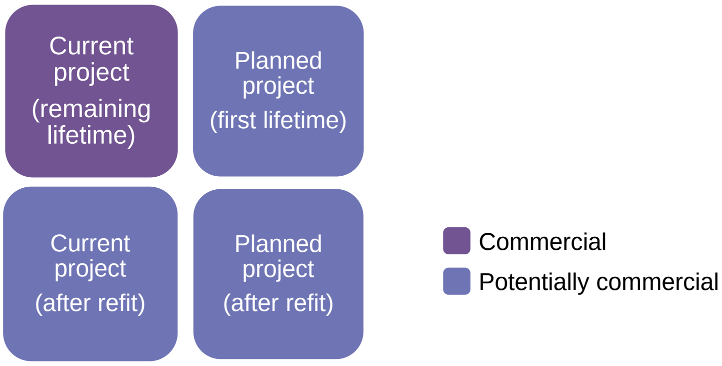
[6] In reality the situation is more complicated: wind capacity factors are determined also by turbine size and height, while biofuel load factors also incorporate agricultural variation and the characteristics of local power markets. For the purposes of this report, we assume the simplest case and keep these constant.

[7] PPA: power purchase agreement, a contract under which one party agrees to buy energy from another at a certain rate for a certain time.

## 3.4. Planned projects and lifetime extensions

As noted earlier, in this study the reported stage of development of each renewable project is used as a proxy for its renewable reserves classification. Commissioned (currently operating) projects are classified as 'commercial projects'. For projects that have been announced but not completed an eight-year cut-off is used: projects announced less than eight years ago are assumed to be in progress and are therefore classed as 'potentially commercial' reserves (planned projects); the rest are assumed cancelled.

**Figure 4: Renewable reserves classification matrix**




*Source: Bloomberg New Energy Finance*

In addition to this first lifetime, we further assume that all projects will be refitted with new equipment and will continue operating at the same annual output for another full lifetime. The reserves associated with a refitted project are considered 'potentially commercial' to take account of the uncertainty associated with the refit.

As an example, a wind asset commissioned in 2008 with a 20-year operating life will operate for 15 years from today for its current lifetime (commercial), after which it would be repowered with new turbines and would operate until 2048 (potentially commercial). Beyond this date, there is too little certainty about the economic and policy environment to justify the asset's inclusion as a commercially exploitable resource.

## 3.5. Comparison of energy reserves

The final step of this analysis is to convert the total energy output of the renewable assets (MWh or TWh for power and heat, mLpa for biofuels) into barrels of oil equivalent (boe) in order to be directly comparable with fossil fuels. This report uses the crude oil energy content defined in the BP Statistical Review of 2012.

However, a simple comparison is complicated by the differences between renewable and fossil fuel supply chains. Hydrocarbon projects deliver primary energy inputs into the energy system, which are then typically converted into other products, or forms of energy such as heat or power. Renewable energy projects, by contrast, produce electricity or biofuels which are predominantly end-products in the energy supply chain. In order to compare renewable energy directly with fossil fuels, they both need to be considered at the same point in the energy supply chain.

In this study, renewable electricity outputs in oil-equivalent units are multiplied by a factor that represents the thermal energy loss from burning oil to produce electricity. We use the figure from the 2012 BP Statistical Review which states that 1 mtoe (million tons of oil equivalent) produces 4.4TWh of electricity, a conversion efficiency of about 38%. Headline figures in this report use this conversion, but charts assuming a direct conversion without this factor are also shown in Section 4.3.

## 3.6. Data sources

BNEF actively maintains a database of over 38,000 renewable energy projects[8], both completed and planned, in all markets around the world. The scope in this study is limited to the wind and bioenergy sectors in Brazil and the US, definitions of which are given in Table 3 below. The analysis is also simplified by only considering renewable energy projects that are operational or at the pre-commissioning stage, which can be considered 'commercial' or 'potentially commercial' respectively.

**Table 3: Types of renewable energy within the scope of this study**

| Sector | Description |
|---|---|
| Wind | Power from any wind project. All wind projects included in this analysis are onshore. |
| Biomass | Power from the combustion of any solids, liquids or gases obtained from biological matter. This includes agricultural and forestry residues, wood pellets, bagasse and black liquor. Capacities recorded for co-firing projects only include the biological fraction. |
| Waste to energy | Power from the combustion of organic solids, liquids or gases that are produced as a waste product of industrial or municipal activity, including landfill gas, anaerobic digestion and incineration of organic landfill waste. |
| Biofuels | Liquid biofuels – ethanol, butanol, bio-oil or biodiesel – produced from organic feedstocks such as sugar or grain crops, animal fats or vegetable oils.<br><br>Power and heat from the biofuel production process is also included in the total energy yield, whether consumed on or offsite. |

*Source: Bloomberg New Energy Finance*

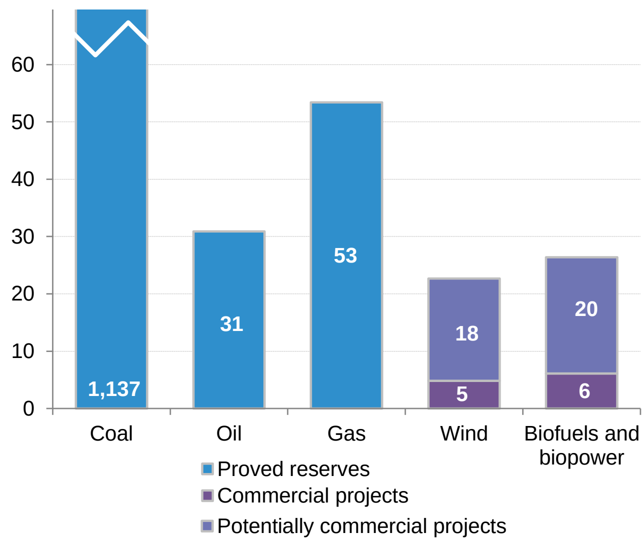
[8] A renewable energy 'project' is defined here as a specific installation of renewable energy equipment with a capacity of at least 1MW power generation or 1 million litres per year biofuel production.

# SECTION 4. RESULTS

## 4.1. United States

The analysis shows that current renewable reserves in the US are significant in comparison with the country's oil and gas reserves (see Figure 5). Using the methodology described in this report, the combined reserves for "commercial projects" in the two renewable sectors (5 billion barrels of oil equivalent (bboe) for wind and 6 bboe for biofuels and biopower) are about one seventh the size of the equivalent combined oil and gas reserves (31 bboe for oil and 53 bboe for gas). Note that 'commercial' fossil fuel reserves in Figure 5 are analogous to 'Proved' reserves according to the definitions described in the previous section.

**Figure 5: US Energy Reserves (bboe)***




*Source: Wind, biofuels and biopower data (31 Jan 2013): Bloomberg New Energy Finance. Oil and gas data: BP Statistical Review (31 Dec 2011). Analysis: Bloomberg New Energy Finance. Note that Commercial projects are equivalent to Proved reserves for fossil fuels.*

** Billion barrels of oil equivalent. Chart excludes other energy sources such as solar PV*

Renewable reserves from "potentially commercial" projects in the US are over three times higher than those of existing projects. The commercial and potentially commercial reserves from wind (22bboe) and biofuels and biopower (26bboe) are almost as large as the country's Proved oil reserves. We do not show potentially commercial fossil fuel projects because these data are not, in general, publically available.

"Commercial" reserves include only the remaining lifetime of projects that are currently in operation, whereas "potentially commercial" reserves include the post-refurbishment life of current projects plus pre- and post-refurbishment lifetime of planned projects. It follows that "potentially commercial" reserves will on their own be larger than "commercial" reserves.

At time of writing, there are few planned projects due for commissioning in 2013. Until the turn of the year, it seemed likely that the main policy support for wind, the production tax credit (PTC), would expire at the end of 2012 with no replacement. While the PTC has now been extended slightly, the anticipated expiry resulted in a glut of projects being rushed to commissioning in 2012, with fewer planned for 2013. However, while there are as yet no clear plans for further federal support mechanisms for wind, the project pipeline is likely to be stronger after 2013 simply because the cost of wind energy deployment is continuing to fall and it is seen as a secure long-term investment.

From 2015, repowering is likely to form a significant part of the overall wind installation market, and the associated reserves account in part for the large "potentially commercial" figure here. The US is host to a large stock of older wind turbines, particularly in California. These older projects make only a small contribution to "commercial" reserves based on the assessment of their short remaining economic lifetimes, but have a greater contribution as "potentially commercial" reserves assuming repowering with new equipment. For simplicity, this study does not assume any increase in capacity or capacity factors that might occur in practice, therefore the reserves from repowering (all of which are "potentially commercial") are likely to be underestimated.

These reserve numbers do not take account of offshore wind, as it is unlikely to contribute significantly to the US energy mix until 2020. Second-generation technologies may allow much faster growth in the production of biofuels from non-food sources, but again this is only likely to impact the bigger picture after 2020. Solar PV is forecast to grow rapidly in the US from 2013, with BNEF predicting 100GW of capacity added by 2020, but this is outside the scope of this study.

**Table 4: US energy reserves at 31 January 2013 (bboe)***

| | | Potentially commercial reserves | | |
|---|---|---|---|---|
| Energy Source | Proved/ Commercial reserves** | Commissioned, after re-investment | Planned, first lifetime | Planned, after re- investment |
| Wind | 4.8 | 6.2 | 5.8 | 5.8 |
| Biofuels and biopower | 6.1 | 10.0 | 5.2 | 5.2 |
| Coal | 1,137 | n/a† | | |
| Oil (onshore) | 31 | n/a† | | |
| Gas (onshore) | 53 | n/a† | | |

*Source: Bloomberg New Energy Finance for wind, biofuels and biopower (31 Jan 2013); BP Statistical Review for oil and gas (31 Dec 2011); Analysis: Bloomberg New Energy Finance*

** Excluding other energy sources such as solar PV and hydro. ** Commercial reserves for fossil fuels are analogous to' Proved reserves' in the BP Statistical Review. † Potentially commercial reserves for fossil fuels are analogous to 'probable reserves'. These figures are not generally published.*

## Sample projects

A number of representative projects are shown in Table 5. Each project is a mid-sized facility, for the US. Note that oil fields tend to be larger, and fewer in number, than renewable projects.

**Table 5: Comparison of reserve-equivalent values from individual US renewable projects**

| Sector | Name / location | Capacity | Load factor | Annual energy production (liquids / fuels) | Assumed life remaining in 2013 (years) | Commercial /Proved reserve remaining* TWh | Commercial /Proved reserve remaining* mboe | Potentially commercial reserve equiv't* TWh | Potentially commercial reserve equiv't* mboe |
|---|---|---|---|---|---|---|---|---|---|
| Wind | Meridian Way, KS | 201 MW power | 38% | 670GWh | 15 | 10 | 16.7 | 13.4 | 22.4 |
| Biomass | Hurt, VA | 79.6 MW power | 80% | 558GWh | 15 | 8.4 | 14.0 | 16.8 | 28.1 |
| Biofuel | Panda bioethanol plant, Hereford, TX | 453 mLpa ethanol | 100% | 435 mLpa | 28 | - | 43.4 | - | 43.4 |
| Oil | Neptune Field, Gulf of Mexico | 30,000 barrels oil & gas / day | n/a | ~4.5m barrels (2012) | 12 | n/a | 62 | n/a | unknown |

*Source: Renewable projects: Bloomberg New Energy Finance renewable energy database. Oil and gas: Wood Mackenzie Upstream Service, July 2012.* Assuming conversions of 1.67mboe per TWh power (accounting for thermal conversion efficiencies), and 3585 boe/mLpa ethanol*

The Neptune field, discovered in 1995 in the Gulf of Mexico, is a $2.3bn project that started production in 2008 and has so far 26 million barrels of oil and gas, with approximately 62 million barrels of Proved reserves remaining. While the project has a maximum production capacity of 30,000 barrels of oil and gas per day, in 2012 the daily production was closer to 12,000 barrels.

The original Proved reserves in the Neptune field were about twice the size of the Panda bioethanol plant, a mid-sized corn ethanol facility in Texas. The largest reserves figure of any biofuels plant in the US belongs to Cedar Rapids ADM in Iowa (not shown in Table 5), commissioned in 2010, which produces 1589mLpa corn ethanol, giving it commercial reserves of over 150 mboe. This figure is twice the original Proved oil and gas reserves figure for the Neptune field. Figures such as these, along with the more stable and predictable revenue profiles for renewable energy projects, should be a welcome confidence boost to investors viewing this sector.

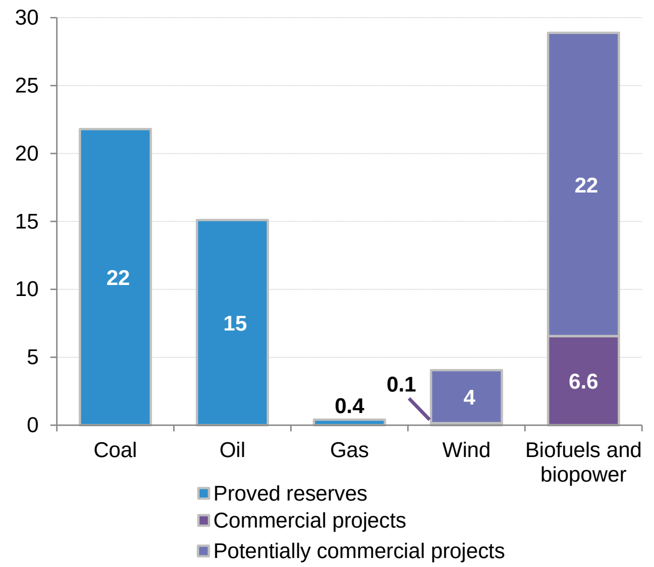
## 4.2. Brazil

In Brazil, reserves in commercial projects from biofuels and biopower are equivalent to over two fifths of the country's Proved oil and gas reserves. The majority of the bioenergy reserves are attributable to Brazil's biofuels industry, the second largest in the world. When taking into account power and heat from bagasse, however, Brazil's bioenergy reserves exceed those of the US.

The Brazilian wind sector, though small, has benefitted from recent changes to policies such as power market regulations which have made it easier for renewable project developers to build large-scale projects. These wind projects, currently listed as 'potentially commercial' reserves, are due to come online in the next few years. Note that we make no estimate of reserves from hydro power in Brazil, a major energy source that provides over 75% of the country's power capacity and 29% of primary energy consumption[9].

The combined commercial and potentially commercial biofuels and biopower reserves of 29bboe are over twice the Proved oil and gas reserves and far exceed those of the wind sector (see Figure 6).

**Figure 6: Brazil Energy Reserves (bboe)***




*Source: Wind, biofuels and biopower data (31 Jan 2013): Bloomberg New Energy Finance. Oil and gas data: BP Statistical Review (31 Dec 2011). Analysis: Bloomberg New Energy Finance. Note that Commercial projects are equivalent to Proved reserves for fossil fuels.*

** Billion barrels of oil equivalent. Chart excludes other energy sources such as solar PV*

The figures above derive from projects that are currently operating ("commercial") or planned, including refits of existing plants ("potentially commercial"). The Brazilian government is, however,

[9] US Energy Information Association, http://www.eia.gov/countries/cab.cfm?fips=BR (2010 data)

on the point of increasing its ethanol blending mandate and is encouraging investment in the biofuels sector through a variety of policy mechanisms. The country's biofuels sector is already the second largest in the world, and the government is driving investment in infrastructure to facilitate greater domestic consumption and to increase export potential. As such the biofuels and biopower reserves are likely to increase from the data shown here.

Note that no attempt has been made to forecast seasonal or multi-year trends in agricultural output for biofuels and biomass. Annual capacity and output are assumed not to change throughout the lifetime of a project and its refitting.

**Table 6: Brazil energy reserves at 31 January 2013 (bboe)***

| Energy Source | Proved/ Commercial reserves** | Potentially commercial reserves: Commissioned, after re-investment | Planned, first lifetime | Planned, after re- investment |
|---|---|---|---|---|
| Wind | 0.1 | 0.2 | 1.9 | 1.9 |
| Biofuels and biopower | 6.6 | 14.5 | 3.9 | 3.9 |
| Coal | 22 | n/a† | | |
| Oil (onshore) | 15 | n/a† | | |
| Gas (onshore) | 0.4 | n/a† | | |

*Source: Bloomberg New Energy Finance for wind, biofuels and biopower (31 Jan 2013); BP Statistical Review for oil and gas (31 Dec 2011); Analysis: Bloomberg New Energy Finance*

** Excluding other energy sources such as solar PV and hydro. ** Commercial reserves for fossil fuels are analogous to' Proved reserves' in the BP Statistical Review. † Potentially commercial reserves for fossil fuels are analogous to 'probable reserves'. These figures are not generally published.*

## Sample projects

A number of representative projects are given in Table 5 below. Each project below is a mid-sized facility, compared to others in Brazil.

**Table 7: Comparison of reserve-equivalent values from individual Brazilian renewable projects**

| Sector | Name / location | Capacity | Load factor | Annual energy production (liquids / fuels) | Assumed life remaining in 2013 (years) | Commercial / Proved reserve remaining*: TWh | mboe | Potentially commercial reserve equiv't*: TWh | mboe |
|---|---|---|---|---|---|---|---|---|---|
| Wind | Gestamp Cabeco Preto IV, Rio Grande do Norte | 19.8MW power | 34% | 59GWh | 19 | 1.1 | 1.9 | 1.2 | 2.0 |
| Biomass | Giasa II Biomass & Waste CDM project, Paraiba | 30MW power | 80% | 210GWh | 24 | 5.0 | 8.4 | 6.3 | 10.4 |
| Biofuel | Bunge Itapagipe plant, Minas Gerais | 84.4 mLpa ethanol, 6MW power and related heat | 100% (ethanol) 60% (power) | 84.4 mLpa ethanol, 31.6GWh power, 59.3GWh heat. | 25 | 2.3 (power and heat only) | 3.8 (power and heat) 7.6 (fuel) 11.4 Total | 2.8 (power and heat only) | 4.6 (power and heat) 9.1 (fuel) 13.7 Total |
| Oil | Marlim Leste Area | 160,000 barrels/day | n/a | ~4 million barrels (2012) | 12 | n/a | 462 | n/a | Unknown |

*Source: Renewable projects: Bloomberg New Energy Finance renewable energy database. Oil and gas: Wood Mackenzie Upstream Service, July 2012.*Assuming conversions of 1.67mboe per TWh power (accounting for thermal conversion efficiencies), and 3585 boe/mLpa ethanol*

The Marlim Leste Area was discovered in 1987 in the Campos Basin but only started production in 2008. The asset has a production capacity of 160,000 barrels per day, and in 2012 it produced a daily average of 120,000 barrels. Its remaining Proved reserves of about 462 million barrels are

40 times the estimated commercial reserves of the Itapagipe bioethanol plant. Brazil's oil sector is growing rapidly, and the country is expected to be a top-five oil producer by 2020. However, it also has abundant aggregated renewable reserves, as evidenced by the above data, even without including hydro power assets.

## 4.3. Changing the point of comparison

As discussed in in the previous section of this report, the conversion of renewable power outputs from MWh to bboe has been carried out on the basis of thermal equivalency in the tables and charts above, assuming a 38% thermal efficiency factor. This converts electrical energy in MWh into to the equivalent volume of oil that would have had to be burned to produce that electricity. These graphs are repeated below (the left-hand chart of each pair: Figure 7 for the US and Figure 9 for Brazil) alongside charts simply convert renewable power outputs into bboe on a straight energy content conversion (Figure 8, US, and Figure 10, Brazil). The latter give lower reserves figures for all electricity projects – wind, biomass and waste-to-energy, both commercial and potentially commercial. By contrast, biofuels are already in liquid form and are unaffected by this difference in conversion. As a result the difference for wind, a drop of over 50% in reserves for Figure 8, is more pronounced than that for biofuels and biopower, at a mere 1bboe lower commercial project reserves in Figure 8.

**Figure 7: US energy reserves with 38% thermal loss conversion factor applied, bboe**

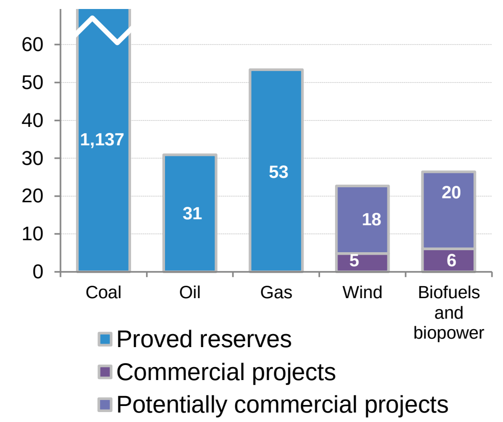



**Figure 8: US energy reserves with 1:1 energy conversion applied, bboe**

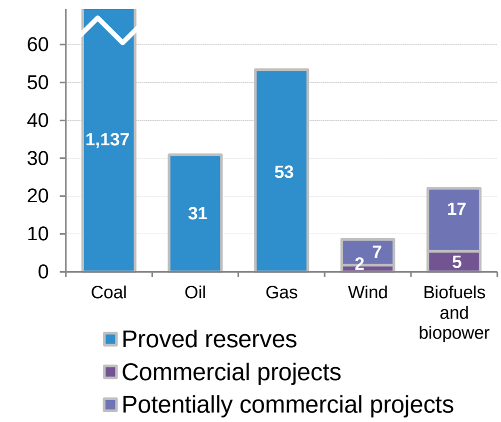



**Figure 9: Brazil energy reserves with 38% thermal loss conversion factor applied, bboe**

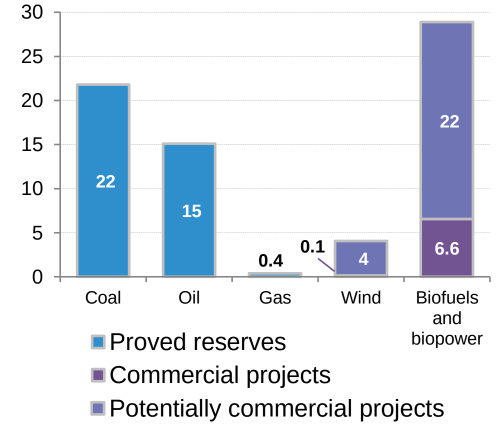
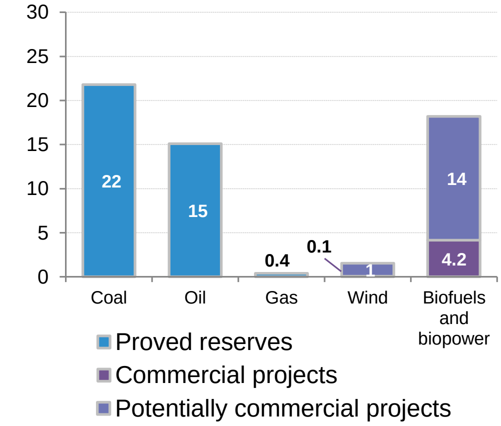



**Figure 10: Brazil energy reserves with 1:1 energy conversion applied, bboe**




*Source: Wind, biofuels and biopower data (31 Jan 2013): Bloomberg New Energy Finance. Oil and gas data: BP Statistical Review (31 Dec 2011). Analysis: Bloomberg New Energy Finance.*

*bboe = billion barrels of oil equivalent. Chart excludes other energy sources such as solar PV*

## 4.4. Analytical assumptions

The renewable reserve estimates made above are highly contingent on the assumptions made in the analysis. Further work could attempt to quantify factors in Table 8 and assess the sensitivity of the reserves estimates to each assumption.

**Table 8: Impact of assumptions on the analysis**

| Factors leading to underestimation | Factors leading to overestimation |
| --- | --- |
| • Repowered wind projects will likely have a higher capacity factor due to technological advances and lower prices.<br>• Bioenergy load factors are likely to improve over time due to technological advances such as in the cellulosic conversion of bagasse.<br>• Early-stage pipeline of projects were not included<br>• Delayed projects were assumed cancelled, but may still be built<br>• Maturity of projects in development may differ between sectors and countries, depending on particular circumstances: time since project announcement is a poor measure of maturity<br>• Advanced planned projects highly likely to be commissioned were classified as 'potentially commercial', but might arguably be 'commercial' | • Not all projects will be repowered or refitted.<br>• No assessment has been made on access or entitlement to the resource. For example potentially commercial reserves may be lower if land leases cannot be renewed, also feedstock sourced from spot markets implicitly assumed as bookable.<br>• Declines in production capacity over a project's lifetime are not taken into account.<br>• Potential effects of land degradation or climate change on agricultural yields for bioenergy were ignored.<br>• Effects of trends and fluctuations in commodity prices (specifically corn and oil) were ignored.<br>• Biomass and biofuel feedstock supply chain risks were ignored<br>• Municipal waste-to-energy 'reinvestment' assumes no change in the composition of waste |

*Source: Bloomberg New Energy Finance*

# SECTION 5. NEXT STEPS

This study, based on project-level data, provides a first estimate of the renewable reserves associated with wind and bioenergy projects in the US and Brazil. However the methodology used is a simplified version of what the industry needs for an effective classification of renewable reserves.

Developing a detailed specification for the methodology will take a substantial effort from both the fossil fuel and renewables communities. Many stakeholders will need to be involved in the process to ensure that the final specification is rigorous, fair and highly-regarded, and to test it on real projects.

**Analytical methodology**

Having developed the methodology in this report, it would be relatively easy to apply it to other countries and to renewable energy sources such as solar, hydro and geothermal power.

In addition, some of the analytical simplifications outlined earlier could be addressed, such as the issue of land use permissions. We could also take into account equipment degradation over time and the improved capacity factors of repowered wind turbines.

**Specification and procedural development**

Any methodology for assessing renewable reserves would have to judge the maturity of projects according to technical, commercial and socio-economic criteria which are not yet fully developed. A specification for collecting and analysing the relevant data is required. There are also questions about what the criteria and benchmarks should be used for judging the projects. For example, when considering the likelihood of a refit to extend the lifetime of a project, how strong should the evidence be for the project to qualify as a particular category? For bioenergy projects, how does the commercial risk change if the project operators buy in the feedstock rather than produce it themselves?

The Renewable Reserves Initiative (RRI) is a consortium of organisations seeking to establish an industry-wide specification. Any experts and organisations interested in moving this agenda forward from a technical or policy perspective are advised to contact one of the members of the consortium.

# REFERENCES

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United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009:

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Wood Mackenzie Upstream Service, November 2012

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http://www.iea.org/

# GLOSSARY OF TERMS

**Capacity factor**

A capacity factor indicates the average output of a renewable energy installation over a certain time as a percentage of the equipment's maximum possible output. It is calculated in the same way as a load factor, but it is used in cases where the energy comes from 'free' renewable sources. In such cases the power output is determined less by economics and more by technical factors, such as the consistency and strength of a renewable resource at a specific location and the ability of the equipment to exploit it.

**Energy (electricity)**

Energy delivered (cumulative), often measured in megawatt-hours or megajoules (1MWh = 3600 MJ). One megawatt-hour of energy would be delivered by a plant operating at megawatt for a duration of one hour.

**Energy (fuel)**

Output of fuel, which can be measured directly in terms of its volume (cubic metres or barrels) or energy content (megawatt-hours or boe). For example, the size of a biofuel project is indicated by its 'mLpa' (million litres per year) capacity. This number of litres can be converted into barrels (volume). It also represents energy that could be released by burning the fuel: this energy can be expressed in terms of the number of barrels of crude oil that would have to be burned to release the same energy (boe).

**Load factor**

A load factor measures the utilisation rate of a power plant. It is calculated based on the average power output over a period of time as a percentage of the maximum capacity. In a liberalised power market, the load factor depends on the relative operational costs of the available generators in the market and the marginal power price at any instant.

**Nameplate capacity**

The maximum output deliverable by a project at full capacity. This is a common way of describing power plants, including fossil fuel and renewable generators. Average energy output over a year is always less than the theoretical maximum because of maintenance downtime, cost-effectiveness, resource availability or other reasons (see also: Load factor, Capacity factor)

**Resource (fossil fuels)**

The full extent of an energy source, including unconfirmed quantities. As such, total resource figures may only be estimated, such as through seismic surveys and exploration drilling. This contrasts with resource figures for wind and solar energy, which can be easily characterised.

**Resource (renewable energy)**

The maximum energy able to be exploited at a given location per unit time (often expressed in units of power). Most renewable resources can be mapped without extensive exploration. Examples include solar radiation intensity (insolation) and wind speed. Resources of these types vary seasonally. Geothermal resources do not vary substantially over time, but require more expensive drilling and exploration.

**Reserve**

A quantity of fossil fuels, usually qualified to indicate their availability. For example Proved or Probable reserves are those not yet extracted but which are available with a specific degree of certainty. Strategic reserves are those already extracted and stockpiled for a particular purpose or situation.

**Reserve, Probable**

Probable reserves have a confidence of over 50% but less than a 90% chance of being recoverable under current economic and political conditions.

**Reserve, Proved**

Proved reserves are those that have at least a 90% confidence of being recoverable under current economic and political conditions.

**Power (electricity)**

Energy output per unit time, usually measured in megawatts (1MW = 1m Joules per second). Power is used to describe a rate of energy delivery. In the case of electricity, the generating capacity of a plant is the maximum power that it can achieve. In general, plants operate below 100% of their nameplate capacity and do so for less than 100% of the time.

# ABOUT US

## Bloomberg New Energy Finance

Bloomberg New Energy Finance (BNEF) is a division of Bloomberg created by the acquisition of New Energy Finance in December 2009. New Energy Finance was founded in 2004 to analyse the changes occurring in the world's energy markets.

Bloomberg New Energy Finance is the world's leading provider of independent news, data and analysis for decision-makers in renewable energy and the carbon markets. It delivers a comprehensive range of subscription-based services. This includes up-to-the minute verified news, the world's largest database of renewable energy players and deals, and our industry-leading research services. Our subscription-based services are supplemented by bespoke consulting, workshops, data-mining and senior-level events.

Our in depth analysis covers the following sectors:

– Renewable energy (wind, solar, bioenergy, hydro, geothermal, marine)

– Energy Smart Technologies (energy efficiency, digital energy & smart grid, energy storage and fuel cells, advanced transportation)

– Carbon (Global-Kyoto, Australia, EU ETS, North America)

– Other (carbon capture & storage, nuclear, renewable energy credits, power, water)

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