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## Executive Summary

In order to determine the potential impact of the biofuel industry on employment opportunities in APEC economies, a model was built to capture the input costs of operating an ethanol or biodiesel plant and translate them into employment figures. Such figures include not only the people involved in operating the plant but those involved in supplying it with feedstock and for feedstock transportation. The model is constructed to accommodate a wide range of inputs, since the experience in biofuel-producing economies indicates that the biofuels industry is subject to many socioeconomic and political influences.

The study relied on data from economies where biofuels have been in production for many years (such as the United States and non-APEC Brazil). Extrapolations to the APEC region were made as required, particularly regarding employment and working conditions by gender. It was found that working conditions for women could be dramatically improved by legislation to facilitate ownership by women of some of the tools of biofuel production, particularly the feedstock supply.

An employment model for first-generation biofuel feedstocks was developed. This model should allow any economy to estimate the ongoing employment that would be created by a given amount of biofuel production for the following combinations of biofuels and feedstocks:

- Ethanol from corn;
- Ethanol from sugar cane;
- Biodiesel from palm oil;
- Biodiesel from soybean oil.

The model could also be readily adapted to other feedstock-to-fuel processes, although this would require better data than appear to be available at the present time and/or more “real-world” experience with using such processes in order to generate valid employment estimates.

Economies like Brazil have previously attempted to increase biofuel employment by limiting the amount of mechanization in the harvesting processes and the amount of automation in the refinery processes. However, such attempts may have limited scope for success, especially in economies that lack Brazil’s production advantages, in view of global competition. There is a trend towards larger refineries, and this tends to dictate more mechanization and automation in both the refinery and feedstock operations. In fact, Brazil now embraces mechanization as the economy seeks to expand exports in its drive to become the ‘Saudi Arabia of ethanol’.

The study suggests that efforts to develop biofuels in APEC economies should emphasize the creation of a knowledge-based economy (KBE) and the upgrading and mechanization of agriculture. Knowledge-based

jobs would be centred on the supply of sophisticated products and services for use in both refinery and feedstock operations. Biofuels represent a very promising entry mechanism into developing a knowledge-based agricultural and processing sector, thanks to the use of local-supply feedstocks and the potential for domestic processing. This qualitative job aspect is an important one. As the biofuels industry expands, those products and services could be sold throughout the APEC region and the world. Such export opportunities could provide a particular boost to employment of women because many of the incremental jobs would be in areas like information processing and systems integration where employment opportunities are already relatively open to women.

In terms of specifics from the analysis, the following estimates apply:

- Corn Ethanol (using the United States as the model of an 'advanced producer') – roughly 37,000 total direct and indirect jobs are associated with corn ethanol production of 34,069 million litres per year (MLy).
- Sugar Cane Ethanol (using Brazil as the model) – about 96,000 total direct and indirect jobs would be created in achieving a sugar cane ethanol output goal of 5,000 million gallons per year (MGy).
- Palm Oil Biodiesel (using Malaysia as the model) – some 41,000 total direct and indirect jobs would be created in achieving an economy-wide palm oil biodiesel output goal of 560 million litres per year (MLy).
- Soybean Oil Biodiesel (using the United States as the model) – about 9,500 total direct and indirect jobs are associated with soybean oil biodiesel production of 2,650 million litres per year (MLy).
- Second-generation biofuels employment impacts were also considered but estimates can only be considered exploratory since commercial-scale plants for the use of second-generation feedstocks are not yet in operation.

The following table shows the various jobs-per-million-litres-per-year (jpMLy) calculations based on the above first-generation models:

**Table ES-1: Jobs per Million Litres per Year for Major Biofuel Feedstocks**

| Biofuel Feedstock and Type | Modeled Employment Per Biorefinery | Assumed Size of Biorefinery | jpMGy | jpMLy |
|---|---|---|---|---|
| Corn Ethanol | 412 | 100 MGY | 4.12 | 1.1 |
| Sugar Cane Ethanol | 1,920 | 100 MGY | 19.20 | 5.1 |
| Palm Oil Biodiesel | 2,930 | 40 MLY | | 73.3 |
| Soybean Oil Biodiesel | 316 | 90 MLY | | 3.5 |

Note: numbers have been rounded.

Figures for jpMLy vary widely because the models are derived from examinations of various producer-country 'role-models'. In other words, significant variability should be expected due to several factors, including the feedstock used, the degree of automation/mechanization in the refinery and field operations, and the location (which impacts costs, productivity, and other factors). For example, the high jpMLy figure for palm oil biodiesel (based on the Malaysia model) is a reflection on the large number of workers needed to harvest and transport the palm fruit, as well as the significant employment created in the extraction and crushing operations. It might also reflect a lower level of mechanization for the economy in general and the palm-oil biodiesel production process in particular.

The table below summarizes various jobs-per-million-litres-per-year (jpMLy) calculations developed from previous employment impact studies. The second column shows the jpMLy based on direct jobs only whereas the third column presents jpMLy calculations based on total (i.e. direct and indirect) jobs. Since some studies refer to direct jobs and others to total jobs, there are gaps in the data (blanks in the table). Most of the jpMLy figures are modest in this table because they are based on United States biofuels operations, which tend to employ much higher levels of automation (in both the refinery and farm sectors). The impact of initial plant construction has been removed from all jpMLy calculations since the job impacts of construction are temporary rather than ongoing. Nevertheless, some analysis of these initial construction impacts has been provided in the report.

**Table ES-2: Jobs per Million Litres per Year as Estimated in Other Biofuel Studies**

| Biofuel Economic Impact Study & Section | **Direct** Jobs Created Per ML of Output Per Year (jpMLy) | **Total** Jobs Created Per ML of Output Per Year (jpMLy) |
|---|---|---|
| Brazilian Ethanol Study – Section 4.1 | 39 | |
| Brazilian Biodiesel Study – Section 4.2 | | 83.3 |
| United States Ethanol Study – Section 4.4 | | 4.4 |
| United States Ethanol Study – Section 4.4 | | 4.2 |
| United States (South Dakota) Ethanol Study – Section 4.4 | | 1.9 |
| United States (Domestic) Biodiesel Study – Section 4.5 | | 13.0 |
| United States (Florida) Biodiesel Study – Section 4.5 | 0.8 | 1.2 |

Note: numbers have been rounded.

The following table provides estimates for *current* ethanol and biodiesel employment based on *current production estimates* (using the above jpMLy estimates). Data on current production are somewhat approximate owing to constraints on available data, some numerical differences between data sources, and varying reporting periods. Nevertheless, the table below suggests that current ethanol employment is around 45,000, while first generation biodiesel employment is roughly 200,000. Most of the current biofuels employment in APEC is concentrated in Indonesia (about 115,000 jobs), the United States (47,000 jobs), Malaysia (24,000 jobs), Thailand (21,000 jobs), The Philippines (19,000 jobs), and Peru (9,000 jobs).

**Table ES-3: Estimated Employment Impacts of Current Biofuel Production in APEC**

| Member Economy | 2008 Ethanol Production (MLy) | jpMLy | Estimated Employment | 2008 Biodiesel Production (MLy) | jpMLy | Estimated Employment |
|---|---|---|---|---|---|---|
| Australia | 243 | 5.1 | 1,000 | 240 | 3.5 | 800 |
| Brunei Darussalam | | | | | | |
| Canada | 931 | 1.1 | 1,000 | 105 | 3.5 | 400 |
| Chile | | | | | | |
| China | 1,900 | 1.1 | 2,000 | 117 | 3.5 | 400 |
| Hong Kong, China | | | | 4 | 3.5 | 14 |
| Indonesia | 140 | 5.1 | 700 | 1,550 | 73.3 | 114,000 |
| Japan | | | | 3 | 3.5 | 11 |
| Korea | | | | 50 | 3.5 | 200 |
| Malaysia | | | | 329 | 73.3 | 24,000 |
| Mexico | | | | 15 | 3.5 | 50 |
| New Zealand | 5 | 1.1 | 6 | 20 | 3.5 | 70 |
| Papua, New Guinea | | | | 7 | 73.3 | 500 |
| Peru | | | | 127 | 73.3 | 9,000 |
| The Philippines | | | | 257 | 73.3 | 19,000 |
| Russia | | | | | | |
| Singapore | | | | 35 | 3.5 | 100 |
| Chinese Taipei | | | | 4 | 3.5 | 14 |
| Thailand | 340 | 5.1 | 2,000 | 260 | 73.3 | 19,000 |
| United States | 34,069 | 1.1 | 38,000 | 2,650 | 3.5 | 9,000 |
| Viet Nam | | | | | | |
| **APEC Total** | **37,628** | | **45,000** | **5,773** | | **197,000** |

Note: numbers have been rounded.

The study also developed estimates for an optimistic scenario of potential first-generation biofuels employment in APEC member economies. By applying the appropriate ethanol and biodiesel jpMLy estimates to each member economy, employment estimates were derived. In the case of APEC economies developing a biodiesel capacity that would not likely be based on palm oil, but other feedstocks such as soybean or recovery of used vegetable oils, we have used soybean biodiesel job creation as a reasonable proxy model for such processes. In this scenario, using data from the recently completed APEC report entitled *Survey of Biomass Resource Assessments and Assessment Capabilities in APEC Economies*, it is hypothesized that the equivalent of 20 percent of the economies' current starch, sugar, and oil crop production might be made available for biofuel production over time (for example, through an improvement in average crop yields of 1 percent per annum in excess of population growth for a 20-year period). For this highly speculative case, *potential* first-generation ethanol employment in APEC member economies was estimated to be about 175,000 jobs while *potential* biodiesel employment was estimated to be about 650,000 jobs.

It is important to note that these reported or estimated impacts are reasonable estimates of the effects that the biofuel sector has or could have on the economy. It would not be appropriate to suggest that the economy would shrink by these amounts if the biofuels industry were not present. In all likelihood, some portion of the land, labour, and capital associated with the biofuel sector would have alternative uses.

**Table ES-4: Hypothetical Employment from First-Generation Biofuel Production in APEC If the Equivalent of One-Fifth of Current Crops were Available as Feedstock**

| Member Economy | Ethanol Potential (MLy) | jpMLy | Potential Employment | Biodiesel Potential (MLy) | jpMLy | Potential Employment |
|---|---|---|---|---|---|---|
| Australia | 3,110 | 5.1 | 16,000 | 412 | 3.5 | 1,000 |
| Brunei Darussalam | | | | | | |
| Canada | 2,180 | 1.1 | 2,000 | 598 | 3.5 | 2,000 |
| Chile | 260 | 1.1 | 300 | 59 | 3.5 | 200 |
| China | 32,000 | 1.1 | 35,000 | 5,680 | 3.5 | 20,000 |
| Hong Kong, China | | | | 10 | 3.5 | 35 |
| Indonesia | 6,730 | 5.1 | 34,000 | 3,670 | 73.3 | 269,000 |
| Japan | 750 | 1.1 | 800 | 853 | 3.5 | 3,000 |
| Korea | 330 | 1.1 | 400 | 284 | 3.5 | 1,000 |
| Malaysia | 100 | 5.1 | 500 | 3,478 | 73.3 | 255,000 |
| Mexico | 3,020 | 1.1 | 3,000 | 250 | 3.5 | 900 |
| New Zealand | 15 | 1.1 | 17 | 143 | 3.5 | 500 |
| Papua, New Guinea | 60 | 5.1 | 300 | 89 | 73.3 | 7,000 |
| Peru | 990 | 5.1 | 5,000 | 329 | 73.3 | 24,000 |
| The Philippines | 330 | 5.1 | 2,000 | 337 | 73.3 | 25,000 |
| Russia | 4,870 | 1.1 | 5,000 | 550 | 3.5 | 2,000 |
| Singapore | | | | | | |
| Chinese Taipei | 80 | 5.1 | 400 | 289 | 3.5 | 1,000 |
| Thailand | 2,700 | 5.1 | 14,000 | 236 | 73.3 | 17,000 |
| United States | 30,000 | 1.1 | 33,000 | 6,213 | 3.5 | 22,000 |
| Viet Nam | 4,570 | 5.1 | 23,000 | 178 | 3.5 | 600 |
| **APEC Total** | **92,000** | | **175,000** | **24,000** | | **651,000** |

Note: numbers have been rounded.

Since the aforementioned survey finds a second-generation biofuel potential from farm and forest residues to be roughly four times as great as this speculative first-generation production potential, the employment associated with second-generation biofuels could also be very substantial, perhaps on the order of 2.4 million jobs. However, since second-generation biofuel production technologies are not yet sufficiently defined to allow reliable estimates of employment generated per unit of production, this can only be considered a rough projection for direct employment creation from second-generation ethanol production.

**Table ES-5: Hypothetical Direct Job Creation from Second-Generation Ethanol Production**

| | Ethanol Potential (MLy) | Potential Employment in Refineries and Transport | Potential Employment in Feedstocks | Grand Total Hypothetical 2nd Generation Employment |
|---|---|---|---|---|
| APEC Total | 509,100 | 467,500 | 1,946,500 | 2,414,000 |

The study also addressed the major social, economic, educational, and institutional barriers faced by women with regard to the biofuels opportunity. The following are some first steps towards dealing with these barriers:

- Encourage participation by small lot holders in biofuels production.
- Integrate biofuels policies with local agri-food policies.
- Develop specific policies (and projects) to encourage the involvement of women in the work force.
- Conduct specific research on women and biofuels employment.

## 1.0 Introduction

This report aims to examine how expanding markets for biodiesel and ethanol for transport fuel may expand employment opportunities for both men and women. It also aims to assess how a given amount of biofuel production will boost such employment in the farm sector and in biorefineries. Finally, it reviews how governments can support the development and sustainability of a biofuels industry.

While the focus of this study is on the employment impacts (and related issues) with first-generation biofuels, second-generation biofuels are also considered where possible. However, we caution that given the premature nature of second-generation biofuels (and the inherit heterogeneity of this emerging field), it is not possible to provide the same level of detail or model development as with first-generation biofuels.

### 1.1 Framework for Analysis

The Doyletech/IBM Global Business Services (IBM GBS) team has developed a supply-side framework for developing the employment model. As shown in **Figure 1**, this framework identifies five input factors and separate paths for employment opportunities in production and technology. The five factors that have a major impact on employment opportunities are described below.

#### 1. Feedstock

Feedstock refers to the plant biomass that is used as “raw material” for biofuel production, e.g., corn or sugar-cane for turning into ethanol, or palm-oil for turning into biodiesel. Employment in biofuels is a function of the particular feedstock used for production. Some feedstocks require much more intensive labour inputs than others in the seeding, cultivation, and harvesting required to render the feedstocks suitable for biofuel production. To illustrate, corn can be produced by mechanized, capital-intensive methods, whereas sugar-cane production is harder to mechanize and therefore tends to lend itself to more labour-intensive techniques. In this report, we develop employment estimates based on our models that take into account feedstock differences.

#### 2. Environmental Impact

Employment in biofuels could be affected by environmental concerns or limitations. For example, although the theoretical production of biofuels in a given region might be high, the environment may constrain production below the theoretical value owing to water shortages, unstable rainfall, soil erosion or depletion. Such constraints would inevitably reduce the employment potential. In this report, we use existing estimates of biofuel productivity in APEC economies from studies that have analyzed environmental factors. Hence, environmental constraints are already built into these estimates.

#### 3. Biorefinery Process

The biorefinery process refers to the established (and emerging) chemical, biological, and mechanical technologies used to convert the feedstock to fuel. Some biorefineries are now quite flexible in that they have the capacity to process a range of feedstocks and materials interchangeably, allowing them to react to price trends more easily. Some biorefineries are less labor-intensive than others because their processes are more automated, which may result in fewer jobs. Advanced biorefineries are envisioned to serve as the foundation of second-generation biofuels, but significant modification of first-generation refineries is also likely.

#### 4. Post Processing Spinoffs

Employment continues beyond just the feedstock-to-biofuels process. For example, there are jobs carrying out the typical blending with fossil fuels just before transport to retail sites and distribution to consumers. However, these are not considered in this report, because they would be few compared to the overall total, and might not be truly biofuels-related (since some such jobs would exist anyway for the blending and transport of conventional fuels). Employment could also be enhanced through further value-added biofuels.

Examples might include new-generation uses of biofuels in applications other than transport such as chemicals, and higher levels of sophistication in engine design and development. These are also not considered in this report, in light of their currently rather speculative nature.

**5. End User Application**

Employment could be affected by the specific application of the biofuel. For example, there could be employment implications if biofuels caused an inter-sectoral shift in vehicle mix. If biodiesel increased relative to (say) gasoline, then there might be increased employment for diesel mechanics, as well as more or fewer vehicle service stations. These changes are real, but very small. They are ignored in this report for the purpose of calculating employment.

In summary, the framework for the analysis is based on the feedstock (the path outlined in red in Figure 1). We will examine how biorefinery output affects the number of biorefinery jobs, as well as how farm output affects the number of farm jobs, and in turn how many jobs are created based on the feedstock used.

Because of the price increases for petroleum products that occurred between 2006 and 2008, a number of APEC member economies are actively investigating the potential of biofuels as substitutes for traditional oil-based fuels. There has been steady growth in biofuel production, and this has created the potential for social and economic benefits, including improved employment opportunities for the rural poor in developing economies. In addition, biofuels can be exported to economies with limited arable land. The increase in agricultural employment has given some economies both increased employment and carbon credits to trade.

Beyond the employment opportunities arising from the production of biofuels are the technological advances from employment in research and development. Ethanol has a higher octane (anti-knock) rating than gasoline. This may provide opportunities for R&D in developing newer flex-fuel engines that can use both biofuels and fossil fuels more optimally, for example using turbocharging with variable boost. By capitalizing on biodiesel, it may be possible to increase diesel engine penetration in economy-wide transport. Finally, there are positive economic impacts and employment gains produced from agricultural products such as corn, palm, sugar cane, and possibly cellulosic waste.

There are substantial macroeconomic implications to substituting biofuels for oil. What would happen in principle is an “income transfer” from oil producers to biomass producers. A major implication of this is expanded employment in agriculture and biofuels production: funds that would have otherwise been used to purchase offshore oil would be diverted to domestic investment.

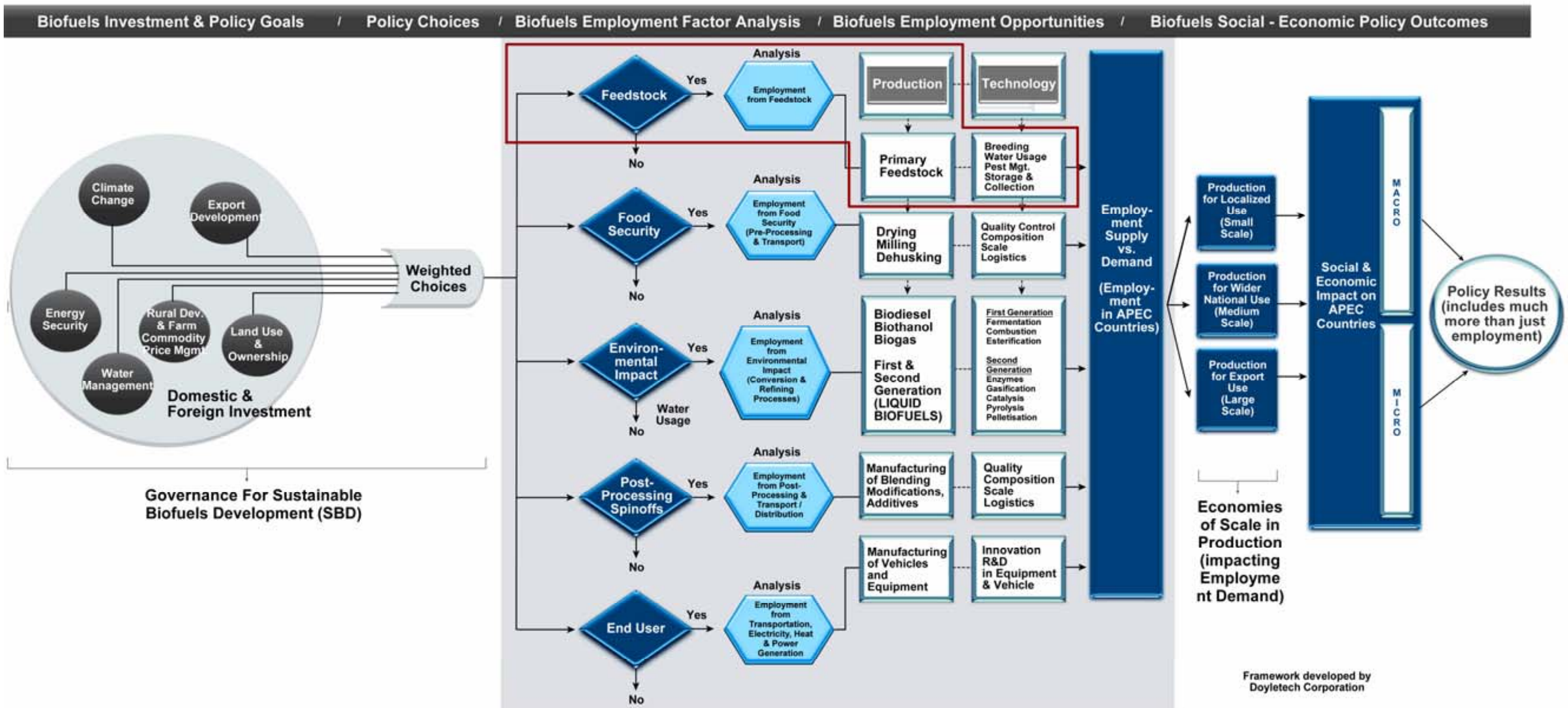
## 1.2 Key Questions

This report addresses the following key questions:

1. To what extent will biofuels production expand over time, and what are the likely employment impacts?
2. How many jobs can be created in the biofuel production and farm sectors, by feedstock type and per unit of biofuel production?
3. Can a model or tool be developed to help planners and policy makers assess the employment impacts?
4. How will the jobs created be apportioned by gender, and what can be done to make the apportionment fairer?

The question of whether a change in employment (through expanded biofuels production and use) can be used for social benefit, particularly improved gender and social equality, is an interesting one on which the current literature is relatively silent. It seems reasonable to suppose that in enhancing employment generally, biofuels can also enhance gender equality and social equity, but further research is needed on this.

**Figure 1: Supply-Side Framework for Developing a Biofuels Employment Model**



## 2.0 Employment Models for Biofuels in APEC

The total impact of the biofuels sector on a given economy is equal to the sum of three components: the *direct effect*, the *indirect effect*, and the *induced effect*. The direct effect consists of jobs and income generated in biofuel feedstock production and refining. Due to the interactions between firms, industries, and social institutions that naturally occur within the regional economy, the direct effect initiates a series of iterative rounds of income creation, spending and re-spending that result in indirect and induced effects. The indirect effects are changes in production, employment, and income that result from the inter-industry purchases triggered by the direct effect. Induced effects then arise due to changes in household income and spending patterns caused by direct and indirect effects.

Since the total impact of workers' expenditures is a multiple of the initial expenditures, it is expressed as a multiplier that is the sum of the direct, indirect, and induced effects divided by the direct effect. Therefore, the total impact of the biofuels sector on a given economy should be larger than the initial expenditures. For example, an output multiplier of 1.5 means that for every million dollars spent (direct expenditure) an additional 0.5 million dollars is generated in the economy.

However, there are two perspectives on modeling employment when it comes to biofuels. The first is a *microeconomic* perspective on how the collective output of biofuel production from individual enterprises impacts direct (agricultural and industrial) and indirect (support) job creation. The major influences on employment opportunities are the amount of biofuel production, the biofuel yield per unit of feedstock, labor input per unit of feedstock production, and labor input per unit of biofuel production in the biorefinery.

The other perspective is *macroeconomic* and is related to the impact that investment has on different plant sizes with respect to GDP, personal incomes, and other macroeconomic variables. The macroeconomic perspective tends to focus on the export value of the bio-ethanol and biodiesel against world oil prices.

We could not find any published biofuels employment models for APEC economies. Instead, we had to rely on interpolating data from the following studies concerning the economic impact of biofuels:

1. **Bio-ethanol as a Basis for Regional Development in Brazil:** "An Input-Output Model with Mixed Technologies" by Marcelo P. Cunha and Jose A. Scaramucci.

2. **An Investigation into the Feasibility of Establishing a Biofuels Industry in the Republic of South Africa:** South Africa Biofuels Task Team, October 2006.

3. **Economic Impacts and Value-Added Benefits of Biofuel in the United States:** United States Department of Agriculture, Office of the Chief Economist, 7-9 November 2002.

4. **An Evaluation of Biodiesel Production Feasibility in Santa Rosa County (January 2005):** commissioned by TEAM Santa Rosa Economic Development Council Inc. (Milton, Florida). Prepared by Hass Center for Business Research and Economic Development.

5. **Opportunities and Issues Surrounding Ethanol as a Renewable Energy Source:** Veron R. Eidman. Department of Applied Economics, University of Minnesota.

6. **European Simulation Model (ESIM):** European Union (EU), 2006.

The ESIM model listed above provides some insights into employment impacts from second-generation biofuels. Most available models used to assess biofuel impacts focus on corn and ethanol feedstocks. Such models are of limited use when it comes to assessing the potential employment from second-generation biofuels from farm and forest residues and grasses, which appear to account for the bulk of long-run biofuel resource potential. [1] However, some inferences can be made about employment per gathered hectare of farm or forest residue, as well as per unit of biofuel produced from such second-generation feedstocks.

There are a number of different tools that can be used to assess the impact of large-scale biofuels production, but employment tends to be extracted from the levels of income affected. These tools include:

- **Input-Output (I/O) Analysis.** I/O analysis can be used to calculate the indirect impacts on employment, GDP, income, and exports. Relevant I/O models consider the size of area planted and the price of the feedstock (among other variables).

- **Social Accounting Matrix (SAM) Analysis or Closed I/O Analysis.** This analysis is an extension of standard Input-Output Analysis and allows for the calculation of the indirect impacts of large-scale ethanol production on household income.

- **Spatially Explicit Equilibrium Models.** These are models that can be used to calculate the impact of various parameters on the demand and supply of food due to biofuel production. The theoretical basis of such models is well developed, and the models are widely used to forecast trends in food consumption which is not part of this report's scope.

There are some limitations to I/O modeling for ethanol which Professor Dave Swenson wrote about in his 2006 paper entitled *Input-Outrageous: The Economic Impacts of Modern Biofuels Production*.[2] The most common restraint in the application of I/O models is the high demand for data. It requires a substantial amount of expert judgment to implement such models. Most of the criteria are only applicable at a macro level and not always possible to apply at the individual enterprise or production plant level.

## 2.1 Social Accounting Matrix (SAM) Analysis

Social Accounting Matrix (SAM) analysis is a system of accounting for the economic transactions occurring in an economy (or portion of an economy) *over a period of one year only*. This analysis is an extension of the standard Input-Output Analysis, and allows for the calculation of the indirect impacts of large-scale ethanol production on household income.

SAM analysis was used in the Iowa and South African biofuel reports previously mentioned. A SAM model creates a "computerized spreadsheet" charting the flow of dollars between local business sectors, households, government, and other non-local consumers of locally-produced goods and services. SAM analysis enables estimates of how spending in one sector of the economy "ripples" through to other sectors. The SAM modeling system used in the reference South African biofuels analysis is a Micro-IMPLAN (Impact Analysis for PLANing) system developed by the United States Forest Service and a product of Minnesota's IMPLAN Group, Inc. The IMPLAN system consists of the software necessary to construct economic accounts, an impact analysis routine, and state and county-level data files containing information related to economic activity and transactions occurring in a state or region over a period of one year.

Economic impact arises directly from the sales, wages, and employment generated by business activity. It also arises indirectly through the "ripple" effect of businesses purchasing goods and services from other local businesses and through biofuels' employees spending wages and other income for household goods and services. These linkages tend to distribute the impact of an activity or event very broadly throughout the economy. With SAM Analysis, the entire process is compressed into a one-year time frame. The impact analysis estimates the direct, indirect, and induced effects as though the entire process occurred in that year. For each year that the spending continues, the effects are replenished. While construction of a biofuel refinery generates employment impacts for just a single year, the growth of feedstocks and conversion of feedstocks to biofuels can generate employment impacts on a permanent basis.

In general, economic impact analysis should also consider the "opportunity cost" associated with the economic activity. Opportunity costs refer to the alternative use of money or resources if they were not expended or invested in a particular way. We did not find opportunity costs included in most of the analyses that have been done on biofuels. Estimating opportunity costs would require estimating the resources (i.e. money spent on importing oil and the related employment) that would leave the area were the industry sector not present. This would include the number of workers and residents who would relocate to other parts to seek employment due to the impact of higher energy costs or the loss of employment and farm income from crops displaced by biofuels. This analysis is beyond the scope of this paper but is discussed in the South African report, the results of which are referenced as an example.

Thus, the results from a SAM Analysis should be regarded as "gross" economic contribution, as opposed to "net" economic contribution. When not accounting for opportunity costs, the estimated employment impacts tend to be overstated. While the reported impacts are reasonable estimates of the effects that the biofuel sector has on the economy, it would not be appropriate to suggest that the economy would shrink by these amounts if the biofuels industry were not present. In all likelihood, some portion of the land, labour, and capital associated with the biofuel sector would have had alternative uses.

### 2.2 Employment Models for Second-Generation Biofuels

Many believe that second-generation biofuel feedstocks will be more sustainable than first-generation feedstocks, for example with respect to the overall magnitude of life-cycle carbon residue emissions reduction. Second-generation feedstocks include residual non-food portions of grain crops as well as including crops that are not used for food purposes, such as switch grass. The outlook for second-generation biofuel technologies critically depends on the future costs of production, oil prices, the value of carbon in the marketplace, and the speed at which second-generation technologies can be developed to industrial scale.

Not surprisingly, models have so far been applied mainly to first-generation biofuels. One of the few models that has been published on the *employment impacts* arising from second-generation biofuels is the 2006 European Simulation Model (ESIM) which was developed for the European Union (EU).[3] Based on an Input-Output model as discussed above, ESIM estimated the employment and GDP impacts based on a 7% and a 14% biofuel market share of all the EU's transportation fuel needs. The following assumptions were used in the model:

- All types of feedstock used for the production of second-generation biofuels would be domestically produced with the exception of 15% being imported wood products.
- The baseline oil price would be $48 per barrel, and reductions in the demand for crude oil due to increased biofuel consumption would reduce the oil price from this baseline.
- The extra cost of producing the biofuel would be met through tax exemptions.
- The global biofuel market would grow and create technology export opportunities for EU companies.

Based on these assumptions, it was estimated that a 7% market share for biofuels would lead to an increase of 105,000 jobs in the EU, while a 14% market share would lead to an increase of 144,000 jobs. Increases of 190,000 in agriculture, 46,000 in biofuel production and distribution, and 14,000 in the food industry would be offset by reductions of 35,000 in services, 21,000 in the conventional fuel sector, 16,000 in transport, 14,000 in the energy sector, and 22,000 in other industrial sectors (totals do not match exactly due to rounding). The employment impacts were expected to be more positive if the extra cost of the biofuels were smaller, such as if there were a higher oil price.

### 2.3 Doyletech's Country Case Approach to Biofuels Employment

The Doyletech approach to the analysis of the APEC biofuels sector uses a spreadsheet approach with proprietary equations to determine employment from biofuel refining plants and associated production of biomass feedstocks for those plants. The methodology does not replace the use of SAM and IMPLAN for Input-Output (I/O) Analysis. In fact, we would recommend that every APEC member economy consider using these models as well.

We will use various ‘mature producer’ economies as ‘working examples’ for our case analysis. Some are non-APEC economies with a more mature biofuel industry; however, they provide objective data that can be used for comparison purposes. For example, the United States and Brazil have employee salary data which can be used to derive very gross impacts of biofuels production on GDP. The collective worth of all production output from each plant (economy-wide output value of biofuel produced) and the estimated amount paid to all workers in the sector as a ratio becomes our method for determining the employment gain due to biofuels. It is only a rough guide but still a conservative way to estimate the employment impact. Furthermore, in the case of first-generation biofuels, our analysis takes into account the feedstock used for the ethanol and biodiesel plants.

The development of new industries can potentially cause employment fluctuations in existing industries. As one of the case studies in Section 4 will indicate, increased biofuels production and employment can cause a reduction in domestic oil refinery output and employment. It is typically the case that the ‘net’ employment impact from a new operation (biofuels or otherwise) is somewhat lower than the overall ‘gross’ impact, partly because new operations tend to be more automated than existing ones. However, there can be employment gains in related and other industries, so the overall net impact is difficult to measure. The focus of this report is on a supply-side analysis; however, it is ultimately changes in the relative demand for similar or competing products that drive net employment impacts.

Before we present these detailed case examples, the next section will provide a brief snapshot of current biofuels production for transport fuel in APEC member economies.

## 3.0 Basic Biofuels Statistics for APEC Economies: An Overview

This section examines current biofuels production levels for transport fuel in APEC member economies. It also summarizes information on the macroeconomic impacts of increased APEC biofuels production and employment. The impacts considered include GDP, production targets and potentials, and trade.

### 3.1 Liquid Biofuels Production

A comprehensive literature review was conducted to develop a macro-level view of biofuels production in APEC economies. **Table 1** shows estimates of current ethanol and biodiesel production for fuel transport in these economies, based on several data sources. Some of the data were distilled from the recent APEC report entitled *The Future of Liquid Biofuels for APEC Economies*.[4] They will be used later in this report as we present our own model of the employment impacts arising from biofuels production.

Gaps in the data (such as the number of operating plants) were filled by additional sources including our own estimates and databases. In some cases, published data are simply not available from government or other sources, and therefore we have made some estimates of our own. For example, our review of the literature did not reveal any authoritative data on the actual number of ethanol and biodiesel plants currently operating in Indonesia, so we relied on unofficial estimates from government experts.

Current ethanol production in APEC economies in 2008 was estimated to be 37,628 ML while current biodiesel production was estimated to be 5,773 ML. It should be noted that the most recently available data (actual *or* estimated) was used. New ethanol and biodiesel capacity is coming on stream all the time, which means that there can be (in the case of some APEC economies) a significant difference between say a 2006 *actual* number and a 2008 *estimate*. Since we seek to capture a snapshot of current production levels, the most recent data (actual *or* estimated) were used. It should also be noted that even in the case of 2007 and 2008 estimated figures, some APEC governments expect to significantly increase their ethanol and/or biodiesel production over the next few years. Many have made a decision to focus attention on either ethanol *or* biodiesel, depending on the types of local feedstocks that are available. Few APEC economies are in a position to encourage *both* ethanol and biodiesel production.

The following are other findings from our literature review and/or from Table 1:

- Primary feedstocks for ethanol production can vary widely. While sugar cane molasses is common, several other feedstocks are gaining ground or being investigated (in particular, cassava).
- Primary feedstocks for biodiesel production can also vary widely. Palm oil, used cooking oil, animal fats, canola, soybean oil are all very common. Alternative feedstocks like jatropha and tallow are also starting to be used in some APEC economies.
- Currently, the largest ethanol producer in APEC is the United States by a wide margin, and the associated feedstock is corn. The next-largest ethanol producers are China and Canada.
- Currently, the largest biodiesel producers are the United States and Indonesia.
- About 200 ethanol plants are operating in APEC economies (mostly in the United States).
- About 300 biodiesel plants are operating in APEC economies (mostly in the United States and Indonesia).

A major finding from the research is that the choice of feedstock in many economies is based on existing crops, existing feedstock production and processing infrastructure, and climate. That is, the decision is not systematically based on which crop might ultimately make the best feedstock in terms of efficiency, cost of production, social or gender considerations, or potential for greenhouse gas emissions reduction.

## Table 1: APEC Current Biofuels Production Estimates (for Transportation)

| Member Economy | Primary Feedstock - Ethanol (in order of importance) | Current Production - Ethanol Amount (ML) | Current Production - Ethanol Year / Est. | Primary Feedstock - Biodiesel (in order of importance) | Current Production - Biodiesel Amount (ML) | Current Production - Biodiesel Year / Est. | # of Current Operating Processing Plants - Ethanol | # of Current Operating Processing Plants - Biodiesel |
|---|---|---|---|---|---|---|---|---|
| Australia | sorghum, wheat, sugar cane | 243 | 2009 | animal fats, used cooking oil, canola | 240 | 2009 | 3 | 7 |
| Brunei Darussalam | n/a | 0 | 2007E | n/a | 0 | | 0 | 0 |
| Canada | cereals (corn 77% and wheat) | 931 | 2008E (f) | animal fats, used cooking oil, canola | 105 | 2007E (a) | 19 | 11 |
| Chile | n/a | 0 | | n/a | 0 | | 0 | 0 |
| China | corn | 1,900 | 2008 (g) | used cooking oil, acid oil | 117 | 2007E (a) | 8 | (c) 7 |
| Hong Kong, China | n/a | 0 | | used cooking oil, animal fats | 4 | 2008 (b) | 0 | 1 |
| Indonesia | sugar cane molasses | 140 | 2007 | palm oil | 1,550 | 2007 | (c) 16 | (c) 42 |
| Japan | sugar cane molasses | 0 | 2006 | used cooking oil | 3 | 2006 | (c) 2 | (c) 2 |
| Korea | n/a | 0 | | used cooking oil, imported soybean oil | 50 | 2006 | 0 | 15 |
| Malaysia | n/a | 0 | | palm oil | 329 | 2007E (i) | 0 | 12 |
| Mexico | n/a | 0 | | animal fats, used cooking oil | 15 | 2006 | 0 | (c) 6 |
| New Zealand | whey (a dairy industry by-product) | 5 | | tallow (a meat industry by-product) | 20 | (c) 2007E | 1 | 3 |
| Papua New Guinea | n/a (but cassava upcoming) | 0 | | palm oil, coconut oil (much smaller) | 7 | 2007E (e) | 1 | 2 (e) |
| Peru | n/a (but sugar cane upcoming) | 0 | | palm oil (jatropha under consideration) | 127 | 2008 | 2 | 1 |
| Philippines | n/a | 0 | | coconut oil | 257 | 2007 | 0 | 7 |
| The Russian Federation | n/a | 0 | | n/a | 0 | | 0 | 0 |
| Singapore | n/a | 0 | | palm oil, soya oil, used cooking oil | 35 | 2007E (a) | 0 | 5 (with more coming soon) |
| Chinese Taipei | n/a | 0 | E (d) | used cooking oil, soybean | 4 | 2007 | 0 (2 planned) | 5 (with 1 under const.) |
| Thailand | cane molasses (8 of 9 plants) | 340 | 2008 (g) | palm oil | 260 | 2007E (i) | 19 | 9 |
| United States | corn | 34,069 | 2008 (g) | soybean oil | 2,650 | 2008E (h) | 139 | 165 |
| Viet Nam | n/a | 0 | 2007E (a) | animal fats, used cooking oil | 0 | (c) 2007E | 2 | (c) 0 |
| **APEC Total** | | **37,628** | | | **5,773** | | | |

Compiled by Doyletech Corporation, 2008 (from several sources).

(a) estimate by SRI Consulting, 2008.
(b) this is current plant capacity; assumed to equal total production output.
(c) estimate by Doyletech Corporation (DT), 2008.
(d) produce no fuel ethanol.
(e) some biodiesel production exists but no data available on production or consumption; therefore, small amount estimated by DT.
(f) Energy Information Administration (EIA), production for 2007.
(g) Renewable Fuels Association (RFA), 2008 World Fuel Ethanol Production Table.
(h) National Biodiesel Board, 2008 estimate.
(i) estimate by FO Licht / USDA.

In order to provide some context to the APEC production numbers by economy, **Table 2** shows the largest fuel ethanol and biodiesel producers in the world (2005). The only APEC economies listed are the United States (ethanol and biodiesel), China (ethanol), Canada (ethanol), and Australia (ethanol). World-wide production of biofuels doubled between 2002 and 2007 and could double again by 2011.[5]

**Table 2: Largest Fuel Ethanol and Biodiesel Producers in the World in 2005** [6]

(APEC Member Economies in **Bold**.)

**Ethanol**

| Economy | Fuel Ethanol Production, ML |
|---|---|
| Brazil | 15,126 |
| **United States** | **14,760** |
| **China** | **1,286** |
| Spain | 302 |
| **Canada** | **260** |
| Sweden | 164 |
| Germany | 152 |
| France | 126 |
| Poland | 86 |
| Finland | 46 |
| **Australia** | **22** |

**Biodiesel**

| Economy | Fuel Biodiesel Production, ML |
|---|---|
| Germany | 1,886 |
| France | 556 |
| Italy | 447 |
| **United States** | **280** |
| Czech Republic | 150 |
| Poland | 113 |
| Austria | 96 |
| Slovakia | 88 |
| Spain | 82 |
| Denmark | 80 |
| U.K. | 58 |

## 3.2 Biofuels Production Targets

**Table 3** shows current biofuel targets for some APEC economies. As mentioned earlier, some economies are developing ambitious plans to promote biofuels. These plans are motivated by high transport fuel costs, increased demand, the desire to be independent of foreign energy sources, and the potential for economic development and/or export opportunities. With respect to targets and policy direction within APEC member economies, the following are our research findings:

- Several economies are changing the focus of their biofuel production in the face of a perceived conflict between food and fuel production. For example, China has decided not to approve any new projects using grain-based ethanol. Japan and Singapore are focusing more on the second-generation biofuels rather than the first-generation feedstocks. Malaysia and Indonesia are starting to look more closely at jatropha, an oilseed plant.

- Malaysia is one of the world's largest producers of palm oil, but the government is encouraging feedstocks like jatropha, nipah, and sago because the price of crude palm oil is high.
- Indonesia is also one of the largest producers of palm oil and faces similar challenges to Malaysia.
- Philippines is the world's largest exporter of coconut oil. Jatropha is being considered.
- If Japan becomes a major consumer of biofuels, most of them will have to be imported, resulting in trade with economies that produce biofuels or biofuel feedstocks for export.
- Singapore appears positioned to focus on developing second-generation biofuels.
- The United States is utilizing the recently developed Renewable Fuels Standard (RFS) to guide biofuels development. It calls for the production of 36 billion gallons of biofuels annually by 2022, with 21 billion gallons coming from advanced biofuels which must be produced using new feedstocks and technologies. Of this, 16 billion gallons or more are expected to be from cellulosic biofuels - derived from plant sources such as farm and forest residues.

**Table 3: Biofuels Targets Adopted by APEC Member Economies**

| Member Economy | Targets |
|---|---|
| Australia | |
| Brunei Darussalam | |
| Canada | 500 ML (biodiesel) by 2010. |
| Chile | |
| China | Biofuel share 15% of transportation energy by 2020. |
| Hong Kong, China | |
| Indonesia | Ethanol - 3,770 ML in 2010; Biodiesel - 5,570 ML in 2010. |
| Japan | Plan to replace 500 ML/year of transportation petrol with liquid biofuels by 2020. |
| Korea | 2% blending of total transport petro-diesel. |
| Malaysia | |
| Mexico | No mandates or specific goals currently, but is actively developing a strategy. |
| New Zealand | Biofuels will have to account for 3.4% of total fuels sold by 2012. |
| Papua New Guinea | |
| Peru | |
| Philippines | The Biodiesel Program - focus is on meeting domestic fuel demand. |
| Russian Federation | |
| Singapore | 1 M Tonnes by 2010 (biodiesel). |
| Chinese Taipei | Considering ethanol production from sugar cane, sweet sorghum, molasses. |
| Thailand | Seeks to replace 3.1 billion litres of petro-diesel. |
| United States | Renewable Fuels Standard (RFS) - 36 billion gallons of biofuels annually by 2022. |
| Viet Nam | 500 ML of fuel ethanol and 50 ML of biodiesel by 2020. |

Every feedstock used in the production of biofuels has its own unique characteristics and its own set of challenges. While some feedstocks are established, others are very new or just at the idea stage.

Significant challenges are associated with ensuring that biofuels production targets are met in a fashion that is economically and environmentally sustainable. If palm can be grown on existing plantations rather than new ones, deforestation can be avoided, along with associated reduction in carbon dioxide absorption. If ethanol is produced from corn or sugar cane in a way that uses corn stover or cane bagasse for process heat, the carbon footprint of transport fuels can be substantially reduced. Second-generation biofuels from farm and forest residues can also ease pressure on agricultural land and substantially reduce life cycle carbon emissions.

### 3.3 Potential Biofuels Production from First-Generation Feedstocks

The 2008 *Survey of Biomass Resource Assessments and Assessment Capabilities in APEC Economies* provides information on potential biofuel production from first-generation feedstocks. Assuming that 20% of the economies' current starch and sugar crops production could be made available for biofuel production, for example through a 1% annual increase in crop yields over a 20-year period, first-generation resource potential would amount to some 92,000 ML of ethanol and 24,000 ML of biodiesel per year, as shown in **Table 4**. This would be sufficient to displace about 7% of current gasoline consumption in the APEC region.

**Table 4: Potential Biofuels Production from First-Generation Feedstocks [7]**
**(Assuming Increased Yields over Time Make the Equivalent of**
**One-Fifth of 2008 Grain Production Available for Biofuels Production)**

| Member Economy | Ethanol Potential (MLy) | Biodiesel Potential (MLy) |
|---|---|---|
| Australia | 3,110 | 412 |
| Brunei Darussalam | 0 | 0 |
| Canada | 2,180 | 598 |
| Chile | 260 | 59 |
| China | 32,000 | 5,680 |
| Hong Kong, China | 0 | 10 |
| Indonesia | 6,730 | 3,670 |
| Japan | 750 | 853 |
| Korea | 330 | 284 |
| Malaysia | 100 | 3,478 |
| Mexico | 3,020 | 250 |
| New Zealand | 15 | 143 |
| Papua, New Guinea | 60 | 89 |
| Peru | 990 | 329 |
| The Philippines | 330 | 337 |
| Russia | 4,870 | 550 |
| Singapore | 0 | 0 |
| Chinese Taipei | 80 | 289 |
| Thailand | 2,700 | 236 |
| United States | 30,000 | 6,213 |
| Viet Nam | 4,570 | 178 |
| **APEC Total** | **92,000** | **24,000** |

The units of measure for both ethanol and biodiesel were converted to ML to be consistent with this report and also for application of our models (to be discussed below). The ethanol estimates in the APEC biomass report were converted from GL to ML (the GL value times 1000) while the biodiesel estimates were converted from Mt to ML (where number of litres equals the number of tons divided by 0.92, biodiesel's specific gravity).

It is possible to derive rough estimates of potential first-generation biofuels employment by multiplying the above figures by appropriate jpMLy figures. Our models (to be fully explained in Section 6.0) provide reasonable estimates for these jpMLy figures. It should be remembered that first-generation biofuels employment is focused on jobs created from the refinery and related farm operations.

**Table 5** shows various jpMLy figures based on our models developed in Section 6.0 below. For example, the corn ethanol employment model shows 412 jobs for a 100 MGy plant, and 412 jobs divided by 100 MGy equals 4.12 jpMGy. To convert this to ML, there are 3.7854 litres per gallon, so a 100 MGy plant is the same as a 378.54 MLy plant. Then 412 jobs divided by 378.54 MLy equals 1.1 jpMLy (rounded).

**Table 5: Estimates of Jobs per Million Litres per Year of Biofuels Production (from Employment Models)**

| Biofuel Feedstock and Type | Modeled Employment Per Biorefinery | Assumed Size of Biorefinery | jpMGy | jpMLy |
|---|---|---|---|---|
| Corn Ethanol | 412 | 100 MGY | 4.12 | 1.1 |
| Sugar Cane Ethanol | 1,920 | 100 MGY | 19.20 | 5.1 |
| Palm Oil Biodiesel | 2,930 | 40 MLY | | 73.3 |
| Soybean Oil Biodiesel | 316 | 90 MLY | | 3.5 |

**Table 6** provides estimates for current ethanol and biodiesel employment based on *current production estimates* (presented earlier in Table 1). These current production estimates can only be considered approximate due to several factors, including a lack of available data, some significant differences between data sources, and varying reporting periods. Nevertheless, a comparison of the results from Tables 6 and 7 suggests that while potential employment in APEC from first-generation biofuel production could be as high as 826,000 (175,000 from ethanol and 651,000 from biodiesel) current employment from such production appears to be around 242,000 (45,000 for ethanol and 197,000 for biodiesel).

**Table 7** applies the appropriate ethanol and/or biodiesel model (and appropriate jpMLy figure) to each member economy to arrive at approximate employment figures. Potential ethanol employment in APEC member economies is estimated to be about 175,000 while potential biodiesel employment is estimated to be about 651,000. Since we are using *estimates of production potential*, the employment figures are not equivalent to current biofuels employment in the refinery and farm sectors in the APEC region. Rather, they represent rudimentary estimates of long-run job potential from first-generation biofuels build-out in the APEC region.

**Table 6: Converting Current Production Estimates into Current Employment Estimates**

| Member Economy | 2008 Ethanol Production (MLy) | jpMLy | Estimated Employment | 2008 Biodiesel Production (MLy) | jpMLy | Estimated Employment |
|---|---|---|---|---|---|---|
| Australia | 243 | 5.1 | 1,000 | 240 | 3.5 | 800 |
| Brunei Darussalam | | | | | | |
| Canada | 931 | 1.1 | 1,000 | 105 | 3.5 | 400 |
| Chile | | | | | | |
| China | 1,900 | 1.1 | 2,000 | 117 | 3.5 | 400 |
| Hong Kong, China | | | | 4 | 3.5 | 14 |
| Indonesia | 140 | 5.1 | 700 | 1,550 | 73.3 | 114,000 |
| Japan | | | | 3 | 3.5 | 11 |
| Korea | | | | 50 | 3.5 | 200 |
| Malaysia | | | | 329 | 73.3 | 24,000 |
| Mexico | | | | 15 | 3.5 | 50 |
| New Zealand | 5 | 1.1 | 6 | 20 | 3.5 | 70 |
| Papua, New Guinea | | | | 7 | 73.3 | 500 |
| Peru | | | | 127 | 73.3 | 9,000 |
| The Philippines | | | | 257 | 73.3 | 19,000 |
| Russia | | | | | | |
| Singapore | | | | 35 | 3.5 | 100 |
| Chinese Taipei | | | | 4 | 3.5 | 14 |
| Thailand | 340 | 5.1 | 2,000 | 260 | 73.3 | 19,000 |
| United States | 34,069 | 1.1 | 38,000 | 2,650 | 3.5 | 9,000 |
| Viet Nam | | | | | | |
| **APEC Total** | **37,628** | | **45,000** | **5,773** | | **197,000** |

**Table 7: Converting Potential Production into Potential Employment**
(Potential Jobs Arising from Conversion of Feedstocks;
Equivalent to One-Fifth of 2008 Grain Production)

| Member Economy | Ethanol Potential (MLy) | jpMLy | Potential Employment | Biodiesel Potential (MLy) | jpMLy | Potential Employment |
|---|---|---|---|---|---|---|
| Australia | 3,110 | 5.1 | 16,000 | 412 | 3.5 | 1,000 |
| Brunei Darussalam | | | | | | |
| Canada | 2,180 | 1.1 | 2,000 | 598 | 3.5 | 2,000 |
| Chile | 260 | 1.1 | 300 | 59 | 3.5 | 200 |
| China | 32,000 | 1.1 | 35,000 | 5,680 | 3.5 | 20,000 |
| Hong Kong, China | | | | 10 | 3.5 | 35 |
| Indonesia | 6,730 | 5.1 | 34,000 | 3,670 | 73.3 | 269,000 |
| Japan | 750 | 1.1 | 800 | 853 | 3.5 | 3,000 |
| Korea | 330 | 1.1 | 400 | 284 | 3.5 | 1,000 |
| Malaysia | 100 | 5.1 | 500 | 3,478 | 73.3 | 255,000 |
| Mexico | 3,020 | 1.1 | 3,000 | 250 | 3.5 | 900 |
| New Zealand | 15 | 1.1 | 17 | 143 | 3.5 | 500 |
| Papua, New Guinea | 60 | 5.1 | 300 | 89 | 73.3 | 7,000 |
| Peru | 990 | 5.1 | 5,000 | 329 | 73.3 | 24,000 |
| The Philippines | 330 | 5.1 | 2,000 | 337 | 73.3 | 25,000 |
| Russia | 4,870 | 1.1 | 5,000 | 550 | 3.5 | 2,000 |
| Singapore | | | | | | |
| Chinese Taipei | 80 | 5.1 | 400 | 289 | 3.5 | 1,000 |
| Thailand | 2,700 | 5.1 | 14,000 | 236 | 73.3 | 17,000 |
| United States | 30,000 | 1.1 | 33,000 | 6,213 | 3.5 | 22,000 |
| Viet Nam | 4,570 | 5.1 | 23,000 | 178 | 3.5 | 600 |
| **APEC Total** | **92,000** | | **175,000** | **24,000** | | **651,000** |

Note: Tables round estimated employment numbers over 1,000 to the nearest 1,000, others over 100 to the nearest 100.
Tables assume 1.1 jpMLy for corn ethanol, 5.1 jpMLy for sugar cane ethanol, 3.5 jpMLy for soy biodiesel, and 73.3 jpMLy for palm biodiesel.

## 3.4 Potential Second-Generation Biofuels Production from Farm and Forest Residues

**Table 8** provides an estimate of second-generation ethanol production potential, from the same APEC report mentioned above.[8] It suggests total APEC ethanol production potential from farm and forest residues could amount to some 509 GL with much of that total coming from China (46%) and the United States (19%). Approximately 1,700 million tonnes (Mt) of feedstock may be available to yield this 509 GL of ethanol output. It is estimated that this potential, if realized, could displace about two-fifths of APEC's current gasoline consumption and one-fifth of its crude oil imports.

**Table 8: Second-Generation Resource Availability for Ethanol Production in APEC Economies** [9]

| Member Economy | Resource Availability (million tonnes; Mt) | Ethanol Potential (GL) |
|---|---|---|
| Australia | 37 | 11 |
| Brunei Darussalam | | |
| Canada | 71 | 21 |
| Chile | 3 | 1 |
| China | 788 | 236 |
| Hong Kong, China | | |
| Indonesia | 74 | 22 |
| Japan | 15 | 5 |
| Korea | 13 | 4 |
| Malaysia | 32 | 10 |
| Mexico | 75 | 22 |
| New Zealand | 6 | 2 |
| Papua, New Guinea | | |
| Peru | | |
| The Philippines | 18 | 5 |
| Russia | 100 | 30 |
| Singapore | | |
| Chinese Taipei | 2 | 1 |
| Thailand | 48 | 14 |
| United States | 324 | 97 |
| Viet Nam | 93 | 28 |
| **APEC Total** | **1,699** | **509** |

The resource potential of second-generation biofuels as shown in Table 8 is roughly four times as great as the resource potential associated with using 20 percent of grain production as feedstock for first-generation biofuels. From this, it could be speculated that the employment impact from second-generation biofuels may also be four times as large. However, a lot will depend on how mechanized the processes become.

## 3.5 Biofuel Trade Patterns

Trade depends fundamentally on the availability of resources surplus to domestic needs in one economy and therefore available for export to other economies. It also depends on relative costs of production. Economic analysis cited in a Biofuels Task Force report to EMM-8 in Darwin indicates that biofuels from several feedstocks such as sugar cane, corn, palm, and jatropha would have significantly different production costs and would therefore present potential trade opportunities if export volumes are available.[10]

Ethanol trade by APEC member economies is significant by world standards. APEC economies imported approximately 3.4 GL of ethanol in 2007.[11] The United States (which imported about 2 GL of this 3.4 GL in 2007) is the largest importer in APEC, as well as worldwide. Meanwhile, APEC member economies exported approximately 1 GL of ethanol in 2007.[12]

China is the largest ethanol exporter in APEC, with significant exports to the United States. Exports from APEC member economies have decreased recently, due to concerns about being able to meet domestic requirements. For example, some APEC economies with official biofuels targets (such as Australia, New Zealand, and Canada) have reduced their exports, whereas some with no clear biofuels targets (such as Indonesia and Viet Nam) have expanded their exports, bringing in additional revenue.

Biodiesel trade among APEC economies is currently much more modest than ethanol trade. The European Union (EU) is the world's largest producer and consumer of biodiesel.

The APEC report *The Future of Liquid Biofuels for APEC Economies* provided some trade data.[13] **Table 9** summarizes these findings (it considers only the imports and exports of biodiesel and fuel ethanol and not the export or import of feedstocks). It is clear that because biofuel production is largely consumed domestically, trade data are often not available or are estimated, rather than compiled systematically.

**Table 9: APEC Biofuel Trade Analysis (2006)**

| Member Economy | Biodiesel | Fuel Ethanol |
|---|---|---|
| Australia | Very small amounts exported | Very small amounts exported |
| Canada | Some imports from United States | Some imports from United States |
| China | About 10,000 tonnes exported in 2006 | |
| Indonesia | Very small amounts exported | |
| Japan | | Discussions underway for imports from Brazil |
| Malaysia | Exports mainly to Japan, United States, and European Union | |
| Peru | Exports planned in future | Exports planned in future |
| The Philippines | Exports mainly to Germany and to several Asian economies | |
| Thailand | | Exports expected to grow as production increases |
| United States | | Imports from Brazil, Central America, and Caribbean |

In terms of second-generation biofuels, the switch to more complex technologies will affect trade. If lignocellulosic materials from forestry, agricultural and urban residues, and dedicated cellulosic crops become the main sources for biofuel production, the economies that will have a comparative advantage in biofuel production in the future may not be the same as those that are competitive at present (with biofuels made from grain, sugar crops, and oil seeds). While it remains to be seen, emerging technologies may be even more capital intensive than current production methods. Thus, it is important that developing as well as developed APEC economies have access to the capital and technology that are needed to develop second-generation biofuel resources and benefit from the associated employment.

There are many different trade measures and trade agreements, and this adds to the complexity of trade dynamics for biofuels. The main framework is set by the World Trade Organization (WTO). Under the WTO, the so-called Doha Development Agenda of 2001 aims to liberalize global trade in agricultural products. However, the current WTO classification of biofuels as tradable goods is uncertain: are they industrial, agricultural, or even environmental goods? Depending on their status, biofuels will be subject to different sets of trading rules and will be treated differently in multilateral trade negotiations. There is increasing evidence that the least trade-distorting way of categorizing biofuels would be to declare them industrial goods so that the risk of harmful subsidization can be minimized.

A lack of uniform technical standards is also affecting biofuel trade among APEC member economies. There is a need for more harmonized biofuel standards, and several initiatives have been launched:

- APEC has been active in the development of guidelines for biodiesel standards that will enhance biodiesel trade.[14]
- Biodiesel feedstocks with less favourable characteristics (e.g. high "pour point" or liquefying temperature of palm biodiesel which can lead to poor performance in cold climates) can still be traded if performance-based standards are developed for their use in blends.
- The Netherlands Standardization Institute (NEN) was recently asked to provide an overview of current international standards for biofuels.[15] This document provides policy makers with insight into standardization efforts, and it suggests how such efforts may link to local or regional regulations.

Environmental policy considerations are also affecting trade. For example, some APEC member economies may be reluctant to import biodiesel derived from palm oil if it cannot be certified as coming from an old growth plantation. There is a desire to reduce the carbon footprint that is being created by trade partners. When new land is opened up in a rainforest or a peat bog, a large carbon impact is created. Large-scale deforestation of mature trees also results in a loss of habitat and biodiversity. There are many other potential impacts such as a displacement of Indigenous peoples, limited water resources, and the use of pesticides. We note that governments and environmental organizations are increasingly turning away from biofuels made in a non-sustainable way and are seeking global support for more sustainable production strategies. This may increasingly affect trade options going forward. The Roundtable on Sustainable Biofuels is bringing together representatives of governments, corporations, and non-government organizations to define criteria, standards, and processes to promote sustainably produced biofuels.

In summary, many believe that there is enormous potential for expanded trade both within APEC economies, as well as between APEC and non-APEC economies. This potential exists because biofuel output is expanding, significant differentials exist in biofuel production costs, and most biofuels (and most feedstocks) in the APEC region have so far been produced and consumed in domestic markets. The next section presents case examples of biofuel production and employment that can be applied to APEC economies.

## 4.0 Case Examples: Using Real World Experiences to Develop an Employment Model

This section investigates several case examples in APEC and non-APEC economies where real world experience with biofuels is relatively well documented and can be used to develop a biofuels employment impact model. The issues and difficulties involved in assessing biofuels employment impacts are also highlighted.

Some of the case examples identify the number of direct jobs being created in the refinery sector (i.e. plant workers) as well as in the agricultural sector (i.e. farmers) to support the refinery. Other examples focus on the indirect and induced employment impacts from these direct refinery and farm jobs.

In addition to the difficulties involved in assessing employment impacts (including multiplier effects) from biofuels, the case examples also reveal a need for more analytical standardization. What one study may consider a direct employment impact, another study would categorize as an indirect one. While many studies investigate the economic impact of biofuels, few focus on estimating employment impacts.

Where appropriate, some analytical standardization can be provided by calculating the number of jobs being created per unit of biofuel production (typically, millions of litres) per year. **Figure 2** summarizes various jobs-per-million-litres-per-year (jpMLy) calculations from the studies. The second column shows the jpMLy based on direct jobs only whereas the third column presents jpMLy calculations based on total (i.e. direct and indirect) jobs. Since some studies refer to direct jobs and others to total jobs, there are gaps in the data (as indicated by the blanks in the summary table below).

Given this study's focus on employment impacts in the refinery and farm sectors, employment arising from initial plant construction has been removed where necessary. Nevertheless, some discussion of these initial construction impacts has been provided in the sections that follow.

**Figure 2: jpMLy Calculations for Various Case Examples**

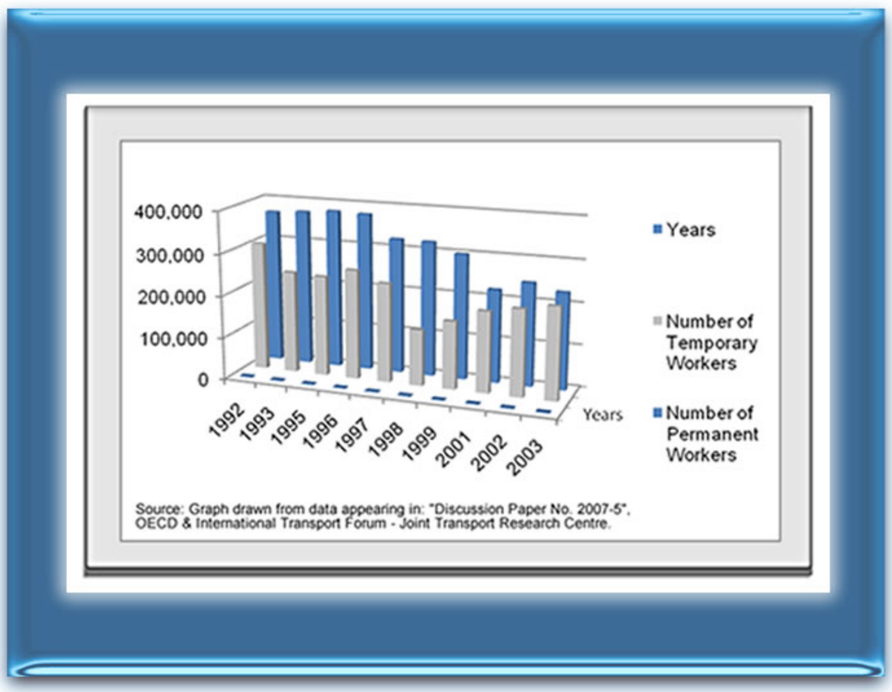
| Biofuel Economic Impact Study & Section | **Direct** Jobs Created Per ML of Output Per Year (jpMLy) | **Total** Jobs Created Per ML of Output Per Year (jpMLy) |
|---|---|---|
| Brazilian Ethanol Study – Section 4.1 | 39 | |
| Brazilian Biodiesel Study – Section 4.2 | | 83.3 |
| United States Ethanol Study – Section 4.4 | | 4.4 |
| United States Ethanol Study – Section 4.4 | | 4.2 |
| United States (South Dakota) Ethanol Study – Section 4.4 | | 1.9 |
| United States (Domestic) Biodiesel Study – Section 4.5 | | 13.0 |
| United States (Florida) Biodiesel Study – Section 4.5 | 0.8 | 1.2 |

## 4.1 The Case of Ethanol in Brazilian Biofuels

In the first five years of Brazil's Proálcool Program, the State of São Paulo expanded the amount of land devoted to sugar cane production by 376,000 hectares (ha), or some 25%. About 36% of this additional land area (135,000 ha) was obtained by displacing other crops on existing farmland, while 64% (241,000 ha) was converted from pasture land. Since sugar cane demands approximately seven times more labour than attending to pasture land, this resulted in a net gain of some 25,500 worker-years of employment (40,500 worker-years generated minus 15,000 worker-years lost). At the time, the unemployment rate in São Paulo was 11.5% and higher employment levels were a key policy target. The production of sugar cane and ethanol is still an important source of employment in São Paulo State, both directly (employment in the sugar cane and ethanol production) and indirectly (employment in the industries that produce intermediate deliveries to the sugar cane and ethanol production sector).

The number of permanent and temporary workers in sugar cane production fell by one third between 1992 and 2003, in part because of increasing reliance on mechanical harvesting. The number of temporary employees fluctuated, first declining and then increasing to about one-half of the earlier total. **Figure 3** shows the combined number of direct jobs in the growing and harvesting of sugar cane and in the production of ethanol for that period.

**Figure 3: Direct Employment in Sugar Cane and Ethanol Production (State of São Paulo, Brazil)**




Note: "Temporary Workers" typically would refer to workers employed in the sugar cane growing season in Brazil, which is about 9 months of the year; i.e., close to full employment.

**Table 10** below shows employment and production data for the entire Brazilian ethanol industry in 2006. The data are approximate because they exclude several indirect impacts from the multiplier effects on employment from the subsequent spending of income and the replacement effects of cane production. Useful insights can be gained from further analysis of the first five years of Proálcool. Just growing crops for biofuel production does not initially displace other agricultural activities, but the longer term effects are not well known. They depend on the normal market forces for agricultural crops as the impact on employment will be dependent on the level of mechanization per type of crop. The net employment effects found from any model should include all direct, indirect, and induced impacts of the sugar cane and ethanol production, and the replaced agricultural activities. But, in this case, information on the total net impact is limited.

**Table 10: Brazilian Ethanol Direct Employment and Production (Estimated)**

| | |
|---|---|
| **Ethanol Employment before Mechanization (2006)** | 700,000 |
| Skilled Positions - Supervisors & Skilled Industrial (30%) | 210,000 |
| Semi Skilled Positions - Truck and Tractor Drivers (10%) | 70,000 |
| Unskilled Positions - Labours in Agricultural & Industrial (60%) | 420,000 |
| | |
| **Ethanol Production from Sugar Cane (2006)** | |
| Total Area Planted with Sugar Cane for Ethanol Production (thousand hectares) | 5,900 |
| Number of Tonnes of Sugar Cane Harvested for Ethanol Production (million tonnes) | 437 |
| Number of Jobs per Million Tonnes of Sugar Cane | 1,600 |
| Total Ethanol Production in 2006 (million litres) | 17,900 |
| **Number of Jobs per ML of Ethanol per year** | **39** |

In 2006, Brazil had some 5.9 million hectares of land planted in sugar cane for ethanol production. This land yielded some 437 million tonnes of sugar cane, which was converted into roughly 17,900 million litres of ethanol (assuming a yield of 41 litres of ethanol per tonne of sugar cane feedstock). With something like 700,000 people employed in the ethanol industry, dividing by the 17,900 million litres they produced, there were roughly 39 direct jobs per million litres of ethanol produced that year (39 jpMLy).

Employment is obviously a key priority in the Brazilian biofuels industry. Most of the legislation pertaining to the industry indirectly addresses employment. An example is legislation where the government specifically aims at reducing the rate of mechanization to avoid unemployment and poverty.

Many other factors give economies like Brazil an edge on the ethanol market. Brazil has the world's largest amount of open land that is used for or could be converted to farm land. It also has a very low cost of labour. A further advantage is the tropical climate which is very favourable for sugar cane production. The following are some key facts about Brazilian ethanol:

- Brazil has the advantage of having two or three growing seasons for sugar cane. This can result in large profit margins (30% of sales or more) for the owners of the Brazilian mills and plantations. The best areas for growing cane in Brazil are near the equator, where the climate is fairly uniform throughout the year.
- With total ethanol production of some 17.9 million litres spread among 351 production plants, the average ethanol refinery in Brazil in 2006 produced about 51 million litres of biofuel.
- Sugar cane producers in Brazil do not use as much fertilizer as corn growers do in the United States, since land used for sugar cane growing has very rich soil with a slower rate of depletion of its nutrients.
- There are about 300,000 cane cutters employed in the Brazilian ethanol industry.[16] Cane cutters earn about $300 to $400 per month if they cut 8 to 10 tons of cane per day for $1.35 per hour each day for six days a week during the growing season of 6 to 7 months.[17] They are paid based on their production.
- Cane cutters can spend up to 10 months of the year living far from their families.[18] Some of the cane cutters have poor living conditions, a high rate of on-the-job injuries, and poor health.

## 4.2 The Case of Biodiesel in Brazilian Biofuels

No actual model was found for the Brazilian biodiesel industry. The main motivation for biodiesel is for social development by the Brazilian government. Another is a desire to diversify the domestic fuel supply. A program was launched in 2004 to produce B2 for the transportation sector. The targeted volumes are 1 billion litres in 2008 and 2.4 billion litres by 2013. This is expected to create 200,000 jobs within the biodiesel industry by 2013. It is assumed that the number of jobs includes both direct and indirect jobs. Currently, there are 14 biodiesel plants with a combined capacity to convert 600,000 tonnes per year of feedstock with a plan to expand to an additional 60 plants.

As will be done with the various case studies in this section, an estimate of the number of jobs created per unit of biofuel production can be calculated. For example, if 200,000 total jobs are created in Brazil from producing 2.4 billion litres in 2013, then 83 jobs are created per million litres of annual biodiesel production:

> 200,000 total jobs to produce 2.4 billion litres of biodiesel in 2013.
>
> 2.4 billion litres = 2,400 million litres
>
> Dividing 200,000 jobs by 2,400 ML of annual production capacity, we get
>
> **83 total jobs impact per ML** of annual biodiesel production in Brazil.

The Brazilian business model for biodiesel is difficult to justify as being feasible because it depends on the feedstock used and there are uncertainties related to the type of biodiesel plant technology choices. The plant's technology must be flexible enough to produce more than one type of oil from Brazil's large selection of feedstock types. Feedstocks like soybean, sunflower, castor, jatropha, peanuts, cotton seeds, and tallow are possible with a flexible feedstock biodiesel conversion plant, but soybean is the preferred choice.

One of the objectives of the Brazilian government is to introduce new types of feedstock that can be cultivated in lands not used for food production. The major challenge is to reduce the production cost of new commercial crops (i.e. palm, castor, jatropha, and babassu - a variety of Amazon palm tree). The hope is to develop a role for family-based agriculture, but past history of Brazilian agribusiness has been characterized by large-scale production with little or no role for family-based agriculture. The harvesting of palm feedstock is currently very manual, but mechanization continues to expand, as shown in **Figure 4**.

**Figure 4: Mechanization of Palm Harvesting vs. Manual Harvesting**

### 4.3 The Case of South African Biofuels Feasibility Studies

Studies have been carried out by the Biofuels Task Force[19] to investigate the feasibility of establishing a significant biofuels industry in the Republic of South Africa. Like the other case examples presented, this one also shows that employment impacts (both direct and indirect) are largely dependent on refinery capacity and the type of feedstock used. We highlight this study here, in part, to bring some light to potential employment impacts in the transport sector.

According to the study, the three dominant energy crops applicable for South African use are sugar cane and maize for bio-ethanol production and soybean for biodiesel production. Although this might not be a comprehensive list of feedstock types to consider for biofuel production, it provides for the major benefits to be derived from minimum intervention in the current agricultural and oil industry structures.

The annual ethanol output from a refinery was used to calculate the number of jobs created in the plant itself. The impact on GDP is that "every plant will add at least 0.05% to the GDP, or 0.074% of the planned domestic growth of 6% a year". The plants were forecast to contribute up to 0.4% to South Africa's total GDP.[20]

As we know, all direct jobs result in the creation of indirect jobs in other sectors of the economy. The South African study not only quantified the direct and indirect employment impacts, but also provided a *sectoral* breakdown of those impacts. For example, as shown in **Table 11**, it was estimated that 4,500 direct and indirect jobs would be created in the *refinery* sector. In the *agricultural* sector, the 10 refineries require 4,300 farmers to supply the feedstock, who induce the creation of 30,000 indirect jobs, so a total of 34,300 jobs would be created. Finally, 1,050 jobs were created in the *transport* sector. The overall aggregate employment impact from the 10 refineries is the sum of these numbers; that is 4,500 + 34,300 + 1,050 = 39,850 jobs.

As will be discussed at the end of these case examples, different studies show a wide variance in terms of transportation employment impacts arising from expanded biofuels production. These impacts depend on many factors such as the type of feedstock used, whether the feedstock can be stored, the location of the refinery, and the number of growing seasons. The South African study indicates that the number of jobs created in the transport sector is significant.

**Table 11: Summary of Biofuel Employment Based on the South African Feasibility Study**

| Number of Jobs Created | Refinery Sector | Agriculture Sector | Transport Sector | All Sectors |
|---|---|---|---|---|
| Direct in Biofuel | 450 | 4,300 | 1,050 | 5,800 |
| Indirect | 4,050 | 30,000 | | 34,050 |
| **Total (Direct + Indirect)** | **4,500** | **34,300** | | **39,850** |

## 4.4 United States Ethanol Models

To estimate the net economic impact of an ethanol plant, it is necessary to measure the following effects:

- Direct effects: the initial change from the addition of the ethanol plant;
- Indirect effects: the inter-industry transactions as the ethanol plant buys inputs from local businesses;
- Induced effects: the changes in local spending that result from income changes in directly and indirectly affected industry sectors.

As indicated previously, the total economic impact (and the related employment impact) is composed of a one-time construction impact of a new ethanol plant as well as the ongoing impact derived from its operation. While the emphasis of this study is on the employment generated from the plant operations and in the farm sector, we will consider for a moment the construction impact.

A typical new ethanol plant will employ about 60 people during the construction phase but mostly from outside the local area.[21] A lot of what goes into the plant comes from outside the local area except for gravel, asphalt, concrete, and some local labour. So most of the impact from plant construction is not felt locally. One way to assess the actual local impact of construction is to find out how much of the project is bid to local suppliers and construction firms and what impact this has on those sectors. One study indicated that if the total investment cost is $73.46 million, then only $3 million of that total would be the local impact while $10.425 million or 15% is the one-time engineering and installation cost.[22]

Employment in the ethanol plant itself is significantly influenced by the maximum production output capacity of the plant. The number of jobs per unit of incremental production can decline as the size of the plant increases. One study estimates that an average plant in the United States (150 million - 190 million liters per year) generates 1 job per 3 to 4 million liters of ethanol production.[23] This equates to roughly 0.3 jpMLy (although it is not clear whether this is based on direct jobs only or total jobs). There has been an increase in farm incomes in the United States but not necessarily a subsequent increase in the number of jobs. An increase in farm productivity does not directly translate into more jobs as mechanization in harvesting and production can improve productivity while higher prices for feedstock can improve farm incomes.

An increase in employment is very important to many communities when an ethanol plant locates in their region. An ethanol plant creates opportunities for both blue- and white-collar workers. The nationwide average annual salary in the United States is estimated to be $43,000.[24] A survey by the Nebraska Ethanol Board found the average ethanol-related salary was around $49,000 in 2006 which was 43% higher than the state average of $34,300.[25]

It is the indirect employment impact that varies widely by study (and by location). For example, an analysis of seven previous U.S. studies found that for plants with a capacity of between 10 and 80 million gallons per year (MGy), indirect labour income generated per plant ranged from $1 million to $47 million per year (depending on location).[26] In fact, one of the studies in the analysis was on a 41 MGy plant which indicated indirect labour income of $2.7 million whereas another study in the survey (this one on a smaller plant of 10 MGy) indicated a higher indirect labour income of $5.1 million per year.

Another study indicated that a new ethanol plant will bring about a rise in economic activity and the availability of new jobs. This, in turn, would contribute to higher levels of income locally. An operational 50 MGy ethanol plant was estimated to add $30 million to the local economy on an annual basis. A 100 MGy plant would contribute $50 million annually.[27] Using estimated employment data from the 50 MGy and 100 MGy plant studies, we can develop a very rough estimate that a little over 4 jobs are created per million litres of annual ethanol production:

For the 50 MGy plant:

836 total jobs to produce 50 million gallons of output capacity per year.

Since 3.7854 litres per US gallon, this is equal to 189 ML of output per year.

Dividing 836 jobs by 189 ML of annual production capacity, we get approximately **4.4 total jobs impact per ML** of annual ethanol production.

For the 100 MGy plant:

1,573 total jobs to produce 100 million gallons of output capacity per year.

Since 3.7854 litres per US gallon, this is equal to 378.54 ML of output per year.

Dividing 1,573 jobs by 378.54 ML of annual production capacity, we get approximately **4.2 total jobs impact per ML** of annual ethanol production.

Typically, a local community will experience a surge in temporary employment during the construction of an ethanol plant as workers from out of state work 24 hours a day erecting a plant with major material purchased from outside the region. Plants require anywhere from 100 to 325 personnel during peak construction. There is a big positive one-time effect on the local economy, especially for towns of just several hundred people.

A study of the economic impacts of South Dakota's ten ethanol plants (based on calendar year 2004) was completed in 2005.[28] It accounted for the differences in plant capacity and economies of scale, as well as the availability of local feedstock among the ten plants. The study developed multipliers to estimate the total output impact, the value-added impact, and the employment generated in South Dakota. The total output multiplier measured the direct, indirect, and induced impact of all ten plants on the South Dakota economy. The value-added multiplier measured only the additional benefit to the state economy from the ten plants. In total, the study found that the plants generated over a billion dollars in total output and over a quarter of a billion dollars in new wealth (i.e. value-added), and stimulated the creation of nearly three thousand jobs. **Table 12** breaks down the jobs into direct, indirect, and induced components. Note that $4.75 million was provided in state subsidies, which was subtracted from the value-added wealth.

**Table 12: Employment and Economic Impact of Ethanol Production on the South Dakota Economy (in 2004)**

| Impact | Total Output (Millions US$) | Value-Added (Millions US$) | Employment |
|---|---|---|---|
| Direct | 676 | 64 | 473 |
| Indirect | 302 | 145 | 1,756 |
| Induced | 77 | 46 | 743 |
| **Total** | **1,055** | **250*** | **2,972** |

***** This number reflects the costs of a $4.75 million state subsidy.

Utilizing the above figures, we can develop a very rough estimate that a little under two (2) jobs are created per million litres of annual ethanol production in South Dakota. The study indicated that current annual capacity of the ten plants in 2004 was 420 million gallons.

2,972 total jobs to produce 420 million gallons of output capacity per year.

Since 3.7854 litres per US gallon, this is equal to 1,589 ML of output per year.

Dividing 2,972 jobs by 1,589 ML of annual production capacity, we get about **1.9 total jobs impact per ML** of annual ethanol production in South Dakota.

This figure for the number of jobs per unit of ethanol production is based on maximum plant capacity rather than actual current production. Because of significant economies of scale (and levels of automation) at work in these plants, there is typically little difference between the number of jobs at current production levels and at maximum plant capacity. For example, assuming in the above example that current total production capacity for the ten plants were only 300 million gallons, jobs per ML per year would be 2.6 instead of 1.9. More employment can be created by several smaller plants distributed over a wide area than by a single large plant. In fact, in this analysis, we are treating all ten South Dakota plants as a single plant producing at maximum capacity. It should also be noted that the ten plants examined in the study were already up and running, so that initial construction impacts were not part of the analysis.

**Figure 5** shows several United States ethanol studies over the last 15 years with multipliers varying from 3.5 to 51 for different states and from 8 to 25 for the economy as a whole.[29] If the multipliers are varying so widely, an important first step is to determine why they are doing so.

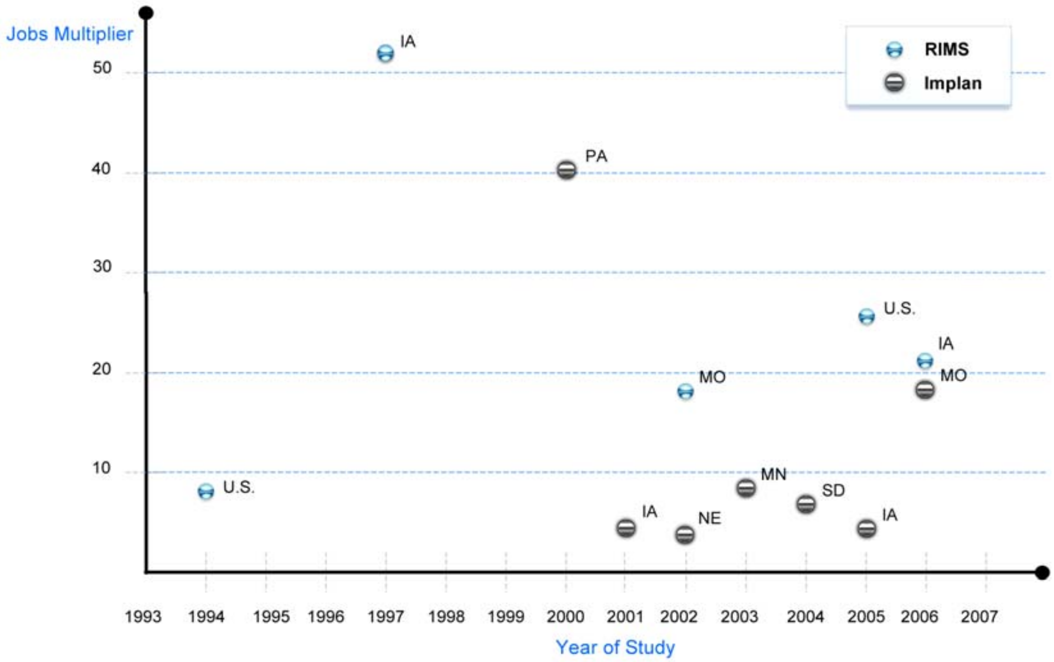
While a comprehensive discussion of multipliers (and economic modeling) is beyond the scope of this study, it can be stated that multiplier values are a critical part of both the RIMS and Implan modeling approaches. Because of the lack of comprehensive regional data, most 'regional' models (that is, for a city or state or county) must estimate multipliers by regionalizing economy-wide values. This is often the source of errors. In the extreme case, a model may be difficult to justify in certain regions. For instance, a county could be very unique in the sense that people spend their disposable income differently than in other counties. These are only some of the reasons why regional multipliers (and results) may be significantly different than one for an entire economy (as evident in Figure 5). Also, the inherent accuracy of multipliers under different modeling systems (RIMS, Implan, or others) is itself the subject of significant debate, and different modelling systems often yield different results.

These factors help to explain the wide-ranging multipliers appearing in Figure 5. Multipliers depend on the underlying Input-Output Model. If it is constructed using data that are out of date, then the multiplier is likely out of date. Multipliers also depend on the size of the region; a larger region can satisfy more regional demand inside the region and thus will have a higher multiplier than a small rural region.

In addition to the issues surrounding the use of multipliers, other difficulties have been noted in terms of assessing the employment impact from U.S. ethanol production. The following are some examples:[30]

- Accurate accounts for the industry are lacking in current models.
- One-time impacts (such as from initial ethanol plant construction) are often not separated out from the on-going impacts.
- The treatment of cumulative federal, state, and local subsidies is not consistent.
- U.S. ethanol production has significant economies of scale which means that increments to productive capacity require little additional labour and few technical enhancements.

**Figure 5: Estimated Multipliers in Various United States Ethanol Studies (Excluding Construction Impacts)**




Source: *Input-Outrageous: The Economic Impacts of Modern Biofuels Production*, page 4. Redrawn by Doyletech.

Key to the Studies Shown:

IA = Iowa
MN = Minnesota
MO = Missouri
NE = Nebraska
PA = Pennsylvania
SD = South Dakota

**Table 13** provides a sample of ethanol employment impact studies that have been conducted in the United States. Clearly, there have been several attempts to model employment impacts using various tools and methods.[31] A major theme in this section on United States ethanol models is that forecasts of employment impacts vary considerably; and the table confirms this.

**Table 13: Sample of United States Ethanol Employment Impact Studies**

| Analyst(s) | Organization | Forecast Tool | Employment Forecast | Forecast Coverage | Forecast Year |
|---|---|---|---|---|---|
| John Urbanchuck | AUS Consultants/ SJH & Co. | US BEA RIMS II Multipliers | Domestically, 114,844 jobs depended indirectly on the operation of all ethanol plants. | Domestic | 2005 |
| Nancy Novack | Federal Reserve Bank of Kansas City | Not known | 200,000 plus additional 214,000 jobs over 10 years (ethanol). | Domestic | 2002 |
| Unknown | Minnesota Dept. of Agriculture | IMPLAN (Input/Output Model) | 356 direct ethanol production jobs created a total of 2,562 jobs. | State | 2003 |
| Piece, Verne, Joe Horner, Ryan Milhollin | University of Missouri | IMPLAN (Input/Output Model) | 4 plants directly employ 154 persons from a total estimate of 2,784 jobs in Missouri for the entire industry. | State | 2006 |
| Michael K. Evans | Midwestern Governor's Conference | Not known | 800 total ethanol production jobs in Iowa for an increase of 5,800 manufacturing and 33,900 additional jobs related to farm incomes. | State | 1997 |
| Unknown | BIOWA | Not known | 10 new bio-refinery plants in Iowa to create 22,000 jobs. | State | 2006 |
| Unknown | Iowa Soybean Association | Not known | Biodiesel to create 15,000 jobs. | State | 2006 |
| Mark Imerman, Daniel Otto | Iowa State University | Not known | 2,400 jobs outside of the production of corn. | State | 2006 |
| Randall Stuefen | Stuefen Research, LLC | Input/Output Model | Ethanol jobs in South Dakota - Direct 474, Indirect 1,756, Induced 743; for a total of 2,972. | State | 2005 |
| Donis N. Petersan | Nebraska Public Power Utility | Input/Output Model | 80 M Gallons per year plant requires 48 direct workers and 163 total jobs in the local rural economy. | State | 2002 |

## 4.5 United States Biodiesel Models

According to a study by the Biodiesel Board (NBB)[32], biodiesel will contribute $24 billion to the United States economy between 2006 and 2015. The study projects that annual production will be 650 million gallons in 2015 and 39,102 jobs will have been created in all sectors of the economy between 2006 and 2015. Both the temporary impacts due to construction and the permanent impacts due to annual production were examined.

In order to develop from this study a rough domestic estimate of the number of jobs created per unit of biodiesel production (jpMLy), it is necessary to remove the construction impact from the overall impact. According to the study, 11,720 jobs (out of the 39,102 total) would be construction jobs created during the period from 2006 to 2015 from the new biodiesel plants that would be built to reach the 650 MGy forecast for 2015. Hence, the permanent jobs impact (from ongoing annual operations) would be 27,382 during the period from 2006 to 2015. Over this same period, annual production would grow from approximately 75 MGy in 2006 (estimated from NBB data) to 650 MGy (estimated by the study), for a net increase of 575 MGy or 2,177 MLy. Hence, about 13 jobs would be created per million litres of annual biodiesel production.

**Permanent Jobs Created Over 2006-2015:** 39,102 - 11,720 = 27,382.

**Total Production Increase Over 2006-2015:**

650 MGy (forecast) - 75 MGy (estimated actual in 2006) = 575 MGy.

**Job Creation Over 2006-2015:**

27,382 permanent jobs to produce 575 MGy of output.

Since 3.7854 litres per US gallon, this is equal to 2,177 MLy of output.

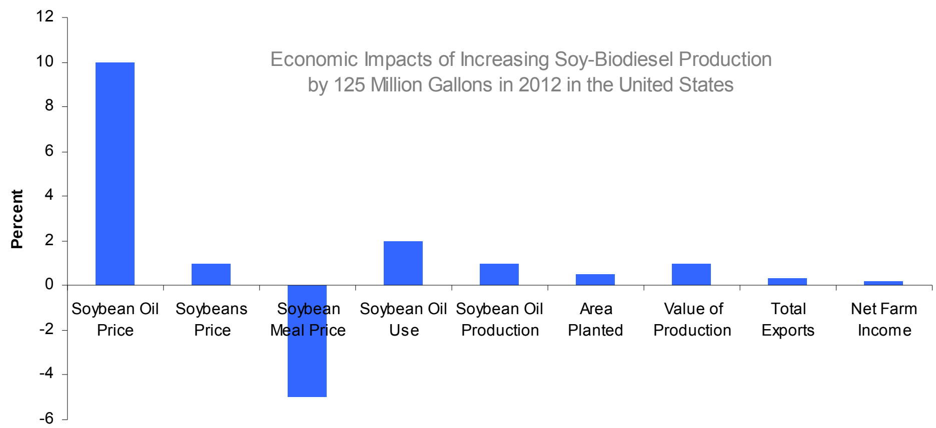
Dividing 27,382 jobs by 2,177 MLy, we get about 13 jpMLy.

This can only be considered a rough economy-wide estimate as several variables must be taken into consideration (including biodiesel plant size and the type of feedstock). It also assumes, of course, that biodiesel is developed on something like the scale the NBB study anticipates.

As should be expected, the NBB study shows that construction may provide a big (but short) boost to local employment while ongoing operations provide a smaller (but more permanent) boost. Nevertheless, about 30% of the total employment impact over the 2006-2015 study period is from construction.

**Figure 6** is based on another economy-wide study in the United States. It suggests that the predicted change in net farm incomes is extremely small with increased (soy-oil) biodiesel production. However, it also shows a very high price for the feedstock (soybean oil) which may contribute to higher farm incomes.

**Figure 6: Economic Impacts of Increasing Soy-Biodiesel** [33]




In the case of Santa Rosa County, a 10 million gallon plant using soybean oil was used as a typical production facility to calculate the potential microeconomic impact of biodiesel production. The impact includes a one-time construction cost and the effects of ongoing operations, primarily in the form of wages paid to employees. Any additional impacts from the purchase of local agricultural products for use in the production of biodiesel were excluded from the analysis because of the absence of local oil processing facilities. The study focused on what a biodiesel project's economic impact would be on Santa Rosa County and the impact from its operations throughout a multi-state region. Using figures calculated from financial information from various feasibility studies and information on employment at a 10 million gallon facility, an input-output model was generated. The model indicates that a biodiesel production facility in Santa Rosa County generates some $4.6 million in one-time economic activity from its construction and $24.8 million in spending each year from its operation.

Benefits from construction and operation of larger biodiesel plants include reduction in equipment cost per gallon of fuel production and reduction in operating expenses due to economies of scale. Large plants also have a greater economic impact on a community but not necessarily a commensurate impact on jobs. Plants with the flexibility to use multiple kinds of feedstock have the advantage of being able to choose feedstock based on price and to operate year-round.

Biodiesel can be easily integrated into existing petroleum distribution systems from handling, chemical, physical, and performance perspectives leading to induced employment. Given the present levels of government incentives and a low enough feedstock cost, biodiesel can be cost competitive for large producers, particularly when used as an additive.

The amount of employment created in building and operating a 10 million gallon plant is shown in **Table 14**. From the research, we have added figures for the number of jobs per ML of annual production capacity in a row at the bottom of the table. Note that these jpMLy calculations are based on ongoing operations only. In other words, the jobs created from initial plant construction (as shown in the first part of the table) were excluded from the calculations in order to be consistent with other jpMLy calculations in this report.

**Table 14: Economic Impact of a 10 Million US Gallon (37.86 Million Litre) Biodiesel Plant in the United States (Santa Rosa County, Florida) (Costs in U.S. Dollars)**

**Construction**

| Estimated Impact of Processing Plant Construction | Direct | Indirect | Induced | **Total** |
|---|---|---|---|---|
| **Total Spending (Output)** | $3,300,000 | $679,000 | $643,000 | **$4,623,000** |
| **Value Added** | $1,415,000 | $372,000 | $406,000 | **$2,192,000** |
| **Incomes Generated** | $1,279,000 | $264,000 | $189,000 | **$1,733,000** |
| **# Jobs Supported** | **44.2** | **10.0** | **8.5** | **62.7** |

**Operation**

| Estimated Impact of Ongoing Plant Operations | Direct | Indirect | Induced | **Total** |
|---|---|---|---|---|
| **Total Spending (Output)** | $23,785,000 | $529,000 | $453,000 | **$24,767,000** |
| **Value Added** | $1,479,000 | $277,000 | $286,000 | **$2,042,000** |
| **Incomes Generated** | $909,000 | $181,000 | $133,000 | **$1,224,000** |
| **# Jobs Supported** | 31.1 | 6.5 | 6.0 | **43.5** |
| **Jobs per MLy (From Ongoing Operations)** | **0.8** | **0.2** | **0.2** | **1.2** |

Source: IMPLAN. (Jobs per MLy were added; dollar figures rounded to nearest thousand.)

We note that the figure developed from this study (1.2 jobs per ML per year) is considerably lower than in the NBB study presented at the beginning of this section. We believe that the major reason for the differential has to do with far fewer jobs being induced in the local agricultural sector in the case of the Santa Rosa facility. Since this facility was designed to use multiple feedstocks and not rely much on local farmers or workers for the cultivation of the feedstock, the study discounted these impacts. In fact, the facility is intended to import feedstock via a nearby shipping port to ensure the reliability of supply. What this implies is that the farm sector impact contributes significantly to the overall employment impact, as is being captured in the NBB study.

## 4.6 Some Lessons from the Case Examples: Modeling and Multiplier Misuse Issues

This section will identify some of the modeling and multiplier issues arising from the case examples. Particular attention is given to the United States experiences and examples, since they are relatively well modeled and documented.

It is a very common fault to assume the economy has an automatic cause and effect in play when employing final demand multipliers from RIMS II or those generated with IMPLAN software and to subsequently interpret it to mean a causation relationship. The following has been extracted with permission from Professor Swenson's paper:[34]

> *"Multipliers are outcome ratios used to describe the magnitude of inter-industrial linkages that exist in an economy as commodities make their way to intermediate or to final demand. These ratios represent the current average production relationships in an economy at a fixed time. Indeed, input-output models are considered to be fixed price models. One must exercise serious caution when inferring the effects of marginal change on the entire economy, especially in terms of job production."*

The following issues and uncertainties are common with regard to estimating employment impacts from first-generation biofuels production.

- **Uncertainty as to the Degree of Marginal Increase in Feedstock Production**

  Economic impacts almost always factor in an increase in local feedstock production (along with all its multiplied-through outcomes). There are some that argue whether this should be the case. The view is that more ethanol production, for example, will result in more corn acres being planted but will come almost entirely at the expense of other crops. Shifts in production from one crop to another may not result in meaningful net employment gains. The answer to this uncertainty is that it all depends on the local situation. Sometimes there may not be significant changes in the amount of agricultural land in production as a consequence of an ethanol refinery placement. However, in those cases where government seeks to encourage the development of a domestic biofuel industry, where excess land and resources are available (and where the economy has significant unemployment), there is likely to be a net employment gain.

- **Uncertainty as to the Degree of Trucking and Transport Impacts**

  Models tend to factor in economic gains for local trucking and transportation operators. While there are surely incremental benefits, there is little consistency in how they are modeled. The cost of transporting the feedstock varies widely depending on such factors as the distance between the refinery and the farms and the number of harvests that are possible. Transport impacts also vary by the type of feedstock. Palm and sugar cane must be transported shortly after harvesting. The transport impacts arising from a multi-feedstock plant can vary widely over a year.

- **Uncertainty as to the Degree of Multiplier Effects**

  Economic models often employ multiplier effects which are developed from variables which are specific to a region. Very often these multiplier effects are used by others for application in other cases or other regions. Obviously, these multipliers do not apply everywhere and under all circumstances. For example, regions with more developed industrial and retail trade opportunities are likely to yield higher multipliers whereas more remote areas are likely to yield lower multipliers. Also, if the ethanol refinery in question is located in an area that has slack or under-used capacities that link to the refinery, then the more full utilization of those capacities will not produce the number of jobs anticipated. Similarly, a refinery twice as large as the one modeled might only create less than twice as many direct jobs and might tap into economies of scale with regional suppliers yielding much lower total job effects. In short, there is no definitive job or regional income multiplier for the biofuels industry.

- **Uncertainty as to the Degree of Emerging Impacts**

  There are always emerging impacts and costs from new economic activity. For example, from an environmental perspective, refineries can be heavy users of water and have a high amount of waste discharge.

**The most basic lesson to be drawn from these issues and uncertainties is that models and multipliers in one APEC economy are not generally transferable to other APEC economies.** Nevertheless, for all practical purposes, researchers and policy makers do rely (to some extent) on such models and multipliers to gain at least a rough idea of what may be expected. Such reference is acceptable as long as there is an understanding of the potential differences and limitations. In order to provide further clarity on how these uncertainties may impact on actual models and multipliers, **Figure 7** shows how some may exaggerate employment impacts; others may underestimate them, and others may be neutral. The analysis is based largely on first-generation biofuels, but some comments are also applicable to second-generation biofuels. The situational examples provided are generalized and open to interpretation.

**Figure 7: Potential Employment Impacts from Modeling and Multiplier Uncertainties**

| | Potential Employment Impact | | |
|---|---|---|---|
| Situational Examples | Exaggerate | Underestimate | Neutral |
| Degree to which there is a marginal increase in feedstock production | A small size farm with a high level of mechanized harvesting may exaggerate the employment multiplier. In this case, the farmer is harvesting more efficiently which could appear to increase the local demand for seed, supplies, etc. If there are many farms in the region like this, it could lead to an exaggerated multiplier being developed for that region. | In the case of manual harvesting, there is more employment but each worker is paid less. This would increase direct employment and therefore appear to create larger indirect and induced impacts. There may be more people employed, but the total economic benefit may not be greater. | There is marginal gain or loss to the multiplier when using mechanized or manual harvesting in the case of a very large plantation. This is due to significant economies of scale. |
| Degree to which there are trucking and transport impacts | The more efficient and larger carrying capacity (i.e. trains and double trailer trucks), the larger the indirect and induced effects. This is because, typically, these forms of transport have higher wages and there are more persons employed in supporting and related industries. If a multiplier is developed based on these larger capacity forms of transport, it may exaggerate the employment impact if the reality is that only small local truckers are used. | | In the case of a biofuel refinery that is able to accept multiple kinds of feedstock, different transport modes may also be used by the refinery (i.e. local truck operators, rail, and even ships). The multiplier associated with one type of transport will be different than with another type of transport. Averaging multipliers for all three transport types may allow a more accurate measure of the overall multiplier effect. |

| | | | |
|---|---|---|---|
| Degree to which there are multiplier effects in declining cost industries | The impact of one additional worker in the mill does not translate into more indirect and induced employment if the mill is able to leverage economies of scale through increased automation. | | Where feedstock is grown in a low cost developing economy and then shipped in bulk to a biofuel refinery in an industrialized economy, the developing economy does not benefit from the multiplier effects of biofuel refining and use. |
| Degree to which there is regional variability of the multiplier | The reuse of a multiplier (that was developed originally under strong economic times) during a time of economic downturn or decline in commodity prices will exaggerate the employment impact. | Care must be taken when multipliers are applied to a specific region. For example, a multiplier developed for an entire economy may not be appropriate for a small rural town or an isolated region. Likewise, a multiplier based on a vast rural economy may not be applicable to a highly urbanized one. If a 'rural' multiplier is applied to a highly urbanized area, it may underestimate the employment impact because an urban area tends to have less economic 'leakages'. | |
| Degree to which there are unacknowledged or emerging impacts | When subsidies are provided for growing a feedstock, they can exaggerate the employment impact. For example, they can lead to higher direct employment than what is economically-determined, which in term will create indirect and induced impacts. This exaggeration can also arise when increased regulation is applied to a market. | A multiplier may underestimate the economic impact on employment when regulatory authorities fail to enforce environmental or work safety or labour (including fair pay) laws. | |

## 5.0 Biofuels Production and Employment: The Barriers Faced by Women

Energy policies have tended to focus on supply-side economics and new technologies with little attention to social issues (including gender issues). An assessment of human needs (those of both men and women) is seldom considered. Women, for the most part, have had much less opportunity to participate in the biofuels industry. Undertaking a needs assessment prior to design of biofuels projects and programs would help to ensure that they are grounded in the local reality faced by women (and men). For women (especially in developing economies and/or rural areas) to see gains from biofuels initiatives, it is clear that relevant policies must address the social, cultural, and economic barriers that women face.

> **"Of the 1.3 billion of the poorest people in the world, 70% of these are women."** Source: Oxfam.

The project team interviewed Dr. Joy Clancy, a leading gender expert in terms of the renewable energy and biofuels sectors.[35] She has argued that there is not enough gender-disaggregated data and research results available on biofuels to make completely informed policy choices.[36] The Food and Agriculture Organization of the United Nations (FAO) has been active in promoting the development of gender-specific statistical databases and in trying to develop related tools and training materials.

The following tables identify the major social, economic, educational, and institutional barriers faced by women in terms of the biofuels opportunity. The list is by no means comprehensive and is not mutually exclusive. That is, there is often significant overlap between one barrier and another, and it is the resultant interaction between them that is most difficult to predict.

Among the key social barriers to employment of women in biofuels feedstock production and refining are:

- Social norms regarding land ownership – often closed to women;
- Social norms regarding household food supply – often women's responsibility;
- Social norms regarding child care – for which the burden falls mainly on women;
- Gender insensitivity or discrimination in the biofuels sector.

Economic barriers to employment of women in biofuels production include:

- Relative difficulty in access to credit for biofuels investment;
- Increasing mechanization of biofuels production processes;
- Consolidation of land holdings as farming is mechanized.

Educational barriers may also impede employment of women in biofuels including:

- Limited access to training and instruction for more highly-skilled jobs, particularly in biorefineries;
- Comparatively low literacy levels in some economies.

Finally, there are a number of institutional barriers to reaching the full potential for use of women's talents in biofuels production:

- Restrictions on the ability of women to enter into contracts;
- Inside the home, women's reliance on small enterprises.

## 5.1 Social Barriers Faced by Women

**Table 15** identifies the social barriers faced by women. The barrier is identified and explained along with a discussion of how it impacts women specifically.

**Table 15: Social Barriers Faced by Women**

| Identified Barrier | Description of the Barrier | Why it can be a Barrier: Possible Impacts on Women |
|---|---|---|
| Social norms regarding land ownership | ➢ In some societies, women are prohibited from owning land. It means that they do not have the opportunity to decide whether or not to grow biofuel feedstocks on land owned by the family. | ➢ Exclusion from decision-making.<br>➢ Impacts where and when women can seek employment. For example, they may require access to daycare to be able to work elsewhere.<br>➢ As mentioned below, a lack of title to land means women can have a difficult time accessing credit, which means they cannot participate financially in biofuels production. |
| Social norms regarding the household food supply | ➢ Energy crop plantations on marginal lands can negatively affect women's ability to meet household obligations, which often include food provision and food security. It can also lead to a loss of edible plant species, which women are also usually responsible for. | ➢ It distorts the supply / demand curve for certain biofuels. |
| Social norms regarding child care | ➢ Women are expected to raise their children without access to daycare. | ➢ It limits career opportunities for women in general. |
| Gender insensitivity by men in the biofuels sectors | ➢ Men may be gender insensitive or be outright discriminatory toward women. | ➢ Without a critical mass of women in the biofuels sectors, gender insensitivity and inequality is always a possibility. This can impact women in both implicit and explicit ways. |

## 5.2 Economic Barriers Faced by Women

**Table 16** identifies the economic barriers faced by women. The barrier is identified and explained along with a discussion of how it impacts women specifically.

**Table 16: Economic Barriers Faced by Women**

| Identified Barrier | Description of the Barrier | Why it can be a Barrier: Possible Impacts on Women |
|---|---|---|
| Inability to access credit | ➢ Since women often lack ownership of land, they are not able to access credit, prohibiting them from being significant investors in biofuels development. Women often do not have ownership of other property which can serve as collateral for loans. | ➢ Women cannot gain financially from increasing biofuels development. Since there is often differential access to financial resources, the income-generating opportunities created by increasing biofuels development may benefit men more than women. |
| Increasing mechanization | ➢ Studies have shown that as agricultural production becomes more mechanized in some economies, the participation of women in that production tends to decrease as more men take over (Clancy and Rossi & Lambrou 2008). It can be stated that as mechanization increases, typically there is a smaller pool of jobs available. | ➢ Women are unable to gain the mechanical skills necessary for biofuels production. |
| Consolidation of land-holdings | ➢ The number of smaller-scale farms is decreasing (as mechanization increases). Studies have attributed this to many physical and social conflicts in some developing economies. It is also believed to negatively impact employment opportunities for women, moreso than for men. | |

## 5.3 Educational Barriers Faced by Women

**Table 17** identifies the educational barriers faced by women. The barrier is identified and explained along with a discussion of how it impacts women specifically.

**Table 17: Educational Barriers Faced by Women**

| Identified Barrier | Description of the Barrier | Why it can be a Barrier: Possible Impacts on Women |
|---|---|---|
| Limited access to training and instruction | ➢ Studies have indicated that women tend to receive on average less training and instruction than men on feedstock plantations.<br>➢ More generally, women in many developing economies do not have the same access to education and training that men have.<br>➢ This barrier is especially limiting at the more highly skilled end of the biofuels employment spectrum, i.e., it constrains women finding higher-paid employment in biorefineries more than in feedstock harvesting. | ➢ Women are less able to obtain jobs outside the home to support their families; therefore, much less able to participate in biofuels production.<br>➢ They lack the educational and social status to partake fully in their workplace and society.<br>➢ Without sufficient education and training, women are excluded from higher-skilled and higher-paid positions and suffer from lower economic status. |
| Lower literacy levels | ➢ Particularly in developing economies, women tend to have lower literacy levels than men. | ➢ Women are less able to obtain jobs outside the home to support their families; therefore, much less able to participate in biofuels production.<br>➢ Biofuel projects and programs must accommodate or ameliorate this literacy issue if women are to be able to participate. |

## 5.4 Institutional Barriers Faced by Women

**Table 18** identifies the institutional barriers faced by women. The barrier is identified and explained along with a discussion of how it impacts women specifically.

**Table 18: Institutional Barriers Faced by Women**

| Identified Barrier | Description of the Barrier | Why it can be a Barrier: Possible Impacts on Women |
|---|---|---|
| Women's ability to enter into a contract | ➢ In some societies, women are prohibited from entering into a financial contract. In other words, they are considered 'legal minors'.[37] | ➢ Women are effectively prohibited from being feedstock suppliers. |
| Women's 'cottage industries' not accounted by governments (and not recognized by some societies) | ➢ Women (especially in developing economies) often operate small 'enterprises' inside the home which are often not reported in the economic statistics. Such activities include dress making, hair dressing, crocheting, palm oil processing, soap making, pottery making, cane work, and many others. These 'cottage industries' are an important income source for women and also allow them to perform their domestic chores.<br>➢ This is an institutional barrier because society (and governments) are not properly accounting for the role that women play in society. | ➢ Women may be reluctant to abandon or curtail their profitable activities, for work on farms or in biorefineries outside the home.<br>➢ Since women's home-based micro-enterprises are largely invisible to government and society, it is difficult to develop policy and programs to help women continue to operate them while also participating in the biofuels industry. |

## 5.5 A Closer Look at the Barriers Facing Women: Case Examples

This section will examine some of the barriers and issues facing women.

### 5.5.1 Working Conditions

It has been documented that some women in Brazil[38] are in such need of work that they migrate to, or are taken into, remote areas of the Amazon to clear forests for cropland and work on plantations. Many of them lack money for travel and depend on companies for food and supplies. Human rights organizations estimate that between 25,000 and 40,000 people could be working under such conditions in Brazil. While some international plantation operators have signed on to Brazil's *Pact for the Eradication of Slave Labour*, they have yet to develop mechanisms to guarantee that their operations are in no way linked to forced labour.

### 5.5.2 Onerous Arrangements

In some economies, palm oil companies[39] have set up massive plantations surrounded by several smaller palm oil plantations on small-farmer-owned land. Palm oil crops depend on massive amounts of fertilizers and pesticides, large trucks for transportation, and nearby mills that can buy and process the fruit within two days of harvest. Poor farmers (women and men) with smaller palm oil plantations are often given starter loans which include seedlings, fertilizers, pesticides, and other inputs. Rather than demand payment in cash, the companies that provide the loans require farmers to sell their palm fruit back to them at prices set not by the market, but by the companies themselves.

### 5.5.3 Mama Cards

Oil palm is a major cash crop in Papua New Guinea (PNG).[40] The demand for biofuel has prompted speculation of a spike in the demand for palm oil; this has sparked increased growing of oil palm in many developing economies. The social and health impacts of this expansion are not fully understood:[41]

> *"The oil palm industry is one of Papua New Guinea's rural success stories. High growth in oil palm exports over the last decade has lifted the incomes of many smallholders, particularly women [42] The increase in incomes for women is primarily facilitated through a scheme known as the mama lus frut scheme. Until the introduction of this scheme, payment for oil palm harvest often ended up with the men even though women and children were all involved in the production of oil palm. Under this scheme, women are provided with harvest nets and their own payment card called the 'mama card', which allows them to collect the fruit, sell it and receive their own payment directly. Their job is to collect loose fruit that have fallen onto the ground at the time of the harvest."* [43]

Proponents of oil palm hailed the *mama lus frut* scheme as an outstanding success for increasing loose fruit collection, bringing women into oil palm production, and increasing their income.[44] However, some have commented that it has become less of an empowerment exercise for women and more of a plan to increase palm fruit harvest to ensure better efficiency and throughput achieved at the mill. Prior to its introduction, the loose fruit wastage represented a loss of revenue and a key concern to the industry. It accounts for up to 14% of the harvest for smallholders[45] with estimated oil losses valued at US$ 300,000 (PGK 1.2m) per year.[46] Some also believe that the *mama lus frut* scheme can put women at risk.[47]

More than 3,000 women have their own mama cards, representing 67% of all smallholder blocks, but they receive a disproportionately low income of only about 26% of the total smallholder oil palm income.[48] Their average weekly income in 2001 was approximately US$ 7.00 (PGK 27.75) per woman.[49]

### 5.5.4 Working Conditions inside the Biofuel Refineries

A review of the previous tables, the above case examples, and the literature in general suggests a gap in the research on female employment in biofuels production. While there is some research available with respect to working conditions and barriers faced by women in the fields (and in the community at large), there is little with respect to the conditions that they face inside the biofuel refinery. As in any refinery setting, working conditions are influenced by safety and security (for example, working on a night shift), health (for example, exposure to noise pollution, poor air quality, or harmful chemicals), and social norms (for example, treatment by male managers). The key question is how these aspects are different in the case of a biofuel refinery. A related question is how working conditions faced by women could vary between a first-generation refinery and a second-generation one.

In addition to working conditions, the larger question is to what extent are jobs even available to women in these mechanized facilities. The following list identifies some of the jobs which are typical of a wide range of biofuel refineries:

- labourers and material handlers;
- mixing and blending operators;
- shipping and receiving clerks;
- chemical equipment operators;
- chemical technicians;
- process control technicians; and

- electrical and industrial equipment repairers and maintenance mechanics.

The extent to which women can access these types of jobs in any specific APEC economy will determine the extent to which women are employed inside the refineries. The levels of experience and education needed for these jobs vary widely. For example, a typical training path for a labourer may be short-term on-the-job training whereas a chemical technician would likely require post-secondary credentials. As more biofuel refineries come on stream, there should be a better understanding of how working conditions in these facilities affect employment opportunities for men and women.

The larger issue arising from the above discussion is the *quality of the jobs created*. While it is not the focus of this study to provide a jobs quality assessment from increased biofuels employment, it is noted that job counts do not necessarily reflect the quality of employment opportunities, nor do they reflect salary levels. Nevertheless, the case studies in Section 4 provided some preliminary insight on the salary levels and the quality of jobs created, both of which are likely to vary widely from economy to economy (and even within a single APEC economy).

Through very difficult to analyze, job quality is an important consideration for planners. Creating jobs within an excessively demanding environment with poor pay and living conditions is not the desired outcome from any developmental activity. We believe personal growth and development opportunities are also part of the job quality picture. For such opportunities to be realized (particularly in developing economies), a shift to higher value-added commercial crops must be accompanied by policy measures to upgrade technology, improve skills, raise productivity, ensure the supply of essential inputs, establish marketing and distribution channels, create linkages between agriculture and industry, and focus on export market opportunities.

### 5.6 Dealing with the Barriers

There are several potential solutions to cope with the social, economic, educational, and institutional barriers that women face with respect to biofuels employment opportunities. Presently, little is really known about the specific barriers that women face and even less about what steps can or should be taken to minimize the barriers. Many biofuels experts believe there is a need for more thorough sex-disaggregrated data on the entire biofuels sector ranging from the employment opportunities to the working conditions in the feedstock plantations, including the associated health and safety risks.[50] As indicated earlier, several APEC economies have aggressive biofuels strategies, and significant growth in biofuels production can be expected going forward. It would be useful to investigate the potential gender-differentiated risks and opportunities associated with these strategies.

- **Encourage Participation by Small Lot Holders in Biofuels Production**

In some economies (particularly developing economies), policies are needed to ensure that small farms can participate in biofuels production. Land consolidation presents several risks, not just to women but to entire communities; it has been the source of much conflict. Policies to strengthen the participation of small farms can help to reduce poverty and hunger, which in turn should benefit women and their families. For such policies to be effective, they will have to provide small lot farmers with better access to capital, technology, and land. Policies should encourage the development of local cooperatives (along with marketing associations, joint ventures and service contracts), whereby farmers can realize some economies of scale.

Policies that increase womens' access to and control over land and other productive assets would improve their welfare and enhance agricultural productivity. For example, Alderman et al (1995) has demonstrated that if men and women farmers were given equal access to quality agricultural inputs (as well as education), agricultural productivity could rise by 20%.[51] Brazil, a mature biofuels developer, has sought to deliberately include small-lot holders (farmers) by using tax incentives to encourage companies to source their feedstock from small-scale farmers and cooperatives.

- **Integrate Biofuels Policies with Local Agri-Food Policies**

Biofuels policies need to take into consideration local agri-food systems and needs. Dedicated energy crop plantations should complement - rather than replace - existing agri-food systems. Rajagopal (2007) has proposed that some crops should be grown in rotation with food crops (or simultaneously) to yield fuel along with food.[52] This would mean that local small farmers including women could receive additional seasonal income without disrupting their existing livelihood.

Government policy programs with respect to biofuels should incorporate a public awareness element. Governments can help make small lot and subsistence farmers more confident and comfortable with the biofuels feedstocks. A public awareness is needed of government incentives and policies for crops that can be used for biofuels; agricultural ministries and extension services should demonstrate to farmers (men *and* women) how growing such a crop can help them financially.

- **Encourage the Involvement of Women in the Work Force**

Governments and NGOs need to develop (or alter) programs so that they encourage the involvement of women in the work force, as well as the education of women. A basic first step towards educating and empowering women is for governments and NGOs to offer grants and scholarships to families that allow for the higher education of their female children beyond primary school. More specifically, scholarships should focus on the agricultural education of women making them literate and able to contribute in a modern agricultural business. One possible way to implement this is for government to establish small self-help groups, led by a trained leader appointed by government or an NGO.

- **Support Research on Women and Biofuels Employment**

As mentioned earlier, more and better data are needed to make truly effective policy decisions on biofuels employment. Much is being assumed or deduced from individual case studies and pilot projects. As indicated in *Gender Equity and Renewable Energies*, Clancy and Oparaocha[53] believe the following specific research needs to be carried out if effective policy decisions are going to be made to overcome the barriers prohibiting women from participating equally in biofuels development:

- Research to identify the processes and structures that have led to women becoming under-represented in the biofuels industry;
- Collection of employment data from the renewable energy sector (i.e. companies, suppliers, associations, etc.) on a gender-disaggregated basis; and
- Evaluation of biofuels employment data according to gender.

Governments should also seek to support women's organizations that assume an advocacy role on gender and energy/biofuels issues. Clancy and Oparaocha recommend that a professional organization for women in renewable energy be created to ensure that the industry is committed to gender equity.[54] In APEC economies where biofuels are expanding, such an organization would seem appropriate.

- **Boost Education and Training Programs for Women**

A key building block for all of the policy measures above is increased education and training. The educational backgrounds of men and women working in the biofuels industry vary widely. Most of them rely on on-the-job training for their skills development. But if women are currently excluded from higher-skilled positions in the industry due to lack of educational and training credentials, they cannot partake in on-the-job training for different positions that require comparable skills or even higher skills. For that reason, focused education and training programs can fill a major gap in employment opportunities for women in biofuels production.

The Canadian experience in formal training for workers in its resource industries might be worth drawing upon to develop programs for the biofuels industry in APEC economies. Canada's forest industry is an example of one in which workers traditionally learned their trades by working with people who had many years of practical experience in the field. However, a survey of the curricula for the Province of Ontario's Community Colleges will reveal that many of them have formalized these training processes into courses that include both field and laboratory work. For example, the Pembroke Campus of Algonquin College in Ontario has a Forestry Technician Course. The Southern Alberta Institute of Technology (SAIT) in the city of Calgary in the Province of Alberta, offers training in oil refinery operations that has replaced or supplemented the informal training that was typical in that industry for many years.

Some community colleges in the United States are also taking a proactive approach to understand the emerging needs of the biofuels industry. Indian Hills Community College in Iowa, for example, recently surveyed the regional ethanol industry and developed job guides for shift maintenance and plant operator positions. This analysis became the basis of the college's new Ethanol Plant Technician program.

Other APEC economies with significant biofuels production potential might also benefit from such focused training programs for positions in biofuel refineries. These could help ensure a ready supply of qualified men and women for the highly skilled technical jobs that second-generation biofuels production will require.

## 6.0 Doyletech Ethanol and Biodiesel Employment Analysis

This section will provide a description of our ethanol and biodiesel employment impact models.

### 6.1 Model Influences

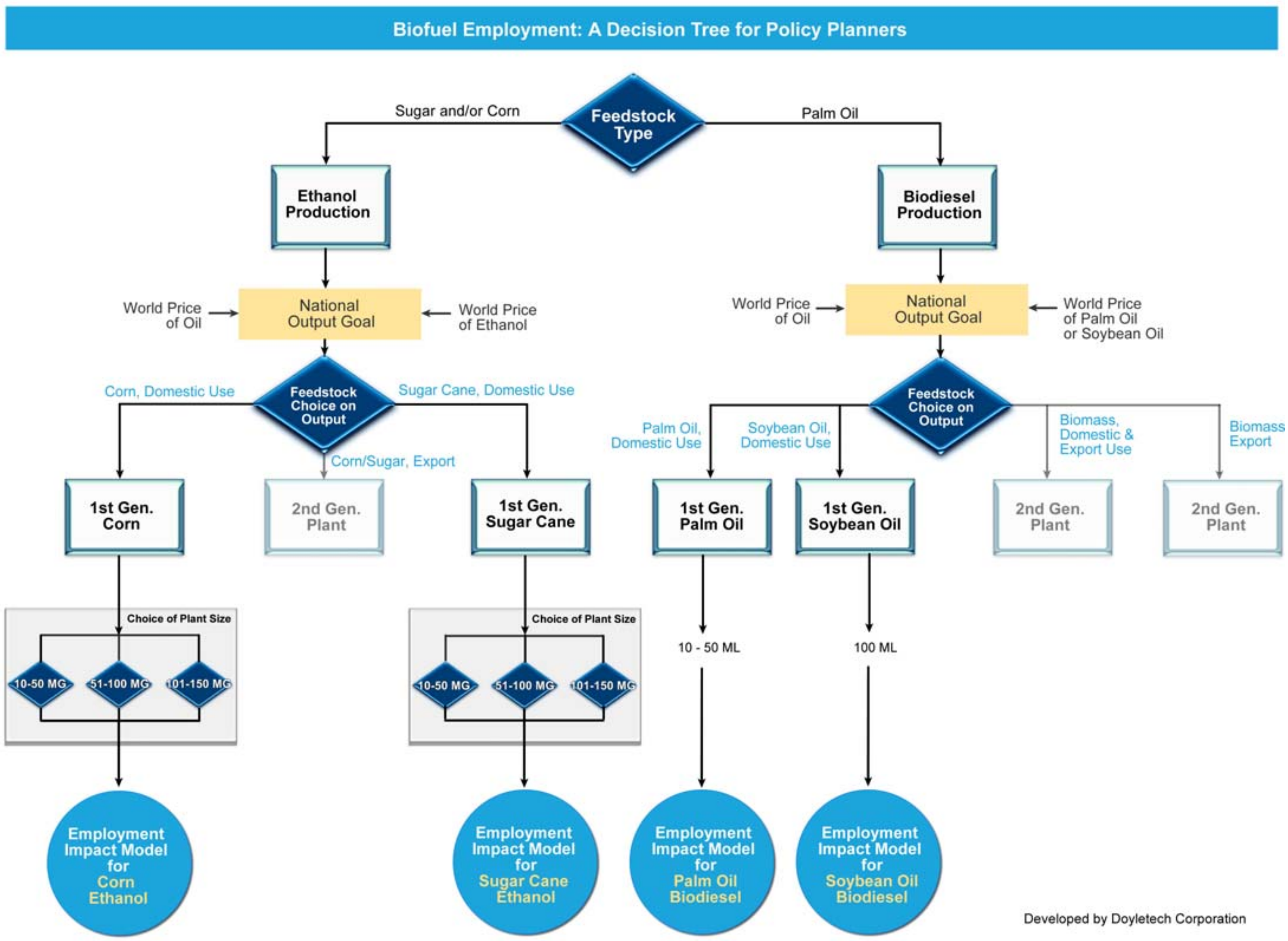
The model is based on ethanol production in the United States and Brazil using corn and sugar cane as the feedstocks respectively. It takes into consideration the work of Don O'Connor who has developed various formulas that estimate biofuel refinery employment.[55]

In the case of the biodiesel model, 70% to 85% of the production cost is the cost of the feedstock.[56] Labour for biodiesel feedstock production in the United States is more expensive because the quoted labour costs include the cost of machinery and the harvesting is becoming more and more mechanized. The employment of both men and women as machine operators is very common, and the rental of combine harvesters is an alternative to owning the equipment. The compensation to operate a machine for hire is a direct contribution to the cost of the feedstock. The speed of the machine, its rate of harvesting, and the yield contribute to the cost of feedstock as well as to the fuel cost to operate the combine harvester.

### 6.2 A Decision Tree for Policy Planners

As shown in **Figure 8**, employment impacts arising from biofuels are largely influenced by broader policy decisions, as well as economy specifics. The main decisions pertain to the choice of fuel and feedstock, which are most often based on supply considerations and local economics. If an APEC member economy has a substantial current (or potential) supply of sugar or corn, then it is likely to emphasize ethanol production, whereas one with a significant supply of palm oil is likely to encourage biodiesel development. This assumes, of course, that biofuels can compete with petroleum-based fuels at prevailing prices. The main opportunities with currently available technology relate to production of bioethanol from corn and sugar and biodiesel from palm and soybean. Corn and sugar cane production for second-generation biofuels will be discussed later in this section. Second-generation biofuel refineries tend to use multiple feedstocks.

**Figure 8: The Policy Envelop for Biofuels Development**




## 6.3 An Employment Impact Model

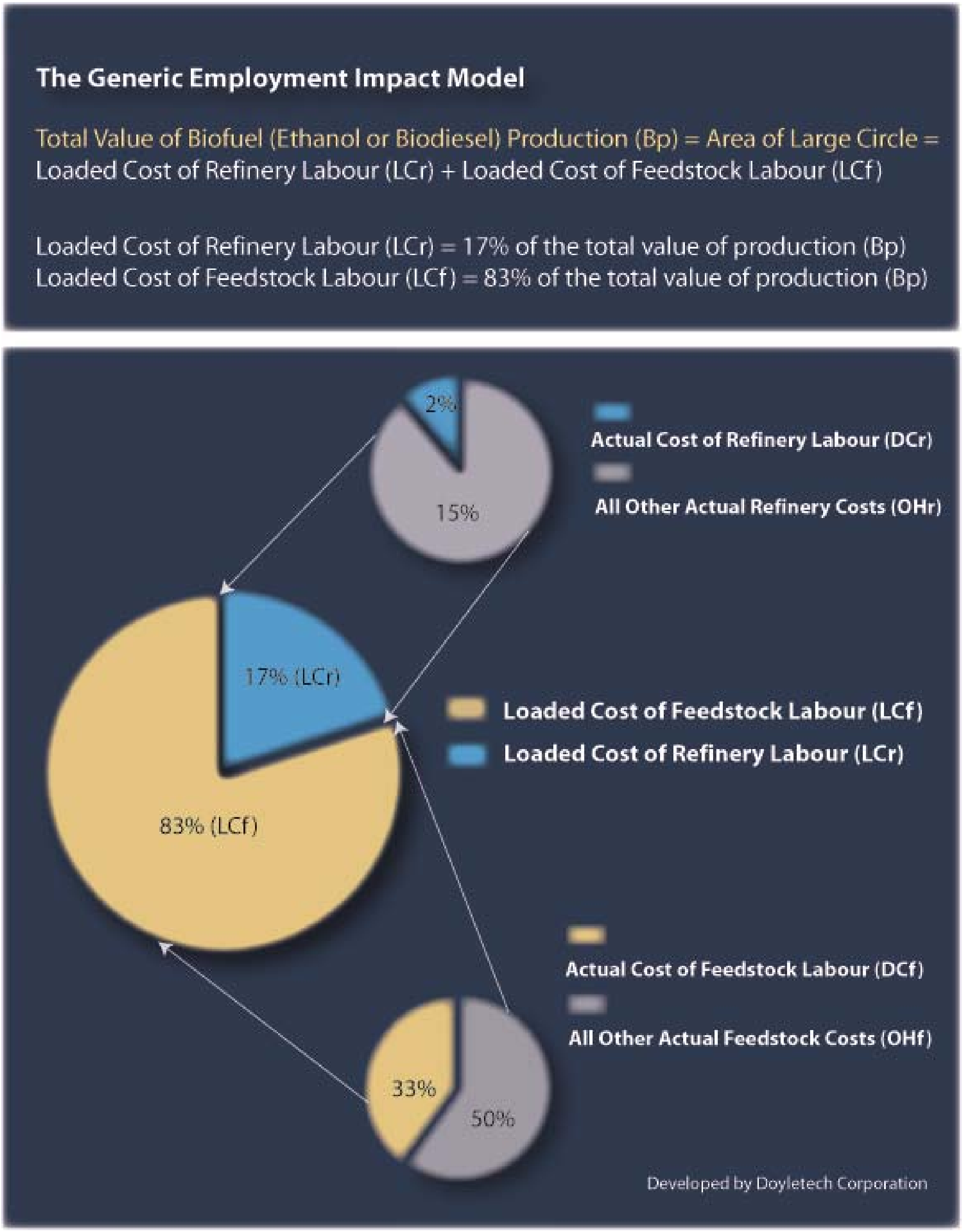
The pie chart shown in **Figure 9** represents our basic employment impact model. The area of the large circle represents the total value of biofuel production, whether it is for a single refinery, the sum of several refineries, or for an entire economy. It consists of two major segments: the “loaded” labour cost of the feedstock and the “loaded” labour cost of operations for the refinery that processes the feedstock.

**Total Industrial Value of a Refinery’s Output =**

**Loaded Cost of Refinery’s Labour (LCr) + Loaded Cost of the Feedstock Labour (LCf)**

A loaded labour cost is the actual cost of the labour plus all of the overhead costs that are associated with what can be accurately defined as refinery or feedstock operations. Such costs include administration and profit but exclude cost items that have a labour component to them. In other words, the loaded labour cost of a refinery or a feedstock operation is equal to the total output (sales) of that operation. The loaded labour cost bridges the gap between labour costs (the major emphasis of this analysis) and refinery output (the major emphasis in the literature on biofuels production). In Figure 9, the sections of the large circle show loaded labour costs while the sections of the small circles show actual (unloaded) labour costs. In all cases, the percentages shown are percentages of the area of the large circle. The cost percentages shown are for illustration purposes only. The analysis which follows gives actual figures for refinery and feedstock labour costs for the production of ethanol (from corn and sugar cane) and biodiesel (from oils).

**Figure 9: Employment Impact Pie Chart**



The difference between the actual and loaded labour cost will be referred to as overhead, but this is different from conventional overhead in that it excludes any labour costs. Therefore, the following equations apply:

**Total Value of Ethanol Production (Bp) =**

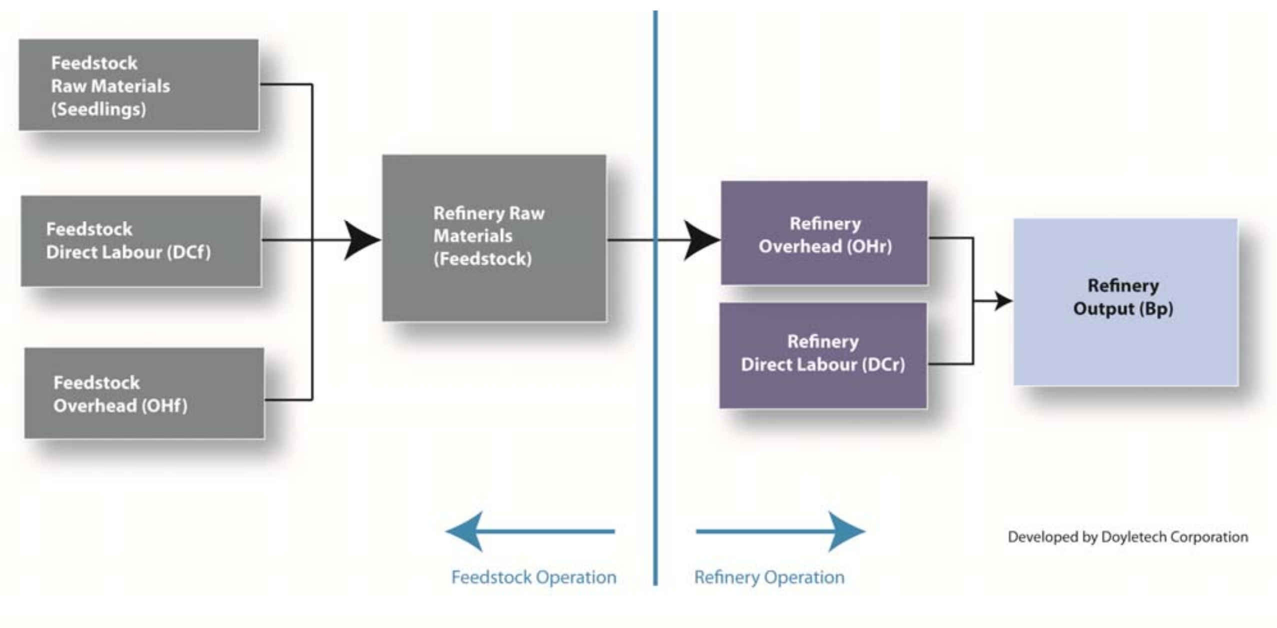
**Loaded Cost of Refinery Labour (LCr) + Loaded Cost of Feedstock Labour (LCf)**

**Where:**

- **Loaded Cost of Refinery Labour (LCr) =** Direct Cost of Refinery Labour (DCr) + Refinery Overhead (OHr), which is all other actual refinery costs.
- **Loaded Cost of Feedstock Labour (LCf) =** Direct Cost of Feedstock Labour (DCf) + Feedstock Overhead (OHf), which is all other actual feedstock costs.

The parameters of this cost model are shown as an input-output diagram in **Figure 10**. In the literature that is available on biofuels production, it is possible to identify the labour components (both direct and overhead) for most refinery operations, sometimes by a process of elimination. To convert from labour costs to the actual number of workers, the labour costs will be divided by the average GDP per employee for the economy being studied.

**Figure 10: An Input-Output Model for Ethanol**




As was identified earlier (see Figure 8), there are four common development pathways in terms of first-generation biofuels in APEC. These are corn-based ethanol, sugar cane ethanol, palm oil biodiesel, and soybean oil biodiesel. We will apply the above model to each of these four cases.

### 6.4 The Corn Ethanol Employment Impact Model

Let us assume that an economy has only one ethanol refinery with an output capacity of 100 million gallons per year (MGy) in U.S. measure or approximately 379 million litres per year (MLy) in metric measure – the economy's domestic goal. Its output of ethanol becomes the entire biofuel industrial output for the refinery and for that economy. Let us also assume that the world price of ethanol is $1 per gallon, which means that the refinery has sales of $100 million per year. Our model assumes that the plant is built and accepts only one type of feedstock to produce ethanol, that the refinery is operating at capacity (100 MGy or 379 MLy), and that its cost structure reflects this. The primary purpose of the model is to provide a tool for policy makers to visualize the relationship between the output of a refinery (or several refineries) and the employment that is created. The two major components of cost for a refinery operation are the cost of the feedstock and the cost of the refinery operations required to convert it into the desired product.

Our goal is to provide an assessment of the employment impact from biofuels production in both the production (i.e. refinery) sector and in the domestic farm sector (i.e. harvesting). Applying our model:

**1. Calculate Direct Cost of Refinery Labour (DCr)**

The direct labour cost for the refinery (DCr) is the number of people required to operate it multiplied by the average salary of refinery workers:

- According to a formula developed by Don O'Connor, an associate of Doyletech, 33 people are required to operate a 100 MGy refinery.[57]
- Our research into United States refinery operations indicates that the average salary for a United States refinery worker was $63,384 in 2006.[58]
- Therefore, the annual **DCr** for a 100 MGy (millions of gallons per year) refinery is calculated as 33 times $63,384 per worker per year or $2.09 million.

**2. Calculate Direct Cost of Feedstock Labour (DCf)**

There are three components to feedstock labour: harvesting, seeding, and transportation (to the refinery). To obtain feedstock employment figures, the following statistics and calculations apply.

**HARVESTING:**

An accepted value for the number of U.S. gallons of ethanol produced per bushel of corn is 2.84.[59] Although the yield per acre varies, we will assume a yield of 426 U.S. gallons of ethanol per acre.

AMOUNT OF CORN TO HARVEST PER YEAR =
Refinery's annual output (100 MGy) ÷ 2.84 gallons per bushel = 35.2 million bushels.

TOTAL NUMBER OF ACRES TO HARVEST PER YEAR =
Refinery's annual output (100 MGy) ÷ 426 gallons per acre = 235,000 acres.

NUMBER OF ACRES OF CORN A COMBINE MACHINE CAN HARVEST PER HOUR = 9.4 acres per hour.[60]

Assume one harvest per year and growing season of six months. Then:

LABOUR HOURS PER PERSON PER YEAR =
25 weeks x 40 hours per week = 1,000 hours per person per year.

HOURS OF LABOUR TO HARVEST PER YEAR = 235,000 acres ÷ 9.4 acres per hour = 25,000 hours per year.

NUMBER OF PERSONS NEEDED TO HARVEST 235,000 ACRES =
25,000 hours ÷ 1,000 hours per person per year = 25 persons.
(This assumes a six month growing season).

**SEEDING:**

Based on our research, we are assuming that the number of persons needed to do seeding is the same as the number of persons needed to do the harvesting. Thus:

NUMBER OF PERSONS NEEDED TO SEED = 25 persons.

Note: We are assuming that the harvesters and the seeders are not the same workers. That is, it is assumed that individual farmers do their own seeding but outsource the harvesting to specialized contractors. Hence, we count both categories as full-time jobs. This is also harmonious with the relatively low figure of $40,500 per job (shown below).

**TRANSPORTATION:**

The cost of transporting the feedstock can vary widely, depending on such factors as the distance between the refinery and the farms that produce the corn.[61] Most of the literature suggests that it is "slightly higher" than the cost of seeding and harvesting combined. We interpret this to mean that it is in the range of 10% greater. Accordingly, we will use a factor of 1.1. Thus:

NUMBER OF PERSONS NEEDED TO TRANSPORT = (25 + 25) x 1.1 = 55 persons.

**TOTAL DIRECT LABOUR FEEDSTOCK PERSONS =**
(Harvesting Labour + Seeding Labour + Transportation Labour) = (25 + 25 + 55) = 105 persons.

AVERAGE U.S. FARM INCOME PER PERSON FOR CORN = $40,500 per person per year.[62]
The people who do the harvesting, seeding, and transportation may earn more than $40,500, but for this analysis, it is assumed that they work for six months and earn $40,500.

**DIRECT COST OF FEEDSTOCK LABOUR (DCf)** = 105 persons x $40,500 per person = $4.25 million.

### 3. Develop the Corn Ethanol Input-Output Factor

In order to calculate the employment impact of a single ethanol refinery, we must arrive at a factor that relates its direct labour costs (as calculated above) to the economy's GDP per employee. We will call this the **Corn Ethanol Input-Output Factor**. This factor is calculated by dividing the value of the refinery's output by the value of its input. In order to calculate the value of ethanol output from the refinery, we will use the figure of $3 per gallon. This figure is taken as being close to observed empirical values in recent years. Thus:

**Calculate the $ Value of the Refinery's Output:**

= (Refinery Output in gallons) x (World Price of Ethanol per gallon)

= 100 MGy x $3 per gallon = $300 million per year.

**Calculate the $ Value of the Refinery's Inputs:**

= (Amount of Corn to Harvest in bushels, from Step 2 above) x (World Price of Corn, per bushel)

= 35.2 million bushels per year x $2 per bushel = $70.4 million per year.

**Calculate the Corn Ethanol Input-Output Factor:**

= (Annual $ Value of the Refinery's Output) ÷ (Annual $ Value of the Refinery's Inputs)

= $300 million ÷ $70.4 million

= 4.26 dollars of output per dollar of inputs.

### 4. Calculate the Corn Ethanol Employment Impact of a Single Plant

Employment from a 100 MGy Corn Ethanol Plant:

= (Plant Output Value) ÷ (Economy-Wide Output per Person)

= (Labour Input Costs) x (Output Value per Dollars of Input) ÷ GDP per Employee

$$= \frac{(DCr + DCf) \times (\text{Corn Ethanol Input-Output Factor})}{\text{Economy-Wide GDP Per Employee}}$$

$$= \frac{(\$2.09 \text{ million} + \$4.25 \text{ million}) \times 4.26}{\$65{,}480 \text{ (United States GDP Per Employee)}}$$

= 412 persons.

In terms of jobs per million litres of ethanol output per year, since there are 3.79 litres per gallon:

412 jobs ÷ (100 MGy x 3.79 L/G) = 412 jobs ÷ 379 MLy = **1.1 jpMLy** (rounded).

### 5. Calculate the Corn Ethanol Employment Impact Economy-Wide

We will use the estimated United States domestic production and the single plant employment impact to arrive at an economy-wide impact. The following calculation applies:

$$= \frac{\text{Economy-Wide Output}}{\text{Output Capacity per Refinery}} \times 412 \text{ jobs per refinery.}$$

If we assume that economy-wide production is 34,069 ML as it was in 2008 (see Table 1), then the total employment impact (in the refinery and farm sectors) is:

$$= \frac{34{,}069 \text{ ML per year of total output}}{379 \text{ ML per year of output per refinery}} \times 412 \text{ jobs per refinery.}$$

= 90 refineries (rounded) x 412 jobs per refinery.

= 37,000 jobs (rounded).

Accordingly, about 37,000 jobs appear to have been created by 34,069 million litres per year of economy-wide corn ethanol production.

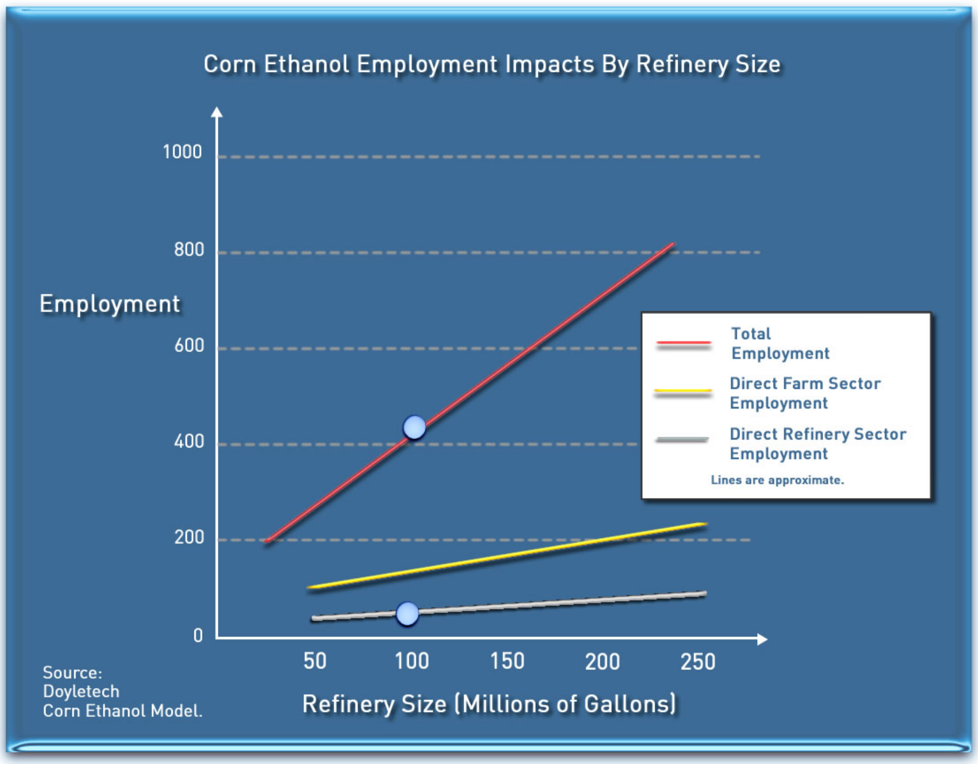
### Summary Comments – Corn Ethanol Employment Impact Model

As the above calculation indicates, if an APEC economy decided it wanted a total domestic output of 34,069 MLy, then it would require 90 typical refineries. However, the relationship between refinery output and employment is not linear. The data used here assumes a typical 100 MGy refinery. For feedstock, the relationship between employment and feedstock output is more linear, but every economy will eventually reach a saturation point where additional employment will not produce additional output.

To quote Professor Dave Swanson: "The number of jobs needed at larger plants is much less per quantity produced. In our experience, ethanol [plants] that were 50 million gallons per year or less nearly all required a base employment level of about 35 jobs - whether it was a 30, 40, or 50 MGy plant. That was the baseline. However, no one is building 50 MGy plants [United States] -- they are building 100 MGy plants or larger. In Iowa, the larger dry mill plants need only 45 workers. Consequently, at the 50 MGy level, one worker produced 1.43 million gallons per year. At the 100 MGy level, one worker produced 2.22 million gallons per year. Output per worker increases by 55 percent, but the number of jobs only goes up by 28 percent. These economies of scale are important for the profitability of those plants in the current environment."[63]

**Figure 11** is a graphical representation of these ideas. Using the above model, various employment impacts were calculated for different refinery sizes. The result is a corn ethanol sensitivity analysis showing that direct refinery employment is typically very modest while employment in the farm sector (feedstock seeding, harvesting, and transport) is typically higher, especially as the size of the refinery increases. It is the multiplier effect of these two impacts which generates the greatest impact. It also suggests that as refineries get very large, the incremental employment impact is smaller.

**Figure 11: Corn Ethanol Sensitivity Analysis** [64]




## 6.5 The Sugar Cane Ethanol Employment Impact Model

This section will present our sugar cane ethanol employment impact model. It will be very similar to the corn ethanol model with differences noted where necessary. Since Brazil is a major sugar cane ethanol producer and data is relatively well documented, it will be used as the basis for our model (some data is from Brazil, converted into U.S. dollars).

### 1. Calculate Direct Cost of Refinery Labour (DCr)

The direct labour cost for the refinery (DCr) is the number of people required to operate it multiplied by the average salary of refinery workers:

- According to a formula developed by Don O'Connor, an associate of Doyletech, 52 people are required to operate a 100 MGy refinery.[65]
- Our research into Brazilian refinery operations indicates that the average salary for a Brazilian refinery worker is $10,200.[66]

- Therefore, the annual **DCr** for a 100 MGy (millions of gallons per year) refinery is calculated as 52 workers times $10,200 per worker per year, or $530,400.

### 2. Calculate Direct Cost of Feedstock Labour (DCf)

To arrive at the feedstock employment figures, the following statistics and calculations apply:

**HARVESTING:**

ETHANOL YIELD FOR SUGAR CANE = 85 litres per tonne.

AMOUNT OF ETHANOL PER HECTARE =
100 tonnes of sugar cane per hectare x 85 litres of ethanol per tonne of sugar cane =
8,500 litres of ethanol per hectare.

Since our data sources are in litres, we need to convert the 100 MGy refinery size into MLy. Thus:
100 MG (per year) refinery = 379 ML (per year) refinery.

AREA TO BE HARVESTED IN HECTARES (FOR OUTPUT OF 379 ML) =
379 ML ÷ 8,500 litres per hectare = 44,588 hectares.

AMOUNT OF SUGAR CANE TO BE HARVESTED IN TONNES (FOR OUTPUT OF 379 ML) =
379 ML ÷ 85 litres per tonne = 4.459 million tonnes.

TOTAL AMOUNT HARVESTED PER WORKER PER SEASON
Average farmer worker cuts 10 tonnes a day of sugar cane; the season is 216 days
= 216 x 10 tonnes per day = 2,160 tonnes per worker per season.[67]

NUMBER OF DAYS TO HARVEST =
4.459 million tonnes ÷ 10 tonnes a day per worker = 445,882 person-days.

NUMBER OF FARM WORKERS TO HARVEST =
445,882 total person-days ÷ 216 days per worker = 2,064 persons (however, not full-time jobs, see discussion below).

A complicating factor is the less-than-one year growing and harvesting season. Typically it is about 36 weeks out of 52 each year. Accordingly, there is a peak demand for workers harvesting the sugar-cane, but it is not sustained throughout the entire year. As seen above, our model generates the number of 446 thousand person-days of labour to provide feedstock for the given plant. This is spread over 216 days, which represents 36 weeks with a typical 6-day work week in the industry. The total number of workers thereby implied in harvesting the feedstock is 2,064. However, this is not equivalent to 2,064 person-years of employment. It is actually less, because the 36 week period has to be annualized in order to match the given plant's output, which is a yearly figure. Thus, we must spread the work effort over 52 weeks to determine the real job creation:

Total days in a year = 52 weeks x 6 days a week or 312 days (out of 365 days).
Total harvest days in a year = 216 (given above).
Therefore, total person-years of employment is 69.23% of the 2,064 (216/312) or 1,429.

Although there is a requirement for 2,064 persons to be in the fields during the peak of the harvesting season, the true figure for annual job-creation is 1,429.

**TRANSPORTATION:**

Since sugar cane must be processed immediately, harvesting (sugar cane cutting) must take place very close to the refinery. This means that transportation costs are significantly less than in the case of corn because the distances are very short. It has been documented that the transportation cost component is approximately 10% of the total number of harvest workers.[68] We are assuming that they get paid about the same as the sugar cane cutters. Thus:

NUMBER OF PERSONS NEEDED TO TRANSPORT = 10% of 1,429 persons = 143 persons.

**TOTAL DIRECT LABOUR FEEDSTOCK PERSONS =**
(Harvesting Labour + Transportation Labour) = (1,429 + 143) = 1,572 persons.

**DIRECT COST OF FEEDSTOCK LABOUR (DCf):**

Based on research, we will assume that each worker is paid US$2,700 for the season. This amount represents a small premium over the average farm worker monthly pay. It should be noted that this amount can vary widely depending on weather and several other factors including minimum thresholds, bonuses, and other benefits received (such as food and lodging). We have taken the figure of $2,700 as representing a fair and reasonable approximation.

= 1,572 persons x $2,700 per year = $4.244 million.

### 3. Develop the Sugar Cane Ethanol Input-Output Factor

In order to calculate the employment impact of a single ethanol refinery, we must arrive at a factor that relates its direct labour costs (as calculated above) to the economy's GDP per employee. We will call this the **Sugar Cane Ethanol Input-Output Factor**. This factor is calculated by dividing the value of the refinery's output by the value of its input:

**Calculate the $ Value of the Refinery's Output:**

= (Refinery Output in gallons) x (World Price of Ethanol per gallon).

= 100 MGy x $3 per gallon = $300 million per year.

**Calculate the $ Value of the Refinery's Inputs:**

= (Amount of Sugar Cane to Harvest in tonnes, from Step 2 above) x
(World Price of Sugar Cane per tonne)

= 4.459 million tonnes per year x $12.65 per tonne = $56.4 million per year.

**Calculate the Sugar Cane Ethanol Input-Output Factor:**

= (Annual $ Value of the Refinery's Output) ÷ (Annual $ Value of the Refinery's Inputs)

= $300 million ÷ $56.4 million.

= 5.32 dollars of output per dollar of inputs.

### 4. Calculate the Sugar Cane Employment Impact of a Single Plant

Employment from a 100 MGy Sugar Cane Ethanol Plant:

= (Plant Output Value) ÷ (Economy-Wide Output per Person)

= (Labour Input Costs) x (Output Value per Dollars of Input) ÷ GDP per Employee

$$= \frac{\text{(DCr + DCf) x (Sugar Cane Ethanol Input-Output Factor)}}{\text{Economy-Wide GDP Per Employee}}$$

$$= \frac{\text{(\$0.53 million + \$4.244 million) x 5.32}}{\text{\$13,230 (Brazilian GDP Per Employee)}}$$

= 1,920 persons.

In terms of jobs per million litres of ethanol output per year, since there are 3.79 litres per gallon:

1,920 jobs ÷ (100 MGy x 3.79 L/G) = 1,920 jobs ÷ 379 MLy = **5.1 jpMLy** (rounded).

**5. Calculate the Sugar Cane Ethanol Employment Impact Economy-Wide**

We will use the domestic output goal for Brazil and the single plant employment impact to arrive at an economy-wide impact. The following calculation applies:

$$= \frac{\text{Economy-Wide Output Goal (or Current Sugar Cane Ethanol Output)}}{\text{Output Capacity per Refinery}} \times \text{1,920 jobs per refinery.}$$

If the economy-wide output goal is 5,000 MGy, then the economy-wide employment impact is:

$$= \frac{\text{5,000 MG per year of total output}}{\text{100 MG per year of output per refinery}} \times \text{1,920 jobs per refinery.}$$

= 50 refineries x 1,920 jobs per refinery.

= 96,000 jobs.

Accordingly, about 96,000 jobs would be associated with 5,000 million gallons per year of economy-wide sugar cane ethanol production.

**Summary Comments – Sugar Cane Ethanol Employment Impact Model**

As the above calculation indicates, if an APEC economy decided it wanted a total domestic output of 5,000 MGy, then it would require 50 typical refineries. In the case of Brazil, mechanization is continuing to drastically reduce the number of sugar cane cutters. One combine harvester performs the work of 60 people. Hence, the employment figures for sugar cane are changing more rapidly than they are for corn.

## 6.6 The Palm Oil Biodiesel Employment Impact Model

Since palm oil is a common feedstock for biodiesel production in APEC member economies, our model will be based on this feedstock (assuming a typical 40 MLy palm oil refinery).

Since Malaysia is a leading palm oil producer and data is relatively well documented, it will be used as the basis for our model (some data is from Malaysia, converted into US dollars). There are two components to a biodiesel refinery using palm oil as feedstock:

- the internal refinery operations;
- the preparation of the palm oil feedstock by "crushing".

The labour costs of each of these two components will be calculated in turn.

**1a. Calculate Direct Cost of Internal Refinery Operations Labour (DCr/internal)**

The direct labour cost for the internal refinery operations (DCr/internal) is the number of people required to operate it multiplied by the average salary of refinery workers:

- According to a formula developed by Don O'Connor, an associate of Doyletech, approximately 8 people are required to operate a 40 MLy refinery.[69]
- Our research into Malaysia palm oil (and related) operations indicates that the average salary for a refinery worker was US $13,000 in 2006.
- Therefore, the annual **DCr/internal** for a 40 MLy (millions of litres per year) refinery is calculated as 8 workers times US $13,000 per worker per year, or US $104,000.

### 1b. Calculate Direct Cost of the Extraction/Crushing Labour (DCr/crushing)

The feedstock for a palm oil refinery is Crude Palm Oil (CPO) from extraction/crushing facilities for palm fruit. Such facilities typically crush the Fleshy Fruit Bunches (FFB) of palm at a rate of 10 to 30 tons per hour and operate 24 hours per day, and an average of 355 days. Assume 10 tons per hour x 24hrs = 240 tons per day, and 240 tons per day times 355 days per year = 85,200 tons per year.

The direct labour cost for the extraction/crushing (DCr/crushing) is the number of people required to operate it multiplied by the average salary of extraction/crushing workers. According to a second formula developed by Don O'Connor, approximately 15 people are required to operate a 240 ton per day extraction/crushing facility, and our research shows that these employees earn the wage of US $350 per month.[70]

- Therefore, the annual **DCr/crushing** for a 240 ton per day extraction/crushing facility = $350 per month x 12 months x 15 persons or US $63,000.

However, it is possible that more than one extraction/crushing plant is required to meet the annual biodiesel refinery's capacity when the demand for CPO by the refinery exceeds the maximum annual capacity of the extraction/crushing facility. If this happens, then we add similar sized facility and multiply the number of personnel for one extraction/crushing facility by integer multiples of maximum amount of CPO for the biodiesel divided by the maximum annual extraction/crushing capacity.

We must first calculate the amount of FFB in tons to be crushed to extract the amount of CPO in tons required to produce the maximum output of the biodiesel refinery. Given that 1,100 litres of biodiesel is produced from 1 ton of CPO, we divide the maximum capacity of the biodiesel refinery (40 MLy) by 1,100 litres per ton of CPO; this equals 36,364 tons of CPO. The 36,364 tons of CPO is the input to the refinery and when divided by 85,200 tons of output extraction facility is less than or equal to 1, so only 15 employees are required.

### 1c. Total Costs of Biodiesel Refining (Refinery and Crushing)

- Total DCr = DCr/internal + DCr/crushing = $104,000 + $63,000 = $167,000.

### 2. Calculate Direct Cost of Feedstock Labour (DCf)

To arrive at the feedstock employment figures, the following statistics and calculations apply:

**HARVESTING:**

AVERAGE FARM WORKER SALARY = US $12 per day.

FLESHY FRUIT BUNCH (FFB) YIELD PER HECTARE = ranges from 5 to 20 tons per hectare. We will assume 10 tons per hectare.

Given that 1 ton of CPO yields 1,100 litres of biodiesel, the amount of CPO to meet maximum refinery capacity = 40 MLy ÷ 1,100 biodiesel litres per ton of CPO = 36,364 tons.

The net amount of land needed to produce 36,364 tons of CPO when the gross yield is approx. 5 tons of CPO per hectare multiplied by the efficiency of the extraction/crushing process, 95%.[71]

The amount of land to be harvested to meet maximum biodiesel capacity =
(36,364 tons of CPO) ÷ (5 tons of CPO per hectare x 0.95 extraction efficiency) = 7,656 hectares.

The amount of FFB in tons that 7,656 hectares yields is:
7,656 hectares x 10 tons/hectare of FFB = 76,560 tons.

The next step is to calculate the number of harvest workers using the above data:

Research indicates a wide variance in the number of hectares one worker can harvest in one day. Factors impacting this yield include weather and light conditions, the number of hours worked in a day, bonuses and incentives, new types of harvesting tools, the height of the trees being harvested, and many other factors. Based on our analysis, we will assume 3 hectares can be harvested, on average, by one worker per day.

Based on research, we assume the length of each harvest is 21 days with 15 harvests per year. This can also vary due to the reasons identified above. This means that harvest workers are working 315 days a year (21 days x 15 harvests).

If we assume that the refinery operates 365 days a year, and we know that 7,656 hectares must be harvested over a year to keep the refinery operating at capacity, then 21 hectares must be harvested and supplied to the refinery per day on average. Given the requirement for 21 hectares to be harvested per day and that one worker can harvest, on average, 3 hectares per day, then 7 workers (21 ÷ 3) are needed per day. However, this analysis assumes that harvesters work 365 days like the refinery does. This is not the case; they work only 315 days as stated above. This means that they must harvest the 7,656 hectares in 315 days, not 365. Hence, each worker must harvest 24.3 hectares per day over 315 days (7,656 ÷ 315). Given that one worker can harvest 3 hectares per day, 8 workers are needed per day. Thus,

NUMBER OF WORKERS TO HARVEST FFB =
8 workers per day x 315 days of harvesting = 2,520 persons per year.

**TRANSPORTATION:**

Crude palm oil is frequently crushed and extracted on the same plantation as where FFB was cut and manually harvested. Thus, transportation from field to extraction facility is very short and close to the refinery as well. This means that transportation costs are significantly less than in the case of other feedstocks because the distances are very short. There is no documentation on the transportation cost (number of truck drivers) and the percentage of total number of harvest workers whom are engaged in transportation of CPO to the refinery as well as the FFB to the extraction/crushing facilities. We are allocating 1% of the total number of harvesters/field workers to transportation and that they get paid about the same as the fruit cutters. Thus:

NUMBER OF PERSONS NEEDED TO TRANSPORT = 1% of 2,520 = 25 persons.

**TOTAL DIRECT LABOUR FEEDSTOCK PERSONS =**
(Harvesting Labour + Transportation Labour) = (2,520 + 25) = 2,545 persons.

**DIRECT COST OF FEEDSTOCK LABOUR (DCf) =**
2,545 persons x $12 per day x 21 days per harvest x 15 harvests per year = $9.62 million

### 3a. Develop the Palm Oil Biodiesel Internal Refinery Operations Input-Output Factor

In order to calculate the employment impact of one biodiesel refinery, we must arrive at a factor that relates its direct labour costs (as calculated above) to the economy's GDP per employee. We will call this the **Palm Oil Biodiesel Internal Refinery Operations Input-Output Factor**. This factor is calculated by dividing the value of the refinery's output by the value of its input:

**Calculate the $ Value of the Refinery's Output:**

= (Refinery Output) x (World Price of B5 biodiesel per litre)

= 40 MLy x $1.27 per litre = $50.8 million per year.

**Calculate the $ Value of the Refinery's Inputs:**

= (Crude Palm Oil input to refinery, calculated in Step 1b above) x (World Price of CPO per ton)

= 36,364 tons x US $650 per ton = $23.64 million per year.

**Calculate the Palm Oil Biodiesel Refinery Input-Output Factor:**

= (Annual $ Value of the Refinery's Output) ÷ (Annual $ Value of the Refinery's Inputs)

= $50.8 million ÷ $23.64 million

= 2.15 dollars of output per dollar of inputs.

### 3b. Develop the Palm Oil Extraction/Crushing Facility Input-Output Factor

In order to calculate the employment impact of an extraction/crushing facility, we must arrive at a factor that relates its direct labour costs (as calculated above) to the economy's GDP per employee. We will call this the **Palm Oil Extraction/Crushing Facility Input-Output Factor**. This factor is calculated by dividing the value of the extraction/crushing facility's output by the value of its input:

**Calculate the $ Value of the Extraction/Crushing Output:**

= Extraction/Crushing Output x World Price of CPO (per ton).

= 36,364 tons x US $650 per ton = $23.64 million per year.

**Calculate the $ Value of the Extraction/Crushing Inputs:**

= (Amount of FFB to Harvest, calculated in Step 2 above) x (World Price of FFB per tonne)

= 76,560 tons per year x US $40 per ton = $3.062 million per year.

Note: prices for CPO and FFB can vary dramatically over time.

**Calculate the Extraction/Crushing Facility Input-Output Factor:**

= (Annual $ Value of the Facility's Output) ÷ (Annual $ Value of the Facility's Inputs)

= $23.64 million ÷ $3.062 million

= 7.72 dollars of output per dollar of inputs.

### 4a. Calculate the Palm Oil (B5) Biodiesel Refinery Employment Impact of a Single Plant

We will use the **Palm Oil Biodiesel Internal Refinery Operations Input-Output Factor** (2.15) to arrive at an employment impact for a single plant.

In the case of palm oil biodiesel, DCf is still defined as the direct labour cost of the feedstock (i.e. the cost of harvesting palm) but in this case it is a direct input cost to the extraction/crushing facility – not to the biodiesel refinery. The following calculation applies:

$$= \frac{\text{DCr/internal x (Palm Oil Refinery Input-Output Factor)}}{\text{Economy-Wide GDP Per Employee}}$$

$$= \frac{\$104,000 \times 2.15}{\$25,590 \text{ (the Malaysian GDP Per Employee)}}$$

= 9 persons (rounded).

### 4b. Calculate the Palm Oil Biodiesel Employment Impact of the Extraction/Crushing Facility

The employment impact of the extraction/crushing facility, which is a direct input to the refinery operation itself, must also be accounted for in the model. This is done by calculating the Direct Cost of the FFB Feedstock (DCf).

We will use the Palm Oil Extraction/Crushing Facility Input-Output Factor (7.72) to arrive at the employment impact for the extraction facility. The following calculation applies:

Extraction Facility Only = (DCf + DCr/crushing) x (Extraction/Crushing Input-Output Factor) / Economy-Wide GDP Per Employee

= ($9.62 million + $63,000) x 7.72 / $25,590 (the Malaysian GDP Per Employee)

= 2,921 persons.

### 4c. Total Biodiesel Employment of a Single Refinery plus Extraction and Plantation Workers

Total employment impact = impact from the Refinery + impact from the Extraction/Crushing Plant = 9 + 2,921 = 2,930 persons.

In terms of jobs per million litres of biodiesel output per year (jpMLy):

2,930 jobs ÷ 40 MLy plant = **73.3 jpMLy** (rounded).

### 5. Calculate the Palm Oil Biodiesel Employment Impact Economy-Wide

We will use the domestic output goal in Malaysia and the single refinery (and extraction facility) employment impact to arrive at an economy-wide impact. The following calculation applies:

= Economy-Wide Output Goal or Current Biodiesel Output / Output Capacity of Refinery x 2,930 jobs per refinery.

It has been stated that a B5 mandate in Malaysia would equal to consuming around 560 ML of biodiesel per year.[72] If we assume the output goal is 560 ML, then the economy-wide employment impact is:

= 560 ML per year of total output / 40 ML per year of output per refinery x 2,930 jobs per refinery.

= 14 refineries x 2,930 jobs per refinery.

= 41,020 jobs.

Accordingly, about 41,000 jobs would be associated with 560 million litres per year of economy-wide palm oil biodiesel production.

## Summary Comments – Palm Oil Biodiesel Employment Impact Model

As the above calculation indicates, if an APEC economy decided it wanted a total domestic output of 560 MLy, then it would require 14 combined refineries and extraction facilities (based on the Malaysia model).

Biodiesel refineries and the palm oil harvesting, extraction, and crushing facilities are sometimes not in the same physical location or even in the same country. Malaysia is the largest producer and exporter of palm oil in the world and already employs more than a half million people directly in harvesting, extraction, and crushing, but it is not a major biodiesel producer. Moreover, with such large numbers of workers already employed in harvesting, extraction, crushing, and transport activities, the incremental employment impact in Malaysia from expanded *refinery* operations may be relatively limited.

## 6.7 The Soybean Oil Biodiesel Employment Impact Model

Doyletech's soybean biodiesel model is based on information found in several reports from the Environmental Protection Agency (EPA), the Biodiesel Board (NBB), the Renewable Fuels Association (RFA), and the United States Department of Agriculture (USDA). Other sources of information included the Europe-based F.O. Licht, the publisher of *World Ethanol and Bio-Fuels Report*; BBI International, which publishes *Ethanol Producer Magazine*; and the American Coalition for Ethanol (ACE), publisher of *Ethanol Today*.

The EPA reports that there are 29,000 jobs in the United States biodiesel industry but this is for all feedstocks, and not soybean alone in making B5 biodiesel. This number of jobs is assumed to be comprised of direct jobs only in harvesting and seeding, transportation, crushing, and refining. The crushing of soybean is normally integrated into the same biodiesel plant. According to the NBB, biodiesel production in the United States was estimated to be 700 MGy (2,650 MLy) in 2008 (as shown in Table 1).

There are several issues which impact any modeling of soybean biodiesel production:

- The lists of biodiesel plants maintained by RFA, NBB, BBI, and ACE respectively do not seem complete. Each contains some plants that are not on the others' list.
- Calculating the number of jobs in the Doyletech model is based on costs and process yield conversions; we have had to use industry data which may or may not be completely accurate.
- There is the question of whether a multi-feedstock refinery can process soybean as a feedstock. The NBB list shows some overlap with other refineries and the feedstock they use but are not listed as multi-feedstock. This impacts the total capacity from a given feedstock and may lead to double counting. In our use of the NBB data, we choose only plants reporting their soybean-based production capacity to determine the average plant size.

Using information from the NBB website and the EPA, **Table 19** shows that soybean-only refineries are 23.4% of the United States capacity while multi-feedstock biodiesel refineries are 65.7% of capacity. All other feedstocks make up the balance. It is assumed that the soybean production chain is representative of the entire biodiesel capacity in terms of job creation.

**Table 19: Biodiesel Feedstock Data**

| Biodiesel Feedstock | Number of Plants / Rated Output | Percent of Total Domestic Capacity | Number of Jobs | Jobs per Million Gallons per year * | Jobs per Million Litres per year * |
|---|---|---|---|---|---|
| Total capacity of biodiesel refineries in the United States (gallons) | 2,954,727,000 | 100.0% | 29,000 | | |
| Total number of soybean refineries | 30 plants | | | | |
| Total capacity soybean only in production (gallons) | 694,400,000 | 23.4% | 6,786 | 9.8 | 2.58 |
| Avg. size of a soybean refinery in production (gallons) | 23,944,828 | | | | |
| Total number of multi-feedstock plants | 112 plants | | | | |
| Total capacity of multi-feedstock in production | 1,940,910,000 | 65.7% | 19,053 | 9.8 | 2.59 |
| Avg. size capacity of a multi-feedstock plant | 17,838,482 | | | | |
| Total number of recycled veg. oil plants | 20 plants | | | | |
| Total capacity of recycled veg. oil plants in production | 26,280,000 | 0.89% | 284 | 10.7 | 2.85 |
| Avg. size of a recycled veg. oil plant | 1,663,529 | | | | |
| Total number of other feedstock plants | 4 plants | | | | |
| Total of other feedstocks (e.g. yellow grease, jatropha, algae, canola, brown grease, tallow, sunflower, palm, chicken fat) | 293,137,000 | 9.9% | 2,877 | 9.8 | 2.59 |

* Arithmetic calculation made by Doyletech.

**Table 20** shows the various factors inherent in biodiesel production from soybean.

**Table 20: Soybean Biodiesel Production Factors**

| Soybean Yields (2008) for Biodiesel |
|---|
| 7.35 pounds of soybean oil per 1 gallon of biodiesel |
| 1 litre of biodiesel requires 1.944 pounds of soybean oil |
| World biodiesel price per gallon = $4.82 (2008) |
| World biodiesel price per litre = $1.27 |
| Number of soybean biodiesel refineries = 30 |
| Avg. size of soybean biodiesel refineries = 26 million gallons per year |
| Soybean oil used in biodiesel = 4,777 million pounds |
| Soybean acreage planted = 69 million acres |
| Yield per harvested acre = 42 bushels per acre in 2008, or 105 bushels per hectare |
| 1,870 million bushels were crushed into 21,365 million pounds of soybean oil with a reported oil yield of 11.43 pounds per bushel |
| Soybean oil price; per pound = $0.36 USD, per tonne = $806.40 USD |
| Crushing margin per bushel = $1.23 |
| Long-term soybean price per bushel = $3.20 USD |
| Farm variable cost per acre = $103 USD |
| Farm variable cost per bushel = $2.46 |

**Table 21** contains the equivalency factors in weight and volume for biodiesel conversion. The chart provides a simple way to convert biodiesel from different units (at constant temperature in Celsius). In the United States, biodiesel is expressed in gallons, while in Europe and other parts of the world metric tonnes and/or cubic meters is used. The density of soybean oil is 993 kg/m3 which is equivalent to 8.286987 pound per

gallon (US) at 20C. This allows a conversion from units of weight to volume. For biodiesel made from soybean feedstock with a density ρ = 993 kg/m3 or 0.993 kg/litre at 20C, the following table illustrates equivalent quantities of biodiesel from soybean feedstock expressed in terms of mass and volume.

**Table 21: Equivalency Factors**

| Litres of Biodiesel | US Liquid Gallons of Biodiesel | Cubic Meters of Biodiesel | Pounds Weight of Biodiesel (lb) | Required Input of Refined Soybean Oil (RSO) Pounds (lb) |
|---|---|---|---|---|
| 1.000 | 0.264 | 0.001 | 1.007 | 1.944 |

**Soybean Oil Biodiesel Refinery and Crushing Employment Impact Model**

There are two components to a biodiesel refinery using soybean oil as feedstock:

- the internal refinery operations;
- the preparation of the soybean oil feedstock by "crushing".

The labour costs of each of these two components will be calculated in turn.

**1a. Calculate Direct Cost of Internal Refinery Operations Labour (DCr/internal)**

The direct labour cost for the internal refinery operations (DCr/internal) is the number of people required to operate it multiplied by the average salary of refinery workers:

- According to a formula developed by Don O'Connor, an associate of Doyletech, 40 people are required to operate a 90 MLy refinery.
- Our research into United States soybean oil operations indicates that the average salary for a refinery worker was US $60,000 in 2008.
- Therefore, the annual **DCr/internal** for a 90 MLy (millions of litres per year) refinery is calculated as 40 workers times $60,000 per worker per year, or $2.40 million.

**1b. Calculate Direct Cost of the Extraction/Crushing Labour (DCr/crushing)**

Based on our research from the published literature, crushing for a 90 MLy biodiesel plant can be done at the rate of 9.31 tonnes per hour. No exact figures seem available for a 90 MLy plant, but figures for a 302 MLy (80 MGy) plant were found. This indicated that 4,000 tonnes of feedstock were required per day to produce 750 tonnes of refined soybean oil (RSO). Scaled proportionally, a 90 MLy plant should use 1,192 tonnes of feedstock and yield 223.5 tonnes of RSO daily. Assuming the plant operates 24 hours per day, it should then produce 9.3125 tonnes of RSO per hour. And if the plant operates 355 days per year (we are assuming some down-time during the year), it should produce 79,342 tonnes of soybean oil per year. We will use a 98.5% conversion efficiency (78,125 tonnes) when calculating the input-output factors in Step 3 below. This allows for expected inefficiencies in the crushing process.

The direct labour cost for the extraction/crushing (DCr/crushing) is the number of people required to operate it multiplied by the average salary of crushing workers. According to a second formula developed by Don O'Connor, approximately 15 people are required to operate a 240 tonnes per day crushing facility, which is approximately equivalent in design and employment structure to a plant producing 223 tonnes per day. Our research shows that an annual salary of $60,000 for these workers is reasonable.

- Therefore, the annual **DCr/crushing** for a 223 tonnes per day crushing facility = $60,000 per worker per year times 15 workers or $0.90 million.

### 1c. Total Cost of Biodiesel Refining (Refinery and Crushing)

- Total DCr = DCr/internal + DCr/crushing = $2.40 million + $0.90 million = $3.30 million.

### 2. Calculate Direct Cost of Feedstock Labour (DCf)

To arrive at the feedstock employment figures, the following statistics and calculations apply:

**HARVESTING:**

SOYBEAN YIELD PER HECTARE = 2.7 tonnes per hectare.

A conversion yield of 552 litres of biodiesel per hectare means that the amount of land needed to produce enough RSO to meet maximum refinery capacity is 90 MLy ÷ 552 biodiesel litres per hectare of soybean feedstock = 163,000 hectares.

At 2.7 tonnes of feedstock per hectare, 163,000 hectares will yield 440,100 tonnes of soybean feedstock.

A 20 foot wide combine harvests at a rate of 1.6 hectares per hour and 8 hour per shift for a total of approximately 12 hectares per shift. Dividing 163,000 hectares by 12 hectares per shift, 13,583 shifts are required. We will assume that harvesting time is equivalent to five months of the year. Thus, dividing 13,583 shifts by 117 harvesting days, we obtain 116 harvest shift-days, which means 116 harvest drivers. This analysis assumes that within a five-month growing season, only 117 days are available for harvesting (due to factors such as bad weather, mechanical breakdowns, driver availability, and other farming-related issues).

COST OF FARM WORKER PER SHIFT = US$350 per shift.

HARVESTING COST = $350 per shift X 13,583 shifts = $4.75 million.

**SEEDING:**

We assume that the work effort and costs for seeding are the same as for harvesting. In the case of soybeans, seeding is taken as the corresponding work as harvesting for the same farmer. This means that the 116 workers are both seeding and harvesting.

SEEDING COST = $350 per shift X 13,583 shifts = $4.75 million.

**TRANSPORTATION:**

Transportation distance from field to crushing and refinery is typically less than 300 km. We could not find data on the transportation cost (number of truck drivers) or the percentage of the total number of harvest workers who are engaged in transportation of RSO to the refinery; we are not counting the labour in storage facilities either. We are assuming a truck load is 20 tonnes per truck.

440,100 tonnes divided by 20 tonnes per truckload = 22,005 truck loads.

Over 117 days per year, this is equivalent to 188 truck loads per day during the growing season.

We assume each truck can make one round trip per day (soybean farming being taken on average as involving greater distances to reach soybean processing plant). Thus, 188 truck loads divided by 1 round trip per day = 188 trucks and 188 truck drivers. However, these drivers only work for approximately half the year. Thus, the full-time equivalent is (188 / 2) or 94 truck drivers.

Hence, transportation of 440,100 tonnes of soybean will require 94 truck drivers per year at an annual wage of $40,500 (we apply the same trucking salary as was used in the US-based corn ethanol model earlier).

NUMBER OF PERSONS NEEDED TO TRANSPORT = 94.

TOTAL TRANSPORTATION COST = 94 truck drivers x $40,500 salary per year = $3.81 million.

**TOTAL DIRECT LABOUR FEEDSTOCK PERSONS =**
(Harvesting and Seeding Labour + Transportation Labour) = (116 + 94) = 210 persons.

**DIRECT COST OF FEEDSTOCK LABOUR (DCf) =**
$9.50 million harvest and seeding cost + $3.81 million transportation cost per year = $13.31 million.

### 3a. Develop the Soybean Oil Biodiesel Internal Refinery Operations Input-Output Factor

In order to calculate the employment impact of one biodiesel refinery, we must arrive at a factor that relates its direct labour costs (as calculated above) to the economy's GDP per employee. We will call this the **Soybean Oil Biodiesel Internal Refinery Operations Input-Output Factor.** This factor is calculated by dividing the value of the refinery's output by the value of its input:

**Calculate the $ Value of the Refinery's Output:**

= (Refinery Output) x (World Price of B5 biodiesel per litre)

= 90 MLy x $1.27 per litre = $114 million per year.

**Calculate the $ Value of the Refinery's Inputs:**

= (Amount of Soybean Oil Input in tonnes) x (World Price of Soybean Oil per tonne)

= 78,125 tonnes per year x $806.40 per tonne = $63 million per year.

Note: Since there are 1.944 pounds of raw soybean oil per litre, a 90 MLy biodiesel plant will require 175 million pounds of RSO which is equivalent to 78,125 tonnes. We are assuming a 98.5% conversion efficiency. If there was 100% efficiency, the 79,342 tonnes from 1b) above could have been used but it is unrealistic to have 100% efficiency in the crushing process.

**Calculate the Soybean Oil Biodiesel Refinery Input-Output Factor:**

= (Annual $ Value of the Refinery's Output) ÷ (Annual $ Value of the Refinery's Inputs)

= $114 million ÷ $63 million

= 1.81 dollars of output per dollar of inputs.

### 3b. Develop the Soybean Oil Crushing Facility Input-Output Factor

In order to calculate the employment impact of an extraction/crushing facility, we must arrive at a factor that relates its direct labour costs (as calculated above) to the economy's GDP per employee. We will call this the **Soybean Oil Crushing Facility Input-Output Factor**. This factor is calculated by dividing the value of the crushing facility's output by the value of its input:

**Calculate the $ Value of the Crushing Output:**

= (Crushing Output) x (World Price of RSO per tonne).

= 78,125 tonnes per year x $806.40 per tonne = $63 million per year.

**Calculate the $ Value of the Crushing Inputs:**

= (Amount of Soybean Harvest) x (World Price of Soybeans per bushel)

= 163,000 hectares per year x 105 bushels per hectare x $3.20 per bushel = $54.77 million per year.

Note: Soybeans yield 42 bushels per acre, and one acre equals 0.4 hectares. Therefore, 105 bushels per hectare.

**Calculate the Crushing Facility Input-Output Factor:**

= Annual $ Value of the Facility's Output ÷ Annual $ Value of the Facility's Inputs

= $63 million ÷ $54.77 million

= 1.15 dollars of output per dollar of inputs.

### 4a. Calculate the Soybean Oil (B5) Biodiesel Refinery Employment Impact of a Single Plant

We will use the **Soybean Oil Biodiesel Internal Refinery Operations Input-Output Factor** (1.81) to arrive at an employment impact for a single plant.

As mentioned previously, DCr/internal is the direct labour cost for the internal refinery operations. The following calculation applies:

$$= \frac{\text{(DCr/internal) x (Refinery Input-Output Factor)}}{\text{Economy-Wide GDP Per Employee}}$$

$$= \frac{\text{\$2.40 million x 1.81}}{\text{\$65,480 (United States GDP Per Employee)}}$$

= 66 persons (rounded).

### 4b. Calculate the Soybean Biodiesel Employment Impact of the Extraction/Crushing Facility

We will use the soybean oil Crushing Facility Input-Output Factor (1.15) to arrive at the employment impact for the crushing facility. The following calculation applies:

$$\text{Crushing Facility Only} = \frac{\text{(DCf + DCr/crushing) x (Crushing Input-Output Factor)}}{\text{Economy-Wide GDP Per Employee}}$$

$$= \frac{\text{(\$13.31 million + \$0.90 million) x 1.15}}{\text{\$65,480 (United States GDP Per Employee)}}$$

= 250 persons (rounded).

### 4c. Total Biodiesel Employment of a Single Refinery plus Crushing/Extraction and Farm Workers

Total employment impact = impact from the Refinery + impact from Crushing Plant = 66 + 250 = 316 persons.

In terms of jobs per million litres of biodiesel output per year (jpMLy):

316 jobs ÷ 90 MLy plant = **3.5 jpMLy** (rounded).

### 5. Calculate the Soybean Oil Biodiesel Employment Impact Economy-Wide

We will use the total domestic output production and the single refinery (and crushing facility) employment impact to arrive at an economy-wide impact. The following calculation applies:

$$= \frac{\text{Economy-Wide Biodiesel Production}}{\text{Output Capacity of Single Refinery}} \text{ x 316 jobs per refinery.}$$

= 2,650 ML per year of total output / 90 ML per year of output per refinery x 316 jobs per refinery.

= 30 refineries (rounded) x 316 jobs per refinery.

= 9,500 jobs (rounded).

***Hypothetical Economy-Wide Soy Biodiesel Employment with All Plants at Rated Capacity***

We have accepted the figure of 2,650 MLy for United States biodiesel production in 2008, and are assuming that all of this production followed soybean oil production chain in terms of job creation. However, total capacity of biodiesel refineries in the United States with all feedstocks is given by the NBB as 2,955 MGy (see Table 19 above). This is equivalent to 11,186 MLy. (Production out of capacity fluctuates with economic conditions.) If the entire hypothetical capacity were to work to produce biodiesel fuel, the total employment impact would be correspondingly larger.

Calculating jobs based on the total hypothetical amount of United States economy-wide refinery capacity:

= Economy-Wide Biodiesel Production / Output Capacity of Single Refinery x 316 jobs per refinery.

= 11,186 ML per year of output / 90 ML per year of output per refinery x 316 jobs per refinery.

= 124 refineries (rounded) x 316 jobs per refinery.

= 39,200 jobs (rounded).

## 6.8 Jobs Created per Million Litre of Production

In summary, **Table 22** provides estimates for the number of jobs created per million litre of production per year (jpMLy) for each of the models. These figures were used in Section 3.3 earlier to estimate current and potential employment in first-generation biofuels. Please note that these models assume that the biofuel refinery is already built and operating at the stated capacity.

**Table 22: Jobs Created per Million Litres of Production (jpMLy)**

| Biofuel Feedstock and Type | Modeled Employment Per Biorefinery | Assumed Size of Biorefinery | jpMGy | jpMLy |
|---|---|---|---|---|
| Corn Ethanol | 412 | 100 MGY | 4.12 | 1.1 |
| Sugar Cane Ethanol | 1,920 | 100 MGY | 19.20 | 5.1 |
| Palm Oil Biodiesel | 2,930 | 40 MLY | | 73.3 |
| Soybean Oil Biodiesel | 316 | 90 MLY | | 3.5 |

## 6.9 Second-Generation Biofuels Employment Impact Models

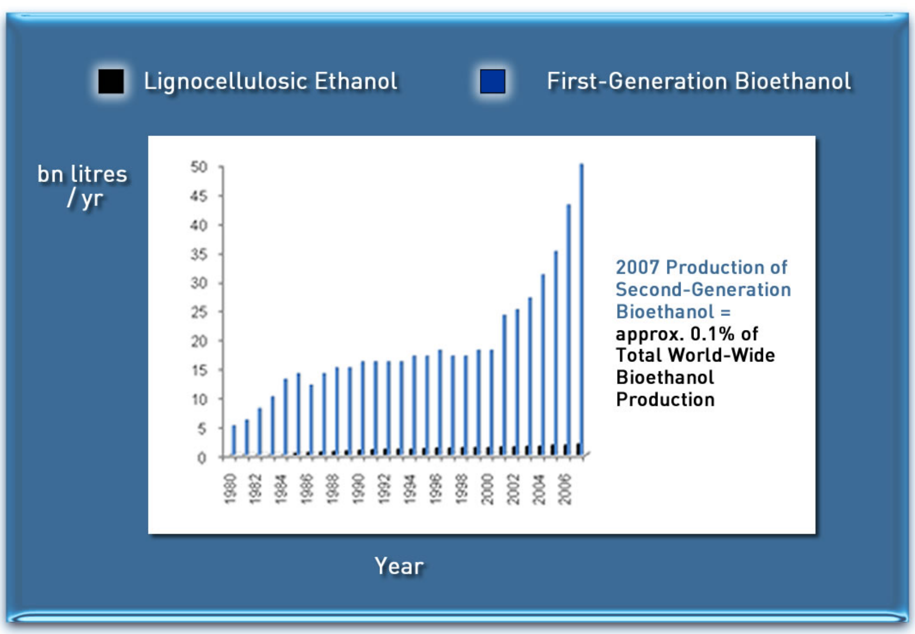
Our review of the literature suggests a wide variance as to when second-generation biofuels will become commercially viable. According to some forecasts, it could happen as early as 2015, or as late as 2020. The basic conversion technologies are not new, but their success is not guaranteed. Those required to convert from feedstock to finished fuel have not been adopted on a commercial scale, and the associated costs of production are expected to be significantly higher than for first-generation biofuels.

Significant R&D and demonstration efforts are being directed towards second-generation biofuels which are likely to represent the most immediate employment impact from second-generation biofuels; the jobs here are mainly for scientists, engineers, chemists, and for other highly-skilled technologies. Since women are typically under-represented in the science and technical fields (even in mature biofuel producer economies), the opportunities here appear even more limited for women than for men – at least over the short-to-medium term. Even in Brazil (a mature biofuels producer), the number of registered women engineers involved as 'environmental engineers' is less than 30% of all registered professional engineers.[73]

As discussed in Section 2.2, significant technological challenges remain before wide scale deployment and large scale employment is possible from second-generation activities. Nevertheless, there are several pilot-scale plants in operation, and the United States expects to complete four commercial-scale demonstration plants by 2014. Also, some first-generation processing facilities may adopt second-generation technologies (in whole or in part) allowing them to lower their production costs. In fact, plans are already underway to convert some corn-to-ethanol plants into cellulose-to-ethanol plants.

As **Figure 12** shows, the quantity of second-generation bioethanol produced in 2007 remains around 0.1% of total world-wide bioethanol production.[74] However, the share should rise rapidly as second-generation technologies mature, since second-generation feedstocks are substantially more abundant than first-generation for potential biofuels production.

**Figure 12: World Ethanol Production from First-Generation and Lignocellulose**




Once second-generation biofuels mature, they should generate jobs in feedstock production and biorefineries much like first-generation biofuels. Within refineries, it may be that jobs created per unit of production are fewer for second-generation biofuels owing to higher levels of mechanization. At the feedstock stage (including transportation of feedstock to refineries for processing), the employment potential of second-generation biofuels would relate not only to the levels of mechanization in farming operations, but also on the density of feedstock production on available lands. Denser feedstocks such as genetically engineered grasses would need less labour, but feedstocks grown in marginal lands, with poor soils or rainfall, would need more labour. As well, lengthy travels from feedstocks' supply sources to biorefineries would result in the more distant feedstocks requiring more jobs for transport.

**Figure 13** assesses the direct employment impacts from a second-generation biofuel plant that uses ligno-celluosic feedstock. It shows the possible direct employment as a function of plant capacity based on different stages of development and the number of hours of operation required. However, the direct impact is confined only to plant employment and transport (i.e. truck) jobs created by the plant. It does not indicate the number of jobs created in the farm sector (arising from the refinery); this is addressed later.

**Figure 13: Approximate Direct Employment Impacts from Second-Generation (Ligno-Celluosic Ethanol Plant)**

| Type of Plant (A) | Plant Capacity Ranges, and assumed annual hours of operation (B) | Biomass fuel required (oven dry tonnes per year) (C) | Truck vehicle movements for delivery to the plant Note: one truck payload is assumed to be approximately 20 tonnes (D) | Land area required to produce the biomass feedstock (% of land within a given radius) Note: the land area requirement would be reduced where crop and forest residue stocks are available (E) | Refinery Employment Based on Doyletech Models (F) | Refinery & Transport Jobs per Million Litres (G) |
|---|---|---|---|---|---|---|
| Small Pilot | 10,000-25,000 l/yr 2,000 hr. | 40-60 | 2-3 per year | 1-3% of land within a 1 km radius | 2 refinery persons plus 1 trucking job | 3 jobs per .010ML to 0.025ML |
| Demonstration | 40,000-500,00 l/yr 3,000 hr. | 100-1,200 | 5-60 per year | 5-10% of land within a 2 km radius | 2 - 6 refinery jobs plus 1 trucking job | 3 - 7 jobs per .04 to 0.5 ML |
| Pre-Commercial | 1-4 ML/yr 4,000 hr. | 2,000-10,000 | 100-500 per year | 1-3% of land within a 10 km radius | 7 - 11 refinery jobs plus 2-4 trucking jobs | 9 - 15 jobs per 1 to 4 ML |
| Commercial | 25-50 ML/yr 5,000 hr. | 60,000-120,000 | 8-16 per day | 5-10% of land within a 20 km radius | 21 - 26 refinery jobs plus 5-12 trucking jobs | 26 - 38 jobs per 25 to 50 ML |
| Large Commercial | 150-250 ML/yr 7,000 hr. | 350,000-600,000 | 50-100 per day & night | 1-2% of land within a 100 km radius | 38 - 45 refinery jobs and 65-130 trucking jobs | 103 - 175 jobs per 150 to 250 ML |

## Direct Employment Impact – Refinery Jobs

In Figure 13 (Column F), we have used Don O'Connor's first-generation plant model to estimate the direct refinery employment. This is a good proxy to use at least initially, because many first-generation plants will be upgraded to second-generation feedstocks and we do not yet have a clear sense of how much more mechanized (less labour-intensive) second generation plants might be. Columns (A) to (E) on plant types, capacity, feedstock requirements, transport needs, and land use, are based on data from the International Energy Agency (IEA) on second-generation biofuels.[75]

It is possible that the number of jobs internal to the refinery will increase with use of second-generation feedstocks and technology. For example, Iogen Corporation in Canada is indicating that its near-term prospective second-generation plant, with a rated output of 50 MGy, will need 100 persons for its operation. This is about two times the staff requirements of an equivalent capacity first-generation plant. The increase comes about from the more varied and complex potential feedstocks that a second-generation plant would use, since more labour is projected to be required for sorting and handling the feedstock supply chain. However, this is going to be dependent in practice on future specifics of feedstock, location, and technology, and it may or may not turn out to be more generally true. It does suggest that second-generation plants will likely require at least as much labour as first-generation ones.

### Direct Employment Impact – Truck Jobs

Since second-generation refineries will eventually become very large, the transport jobs created may be significant. As the text box below indicates, the number of truck jobs created varies widely based on the development type. These numbers were incorporated in Figure 13 above. Figure 13 also indicates the radius of truck travel each class of plant will require in order to gather feedstocks. Column F shows the number of direct refinery workers along with the number of direct trucking jobs. Column G expresses these two direct impacts in terms of jobs per ML per year of production.

**Calculating Employment from Trucking of Biofuel Feedstock**

A **pilot plant**, using just 40 to 60 tonnes of feedstock per annum, will need 2 or 3 standard 20-tonne truckloads of feedstock to meet the requirements. The required feedstock can be obtained within a 1-kilometre radius of the plant. The feedstock deliveries can be accomplished by a single driver (part-time).

A **demonstration plant**, with 100 tonnes to 1,200 tonnes of feedstock requirements per year, will require 5 to 60 standard 20-tonne truckloads annually. The feedstock can be obtained within a 2-kilometre radius. This can still be accomplished by a single driver.

The **pre-commercial refinery**, requiring 2,000 to 10,000 tonnes of feedstock annually, needs 100 to 500 standard 20-tonne truckloads per year, or 2 to 10 truckloads per week. Moreover, the radial distance for obtaining the feedstocks will have to go up to 5 times more than the demonstration plant or 10 times more than the pilot plant. This would be approximately 10 kilometres. Therefore, significant extra time will be taken in transporting the feedstocks along roadways. Allowing for loading and unloading time, we estimate that this requirement will result in a need for drivers in the range of 2 to 4 persons (full-time).

The **commercial refinery**, which requires 60,000 to 120,000 tonnes of feedstock per year, will need 3,000 to 6,000 standard 20-tonne truckloads annually or approximately 8 to 16 per day on a 365-days-per-year basis. Moreover, the radial distance has to go up to 10 times that of the demonstration plant, or approximately 20 kilometres. Therefore, each trip will be longer than any previous, and we estimate accordingly that, again allowing for loading and unloading time, each driver will only be able to make 1 or 2 trips per day. Total number of drivers per day would be in the range of 4 to 8. As well, it is assumed that no driver would work 7 days a week. An allowance for driver substitutes owing to weekends, sickness, truck maintenance, etc. has to be included. We estimate this as a 30% factor. Accordingly, 5 to12 full-time drivers would be required.

The **large commercial refinery**, which requires 350,000 to 600,000 tonnes of feedstock per year, will require 17,500 to 30,000 standard 20-tonne truckloads annually, or approximately 50 to 100 truckloads per day, again using a 365 days-per-year basis. The radial distance has to go to 10 times the pre-commercial, or approximately 100 kilometres. Only one trip can be accomplished per driver per day. Accordingly, 50 to 100 drivers will be needed per day. Again the same considerations for weekends, sickness and other factors, must be included in the calculations. Taking the same 30% factor for these, we derive 65 to 130 jobs for drivers.

### Total Employment Impact – Refineries and Transport and Farm Sector

In this section, we calculate the hypothetical total job creation for second-generation ethanol production, taking into account all of refinery, transport, and feedstock jobs. In **Figure 14A**, we project the hypothetical number of jobs created in second-generation refineries and transport. Our methodology was as follows:

- Our job creation figures for refinery and transport were based on the second-generation ethanol potential across APEC as given in Table 8 from Section 3.4, but expressed in millions of litres (ML).

- For each APEC economy, we assessed whether prospective second-generation ethanol plants would be "commercial" or "large commercial" in size, under the assumption that the potential second-generation ethanol production would be coming in the 2015-plus timeframe, and hence that the technologies would be relatively proven. In general, we assumed developed APEC economies would be using "large commercial" plants, while ones in developing and emerging economies would be "commercial" scale.
- From Figure 13, we developed employment factors for "commercial" and "large commercial" plants. These employment factors relate the number of refinery and transport jobs per million litres annual production of ethanol. For "large commercial" we calculated the employment factor as 0.7, and for "commercial" we calculated the employment factor as 1.

**Figure 14A: Second-Generation Potential Employment in Refineries and Transport Based on Potential Production**

| Member Economy | 2nd Generation Ethanol Potential (ML Per Year) | Assumed Size of 2nd Generation Refinery | Employment Factor (Jobs Per ML Per Year) (Refineries + Transport) | Potential Employment (Refineries + Transport) |
|---|---|---|---|---|
| Australia | 11,000 | Large Commercial | 0.7 | 7,700 |
| Brunei Darussalam | | | | |
| Canada | 21,300 | Large Commercial | 0.7 | 14,900 |
| Chile | 900 | Commercial | 1.0 | 900 |
| China | 236,000 | Commercial | 1.0 | 236,000 |
| Hong Kong, China | | | | |
| Indonesia | 22,200 | Commercial | 1.0 | 22,200 |
| Japan | 4,500 | Large Commercial | 0.7 | 3,200 |
| Korea | 3,900 | Large Commercial | 0.7 | 2,700 |
| Malaysia | 9,700 | Commercial | 1.0 | 9,700 |
| Mexico | 22,400 | Commercial | 1.0 | 22,400 |
| New Zealand | 1,700 | Commercial | 1.0 | 1,700 |
| Papua, New Guinea | | | | |
| Peru | | | | |
| The Philippines | 5,400 | Commercial | 1.0 | 5,400 |
| Russia | 30,000 | Commercial | 1.0 | 30,000 |
| Singapore | | | | |
| Chinese Taipei | 600 | Large Commercial | 0.7 | 400 |
| Thailand | 14,300 | Commercial | 1.0 | 14,300 |
| United States | 97,300 | Large Commercial | 0.7 | 68,100 |
| Viet Nam | 27,900 | Commercial | 1.0 | 27,900 |
| **APEC Total** | **509,100** | | | **467,500** |

In **Figure 14B**, we project the hypothetical number of jobs created in feedstock harvesting to serve second-generation ethanol plants. Our methodology was as follows:

- We used the same data for potential ethanol production as given in Table 8 from Section 3.4.
- We assessed which one of our feedstock production models – corn or sugar cane – was most likely to represent a reasonable proxy for second-generation feedstock production. In general, we assumed that economies in cooler climates would be closer to the corn feedstock model, while economies in warmer climates would follow more closely to the sugar cane model. It is not a case of assuming each economy will necessarily use corn or sugar cane as the second-generation feedstock, rather, it is a case of assuming feedstock production (whatever it may actually turn out to be) will more closely follow the feedstock job creation captured in our two respective models.
- For both corn and sugar cane feedstock models, we derived a feedstock employment factor. For corn, we calculated this on the basis of feedstock jobs per million litres of ethanol production. For a 378.5 million litre per year plant, our corn cost model in Section 6.4 above shows a requirement for 25 workers in harvesting feedstock, which is 6.6 workers per million litres of ethanol annual production, although this is based on a 6-month growing season. On a Full-Time Equivalent (FTE) basis, it is 12.5 workers for a 378.5 million litre per year plant, which is 3.3 workers in harvesting. We selected the 3.3

workers figure for calculating the second-generation feedstock labour per million litres per year, as being more conservative, and also for representing better the fact that second-generation feedstocks in developed economies are more likely to be gathered as a marginal-cost and marginal-labour activity based on already-harvested residues.

- For sugar cane, we used the cost model developed in Section 6.5. This shows one worker can cut 2,160 tonnes of cane in an annual season. Each tonne produces 70 litres of ethanol. Accordingly, each worker is responsible in the model for 151,200 litres of ethanol production annually, or 0.1512 million litres. In other words, there are 6.6 direct jobs per ML of annual production (jpMLy). This is the employment factor we used for those economies whose ethanol potential we assessed as more closely following the sugar cane model for feedstock harvesting.

**Figure 14B: Second-Generation Potential Employment in Feedstocks Based on Potential Production**

| Member Economy | Ethanol Potential (ML) | Assumed Proxy Feedstock Harvesting Model | Corn Feedstock Employment Factor of 3.3 jpMLy | Sugar Cane Feedstock Employment Factor of 0.1512 ML per Worker (or 6.6 jpMLy) | Potential Employment (Feedstocks) |
|---|---|---|---|---|---|
| Australia | 11,000 | Corn | 36,300 | | 36,300 |
| Brunei Darussalam | | | | | |
| Canada | 21,300 | Corn | 70,300 | | 70,300 |
| Chile | 900 | Sugar Cane | | 6,000 | 6,000 |
| China | 236,000 | Corn | 778,800 | | 778,800 |
| Hong Kong, China | | | | | |
| Indonesia | 22,200 | Sugar Cane | | 146,800 | 146,800 |
| Japan | 4,500 | Corn | 14,900 | | 14,900 |
| Korea | 3,900 | Corn | 12,900 | | 12,900 |
| Malaysia | 9,700 | Sugar Cane | | 64,200 | 64,200 |
| Mexico | 22,400 | Corn | 73,900 | | 73,900 |
| New Zealand | 1,700 | Corn | 5,600 | | 5,600 |
| Papua, New Guinea | | | | | |
| Peru | | | | | |
| The Philippines | 5,400 | Sugar Cane | | 35,700 | 35,700 |
| Russia | 30,000 | Corn | 99,000 | | 99,000 |
| Singapore | | | | | |
| Chinese Taipei | 600 | Corn | 2,000 | | 2,000 |
| Thailand | 14,300 | Sugar Cane | | 94,600 | 94,600 |
| United States | 97,300 | Corn | 321,100 | | 321,100 |
| Viet Nam | 27,900 | Sugar Cane | | 184,500 | 184,500 |
| **APEC Total** | **509,100** | | | | **1,946,500** |

In **Figure 14C**, we show cumulative job creation across APEC by adding the results of the refinery and transport second-generation job projections to the second-generation feedstock job projections.

### Market Readiness of Second-Generation Biofuel

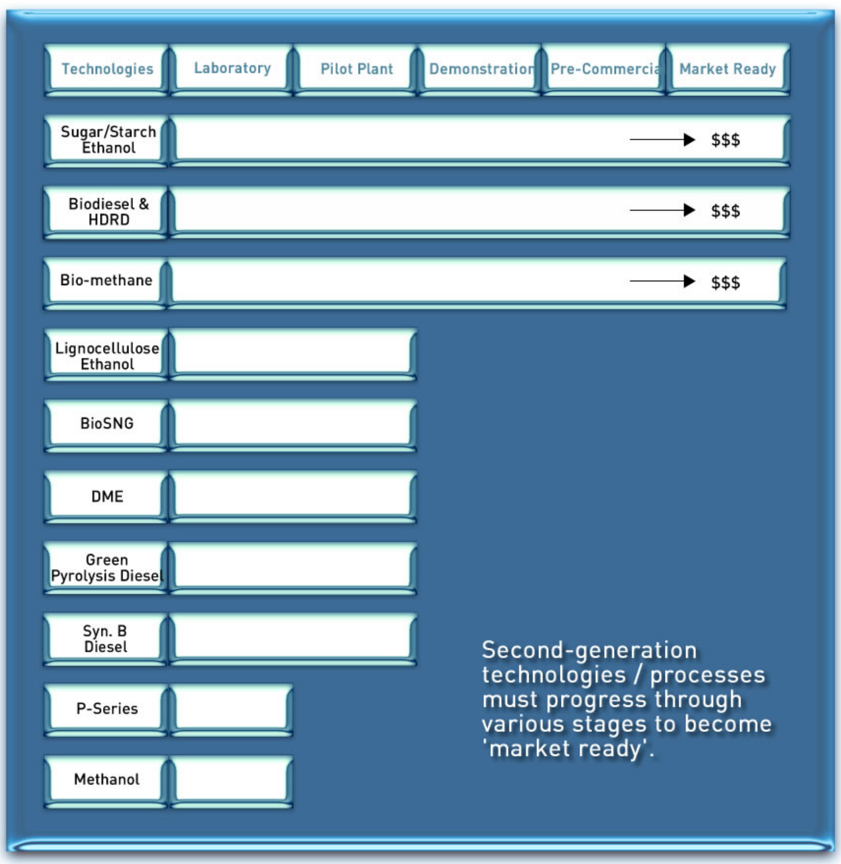
**Figure 15** presents a market readiness map to assess the second-generation biofuels opportunity. It shows the various stages that second-generation biofuels must progress through to get from the laboratory to the marketplace. Most of the employment will be in R&D, at least until 2020 but it is difficult to determine how many research jobs, as they will be spread among a vast number of universities and public and private research organizations around the world. Their goal will be to achieve the lowest cost processes with the largest biofuel output.

Processing technologies can convert a variety of different biomass feedstock into biofuels. The more feedstocks that are applicable for biofuel production, the more feedstock will be available in a certain region or economy. A larger amount of available feedstock will increase the potential output in biofuel production which results in greater energy security and potential employment. The figure indicates that three second-generation technologies and processes are already at the ‘market ready’ stage. However, this does not mean there is commercial deployment.

**Figure 14C: Second-Generation Total Hypothetical Employment**

| Member Economy | Ethanol Potential (ML) | Potential Employment in Refineries and Transport | Potential Employment in Feedstocks | Grand Total Hypothetical 2nd Generation Employment |
|---|---|---|---|---|
| Australia | 11,000 | 7,700 | 36,300 | 44,000 |
| Brunei Darussalam | | | | |
| Canada | 21,300 | 14,900 | 70,300 | 85,200 |
| Chile | 900 | 900 | 6,000 | 6,900 |
| China | 236,000 | 236,000 | 778,800 | 1,014,800 |
| Hong Kong, China | | | | |
| Indonesia | 22,200 | 22,200 | 146,800 | 169,000 |
| Japan | 4,500 | 3,200 | 14,900 | 18,100 |
| Korea | 3,900 | 2,700 | 12,900 | 15,600 |
| Malaysia | 9,700 | 9,700 | 64,200 | 73,900 |
| Mexico | 22,400 | 22,400 | 73,900 | 96,300 |
| New Zealand | 1,700 | 1,700 | 5,600 | 7,300 |
| Papua, New Guinea | | | | |
| Peru | | | | |
| The Philippines | 5,400 | 5,400 | 35,700 | 41,100 |
| Russia | 30,000 | 30,000 | 99,000 | 129,000 |
| Singapore | | | | |
| Chinese Taipei | 600 | 400 | 2,000 | 2,400 |
| Thailand | 14,300 | 14,300 | 94,600 | 108,900 |
| United States | 97,300 | 68,100 | 321,100 | 389,200 |
| Viet Nam | 27,900 | 27,900 | 184,500 | 212,400 |
| **APEC Total** | **509,100** | **467,500** | **1,946,500** | **2,414,000** |

**Figure 15: Market Readiness Map for Second-Generation Technologies / Processes**



# 7.0 Conclusions and Recommendations

## 7.1 Summary of Key Findings

There are a number of key conclusions coming out of this research, as follows:

- **Biofuels create jobs.**

There are positive job gains in all of: feedstock harvesting; seeding; transport; and biorefineries. In summary, **Table 23** provides our estimates of the jobs created through current APEC first-generation ethanol and biodiesel production.

**Table 23: Total Jobs Created from Current APEC Ethanol and Biodiesel Production**

| | Current Ethanol Production (MLy) | Estimated Ethanol Employment | Current Biodiesel Production (MLy) | Estimated Biodiesel Employment |
|---|---|---|---|---|
| APEC Total | 37,628 | 45,000 | 5,773 | 197,000 |

**Table 24** provides estimates for the number of jobs created per million litres of production per year (jpMLy) for each of the first-generation production models.

**Table 24: Jobs Created per Million Litres of First-Generation Production (jpMLy)**

| Biofuel Feedstock and Type | Modeled Employment Per Biorefinery | Assumed Size of Biorefinery | jpMGy | jpMLy |
|---|---|---|---|---|
| Corn Ethanol | 412 | 100 MGY | 4.12 | 1.1 |
| Sugar Cane Ethanol | 1,920 | 100 MGY | 19.20 | 5.1 |
| Palm Oil Biodiesel | 2,930 | 40 MLY | | 73.3 |
| Soybean Oil Biodiesel | 316 | 90 MLY | | 3.5 |

- **Second-generation biofuels technology will assist job-creation.**

**Table 25** provides estimates for the number of direct jobs created for second-generation technologies.

**Table 25: Hypothetical Total Direct Jobs Created from Second-Generation Ethanol Production**

| | Ethanol Potential (MLy) | Potential Employment in Refineries and Transport | Potential Employment in Feedstocks | Grand Total Hypothetical 2nd Generation Employment |
|---|---|---|---|---|
| APEC Total | 509,100 | 467,500 | 1,946,500 | 2,414,000 |

In light of second-generation biofuels technologies' use of marginal or otherwise-not-used lands for feedstock supply, the production of biofuels would represent clear gains in job creation without any prospective impact on other land uses.

- **Biofuels represent a positive growth path for upgrading rural skill sets and incomes.**

Biofuels not only create jobs in rural areas through new biorefineries and new feedstock harvesting, seeding, and transportation activities, but biofuels also provide a logical growth path into increased mechanization and higher productivity. Plant size and feedstock harvest areas can be justifiably increased over time in light of biofuels high-value product profile, and this means that rural areas can gradually increase their productivity and attendant potential incomes.

- **At present, women are not fully engaged in the biofuels sector, but this can change.**

While women face some barriers at present to being fully engaged in the biofuels sector, this can change over time as the sector grows and becomes more productive. A number of initiatives described above are underway or being actively considered within APEC economies, and women are forecast to increase gradually their participation in the sector.

### 7.2 Follow-on Research Work

We propose two questions which can now be answered from the study:

1. **Can change in employment, through expanded biofuels production and use, be used for social benefit, particularly improving gender equality and social equity?**

   The answer is a qualified 'yes' – as the quality and quantity of jobs can be limited by several factors and influences.

   Our research shows that larger production plants do not hire many more workers than an average size plant. Size is based on output capacity to process a given feedstock into ethanol or biodiesel. As the size increases, so does the demand for more efficient harvesting methods. Export demands for ethanol or biodiesel require more mechanization to keep the plant operating at high efficiency. Currently, women appear to be at more risk for abusive working conditions than men due to the lack of empowerment and the increased mechanization (as manual labour for harvesting is eliminated).

   While a reduction in rural poverty and unemployment is likely, it is cautioned that biofuel harvesting and production, by itself, may not necessarily employ enough persons at fair wages to make the significant impact that some developing APEC economies may like for their people. There is also the issue of whether investment in a nation's biofuel industry is foreign or domestic. If all the profits from production are repatriated back to foreign investors as opposed to being reinvested back into the local economy, the social benefit or employment impact may be much smaller.

   The issue of foreign versus domestic investment transcends all economic development policy. There are positives and negatives for each investment strategy, particularly in terms of direct and indirect employment impacts. For foreign-owned operations, a larger proportion of management jobs will be created remotely, particularly in this day and age when management information is readily available throughout the enterprise. However, a large proportion of the direct jobs will always have to be performed locally because the major assets are raw materials and they are not mobile. (This is unlike the situation for more technology-intensive companies where the major asset is know-how that can easily be transferred to a head office – or to a location that can exploit it more efficiently.) The real question is what mix of foreign and domestic ownership is realistically possible at a specific point in time for the specific APEC economy in question. For some economies, expanding the activity of foreign-owned firms may result in the creation of biofuels employment that otherwise would not exist. In other economies, this may not be the case at all. Over the long term, a sustainable domestic biofuels industry should welcome investment by companies from throughout the APEC region so that the potential employment benefits of sustainable biofuels production can be fully realized.

   As was shown in Figure 1, there are many employment paths within the biofuel industry, and significant social benefits can be obtained through the investment of the savings made in import substitution of oil and the reinvestment of profits from biofuel exports. An alternative to multinational agri-businesses for employment is to operate smaller cooperative refineries for producing both ethanol and biodiesel. The community and the workers surrounding these plants could have a better say in what priorities need attention (such as better living and working conditions). In some cases, an all-women's cooperative (and training to better handle the machinery for mechanized harvesting) could provide the flexibility and empowerment for women and their families.

As demonstrated several times in this report, refinery size not only impacts direct refinery employment but also overall employment in a region. More employment (particularly direct employment) may actually be created by several smaller refineries distributed over a wide area than by one very large refinery. However, there are other perspectives at play and other issues of concern than employment. For example, refinery operators are typically concerned first and foremost about profit margins and competitive positioning. They will select the size of plant that best meets those objectives, and employment is mainly an output from these considerations rather than an input.

**Recommendation:**

In addition to expanded biofuels employment opportunities, investments / improvements in rural education, healthcare, housing and infrastructure would help provide more opportunities for women (and their families) to escape from poverty.

There is a role for government in addressing gender inequality issues. When women are given the opportunity to manage their own affairs and make their own money, their overall health (and that of their family and community) improves.

Investment in biofuel technology (as part of a greater knowledge-based economy for developing and emerging economies) is essential to sustaining a competitive edge.

### 2. Could this project provide a credible tool for APEC stakeholders to use in assessing biofuel employment and messaging?

The answer is a qualified 'yes' – as the effectiveness of any tool depends on how it is used, the quality of the available data, and whether its resultant output is realistic. Much is made about the biofuel industry's potential to create employment but studies are presenting a very wide range of economic and employment impacts. While there are many factors which explain these variances (such as the feedstock used and the level of plant and farm mechanization), it is clear that there are significant differences in how the modeling is being done and the role that multiplier effects play.

Future work to develop expanded models of biofuels employment will require better industry and country data, greater clarity on second-generation feedstocks and technologies, consideration of the demand-side, and improved definitions of the industry. Some key issues are as follows:

- Industrial Definitions: The various components of the biofuels industry do not fall into standard industrial classification systems. The range of jobs and industries within 'biofuels' ranges from the refinery to the fields and includes many other related industries (or parts thereof) such as various transportation and storage industries. Obviously, a 'chemical' definition for biofuels is far too restrictive, as is an 'agricultural' definition.

- Supply-Chain Analysis: An end-to-end supply chain analysis would serve as a good foundation for defining a particular biofuels industry. However, such an analysis would vary widely depending on many factors (such as the type of feedstock involved and the economy in which the industry is located). It would also seem that every second-generation biofuel would require its own supply-chain analysis at this point in time.

- Supply and Demand Side Analysis: As a supply-side analysis employment model, this study does not explicitly address the demand side. That is, it uses the plant size to determine the amount and cost of feedstock needed to operate it at maximum capacity. This in turn determines not only the employment in the plant but also in the farm and transport sectors that supply to the plant. Consideration of the demand side (which was not part of this project's mandate) would alter the results from our models. It would also assist in developing better 'net' employment impacts, but the scope of such a project would be much larger. In some cases, gaps between supply and demand could cause little change to the employment numbers; in other cases, adjustments to the employment numbers might be significant.

- Better Sex-Disaggregated Data: There is a need for more thorough sex-disaggregated data (and information) on the entire biofuels sector ranging from employment data and opportunities to working conditions in the plants and fields, to sustainability and implementation considerations. There is also a need to identify gender ratios (and differences) at every level of the biofuel industry (research and development, processing, post-processing, agriculture, transportation, and so forth).

**Recommendation:**

APEC should standardize on a common method and toolset for estimating employment from biofuels. We have provided the basis for understanding the parameters, and this study can be the beginnings of such a tool for future policy and messaging on the employment value of biofuels.

The practical challenge will lie in developing a credible tool that allows for the routine evaluation of all of the inputs to biofuel employment for any APEC member economy. Such a tool is essential for making informed biofuel policy choices at the scale of local communities and regions, all the way up to economy-wide, regional and global agreements.

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