



APEC Biofuels Task Force

Review of Activity

APEC Expert Group on New and
Renewable Energy Technologies

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Biofuels development and use depends on several key factors:

- **Biofuel Economics** (cost of ethanol vs. petrol and biodiesel vs. diesel)
- **Biofuel Trade Opportunities** (created by production cost differentials)
- **Biofuel Infrastructure** (cost and time to build biofuel filling station network)
- **Fuel-Flexible Vehicles** (practical path of uptake into the automobile market)
- **Biofuel Resources** (current and potential availability of biofuel feedstocks)



Four-Fifths of All APEC Economies Participate in the Biofuels Task Force

- **Australian** Department of Resources, Energy and Trade; Bioenergy Australia; Commonwealth Science and Industrial Research Organisation (CSIRO); Biodiesel Association of Australia; Queensland University of Technology
- **Canada** Agriculture and Agri-Food
- **Chile** Ministry of Agriculture
- **China** Energy Bureau and Energy Research Institute
- **Hong Kong** Electrical and Mechanical Services Dept.
- **Indonesia** Ministry for Economic Affairs, Ministry of Energy and Mineral Resources
- **Japan** Observers: New Energy and Industrial Technology Development Organization (NEDO); Institute of Energy Economics Japan (IEEJ)
- **Korea** Ministry of Commerce, Industry and Energy (MOCIE); Korea Institute of Energy Research; Korea Energy Economics Institute
- **Malaysia** Ministry of Plantation Industries & Commodities; Malaysian Palm Oil Board
- **Mexico** Secretariat for Energy (SENER)
- **New Zealand** Resource Development Limited
- **Peruvian** Association of Sugar and Biofuel Producers; Maple Corporation
- **Philippines** Department of Energy (DOE)
- **Russian** National Biofuels Association
- **Chinese Taipei** Industrial Technology Research Institute (ITRI)
- **Thailand** Dept. of Alternative Energy Development and Efficiency (DEDE); Thailand Institute of Scientific and Technological Research (TISTR)
- **United States** Dept. of Energy; Dept. of Agriculture, Argonne National Laboratory



Biofuels Task Force Report to EMM-8 (Darwin, Australia, May 2007)

- *"We welcomed the report of the APEC Biofuels Task Force. Among its key findings are that biofuels from several crops **are cost-competitive** at current oil prices, that biofuels **can lower greenhouse gas emissions** and that biofuels **can displace a sizeable share of oil use** over time."*
- *"Biofuels production should be advanced in line with sustainable development objectives. We encourage intensified efforts to develop and deploy techniques for the cost-effective use of non-food feedstocks, such as farm and forest residues and grasses, which hold the greatest potential for expanded biofuels production and greenhouse gas reductions."*



Survey of Biofuel Resource Assessments and Assessment Capabilities by NREL

- Second Generation Potential is Large
 - Second-generation biofuels from farm and forest residues could displace 40% of gasoline use and 20% of crude imports APEC-wide
- First Generation Potential is Modest
 - Grain crops equivalent to one-fifth of current production would only displace 7% of gasoline and 3.5% of crude oil imports in the region.
 - Oil crops equivalent to one-fifth of current production would only displace 7% of diesel consumption and 2 percent of crude imports.



Potential of Biofuels on Marginal Lands in APEC Economies (NREL)

- Found that biofuels from feedstocks grown on marginal lands could displace a fifth of crude oil imports in the APEC region if they could be economically developed.
- Followup could show distribution of costs in finer squares of area – the portions of marginal lands where development could be cost-effective.



Assessment of Biomass Resource Elasticity in APEC Economies (CARD)

- Substantial increase in available biofuel feedstocks from agricultural crops and associated farm residues is possible with better seeds, fertilizer and irrigation.
- From 1998-2008, yields increased 3.2%/year for corn and 2.2%/year for palm oil.
- Since second-generation ethanol from crop residues could displace 33% of gasoline consumption, a 10% increase in average crop yields could displace 3.3%.



Resource Potential of Algae for Biodiesel Production in APEC (CSIRO)

- Method 1: human and animal waste on flat, low-cost land within 15 degrees of equator: 20B liter/year
- Method 2: waste water around electric power plants: 38B liter/year
- Method 3: production wherever there is sufficient land and water: much larger potential if nutrients could be sourced cost-effectively.



Study of Employment Opportunities from Biofuel Production in APEC (IBM)

- Jobs per million liters per year
 - 1.1 jpMLY for ethanol from corn
 - 5.1 jpMLY for ethanol from sugar cane
 - 3.5 jpMLY for biodiesel from soy
 - 73.2 jpMLY for biodiesel from palm
- Implied Jobs in 2008
 - Ethanol 38 B liters, 45,000 jobs
 - Biodiesel 5.8 B liters, 197,000 jobs
- Farm and forest residue potential
 - Ethanol 509 B liters/y, 2.4 million jobs



Biofuel Feedstock Costs, Technology and Economics in APEC Economies (BBI)

- Comparative costs from 2005-2009:
 - Brazilian sugarcane consistently less expensive to produce than gasoline.
 - U.S. corn ethanol sometimes cheaper than gasoline but not consistently.
 - Hard for palm biodiesel to compete when palm oil prices are high.
 - Cellulosic ethanol from farm residues, with future technology, would have been cost-competitive with gasoline.



Strategies for Developing Biofuel Transportation Infrastructure (BBI)

- Best transport mode by distance:
 - Trucks up to 500 km to market
 - Barge or rail up to 1,500-2,000 km
 - Rail superior for trips over 2000 km
- Dedicated ethanol pipeline requires volumes of 15 billion liters per year or more to be cost-effective
 - Potential markets in China/Asia and United States/North America



Sustainable Biofuels Development Practices in APEC (Winrock)

- Improve yields through better seed, drip irrigation, no-till cultivation, crop rotation, land conservation.
- Regulate land use to encourage planting of feedstocks on farmland, degraded land, and marginal land.
- Use voluntary programs to boost yields, use of marginal land, integration of crop and animal cultivation, and recycling of wastes and reduce fertilizer requirements.

**EWG-43 Agenda Item 14
Alternative Transport Fuels**

**FINAL REPORT ON THE
APEC BIOFUELS TASK FORCE**

Overview of Biofuels Task Force Activity

Seventeen APEC economies participated in the Biofuels Task Force as members or observers: Australia, Canada, China, Chile, Hong Kong, Indonesia, Japan (observer), Korea, Malaysia, Mexico, New Zealand, Peru, Philippines, Russia, Thailand, Chinese Taipei, and the United States. The Asia Pacific Energy Research Centre (APEREC) and Expert Group on New and Renewable Energy Technologies (EGNRET) were also represented, and Brazil was a non-APEC observer. Work was carried out through an Executive Committee and Task Groups on biofuel economics and trade, biofuel vehicles and infrastructure, and biofuel resources.

A brief chronology of Task Force activity is as follows:

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|---------|---|
| 2005/10 | Seventh APEC Energy Ministers Meeting (EMM-7) in Gyeongju, Korea endorses creation of a Biofuels Task Force as part of a balanced approach to oil security including investment, fuel efficiency and alternative fuels. |
| 2006/05 | First Biofuels Task Force meeting in Singapore agrees upon terms of reference for the Task Force which are endorsed by EWG-32, to include focus on biofuel economics and trade, fuel flexible vehicles and infrastructure, and resources. |
| 2006/10 | Second Biofuels Task Force meeting in China drafts initial consensus messages for ministers on biofuel economics, infrastructure and resources. |
| 2007/01 | Third Biofuels Task Force meeting in Japan reviews consensus messages, and work gets underway on a study of liquid biofuels, guidelines for developing biodiesel standards, and a survey of biomass resource assessment in APEC. |
| 2007/05 | Report of the Biofuels Task Force is welcomed by the Eighth Energy Ministers Meeting (EMM-8) in Darwin, with findings that biofuels from several crops are cost-competitive and biofuels can displace a sizeable share of oil use over time. |
| 2007/10 | Fourth Biofuels Task Force meeting in Thailand incorporates workshop on technical standards to promote biofuel trade, and Budget and Management Committee of APEC approves projects on biofuels and employment, biofuel resource elasticity, and potential biofuel resources on marginal lands. |
| 2008/10 | Fifth Biofuels Task Force Meeting at National Renewable Energy Laboratory in the United States incorporates workshop on biofuel resource assessments, and BMC approves a project on biofuel feedstock costs, technology and economics. |
| 2008/12 | Survey of biofuel resource assessments and assessment capabilities completed, with finding that biofuels from farm and forest residues could potentially displace one-fifth of crude oil imports in the APEC region. |
| 2009/05 | BMC approves a project on potential for biodiesel production from algae. |

2009/07	BMC approves projects on sustainable biofuel development practices and on strategies for developing biofuel transmission and distribution infrastructure.
2009/10	Project on potential biofuel resources on marginal lands completed, with finding that biofuels from feedstocks grown on marginal lands could displace a fifth of crude oil imports in the APEC region if they could be economically developed.
2009/12	Project on biofuel resource elasticity completed, documenting the substantial increase in available biofuel feedstocks from agricultural crops and associated farm residues that is possible with technological advances over time.
2010/02	Project on biofuels and employment completed, with estimates of jobs created per million liters per year of production for ethanol from corn and sugarcane and for biodiesel from palm and soy as well as overall employment generated.
2010/04	Sixth Biofuels Task Force meeting in Kuala Lumpur, Malaysia, incorporates a workshop on sustainable biofuel development practices and discussion of messages for energy ministers from the task force studies undertaken so far.
2010/11	Project on biofuel economics completed, with cost comparisons of ethanol and biodiesel with conventional petroleum-based gasoline and diesel over time.
2010/11	Project on sustainable biofuel development practices completed, with detailed examples from APEC economies of planning and research, regulatory and policy initiatives, private and voluntary initiatives, and monitoring efforts.
2011/05	Project on biofuel transportation and distribution infrastructure is completed, with indications of where dedicated ethanol pipelines could make sense.
2011/09	Workshop on Algal Biofuels takes place during the Senior Officials Meetings in San Francisco, prior to the Transportation and Energy Ministerial Conference.
2011/12	Project on resource potential of algae for production of biodiesel is completed.

APEC Biofuels Projects Completed in 2008

Several projects with Biofuels Task Force involvement were completed in 2008:

- An assessment of guidelines for developing biodiesel standards in APEC.
- A study of the future of liquid biofuels in the APEC region.
- A survey of biomass resource assessments and assessment capabilities.

Guidelines for the Development of Biodiesel Standards in the APEC Region

The project's objective was to establish guidelines for development of biodiesel standards in the APEC region that will enhance biodiesel trade. The use of biodiesel for transport can reduce air emissions, increase domestic supply of renewable fuel and create new markets for agricultural sectors. Biodiesel fuel can be produced from various animal fats and vegetable oils, but the quality of biodiesel produced depends on the natural characteristics of feedstocks. The feedstocks for biodiesel production in Europe and the United States (such as soy and rapeseed) are completely different from

those in key developing APEC economies (such as palm), and allow the production of biodiesel with superior performance in cold weather. Thus, if blends of biodiesel from Asian feedstocks are to be widely traded (especially to economies with colder climates) they will need to take into account the European and American biodiesel standards (EN 14214:2003 and ASTM D 6751:2003) which are already developed and widely used.

This project, initiated by the Expert Group on New and Renewable Energy Technologies under the APEC 21st Century Renewable Energy Development Initiative Collaborative IX, received a grant of \$50,000 from the APEC Support Fund for 2007. It was led by Ms. Peesamai Jenvanitpanjakul, Acting Director of the Environment, Ecology and Energy Department at the Thailand Institute of Scientific and Technological Research (TISTR). An RFP was issued in 2007, and Hart Energy Consulting was selected to do the work. A workshop was held in Bangkok on 25-26 October 2007, in coordination with the Fourth Task Force meeting. A second workshop was held in Taipei on 16-18 July 2008. A background report, issued in April 2008, catalogues technical standards for biodiesel across all APEC economies. This report and the workshop presentations can be downloaded from www.egnret.ewg.apec.org. The report can also be found at www.apec.org/apec/publications/all_publications/energy_working_group.html,

The subject of biofuel standards was raised at a meeting of the APEC Automotive Dialogue in Singapore on 10-12 September 2008, in which the Chair of the Task Force participated. A representative of the Japan Automotive Industry made a presentation on recommended biofuel specifications for a Worldwide Fuel Charter, including ethanol and biodiesel, and noted that comments on this Charter were requested by 30 September. The Chair then offered the project background report in its entirety as a set of comments on the Charter. A final project report was issued in early 2009.

Study of the Future of Liquid Biofuels in APEC Economies

The study compiles baseline data and information on the development of liquid biofuels in APEC economies. Topics include liquid biofuel technology, fuel specifications, potential benefits to auto-manufacturers, national energy policies, and regional directives in supporting and promoting the use of liquid biofuels to lessen the over-dependence on fossil fuels and to cope with environmental issues resulting from the use of fossil fuels.

This project was initiated by Thailand through the Energy Working Group and received a grant from the APEC Support Fund in 2006. The National Renewable Energy Laboratory (NREL) of the United States was the sole bidder on the project and was offered a sole source contract in August 2006. A project report was issued in early 2008.

As part of the project, a biofuels website has been established at www.biofuels.apec.org. This includes basic data on ethanol and biodiesel production by year and economy, typical feedstocks for biofuels in each economy, biodiesel blends and standards by economy, cost analyses and resource assessments from the Biofuels Task Force and other sources, installed production capacity for biofuels, biofuels trade, and other useful information.

Survey of Biomass Resource Assessments and Assessment Capabilities in APEC

The project aims to understand what biomass resource assessments have been undertaken in APEC economies, as well as the capability of APEC economies to undertake such assessments. Particular attention is paid to the potential of various crops, crop residues, forest wastes and urban wastes to be utilized for production of bioethanol and biodiesel to displace oil use in the transport sector and thereby to grow oil exports or limit oil imports.

Various APEC economies have credible biomass resource assessments. By sharing information, the project provides a clearer picture of potential biomass resources throughout the APEC region, and thus a real sense of the potential of biofuels to limit the upward pressure on oil prices and growing oil import dependency over the long term.

Most APEC economies have extensive capabilities to assess biomass resources, such as the level of geographic detail at which data on yields of crops, crop residues, forest residues and urban residues are available. The project report provides a shared view of their capabilities to systematically assess biofuel resources and suggest practical ways to improve these capabilities so that the resource potential can be better understood.

This project received a grant of \$50,000 from the APEC Support Fund for 2007. An RFP was issued, two proposals were received, and the National Renewable Energy Laboratory (NREL) of the United States was selected as the contractor. The project was led by Anelia Milbrandt, Research Scientist, NREL, and supported by Ralph Overend, Chief Scientist, National Biofuels LP. The U.S. Department of Energy also provided \$50,000 to support this and related work on biofuels resource assessment at NREL.

During a Workshop on Biofuel Resource Assessment that took up the second day of the Fifth Task Force meeting, Milbrandt presented key findings from the draft report while others provided additional information for inclusion in the final version. Presentations were offered by workshop participants on biofuel resource assessments in Australia, Canada, Indonesia, Japan, Malaysia, New Zealand, Russia, and Chinese Taipei. Information from these presentations was incorporated in a revised draft report after the meeting, and a final report should be issued to the APEC Secretariat in November. A guest presentation was also provided on biofuel resources from sugarcane in Brazil. The Biomass Inventory Mapping and Analysis Tool used in Canada was demonstrated as well. Copies of the presentations were posted on the website at www.biofuels.apec.org.

The final project report was issued in December 2008, distributed to Task Force members, and made available through the Task Force website to the general public. The findings were also presented to participants in the APEC Automotive Dialogue in Seoul and the Biomass 2009 Conference in Washington in March 2009.

There is a substantive evaluation for almost every APEC economy, including estimates of the portion of conventional petroleum demand for transport that might potentially be displaced. Many economies have surprisingly sophisticated capabilities to map biofuel

resources using geospatial satellites, which could be applied to help ensure that future biofuels development is sustainably focused on existing cropland.

The key finding is that second-generation biofuels from farm and forest residues could potentially displace two-fifth of gasoline use and one-fifth of crude oil imports in the APEC region as a whole. A corollary finding is that first-generation resources from conventional food crops have far less long-run potential. Even if rising crop yields made it possible to use the equivalent of 20 percent of today's grain production for biofuels over time, first generation feedstocks could displace only about 5 percent of crude oil imports in the region. So the second generation potential is several times larger than the first generation potential.

But of course, there are substantial variations among economies. In land-poor economies like Japan, Korea and Chinese Taipei, the second-generation ethanol potential amounts to less than 2 percent of crude oil imports. In the United States, with vast agricultural output but an equally enormous appetite for transport fuel, the second generation potential from farm and forest residues amounts to about 9 percent of crude imports – substantial but not immense. In quite a few economies, as varied as Australia, Canada, New Zealand, the Philippines and Thailand, the crude displacement potential from such residues is in a moderate range between 17 and 26 percent. In Indonesia and Malaysia, with large agricultural sectors and modest demand for transport fuel, the estimated potential is 51 percent and 59 percent, respectively. In China, the potential is estimated at nearly 90 percent, but this will decline as transport fuel demand continues its rapid upward trend.

APEC Biofuels Projects Completed in 2009 and 2010

To progress the work on resource assessment, several studies that were started with APEC support in 2008 or 2009 were completed in 2009 or 2010:

- An Assessment of Biomass Resources from Marginal Lands assesses the potential for production of “second-generation” feedstocks like jatropha and grasses on lands which are poorly suited to conventional agricultural crops.
- An Assessment of Biomass Resource Elasticity examines how technological advancements in agriculture may stimulate greater output of biofuel feedstocks, including greater yields of both crops and associated farm residues, over time.
- A Study of Employment Opportunities from Biofuel Production examines how biofuel production can create jobs for both men and women in APEC economies.
- A project on biofuel economics shows how the costs of ethanol and biodiesel from various feedstocks fluctuates with feedstock costs and compares with the cost of conventional gasoline and diesel over the period from 2006 through 2009.
- A project on sustainable biofuel development practices catalogues a variety of activities in a wide range of APEC economies including planning and research, regulatory and policy initiatives, voluntary programs and initiatives, and monitoring.

Assessment of Biomass Resources from Marginal Lands in APEC Economies

The project aims to understand how the biofuel resource potential in APEC economies may be augmented through the development of marginal and underutilized lands that are poorly suited to conventional agricultural crops (due to limited water, poor soil quality and other factors) but well suited to the production of non-food biofuel feedstocks such as jatropha (for biodiesel) and grasses (for ethanol). It should also build the capacity of developing APEC economies to assess the potential for additional biofuels production from such lands.

APEC economies have large amounts of marginal land that is underutilized but holds potential for the production of nonfood biofuel feedstocks such as jatropha and grasses. However, the amounts of such land in most economies had not been systematically assessed. The project provides a clearer picture of the marginal land available to biofuel resource production throughout the APEC region, and thus a better sense of the potential of biofuels to limit the upward pressure on oil prices and growing oil import dependency.

The project was approved by the APEC Budget and Management Committee in August 2007 with a \$45,000 grant from the APEC Support Fund. Pursuant to an RFP issued in early 2008, the National Renewable Energy Laboratory in the United States was chosen to perform the work. Anelia Milbrandt of NREL was the lead project consultant. The final project report was issued in October 2009 for posting on the APEC website.

Marginal lands are defined as lands with poor climatic or physical characteristics that make them difficult to cultivate for conventional crops. Examples of such characteristics include limited rainfall, extreme temperatures, low-quality soil, and steep slopes. The study examined twelve types of marginal lands according to a system developed by the United Nations Food and Agriculture Organization (FAO). Then, using a Geographic Information System (GIS) to exclude protected areas and other environmentally sensitive lands, the study estimates that some 4 million square kilometers (or 400 million hectares) of marginal lands are available in the APEC region, representing 6.5 percent of the total land area. Total annual biomass resource potential on these marginal lands is estimated at some 1.3 billion tonnes of biomass, which converts into 540 billion liters of ethanol or 260 million tonnes of gasoline equivalent. Since APEC uses about 621 million tons of gasoline and imports about 1.3 billion tons of crude oil, ethanol potential from marginal lands could displace two-fifths of the region's gasoline consumption or one-fifth of its crude oil imports. By coincidence, this potential is similar in size to the potential estimated in the earlier NREL study of resource potential from farm and forest residues. However, there are caveats associated with the density of feedstock that could be grown on marginal lands; since the yields on most such land are sparse, large portions of the potential may not be well-suited to planting and harvesting on a cost-effective basis.

Assessment of Biomass Resource Elasticity in APEC Economies

This project shows how biofuel resource potential could be affected by the market price of biofuel feedstocks and the application of available techniques to boost output. With

higher feedstock prices, it becomes economical to farm more intensively, with more careful irrigation, using more expensive and higher-yielding seed. This should lead to greater production potential, easing tradeoffs between food and fuel production.

This project was approved by the APEC Budget and Management Committee in October 2007 with a \$45,000 grant from the APEC Support Fund. Pursuant to an RFP issued in early 2008, three professors from the Center for Agriculture and Rural Development (CARD) at Iowa State University were selected to perform the work. The project report was completed in November 2009.

The initial phase of the project involved a literature review, which reveals that crop yields are a function of a variety of economic, environmental and technological variables. Factors which have a positive effect on crop yields include land improvements, conservation tillage, denser planting, earlier planting, irrigation, pest control, weed control, fertilizer use, farm programs, and R&D investments in new plant varieties. Factors that have a negative effect on crop yields include land degradation (such as through soil loss, soil compaction, or loss of soil fertility) and reduced rainfall. Several studies have shown a substantial and statistically significant relationship between feedstock prices and crop yields, presumably because such factors can boost such yields.

The study indicates that several technological factors can substantially boost biofuel yields over time for a variety of crops in a wide range of economies. These factors include agricultural inputs such as fertilizer and advanced, high-yielding seed. Yield trends are reported for several key conventional biofuel feedstocks, including corn, sugar, soy, and palm, for almost every APEC economy. From 1998 to 2008, the average yield increased 3.2 percent per annum for corn (the most common feedstock for ethanol) and 2.2 percent per annum for palm oil (the main feedstock for biodiesel) in APEC.

Estimates are then made of the potential for increasing yields over time, which could raise the availability not only of first-generation grain feedstocks over and above food requirements, but also of associated farm residues for second-generation production of ethanol from lignocellulose. The 2008 Survey of Biofuel Resource Assessments, cited above, estimated that ethanol from currently available crop residues could potentially displace about 33 percent of gasoline consumption. Thus, a 10 percent increase in average APEC crop yields over a 10 year period – well within the trends of recent decades – could potentially displace an additional 3.3 percent of gasoline consumption.

Study of Employment Opportunities from Biofuel Production in APEC Economies

This project aims to understand how the expanding markets for biodiesel and ethanol for transport fuel may expand employment opportunities for men and women in APEC economies. The focus is on how biofuel production may boost employment in the farm sector (which raises the feedstocks for production) and the biofuel sector (which converts the feedstocks to biodiesel and ethanol) and may thereby advance rural development goals.

Various APEC economies are aware that expanded biofuel markets may stimulate employment opportunities, but not of the extent that a given amount of biofuel production will boost the farm and/or biofuel sectors. The project should give energy experts, agricultural economists, labor economists, and officials in energy, agriculture and economy ministries a clearer picture of the potential of expanded biofuels markets to boost employment in the farm and biofuel sectors of APEC economies.

This project was approved by the APEC Budget and Management Committee in October 2007 with a \$45,000 grant from the APEC Support Fund. Pursuant to an RFP issued in early 2008, IBM Global Business Services Canada and Doyletech were chosen to perform the work. The project report was completed in November 2009.

The project assesses employment arising from ethanol and biodiesel plants, as well as related employment in the farm sector of APEC economies. This involves calculations of jobs created per million liters per year of biofuels production. It also involves the synthesis of estimates of “multiplier effects” of biofuels production on other economic activity, as well as opportunity costs that might occur through loss of employment in oil production and refining sectors when oil is replaced by biofuels. Biofuels employment models were built to give quantitative projections of employment opportunities associated with bioethanol and biodiesel production from various agricultural feedstocks.

The project report finds that some 1.1 jobs per million liters per year (jpMLy) of output are generated for production of ethanol from corn (as in the United States), 5.1 jpMLy for production of ethanol from sugar cane (as in Brazil), 3.5 jpMLy for production of biodiesel from soybean oil (as in the United States), and 73.3 jpMLy for production of biodiesel from palm oil (as in Malaysia or Indonesia). Considering current production levels of some 38 billion liters per annum for ethanol and 5.8 billion liters per annum for biodiesel, these factors translate to some 45,000 jobs in ethanol production and 197,000 jobs in biodiesel production. Considering potential ethanol production from non-food feedstocks such as farm and forest residues, which the 2008 NREL work cited above estimates at over 509 billion liters per annum, these factors would imply an eventual potential for 2.4 million new jobs from such second-generation ethanol production.

Project on Implications of Biorefineries for Energy and Trade in the APEC Region

This project, which was undertaken by the Expert Group on New and Renewable Energy Technology under the APEC 21st Century Renewable Energy Development Initiative Collaborative IX, examined the benefits of biorefineries that can produce a variety of useful co-products in addition to biofuels, thereby helping to make biofuels more economically viable in the marketplace. The objective was to provide APEC decision makers with recent advances in biorefinery development. A workshop was held in Chinese Taipei in October 2009, in conjunction with the 33d meeting of EGNRET, to discuss the future of biorefineries from the perspectives of technology, economics, market penetration, standards and regulations, and trade opportunities. A report has been prepared to integrate and synthesize the information developed in the workshop. It is available on the EGNRET website at: <http://202.168.200.38/reports/index.html>

The project, led by Chinese Taipei, was approved by the APEC Budget and Management Committee in October 2007 with a \$50,000 grant from the APEC Support Fund.

Biofuel Feedstock Costs, Technology and Economics

This project aims to expand, refine and update the analysis of biofuel economics that was presented in the Biofuels Task Force Report to the 8th Energy Ministers Meeting (EMM-8). That analysis found that biofuels from a variety of feedstocks are cost-competitive with fuels derived from petroleum. But costs of conventional feedstocks have fluctuated widely, as have the costs of petroleum products with which biofuels compete, so the project will update the analysis with current and projected feedstock costs and petroleum product costs. And technology for biofuels from non-food feedstocks is advancing rapidly, so the project will update the analysis with the latest cost assumptions for such second-generation biofuels.

In October 2008, the project received \$50,000 in support from the APEC Operating Account. An RFP was issued in March 2009, and five competing bids were submitted. In June 2009, a contract was awarded to BBI International. A draft report was provided in March 2010, discussed at the Sixth Task Force meeting in April, and finalized in November 2010.

Study of Sustainable Biofuel Development Practices

This project surveyed practices that allow biofuels to be planted and harvested in a sustainable fashion. The goal was to identify means for ensuring that biofuels development is cost-effective, does not compromise the security of food supplies, does not deplete available water resources, and does not result in a net increase of carbon dioxide emissions. Particular emphasis was given to practices which can avoid the destruction of carbon sinks such as savannahs and rain forests, which might result from the direct or secondary land use effects of feedstock production (from planting of the feedstocks themselves or the planting of other crops that the feedstocks have displaced).

Such practices may include the systematic documentation of the geographic source of biofuel feedstocks, the systematic tracking of land use in particular areas, the compensation of biofuels cultivation with reforestation efforts elsewhere, or other measures under consideration. As the implementation of such practices may entail significant financial and human resources, attention should be paid to the cost and practicality of different practices that have been proposed. Consideration was given to sustainability criteria being developed through multilateral fora like the Global Bioenergy Partnership (GBEP), the Roundtable on Sustainable Palm Oil (RSPO), and the Roundtable on Sustainable Biofuels (RSB), as well as within individual APEC economies.

The project received \$80,000 from the APEC Operating Account in July 2009. Pursuant to an RFP in August 2009, three competing bids were received. A team was formed to evaluate the bids, and a contract was awarded to Winrock International in January 2010. The project report was completed in November 2010.

A Workshop on Sustainable Biofuel Development Practices was held as an integral part of the Sixth Task Force meeting on April 28, 2010. Presentations on sustainable development practices were made by the delegates from Australia, Japan, Malaysia, Philippines, Chinese Taipei and United States. Several key conclusions were noted:

Land requirements for biofuel production can be significantly reduced – perhaps by as much as half - through intensified efforts to boost biofuel feedstock yields. It is estimated that palm oil yields could double from 4 to 8 tons per hectare in Malaysia, while sugarcane yields could nearly double from 70 to 136 tons per hectare in the Philippines. Among the key technological options for doing so are the use of higher-yielding seed, the use of drip irrigation, no-till cultivation, and crop rotation. Among the key institutional options for bringing these technologies to market are improved agricultural extension services. An associated option is conservation to reduce fertilizer requirements, which not only raises yields, but reduces costs and emissions of the greenhouse gas nitrous oxide.

Land use regulation can also play a significant role in ensuring sustainable biofuels development. A key approach is documentation to encourage the planting of biofuel feedstocks on currently cultivated agricultural lands, degraded lands and marginal lands, which typically incurs a carbon deficit of less than one year, and to rule out the new planting of biofuel feedstocks in rain forests and peat bogs. This is essential to biofuel export prospects, in view of pending requirements for certification that land for biofuel feedstocks was already planted at the end of 2007 (in the United States) or that no high-carbon-stock land was converted as of the start of 2008 (in the European Union).

A third element of sustainable biofuels development in APEC is the encouragement of second generation biofuels through R&D efforts to reduce costs and programs to encourage the collection and aggregation of feedstocks such as farm and forest residues, abundant in agricultural economies and present even in “land-poor” economies.

The survey report identifies several types of planning and research activities to promote sustainable biofuels development. These include geophysical mapping to assess the sustainability of land and water use for biofuel production in different places, life cycle assessments of greenhouse gas emissions, development of more sustainable biofuel feedstocks (requiring less land or water, for example), and sustainable biofuel plans.

The survey also identifies a variety of regulatory and policy initiatives to support sustainable biofuels production. One approach, adopted in Australia, Japan and the United States, is to have legally mandated volumes for sustainable biofuels. A complementary approach, used in China and the United States, is to adopt greenhouse gas reductions for all fuels, including biofuels. A third approach, used in China, Hong Kong, Indonesia, Korea, Malaysia and Mexico, is to have sustainability regulations for all biofuels.

Perhaps the most interesting aspect of the survey relates to a wealth of voluntary programs and initiatives. Several of these initiatives aim to reduce land use change and greenhouse gas emissions. They do so by various means including through greater use of underutilized marginal or degraded lands, integration of crop and animal cultivation to reduce total land

requirements, improved productivity of land under cultivation, capturing and reusing waste streams from biofuel production, and reducing fertilizer requirements for biofuel feedstocks.

APEC Biofuels Projects Completed in 2011

Two additional projects were completed during 2011.

- A project on the resource potential of algae for biofuels was approved in May 2009.
- A project on biofuel infrastructure strategies was approved in July 2009.

Resource Potential of Algae for Biodiesel Production in the APEC Region

This project used a common methodology across APEC economies to assess the amount and location of algal biomass in the APEC region that could be suitable for the production of biodiesel. Algal biomass offers the possibility of a sustainable, low GHG emissions feedstock that is widely available, grows rapidly, yields more biofuel per hectare than oil plants, contains no sulfur or other toxic substances, is highly biodegradable; does not involve destruction of natural habitats, and does not compete with food production on agricultural land. Microalgae contain up to 40 percent lipids by weight and can be grown in many places such as bogs, marshes, swamps, salt lakes, wastewater treatment ponds, and deposits of animal waste. Algae could thus provide a major resource potential of biofuels to displace petroleum.

In May 2009, the project received \$50,000 in support from the APEC Operational Account. An RFP was issued in August 2009, and a joint bid was received from a consortium of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia and Sandia National Laboratory (SNL) in the United States. The consortium was awarded a contract to perform the work, but the laboratories were reluctant to sign the standard APEC contract due to legal concerns about the intellectual property provisions, in which the call for background information associated with the work was interpreted by lawyers as permitting access by to all the intellectual property the laboratories have ever generated. Finally a solution was reached in February 2011 whereby a contract was signed with a consulting firm, Temaplan, with which the CSIRO researcher, David Batten, is affiliated.

Three alternative methodologies for assessing algal biofuel resources were outlined. Estimates of algal biofuel potential were made in parallel for a variety of APEC economies using each of these methodologies, and results were reported in December 2011.

One way of looking at algal resource potential is to look at human waste and animal waste as a nutrient source. If you look at the total waste available in APEC economies within 15 degrees of the equator (where sunlight is adequate for algae to grow efficiently), there are roughly 20 Mt of waste available – which could yield about 204 Mt of algae. However, adjusting for the practical availability of flat, low-cost land adequate energy and transportation infrastructure, it was estimated that less than 30 percent of this potential could be realized – 58 Mt of algae or 20 billion liters of biodiesel per annum. This could displace 23 percent of automotive diesel fuel in Indonesia, 16 percent in Viet

Nam, 14 percent in Thailand, 11 percent in China, 9 percent in the Philippines, 8 percent in Mexico, and 7 percent in Malaysia, or 5 percent in the APEC region as a whole. But further considering the incomplete collection of animal and human wastes, more like 21 Mt of algae would likely be available, displacing just 2 percent of fossil diesel in APEC.

A second way of looking at algal resource potential is to look at production from waste water around existing electric power plants. This could yield up to 211 Mt of algae or roughly 71 billion liters of biodiesel per annum. But if variations in temperature are considered, a more practical estimate would be 113 Mt of algae or 38 billion liters yearly. This would be enough to displace 70 percent of automotive diesel use in Papua New Guinea, 20 percent in Indonesia and Peru, 13 percent in Viet Nam, 12 percent in Hong Kong and Thailand, 10 percent in Australia and China, 8 percent in the Philippines and Singapore, and 7 percent in Brunei, Mexico, the United States and APEC as a whole.

Still a third way is to assume that algae could be grown and collected almost anywhere there is sufficient land and water – without the need for a waste stream. This could yield a much larger potential –assuming the right strains of algae could be developed and provided that sufficient nutrients could be sourced and then recycled in a practical and cost-effective fashion. The promise is greatest in economies with a lot of marginal coastal land such as Australia, Chile, Indonesia, Mexico, Russia and United States.

A workshop was organized on September 12, 2011 to explain key outputs of the study during the third set of 2011 APEC Senior Officials Meetings in San Francisco, California. Workshop papers were posted on the website of the Expert Group on New and Renewable Energy Technologies at www.egnret.ewg.apec.org/workshops/AlgalBiofuels/index.html.

Biofuel Transportation and Distribution Infrastructure Strategies

Project synopses on biofuels transportation and distribution infrastructure were developed by the Task Force Chair in cooperation with the APEC Automotive Dialogue and endorsed by the Dialogue at its meeting of 10-12 September 2008. The two synopses were combined into a single synopsis, endorsed at EWG-37. A full-scale project proposal to look at effective strategies for transportation and distribution infrastructure was drafted by the Chair for consideration by the Auto Dialogue at its meeting in Seoul on March 31 – April 1, 2009, and the Auto Dialogue endorsed this proposal.

The transportation portion of the project develops a set of criteria for evaluating options to expand the transportation infrastructure for biofuels. Among these criteria are the size of current biofuel mandates, projected biofuels production from different feedstocks, the degree to which such production is geographically concentrated or dispersed, the extent to which current and future biofuel supply can be absorbed by local markets for transport fuel, the quality of existing transportation (road, rail and ship/barge) networks, the likely durability of supply and demand at the sending and receiving ends of proposed pipelines, and the cost of constructing long-distance ethanol pipelines compared with the costs of conventional transportation modes such as trucks, rail, ships and barges.

The distribution component of the project briefly considers approaches to facilitate the expansion of distribution infrastructure for ethanol and biodiesel. One approach is the formation of government-industry partnerships to identify regions where biofuel production is expected to be concentrated and where targeted expansion of biofuel filling stations could help demand and supply to evolve in a systematic, reinforcing fashion. Other approaches might include financial incentives for the construction of biofuel filling stations and the planning of major highway projects that incorporate such filling stations.

In July 2009, the project received \$80,000 from the APEC Operating Account. An RFP was issued in August 2009, and three competing bids were received. A contract was signed by BBI International in January 2010, and the project was completed in May 2011.

For each of the conventional biofuel transport modes – truck, rail, barge – the study looked at key cost components and translated them into a cost per liter of biofuel transported over a range of distances. Some of the costs are fixed – regardless of distance – such as loading and unloading. These are relatively low for trucks and high for barges and rail – tending to favor trucks for shorter trips (shorter transport routes to market). Other costs are time-dependent or distance-dependent. Trucking costs are time-dependent – due to wage costs for drivers, while the labor component per unit of fuel transported is much lower for barge or rail – tending to favor barge or rail for longer transport distances. Distance-dependent costs – per liter per kilometer – are only about half as high for rail as for trucks or barges, so rail is especially favored for very long distances.

Using North America as an example, it was found that:

- Trucks are most suitable for moving biofuels less than 500 km to market.
- Barge transport is competitive with rail for distances of up to 1,500 or 2,000 km if there is not a significant intermodal component (with a major portion of the distance covered by trucks)
- For distances greater than 1,500 or 2,000 km, rail has a growing advantage.

These costs of conventional options were then compared with the cost of pipeline transport to assess where a dedicated biofuel pipeline might make sense. In a recent report by the U.S. Department of Energy, it was found that in view of the significant scale economies associated with pipelines, a minimum transport volume of 15 billion liters would be needed for a financially and economically viable ethanol pipeline from the mid-continental U.S. corn belt to the population centers of the U.S. east coast. Pipeline transport at this volume would cost about 4 or 5 cents per liter for shipment over a distance of 2,700 km. This compares to 5 or 6 cents per liter for transport by rail.

On the basis of such cost comparisons, the study found that a dedicated ethanol pipeline would likely make sense only for economies or groups of economies with an aggregate ethanol supply of 16 to 20 billion liters per year. Considering current biofuel mandates and second generation production potential from nonfood feedstocks such as farm and forest residues, the likely candidates would be China (and neighbors in Asia) and the United States (and neighbors in North America).

Messages for APEC Energy Ministers

Participants in the Task Force meetings discussed key messages that might be conveyed to APEC energy ministers from the Task Force studies that have been completed so far. The Chair suggested several key messages from each of the studies completed:

Survey of Resource Assessment and Assessment Capabilities:

- Second-generation biofuels from farm and forest residues could potentially displace two-fifths of gasoline use and one-fifth of crude oil imports in the APEC region.
- First generation resources from conventional food crops have far less potential. Even if rising crop yields made it possible to use the equivalent of 20 percent of today's grain production for biofuels over time, first generation feedstocks could displace only about 5 percent of crude oil imports in the region.

Survey of Biofuel Resources on Marginal Lands:

- Some 400 million hectares) of marginal lands are available in the APEC region, representing 6.5 percent of the total land area.
- Annual biomass resource potential on these marginal lands is some 1.3 billion tonnes of biomass, 540 billion liters of ethanol, or 260 million tonnes of gasoline equivalent.
- Since APEC uses about 621 million tons of gasoline and imports about 1.3 billion tons of crude oil, ethanol potential from marginal lands could displace two-fifths of the region's gasoline consumption or one-fifth of its crude oil imports.
- By coincidence, this potential is similar in size to the potential estimated in the earlier NREL study of resource potential from farm and forest residues. But since yields on most marginal lands are sparse, large portions of the potential may not be well-suited to planting and harvesting on a cost-effective basis.

Study of Biofuel Resource Elasticity:

- High-yielding seed and fertilizer can substantially boost biofuel yields over time for a variety of crops in many APEC economies.
- From 1998 to 2008, the average yield increased 3.2% per year for corn (the most common feedstock for ethanol) and 2.2% per year for palm oil (the main feedstock for biodiesel) in APEC.
- Increasing yields over time could raise the availability not only of first-generation grain feedstocks over and above food requirements, but also of associated farm residues for second-generation production of ethanol from lignocellulose.

- Since the 2008 Survey of Biofuel Resource Assessments estimated that ethanol from currently available crop residues could potentially displace about 33% of gasoline consumption, a 10% increase in average APEC crop yields over a 10 year period – well within the trends of recent decades – could potentially displace an additional 3.3% of gasoline consumption.

Study of Biofuel Employment Opportunities:

- Some 1.1 jobs per million liters per year (jpMLy) of output are generated for production of ethanol from corn (as in the United States), 5.1 jpMLy for production of ethanol from sugar cane (as in Brazil), 3.5 jpMLy for production of biodiesel from soybean oil (as in the United States), and 73.3 jpMLy for production of biodiesel from palm oil (as in Malaysia or Indonesia).
- Considering current production levels of some 38 billion liters per annum for ethanol and 5.8 billion liters per annum for biodiesel, these factors translate to some 45,000 jobs in ethanol production and 197,000 jobs in biodiesel production.
- Considering potential ethanol production from non-food feedstocks such as farm and forest residues, which the 2008 Resource Survey estimates at over 509 billion liters per annum, these factors would imply an eventual potential for 2.4 million new jobs from such second-generation ethanol production.

Study of Biofuel Feedstock Costs, Technology and Economies

- For the period from 2005 through 2009,
 - Brazilian ethanol with attached cogeneration facilities consistently had a lower production cost than gasoline.
 - U.S. corn ethanol had a lower cost than gasoline at times.
 - For brief periods, low palm oil prices and high diesel prices made biodiesel cost competitive, but it is hard for palm biodiesel to compete when palm oil prices are high.
 - A cellulosic ethanol biorefinery, with capital costs and ethanol yields along the lines anticipated for future commercial plants using the best available technologies, would have been cost competitive with gasoline.

Study of Algae for Biodiesel Production

- Algae could potentially displace 7 percent or more of automotive biodiesel needs.

Looking Ahead

The Biofuels Task Force completed its activity at the end of 2011. Future studies on biofuel resource potential, costs, and trade issues may be conducted as needed under the auspices of the Expert Group on New and Renewable Energy Technologies.