The Unexpected Challenges of Using Energy Intensity as a Policy Objective: Examining the Debate over the APEC Energy Intensity Goal

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ABSTRACT

Energy intensity (energy demand per unit of economic output) is one of the most widely used indicators of energy efficiency in energy policy discussions. Yet there has been surprisingly little examination of the general properties and limitations of energy intensity. A recent policy discussion within the APEC community over APEC's region-wide energy intensity improvement goal clearly exposed some of these properties and limitations. In particular, there were three significant findings along the way that were unexpected by most of the participants, including the author. These findings may be of interest to anyone who is studying international trends in energy efficiency improvement, or who is seeking to define international indicators of energy efficiency improvement.

The three findings are as follows: 1) Energy intensity improvement is happening surprisingly quickly, but not quickly enough to meet the world's energy challenges. 2) It is difficult to find a definition of energy intensity that can make it suitable for use as an indicator of regional energy efficiency. 3) Whether the GDP's of individual economies are converted to common currency using market exchange rates or purchasing power parity (PPP) can dramatically change regional energy intensity improvement calculations.

Introduction

Energy intensity (energy demand per unit of economic output) is one of the most widely used indicators of energy efficiency in energy policy discussions. Yet there has been surprisingly little examination of the general properties and limitations of energy intensity.

A recent policy discussion within the APEC community over APEC's region-wide energy intensity improvement goal clearly exposed some of these properties and limitations. In particular, there were three significant findings along the way that were unexpected by most of the participants, including the author. These findings may be of interest to anyone who is studying international trends in energy efficiency improvement, or who is seeking to define international indicators of energy efficiency improvement.

The three findings are as follows:

Finding #1 – Energy intensity improvement is happening surprisingly quickly, but not quickly enough to meet the world's energy challenges.

Finding #2 – It is difficult to find a definition of energy intensity that can make it suitable for use as an indicator of regional energy efficiency.

Finding #3 – Whether the GDP's of individual economies are converted to common currency using market exchange rates or purchasing power parity (PPP) can dramatically change regional energy intensity improvement calculations.

Suehiro[1] provides a discussion of some of the general properties of energy intensity as an indicator, focusing especially on the choice of market exchange rates vs. PPP highlighted in our Finding #3. However, the existing literature on the properties of energy intensity is heavily focused on building models to decompose energy intensity improvement into various explanatory factors.[2] Perhaps more relevant to this paper is the literature on a related indicator, *emissions* intensity (emissions per unit of economic output), since the properties and limitations of emissions intensity appear to have been more widely examined,[3] and some of these properties also apply to energy intensity. In particular, this literature finds that there is a tendency for emissions intensity to decline over time with improvements in economic productivity and shifts away from energy-intensive industry. However, emission intensities can decline even as emissions *rise*. This literature also points out that improving emissions intensity is attractive to policymakers as a policy goal because, unlike an absolute emissions goal, emissions under an intensity goal can vary with economic activity. An emissions intensity goal is therefore less likely to be perceived as limiting growth, an especially critical property for developing countries.

Background on APEC's Energy Intensity Goal

Asia-Pacific Economic Cooperation (APEC)[4] is a multi-lateral organization of 21 Pacific Rim economies whose primary mission is to "to support sustainable economic growth and prosperity in the Asia-Pacific region".[5] APEC member economies have a combined population of about 2.7 billion people and account for about 54 percent of world GDP.[6] Unlike some multi-lateral organizations, APEC operates on an entirely voluntary basis—there are no binding commitments and no penalties for non-compliance. Compliance is achieved through "mutual discussion and mutual support in the form of economic and technical cooperation".[7] Because APEC is privileged to have the People's Republic of China, Chinese Taipei, and Hong Kong, China all as members, APEC refers to its members as 'economies' rather than 'countries'.

APEC promotes regional cooperation in a wide variety of areas related to economics and trade, including energy. One of APEC's key energy initiatives is an APEC-wide regional goal for energy intensity reduction. Such a goal was first agreed to at the APEC Leader's Meeting in Sydney, Australia in September 2007. The annual APEC Leader's meetings bring together the Presidents, Prime Ministers, or other political leaders of each of the APEC economies. In their *Sydney APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development,* the Leaders announced that they would

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[1] Shigeru Suehiro, "Energy Intensity as an Index of Energy Conservation: Problems in International Comparison of Energy Intensity of GDP and Estimate Using Sector-Based Approach", *IEEJ Energy Journal*, 2007, available in PDF at http://eneken.ieej.or.jp/en/data/pdf/400.pdf.

[2] Two recent papers with good reviews of this literature are Ian Sue Wing, "Explaining the Declining Energy Intensity of the U.S. Economy", *Resource and Energy Economics,* Volume 30, Issue 1, January 2008, pp. 21-49, available in PDF at http://people.bu.edu/isw/papers/energy_intensity.pdf and Chunbo Ma and David I. Stern, "China's Changing Energy Intensity Trend: A Decomposition Analysis", *Energy Economics,* Volume 30, Issue 3, May 2008, pp. 1037-1053, available in PDF at http://www.economics.rpi.edu/workingpapers/rpi0615.pdf.

[3] See, for example, William Pizer, "The Case for Intensity Targets", Resources for the Future Discussion Paper 05-02, 2005, http://rff.org/Documents/RFF-DP-05-02.pdf; Timothy Herzog, Kevin A. Baumert, and Jonathan Pershing, "Target: Intensity, An Analysis of Greenhouse Gas Intensity Targets", World Resources Institute Report, November 2006; Ian Sue Wing, A. Denny Ellerman, Jaemin Song, "Absolute vs. Intensity Limits for CO2 Emission Control: Performance Under Uncertainty", MIT Joint Program on the Science and Policy of Global Change Report No. 130, January 2006, http://hdl.handle.net/1721.1/31204.

[4] See www.apec.org.

[5] See http://www.apec.org/About-Us/About-APEC/Mission-Statement.aspx.

[6] See APEC Secretariat, *APEC at a Glance* brochure, November 2010, http://publications.apec.org/publication-detail.php?pub_id=1077, p. 2.

[7] Ibid, p. 2.

> "highlight the importance of improving energy efficiency by working towards achieving an APEC-wide regional aspirational goal of a reduction in energy intensity of at least 25 per cent by 2030 (with 2005 as the base year)"[8]

However, at their subsequent meeting in Honolulu in November, 2011, the Leaders adopted a more ambitious goal of aspiring "to reduce APEC's aggregate energy intensity by 45 percent by 2035".[9]

Between these two events, there was extended discussion within the APEC community, focusing especially on APEC's Energy Working Group (EWG), as to whether the goal should be revised and, if so, what the revised goal should be. The Asia Pacific Energy Research Centre (APERC) had the privilege of providing much of the analysis that supported this discussion. APERC is an independent research institute, generously sponsored by the Japanese government, which supports the energy-related activities of APEC through both research and cooperative efforts to promote energy efficiency and low-carbon energy supply.[10]

Because of the three findings discussed above, the analysis of APEC's energy intensity target was an especially interesting and challenging one. Each of these findings became a focus of discussion, at least for a time, within the EWG. Since the findings revealed themselves chronologically in the sequence listed above, this paper will be presented as something of a memoir of APERC's involvement with the analysis of APEC's energy intensity goal, and challenges posed by each finding.

Setting the Scene

The author had no involvement in the discussions leading-up to the Sydney Declaration and the original 25% APEC-wide aspirational energy intensity reduction goal. However, answers to a two obvious questions about the Sydney Declaration, as best the author has been able to discern, are probably appropriate to set the scene.

- *Why did they choose an energy efficiency goal rather than an emission reduction goal?* Participants in the EWG discussions prior to the Sydney Declaration have told the author that there was some consideration given to having an emissions-related target, such as emissions intensity. However, there were objections on the grounds that APEC should not be competing with or circumventing the global climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), and should properly keep its focus on energy efficiency.
- *Why did they choose 25%?* 25% in 25 years is certainly a round number that sounds impressive. While some economies may have done analysis of the goal for their own internal purposes, participants in the EWG discussions prior to the Sydney Declaration have told the author that little analysis was discussed regarding the figure to be chosen.

Finding #1 – Energy intensity improvement is happening surprisingly quickly, but not quickly enough to meet the world's energy challenges.

APERC first looked into the question of the adequacy of the 25 percent goal in its November 2009 *APEC Energy Demand and Supply Outlook 4th Edition*[11]. The *APEC Energy Demand and Supply Outlook* is a publication that APERC has historically produced every two or three years containing long-run (25 year) projections of APEC's energy demand and supply situation.

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[8] See http://www.apec.org/Meeting-Papers/Leaders-Declarations/2007/2007_aelm/aelm_climatechange.aspx.
[9] See http://www.apec.org/Meeting-Papers/Leaders-Declarations/2011/2011_aelm.aspx.
[10] See http://www.ieej.or.jp/aperc/about_aperc.html.
[11] See http://www.ieej.or.jp/aperc/publications.html.

APERC's projections in the *Outlook 4th Edition* indicated that under business-as-usual, assuming that energy intensity is defined as primary energy supply per US dollar of GDP at purchasing power parity, the goal could be easily be met under business-as-usual assumptions. By 2030, the projections indicated that APEC region primary energy supply will increase by about 45% compared to 2005, while GDP will increase by about 235%. As shown in Figure 1 below, the net impact will be a decrease in energy intensity of about 38%.

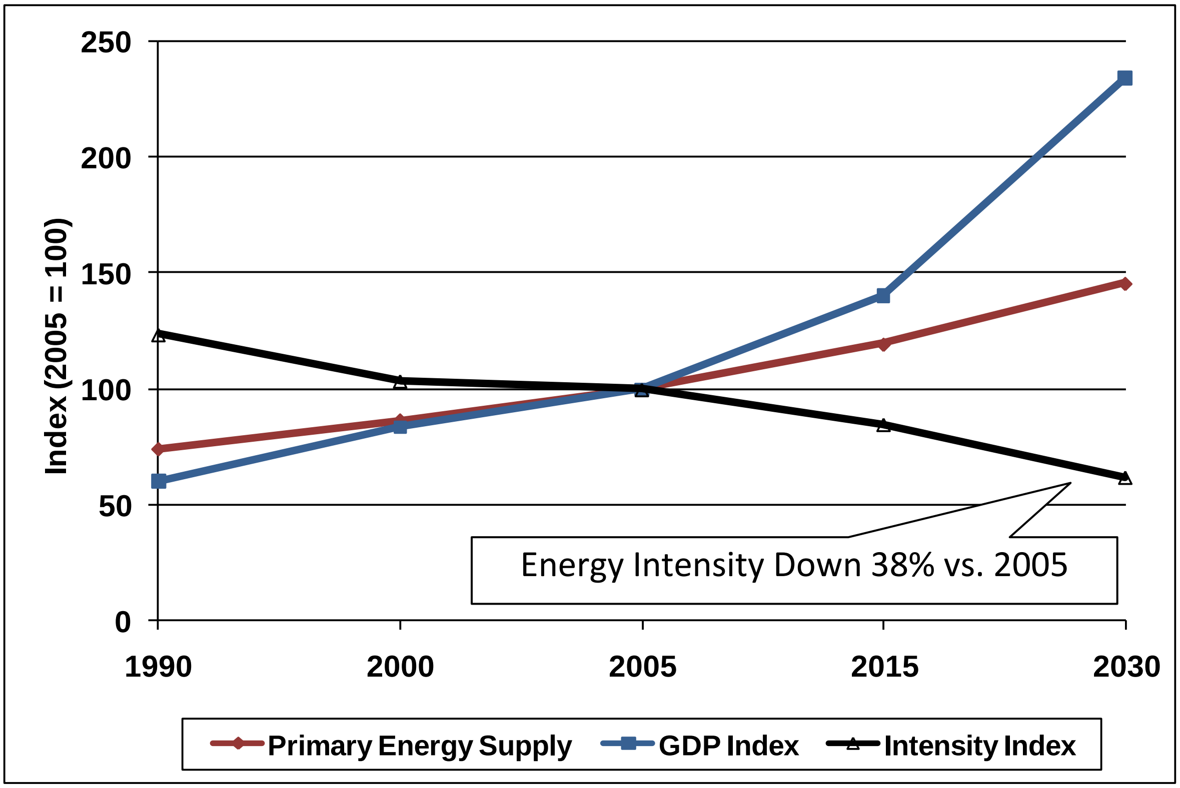

Figure 1 Projected APEC Business-As-Usual Primary Energy Demand, GDP, and Energy Intensity

While it may be good news that energy intensity improvement appears to be happening so quickly, the *Outlook 4th Edition* also had some bad news: even with this improvement in energy intensity, over the 2005-2030 time period, APEC's oil imports from outside the APEC region were likely to grow by about 70%, while CO_2 emissions from fuel combustion were likely to grow by about 40%. Hence, the business-as-usual outlook raises serious concerns regarding both energy security and environmental sustainability.

Of course, there were concerns at first both inside and outside APERC as to whether these projections were really correct. Therefore, APERC undertook further analysis focusing on APEC's energy intensity goal, finally published in August 2010 under the title *Pathways to Energy Sustainability; Measuring APEC Progress in Promoting Economic Growth, Energy Security, and Environmental Protection.*[12]

It should be noted that energy intensity can be measured in two ways: *primary energy intensity* is primary energy (raw fuels before conversion to electricity or refining of crude oil) divided by GDP; *final energy intensity* is final energy (energy in the form it is finally used) divided by GDP. The APEC Leaders did not specify which measure they had in mind, so the *Pathways* Report considered both.

[12] See http://www.ieej.or.jp/aperc/publications.html.

The Pathways report presented three types of additional evidence which suggested that the conclusions of the *Outlook 4th Edition* were correct.

1. *The energy intensity of the APEC region has historically declined fairly steadily over the 25 years prior to 2005.* Between 1980 and 2005, the primary energy intensity of the region excluding Russia and Viet Nam (for which comparable data are unavailable prior to 1990) declined by 31%, an average annual rate of 1.5%. Over the same period, the final energy intensity of the region declined by 39%, an average annual rate of 1.9%. From 1990 to 2005, when data for all APEC economies is available, the primary energy intensity of the region declined by 20%, an annual average rate of 1.5%. Final energy intensity declined by 25%, an annual average rate of 1.9%. A continuation of a 1.5% decline over the next 25 years would bring an overall decline of around 31%, while a continuation of a 1.9% annual decline would bring an overall decline of around 38%, both comfortably exceeding the APEC Leaders' goal and not far from APERC's business-as-usual projection.
2. *Since 2005, energy intensity of the APEC region has continued to improve.* At the time the *Pathways* report was published, data were available only for 2006 and 2007, but they indicated an average annual reduction in primary energy intensity of 2.2 percent per year and an average annual reduction in final energy intensity of 2.3 percent per year, well above the historical trends discussed above. (Subsequently, data for 2008 and 2009 have become available. They indicate that with the onset of the economic crisis, the rate of APEC energy intensity improvement slowed in 2008 and almost stopped in 2009. Therefore, over the 2005-2009 time period, primary energy intensity improved at an average rate of 1.5% per year, while final energy intensity improved at an average rate of 1.6% per year.[13] Even at these rates, the 25% goal would be exceeded by 2030, and the 2008-2009 results are probably anomalous in any case.)
3. *A comparison of APERC's projections with those of other modeling efforts indicates a remarkable degree of similarity.* Projections of APEC energy intensity based on the results in the International Energy Agency's *World Energy Outlook 2008* indicated a 38% intensity improvement, almost exactly matching APERC's independent *Outlook 4th Edition* projection.[14] A comparison with the United States Energy Information Administration's *International Energy Outlook 2009* model results is slightly larger at 40% intensity improvement.[15] Hence, there are three independent modeling efforts that have arrived as essentially the same conclusion about APEC's projected business-as-usual intensity reduction. (A subsequent review of APERC's own *APEC Energy Demand and Supply Outlook 2006,* which was developed under a different APERC president and vice-president, and a mostly different research staff, and which used a different set of demand models and model assumptions from the *Outlook 4th Edition,* indicates that it projects a 39% improvement in primary energy intensity and a 38% improvement in final energy intensity by 2030. Hence there are actually four independent modeling efforts that have arrived as essentially the same conclusion about APEC's projected business-as-usual intensity reduction.)

The *Pathways* report also outlined an example of how a sustainable scenario for energy development in the APEC region could be achieved. The scenario shows how the energy sector in the APEC region could contribute towards

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[13] These results are APERC calculations based on historical energy data from the International Energy Agency and historical GDP data from HIS Global Insight.

[14] Additional non-published data on their model results were provided by the International Energy Agency to APERC to facilitate these calculations. The raw data is © OECD/IEA 2009, calculations by APERC. See http://www.iea.org/weo/2009.asp.

[15] These results are APERC calculations based on projections of energy demand and GDP published by the United States Energy Information Administration in their *International Energy Outlook 2009,* see http://www.eia.gov/forecasts/archive/ieo09/index.html.

limiting global warming to 2°C by limiting greenhouse gas concentrations in the atmosphere to 450 PPM of CO2-equivalent. This scenario would require a roughly 50% improvement in primary energy intensity by 2030, along with other measures to promote non-fossil energy as well as carbon capture and storage.[16]

An early draft of the *Pathways* report was published on the website of the APEC Energy Ministers meeting in Fukui, Japan, prior to the meeting in June 2010. At that meeting, the Ministers decided that a reconsideration of the 25% goal was needed. In their Fukui Declaration, the Energy Ministers directed the EWG to:

> "Assess the potential for reducing the energy intensity of economic output in APEC economies between 2005 and 2030, beyond the 25 percent aspirational goal already agreed by the APEC Leaders, with assistance from APERC, EGEDA [the APEC Expert Group on Energy Data and Analysis], and EGEEC [the APEC Expert Group on Energy Efficiency and Conservation]". [17]

Finding #2 – It is difficult to find a definition of energy intensity that can make it suitable for use as an indicator of regional energy efficiency.

The Ministers directed the EWG to reassess the goal, but what should the new goal be and exactly how should it be measured? Measurement turned out to be a surprising difficult question. As noted above, there are two commonly-used measures of economy-wide energy demand: primary energy and final energy. The two differ by the losses in energy transformation processes, especially electricity generation and refineries, which are included in primary energy but not included in final demand.

As noted above, the Sydney Declaration did not specify what measure of energy demand was to be used to calculate energy intensity. Nor does there appear to be any standard set by the International Energy Agency (IEA). The IEA's *World Energy Outlook* discusses intensity based on primary energy.[18] However, another IEA publication specifically devoted to the topic of energy indicators focuses throughout on energy intensity calculated using final energy.[19]

It is natural to assume that primary energy is the best measure to use for calculating energy intensity improvement, since it is the broader measure that can reflect improvements in electricity generation and refinery efficiency, as well as end-use efficiency. However, since various types of electricity generation have different levels of conversion efficiency, changing the mix of electricity generation can change the apparent overall efficiency of electricity generation[20], and such changes do not always align with the ultimate objectives of the APEC energy intensity goal.

This message was clearly driven home to the author several months after the Fukui Declaration in a discussion with an energy policy analyst from Hong Kong, China. The analyst explained that Hong Kong was considering a proposal

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[16] See Chapter 5 of the Pathways report at http://www.ieej.or.jp/aperc/publications.html. The Sustainable Scenario in the Pathways report was based on model results from the 450 Scenario of the International Agency's *World Energy Outlook 2009.* Additional non-published data on their model results were provided by the International Energy Agency to APERC to facilitate these calculations. The raw data is © OECD/IEA 2009, calculations by APERC. See http://www.iea.org/weo/2009.asp.

[17] See http://www.apec.org/Meeting-Papers/Ministerial-Statements/Energy/2010_energy.aspx.

[18] International Energy Agency, *World Energy Outlook 2011, http://www.iea.org/weo/,* see, for example, Figure 2.5.

[19] See International Energy Agency, *Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis,* http://www.iea.org/papers/2008/indicators_2008.pdf, see for example, p. 15.

[20] This point is a focus of Jacques Percebois, "Is the Concept of Energy Intensity Meaningful?", *Energy Economics,* Volume 1, Issue 3, July 1979, pp. 148-155, http://www.sciencedirect.com/science/article/pii/014098837990046X.

to build a nuclear power plant. He explained that Hong Kong, as a member of APEC, wanted to help APEC meet its energy intensity improvement goal, but when they did the calculations for the impact of the nuclear power plant, they showed that it would make Hong Kong's energy intensity increase, that is *get worse*. This did not seem right to him, since the nuclear plant would reduce Hong Kong's greenhouse gas emissions and reduce Hong Kong's dependence on imported fossil fuels, both goals that the APEC Leaders presumably wished to encourage with their energy intensity improvement goal. He asked me if his calculations were correct.

The answer is that his calculations are indeed correct, at least if primary energy is used to calculate energy intensity, due to a rather strange anomaly in the international standards for energy statistics. For fossil generation plants, the primary energy is obviously the fuel burned and the efficiency of the plant is the electrical energy output divided by the fuel energy input. For a nuclear plant, the definition of 'efficiency' is not so obvious, since the heating value of the nuclear fuel cannot be clearly established. So, for a nuclear plant, the primary energy is defined to be content of the steam leaving the reactor for the turbine, implying that the efficiency of the plant is the electrical energy output divided by the steam energy input.[21]

By this definition, the efficiency of a nuclear plant is typically relatively low. In 2009, the worldwide average efficiency of nuclear plants was about 33%.[22] Since many countries do not even keep statistics on the energy content of the steam produced in nuclear plants, the standard approach for estimating it in these cases is to impute it from the electricity output at an assumed efficiency rate of 33%.[23]

For geothermal plants, the principle is the same: the energy in the geothermal steam is the primary energy and the electricity produced is the final energy. However, for geothermal plants, because of the relatively low temperature of most geothermal steam, the worldwide average efficiency turns out to be an even more dismal 11%.[24] Again, since many countries do not keep statistics on the energy content of the geothermal steam produced, the standard approach for estimating it in these cases is to impute it from the electricity output at an assumed efficiency rate of 10%.[25]

Fossil fuel plant efficiencies are typically much higher—the worldwide averages were 36% for coal plants and 49% for natural gas plants in 2009.[26] Hence, when an economy converts from fossil fuel to nuclear or geothermal

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[21] See International Energy Agency, Organisation for Economic Co-Operation and Development, and Eurostat, *International Energy Statistics Manual,* 2004, http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/NRG-2004/EN/NRG-2004-EN.PDF, p. 22.

[22] This figure is the author's calculation based on worldwide statistics from the International Energy Agency's *Energy Balances of Non-OECD Countries 2011,* which shows a that nuclear plants had a primary fuel input of 703.2 mtoe, and an output of 2,696,765 GWh, or 231.88 mtoe, of electricity plus 0.52 mtoe of marketable heat for a total output of 232.4 mtoe.

[23] See International Energy Agency, Organisation for Economic Co-Operation and Development, and Eurostat, *International Energy Statistics Manual,* 2004, http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/NRG-2004/EN/NRG-2004-EN.PDF, p. 138.

[24] This figure is the author's calculation based on worldwide statistics from the International Energy Agency's *Energy Balances of Non-OECD Countries 2011,* which shows a that geothermal electricity and CHP plants had a primary fuel input of 55.931 mtoe, and an output of 66,672 GWh, or 5.73 mtoe, of electricity plus 0.23 mtoe of marketable heat for a total output of 5.96 mtoe.

[25] See International Energy Agency, Organisation for Economic Co-Operation and Development, and Eurostat, *International Energy Statistics Manual,* 2004, http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/NRG-2004/EN/NRG-2004-EN.PDF, p. 138.

[26] These figures are the author's calculations based on worldwide statistics from the International Energy Agency's *Energy Balances of Non-OECD Countries 2011,* which show a that coal electricity and CHP plants had a primary fuel

electricity generation, their generation efficiency will *decrease* and their primary energy intensity will increase (*get worse*). Note that this anomalous result does not apply to non-thermal types of renewable energies that are converted directly to electricity without the intermediate step of producing steam or heat, such as hydro, wind, and solar photovoltaics. For non-thermal renewables, the primary energy input is defined to be the same as the electricity output, effectively counting them as 100% efficient.[27] Since one might assume that low-carbon, non-fossil electricity generation, such as nuclear and geothermal, is something that the APEC Leaders would be seeking to promote, or at least not to discourage, with the APEC energy intensity goal, it is apparent that using primary energy to measure energy intensity does not align with their ultimate objectives.

An alternative to using primary energy to measure the APEC energy intensity goal would be to use final energy. This approach would give a clear measure of end-user energy efficiency, which is the focus of energy efficiency improvement efforts in many economies. However, it would not reflect any improvements an economy makes in the efficiency of its electricity generation, which in many economies represents a major opportunity to improve energy efficiency.

Therefore, APERC proposed a hybrid measure called 'final energy plus' which would include final energy demand plus conversion losses for fossil-fueled electricity plants only. The argument for this measure was that fossil fuel plant losses result in greenhouse gas emissions and fossil energy imports, while nuclear and geothermal losses are more benign. This definition would also standardize the treatment of all non-fossil energy, since nuclear and geothermal generation would effectively be counted as 100% efficient just like the non-thermal renewables. However, within the EWG there were objections that this measure was not a commonly used definition, and would therefore be confusing to policymakers. Also, some EWG members felt that this definition would cause the APEC energy intensity reduction goal to look a bit too much like an emission reduction goal, an alternative the EWG had already rejected.

Fortunately, all of APEC's analysis of projected energy intensity improvement indicated that it made little difference whether one used primary energy or final energy to calculate energy intensity—for any given set of assumptions, the projected improvement always seemed to work out about the same either way. So, from the perspective of calculating projected improvements in energy intensity, the measure selected did not matter that much in the end. Perhaps for this reason, the EWG has still never taken a position on which definition should be used.

However, from the perspective of incentives to APEC economy policymakers, the measure of energy demand selected does matter. Under the primary energy intensity definition, policymakers seeking to contribute to the APEC-wide energy intensity goal should avoid nuclear and geothermal generation. Under the final energy intensity definition, they should not concern themselves with generation efficiency at all. Neither seems right to the author.

Finding #3 – Whether the GDP's of individual economies are converted to common currency using market exchange rates or purchasing power parity (PPP) can dramatically change the energy intensity improvement calculations.

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input of 2041.13 mtoe, and an output of 8,110,286 GWh, or 697.36 mtoe, of electricity plus 43.96 mtoe of marketable heat for a total output of 741.32 mtoe. Natural gas electricity and CHP plants had a primary fuel input of 918.98 mtoe, and an output of 4,301,367 GWh, or 369.85 mtoe, of electricity plus 76.92 mtoe of marketable heat for a total output of 446.77 mtoe.

[27] See International Energy Agency, Organisation for Economic Co-Operation and Development, and Eurostat, *International Energy Statistics Manual,* 2004, http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/NRG-2004/EN/NRG-2004-EN.PDF, p. 118 and 137.

Discussions within the EWG of APEC's energy intensity improvement target took a surprising turn as the deadline approached for recommending a new target in time for consideration at the APEC Economic Leaders' Meeting in Honolulu, Hawaii in November 2011. One EWG participant, who was skeptical of APEC's ability to meet a more ambitious energy intensity goal, cited a recent study of the ASEAN+6 economies by the Economic Research Institute of ASEAN and East Asia (ERIA)[28], which concluded that their energy intensity would improve in the 2005-2030 time period by only 9.9% under business-as-usual, and only 26.7% under an "Alternative Policy Scenario" (APS) incorporating additional goals and action plans.

The ASEAN+6 economies are not the same as the APEC economies. However, 12 of the 21 APEC economies are also in the ASEAN+6, so the results of this new study appeared to be difficult to reconcile with the results of other studies, discussed under Finding #1 above, which projected much higher 2005-2030 business-as-usual improvement in energy intensity.

It turns out that the major explanation for the difference between the ERIA results and other model results lies in the way GDP's for each economy were converted to US dollars. ERIA used year 2000 market exchange rates, while the other models and historical results cited in this paper used Purchasing Power Parity (PPP) rates. If the ERIA results are recalculated using PPP's, the results become consistent with those of other models.

The PPP approach converts currencies at a rate based on how much they can buy compared to a US dollar, rather than the rate that would be offered at a bank. It could be argued that, for purposes of calculating energy intensities, PPP is the more appropriate method for converting currencies. PPP is superior for calculating energy intensities because an economy's energy use should be fundamentally related to how much their GDP will buy, rather than how much it would be worth if it were converted to US dollars at a bank. Also, market exchange rates can be subject to dramatic fluctuations, which could cause energy intensities to fluctuate dramatically if GDP were valued at market exchange rates, even if the way the economy uses energy has not changed. Therefore, APERC recommended, and EWG concurred, that the PPP approach be used. However, this view is not universally-shared among energy economists. In addition to ERIA, the International Energy Agency's *World Energy Outlook 2011* calculates energy intensity using market exchange rates even though GDPs are usually expressed in PPP.[29]

To see why the choice of market exchange rates vs. PPP has such a dramatic impact on energy intensity calculations, we have to look at the underlying data. Table 1 below shows the original ERIA results economy-by-economy. The 2005-2030 primary energy intensity improvement would be 4.2% for the ASEAN+6 economies that are also members of the APEC and 9.9% for all the ASEAN+6 economies.

At first glance, the individual economy improvements in Table 1 appear to be broadly consistent with the results of other modeling work, especially considering the large projected improvements in energy intensity in the two largest energy consuming economies, China and India. What seems odd are the total values for the APEC ASEAN+6 economies and for the entire ASEAN+6. For example, the 4.2% BAU case total improvement for the APEC ASEAN+6 economies is smaller than the corresponding figure for every individual economy. How can this be?

[28] Shigeru Kimura (editor), *Analysis of Energy Saving Potential in East Asia Region,* ERIA Research Project Report 2010, Number 21, http://www.eria.org/research/y2010-no21.html.

[29] International Energy Agency, *World Energy Outlook 2011,* http://www.iea.org/weo/. For an example of energy intensity calculated using market exchange rates, see Figure 2.5. Note, however, that this treatment is not consistent: see Figure 7.5. See p. 57 on the use of PPPs to calculate GDPs.

	2005 GDP	2005 Energy	Energy/GDP		2030 GDP	2030 Energy	Energy/GDP	Improvement
	(billion 2000 US$)	(mtoe)			(billion 2000 US$)	(mtoe)		
APEC members:								
Australia	468.4	122	0.260		898.4	184	0.205	-21.4%
Brunei	6.6	2.6	0.394		16.8	5.4	0.321	-18.4%
China	1893	1505.2	0.795		11996	5011.6	0.418	-47.5%
Indonesia	207.9	135.1	0.650		937.3	544.5	0.581	-10.6%
Japan	4980.0	517.8	0.104		6984.0	503.5	0.072	-30.7%
Korea	639.6	218.5	0.342		1449.6	323.7	0.223	-34.6%
Malaysia	112.5	62.8	0.558		347.1	120.1	0.346	-38.0%
New Zealand	61.7	15.2	0.246		100.9	18.5	0.183	-25.6%
Philippines	94.5	33.8	0.358		395.4	120.4	0.305	-14.9%
Singapore	114.7	27.7	0.241		296.4	45.1	0.152	-37.0%
Thailand	157	98.9	0.630		419.9	247.7	0.590	-6.4%
Viet Nam	44.8	27.3	0.609		280.1	156.8	0.560	-8.1%
Total - APEC	**8780.7**	**2766.9**	**0.315**		**24121.9**	**7281.3**	**0.302**	**-4.2%**
Non-APEC members:								
Cambodia	5.7	1.3	0.228		35.0	8.6	0.246	7.7%
India	645	379.9	0.589		4513.0	1346.9	0.298	-49.3%
Lao PDR	2.4	0.5	0.208		15.0	6.2	0.413	98.4%
Myanmar	13.3	5.8	0.436		131.1	22.4	0.171	-60.8%
Total - All	**9447.1**	**3154.4**	**0.334**		**28816.0**	**8665.4**	**0.301**	**-9.9%**

Table 1 – Original ERIA Primary Energy Intensity Improvement Results by Economy[30]

The answer lies in the fact that there is a disconnect here between GDP and energy demand. In 2005, more than 53% of the total 2005 GDP of the ASEAN+6 is contributed by Japan. On the other hand, 48% of the total 2005 energy demand of the ASEAN+6 is contributed by China. Between 2005 and 2030, Japan's economy is projected to grow slowly, while China's economy is projected to grow quickly. Hence, total ASEAN+6 GDP growth tends to be pushed down by Japan, while total ASEAN+6 energy demand tends to be pushed up by China. Since energy intensity is energy demand divided by GDP, this would explain why total primary energy intensity improvement for the ASEAN+6 economies that are also members of APEC is only 4.2% and why total primary intensity improvement for all ASEAN+6 economies is only 9.9%.

[30] For consistency with other tables in this paper, results in Table 1 were calculated from the primary energy and GDP figures given in Annex 1 to the ERIA report. In some cases, the figures differ slightly from the figures given in Table 5 of the ERIA report due to rounding errors.

APEC Members	2005 GDP (billion 2000 US$)	2005 Energy (mtoe)	Energy/GDP		2030 GDP billion 2005 PPP US$	2030 Energy (mtoe)	Energy/GDP	Improvement
Australia	671.5	122	0.182		1287.9	184	0.143	-21.4%
Brunei	17.6	2.6	0.148		44.8	5.4	0.121	-18.4%
China	5333.2	1505.2	0.282		33796.7	5011.6	0.148	-47.5%
Indonesia	707.9	135.1	0.191		3191.5	544.5	0.171	-10.6%
Japan	3870.3	517.8	0.134		5427.7	503.5	0.093	-30.7%
Korea	1027.4	218.5	0.213		2328.5	323.7	0.139	-34.6%
Malaysia	299.6	62.8	0.210		924.4	120.1	0.130	-38.0%
New Zealand	100.7	15.2	0.151		164.7	18.5	0.112	-25.6%
Philippines	250	33.8	0.135		1046.0	120.4	0.115	-14.9%
Singapore	180.1	27.7	0.154		465.4	45.1	0.097	-37.0%
Thailand	444.9	98.9	0.222		1189.9	247.7	0.208	-6.4%
Viet Nam	178.1	27.3	0.153		1113.5	156.8	0.141	-8.1%
Total - APEC	**13081.3**	**2766.9**	**0.212**		**50981.1**	**7281.3**	**0.143**	**-32.5%**
Non-APEC members:								
Cambodia	20.1	1.3	0.065		123.4	8.6	0.070	7.7%
India	2341	379.9	0.162		16379.7	1346.9	0.082	-49.3%
Lao PDR	10.2	0.5	0.049		63.8	6.2	0.097	98.4%
Myanmar	13.3	5.8	0.436		131.1	22.4	0.171	-60.8%
Total - All	**15465.9**	**3154.4**	**0.204**		**67679.1**	**8665.4**	**0.128**	**-37.2%**

Table 2 – ERIA Primary Energy Intensity Improvement Results by Economy Recalculated Using 2005 Purchasing Power Parities (PPP)

Table 2 shows Table 1 recalculated using PPP's. To make this table, the 2005 GDPs of each economy in 2005 PPP US dollars were obtained from the World Bank,[31] and were substituted for the original 2005 GDP values. A currency conversion factor was also calculated, equal to each economy's 2005 GDP in 2005 PPP US dollars divided by the economy's original 2005 GDP at market exchange rates. Each economy's 2030 GDP was then multiplied by this conversion factor to obtain a 2030 GDP in 2005 PPP US dollars. Note that this currency conversion did not change either the 2005-2030 percentage growth of each economy's GDP nor the individual economy

[31] World Bank, *Global Purchasing Power Parities and Real Expenditures: 2005 International Comparison Program*, Washington, DC, 2008, pp.23-28, http://siteresources.worldbank.org/ICPINT/Resources/icp-final.pdf. This publication did not provide PPP figures for Myanmar, so Myanmar's GDP values in Table 2 were left unchanged.

improvements in energy intensity. It did, however, dramatically change the absolute energy intensities (energy/GDP) for some economies.[32]

In Table 2, GDP's are much better aligned with energy use, with China and other fast-growing economies making a much larger contribution to total GDP compared to Table 1. As a result, total energy intensity improvement is much larger: 32.5% for the ASEAN+6 economies that are also members of APEC and 37.2% for all ASEAN+6 economies. A similar recalculation of ERIA's Alternative Policy Scenario (APS) would give a 2005-2030 primary energy intensity improvement of 44.3% for the ASEAN+6 economies that are also members of APEC and 48.8% for all ASEAN+6 economies. These results are generally consistent with the results of the other models cited in this paper.

Conclusion

This paper has highlighted three significant findings related to energy intensity calculations in the analysis of the APEC energy intensity improvement goal. The three findings are as follows:

Finding #1 – Energy intensity improvement is happening surprisingly quickly, but not quickly enough to meet the world's energy challenges. Large reductions in energy intensity, on the order of 35-40%, can be expected between 2005 and 2030. However, because of expected rapid economic growth, these improvements in energy intensity will not stop the growth of energy demand, with its associated threats to the environment and the stability of the world economy.

Finding #2 – It is difficult to find a definition of energy intensity that can make it suitable for use as an indicator of regional energy efficiency. Energy intensity, if calculated based on primary energy demand, will increase (get worse) if an economy uses more nuclear and geothermal electricity generation. Energy intensity, if calculated based on final energy demand, will not reflect improvements in electricity generation efficiency at all.

Finding #3 – Whether the GDP's of individual economies are converted to common currency using market exchange rates or purchasing power parity (PPP) can dramatically change the energy intensity improvement calculations. Energy intensity improvement for a grouping of economies will typically be much larger if calculated using purchasing power parities than if calculated using market exchange rates. The reason is that market exchange rates tend to assign lower values to the GDPs of fast-growing developing economies. The author recommends using PPPs because of their relative stability, and because it is the actual purchasing power of each GDP that will drive an economy's energy use.

Although the findings discussed here relate specifically to the 21 APEC member economies, it may be hypothesized that similar findings would apply to the entire world and to other regional groupings of economies. Further research is needed to verify this hypothesis.

[32] The dramatic difference that using market exchange rates vs. PPP's can have on energy intensity can have for China is noted in footnote 2 of Dabo Guan, Klaus Hubacek, Christopher L. Weber, Glen P. Peters, and David M. Reiner, "The drivers of Chinese CO2 emissions from 1980 to 2030", *Global Environmental Change*, Volume 18, Issue 4, pp. 626-634, available in PDF at http://eprints.whiterose.ac.uk/5405/1/hubacekk9.pdf.