KAPSARC
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King Abdullah Petroleum Studies and Research Center

Workshop Policy Brief

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Measuring the energy intensity of nations: Towards a framework for transparent comparisons

Summary for policymakers

In September 2013, KAPSARC hosted a workshop in London to explore whether it was feasible and reasonable to gain a better understanding of national energy intensity by measuring the embodied energy in goods traded across national borders. If so, this information could provide decision-makers with a more transparent picture of a nation's energy intensity and greenhouse gas emissions.

In order to make meaningful comparisons of indicators between countries, the need to take into account specific national economic circumstances was highlighted. Important factors include: the path of historical economic development, industrial specialization, natural resource endowments, demographic change, cultural norms, energy prices, urbanization, geography, and climate. As a significant part of the profile of a country's energy intensity is embodied in its imports and exports of goods, the effect of moving towards metrics that normalize for the embodied energy and carbon in trade was also discussed.

Energy intensity targets may serve as good benchmarks for countries seeking to moderate their energy consumption relative to their economic growth. Moreover, energy productivity was also identified as a closely related, but more positive, metric that may provide a clearer focus on strategies to align economic growth with energy efficiency and achieving environmental outcomes. This is because while it is difficult to achieve consensus on national greenhouse gas reduction targets, all nations are likely to support ambitious energy productivity goals. National target setting based on this information may therefore offer a constructive path towards agreement on targets and actions aimed at achieving both climate and energy goals at the international level.

About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is an independent, non-profit research institution dedicated to researching energy economics, policy, technology, and the environment across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

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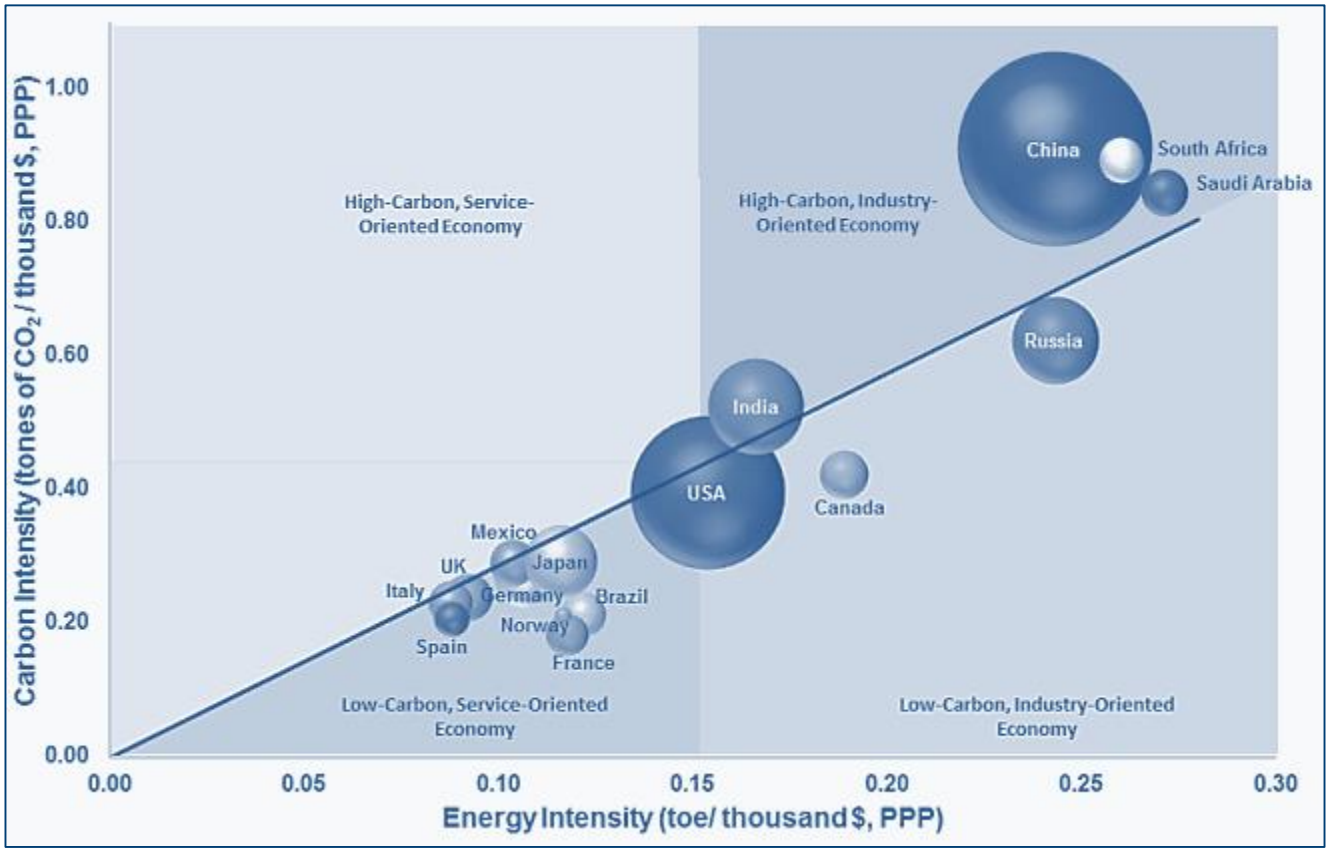

Figure 1: International comparisons require an understanding of national circumstances (bubble size reflects scale of energy-related carbon emissions, quadrants are indicative only). Data source: KAPSARC analysis, OECD Library, World Bank, and Eora-MRIO, year 2010.

Background to the workshop

In September 2013, some 30 international experts drawn from across industry, government, and academia gathered in London for a two-day workshop to examine energy intensity as a tool for informing policy, and how it is viewed once the embodied energy in trade is accounted for.

Under examination was the question of whether energy intensity and energy productivity targets used in conjunction with methods to incorporate the embodied energy in trade could help provide clearer insight for policymakers on the nature of their countries' energy and climate change goals.

Because intensity targets are expressed relative to economic output, they have the advantage of offering targets for countries seeking prudent energy consumption commensurate with their economic development. Such targets are more palatable for countries that expect to experience substantial growth. Developing nations, such as China and India, have been strong supporters of intensity targets. Among OECD countries, governments and corporations have used intensity targets widely because they fit naturally with the notion of 'green growth'.

However, within the scope of global climate change, intensity targets have been criticized by some as

'environmentally weak' as they are expressed relative to GDP. Thus, if GDP increases, say due to a rise in export prices, then energy/carbon intensity is reduced, but without any environmental improvement. In addition, a host of national factors, including the stage of economic development, natural resource endowments, areas of industrial specialization, energy pricing, population, geography, and climate, make it almost impossible at first glance to assess intensity targets as fair or realistic. A framework for making international comparisons is needed.

As countries organize their positions heading into the 2015 UNFCCC Conference of the Parties in Paris, the demand for a rigorous evidence base to empower balanced debate on the options around energy intensity and embodied energy in trade is likely to be high. KAPSARC's research seeks to provide policymakers with new insights into the constructive role intensity indicators may play in boosting economic productivity and contributing to international energy and global climate change agreements.

Energy or carbon intensity?

Energy intensity measures the energy needed to produce one unit of economic output, while carbon intensity measures the emissions generated to produce that same unit. Both metrics tend to be used by policymakers when setting economy-wide environmental targets.

One question raised early in the workshop was, "Why energy intensity and not carbon intensity?" Participants discussed which of the two metrics is more pertinent for energy and environmental policy development. It was noted that both metrics are closely linked, because most carbon emissions occur as a result of energy use. Carbon intensity can be derived from energy intensity by multiplying the latter by a coefficient—the emissions per unit of energy used. In the medium-term, this coefficient is quite stable because of the gradual nature of change in an economy's energy mix. In the long-term, the link between energy intensity and carbon intensity may become decoupled if the energy mix is significantly decarbonized. Figure 1 highlights how energy and carbon intensity are strongly coupled at present due to the fossil fuel dominant energy mix in most countries.

While some countries are reluctant to implement strong carbon dioxide mitigation policies, all countries are unambiguously in favor of enhancing their energy efficiency to boost economic productivity. This is because of the benefits such targets bring them in terms of moderating energy consumption and reducing waste, which are worthwhile goals irrespective of the issue of climate change. Therefore, gaining consensus internationally around energy intensity targets may prove more viable because of the policy focus they provide on boosting energy productivity. This may help bridge past disagreements between service-oriented economies and industrial-based economies on absolute emission targets and timetables.

How to make meaningful comparisons of national energy intensity measures

A more transparent understanding of the nature of a country's energy and greenhouse gas profile relative to other nations is important if energy productivity and intensity are to play a larger role in national and international policy deliberations. However, the point was raised that simple comparisons can be misleading if not contextualized according to national circumstances. Some of these circumstances are controllable, such as the efficiency of processes and adoption of new technologies, and some are uncontrollable, such as average temperatures and physical geography. The 'field of play' for action by policymakers is the controllable factors.

The structure of a country's economy and stage of economic development play important roles in shaping its energy intensity. Structural economic factors are relatively stable in the short- to medium-

term and thus can be measured and accounted for in energy intensity comparisons. As a country develops from an agricultural or resource-intensive base, towards industrialization and manufacturing, and finally to a more service-oriented economy, it usually goes through different phases of energy supply and use. To make meaningful comparisons between countries, it is therefore necessary to account for the stage of development. This can be done by tracing the historical pathway of the different sectors.

"A switch in the structure of the economy toward the service sector may reduce what appears to be your energy use and can wrongly be interpreted to be an increase in energy efficiency."

Countries also have different natural resource endowments and comparative advantages in different sectors. This raises the question whether it might make sense, from a global perspective, for countries with a comparative advantage in energy-intensive sectors to have higher energy intensity.

Climate was identified as a factor influencing energy intensity through the necessity of heating or cooling. Research presented at the workshop suggested local climate plays a limited but material role in defining national energy intensity patterns, although at higher levels of regional disaggregation temperature can have a greater effect. The use of energy in water supply also yields a similar result. This will be an increasingly important issue as desalination becomes more widespread.

A key area of discussion for country comparisons was the use of GDP in calculating energy intensity and productivity. Normalizing GDP to a common currency using market exchange rates results in a different value than when it is calculated using purchasing power parity (PPP). In the case of India, its energy intensity calculated with market exchange rates is 44% higher than the one calculated on a PPP basis. A similar issue arises when incorporating commodity prices into the GDP of resource-dependent economies. Higher or lower prices will overshadow any change in the efficiency of energy consumption.

Using physical units of output instead of economic output like GDP was suggested as an alternative for comparisons of energy intensity and productivity. Calculating energy intensity based on physical output, like energy consumed per ton of steel produced, is more reflective of material and process efficiencies. However, comparisons for this approach would be limited to industrial sectors, and physical output data may not be as readily available as economic output. In addition, multiple energy intensity metrics would be required for each product or sector, whereas in international negotiations there are benefits from having a single metric.

Accounting for the embodied energy in trade

A country's energy intensity is typically calculated based on the energy consumed within its borders, including energy consumed to produce goods and services, regardless of whether those goods are consumed domestically or exported. One pitfall of this approach, which was raised at the workshop, is that it creates a metric that institutionalizes the problem of carbon and energy leakage. This is where it is possible for some countries to import embodied energy and carbon from other countries that, due to their comparative advantage, resource endowments, or other factors, are able to produce energy-intensive goods more competitively.

Participants referred to this phenomenon, essentially the shift of industrial activities towards services in advanced economies, providing impetus for the expansion of industrial output in developing economies, as 'offshoring' energy- or carbon-intensive activities. While the idea of 'offshoring' has perhaps assumed a degree of intentionality that does not exist in practice, the result of such shifts means that

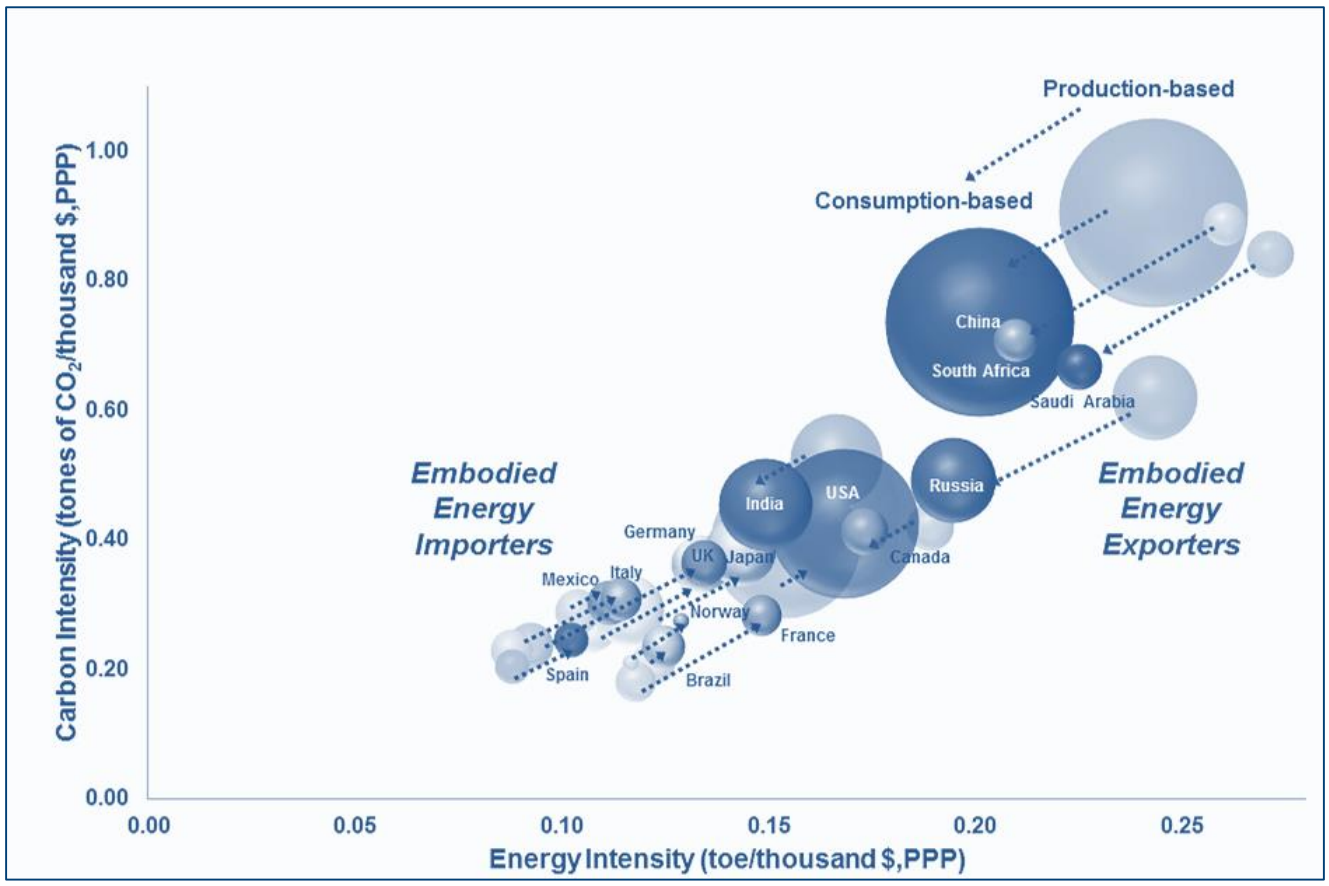

Figure 2: Shifting from production-based to consumption-based metrics leads to convergence between net exporters and importers of carbon and embodied energy in trade. Data source: KAPSARC analysis, OECD Library, World Bank, and Eora-MRIO, year 2010.

the country 'offshoring' an energy-intensive industry may see an improvement in its national energy intensity, while globally, energy and carbon intensity may rise and social welfare deteriorate, at least from an energy consumption perspective.

Consumption-based metrics were discussed at the workshop as a potential alternative to the production-based approach used currently in international negotiations. Such metrics are more indicative of lifecycle energy consumption in the supply chains of goods and services. Because the consumption approach transcends national boundaries, it provides a clearer picture of the energy or carbon leakage issues.

In Figure 2, the effect of the shift from a production- to a consumption-based approach on the energy intensity of a selected group of nations is shown. As can be seen, a consumption-based approach narrows the difference between countries with high embodied energy exports, such as China, and those with high embodied energy imports, such as European Union countries and the United States.

"We have been using production-based accounting, not because we are bad, but because it's definitely an easier approach."

Some participants at the workshop argued that the consumption-based measure is more reflective of a country's global impact on energy consumption and carbon emissions. This would seem to support the case for increased attention to be given to this metric.

Embodied Energy in Net Imports (Mtoe)

Embodied Energy in Net Exports (Mtoe)	China	Russia	India	Saudi Arabia	South Africa	Canada	South Korea	Australia	Spain	ROW	Italy	France	Germany	UK	Japan	USA	**Total Net Exports**
China		-6.2	4.9	1.5	1.7	9.7	-1.6	7.6	7.0	181.7	9.3	12.6	26.4	16.3	46.5	90.4	**407.7**
Russia	6.2		2.8	0.2	0.0	1.3	1.9	0.1	3.2	61.9	3.5	7.6	12.2	5.5	11.0	8.3	**125.6**
India	-4.9	-2.8		-4.6	-0.1	2.0	-0.1	-0.6	1.6	35.8	3.0	2.5	5.0	4.8	2.5	22.7	**67.1**
Saudi Arabia	-1.5	-0.2	4.6		0.1	0.0	5.9	1.0	1.1	5.5	0.3	0.6	-0.9	1.2	6.0	1.9	**25.6**
South Africa	-1.7	0.0	0.1	-0.1		0.4	0.3	0.1	0.3	15.8	0.7	0.7	1.5	2.4	1.8	3.3	**25.4**
Canada	-9.7	-1.3	-2.0	0.0	-0.4		-0.8	-0.1	0.0	-5.6	-0.4	-0.1	-0.3	0.3	2.5	39.8	**22.0**
South Korea	1.6	-1.9	0.1	-5.9	-0.3	0.8		-0.5	0.8	2.9	0.5	0.6	0.5	1.9	6.6	7.6	**15.5**
Australia	-7.6	-0.1	0.6	-1.0	-0.1	0.1	0.5		0.0	0.9	0.0	0.0	0.0	0.2	5.2	0.0	**-1.4**
Spain	-7.0	-3.2	-1.6	-1.1	-0.3	0.0	-0.8	0.0		-8.2	0.4	2.3	-2.5	-0.1	0.1	1.9	**-20.1**
ROW	-181.7	-61.9	-35.8	-5.5	-15.8	5.6	-2.9	-0.9	8.2		28.6	37.2	63.9	47.9	34.1	14.5	**-64.7**
Italy	-9.3	-3.5	-3.0	-0.3	-0.7	0.4	-0.5	0.0	-0.4	-28.6		-0.2	-7.1	0.2	0.5	3.9	**-48.5**
France	-12.6	-7.6	-2.5	-0.6	-0.7	0.1	-0.6	0.0	-2.3	-37.2	0.2		-7.0	1.4	1.0	1.6	**-66.7**
Germany	-26.4	-12.2	-5.0	0.9	-1.5	0.3	-0.5	0.0	2.5	-63.9	7.1	7.0		3.5	-0.1	8.2	**-80.3**
UK	-16.3	-5.5	-4.8	-1.2	-2.4	-0.3	-1.9	-0.2	0.1	-47.9	-0.2	-1.4	-3.5		-1.1	-1.0	**-87.5**
Japan	-46.5	-11.0	-2.5	-6.0	-1.8	-2.5	-6.6	-5.2	-0.1	-34.1	-0.5	-1.0	0.1	1.1		4.1	**-112.5**
USA	-90.4	-8.3	-22.7	-1.9	-3.3	-39.8	-7.6	0.0	-1.9	-14.5	-3.9	-1.6	-8.2	1.0	-4.1		**-207.2**
Total Net Imports	**-407.7**	**-125.6**	**-67.1**	**-25.6**	**-25.4**	**-22.0**	**-15.5**	**1.4**	**20.1**	**64.7**	**48.5**	**66.7**	**80.3**	**87.5**	**112.5**	**207.2**	

Table 1: This table shows the embodied energy in the net trade of goods and services in 2010. Dark blue denotes outflows of embodied energy from the exporting nation on the row to the importing nation on the column (>0.5 Mtoe). Medium blue denotes inflows of embodied energy into the exporting nation on the row (<–0.5 Mtoe). Due to uncertainties that arise from the type of dataset used, the effects of spatial aggregation, the effects of sector aggregation, and methodology, all flows with a magnitude less than 0.5 Mtoe are in light blue cells as these flows can easily change between positive and negative values. Feedback effects have been included. Data source: KAPSARC analysis, OECD Library, and Eora-MRIO.

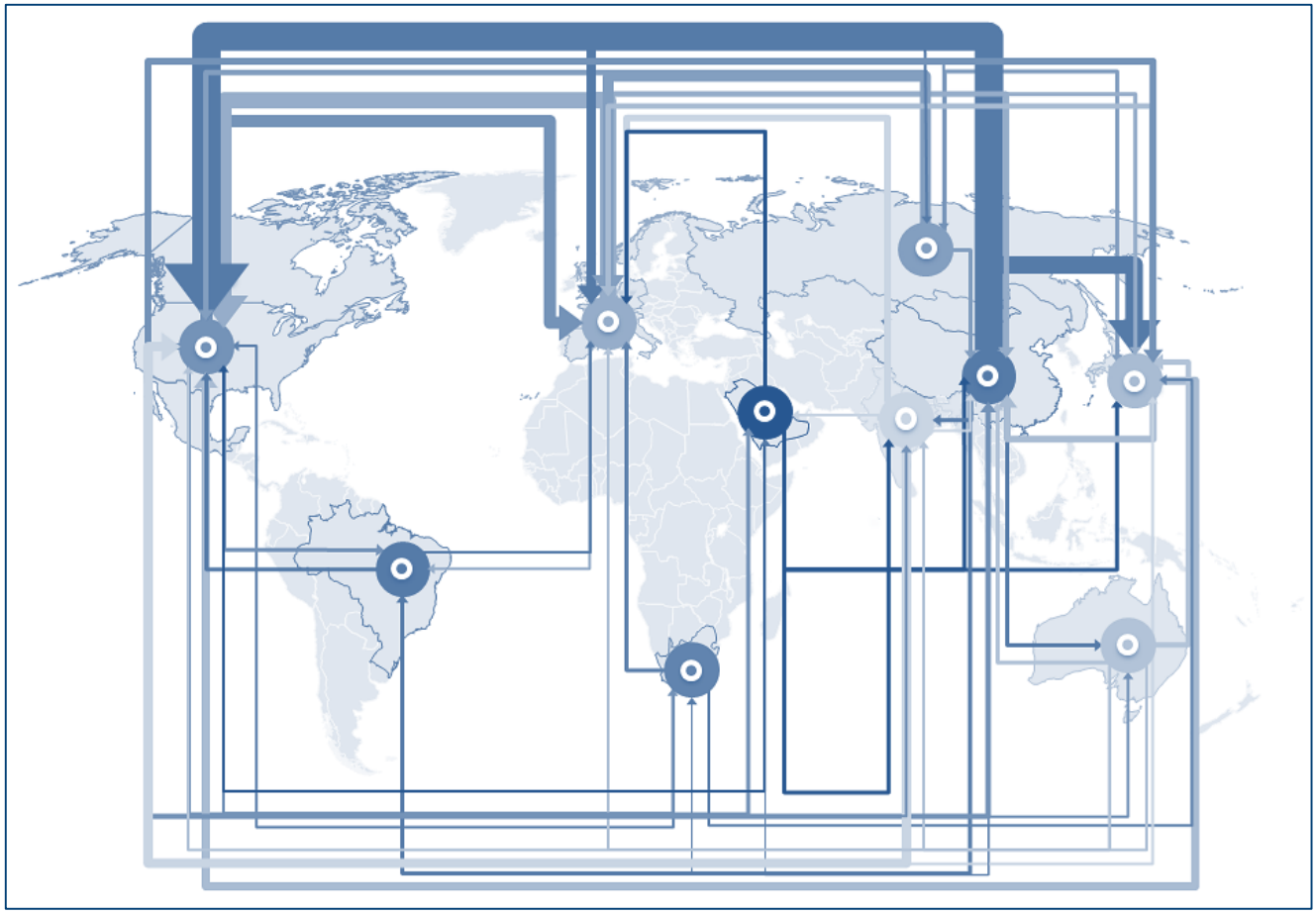

Figure 3: Global embodied energy flows. Data sources: KAPSARC analysis, OECD Library, Eora-MRIO, year 2010.

Consumption-based energy intensity also highlights the relationships between countries (see Table 1 and Figure 3). For example, the United States' consumption-based energy intensity is dependent in part on the energy intensity of its suppliers, such as Chinese industries. Greater awareness of these connections may provide the basis for improved cooperation by shifting focus towards making supply chains more efficient. Participants discussed how gains in energy productivity in one country, such as through an energy efficiency investment, can affect its own consumption-based energy intensity, while also improving that of other countries through these trade linkages. Although many corporations are using this consumption-based approach to quantify their energy or carbon footprints, it has not been widely translated into national or international assessments.

A question was raised whether there is a role for consumption-based metrics in policy formulation given the wide array of energy indicators already at the disposal of policymakers. Some participants noted the potential promise of the consumption-based metric, while others pointed out that it is more complex to calculate and explain to policymakers. More technically, calculating consumption-based metrics requires the use of multi-regional input-output (MRIO) tables, and using the tables for this purpose is relatively new and data-intensive. Most participants, however, agreed that refining these methodologies is an important priority for research.

Informing policy

While increasing the transparency of the energy consumption and greenhouse gas emission profile of a country is a useful exercise in its own right, a consumption-based approach may also have important policy implications for managing carbon/energy leakage.

Given the lack of absolute emissions targets by countries party to the Kyoto Protocol, concerns have been raised about the 'offshoring' of energy-intensive industries to countries without a binding constraint. Many countries, including the United States, have pointed to this as a deal-breaker for agreeing to any global agreement.

It was noted that carbon leakage can be classified as either 'policy-induced' or 'consumption-induced'. Policy-induced carbon leakage stems from fragmented climate policy, where production shifts from 'high-carbon-price' to 'low-carbon-price' countries. In contrast, consumption-induced carbon leakage refers to those emissions embodied in the net imports of goods and services consumed in a country, unrelated to any explicit greenhouse gas mitigation policy.

It has been shown that policy-induced carbon leakage is small relative to consumption-induced leakage. In fact, over the last two decades, the net import of embodied emissions in goods and services by countries with absolute emissions targets was several times larger than their total emissions reduction.

Consumption-based targets have been proposed as a potential means for evaluating and developing solutions to carbon leakage. Consumption-based indicators are not policy mechanisms themselves, but rather, potential tools to help policymakers have a more transparent view of the energy and carbon intensity of their country.

Participants noted that it would be challenging for nations to reorient from targets and timetables based on production-based to consumption-based metrics. Moving to a new approach requires fresh deliberations at the national and international levels, making the short-term implementation of such targets unlikely.

Border carbon adjustments were discussed as one potential policy option to address the carbon leakage problem. Currently, carbon prices around the world are strikingly different, leading to concerns that industries will shift away from countries with high carbon prices. In theory, border carbon adjustments can be used to 'level' those prices, preventing the diffusion of intensive industry from high- to low-carbon price regions.

In the workshop it was shown how this process could operate through trade retaliation. A country that imposes a border carbon adjustment on its imports from another will, in theory, trigger the exporter to impose a border carbon adjustment itself to stake claim to the rents. Retaliation is the device that spreads border carbon adjustments among countries.

Arguments against border carbon adjustments hinge on whether they are legally applicable, and if they are, on the economic theory that more trade increases welfare and that tariffs reduce trade. As there is a risk of 'overcompensating' for the environmental externality, the net effect of border carbon adjustments on global welfare is less clear. Furthermore, to be robustly calculated, the level of these adjustments on imported goods and services would need to be matched to their embodied emissions. This could be determined through consumption-based accounting, but may be difficult. There is also the risk that the process could become utilized as a veil for simple trade protection.

Next steps

The workshop discussions highlighted several promising avenues for future research and collaboration with participants. Some of the future steps identified include:

- Developing the consumption-based energy intensity metric further and refining the way it is computed.
- Assessing the relative strengths and weaknesses in production-based and consumption-based accounting in order to improve the indicators.
- Investigating the applications of consumption-based indicators for policy.
- Analysis of the policy mechanisms for meeting consumption-based targets and accounting for energy and carbon leakage.
- Evaluating the means for connecting energy consumption along global supply chains.
- Developing and expanding the scope for data normalization and cross-country comparisons of energy intensity. Conduct normalizations for key factors influencing the energy consumption of nations such as economic structure, resource endowments, competitive advantage, temperature, energy prices, and demographic change.
- Further investigation and quantification of the determining factors of an economy's energy intensity.
- Producing a diagnostic framework for identifying cost-effective investment opportunities to reduce energy intensity or boost energy productivity globally.

About the workshop

KAPSARC convened a workshop in September 2013 with some 30 international experts to discuss energy intensity and productivity indicators. The workshop was held under Chatham House rules.

Participants included:

Khalid Abuleif – Advisor to the Minister, Ministry of Petroleum and Minerals, Kingdom of Saudi Arabia

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Berenice Garcia-Tellez – Senior Research Analyst, KAPSARC

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