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Solar Cooker Near Leh, Jammu and Kashmir State, India, 2009. Photo by Kiran Jonnalagadda (Permission under CC BY-SA 2.0).

INTRODUCTION

This issue from ESI's Energy and the Environment Division provides a sample of ongoing research work relating to energy and the environment, ASEAN and the world.

Since the 19th century, energy has become an important element driving national and global economic development, but it has also resulted in many environmental issues. For example, the increase in greenhouse gas (GHG) emissions could cause the earth's surface temperature to rise with potentially devastating effects on ecosystems, biodiversity and the livelihoods of people worldwide. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014), 76 per cent of the GHG emissions in 2010 were carbon dioxide (CO_2) emissions from fossil fuels, industrial processes, forestry and other land uses; the remaining shares were methane (16 per cent), nitrous oxide (6 per cent) and fluorinated gases (2 per cent). The International Energy Agency (IEA) found that the CO_2 emissions from fuel combustion doubled from 13.9 billion tons in 1971 to 32.3 billion tons in 2015. In late 2015, the countries of the world agreed in Paris to monitor and control the GHG emissions, especially CO_2

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emissions, aiming to limit the global temperature rise to below 2°C.

Besides GHG emissions, there are also air pollutants resulting from fossil fuel combustion, such as sulphur oxides (SOx) and particulate matter (PM). For example, sulphur dioxide (SO_2) contributes to death and serious respiratory illnesses due to its fine particles. It also acidifies surface water and reduces biodiversity, damages forests through direct impacts on leaves and needles, acidifies soil and depletes soil of its nutrients. According to the recently released economic assessment report by the Organisation for Economic Co-operation and Development (OECD) (2016), global air pollution-related healthcare costs are projected to increase from USD 21 billion in 2015 to USD 176 billion in 2060. The annual global welfare costs associated with premature deaths due to outdoor air pollution, are projected to rise from USD 3 trillion in 2015 to USD 18–25 trillion in 2060. Reducing the impacts from energy-related environmental issues not only requires national energy and environmental policy support, but also international agreements and green technology innovations.

Energy subsidy policies have been widely used to help protect disadvantaged groups from high energy prices and to give domestic firms cost advantages over foreign competitors. However, energy subsidies distort the price signals to final users and give them no incentive to conserve energy. They also discourage investment in energy efficiency, renewable forms of energy and infrastructure, and impose large fiscal costs. Since the 1990s, the OECD countries have made efforts towards not using or reducing energy subsidies, but fossil fuel subsidies are still prevalent in Southeast Asian countries. In this issue of the Bulletin, ESI Research Fellow, Dr. Li Yingzhu, examines the energy subsidy developments in Malaysia and develops a computable general equilibrium (CGE) model to evaluate the impacts on the Malaysian economy of removing petroleum and gas subsidies. The findings show, in different scenarios, that removing the energy subsidies would improve economic efficiency and raise GDP by 0.65 per cent. At the same time, the budget deficit would be largely reduced, and carbon emissions would be reduced by 1.84 to 6.63 per cent.

In the most recent inventory accounting, most of the GHG emissions, including CO_2 and methane emissions declined. But the hydrofluorocarbon (HFC) emissions found in air conditioners and refrigerators have risen rapidly. The figures from the US Environment Protection Agency (US-EPA) show that GHG emissions decreased by 2 per cent between 2014 and 2015, but HFC emissions rose by more than 4 per cent. Scientists are concerned about the rise in HFC use because HFC emissions are thousands of times more potent on a pound-per-pound basis than carbon dioxide. It is estimated that if there is no control over the growth of HFC emissions, nearly the entire benefit obtained from controlling CO_2 emissions to stabilise them at the 450 ppm concentration level could be cancelled.[1] ESI Research Fellow, Mr. Gautam Jindal discusses the history of the Montreal Protocol, inclusion of the HFC emissions in the Kigali Amendment to the Montreal Protocol and the policy implications of the Kigali Amendment.

With the steady increase in international trade, developed countries can import polluted goods/services from developing countries instead of producing them domestically. This is called embodied emissions in international trade resulting in “carbon leakages”. However, embodied emissions in trade do not help reduce the global emissions. The “consumption-based” emissions inventory has been proposed to implement the “production-based” emissions inventory by accounting for the trade balance of embodied emissions. Many empirical studies have shown that the emissions embodied in a country’s international trade, measured as a percentage of its total emissions, have been increasing over time. Dr. Yang Xue, a Research Fellow at the Centre for Maritime Studies at NUS, uses a multiregional input-output (MRIO) model to analyse the embodied SO_2 emissions in international trade for 40 world economies. The results show that China became the largest embodied SO_2 exporter, and that the largest embodied SO_2 flows occurred in China-US and China-EU trade. International collaboration is required to reduce the global SO_2 emissions.

One strategy to control GHGs and air pollutants resulting from fossil fuel combustion is to switch to renewable forms of energy, such as solar, wind, biomass and geothermal. According to an IEA report published in 2017, renewable forms of energy already accounted for 19.3 per cent of global energy consumption in 2015, and 24.5 per cent of power generation in 2016. More than half of all new electricity capacity installed was from renewable forms of energy in 2015. Since 2001, most of the renewable energy growth can be attributed to solar photovoltaics and liquid biofuels. Technology innovation is essential to the adoption of renewable energy. Patents remain central in empirical research on innovation and can provide information to track renewable technology developments. ESI Research Fellow, Dr. Zhong Sheng, uses the Worldwide Patent Statistical Database to study the solar energy technology developments from 1970 to 2015. The findings are that (a) global innovation output in solar energy has grown at an average annual rate of 10 per cent since 1970 and reached a peak in 2011; (b) innovation activities have been concentrated in major economies such as Japan, the US and China; and (c) the business sector plays a dominant role in innovation activities.

We hope you find these articles of interest and welcome your views and comments.

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(on behalf of the ESI Bulletin Team)

1 Institute for Governance and Sustainable Development. *Testimony of Durwood Zaelke - Before the U.S. Senate Environment and Public Works Committee: In Support of the Super Pollutant Act*, 2014, p. 2.

Impact Assessment of Fuel Subsidy Reform: A CGE Application to Malaysia

Dr. LI Yingzhu, ESI Research Fellow

Traffic in Jalan Pudu, Kuala Lumpur, Malaysia, looking east from the Puduraya bus station footbridge, 2007. Photo by Gary Houston (Permission under CC0).

Introduction

In many countries, subsidising energy is an important policy to assist disadvantaged groups cope with the market prices of fossil fuels and electricity and to give domestic firms a cost advantage over foreign competitors. However, economists and environmentalists have long opposed energy subsidies. Subsidies are criticised for sending distorted price signals to energy consumers. It is believed that they result in the over-consumption of energy and consequently hasten the depletion of fossil resources and aggravate environmental degradation. In addition, subsidies usually put heavy pressure on fiscal budgets. Even if the subsidies are provided by state owned corporations indirectly, and do not explicitly appear on the fiscal budget, they implicitly reduce government revenues. Moreover, despite the good intention to help disadvantaged groups, energy subsidies are usually applied to all in practice and higher income groups typically enjoy disproportionately large shares of the subsidy benefits.

Phasing Out Energy Subsidies

Since the Rio Earth Summit in 1992, developed countries have made great efforts to phase out energy subsidies. However, the policy is still prevalent in the ASEAN countries, especially Malaysia. Officially, an Automatic Pricing Mechanism (APM) has been used since 1983 to price petroleum products on the basis of factors such as reference product costs, operational costs and corporate margins, taxes and subsidies. However, the APM is in effect more like a tool for calculating sales tax exemption or subsidies that are needed to cover the gap between a regulated retail price and the market price.[1] According to Malaysia's own statistics, the budget for petroleum subsidies was only RM 27 million in 1990, but increased to RM 458 million in 1999, RM 3.2 billion in 2000 and RM 9.6 billion in 2010. An all-time high of RM 17.6 billion was reached in 2008 when oil prices reached historically high levels.[2]

The spiralling budget deficit motivated the Malaysian government to reform the subsidy policies. Table 1 provides an overview of Malaysia's petroleum subsidy reforms over the years. Apart from an ad hoc price increase in 2013, the initial actions were not successful over all. The collapse of oil prices in 2014 allowed the government of Malaysia to implement a managed float system, which takes into consideration the latest changes in petroleum production and markets to determine diesel and gasoline prices. However, the fundamentals of the APM have not been changed. When oil prices increase again, it is not clear whether the government can continue with the floating price system and resist the return of subsidies.[3]

To reduce the electricity tariffs paid by end users, the state-owned PETRONAS is required to supply natural gas to power generators at a regulated price which is much lower than the market price. Natural gas sold to non-power sectors such as industries and the commercial

Table 1: Overview of Malaysia's Petroleum Subsidy Reform

Time	Reform	Results
May 2010	▪ Launch of Subsidy Rationalisation Programme (SRP) ▪ Planned to increase the prices of subsidised commodities by pre-specified amounts every 6 months until 2014	▪ Most price adjustments not realised ▪ Suspended in March 2012
Sep 2013	▪ An ad hoc increase in the price of diesel and petrol ▪ The first adjustment since 2011	▪ No reform made to the APM
Dec 2014	▪ Subsidies for gasoline and diesel removed	▪ Successful due to low oil price ▪ No reform made to the APM

Compiled by the author.

sector are also heavily subsided, although not to the same extent. Based on data provided by Petronas, it is estimated that the company's foregone revenue in 2010 amounted to RM 11.2 billion and RM 7.9 billion for supplying gas to power and non-power sectors, respectively.[4] Since 2014, the regulated natural gas price has been raised several times on an ad hoc basis. The adjustments, and particularly the low oil price have narrowed the gap between the regulated price and the market price. However, as with the pricing of petroleum, the nature of price regulation has not changed yet.

To assess the impacts of different fuel subsidy reform schemes on the Malaysian economy and households, a static computable general equilibrium (CGE) framework was developed based on Malaysia's input-output (I-O) tables for 2010. In the model, the Malaysian economy consisted of 15 non-energy sectors and 5 energy sectors (i.e., electricity, crude oil, natural gas, other mining and petroleum). The households were divided into four groups, i.e., the 15 per cent with the lowest income (H1), 40 per cent lower-middle income (H2), 30 per cent upper-middle income (H3) and 15 per cent highest income (H4) households. Five alternative scopes of reform were considered:

1) Removal of petroleum subsidies
2) Removal of gas subsidy in the power sector
3) Removal of all gas subsidies
4) Removal of petroleum and gas subsidies in the power sector
5) Removal of petroleum subsidies and all gas subsidies

As for government behaviour, two extreme situations were tested: first, fiscal expenditure was fixed at the 2010 level because cutting the budget deficit was the primary incentive for the government; and second, the saved budget or increased government revenue was spent on education, health and other public services, etc. and infrastructure development as in 2010.

Simulated Impacts

Table 2 displays the simulated impacts of the 10 sub-scenarios discussed above. The results show that removing fuel subsidies could produce both economic and environmental benefits. GDP growth would be maximised when all the fuel subsidies were removed. Retaining the gas subsidies for industries and commercial sectors could reduce slightly more carbon emissions

Table 2: Simulated Macro Impacts with a) Fixed Fiscal Expenditure and b) Floating Fiscal Expenditure (%)

	1)		2)		3)		4)		5)	
	a.	*b.*	*a.*	*b.*	*a.*	*b.*	*a.*	*b.*	*a.*	*b.*
GDP	*0.07*	*0.04*	*0.28*	*0.28*	*0.53*	*0.53*	*0.38*	*0.35*	*0.65*	*0.61*
Exports	*1.01*	*−0.28*	*−0.53*	*−0.64*	*−0.72*	*−1.00*	*0.43*	*−0.93*	*0.21*	*−1.28*
Budget deficit	*−28.2*	*−0.53*	*−3.92*	*0.63*	*−7.84*	*1.11*	*−31.7*	*0.15*	*−35.0*	*0.65*
Government consumption	-	*8.19*	-	*0.82*	-	*1.73*	-	*8.80*	-	*9.50*
CO_2 emissions	*−1.84*	*−2.09*	*−4.64*	*−4.67*	*−4.22*	*−4.27*	*−6.37*	*−6.63*	*−5.90*	*−6.17*
H1 consumption	*−1.13*	*−0.99*	*−0.25*	*−0.24*	*−0.01*	*0.02*	*−1.32*	*−1.16*	*−1.02*	*−0.86*
H2 consumption	*−1.25*	*−1.11*	*−0.09*	*−0.08*	*0.21*	*0.23*	*−1.27*	*−1.11*	*−0.92*	*−0.76*
H3 consumption	*−1.42*	*−1.34*	*0.08*	*0.09*	*0.48*	*0.50*	*−1.25*	*−1.16*	*−0.79*	*−0.70*
H4 consumption	*−1.61*	*−1.70*	*0.23*	*0.22*	*0.73*	*0.71*	*−1.28*	*−1.37*	*−0.71*	*−0.82*

at the cost of nearly halved GDP growth, which seems not worth it. Households at all income levels would be worse off in most scenarios as the impacts of rising price levels dominate. In the petroleum subsidy scenarios, the lower income groups tend to suffer less because petroleum products account for smaller portions in their consumption baskets. In gas subsidy scenarios, the two high income groups (H3 and H4) are always better off than the baseline as the gas supplier's increased operating surplus is ultimately distributed disproportionally to higher income groups and this dispels the impacts of inflation. In addition, simulations also show that compensation policy, in the form of direct transfers or income tax rebates, could make the most disadvantaged group no worse than the baseline while having negligible impacts on GDP growth and emissions reduction.

1 International Institute for Sustainable Development, "A Citizens' Guide to Energy Subsidies in Malaysia", *International Institute for Sustainable Development*, IISD, Winnipeg, Manitoba, 2013.

2 K. A. Hamid and Z.A. Rashid, "Economic Impacts of Subsidy Rationalization in Malaysia" in Y. Wu, X. Shi, F. Kimura (eds), *Energy Market Integration in East Asia: Theories, Electricity Sector and Subsidies* (Jakarta: Economic Research Institute for ASEAN and East Asia, 2012).

3 Shi, X., "The Future of ASEAN Energy Mix: A SWOT Analysis" *Renewable and Sustainable Energy Reviews* 53, (2016): 672–80.

4 S. Ilias, R. Lankanathan and W. Poh, "Low Inflation, but at a High Price, Malaysia CPI: Inflation and Subsidy" Maybank IB Research, Malaysia, 2012.

Montreal Protocol's Kigali Amendment: A Game-changing Environmental Agreement

Mr. Gautam JINDAL, ESI Research Fellow

U.S. Secretary of State John Kerry delivers remarks during a plenary session of the conference about amending the Montreal ozone layer protection protocol held on 14 October 2016, at the Radisson Blu Hotel and Conference Centre in Kigali, Rwanda, 2016. Photo by U.S. Department of State (Permission under Wikimedia Commons).

Introduction

In December 2015, the world witnessed a truly historic event when 190 countries negotiated the Paris Agreement for managing global climate change. However, hidden behind all the fanfare and media attention devoted to this Agreement, another environmental game-changing agreement was negotiated in Kigali, Rwanda.

The "Kigali Amendment" to the *Montreal Protocol on Substances that Deplete the Ozone Layer* is a modification to the scope of the Protocol that includes a set of extremely powerful greenhouse gases called hydrofluorocarbons or HFCs under the Protocol's coverage. Successful enforcement of this amendment could result in potential emission reductions of 70 billion tons of CO_2 equivalent and could mean avoiding an increase of up to 0.5 °C in the global temperature by 2100. This would be a significant contribution towards the Paris Agreement objective of limiting the future global warming increase to below 2° Celsius.

The Montreal Protocol

The Montreal Protocol is the first and only universally ratified treaty in the history of the United Nations. It was introduced to cap and then phase out the production and consumption of harmful ozone depleting chemicals, mainly chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). These have been used mostly as the cooling fluid in refrigeration and air conditioning, and their emissions into the atmosphere were causing the formation of the "Ozone hole".

The original Montreal Protocol was agreed on in 1987 and entered into force in 1989. It has since become

one of the most successful environmental treaties and it has already led to the ozone layer beginning to repair itself. One of the key reasons for this success was a provision that allowed the Parties to adjust the Protocol in order to accelerate the pace of reduction for chemicals that are already covered, and to amend the protocol to control new chemicals. Adjustments are automatically applicable to all Parties whereas amendments must be ratified by a Party to be applicable to it. Since 1989, the Protocol has been adjusted six times and amended four times, before Kigali.

The Debate on Inclusion of HFCSs

The success of the Montreal Protocol led to the unintended explosive growth in the production, consumption and emissions of HFCs over the last decade, as they replaced CFCs and HCFCs in refrigeration and air-conditioning and other end uses such as fire-suppression, foams and aerosols. While HFCs do not cause any direct impact on the ozone layer, they can trap thousands of times more heat in the atmosphere as compared to carbon dioxide. HFC emissions currently account for only one per cent of global greenhouse gas (GHG) emissions, however they are growing at a rate that is faster than all the other GHGs. Studies have estimated that uncontrolled growth of HFCs could nearly cancel the entire benefit obtained from controlling CO_2 emissions to stabilise them at the 450 ppm concentration level.[1]

The issue of whether HFCs should be controlled under the Montreal Protocol has been under debate since 2009 when a proposal to this effect was first submitted by the Federated States of Micronesia, and another joint proposal was submitted by the US, Canada, and Mexico. Since then, developed countries supported by smaller states such as African nations and island states, argued for bringing HFCs under the Montreal Protocol, stating that the Protocol had a moral obligation to deal with this problem, being responsible for increased HFC usage in the first place. They also argued that the Protocol was much better equipped to achieve timely restrictions and reductions in HFC consumption given its successful track record. Furthermore, the Montreal Protocol community held the expertise required for enabling the HFC phase-out since they had already gained expertise in the CFC phase-out and subsequent HCFC phase-out.

On the other hand, developing countries such as the BASIC group (Brazil, China, India and South Africa) mainly advocated the status quo, which was to address HFC emissions mitigation under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. This would also give countries the flexibility to prioritise their mitigation options such as renewable energy, energy efficiency, afforestation, or reducing HFCs, amongst others. This also supported the concept of “nationally determined” and “nationally appropriate” mitigation action which was being promoted aggressively at the UNFCCC negotiations under the Durban Platform at that time.

The debate finally came to a rest in 2015 when countries opposed to the inclusion of HFCs relented and agreed to the “Dubai Pathway on HFCs” which committed the Parties to amend the Montreal Protocol when they met in Kigali in 2016.

The Kigali Amendment

Between Dubai and Kigali, the Parties met as many as four times to iron out as many issues as possible. These points of disagreement included HFC consumption freeze dates and the respective phase-down schedules for countries that are at different stages of shifting from HCFCs to HFCs and thus require different amounts of time to recover investments made by industry in research, development and production of new HFC-based equipment, training manpower etc.

The Kigali Amendment resolved these issues by dividing the two groups of countries under the Montreal Protocol (Article 5 countries include the developing countries, while Non-Article-5 countries include all others) into two sub-groups each. Group 1 of the A5 Parties consists of the majority of developing countries, including Singapore, while Group 2 consists of the Gulf States, India, Pakistan, Iran and Iraq. Similarly, Non-A5 Parties consist of most of the developed countries whereas the second group consists of Russia, Belarus, Kazakhstan, Uzbekistan and Tajikistan.

The Amendment sets out milestones between 2020 and 2050 for phasing down HFC consumption for each of the four sub-groups. At each milestone, the Parties are required to reduce HFC consumption against a “Baseline”, which consists of average HFC consumption for a three-year period, with an added percentage of HCFC consumption.

The exact baselines and phase-down schedules for each of the four sub-groups are not discussed further in this brief (readers are referred to the Kigali Amendment text for the exact details). However, the basic difference between the two sub-groups is that the first sub-group of Parties faces a tougher baseline and a faster phase-out schedule compared to the second sub-group. For example, Singapore must cap its HFC consumption in 2024, whereas Saudi Arabia is obliged to do so only in 2028.

These sub-groups basically reflect the Protocol’s recognition that the world can no longer be categorised as simply developed and developing, and that these divisions are increasingly beginning to blur. However, the fact that the amendment ended up with only two sub-groups for the Article 5 countries is a relief given that at one time, the negotiators were discussing the possibility of having five to six sub-groups just within developing countries.

At the time of writing, 39 parties to the Montreal Protocol had ratified the Amendment, which will enter into force on 1st January 2019.

Implications of the Kigali Amendment

Besides economic considerations and safeguarding their respective refrigeration and air conditioning industries, one of the major reasons for countries’ aversion to restricting HFCs has been the lack of safe

alternatives. Currently, we can use our refrigeration and air conditioning systems without any safety issues because CFCs, HCFCs and most HFCs are non-toxic and non-flammable. However, proposed replacements for HFCs –which include low global warming impact (GWP) HFCs that are a new generation of chemicals called hydrofluoroolefins (HFOs) and natural substances such as ammonia and propane– have either flammability or toxicity issues.

However, this has not stopped countries from adopting alternatives wherever they can be used safely. For example, even though exposure to a small concentration of ammonia in the atmosphere can cause damage to the eyes, skin, and lungs and can also result in death, industrial establishments that have particularly high cooling requirements such as breweries, pharmaceuticals, cold-storages, etc. have been using ammonia-based chillers and freezers for a number of years. This is because ammonia-based equipment offers much higher energy efficiency levels compared to HFCs, resulting in substantial cost savings. At the same time, the safety risk is mitigated by using custom designed equipment to prevent the leakage of refrigerant gas, and this equipment is operated by trained personnel.

With the Kigali amendment, the Parties have now shifted their focus towards enabling the adoption of HFC alternatives in other applications such as domestic air conditioning, commercial refrigeration, and refrigerated transport among others. Towards this objective, the Parties have met at numerous forums to discuss the safety standards related to the use of HFC alternatives in refrigeration and air conditioning equipment.

Conclusion

The Kigali Amendment marks the beginning of a new chapter for the Montreal Protocol. The successful implementation of the Protocol to the present provides much needed confidence that HFC consumption and emissions will be restricted and reduced in a timely manner, thereby complementing global GHG emission reduction efforts under the Paris Agreement. Former US Secretary of State John Kerry called it "*… likely the single most important step we could take at this moment to limit the warming of our planet and limit the warming for generations to come*".

1 Institute for Governance and Sustainable Development. *Testimony of Durwood Zaelke - Before the U.S. Senate Environment and Public Works Committee: In Support of the Super Pollutant Act,* 2014, p. 2.

Global Virtual SO_2 Emission Transfers Embodied in International Trade

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A Model of Tesla Model S Drive, 2011. Photo by Steve Jurvetson (Permission by CC 2.0).

Introduction

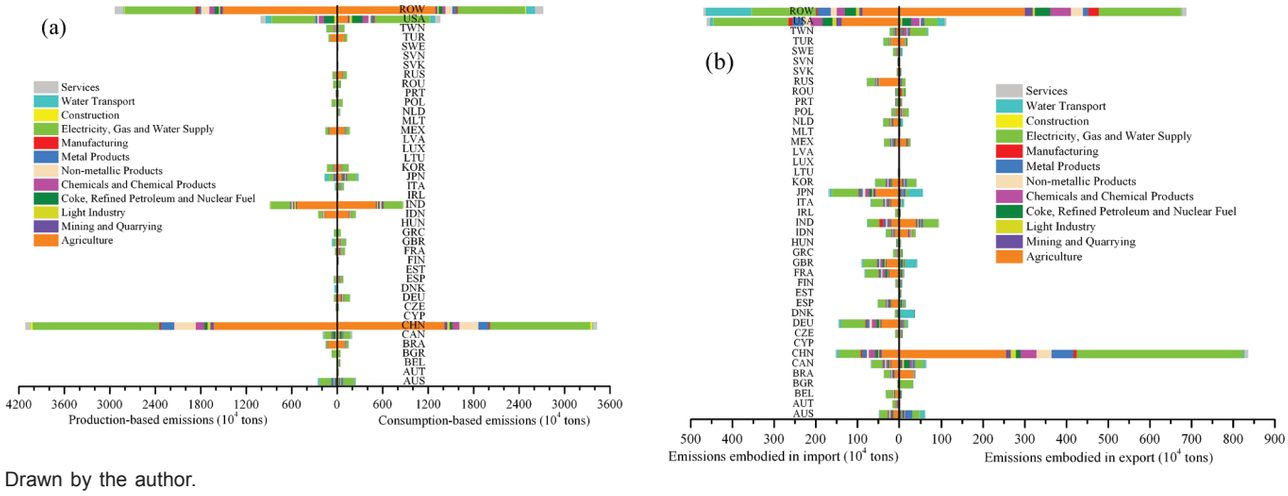
On the back of trade globalisation, geospatial separation of production and consumption for the environment followed.[1] When production takes place beyond countries' borders, the associated impacts are displaced away from the point of consumption. One example is iron ore mined and processed into raw iron in China, which is exported to a German car manufacturer that uses steel for the chassis of cars destined for the United States' market. Environmental pollution caused by mining and manufacturing in China and Germany then becomes 'embodied' in the consumption of cars in the US, i.e., environmental damage is transferred from the US to China and Germany through international trade.

Air pollution is one of the most serious global environmental issues and is significantly affected by international trade. In 2007, 30 per cent of global primary

fine particulate matter ($PM_{2.5}$) emissions were embodied in trade, mainly in exports from China and India and imports to the US and Europe.[2] Numerous efforts have been made to study the global environmental problem,[3] but so far these have insufficiently addressed the trade-related increase in many types of air pollutants. This study articulates how international trade influences the flow of SO_2 emissions through countries. Based on the World Input-Output Database (WIOD) and fuel-related SO_2 emissions inventory for 40 world economies in 2009, a multiregional input-output (MRIO) model was employed to investigate the impact of international trade on SO_2 emissions induced by each economy. The results could help provide insights for the development of effective policies aimed at reducing global atmospheric SO_2 emissions and allocating national responsibilities worldwide.

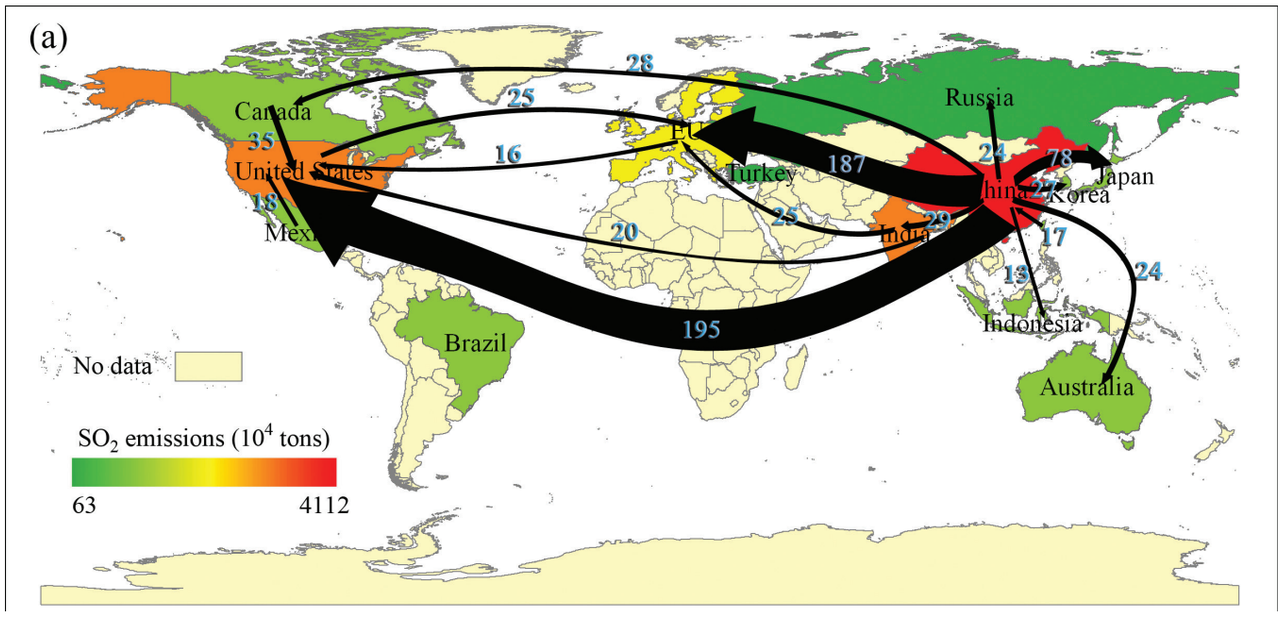
A total of 111.74 million tons (Mt) of atmospheric SO_2 was discharged globally in 2009, of which 82.39 Mt (74 per cent) was discharged by the 40 countries in the WIOD, and the other 29.35 Mt (26 per cent) was released by the rest of the world. From the consumption emissions perspective, the 40 countries accounted for 76 per cent of the total emissions, and the rest of the world held the other 24 per cent of the total. Excluding the rest of the world, China, the US and India were the top three emitters both from the producer and consumer perspectives (see Figure 1a); they discharged 41.12 Mt (37 per cent), 10.11 Mt (9 per cent), and 8.93 Mt (8 per cent) of SO_2 based on production, respectively, and 34.29 Mt (31 per cent), 13.61 Mt (12 per cent) and 8.76 Mt (8 per cent), based on consumption, respectively. The total population of the three countries accounted for over 41 per cent of the world's total. For both the production or consumption emissions, electricity, gas and water supply and agriculture dominated the emissions, accounting for 41 per cent and 40 per cent of the national total, respectively (see Figure 1a). Different from China, in the US, the electricity, gas and water supply sector was the unique leading sector for SO_2 emissions, while in India, agriculture dominated the emissions.

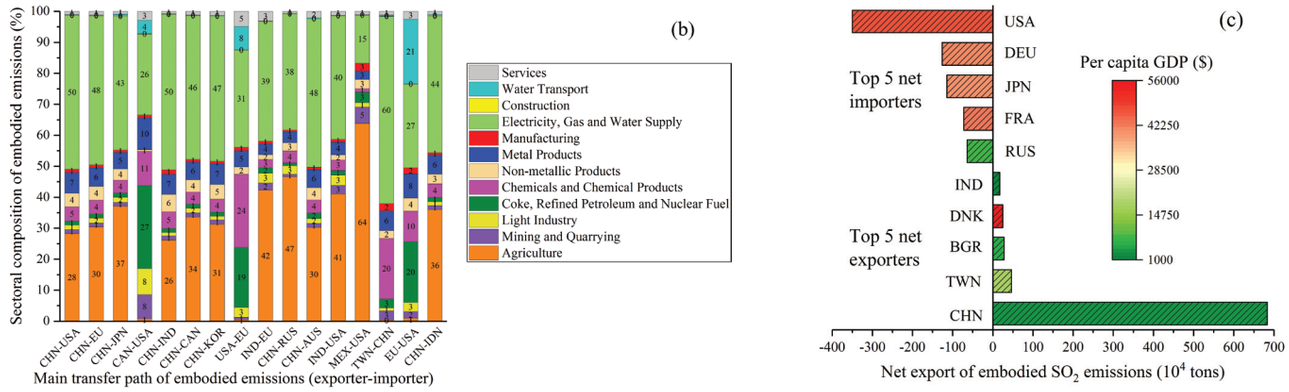
Figure 1 (a) Production- and Consumption-based SO_2 Emissions for 40 Countries in 2009; (b) SO_2 Emissions Embodied in Imports and Exports of 40 Countries in 2009



Drawn by the author.

Figure 2: (a) Main Transfer Path of Embodied SO_2 Emissions in International Trade; (b) Sectoral Composition of Embodied SO_2 Emissions for the Main Transfer Path; (c) Net Export of SO_2 Emissions and Per Capita GDP of the Top Five Net Importers and Exporters.





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From the perspective of imports and exports, China was far ahead of the other countries, becoming the largest embodied SO_2 exporter (it exported a total of 8.36 Mt-SO_2) (see Figure 1b). The main export sectors of China were also electricity, gas and water supply and agriculture, accounting for 48 per cent and 31 per cent of the national total exports, respectively. By contrast, the main importing country was the US with 4.62 Mt of imports. Electricity, gas and water supply and agriculture also dominated the US' imports.

Figure 2a shows the largest gross fluxes of embodied emissions among the 40 countries, with countries shaded according to the actual SO_2 emissions of each country. For ease of description, 27 EU countries were merged into one region called the EU. With the 1.95 Mt-SO_2 emissions, the flow from China to the US accounted for the largest amount, which was followed by the routes from China to the EU and from China to Japan with 1.87 Mt and 0.78 Mt, respectively. On the other hand, electricity, gas and water supply dominated three paths, accounting for 56 per cent, 48 per cent and 43 per cent of the total embodied emissions, respectively, which was followed closely by agriculture with 28 per cent, 30 per cent and 37 per cent, respectively caused by the high emission intensity of agriculture in the three largest agriculture export countries (China, India, and Mexico) with approximately 19 ton/million dollars, 19 ton/million dollars, and 20 ton/million dollars, respectively. Different from most transfer paths which were dominated by electricity, gas and water supply, the routes from Mexico to the US were dominated by agriculture (64 per cent), primarily due to the close distance between the two countries and the developed agricultural sector of Mexico.

We also observed that the embodied atmospheric SO_2 emissions were generally moving from countries with lower per capita GDP to countries with higher per capita GDP. This was supported by a previous study.[4] As illustrated in Figure 2c, four of the top five net importers (US, Germany, Japan, France, and Russia) had a per capita GDP above 40 thousand dollars, while four of the top five net exporters (China, Taiwan, Bulgaria, Denmark and India) had a per capita GDP less than 20 thousand dollars. This may have been caused by stricter environmental regulations in developed countries and greater economic development needs in developing countries.

Conclusion

The results have two main policy implications with respect to global atmospheric SO_2 reductions. First, economically developed countries should undertake more responsibilities with respect to global emissions. As developed countries often imported products with high embodied emissions from developing countries, they transferred the environmental burden to developing countries through international trade. For instance, as the largest net importer, the US imported 34 per cent of embodied SO_2 from other nations, especially from China, which accounted for 14 per cent of the total consumption emissions of the US. Second, clean energy should be employed in power production and agriculture. Given that the two sectors are the main sources of SO_2 discharge, replacing fossil fuels with clean energy in these sectors could greatly decrease the global emissions.

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Global Innovation in Solar Energy Technologies

Dr. ZHONG Sheng, ESI Research Fellow

Introduction

Economic development and improvements in living standards require expansion of industrial production and this in turn requires massive increases in energy consumption which, at this point in time, are largely met by exhaustible fossil fuels. The share of fossil fuels in global energy consumption has remained quite stable from 1990 (80.7 per cent) to the present (80 per cent in 2015).[1] The economic activities based on fossil fuels have caused substantial externalities such as harm to human health, climate change and damage to the environment.[2] If the heavy dependence on fossil fuels continues, the prospects for sustainable development will be greatly challenged. An energy transition towards

renewable energy is strongly needed.

Technology which facilitates an energy transition can provide long-term potential solutions to environmental problems,[3] and play a crucial role in the pursuit of sustainable development.[4] Understanding the relevant technological domains is critical for the design of appropriate development strategies. An analysis of comprehensive patent data from the European Patent Office (EPO), relating to solar energy technologies, is presented here.

Brian Lawson and Kenesaw Burwell work on panels that the Energy Department is using to leverage a Power Purchase Agreement with Sun Edison and Xcel Energy, 2012. Photo by ENERGY.COM (Permission under Wikimedia Commons).

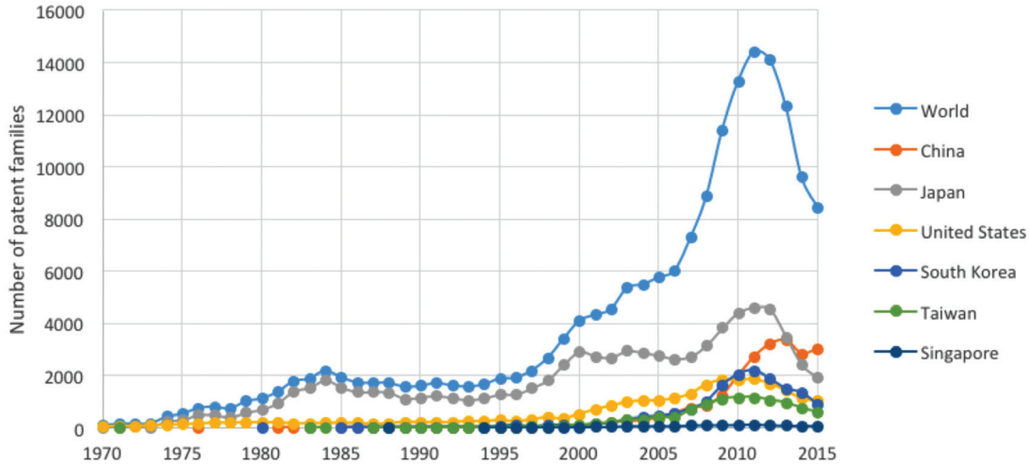
Patents remain central in empirical research on innovation, despite their limitations in measuring the introduction of new products, processes and services.[5] They can provide comprehensive information (e.g., filing year, inventor and innovative characteristics) and track technological development. The EPO Worldwide Patent Statistical Database (PATSTAT) provides the key data, covering most leading economies since the beginning of the patent system. Of particular interest here is solar energy technologies that convert radiation energy into electrical energy, which are under the International Patent Classification (IPC) classes H01L 25, H01L 27 and H01L 31. These IPC classes are regarded as solar energy technologies in the Green Inventory list of the World Intellectual Property Organization (WIPO).[6]

Stylised Fact 1: Average Annual Growth of 10 Per Cent since 1970 and a Peak in 2011

In the entire EPO PATSTAT (2017 Autumn release), 183,937 patent families under the selected IPC classes have been identified, covering 148 economies from 1904 to 2016. The first patent was filed in Austria in 1904 by Richard Norman Lucas and Henry Leitner from the UK. The first patent by a company inventor was filed in 1911 by Western Electric of the US. Figure 1 graphs the number of patent families in this field from selected economies from 1970 to 2015.

Prior to 1970, the global innovation output was relatively limited. The number of patents began to increase in 1970 with neutral growth until 1995, after which the growth accelerated. From 2005, global innovation output has had a much higher growth rate than before and reached a peak in 2011, after which the number of patents declined. The average annual growth of patents in this field from 1970 to 2015 was about 10 per cent. Selected major economies follow similar trends. In most years, Japan contributes most patents in the world, followed by the US. Since 2014, China has contributed the largest number of patents in this field.

Figure 1: Number of Patent Families in Solar Energy Technologies by Year, 1970 – 2015



Source: Drawn by the author.

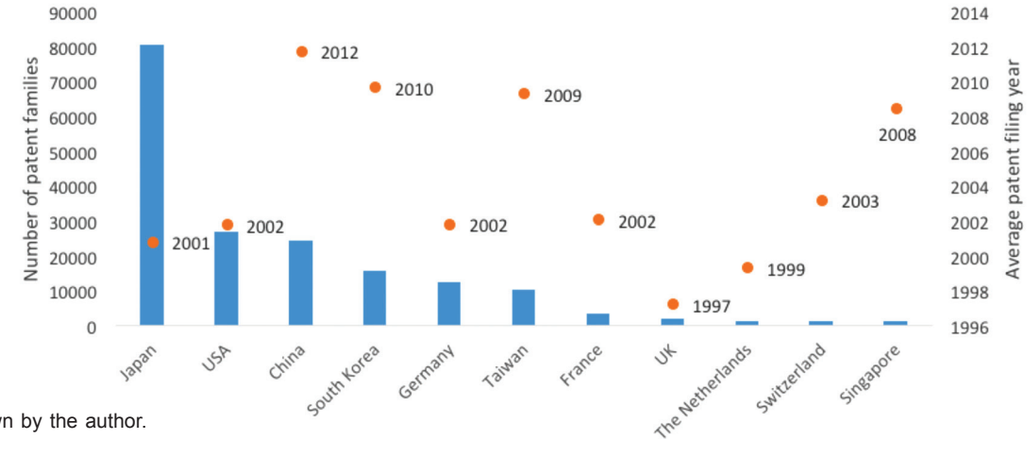
Stylised Fact 2: Dominance of Incumbent Innovators and Increasing Contribution of Latecomer Innovators

Among 148 economies participating in innovation activities in this field, a total of 11 economies have contributed more than 1000 patent families or more. Figure 2 presents these economies – the number of patent families they have and the average patent filing years of their patents. Japan has been the most active innovator in this field, with the most patents (80,427), followed by the US (27,019), China (24,667), South Korea (15,758), Germany (12,495) and Taiwan (10,488).

Other important innovators include France, the UK, the Netherlands, Switzerland and Singapore.

The average patent filing year is used to distinguish between incumbent innovators and latecomer innovators (see Figure 2). The smaller this indicator, the longer the economy has been in this field. The incumbent innovators are also early industrialisers, with an average year of 2003 or earlier than 2003, including Japan, the US, Germany, France, the UK, Netherlands and Switzerland. The latecomer innovators are also those that are traditionally viewed as newly industrialised / emerging economies, averaging the year of 2008 or later than 2008, including China, South Korea, Taiwan and Singapore. The figure shows that the incumbent innovators have contributed the largest share of patents in this field, while the innovation outputs from latecomers have been increasing in recent years.

Figure 2: Number of Patent Families in Solar Energy Technologies and Average Patent Year



Source: Drawn by the author.

Stylised fact 3: Dominance of the Business Sector

Figure 3 shows the profile of institutional innovators in innovation in this field over time. It is evident that the business sector, as represented by company innovators, comprises the bulk of institutional innovators over the entire period from 1970 to 2015. Most solar energy patents were developed only by company innovators. Since 2000, the university innovators have contributed an increasing number of patents. However, the innovation collaboration among industries, universities and the public sector is very limited.

Conclusion

Three key stylised facts arise. First, global innovation output in solar energy has grown at an average annual rate of 10 per cent since 1970 and it reached a peak in 2011. Second, the innovation activities in this field have been concentrated in several major economies. Most patents in this field were contributed by incumbent innovators. There has been an increasing contribution from latecomer innovators in recent years. Third, the business sector has an overwhelming dominance in the innovation activities. Collaboration among the industrial sector, universities and the public sector is very limited. Greater efforts will be needed to address important issues such as innovative capability, changing innovation patterns and the mechanisms behind such dynamics. Policies should be directed towards better exchange and application of knowledge and skills across regions and sectors, by matching local economic and technological competencies to appropriate development strategies.

1 *World Development Indicators,* the World Bank.

2 H. Allcott and M. Greenstone, "Is There an Energy Efficiency Gap?", *Journal of Economic Perspectives, 26* (1) (2012): 3–28. doi:10.1257/jep.26.1.3

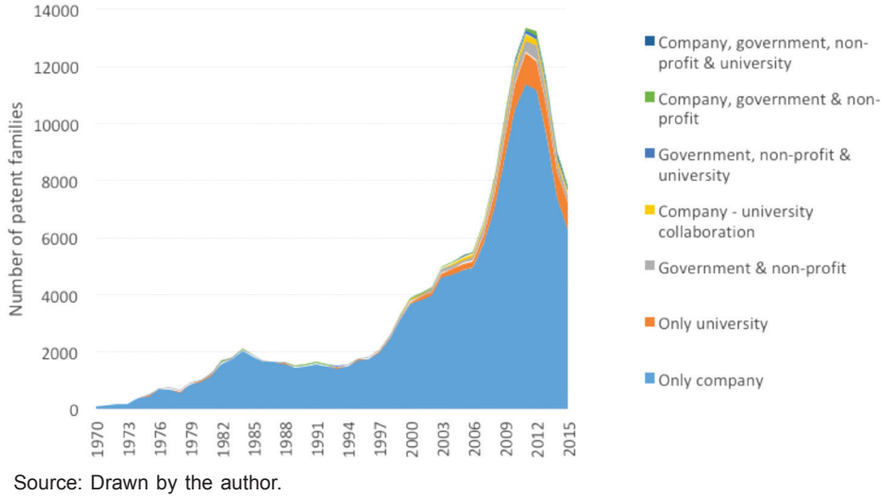
3 I. Dincer, " Renewable Energy and Sustainable Development: A Crucial Review", *Renewable and Sustainable Energy Reviews, 4* (2) (2000): 157–75. doi:10.1016/s1364-0321(99)00011-8

4 D. Acemoglu, "Directed Technical Change" *Review of Economic Studies, 69* (4) (2002): 781–809. doi:10.1111/1467-937x.00226; D. Acemoglu, P. Aghion, L. Bursztyn and D. Hemous, " The Environment and Directed Technical Change" *American Economic Review, 102*(1) (2012): 131-66. doi:10.1257/aer.102.1.131

5 Z. Griliches, " Patent Statistics as Economic Indicators: A Survey", *Journal of Economic Literature, 28*(4) (1990): 1661–1707; K.G. Huang, "China's Innovation Landscape" *Science, 329* (5992) (2010): 632–33. doi:10.1126/science.1190212

6 WIPO Green Inventory list: http://www.wipo.int/classifications/ipc/en/green_inventory/.

Figure 3: Profile of Institutional Innovators by Year, 1970 – 2015



Source: Drawn by the author.

Staff Publications

Internationally Refereed Journal Articles

Dina Azhgaliyeva, "The Effect of Oil Revenue Funds on Social Welfare", *Public Finance Review* 46 (4) (2018): 692-712.

Cuixia, G., **Su Bin**, Sun, M., Zhang, X.L. and Zhang, Z.H., "Interprovincial Transfer of Embodied Primary Energy in China: A Complex Network Approach" *Applied Energy* 215 (2018): 792-807.

Zhang, S., **Philip Andrews-Speed** and Li S., "To What Extent will China's Ongoing Electricity Market Reforms Assist the Integration of Renewable Energy?" *Energy Policy* 114 (2018): 394-402.

Philip Andrews-Speed and Zhang, S. "China as a Low-Carbon Energy Leader: Successes and Limitations" *Journal of Asian Energy Policy* 2 (1) (2018): 1-9.

Goh Tian, **Ang Beng Wah**, "Quantifying CO_2 Emission Reductions from Renewables and Nuclear Energy – Some Paradoxes", *Energy Policy* 113 (2018): 651-662

Ang Beng Wah, Goh Tian, "Bridging the Gap Between Energy-to-GDP Ratio and Composite Energy Intensity index", *Energy Policy* 119 (2018): 105-112

H. Wang, **Ang Beng Wah**, "Assessing the Role of International Trade in Global CO_2 Emissions: An Index Decomposition Analysis Approach", *Applied Energy* 218 (2018): 146-158

ESI Policy Briefs

Yao Lixia, Philip Andrews-Speed and Mohammad Zia, "China-Indonesia Coal Relationship: A New Phase under the Belt and Road Initiative" *ESI Policy Brief 23* (10 May 2018).

Reports

Allan Loi, "Singapore's Case Study", in H. Kimura and H. Phoumin (eds). *Technical Improvement Report on Energy Outlook and Energy Saving Potential in East Asia.* ERIA Research Project Report 2016, No. 8, pp. 187-89.

Allan Loi, "Review of Nationally Determined Contributions of Singapore", in H. Kimura and H. Phoumin (eds) *Technical Improvement Report on Energy Outlook and Energy Saving Potential in East Asia,* ERIA Research Project Report 2016, No. 8, pp. 267-69.

Liu Yang and Zhong Sheng., "A Key Pillar of Energy Transition: Smart Grid Innovation Trends" *Member Journal of Global Energy Interconnection Development and Cooperation Organisation (GEIDCO)* 10 (2018): 38-39.

Book Chapters

Philip Andrews-Speed, "Governance of the Electricity Sector**",** in L. Lester and M. Thomas (eds) *China's Electricity Sector: Challenges and Changes* (Palgrave, 2018), pp. 31-51.

Philip Andrews-Speed, "Institutions and the Governance of the Resources Nexus: The Case of Nitrogen Fertilizers in China", in T. Marsden (ed), *The Sage Handbook of Nature* (Sage, 2018), pp. 1287-1307.

Philip Andrews-Speed, "China's Evolving Energy Policy: The Case of Electricity", in J. Considine and K.W. Paik (eds) *Handbook of Energy Politics (Edward Elgar),* pp. 179-212.

Christopher Len, "The Indian Ocean and China's Expanding Influence: Prospects for Cooperation among the Key Asian Energy Importers", in Jivanta Schöttli (ed), *Maritime Governance and South Asia: Trade, Security and Sustainable Development in the Indian Ocean* (Singapore: World Scientific Publishing)*,* pp. 181-94.

Ho, S. M., S. Wagh, A. Kadier, I.A. Gondal, **N.A. Putra**, and M.K. Mishra, "Renewable Technologies", in S.M. Ho (ed), *Renewable Energy and Wastewater Treatment Vol 1.* (Madhya Pradesh, India: Ideal International E-Publication), pp. 1-32.

Other Publications

Gautam Jindal, "A Guide to Singapore's Recently Announced Carbon Tax", *Asian Power,* 6 April 2018.

Zhong Sheng, "A Key Pillar of Energy Transition: Smart Grid Innovation Trends", *Journal for Member Organizations of Global Energy Interconnection Development and Cooperation Organization (GEIDCO),* Issue 10*,* 1 May 2018.

Melissa Low, "Getting to 2 Degrees or Less: What Will it Take to Limit Climate Change?", *ENVISION Issue 14,* 1 June 2018.

Allan Loi and Nur Azha Putra, "Oil Prices have Gone Up and it May Affect Your Electricity Bill", *Channel News Asia,* 28 June 2018.

Nur Azha Putra and Philip Andrews-Speed, "Prospects for Nuclear Power in ASEAN", *The Diplomat,* 28 June 2018.

Philip Andrews-Speed and Christopher Len, "The Security of Sea Lanes in the Indian Ocean", *Middle East Institute Insight* 184, 15 May 2018.

Staff Presentations and Moderating

27 June Melissa Low presented "A Leading Green Economy" at the *PublicAction Movement to Read the Sustainable Singapore Blueprint,* organised by Lepak in SG, Singapore.

25 June Li Yingzhu presented "Energy and Climate Modelling at ESI" at the *GEMCLIME Annual Meeting,* University of Gothenburg, Sweden.

24 June Su Bin presented "Multiplicative Structural Decomposition Analysis of Aggregate Embodied Energy/ Emission Intensities" at the *5th Energy and Climate Economics Forum,* Guilin University of Electronic and Technology, China.

21 June Dina Azhgaliyeva presented "Financial Modelling of Solar PV and Energy Storage for Singapore" at

Singapore's Long-Term Energy Future Solar PV and Energy Storage, a workshop organised by ESI.

20 June Dina Azhgaliyeva moderated "Prospects for Solar PVs and Storage Technologies in the Future Energy Landscape", delivered by Mr. Jeffrey Logan, Chief Analyst, National Renewable Energy Laboratory (NREL) at an ESI seminar.

20 June Liu Yang presented "Prospects for Solar PVs and Storage Technologies in the Future Energy Landscape", at *Singapore's Long-Term Energy Future Solar PV and Energy Storage Conference,* organised by ESI.

18 June Zhong Sheng presented "Exploring Technological Trajectories and Technological Catch-Up in Solar Energy: Evidence from Patent Data", at the *Green Transformation and Competitive Advantage: Evidence from Developing Countries Conference,* German Development Institute, Bonn, Germany.

14 June Su Bin presented "Structural Decomposition Analysis Applied to Energy and Emissions: Recent Developments and Future Trends", Hunan University, China.

13 June Liu Yang presented "Prospects for Energy Efficiency in ASEAN: Evidence from Decomposition Analysis and Cross-Country Comparison", at the *41st International Association of Energy Economics (IAEE) Conference,* organised by the Benelux Association of Energy Economics and the IAEE, Groningen, Netherlands.

13 June Brantley Liddle presented "Revisiting the Income Elasticity of Energy Consumption: An OECD & Non-OECD Country Panel Analysis.", at the *41st IAEE International Conference,* organised by the Benelux Association of Energy Economics and the IAEE, Groningen, Netherlands.

13 June Yao Lixia presented "Belt and Road Initiative in Southeast Asia's Energy Sector: Impacts and Implications for the Region", at the *38th International Academic Conference,* Prague, Czech Republic.

08 June Liu Yang presented "Battery Storage Technology for Clean Energy", at the *Asia Clean Energy Forum,* Manila, Philippines.

07 June Liu Yang presented "Integrating Solar Photovoltaics and Storage into a Long-Term Energy Technology Portfolio: Business Model Innovation and Lessons from Singapore", at the *Asia Clean Energy Forum,* Manila, Philippines.

05 June Liu Yang presented "Cross-Country Dynamics in Energy Productivity: Evidence from 47 Economies over the Period 2000 – 2015", at the *Asian Development Bank,* Manila, Philippines.

28 May Liu Yang moderated "Prospects for Energy Storage in Singapore" at *Energy Storage: New Business Models for Singapore and Asia,* organised by Enrupt, Collision 8, Singapore.

25 May Yao Lixia was a discussant at the *ESI Conference on the Belt and Road Initiative for the Energy Sector in ASEAN and Singapore: Trends, Prospects and Implications*.

24 May Yao Lixia presented "Belt and Road Initiative for the Energy Sector in ASEAN and Singapore: Trends, Prospects and Implications" at the *ESI Workshop on Belt and Road Initiative for Energy Sector in ASEAN and Singapore: Trends, Prospects, and Implications*, Singapore.

24 May Melissa Low presented "The Role of Carbon Pricing in Tackling Climate Change: A Case Study from Singapore" at the *ASEAN CSR Network Webinar,* Singapore.

23 May Liu Yang presented "Energy Market Design in the Smart Grid Area" at the *9th Clean Energy Ministeria,* Malmo, Sweden.

21 May Liu Yang presented "Pathways for Energy Efficiency: China's Experience and Implications for ASEAN" at the *Energy Efficiency (EE) Global Forum 2018,* Copenhagen, Denmark.

21 May Philip Andrews-Speed presented "The Internationalization of China's Energy Industries: Trade, Investment, Construction and Technology" at the *China's Rise and International Trade and Monetary Affairs Conference*, organised by the Chinese Academy of Sciences, Beijing.

18 May Melissa Low presented "Significance of MRV in Driving Low Carbon Future in ASEAN Countries" at the *ASEAN Centre for Energy Webinar*, Singapore.

17 May Su Bin presented "Singapore's Energy/Climate Policy and Research Developments", at the North China Electric Power University, China.

8 May Allan Loi presented "Open Electricity Market: How Competitive Can It Get?", at the *Electricity Market Liberalization for Small Businesses Seminar,* SGX Centre Auditorium, Singapore.

5 May Su Bin presented "Impacts of Verified Emissions Announcements on the Co-movements between Trading Behaviour and Carbon Price in the EU-ETS" at *Workshop on Carbon Price Volatility, Determinants and Stabilization Mechanism,* Wuhan University, China.

3 May Philip Andrews-Speed presented "The Southeast Asia-Arctic-Climate Nexus: An Energy Perspective", at the *Connecting Arctic To Asia Through Climate Change Conference,* French Embassy, Singapore.

24 March Melissa Low presented "Challenges and Solutions to Energy Sustainability in Singapore" organised by the Geography Teachers' Association, University Town, National University of Singapore, Singapore.

12 March Liu Yang presented "Policies to Promote Renewable Energy and Energy Security in Central Asia", at the *Asian Development Bank Institute Workshop on Energy Security and Renewable Energy,* Baku, Azerbaijan.

09 March Liu Yang presented "Utilities Transformation in ASEAN", at the *International Energy Agency World Energy Investment Roundtable,* Paris.

21 February Brantley Liddle presented "The Importance of Consumption-based Accounting and the Trade-Carbon

Emissions Nexus", at *Division of Environment and Sustainability Seminar*, Hong Kong University of Science and Technology, Hong Kong.

28 November Anthony David Owen was a discussant at the joint ESI- Institute for South Asian Studies (ISAS), Conference: *Towards a Low Carbon Asia: The Challenges of Ensuring Efficient and Sustainable Energy,* Orchard Hotel, Singapore.

27 November Liu Yang was a discussant for "Energy Transition: From Fossil Fuel to Renewables", at the *South Asia's Challenges and Opportunities in Sustainable Energy Transitions Workshop,* organised by ESI and ISAS, UNDP Auditorium, Singapore.

27 November 2017 Liu Yang moderated "Climate Change", at the *South Asia's Challenges and Opportunities in Sustainable Energy Transitions Workshop,* organised by ESI and ISAS, UNDP Auditorium, Singapore.

27 November 2017 Hari M P was a discussant for "Power and Electrification", at the *South Asia's Challenges and Opportunities in Sustainable Energy Transitions Workshop,* organised by ESI and ISAS, UNDP Auditorium, Singapore.

27 November 2017 Anthony David Owen moderated "Power and Electrification", at the *South Asia's Challenges and Opportunities in Sustainable Energy Transitions Workshop,* organised by ESI and ISAS, UNDP Auditorium, Singapore.

Staff Media Contributions

Nur Azha Putra interviewed by *Berita Harian* on "Faktor Geopolitik, Harga Minyak Jejas Tarif" (Geopolitical Factors, Oil Prices Affect Tariff), 31 June 2018.

Allan Loi interviewed by *Lianhe Zaobao* on "Electricity Tariffs in Singapore", 25 June 2018.

Philip Andrews-Speed interviewed by *Radio Free Asia* on "China: Oil and Gas Pipeline Merger", 18 June 2018.

Allan Loi quoted in "Sizzling Competition, 'Encouraging' Sign-ups as Electricity Market Opens up in Jurong", *Channel News Asia*, 26 April 2018.

Philip Andrews-Speed interviewed by *Radio Free Asia* on "China: Coal Consumption", 25 April 2018.

Melissa Low interviewed by *Channel News Asia* on "International Maritime Organisation Regulation on Shipping", 20 April 2018.

Philip Andrews-Speed quoted in "China and Philippines Joint Exploration Agreement", 9 April 2018.

Allan Loi interviewed by *Power 98 FM* on "Electricity Market Liberalisation", 16 March 2018.

Recent Events

20 June, "Prospects for Solar PVs and Storage Technologies in the Future Energy Landscape" (ESI Conference)

Mr. Jeffrey Logan, Chief Analyst, National Renewable Energy Laboratory (NREL) (Photo by ESI).

This international conference gathered around 100 stakeholders to discuss the long-term outlook for the electricity sector, with a particular focus on how developments in solar PV, energy storage technologies, as well as business models will help forge the future of Singapore's electricity landscape and beyond.

The ten international and local speakers came from the Clean Energy Ministerial (CEM)/International Energy Agency (IEA), National Renewable Energy Laboratory (NREL, USA), Commonwealth Scientific and Industrial Research Organisation (CSIRO, Australia), International Renewable Energy Agency (IRENA), Energy Studies Institute (ESI), World Bank, RedDot Power, India Energy Storage Alliance, University of Tasmania and RedFlow. They made presentations on topics relating to power system transformation, roadmaps for clean energy transitions, policy and innovative business models and emerging storage technologies.

18 June, "A View to Future Urban Energy Systems Modelling and Analysis" (ESI Seminar)

Dr. Jimeno A. Fonseca, Senior Researcher and Project Coordinator for the Multi-Scale Energy Systems for Low-Carbon Cities (MuSES) project at the Future Cities Laboratory, Singapore ETH-Centre delivered a presentation on state-of-the art urban energy systems modelling and analysis at the district level. His presentation provided examples of key current applications of these models and provided an overview of future challenges in the field.

31 May, "Energy Efficiency Standard in ASEAN" (ESI Seminar)

Mr. Rio Jon Piter Silitonga, Technical officer for *the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025* from the ASEAN Centre for Energy (ACE) delivered a presentation highlighting the findings from a report by the ASEAN Standard Harmonization Initiatives for Energy Efficiency (ASEAN-SHINE). He also discussed

Mr. Rio Jon Piter Silitonga (Photo by ESI).

the *Regional Policy Roadmap on Standard Harmonisation for Air-Conditioning*. The report focuses on ASEAN initiatives relating to technical standard harmonisation for energy efficient air conditioning in the Southeast Asian region and noted that doing so could boost trade in the region by as much as 4.55 per cent and save a potential Bt21.5 billion (USD 669 million) in energy costs. Mr. Rio emphasised that testing standard harmonisation is important and in line with the aspirational goal of reducing energy intensity in ASEAN by 20 per cent by 2020 as a medium target, and 30 per cent as a long-term target based on the 2005 level, as stipulated in the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025.

25 May, "Belt and Road Initiative for the Energy Sector in ASEAN and Singapore: Trends, Prospects, and Implications" (ESI Conference)

This conference brought together scholars and experts from Mainland China, Hong Kong and Southeast Asia to discuss Chinese investment in ASEAN's energy sector. The panellists reviewed the Belt and Road Initiative (BRI) in ASEAN's energy sector and assessed how successful it will likely be in facilitating the construction of ASEAN's energy infrastructure. They also examined the impacts of the investments, and benefits and threats brought about by an integrated ASEAN energy market for Singapore. The delegates were from government, industry, research institutes and the media.

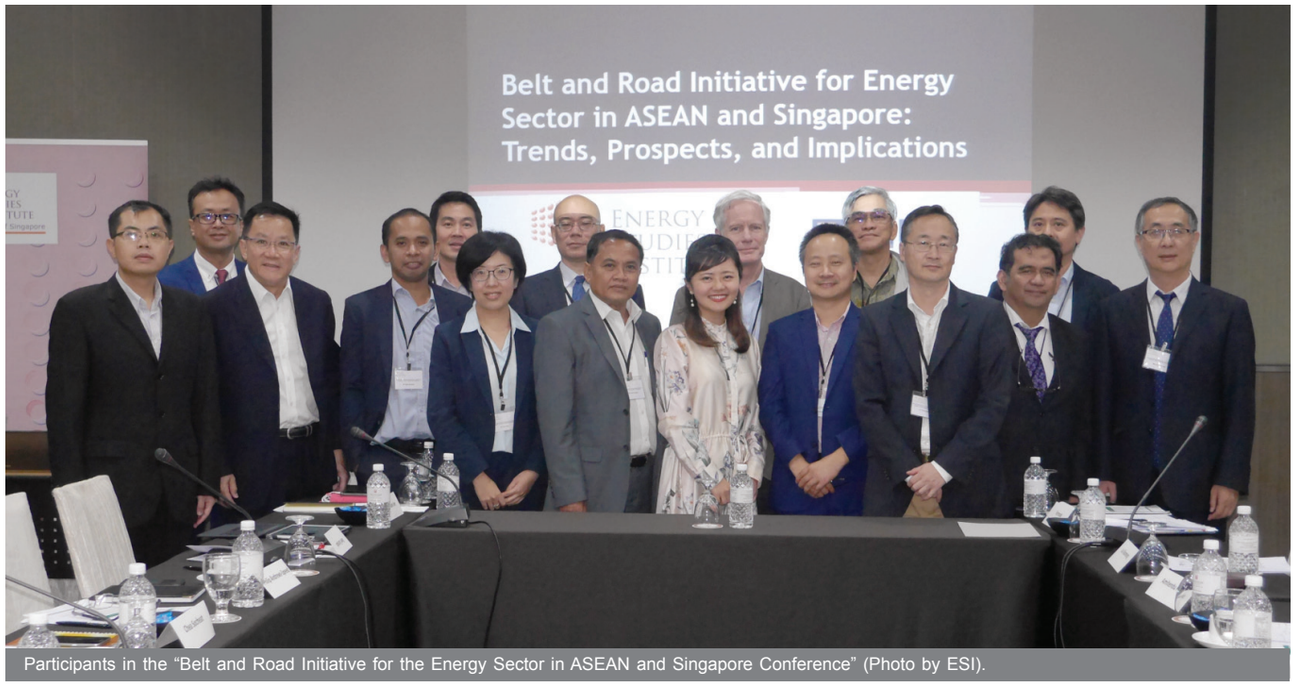
3 May, "Connecting the Arctic and Asia through Climate Actions and Sustainable Development" (Joint Workshop)

The Ambassador of France to Singapore, His Excellency Marc Abensour welcoming the speakers and audience (Photo courtesy of the Embassy of France in Singapore).

Organised by the French Embassy as part of the Voilah! French Festival, Dr. Philip Andrews-Speed, ESI Senior Principal Fellow delivered a presentation entitled, "The Southeast Asia – Arctic – Climate Nexus: An Energy Perspective" alongside Professor Mikaa Mered of the Free Institute of International Relations Studies in France. The event was opened by His Excellency Marc Abensour, Ambassador of France to Singapore, Her Excellency Barbara Plinkert, EU Ambassador to Singapore and Ms. Amy Hing, Deputy Permanent Secretary, Ministry of the Environment and Water Resources of Singapore.

26 April, "Exploring Green Bond Premiums: What Makes Green Bonds Different from Conventional Bonds" (ESI Seminar)

Dr. Shu Tian, Economist, and Dr. Donghyun Park, Principal Economist from the Asian Development Bank (ADB), discussed recent ADB research on green bonds. The main focus of this research is quantification of the differences between green bonds and conventional bonds. The speakers provided an overview of the development of green bonds, a financial instrument



Participants in the "Belt and Road Initiative for the Energy Sector in ASEAN and Singapore Conference" (Photo by ESI).

Dr. Shu Tian and Dr. Donghyun Park (Photo by ESI).

designed to deal with environmental externalities and climate change. Dr. Shu Tian presented some general market criteria (e.g., green bond principles) and major challenges that restrict the green bond market, such as a lack of universally accepted standards and pricing mechanisms. Then she explained the data sources and econometric strategies that were used to assess the factors making green bonds different from conventional bonds. The research showed that the issued amount, rather than the yield level, plays a crucial role in shaping the difference between these two types of bonds, and proposes a better standardised monetization of environmental benefits.

11-12 April, Conference On "Evolving Global Nuclear Energy Landscape: Emerging Challenges and Opportunities 2018 (ESI Conference and Workshop)


Some participants at the Conference on the "Evolving Global Nuclear Energy Landscape" (ESI Photo).

Organised by the ESI and Centre for International Law (CIL) at NUS, this event was specifically aimed at contributing towards understanding the context, challenges and emerging opportunities arising from ongoing changes taking place in the nuclear industry.

The discussions centred around the governance of nuclear power in newcomer countries, the role of political and industrial interests, and challenges relating to the management of construction, supply chains and projects. Reflections on the rise of Russia and China as nuclear exporters, and Bangladesh and Turkey as newcomers to nuclear power, provided an interesting backdrop for exchanges on the expectations of the international nuclear community and Western nuclear power countries.

11 April, "Green Financing Opportunities in ASEAN" (ESI Seminar)

Mr. Mikkel Larsen, Managing Director and Chief Sustainability Officer at the Development Bank of Singapore (DBS) shed light on the regional challenges and opportunities for green finance in the context of the member states of the Association of Southeast Asian Nations (ASEAN). He also shared his experience with aligning sustainability considerations in the broader DBS corporate strategy. He noted that being one of Singapore's largest banks, DBS recognises its role in shaping the green finance agenda early on and added that DBS is seen as the frontrunner in green finance in the domestic market and is the only Southeast Asian bank which has signed the Task Force on Climate-related Financial Disclosures (TCFD).

Contact

- Collaboration as a Partner of ESI (research, events, etc)
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