ESI Bulletin

ENERGY STUDIES INSTITUTE
National University of Singapore

ESI Bulletin on Energy Trends and Development (Volume 9 / Issue 4 • October 2016)

Coal-fired Power Plant in Shuozhou, Shanxi, China, 2010. Photo by Kleineolive (Permission under CC BY 3.0).

INTRODUCTION

The theme of this issue is modelling and analysis of low-carbon technologies and investment strategies.

The increases in global temperatures, rise in sea levels and changes in weather patterns have garnered worldwide attention since the 1990s. Scientists attribute all of these to the steadily increasing greenhouse gas emissions resulting from human activities. Obviously, the ensuing accelerated biodiversity loss, aggravated coastal erosion, and more frequent extreme weather events, etc., will have significant impacts on human beings. In order to prevent climate change from accelerating, many countries/regions have launched comprehensive policy packages to mitigate emissions. Carbon pricing in the form of a tax, emissions trading, border-tax-adjustments, etc., and investment in emission mitigation activities such as energy efficiency improvements, low-carbon technology RD&D and promotion of renewable energy, are some of the major types of policy instruments. Nevertheless, uncertainty is inevitable throughout the policy design and implementation process.

Since the early 1990s, modelling has been used widely in the policy analysis of energy and environmental issues at the local, national, regional and global levels, providing quantitative insights into energy RD&D and investment strategies, climate mitigation and adaptation pathways, as well as the associated potential impacts on economic development, social welfare and ecosystem sustainability. In addition, simulating and comparing different scenarios enables us to explore innovative policy designs that could effectively constrain the impacts of uncertainty or uncover the potential of existing policy instruments and integration with other instruments.

This is a compilation of the presentations on energy modelling made at ESI's *3rd Asian Energy Modelling Workshop on Carbon Pricing and Investment towards Low Emissions: Uncertainties and Potential*, held 25-26 February 2016, to which twelve speakers were invited from Australia, China, Germany, Japan, Norway,

In this issue ...

Singapore, South Korea, and the Philippines. The presentation summaries here focus on low-carbon technologies and investment strategies around the world and their implications for Asian countries. The next issue will provide summaries of the other papers offering modelling and analysis of carbon markets and carbon pricing.

Dr. Qi Shaozhou, Professor and Director of the Climate Change and Energy Economics Study Centre (CCEE) at Wuhan University in China, presented “Analysis of the Formation Mechanism of the Chinese Carbon Market Price Based on the Ensemble Empirical Mode Decomposition (EEDM) Method”. The carbon price of China’s six pilot markets over the April 2014 to December 2015 period were decomposed into several independent intrinsic mode functions (IMF) with different time scales and a trend term. The obtained IMF sequences were reorganised into three parts, including the high-frequency component, low-frequency component, and the long-term to analyse the formation mechanism of the pilot carbon prices. The empirical results show that (a) the market supply and demand imbalance caused by short-term market behaviour exerts a greater impact on the carbon price of Hubei and Beijing’s markets; (b) the carbon prices of most pilot markets, excluding Guangdong, are greatly influenced by the shock of major events; and (c) the internal mechanism has a significant impact on the carbon price of Shenzhen, Shanghai and Guangdong.

Dr. Wei Taoyuan, Senior Researcher at the Center for International Climate and Environmental Research – Olso (CICERO) in Norway, presented “Business as Unusual: The Implications of Fossil Divestment for Financial Flows, Economic Growth and the Energy Market”. Green bonds and fossil divestment have emerged as bottom-up approaches to climate action within the business community. Recent pledges by large banks and institutional investors have reached levels that have the potential to contribute markedly to a low carbon transition. Dr. Wei’s presentation traced the impact of green finance in a multi-regional global general equilibrium model with non-fossil and non-coal segments of financial flows, in addition to the usual unconstrained market for funding. The results showed that green finance shifts the investment towards industries generating more value added and increasing GDP, future savings and investments. Over the period towards 2030, the amount of CO_2 emissions avoided through the use of green finance was recently equal to the total emissions of the European Union and Japan.

Dr. Koji Tokimatsu, Associate Professor at the Tokyo Institute Technology (TIT) in Japan, presented “Global Zero Emissions Scenario Analysis”. His presentation investigated the prospects of three zero-emissions scenarios for reaching the target to limit global mean temperature rise to 2°C or below, and compared them with the business-as-usual (BAU) scenario. The global model minimises the supply costs for the various energy, materials, biomass and foods sectors to generate various zero emissions scenarios, including the “2100 zero emissions” scenario, “350 ppm zero emissions” scenario, and “net zero emissions” scenario. The role of biomass in energy carbon capture and storage (BECCS) with forested land was also assessed. The results indicated that the 2°C target can be achieved in the “net zero emissions” scenario, while the “350 ppm zero emissions” and “2100 zero emissions” scenario would result in a temperature rise of 2.4°C and 4.1°C, respectively. BECCS contributed to meeting zero-emissions requirements while providing a limited contribution to energy supply. The findings also indicate substantial future challenges for the management of forested land.

Dr. Ma Tieju, Professor and Director of the Institute of Energy Economics and Environment Management at the School of Business, East China University of Science and Technology in China, presented “Optimising the Layout of Initial Alternative Fuel Vehicles (AFV) Refuelling Stations and Experiments with Agent-based Simulation”. The number of refuelling stations for AFVs is limited during the early stages of diffusion of AFVs. Different layouts of these initial stations will result in different degrees of driver concern regarding refuelling and will therefore influence individuals’ decisions to adopt AFVs. Using Shanghai as the basis of computational experiments, different optimal layouts using a genetic algorithm were generated to minimise the total concerns of different targeted drivers, and agent-based simulations were conducted on the diffusion of AFVs with these layouts. The main findings of the study were (a) targeting drivers in the city centre can induce the fastest diffusion of AFVs if the technologies are mature; and (b) it is possible that a larger number of initial AFV refuelling stations may result in slower diffusion of AFVs because they may not have sufficient customers to survive.

Dr. Shi Xunpeng, Senior Research Fellow and Deputy Director of the Economics Division at ESI presented “Gas Trading Hubs and Transition to Hub-Indexed and Destination-Flexible Contracts in East Asia”. In East Asia’s gas markets, issues such as gas trading hubs, hub-indexed pricing and destination flexibility are being debated. Current initiatives involve the creation of gas trading hubs and price benchmarks in a few countries, among which competition is a concern. Dr. Shi first examined the impact of East Asia’s pricing benchmark change and contract flexibility improvements on the regional and global gas markets. The results showed that both price benchmark change and contract flexibility improvements would benefit the world as well as East Asian importers, but that the impacts differ among both exporters and importers. Nevertheless, the changes can generate net benefits for all stakeholders as a whole. The competition of benchmark hubs and the claims that destination restrictions cause the Asia Premium are not supported. This implies that the removal of destination clauses is of higher priority to Japan, Korea and Chinese Taipei than changing to hub-indexation. The study also suggests that East Asian importers should cooperate among themselves and with exporters to facilitate the market transition in East Asia.

Dr. Sheng Yu, Senior Economist at the Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES) in Australia, presented “The Implications of a Carbon Price on Bunker Emissions in Australia: Application of the GTEM Model”. Under current international agreements, no countries include bunker emissions in their national inventory of greenhouse gas emissions. Both the Kyoto Protocol and the COP 21 in Paris encouraged countries to be responsible for limiting and reducing emissions associated with bunker fuels by working through the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO). This leaves the possibility of extending the coverage of the global carbon charge to include bunker emissions as well. Dr. Yu analysed the impacts on the Australian economy and Australia’s trade competitiveness of extending a global carbon charge to international bunker emissions, by using the Global Trade Environmental Model (GTEM). An emissions reduction of 5 per cent below 2000 levels by 2020 was developed for the Australian government. This policy was implemented via a multi-stage global action involving international trade in allocated emissions rights which excludes bunker emissions.

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

Dr. Su Bin, Senior Fellow
(On behalf of the ESI Bulletin Team)

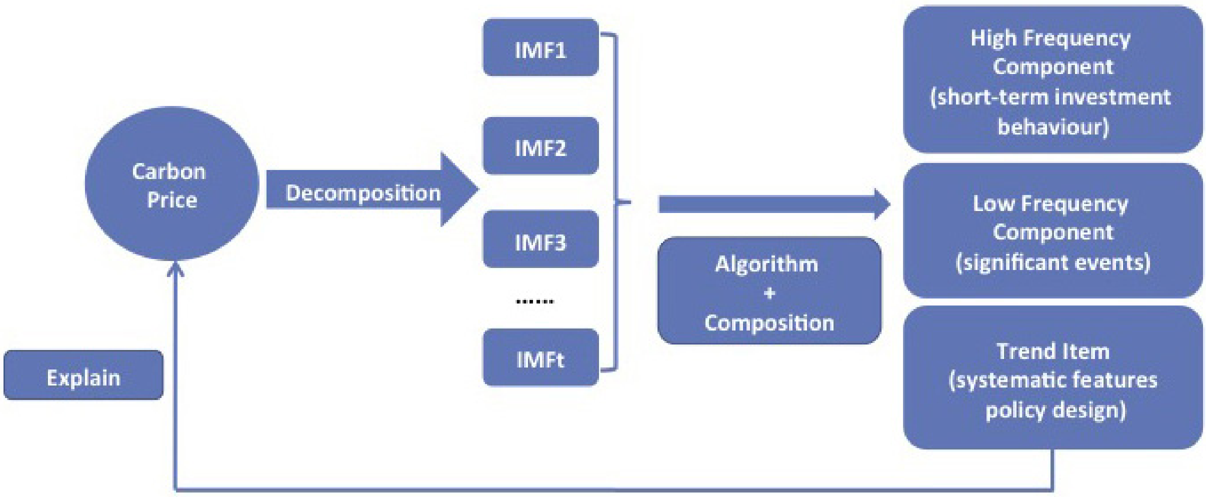
Analysis of the Formation Mechanism of the Chinese Carbon Market Price Based on the EEMD Model

Dr. Qi Shaozhou, Wuhan University, China

Shenzhen CBD and River, China, 2011. Photo by SSDPenguin (Permission under CC BY 3.0).

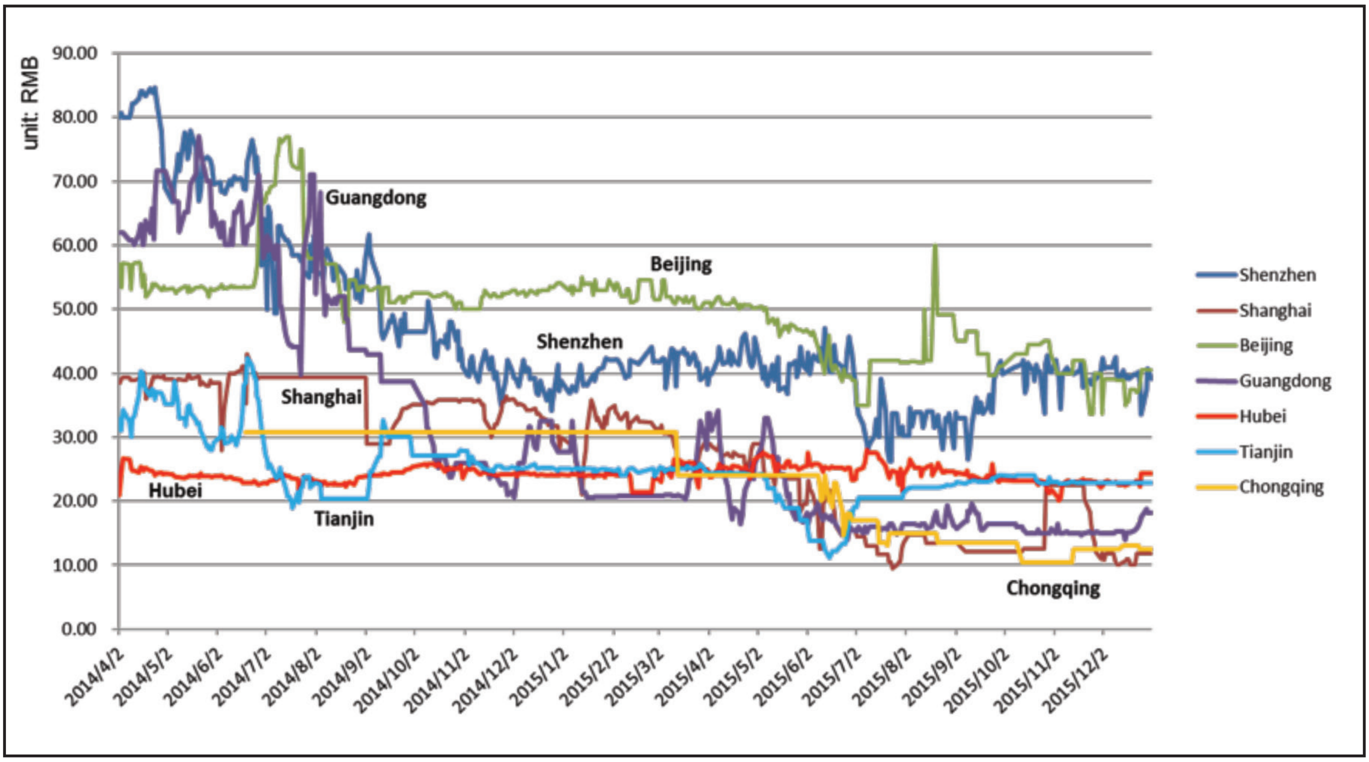
In this study, the author analyses the price fluctuations of China's pilot carbon price schemes on the basis of the Ensemble Empirical Mode Decomposition (EEMD) Model. The goal is to understand the formation of the carbon pricing mechanism on the basis of short term investment behaviour, significant events, and policy design. This analysis is useful in that different price fluctuations in pilot markets allow for better forecasting of future carbon prices and also give reference to the establishment and risk supervision of the national carbon market in 2017. The EEMD is used on the price and trade data, where each carbon price is divided into independent intrinsic mode functions (IMFs) with different frequencies according to the characteristics of the data. These are then analysed based on frequency components (see Figure 1).

Figure 1: Research Methodology



Source: Drawn by Qi Shaozhou.

Figure 2: Carbon Prices in China's Seven Pilot ETS Schemes



Source: Drawn by Qi Shaozhou.

In 2015, China's seven ETS pilot schemes saw a combined trading volume of 38,000 kilotonnes of CO_2 and a total trade value of 1.2 billion yuan. Hubei Province, with more than a 55 per cent share in volume and a 43 per cent share in value saw the largest trade volume and value in China. The carbon prices generally tend to fall into three price ranges, and showed a decreasing price trend over the pilot period. Through the EEMD, the carbon prices of six pilot markets were decomposed into independent IMFs. Each IMF is composed of a high frequency component, a low frequency component and a trend term. This enables analysis of the impact of short term investment behaviour, events and policy design, respectively. The key indicators analysed in each of the IMFs are: (a) the variance ratio which explains the contribution of each IMF to total volatility, (b) mean period which is the time span of influencing factors, (c) the Pearson Correlation which denotes a linear correlation, and (d) the Kendall Correlation which checks for common trends.

An empirical analysis of the results for the seven pilot schemes' price series found that the sum of the IMF's variance ratio was significant in three of them, namely, Hubei (58.9 per cent), Beijing (51.1 per cent) and Tianjin (40.7 per cent), while mean periods for all the price time series showed similarities in periods of various EMF components. Hubei's market price showed a stable long term trend due to frequent short term trading and the highest liquidity among all the pilot schemes. The Beijing, Tianjin and Shenzhen markets generally showed higher prices and a slightly decreasing longer term trend. The "U" shape of Shanghai's price series indicates that there was significant price fluctuation and oversupply in the market. Guangdong's market is unique in that prices were plummeting, pointing to a relatively serious issue in the effect of the market mechanism on prices (see Figure 2).

Thus, Hubei's carbon price was mostly influenced by the variance of the IMFs while Guangdong's was least affected. The increase in both the Pearson and Kendall Correlations with the increase over the period shows that factors with longer periods had greater influence on the carbon price. Individual decomposition of the IMFs shows that a IMF6 (a 6-month period) had a greater variance ratio in 2015, and an IMF5 (a 5-month period) had a greater variance in 2014. Hence, in 2014 and 2015 the three months' effects and six months' effects, respectively, had significant influence on the carbon prices.

A structural analysis of the carbon price, which decomposes prices into high, medium and low frequency parts show that all three components had distinct influences on the carbon prices. It was found that Hubei's and Beijing's carbon prices were mainly influenced by short term investment behaviour and significant events. Tianjin's and Shanghai's carbon prices were influenced by significant events and policy design while Guangdong's were mainly decided by policy design. Thus it can be inferred that during the compliance period, Hubei's and Beijing's carbon prices were mainly decided by short term investment behaviour while the other markets were relatively more influenced by policy design. A year by year analysis found that the influence of major events slightly increased for each pilot market in 2015.

In conclusion, volatility in carbon prices was seen to be jointly determined by system design, the effect of significant events and short term investor behaviours. It was also concluded that the efficacy of a good policy design is measured less by the influence of the market system on carbon price volatility. Also the effect of market liquidity can be measured by the influence of short term investor behaviour on price volatility.

This summary of Dr. Qi's presentation was written by ESI Research Associate, Mr. M. P. Hari.

Business as Unusual: The Implications of Fossil Fuel Divestment for Financial Flows, Economic Growth and the Energy Market

Dr. Taoyuan Wei, Senior Researcher at the Center for International Climate and Environmental Research-Oslo, Norway

Anagasaki Natural Gas-fired Power Plant in Ichihara, Chiba, Japan, 2012. (Permission under CC BY-SA 3.0).

The trend towards green finance today is mainly in the form of pledges to invest in green projects or to abstain from investments in fossil fuel industries. Over the last few years, the fossil fuel divestment movement started as an activist campaign and has developed into a policy of corporate social responsibility among large investors.

For example, during the 2014 UN Climate Summit in New York, the Rockefeller Brother Fund pledged to divest its total endowment by eliminating its exposure to coal and oil sands to less than 1 per cent of their total portfolio by the end of 2014. In 2015, the Norwegian Government Pension Fund Global (GPFG) decided to divest its portfolio of USD 900 billion by 2020 at the latest, and the French global insurance company AXA with around EUR 1200 billion in assets pledged to divest in coal extraction and coal-based power production. The Bank of America was the first large bank to join the divestment initiative early in 2015, followed recently by Citigroup's pledge to cut lending not only for mountain top removal strip mining, but also later to all coal mining.

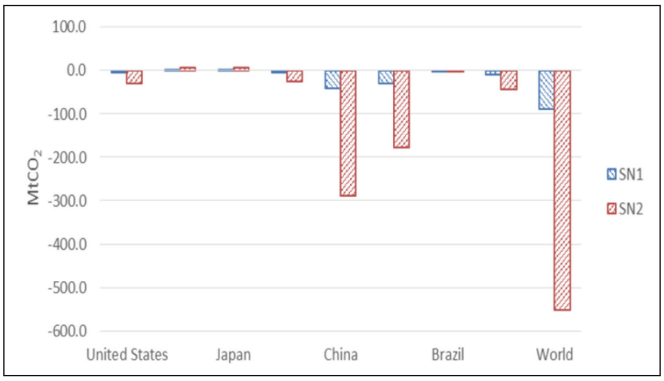
A timely question is how green bonds and divestment in fossil fuel industries will affect the economy and climate change mitigation. Therefore, a multi-sector, multi-region recursive computable general equilibrium (CGE) model, *GRACE*, which emphasises segmented financial flows in the global financial market and the production of energy, was used to analyse how dedicated green investment flows and divestment in fossil industries might affect the economy, financial flows, energy trends and emissions. *GRACE* covers eight regions, namely the US, the EU, Japan, Russia, China, India, Brazil, and the rest of the world (RoW). Each region has 15 production sectors, five of which are energy sectors (coal, crude oil, refined oil, gas and electricity). The electricity is generated using nine technologies: coal, gas, oil, hydro, nuclear, biomass, solar, wind and other renewables.

The Global Trade Analysis Project (version 9) database was used for parameter calibration. The cost structure of electricity generation technologies followed the *Projected Costs of Generating Electricity 2010* compiled by the IEA/OECD and NEA.[1] Regional GDP and energy consumption in the business-as-usual (BAU) scenario roughly followed the International Energy Agency's *World Energy Outlook 2014*.[2] Regional population growth was taken from the medium fertility scenario of *World Population 2012* compiled by the United Nations Procurement Division. It was assumed that labour could flow freely across sectors, but capital and natural resources were sector-specific. The investment flows were split into three segments: non-fossil finance, non-coal finance and unconstrained finance, where the non-fossil finance represented green bonds and the non-coal finance covered coal divestment flows. The two flows of green finance imposed an endogenous premium on fossil capital accumulation, reflecting the relative shortage of access to finance. The risk of investing in a sunset industry has been an additional cost for fossil fuel finance.

Two alternative scenarios, SN1 and SN2, were simulated against the BAU development path. Both scenarios introduced green bonds as the only source of non-fossil funding and assumed that investor groups were told to avoid investment in coal, i.e., coal extraction and coal-based electricity generation. In SN1, the amount of issued green bonds increased from USD 100 billion in 2015 to USD 1000 billion in 2020. The level of coal divestment was estimated on the basis of the pledges of AXA France and the Norwegian Government Pension Fund Global (GPFG), assuming that other investors follow suit and the total annual flow of funding unavailable for the coal industry amounted to twice the pledges of AXA and the GPFG. SN2 is similar to SN1, keeping the same path for green bond increase but scaling up the amount of coal divestment by extending the divestment pledges to the entire insurance industry and the sovereign wealth funds of oil and gas producing countries in the Middle East.

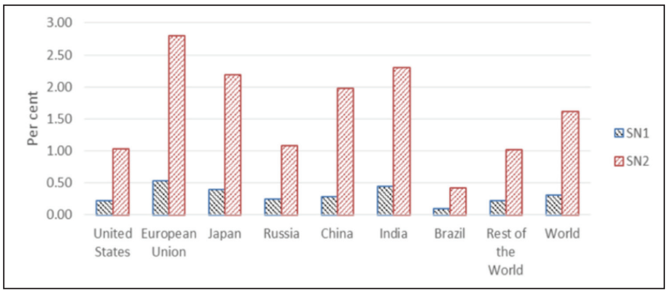
The simulation results had similar patterns in both scenarios,

Figure 1: Emissions of CO_2 Deviations from BAU in 2030



Source: Drawn by Taoyuan Wei.

Figure 2: GDP Deviation from BAU in 2030



Source: Drawn by Taoyuan Wei.

but markedly scaled up in SN2. For example, green bonds and coal divestment avoids around 100 million tonnes of CO_2 emissions in SN1 and 550 million tonnes of CO_2 emissions in SN2 if compared to BAU emissions in 2030. Noticeably, emission reductions are almost exclusively generated in China and India (see Figure 1). Worldwide GDP in 2030 increased by about 0.3 per cent in SN1 and 1.6 per cent in SN2, implying that high reductions in carbon intensity due to green bonds and coal divestment have the potential to increase welfare (see Figure 2). Notably, the GDP increase appears in every region but is most pronounced in the EU, followed by India, Japan and China. In 2030, the share of green finance is particularly high in Japan (35 per cent) and the EU (34 per cent), followed by India (27 per cent) and China (24 per cent). The highest divestment premium to the coal industry falls on Russia, amounting to 8 per cent additional cost in 2030. China follows with 7.2 per cent and the RoW comes next with 3.4 per cent. The EU has a negligible coal premium, as green finance is in high supply and the electricity market shows limited growth potential. The simulation results in this study may even have underestimated the effectiveness of green bonds and coal divestment, as increases in renewable investments and the resulting impacts are not included in the model.

This summary of Dr. Wei's presentation was written by ESI Research Fellow, Dr. Li Yingzhu.

1 IEA/OECD and NEA, *Projected Costs of Generating Electricity 2010* (Paris: International Energy Agency/OECD, 2010).

2 IEA. *World Energy Outlook 2014* (Paris: International Energy Agency/OECD, 2014).

Global Zero Emissions Scenario Analysis

Dr. Koji Tokimatsu, Associate Professor at the Tokyo Institute of Technology, Japan

The United Nations Framework Convention on Climate Change (UNFCCC) set an important objective: "stabilisation of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The goal to limit global warming to 2°C above the preindustrial level has been widely discussed. After the 2009 Copenhagen Conference, a goal of 1.5°C also appeared in official UN documents and some delegations have suggested 1°C.

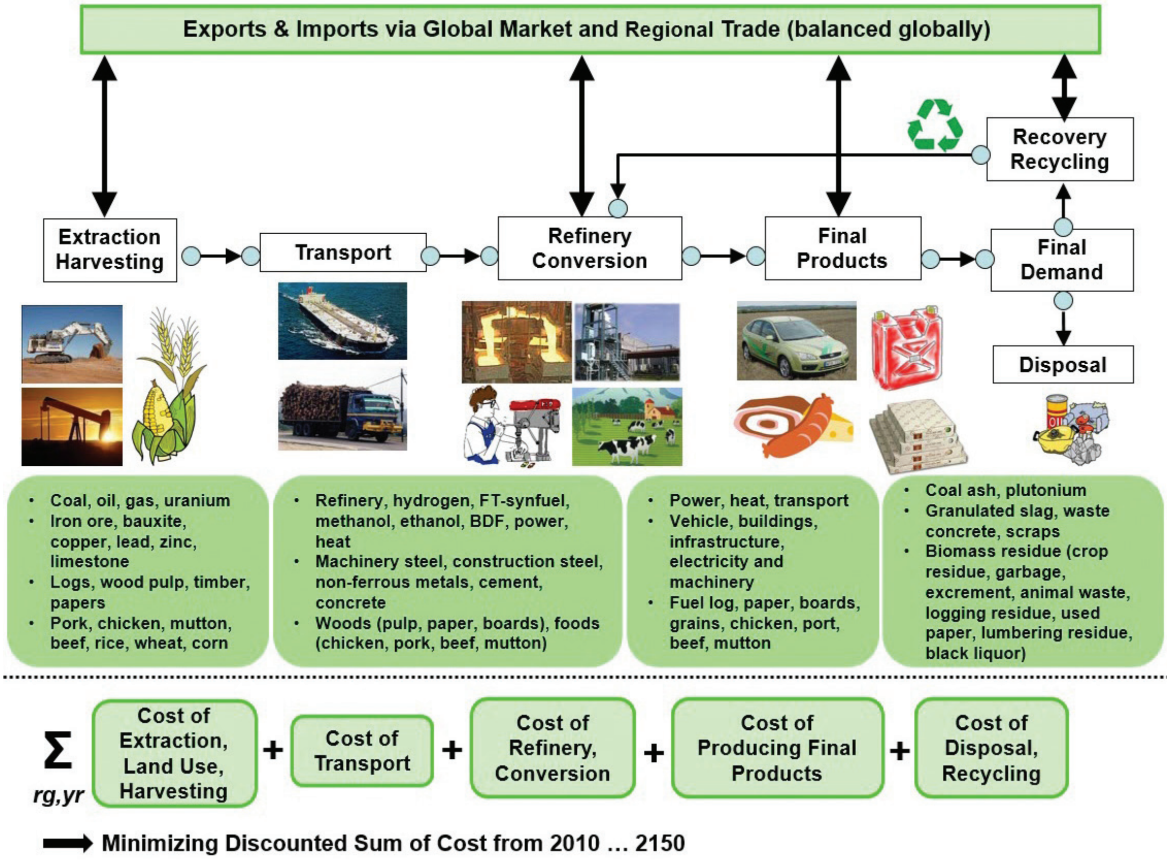
The 4th Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) included six zero and negative emissions scenarios. This report became one of the drivers for studies focusing on biomass energy with carbon capture and storage (BECCS). Subsequently, the 5th Assessment Report by the IPCC stated that targeting a global mean temperature below 1.5°C is so challenging that few modelling studies have explored emissions scenarios leading to concentrations below 430 parts per million (ppm) CO_2-eq by 2100. However, such modelling studies are needed to assess these more stringent goals and to determine how such scenarios can be constructed. In response, a model was introduced to investigate the feasibility of achieving the aforementioned zero emissions scenarios.

As schematised in Figure 1, the overall modelling framework had a conventional approach of minimising total system costs through linear programming. The model included production, transportation, conversion, final production, disposal, and recycling. The costs consisted of production of resources, land use and land use changes, inter-regional transportation, energy conversion, production of materials, final demand, wood products, disposal of used products, and materials recycling. The global model included 10 regions with a time horizon of 2010 to 2150 with a 10-year time step. The modelling framework consisted of three hard-linked models producing an internally consistent least-cost scenario for the three types of resources considering land use change. These models were developed from the bottom-up using detailed technology options to meet the exogenous demand through the transformation of resource supply.

Coal-fired Power Plant in Longjing, Taichung, Taiwan, 2010. (Permission under CC BY 3.0).

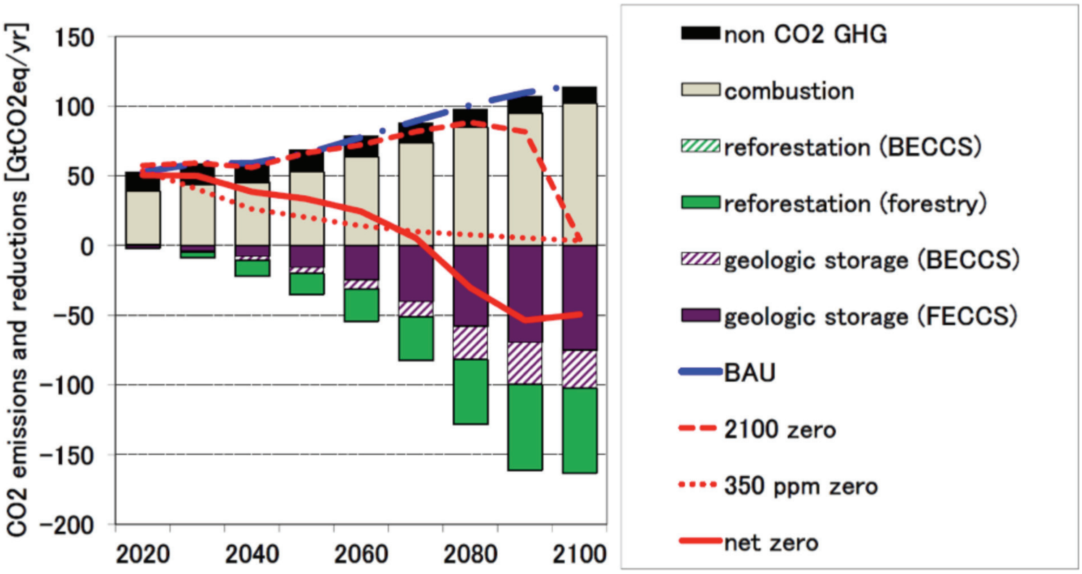
The modelling analysis consisted of four scenarios: "business-as-usual (BAU)" without any climate policy intervention; "2100 zeros" in which the emissions level after 2100 is kept at zero, assuming no emission control prior to that date; "350 ppm zero" whose emission trajectories are zero emissions towards the end of this century, which can be achieved by giving cumulative emissions of WRE-350 from 2010 to 2150 as an emission constraint; and "net zero", whose cumulative emissions from 2010 to 2150 are zero. This is not meant to keep the emissions level at zero over the time horizon.

Figure 1: Simplified Representation of the Model Structure



Source: Koji Tokimatsu's Presentation Slide.

Figure 2: CO_2 Balance by Scenario

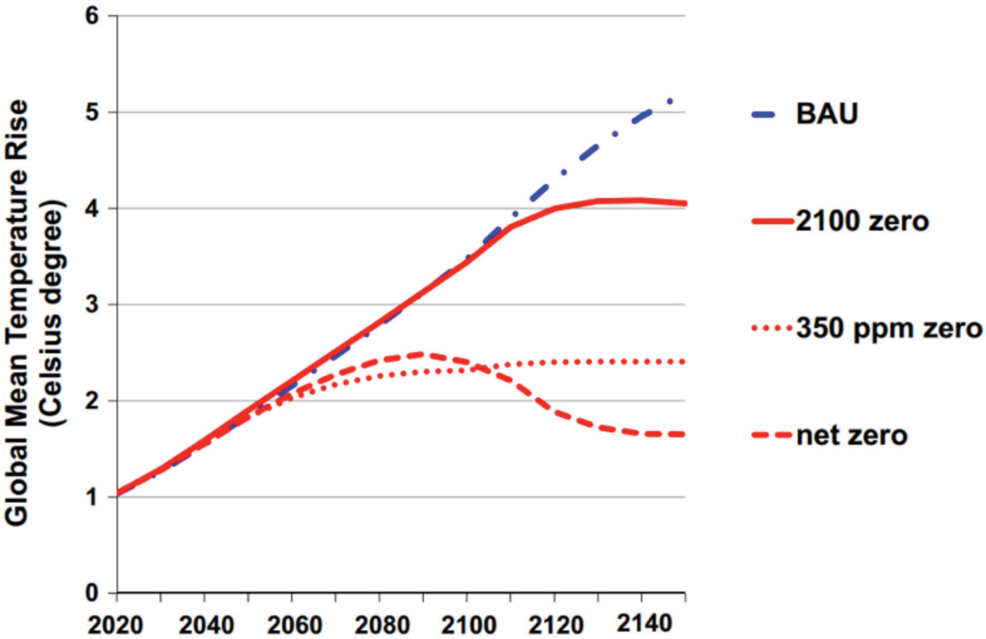


Source: Drawn by Koji Tokimatsu.

The CO_2 balance shown in Figure 2 varies considerably among the four scenarios when non-CO_2 GHG emissions are included. Among the geological storage options, the major contributor is fossil energy with carbon capture and storage (CCS), followed by sequestration of forestry in stand growth and afforestation, and BECCS. The amounts of CO_2 stored and sequestered in 2100 in the three zero-emissions scenarios are approximately two to three times larger than the current emissions level. The cumulative CO_2 stored is approximately 6,000 Gt-CO_2 in the "350 ppm zero" and "net zero" scenarios, and approximately 2,000 Gt-CO_2 in the "2100 zero" scenario.

Correspondingly, as shown in Figure 3, the global mean temperature rise in 2150 for the "net zero" scenario reaches some 1.7°C. The global mean temperature experiences a gradual increase in the "350 ppm zero" and "2100 zero" scenarios until a stabilisation occurs at 2.4°C and 4.1°C, respectively. In contrast, the BAU scenario leads to an increase of about 5.2°C. Excluding the non-CO_2 GHG emissions, the increases would be 0.3, 1.3, 3.4, and 4.7°C, respectively.

Figure 3: Global Mean Temperature Rise by Scenario



Source: Drawn by Koji Tokimatsu.

Based on the modelling analysis, net zero is required to meet the below 2°C target. It is insufficient to adopt the 350 ppm zero scenario when non-CO_2 GHG emissions are included. With the current state of technology development, it is impossible to reach the 1.5°C target unless radical innovations in technology emerge. On the contrary, if the 4°C target is adopted (similar to the 3.6°C in the "New Policy Scenario" in the *World Energy Outlook 2012*[1]), the world is allowed to emit GHGs without constraint until the end of this century to prepare for zero emissions thereafter as depicted in the "2100 zero" scenario. The BAU scenario will result in a rise of 5°C, which is close to 5.3°C in the "Current Policy Scenario" of the *World Energy Outlook 2012*. To achieve the net zero target, BECCS demonstrates a robust option that should be encouraged for deployment. In addition, fossil energy with CCS, nuclear, and renewable energy all need to play a role in the net zero scenario.

This summary of Dr. Tokimatsu's presentation was written by ESI Research Fellow, Dr. Victor Nian.

1 International Energy Agency. *World Energy Outlook 2012* (Paris: OECD/IEA, 2012).

Optimising the Layout of Initial Alternative Fuel Vehicle Refuelling Stations and Experiments with Agent-based Simulation

Dr. Tieju Ma, Professor at the East China University of Science and Technology, China

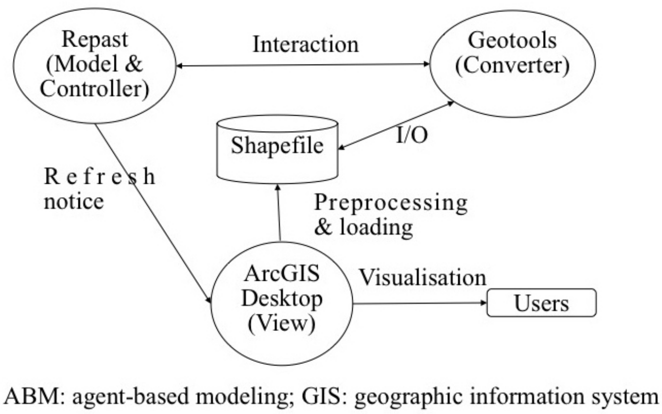
Agent-based modelling is one of a class of computational models used for simulating the actions and interactions of autonomous agents (individual or collective entities such as organisations or groups) with a view to assessing their effects on the system as a whole. It combines elements of game theory, complex systems, emergence, computational sociology, multi-agent systems, and evolutionary programming. It can be used for studying the emergence from complex adaptive systems. A complex adaptive system is a "complex macroscopic collection" of relatively "similar and partially connected micro-structures" formed in order to adapt to the changing environment and increase its survivability as a macro-structure. Emergence is the way macro-structures arise from a multiplicity of interactions among micro-structures. An agent is an autonomous decision entity capable of learning, adaptation, and reproduction. Agents may not necessarily be rational in making decisions, but they follow an explicit set of action rules in the system.

The adoption of alternative fuel vehicles (AFVs) can be studied through an agent-based modelling analysis. For example, Stephan and Sullivan used an agent-based model to study the interplay between the diffusion of hydrogen vehicles and hydrogen refuelling stations. In this model, both the driver and the station owners act as agents. The utility function of a driver follows a combination of vehicle price (fixed benefits), fuel price (variable benefits), pride of using new technology (social value), and concern over the inconvenience of refuelling. The concern over the inconvenience of refuelling will have a stronger negative impact on the driver's utility if the distance between two refuelling stations is greater than the driver's comfortable distance. The utility function of a hydrogen station owner is primarily determined by the total patrons. Once a station is built, it is assumed to operate for at least half a year before the next decision point can be reached (either decommission or continued operation).

Linking the conceptual agent-based modelling framework with Geographic Information System (GIS) data for optimising the layout of initial AFV refuelling stations can facilitate realistic output from the modelling analysis. In this case, a vector-based integration of an agent-based model and GIS

Shanghai Traffic, 2006. Photo by JakeLM (Permission under CC BY 2.5).

Figure 1: Vector-based Integration of Agent-based Model and GIS

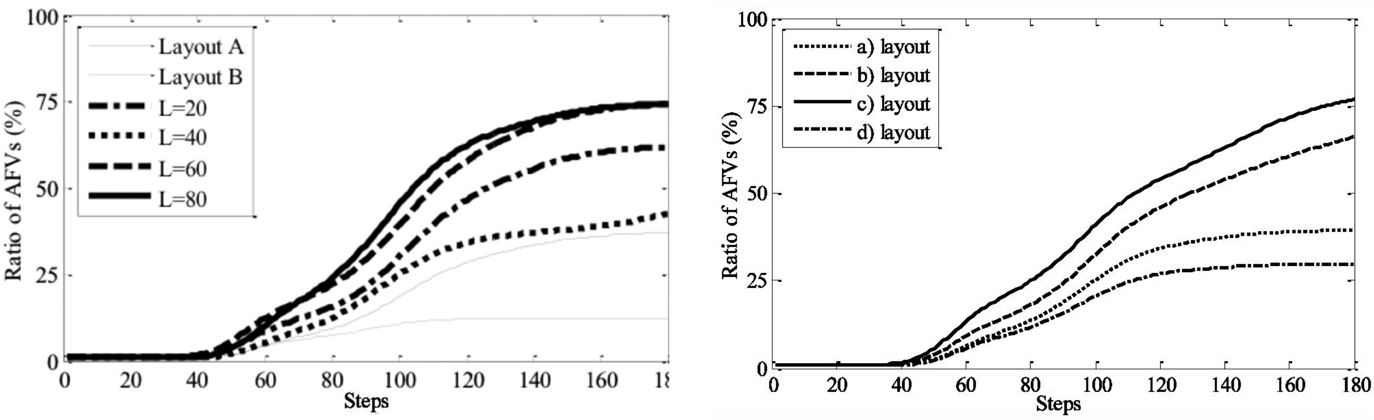


Source: Drawn by Ma Tieju.

data is introduced using Shanghai as a case study. Figure 1 shows the overall structure of the modelling framework. The driving routes are generated through a combination of factors, including distribution of population, living and working quarters and GDP, and spatial distribution of drivers' living and working quarters, and the main road network in the urban area. In addition, a genetic algorithm is used to minimise the concern over the distance between two refuelling stations.

Using Shanghai as the basis of computational experiments, the first step was to generate different optimal layouts using a genetic algorithm to minimise the total concerns of different targeted drivers. In the first experiment, three possible layouts for an initial number of 10 refuelling stations were generated by targeting all 8,000 drivers, namely, (a) random layout in the city centre, (b) random layout in the whole city, and (c) layout generated by the genetic algorithm. The influence of population size in the genetic algorithm to the diffusion of AFVs was further tested by varying L from 20 to 80 in the left image of Figure 2. Subsequently, an agent-based model was applied to simulate the diffusion of AFVs with these layouts with different proportions of drivers, namely, (a) all drivers, (b) dynamic selection,

Figure 2: Diffusion of AFVs Based on Different Target Driver Populations: All Populations (left) and Selected Proportions (right)



Source: Drawn by Tieju Ma.

(c) drivers in the city centre, and (d) drivers in the suburbs. These results are shown in the right image of Figure 2.

Assuming mature AFV technology, targeting drivers in the city centre can facilitate the fastest diffusion of AFVs. Through further investigation into the influence of the number of initial refuelling stations, it is possible that a larger number of initial AFV refuelling stations may result in slower diffusion of AFVs because these initial stations may not have sufficient customers to survive.

It is noteworthy that the AFVs studied in this modelling analysis are applicable only to those with a refuelling pattern similar to that of conventional vehicles. Despite this limitation, the simulations remain relevant for drawing insights about cities that are trying to promote the diffusion of AFVs. Although the model incorporated a number of realistic assumptions about urban road networks, and the social and economic characteristics of Shanghai, this research work is still considered theoretical. With the incorporation of demographic and other data, the agent-based model can expect more realistic results for policy discussion.

This summary of Dr. Ma's presentation was written by ESI Research Fellow, Dr. Victor Nian.

Gas Trading Hubs and Transition to Hub-Indexed and Destination-Flexible Contracts in East Asia[1]

Dr. Xunpeng Shi, Senior Research Fellow at the Energy Studies Institute, National University of Singapore

Osaka Gas Iwasaki Site (left) and Dome City Gas Building (right), which houses Osaka Pipeline Department of Osaka Gas, in Nishi-ku, Osaka, Osaka Prefecture, Japan Osaka Gas Iwasaki Site. 2010. Photo by J o (Permission under CC BY-SA 3.0).

In the East Asian gas markets, issues such as the establishment of gas trading hubs, hub-indexed pricing, and destination flexibility are being debated. Current initiatives involve the creation of gas trading hubs and price benchmarks in a few countries, among which competition is a concern. This paper examines the impact of East Asia's pricing benchmark change and contract flexibility improvements on the regional and global gas markets. It uses the Nexant World Gas Model (WGM)[2] (Nexant, 2016) to study the effects of hubs, adoption of spot market prices as trading benchmarks, and the improvement of flexibility in contracts in East Asia. A Baseline Scenario was developed as a reference case to study how the international gas market might evolve to 2035. In this scenario, all the contracts have "take or pay" (TOP) and destination clauses built in and long term contracts are indexed to oil prices. This is the reference case with which we compare the results from our alternative (policy) scenarios. The difference between scenarios is analysed to draw recommendations.

A total of six alternative (policy) scenarios were set up and simulated. In Scenario 1, 'Shanghai Hub' (S1), China's Shanghai hub (spot) prices become the price benchmark for both pipeline gas and LNG imports into East Asia. All active pipeline and LNG contracts post-2025 in the East Asian importers (China, Japan, South Korea and Chinese Taipei) are indexed to the Shanghai hub price, a pricing mechanism that is similar to how natural gas is currently priced in the United States and the United Kingdom. In Scenario 2, 'Tokyo Hub' (S2), Japan's Tokyo hub (spot) prices replace the Shanghai hub prices as the price benchmark for both pipeline gas and LNG trading by the East Asian importers, while everything else is identical with Scenario S1. This allows for a study of the effect of different benchmark hubs in East Asia.

In Scenarios 3 and 4, we remove the destination clauses from all LNG contracts[3] with destination as the East Asian region. In Scenario 3, 'Hub no DS' (S3), we assume that the regional market is indexed to the Shanghai hub price, while Scenario 4, 'Oil no DS' (S4), retains the pricing status quo of a mix of predominantly oil indexed contracts as in the Baseline Scenario. We subdivide scenarios into 3a, 3b and 4a, 4b. Scenarios 3a and 4a have a start date of 2020 for destination-free contracts while Scenarios 3b and 4b have a start date of 2025. The different starting points used in the simulations were based on the concept that hub indexation needs hub creation and domestic market liberalisation which may take a decade to complete. In contrast, removal of destination clauses is a pure contractual arrangement and does not rely on other factors that need long preparation times. Scenarios 3b and 4b are simulated to be comparable with Scenario 1 and the Baseline Scenario.

The simulations demonstrate that a change in the gas pricing benchmark and removal of the destination clause in the four East Asian importers will have significant benefits for East Asia and the world. However, the impacts on different stakeholders vary. Although some LNG exporters will lose their markets in China, their exports could be directed to other East Asian importers. The reduction of total gas procurement costs indicates that the exporters could benefit from the policy changes as well.

Furthermore, whether it is the Shanghai or Tokyo hub price that is adopted as the benchmark price for the four East Asian gas importers will not make a significant difference. This suggests that multiple hub initiatives are not mutually exclusive and there is likely to be more than one hub that offers different benchmark prices. This study also finds that the "Asian Premium" is not caused by a destination restriction as the price reductions in the non-DS scenarios are marginal. It further demonstrates that the impact of relaxation in the destination clause outweighs any change in the pricing formula in Japan, Korea and Chinese Taipei. However, for China, a change in the indexed benchmark is still significant due to the importance of pipeline imports in the long-term supply.

This paper implies that given the existence of common benefits and a lack of competition among hubs, the East Asian importers and exporters should cooperate with each other to facilitate the East Asian market transition. While removal of destination clauses should be given priority by other East Asian importers due to the large benefits and low level of difficulty, hub creation should be given equal consideration in China due to the large benefit resulting from a switch to hub indexation for pipeline imports.

This summary of Dr. Shi's presentation was written by ESI Research Associate, Mr. M.P. Hari.

1 The full paper can be found at: Shi, X., and M.P. Hari., "Gas and LNG Trading Hubs, Hub Indexation and Destination Flexibility in East Asia", *Energy Policy* 96 (2016): 587-59.

2 The Nexant World Gas Model is a current information model. In simulations, the model combines supply, demand and infrastructure information to determine a market price that allows production, exports and imports to balance consumption in each year. Market clearance is assumed to happen at a price where the supply at the marginal cost of procuring gas is sufficient to meet demand.

3 Pipelines, due to their node to node connections (e.g. Russian Far East to China) do not allow for destination flexibility as is the case with LNG shipments to different ports. Hence pipeline contracts are not changed in either of the destination flexibility scenarios.

The Implications of a Carbon Price on Bunker Emissions: Application of the GTEM Model

Dr. Yu Sheng, Senior Economist at the Australian Bureau of Agriculture and Resource Economics and Sciences, Australia

Introduction

The emissions from the bunker fuels consumed by ships or planes in international trade have increased by about 50 per cent over the past two decades. However, there are no countries which include bunker emissions in their national inventory of GHGs under the current international agreements. Instead, the UNFCCC COP21 in Paris encouraged countries to limit their bunker emissions. This leaves the possibility of extending the coverage of the global carbon charges to include bunker emissions. Therefore a bunker emissions charge could mitigate international bunker emissions and fund cleaner technology projects globally.

In implementing a global bunker charge, what would be the cost in terms of economic growth and trade? Take Australia as an example. As it is located far away from its major trading partners, would the bunker charge alter its competitive and comparative advantage significantly? To answer these questions, this study analyses the impacts of extending a global carbon charge to international bunker emissions on the Australian economy and its trade competitiveness by using the Global Trade Environmental Model (GTEM). An emission reduction of 5 per cent below 2000 levels by 2020 by the Carbon Pollution Reduction Scheme (CPRS)-5 is developed for the Australian economy.

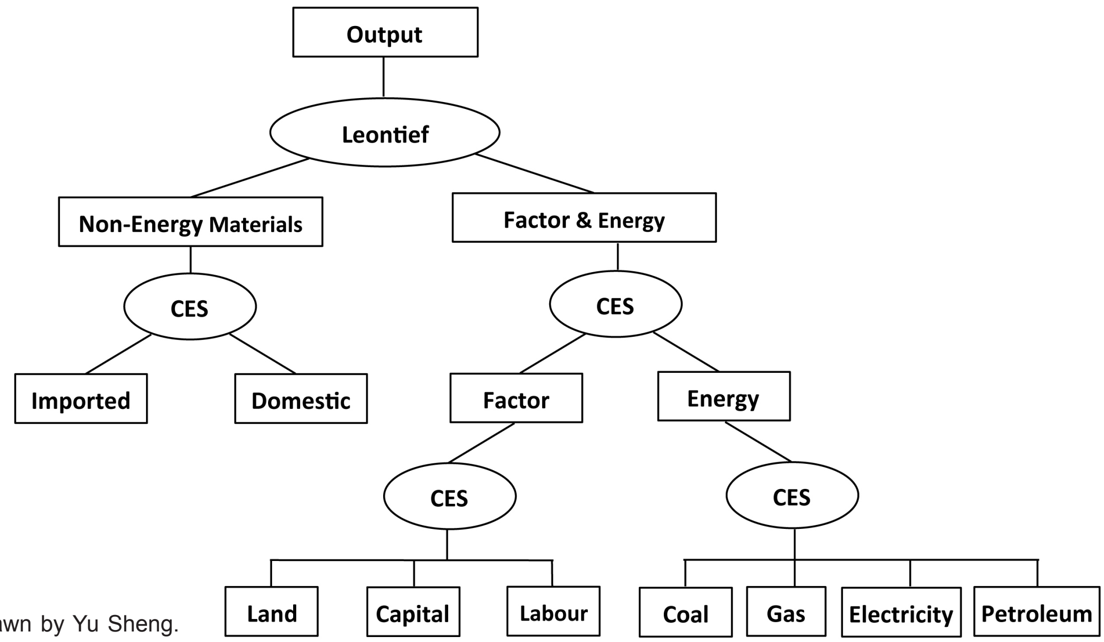
"Happy Sky" (Heavy Load Carrier) off Marina South Pier, Singapore, 2015. Photo by CE Photo Uwe Aranas (Permission under CC BY-SA 3.0).

GTEM is a general dynamic global computable general equilibrium model which can address total, sectoral, spatial, and temporal efficiency of resource allocation globally. It has the capacity to capture the global implications and issues that involve long time horizons of policy changes on large numbers of economic variables in all sectors of the economy, including GDP, prices, consumption, production, trade, investment, efficiency, competitiveness, and GHGs under different economic scenarios and exogenous shocks. The technology model in GTEM is presented in Figure 1. The economic module, population module (see Figure 2), and environmental module are included in the GTEM module system.

In this study, the structure of the GTEM database was adjusted to identify the bunker sectors and their emissions separately, and adapted to distribute bunker charge revenues to non-Annex I countries in proportion to their share of imports in global trade and population. The standard version of the GTEM database excludes bunker emissions in accordance with the Kyoto Protocol, since individual countries ignore them in their national accounts, but the GTEM emissions database is expanded to include them. The economic effects of the bunker charge will be partially determined by assumptions of the bunker charge revenue distribution. The GTEM was adapted to distribute the revenue to countries in proportion to the share of their imports in the total value of global trade.

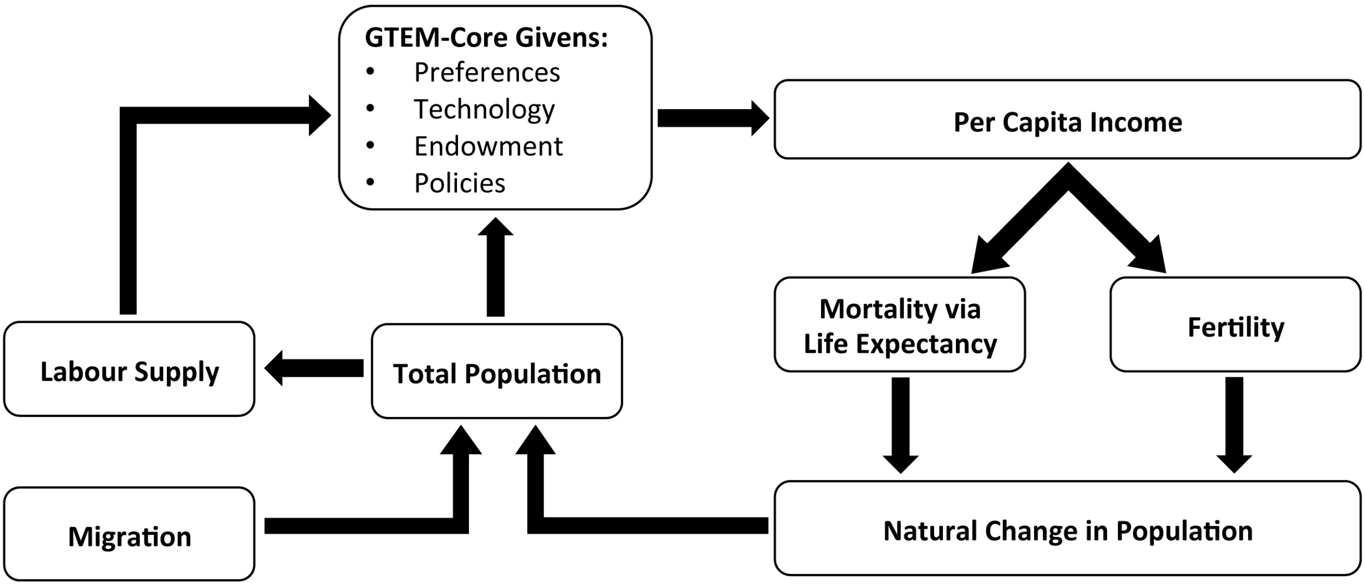
In this study, the CPRS-5 Scenario was implemented with a global carbon charge (tax) constituting the central scenario. Under the two scenarios, the GTEM model was simulated with (policy scenario) and without (reference case) the bunker charge. The difference between the two simulations yielded the economic impact of including bunker emissions under the global carbon charge. Other scenarios were developed to examine the sensitivity of the key results to the assumed carbon price path. The results showed that the global bunker emissions were projected to decline by 3.6 per cent in the first year (2010) of implementation. In subsequent years, the rate of decline moderates as the carbon price rises by 4 per cent annually. As the bunker charge increases in line with the carbon price, the cost of combusting bunker fuels increases and this puts upward pressure on the cost of global transport of goods by air and sea. As freight costs increase, the trade volumes adjust gradually and the quantity of shipping services demanded is projected to decrease, resulting in reducing the combustion of bunker fuels and bunker emissions. The global bunker emissions are projected to fall by an

Figure 1: GTEM Production Technology



Source: Drawn by Yu Sheng.

Figure 2: GTEM Population Module



Source: Drawn by Yu Sheng

estimated 5.2 per cent relative to the reference case by 2030.

The projected bunker charge revenue collected will increase in the simulation. It was estimated to be USD 75 billion in 2030 compared with USD 19 billion in 2010 (base year 2001 dollars). The increase in the bunker charge revenue in 2010-2030 is partly explained by a 4 per cent annual growth in the charge rate and partly by the growth of bunker emissions arising from increased international transport of goods, respectively. Besides, the world's main economies like Australia, China, US, Japan and the EU are projected to experience a small exogenous shock in real GDP as a result of a bunker charge, and the results imply that regardless if the economy loses or gains in terms of real GDP, the estimates are very small. For example, if a commodity has comparative advantage in Australia, it will appear prominent in exports and the simulation indicates that the share of commodities is unaffected by imposing the bunker tax.

As increasing the bunker charge would increase the cost of transporting internationally traded goods, countries such as Australia, located far from their trading partners, are legitimately concerned about the possible income and competitive effects. From the GTEM module, it was found that including bunker emissions in a standard CPRS-5 environment would have a very small impact on Australian exports and production of commodities. Its impact on real GDP and real GNP were estimated to be less than -0.25 per cent. This confirms that while the concerns of some are warranted, the magnitudes of any effects are likely to be small. With the inclusion of bunker emissions in the carbon tax environments assumed in this study, the competitive and comparative advantage position of Australia in the international trade remains unaffected, which means the bunker tax can be viewed as a useful way to abate the GHGs in Australia. As an alternative policy to achieve an emissions reduction target, a bunker charge has been regarded as a possible source of generating funds to assist with technology transfers to developing countries.

This summary of Dr. Sheng's presentation was written by ESI Visiting PhD student, Mr. Zhonghua Zhang, from the Beijing Institute of Technology.

Staff Publications

Internationally Refereed Journals

Su Bin and Elspeth Thomson, "China's Carbon Emissions Embodied in (normal and processing) Exports and Their Driving Forces, 2006-2012" *Energy Economics* 59 (2016): 414-22.

Zhang Ming and **Su Bin,** "Assessing China's Rural Household Energy Sustainable Development Using Improved Grouped Principal Component Method" *Energy* 113 (2016): 509-14.

Books and Book Chapters

Allan Tian Sheng Loi and Jacqueline Yujia Tao, "Singapore Country Report" in S. Kimura and P. Han. (eds.) in *Energy Outlook and Energy Saving Potential in East Asia 2016*. ERIA Research Project Report 2015-5, Jakarta: ERIA, 2016, pp. 297-322.

Staff Presentations and Moderating

1 September Allan Loi presented "Results of Econometric Estimation for Singapore's Country Report 2016", at the *1st ERIA Working Group Meeting for Analysis of Energy Saving Potential in ASEAN and East Asia* organised by the Economic Research Institute for ASEAN and East Asia (ERIA).

31 August Philip Andrews-Speed moderated at the ESI Workshop, *Gas Market Transition in ASEAN and East Asia*.

31 August Anton Finenko presented "Who Benefits from Renewables in Liberalised Electricity Markets", at the *1st International Association of Energy Economics (IAEE)*

Eurasian Conference 2016 organised by the International Association for Energy Economics.

30 August Philip Andrews-Speed presented "The Outlook for China's Low Carbon Energy Transition" at Young China Watchers, Singapore.

24 August Philip Andrews-Speed presented "Component Analysis Approach" at the *National Australian Institute of Energy Conference*, Perth, Australia.

17-18 August Christopher Len, Philip Andrews-Speed and Melissa Low moderated at the ESI Workshop, *Transitions and a Globalised Arctic: The Role of Science, Technology and Governance*, at Hotel Jen Tanglin, Singapore.

18 August Philip Andrews-Speed presented "Energy Transitions in a Globalised Arctic: Key Findings" at the ESI Workshop, *Energy Transitions and a Globalised Arctic: The Role of Science, Technology and Governance,* at Hotel Jen Tanglin, Singapore.

17 August Yao Lixia presented "Comparative Analysis of Renewable Energy Policy in East Asia: A Principal Component Analysis Approach" at Heriot-Watt University, Edinburgh, UK.

Staff Media Contributions

Philip Andrews-Speed was interviewed by *Wall Street Journal* on China's national oil company reforms, 14 September.

Philip Andrews-Speed was interviewed by *China Oil and Gas Monitor* on China's oil stocks, 7 September.

Philip Andrews-Speed was interviewed by *Radio Free Asia* on reducing China's coal over-capacity, 22 August.

Philip Andrews-Speed was interviewed by *CNBC Asia* on the outlook for ASEAN energy, 18 August.

Recent Events

30-31 August, Gas Market Transition in ASEAN and East Asia: The Role of Market Liberalisation and Integration (ESI Workshop)

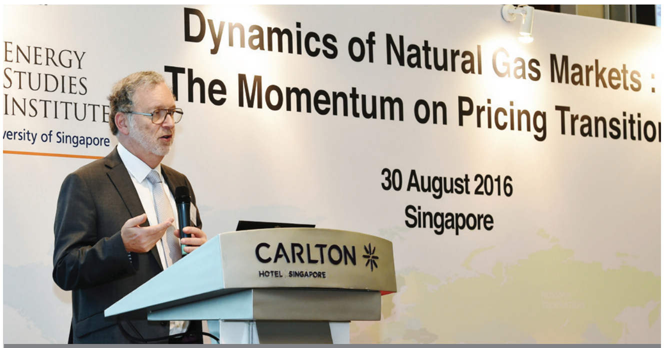
As East Asia continues to develop and modernise, its demand for energy is soaring at a time when massive changes are occurring in the gas and LNG markets. Hence, ESI decided to hold a workshop focusing on regional gas market development and integration, the future of long term contracts and oil-indexed pricing, gas market liberalisation, and the development of gas trading hubs and spot prices. Organised by Dr. Shi Xunpeng, Senior Fellow and Deputy Head of the Energy Economics Division at ESI, gas market experts from industry, academia, consulting firms and think tanks were invited from 14 countries to put forward different viewpoints, and to discuss and debate the key issues. The Workshop was organised into four sessions, with three closed door sessions for invited participants and one public session with a book launch event.

In the opening session, "Changing Gas Markets: What's Ahead of Us", the panellists outlined the current gas market developments in the region, aspirations for gas hubs and spot pricing and the impacts of spot prices on project financing. The next sessions were "Dynamics of Natural Gas Markets in East Asia and the Pricing Transition" and "Policy Developments towards Competitive East Asian Markets". Other regions' gas market and hub development were also discussed. On Day 2, the speakers examined the hub-building measures now taking place in Asia. In the session entitled "Creating a Functional Benchmark in East Asia: The Way Forward", the gas hub development in China, Japan and Singapore were discussed, along with gas market development in South Korea. The key lessons from hub market development in other important commodity markets, namely oil and iron ore, and the experience of the Dojima Rice Exchange were also presented. The final session was devoted to the prospects for gas market integration in the ASEAN from the perspectives of Malaysia, Indonesia and Thailand, and how the Trans-ASEAN gas pipeline (TAGP) can potentially support ASEAN gas market integration.

Dr. Shi Xunpeng, Ms. Anne-Sophie Corbeau, Dr. Ken Koyama, Mr. Bradford Leach and Mr. Dmitry Sokolov (Photo by ESI).


Participants at the *ESI Gas Market Workshop* (Photo by ESI).

A fundamental question that the participants grappled with was "as natural gas and LNG are in the midst of huge changes how can the world and this region respond appropriately?" The economic rationale for increased use of coal in the region's energy mix cannot be denied. Oil-indexed contracts cannot be wished away because they still comprise a majority of supply options and there is no



Professor Jonathan Stern at the *ESI Gas Market Workshop* (Photo by ESI).

doubt that buyers will continue to sign new oil-indexed agreements to secure supply. As for natural gas, its increased use seems to be more a political decision than an economic one. Gas could serve as the bridging or complementary fuel for renewable energy sources whilst smart grids and new forms of energy storage are perfected. One way to increase the desirability of gas would be to develop improved infrastructure so that it could better compete with coal. Efforts to enhance the integration of the region's gas infrastructure should go hand in hand with cost-benefit analysis of regional energy cooperation.

29 August, Strategic Management Approaches to Confront Global Warming (ESI Seminar)

Professor Michael Nippa, Faculty of Economics and Management at the Free University of Bozen-Bolzano delivered a presentation on strategic management

Professor Michael Nippa (Photo by ESI).

approaches to confront global warming. Using key visualisations from NASA, he spoke about the changing climatic patterns resulting from global warming. Stating that the current global concentration of CO_2 is pegged at 404.39 ppm, he led the audience through some summaries of non-technical evaluations – increasing perceptions of the impacts of climate change on daily life, increasing awareness amongst elites that something needs to be done and increasing demonstration of concern and desire to do something about global warming among corporate captains across the globe. According to Dr. Nippa, the status quo on policy measures and the constraints of democratic styles of governance with respect to introducing large-scale economic or policy measures together hinder long term reforms needed for climate change actions. Finally, given that there is very little literature on how strategic management can influence action on climate change (only eight articles have been published in leading journals), Dr. Nippa suggested three categories of strategic approaches to global warming: individual level, firm level and national level. By way of conclusion, he urged the climate change research community to think of questions that the community of strategic management scholars can use to help direct their efforts in linking climate change to this management domain.

22 August, Maritime Governance Lessons from the Barents Sea to the Pacific Arctic (ESI Seminar)

Professor Rasmus Gjedssø Bertelsen and His Excellency Tormod C. Endresen

Professor Rasmus Gjedssø Bertelsen, Professor of Northern Studies and the Barents Chair in Politics, University of Tromsø-The Arctic University of Norway, discussed the extent to which the Barents Sea and Pacific Arctic marine management, embedded in the international system, can be compared. Since maritime issues are at the forefront of Northeast Asian and Pacific Arctic affairs and reflect the state of affairs between these powers, Professor Bertelsen highlighted various research and policy lessons that could be of relevance to the region of Southeast Asia. The Ambassador from Norway to Singapore, His Excellency Tormod C. Endresen, delivered the opening address and participated in the Q&A session.

17-19 August, Energy Transitions and a Globalised Arctic: The Role of Science, Technology and Governance (ESI Event)

Guest of Honour Minister of State in the Prime Minister's Office and Ministry of Manpower, Mr. Sam Tan Chin Siong, speaking with two participants.

This three-day event consisted of a one-and-a-half-day workshop and a half-day conference. It brought together a small group of stakeholders and experts from different backgrounds and regions for focused and interactive discussions on energy matters, to enhance the stewardship of a globalised Arctic, and contribute to sustainable energy initiatives both in the Arctic and the wider world. The participants – from the Arctic, Southeast Asia and Singapore – also discussed research gaps, complementary interests, and collaboration opportunities.

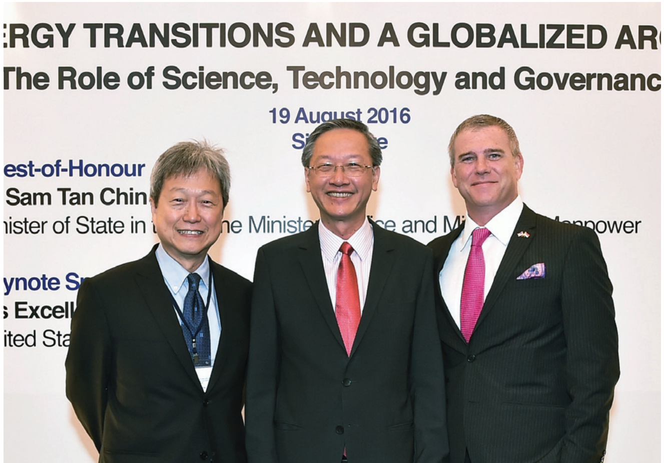
The workshop, which took place on 17 and 18 August, examined a range of issues related to the Arctic which are also of relevance to the wider world. These ranged from the governance of sustainable energy transition, access to energy in remote locations, maritime infrastructure and shipping, and issues related to innovation, resilience and capacity-building. In this context, the participants exchanged views on the energy transition challenges surrounding remote and "islanded" communities in the Arctic and Southeast Asia.

Participants at the *Energy Transitions and a Globalised Arctic* event (Photo by ESI).

The half-day conference that was held on the third day welcomed Guest-of-Honour Mr. Sam Tan Ching Siong, Minister of State in the Prime Minister's Office and the Ministry of Manpower, and the United States Ambassador to Singapore, His Excellency Kirk Wagar who gave a keynote address. The conference panellists provided a brief overview of the key findings from the four discussion topics of the workshop. Finally, the panellists and members of the audience engaged in discussion during the concluding Q&A session.

This three-day event was supported by the Ministry of Foreign Affairs, Singapore. The US Office of Naval Research – Global also provided funding for the workshop.

Session 1 of the Arctic Conference (Photo by ESI).



From left to right: ESI Executive Director, Professor S.K. Chou, Minister of State in the Prime Minister's Office and Ministry of Manpower, Mr. Sam Tan Chin Siong and United States Ambassador to Singapore, His Excellency Kirk Wagar (Photo by ESI).

New Staff

Keegan GAN

Keegan GAN joined the Energy Studies Institute as a Publications Officer in October 2016, and helps the Institute produce a range of publications that consist of a regular bulletin, policy reports, academic articles, and opinion-editorial pieces.

Prior to that, he was the editor at a wellness magazine known as *The Active Age* and has also held editorial roles at various other publications. He graduated from Oklahoma City University with a B.A. in Mass Communications.

Keegan has more than nine years of professional experience in the publishing/media industry, editing and writing articles across all genres and styles on various media platforms.

Contact

- Collaboration as a Partner of ESI (research, events, etc)
- Media Enquiries
- ESI Upcoming Events
- ESI Mailing List

Ms. Jan Lui
jan.lui@nus.edu.sg

The *ESI Bulletin on Energy Trends and Development* seeks to inform its readers about energy-related issues through articles on current developments. Our contributors come from ESI's pool of researchers, local and overseas research institutes, local government agencies and companies in the private sector. You can download past issues from www.esi.nus.edu.sg.

We welcome your feedback, comments and suggestions. The views expressed in each issue are solely those of the individual contributors.

Energy Studies Institute
National University of Singapore
29 Heng Mui Keng Terrace, Block A, #10-01 Singapore 119620 Tel: (65) 6516 2000 Fax: (65) 6775 1831 Email: jan.lui@nus.edu.sg www.esi.nus.edu.sg

 ISSN 2424-8169 (print) ISSN 2424-8177 (online)