Towards a Sustainable Environment – Challenges in Applying Cleaner Technologies to Reduce Emissions at the Transportation Sector

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ABSTRACT

Transportation sector is a significant contributor to the global emissions especially at industrialized countries (e.g. Australia, EU and the US) and is one of the main causes of the global climate change. While global schemes of emission reduction (e.g. emission trading) have been largely criticised due to its uncertainties, efforts to promote an alternative option by adopting cleaner technologies end up with several barriers. As an example, to substitute fossil fuels with vehicles using alternative energy such as Hydrogen deals with market based challenge especially to accommodate the demand of a fashionable and reliable vehicle. This paper attempts to review the application of cleaner technologies as a part of implementing cleaner production in the transportation field and discuss the advantages and the obstacles. The study also found how scientific approaches such as Life Cycle Assessment (LCA) might have either strength or weakness to convince the market regarding cleaner technology applications.

Key words: Cleaner technology, Emission reduction, Transportation Sector

Introduction

Transportation is an important sector in the human civilization. It has an essential role to travel people from one place to another. Transportation is also closely related to land use generation and development where representing the spatial dynamic of a city. In the field of economy, transportation is an important tool to travel goods and resources.

The increase in travel demand raised the competition among automotive industries to provide convenient and reliable vehicles to satisfy their customers. While automotive industries are taking great efforts to maximize their profit and deliver good service, there are significant environmental problems created that favour automotive industries to innovate and create environmental friendly products.

Transportation sector is a significant contributor to the global emissions especially at industrialized countries (e.g. Australia, EU and the US) and is one of the main causes of the global climate change. The world is now taking serious actions through promoting emissions reduction schemes and empowers climate change legislations. While there are obstacles following the efforts, reducing emissions by implementing cleaner technologies is considerably wise. It is a concrete action to combat climate change and is capable to meet the goals of sustainable development.

There had been considerable efforts to investigate opportunities to adopt cleaner technologies, which are mainly by assessing the possibility to substitute fossil fuels with other alternative energies such as Hydrogen. This paper attempts to review the application of cleaner technologies as a part of implementing cleaner production in the transportation field and discuss the advantages, obstacles and other particular findings.

Materials and method

This research investigates a synthesis of the most relevant and recent findings related to emission reduction and the application of cleaner technologies at the transportation sector. A simplified content analysis was done to discover, negotiate and raise the awareness of newly constructed understanding towards the challenge of
applying emission reduction strategies.

Results and discussion

Transportation:

Transportation is an important complementary to the economy and spatial planning. It determines the land use development by associating travel patterns of a particular region while travel pattern itself generates from the availability of infrastructures (e.g. roads and highways) and the pattern of urban structures (Bartholomew, 2007). For instance, the development of new transportation infrastructures may open isolated areas and develop networks, which connect remote areas to several growth centres (business centre, shopping centre, schools etc.). Usually, the development of new roads is followed by development of other facilities (e.g. housing, commercial facilities etc.). Another example is the growth of a certain region itself due to the development of commercial facilities or business centres, which will increase the transportation intensity and lead to further traffic congestion.

Transportation also plays an important role to the economic activities. In terms of the demand and supply chain, transportation has a positive correlation to the chain and it is a catalyst to the distribution of goods (Wilson, 2008). The disruption of transportation system will lead to the deteriorated market of supply and demand and will affect the whole system.

Hence, there are mismatches between transportation and urban development policy that lead to ineffective urban transportation, which causes further environmental degradation. At least there are two examples, the traffic congestion and the longer distance of travelling that increases emissions (Cervero and Wu, 1998; Lawless and Gore, 1999)

Environmental Issues:

One of the biggest environmental issues regarding transportation is the use of unrenewable fossil fuels that produce high emissions. More than 80% of the total green house gas emissions came from fossil fuel combustion and had became a significant cause of climate change (Knoepfel, 1995; Bradshaw et al., 2004). The world’s emission experienced a sharp growth especially during the 1999 to 2004 period when the green house gas emissions grew by 35% above the level at the earliest era of industrialisation and predicted to rise by another 52% during 2004 to 2030 period. The effects of climate change are present today, including the increase of the average global temperature by 0.7°C and the rise of sea level that reached up to 175 mm during 1900 to 2004 (Ugalde et al., 2007). Indeed, it is emerging to take serious action in combating climate change by reducing emissions from strategic sectors such as transportation.

As one of the industrialised countries consuming higher fossil fuels, Australia experienced a growth rate of emissions for more than 27% since 1990. It is also the second largest emitter with the amount of more than 70 MCO2-e released to the air. Another evident came from the European Union (EU), where the use of fossil fuels is significantly intensive. Similar to Australia, the EU transportation sector is the second largest consumer of fossil fuels, as well as the second largest emitter sharing 21% of the total green house gas emissions. In terms of emissions distribution by region, although Annex I and II countries still share larger amounts, non-annex countries especially Asia experienced a massive increase in their emissions. The emission level experienced a 63% growth during the 1992 to 2004 period. The global emissions shared by individual countries points that USA and China are two largest emitter as shown in the following table.

| Table 1: Global Share of Emissions by Regions, 2000 |
| --- | --- |
| No. | Nation | % of global emissions |
| 1. | USA | 20.6 |
| 2. | China | 14.7 |
| 3. | EU25 | 14.0 |
| 4. | Russia | 5.7 |
| 5. | India | 5.6 |
| 6. | Japan | 3.9 |
| 7. | Brazil | 2.5 |
| 8. | Canada | 2.0 |
| 9. | Republic of Korea | 1.5 |
| 10. | Mexico | 1.5 |
| 11. | Indonesia | 1.5 |
| 12. | Australia | 1.5 |
| 13. | South Africa | 1.2 |
| 14. | Others | 23.8 |

Source: (Prime Ministeral Task Group on Emissions Trading, 2007)
The transportation sector is predicted to experience a vast growth and likely to increase their emissions up to 58% in 2030 (Quadrelli and Peterson, 2007). The numbers of vehicles, travel time and travel distance is likely to increase rapidly in the future together with the population and economic growth. In terms of gas emissions, motor vehicles emit hydrocarbons, nitrogen oxides, carbon monoxide, sulfur oxides, toxic substances (benzene), acetylene, formaldehyde, fine particles, butadiene, and lead. These gases are extremely harmful to the environment and people’s health.

Efforts to Reduce Transportation Emissions:

There had been considerable efforts to reduce the global emissions. There are three schemes introduced by the Kyoto Protocol, the clean development mechanism (CDM), joint implementation (JI) and the popular cap and trade system (emissions trading). Indeed these were schemes under the international agreement of the protocol. There are several other efforts implemented, or being develop relating to transportation policies and designs.

Regarding the Kyoto Protocol, one of the schemes that the world claimed to be the most effective and considerably lower in terms of costs is the cap and trade system. Australia and the European Union (EU) are two regions that are serious in combating climate change. Australia introduced a carbon pollution reduction scheme (CPRS) by setting the targets of reducing 60% of the national emissions below 2000 levels by 2050 (The Department of Climate Change, 2008). The scheme also declared a serious commitment to include transportation in the CPRS considering the high level of emissions this sector produced. Meanwhile, the EU through the emissions trading scheme attempts to reduce the emissions level by 20% below the 2005 level in 2020 (The European Union emission trading scheme – White paper). Although EU was the first region to undertake the emissions trading scheme, the scheme did not cover all source of emissions, including transportation due to difficulties of tracking and accounting the emissions.

Emission trading is a breakthrough in the global effort of combating climate change. The scheme offers an opportunity especially to firms to reduce their emissions at a lower cost as well encouraging polluters to reduce their emissions gradually. Despite this advantage, emissions trading schemes create ignorance and are lack of democratic approach that made the scheme difficult to present the central issue of climate justice (Lohmann, 2008). The scheme also created dangerous equivalences together with generating neo-colonial mythologies as well as undermining the need of adequate knowledge to analyse the possibility of technological changes.

Proponents of emissions trading also claimed that this scheme has trouble to address effective emissions reduction outcomes (Buchner and Carraro, 2008). For instance, great emitters like USA have not yet ratified the Kyoto Protocol and will be even more difficult to track their emissions reduction performance at the global level. Furthermore, even the protocol is binding industrialized countries to adopt the schemes, each region have their own flexibility in terms of setting targets and deciding what sectors are to be covered. At least the evident of EU emissions trading scheme that failed to include transportation into the scheme is an important example of the cap and trade weaknesses. It is emerging that alternative methods to reduce emissions should be effectively adopted worldwide. The example of this is incorporating cleaner technologies which is easier to implement and higher in the degree of certainties about the amount of emissions that can be reduced.

There are some other examples of action to reduce emissions from transportation (Plax et al., 2008; Tukker et al., 2008). One is to encourage people to travel by public mass transportations to solve problems related to traffic congestion. It may be one sensible approach to tackle problems related to the massive increase in the number of people travelling individually or the increase of vehicle ownership. As mentioned in the earlier part, traffic congestion fosters the amount of emissions released to the air as well as the increase number of commuter travelling in longer distance. The reason is that people tend to have longer travel time due to increasing number of vehicles. Therefore, solving problems related to traffic congestion and develop an effective transportation design is another option that is likely to reduce green house gas emissions resulting from transportation effectively and with regard to the sustainable development.

Another example is to improve the environmental capacity of transportation infrastructures known as the maximum number of vehicles expected to pass in an hourly rate within the capacity of the surrounding environment in absorbing emissions. The current practice of the typical environmental road capacity is critical. The main point of this system is to maximize the capacity of current infrastructures by controlling optimal speed. Indeed, there are two main reasons for this approach to be unlikely effective in reducing transportation emissions.

First, this approach tends to maintain the smoothness of movement and controlling the optimal speed, while it does not cover the objectives of transportation planning which is to facilitate as many as people or goods with a safe, rapid and economic efficient vehicles. The nature of transportation planning is to mobilize
people with the most effective and efficient services. Therefore, maintaining optimal speed and the smoothness of movement does not guarantee that the transportation system is adequate to facilitate effective mobilisation. This approach only consider the outcomes of the flow entities, not the actual need of transportation as means of travelling people or goods from one place to another in the most effective way.

Second, the design of the typical system is to increase the movement space of vehicles. In a certain stage, the more convenient conditions of the infrastructure will generate the number of vehicles entering the system. Obviously, this phenomenon is against the hope of reducing emissions through transportation planning and management, which aimed to reduce the pollution intensity by reducing the amount of traffic. Nevertheless, efforts to eliminate traffic congestions and long distance travels through designing infrastructure and policy enforcement is just one of the several efforts of emission reduction that have high degree of uncertainties. Considering the weaknesses of emissions trading and options related to infrastructure and policy design, there is an alternative approach that is more affordable, adaptive and realistic known as the application of cleaner technologies (Buchner and Carraro, 2008). This option is less likely to give opportunity to states or firms to free ride the framework like what possibly might happen in the cap and trade system. The other important finding presented is that a firm or states will develop their self-enforcement better when incorporating cleaner technology rather than dealing with other schemes such as emissions trading. Indeed, a high commitment on reducing emissions should be presented to bring the best outcomes to support the achievement of environmental sustainability.

Integrating Cleaner Production:

As already mentioned in the earlier part of this paper, the biggest environmental concern related to transportation is the high level of greenhouse gas emissions produced from this sector. Thus, as the climate change legislation and other efforts relating to transportation system design are facing obstacles that made the way to reduce emissions effectively became difficult, cleaner production (cleaner technology application) is an alternative approach that brings the hope of better environmental outcomes.

The Cleaner Production Context:

Cleaner production is one of the important approaches to solve today’s environmental problems. It is an integral part of the sustainable development mission carried by Agenda 21, which means cleaner production is capable to support the process of solving current environmental problems, providing inter-generational and intra-generational equity and likely to deliver long term benefits for the future generation.

By the notion that unsustainable economic activities related to production and consumption (e.g. the use of non-renewable resources and the failure in manage wastes) is a significant causes of environmental degradation, the application of cleaner technologies could be a strategic alternative approach (Tukker et al., 2008).

Cleaner production is known as a sophisticated strategy to solve environmental problems that guide industries or companies to produce more goods that are environmental friendly with fewer dependants on non-renewable resources and is likely to be cost effective. The dimension of cleaner production is not just between industries and the environment, but also dealing with delivering good services to the consumer, while the consumer have the responsibility to minimize wastes during the consumption process. Cleaner production is about creating a cleaner life cycle of certain products (Al-Yousfi, 2004).

The cleaner production’s mission in the transportation field is to create a sustainable urban transportation system that is capable of moving peoples and goods effectively while minimising the negative effects of the production and operation processes to the environment.

Cleaner Production Opportunities:

There are several methods of applying cleaner technologies in the transportation sector. The most popular strategy is minimising the use of non-renewable energy, and substitute it with technologies that are environmental friendly and acceptable to be adopted by consumers.

The progress of the global efforts to reduce transportation emissions is great. The world is now concentrating on reducing the use of gasoline-fuelled cars that had been the major cause of urban air pollution. Indeed, the biggest challenge is the ongoing growth of motor vehicle that is currently reaching up to 60 million units per annum. The current largest automotive market is the Northern and Southern America and followed by Europe. The market trend is predicted to shift by year 2020, where Asia will be the next leading market (Walsh, 2008).
As already mentioned in the earlier section, motor vehicles release dangerous greenhouse gases that are harmful to the environment and people’s health. Hence, the world is engaging three technology-based approaches to reduce emissions from transportation sectors, which are:

1. Applying stringent standards of fuel efficiency.
2. Introducing the use of lower-carbon fuels and developing cleaner vehicle technologies
3. Restricting and reducing the use of gasoline-fuelled vehicles.

There are important considerations in the application of alternative fuels. Fuels must be applicable, environmentally acceptable, technically feasible, economically competitive and is ready to enter the market (Balat, 2008).

Several industrialized countries (e.g., Australia, Canada, China, Japan, Europe, Singapore and the United States) are currently serious in developing alternative fuels. One of the important findings are the introduction of Hydrogen as an affordable alternative fuel for future transportations. The potential use of Hydrogen as an alternative fuel requires manufacturing processes. Albeit this condition, there are possibilities to produce Hydrogen eternally in an unlimited amount using renewable energy resources. This is potentially a good practice of sustainable development especially in facing the challenge of non-renewable resource depletion. The current production of Hydrogen is approximately 44.5 tonnes per annum or about 2% of the total demand of primary energy (Balat, 2008). The world is expecting that by 2040, Hydrogen fuels are able to replace the total consumption of petroleum that is considerably unsustainable.

The technical advantages of Hydrogen as a transportation fuel listed below:

1. Possible to produce from primary resources that are ready to be accessed.
2. Hydrogen is the best alternative component to replace gasoline. It has similar quality with gasoline in terms of internal combustion. Hydrogen can use directly as a fuel in an internal combustion engines.
3. Hydrogen has a high octane number, fast burning speed and less flammable.
4. The outputs of the combustion process are water and small amount of NOx, which are relatively clean and less likely to harm the environment.

In terms of economic competitiveness, it is possible to produce Hydrogen fuels at a relatively low cost through the centralized steam methane reforming (SMR) method. The current production process of Hydrogen is mainly through coal gasification, which is costly. However, this method may no longer be applicable in the future as producing Hydrogen expect to use more renewable resources. The other method of Hydrogen production is the biomass based resources. This process is environmentally acceptable but the cost is considerably uneconomical. Meanwhile, the cleanest method of producing Hydrogen fuels is through the electrolysis of water. The weakness of this method is the great amount of electricity required during the process. Hence, future Hydrogen fuel production needs to consider the use of renewable resources and technologies that are relatively low cost.

Based on this short review, the general conclusion is that Hydrogen is potentially capable to be an alternative fuel in the future, replacing gasoline that is currently critical due to high level of emissions and is associated with the rapid increase of non-renewable energy depletion. Hydrogen is also capable of meeting the criteria of applicable alternative fuels (environmentally acceptable, technically feasible, economically competitive and is ready to enter the market) that is acceptable to meet the future conditions although issues associated with cost effectiveness is still questionable.

The Barriers towards Using Hydrogen Fuels:

The earlier section provides the objective of cleaner production, which is the process of creating a better life cycle of products. Thus, the barriers that will discuss are from both the production and consumption point of view.

From the production point of view, there are barriers associated with cost effectiveness, where the Hydrogen production method by applying renewable resources or processes that are environmental friendly is facing the challenge of a high production cost. The other challenge in the production area is related to storage fuels. Hydrogen fuels require larger storage due to its low density. The form of hydrogen fuels stored in the vehicle can be as a compressed gas, in cryogenic containers as liquids or as metal bounded gas in metal hydrides. Hydrogen which are stored as compressed gas will not have the same quality performance as gasoline. It is possible afterwards to optimize the Hydrogen quality performance through absorbing it into metal hydrides, but this step increases the weight of the system significantly due to the heavy metals engaged in this system. The size of Hydrogen fuel storage is estimated to be four times larger than the usual gasoline tanks (Balat, 2008).
In the consumption area, there are barriers related to the consumers’ scepticisms regarding the application of cleaner technologies in terms of alternative fuels application. Recent finding from the examination of the consumers’ assumption and understanding about the environmental matters and issues related to the need of a cleaner transportation system in California, US revealed that most drivers (consumers) are aware of the issues associated with global warming and climate change. However, their awareness did not influence their preference and behaviour in consuming or purchasing goods that are environmental friendly. Consumers are doubtful of the benefit of applying cleaner technology into vehicles to deliver good environmental outcomes. They were also not sure whether those technologies are capable in meeting the consumers demand. Consumers were worried that the new design of environmental friendly vehicles is lack of power, smaller and less fashionable (Plax et al., 2008).

The Life Cycle Assessment (LCA) related to Hydrogen Fuels:

LCA is a tool to monitor and identify environmental impacts of certain products / processes of the whole production and consumption chain from resource inputs up to disposals (Wanichpongpan and Gheewala, 2008). LCA is also an essential tool to assist stakeholders to enhance the decision making process of particular projects (Niederl-Schmidinger and Narodoslawsky, 2008).

LCA distinguish into two different contexts. First, LCA is a tool for identifying environmental impacts of certain production and consumption process happening in the past. Second, LCA is a tool for identifying possible impacts that may happen in the future. Both LCA are useful to support the decision-making process especially in terms of technological choice (Sanden and Karlstrom, 2006).

The article (Sanden and Karlstrom, 2006) also presented an example of an LCA conducted to assess the environmental impacts and benefits of applying cleaner technologies related to Hydrogen fuels in Europe. The result showed that the use of hydrogen was not an effective option to reduce the global emissions because the global system is not yet familiar with hydrogen fuel vehicles. The authors then argued the weakness of the certain LCA findings that the process was misleading the actual potential of hydrogen fuels. Besides the research investigated a short-time impact analysis, the assessment also ignored the transport demand variable and assumed that there are no changes in vehicle type and driving cycles. This is considerably against the reality that technological inventory may lead to significant changes in consumers demand and the creation of new types or models of vehicles in the future. We should be aware that the benefits of Hydrogen fuels in reducing emissions would appear in a longer period as well as to integrate it into people’s lifestyle.

Therefore, LCA should deliver accurate measurements regarding the advantages of Hydrogen fuels as a part of the cleaner technology campaign. Misleading results of the assessment will increase people’s doubt regarding the advantages of cleaner technologies.

Conclusions:

Transportation sector is a significant global emitter that requires great attention of reducing the emissions. The world had recently taken serious actions of combating climate change. Under the Kyoto Protocol, several parts of the world introduced emissions trading schemes and placed certain consideration to include transportation sector into the trading system. Other parts adopted schemes that are more specific on reducing transportation emissions such as improving the environmental capacity of transportation infrastructures. There are obstacles related to the degree of uncertainties of these methods that made it difficult to deliver good environmental outcomes.

Cleaner production is promising better environmental outcomes through a more effective and reasonable action of reducing emissions. The world is now engaging serious actions to replace the use of non-renewable fossil fuels that is harmful to the environment with hydrogen fuels as an alternative resource that meets the criteria of environmentally acceptable, technically feasible, economically competitive and is ready to enter the market. The advantages of using Hydrogen fuels are the possibility of producing it from primary resources that are ready to be accessed, the quality that gives similar performance to gasoline when stored in to internal combustion machines, the high octane number, fast burning and less flammable and finally the outputs of combustion that are particles which are harmless to the environment. There is also an opportunity of producing Hydrogen fuels at lower cost, which is through the centralized steam methane reforming (SMR) process. Despite the remarkable advantages, there are barriers of applying this particular technology, which are the relatively high cost when using renewable resources, the problems related to hydrogen storage and barriers related to consumers’ scepticism of this technology to be applicable.

In order to minimize the barriers, technical development to establish low cost production process and designing an effective storage system should go on. Meanwhile, one that is also important is to investigate
LCA that delivers accurate assessment results and provide high degree of certainties regarding the benefits of applying Hydrogen fuels. This is an essential campaign effort of making the community understand the scientific justifications of engaging cleaner production to solve current and future environmental problems. A misleading result will increase the consumers doubt to purchase these vehicles in the future, and thus will result an ineffective outcomes of cleaner technology applications.

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