Energy Consumption in the Industrial sector in the United States of America and China, a comparison of current and future energy intensities

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Abstract

The following paper seeks to outline the comparison of energy intensities by major energy consuming industries between Mainland China and United States, two Asia Pacific economies that are also two of the world's largest energy consumers.[1]

Our analysis shows that between 2010 and 2035 energy intensities in the US and China are expected to converge across most sectors within the industrial sector, with the exception of the iron and steel sector, a group we identify as "other" industries, and the transport equipment sub-sector.

Overall convergence across most sectors can most likely be attributable to the Chinese Government's aggressive energy efficiency promotion and energy intensity improvement policies. Whilst non- convergence in the iron and steel sector is most likely explained by the fact that China is the world's largest steel producer[2] and their use of the oxygen blast furnace process in the production of steel as opposed to the US's use of the electric furnace, a much more energy efficient process. In addition to this non-convergence in the 'other' industries sector is fuelled by China's rapid growth in the construction and textiles and apparel sectors (by industrial GDP) which have historically (1990-2009) been much more energy intensive than the US.

Introduction

Energy intensity and its reduction has been a major concern for most economies globally, especially in the Asia Pacific Economic Co-operation (APEC) region. Over the long term, from 1990-2035 energy intensity has declined significantly across all industrial sectors in both the US and China. This paper, through long term energy consumption modeling and industrial GDP by sector projections (from 2010-2035) of the significant energy consuming sectors within the industrial sector in both China and the US seeks to analyze the long term energy intensity trend of these economies and how these trends compare against each other.

On average, in all sectors except for iron and steel, the transport machinery sub-sector, and a group which we call 'other' industries, convergence of energy intensities of the US and China begins to start from the mid- 2000's to 2010. Given China's direct influence over its State Owned Enterprises, policy implementation is likely to be effective, which could be a factor in the steady and solid improvement and convergence of energy intensities across the whole industrial sector in general.

In 2009 China launched the "Steel Revitalization Plan"[3] which aims to eliminate overcapacity in the iron and steel sector and promote energy efficient solutions for the industry. A contributing factor to the higher energy intensity in the iron and steel industry in China compared to the US is China's predominant use of the high energy intensity oxygen blast furnace steel production method as opposed to the US's predominantly used and more energy efficient electrical blast furnace process. If the policies and strategies implemented under the above mentioned plan prove to be highly successful energy efficiency promotion strategies in the steel sector may prove useful in further improving energy intensities. However if not convergence may remain unattainable for some time, much past the end of the projection period (2035).

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[1] 2011. World Energy Outlook 2011. *International Energy Agency*

[2] New, R., 2011. Metals-Steel and Steel Making Raw Materials. *Australian Bureau of Agricultural and Resource Economics-Australian Commodities March 2011*, pp. 169-173

[3] Tang, R., 2010. *China's Steel Industry and Its Impact on the United States: Issues for Congress.* Congressional Research Service (CRS), CRS Report for Congress

By industrial GDP projections up to 2035, the fastest growing sectors in the "other" industries category in China are construction and textiles and apparel. In the US the fastest growing sector within this category is also construction. A reason for the large discrepancy in energy intensity could be past large energy efficiency differences in these sectors between each economy. Over 2001-2010 energy efficiency in the construction sector in China was 15 times higher than that of the US, whilst energy intensity in the textile and apparel sector over this same timeframe was 4 times higher in China compared to the US.

This paper provides a basic analysis of the above mentioned topics which is based on an industrial model created for the Asia Pacific Energy Research Centre (APERC) publication "APEC Energy Outlook 5th Edition", to be published in late 2012. The Outlook publication seeks to provide energy supply and demand projections across all sectors, including the industrial sector, of the 21 APEC economies from 2010 to 2035.

There is some literature regarding the convergence of energy intensities between various economies and economic regions, with varied results and conclusions. Our findings are in line with those of Liddle (2010), who finds that between 1971 and 2006, in general there has been continued convergence of energy intensities between economic regions, namely OECD countries and Eurasian countries.[4]

Nature of Projections

In this paper energy intensity is defined as energy consumption within the industrial sector divided by industrial GDP (ktoe/ thousand $US dollar). GDP is in $US as at 2005. For individual sectors and in some cases sub-sectors the corresponding industrial sector GDP has been applied. The historical period referred to in this paper is from 1990-2009 (unless otherwise specified), whilst the Outlook period (projection period) is from 2010-2035. Results are preliminary and based on a Business as Usual Case (BAU). BAU is defined as the expected energy situation in the industrial sector in each respective economy up till 2035, based on all currently legislated policies within our Outlook time frame. A major input into the model was GDP projections, sought from an external organization, Global Insight. Historical energy consumption data is from the International Energy Agency 2011 database[5].

The main drivers of the simple econometric model used to make the following projections are; historical energy consumption, historical and projected sector level GDP, and world energy prices. Energy demand has been modeled by historically speaking, major energy consuming industrial sectors, by fuel. A three year energy intensity per sector moving average has been applied for accurate modeling purposes to account for any statistical discrepancies.

Classification of Industries

Focus industries to be modeled were identified based on level of energy consumption and energy intensity so that in the interests of time and simplicity a generic model could be applied to all 21 APEC economies, including the United States and China. Industrial classifications are in line with the International Standard Industrial Classification system. The disaggregated industries are; Iron and Steel, Chemical and Petrochemical, Non-metallic Minerals, Machinery, Food and Tobacco, and Paper, Pulp and Printing, at this preliminary stage the Transport Equipment sub-sector (part of Machinery sector) has been broken out as well. Machinery includes fabricated metal products, machinery equipment and appliances, computers and office machinery, electrical machinery and communications equipment, including semi-conductors and TVs. Paper and pulp industry includes paper and pulp and printing and publishing. The "Other" industries include; Textiles and Apparel, Rubber and Plastics Products, Medical, Precision and Optical, Furniture, Jewelry, Toys, Musical, Other Goods, Recycling, Non-ferrous metals, Mining of Metals and Quarry, and Construction. A separate model was created for Agriculture which is therefore not included in the following discussion. Because the treatment of the Transport Equipment sub-sector is still unclear at this stage, even though it has been identified as a non-converging sub-sector it will not be discussed in detail.

[4] Liddle, B., 2010.Revisiting world energy intensity convergence for regional differences. *Applied Energy*, 87(10), pp.3218-3225

[5] 2011. International Energy Agency 2011 World Energy Statistics database. *International Energy Agency*.

Results

Figure 1: Iron and Steel Sector energy intensity (ktoe/'000 $USD)

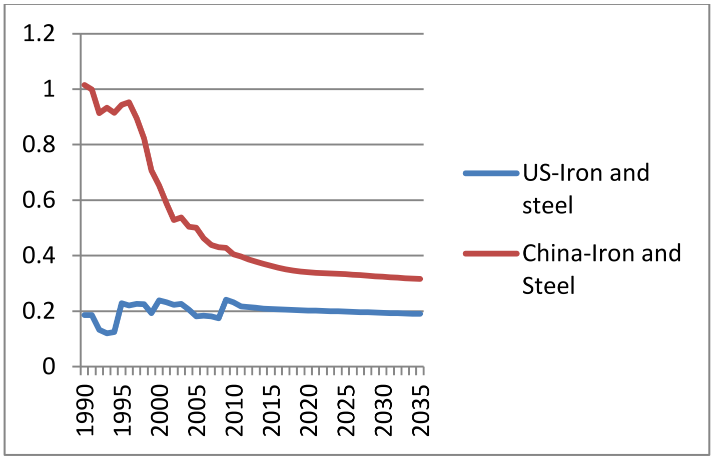


Figure 2: Chemical and Petrochemical Sector energy intensity (ktoe/'000 $USD)

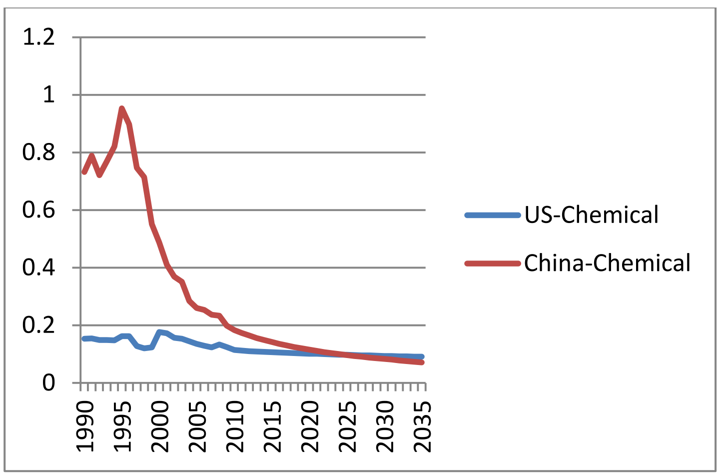


Figure 3: Non-metallic Minerals Sector energy intensity (ktoe/'000 $USD)

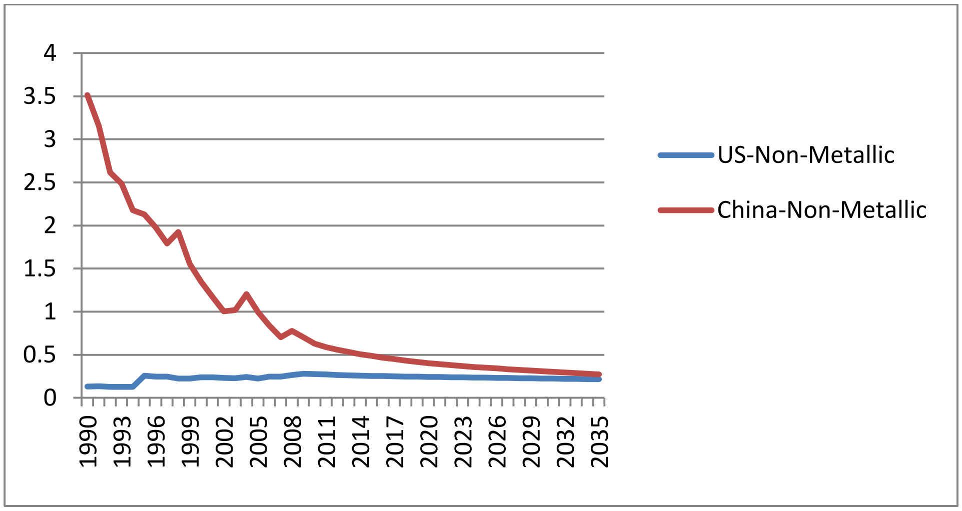


Figure 4: Transport Equipment Sub-sector energy intensity (ktoe/'000 $USD)

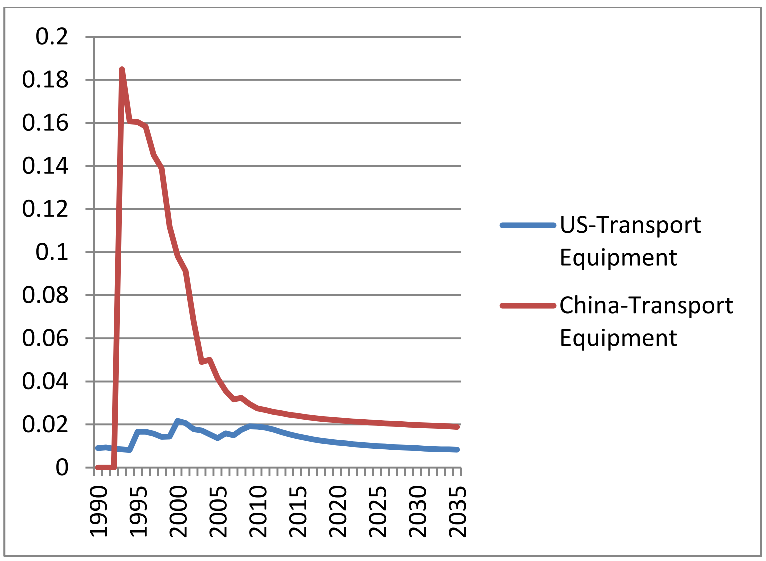


Figure 5: Machinery Sector energy intensity (ktoe/'000 $USD)

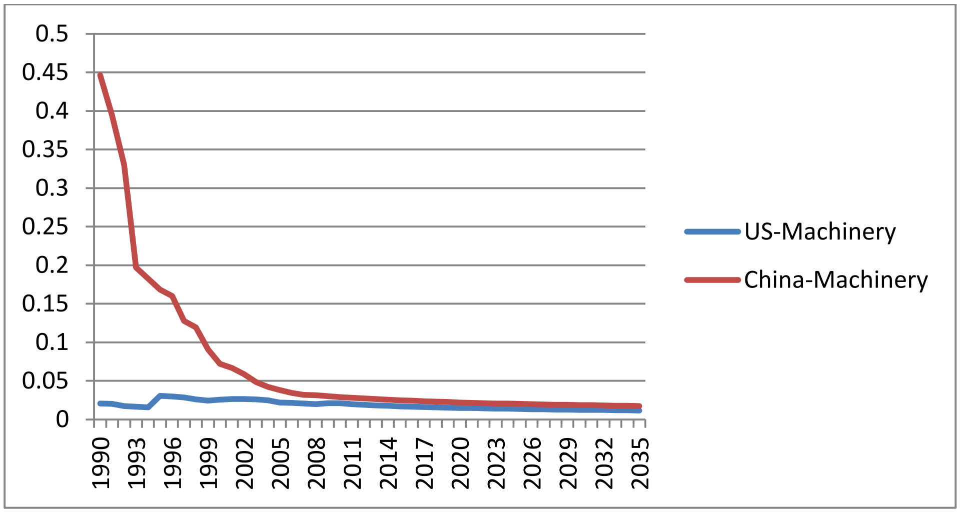


Figure 6: Food and Tobacco Sector energy intensity (ktoe/'000 $USD)

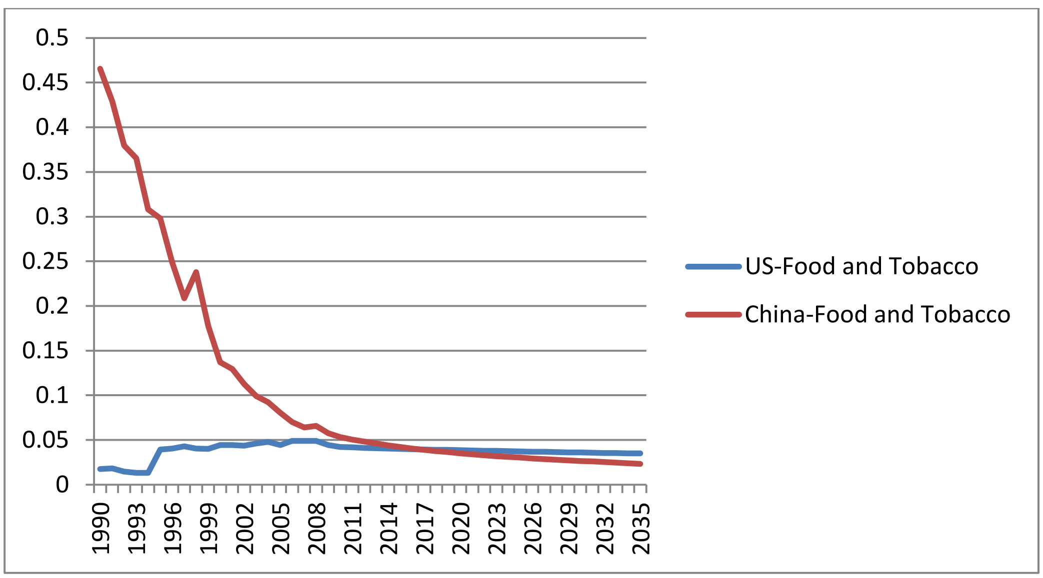


Figure 7: Paper and Pulp Sector energy intensity (ktoe/'000 $USD)

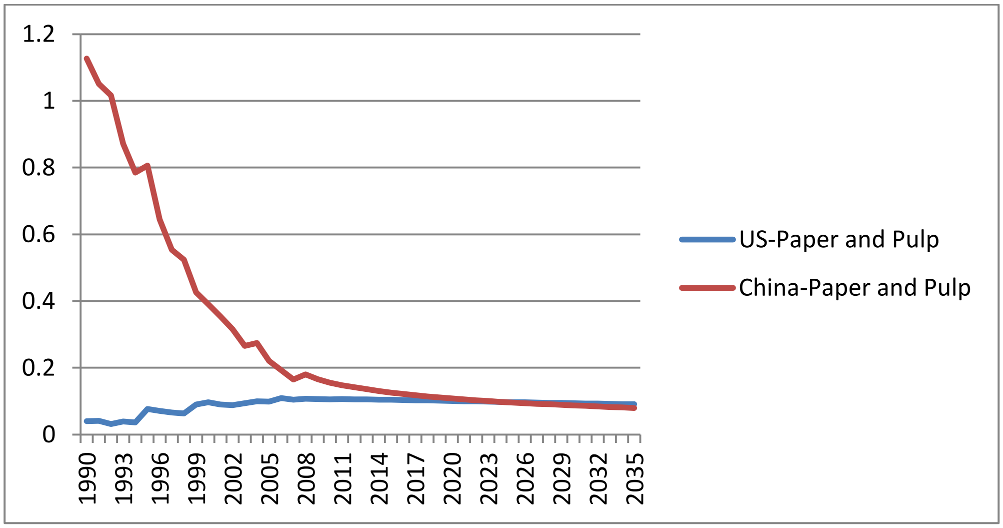


Figure 8: "Other" Sector energy intensity (ktoe/'000 $USD)

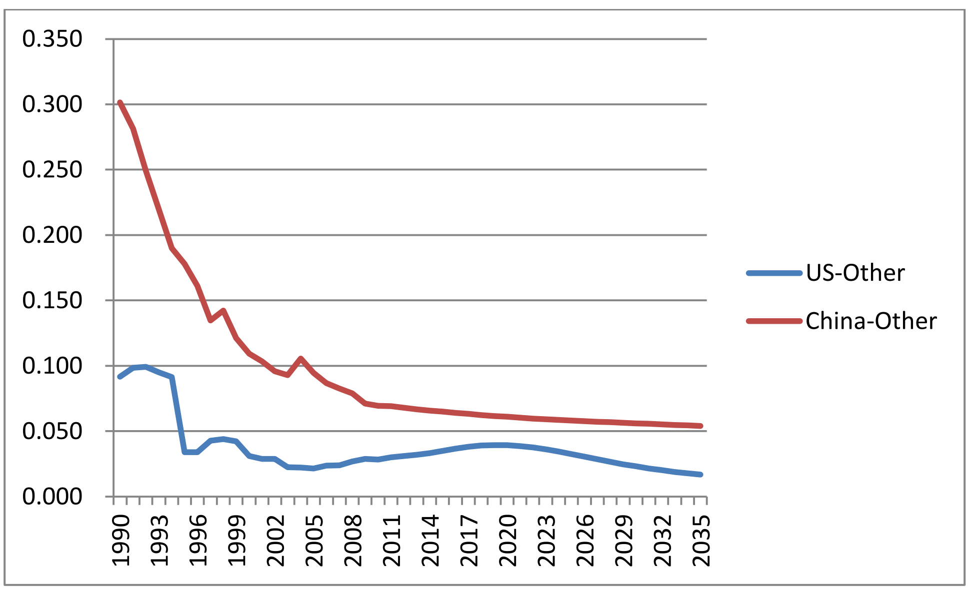
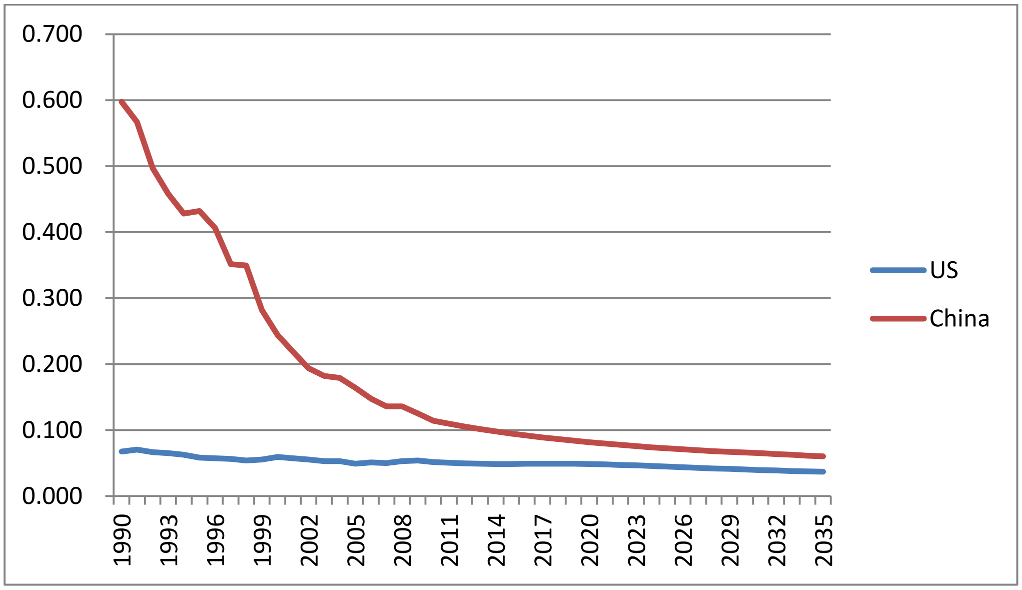


Figure 9: Total energy intensity in the Industrial Sector (ktoe/'000 $USD)

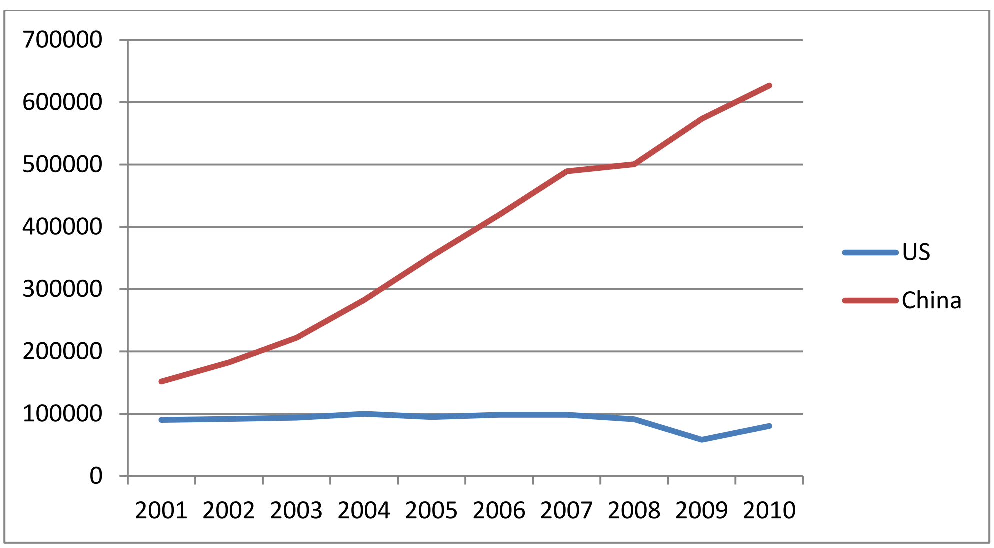


Analysis of the Steel industry in China and the US

According to the World Steel Association's, Steel Statistical 2011 Yearbook[6], crude steel production between the period 2001-2010 in China has been on average, nearly 4.5 times more than in the US. The trend of increased steel production is forecast to continue in China in the medium term due to forecast strong economic growth.[7]

The following graphs are based on statistics from the Steel Statistical 2011 Yearbook.

Figure 10: Total production of iron ore in China and the USA (ktoe)



[6] 2011. Steel statistical year book 2011. *World Steel Association*

[7] New, R., 2011. Metals-Steel and Steel Making Raw Materials. *Australian Bureau of Agricultural and Resource Economics-Australian Commodities March 2011*, pp. 169-173

It can be seen in the following two figures, that the bulk of China's crude steel production is manufactured through the oxygen blast furnace process (on average 87 per cent of steel was produced this way between 2001-2010, around 90 per cent in 2010), whilst the US tends to opt for electrical furnaces (on average 55 per cent between 2001-2010, 61 per cent in 2010).

Figure 11: Crude steel production through Oxygen blast furnaces (ktoe)

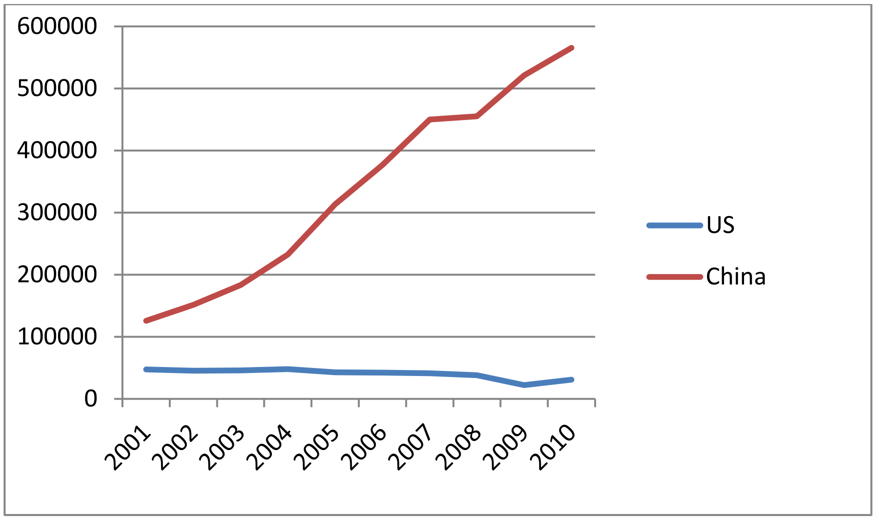
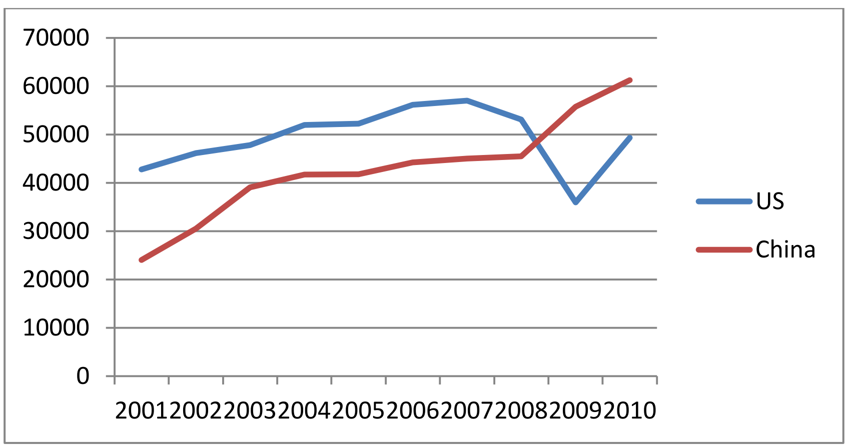


Figure 12: Crude steel production through Electrical blast furnaces (ktoe)



The oxygen blast furnace process tends to be highly energy intensive due to its predominant use of iron ore for the production of steel, where as electrical blast furnaces use more scrap metal and therefore are less energy intensive.[8] The amount of coal use and heat generation in the oxygen blast furnace process is what makes it so energy intensive, where as with the electrical blast furnaces; an electric current is used to melt scrap metal, rendering the process more energy efficient in comparison.[9] The steel industries in the US have been structured to recycle scrap, and are therefore dependent on the material.[10] The availability of scrap metal tends to be more readily sourced within highly industrialized countries such as the US, due to the average high per capita income and therefore ability to purchase materials which at the end of use will have scrap value. According to the US Geological Survey, the recycling rates for appliances in the US was 90 per cent, and for steel cans it was more than 66 per cent. Recycling rates for construction materials in 2009 were approximately, 98 per

[8] 2009. IEA Energy Technology Transitions for Industry-Strategies for the Next Industrial Revolution. *International Energy Agency*, pp. 50-75
[9] 2009.International Energy Agency Energy Outlook 2009. *International Energy Agency*, pp. 87-89
[10] Fenton, D.M., 2011.Iron and Steel Scrap. U.S. Geological Survey, *Mineral Commodity Summaries January 2011* <http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel_scrap/mcs-2011-fescr.pdf>

cent for plates and beams and 70 per cent for rebar and other materials. The recycling rates for appliances, cans, and construction steel are expected to increase in the US beyond 2009.[11]

Analysis of the breakdown of "Other" industries

It is important to note that under 'other' industries, on average the main individual contributors to China's industrial GDP over the Outlook period include; the construction sector (25 per cent of GDP), and textiles and apparel sector (13 per cent of GDP) (Figure 13). In the case of the US, the most significant contributor in the "other" industries sector on average over the Outlook period is construction (20 per cent of GDP) (Figure 14). Construction is a relatively low energy intensive sector but the textiles and apparel sector is considered a highly intensive industry by the United Nations Industrial Development Organization.[12]In the US, energy intensity in the construction sector between 1990 and 2009 averaged 0.002 ktoe/'000 $USD, over the same period in the same sector China's energy intensity averaged 0.03 ktoe/'000 $USD (15 times higher than the US). On average between this same period energy intensity in China's textiles and apparel sector averaged 0.2 ktoe/'000 $USD while in the US energy intensity averaged 0.05 ktoe/'000 $USD (4 times higher than the US). The non-convergence in this category can thus most likely be explained by the expected continued growth of China's construction industry, which in the past has been much more energy intensive than the US, and the growth of its highly intensive textiles and apparel sector.

Figure 13: China Sectors in "Other" industries by industrial GDP Million $USD (2005)

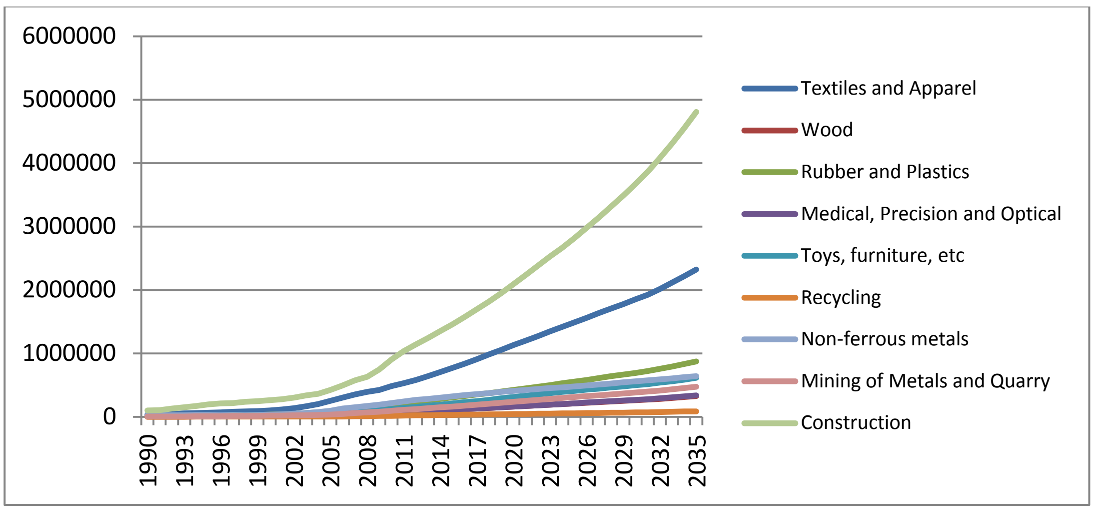
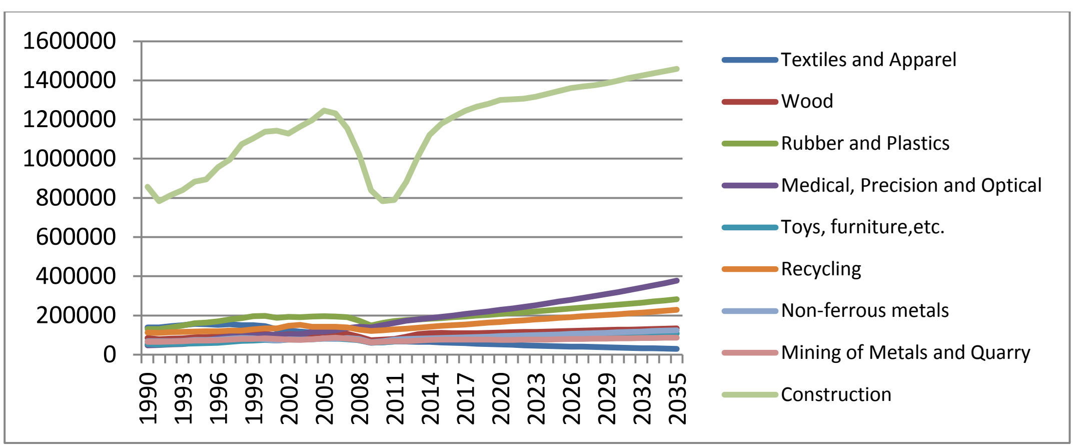


Figure 14: US Sectors in "Other" industries by industrial GDP Million $USD (2005)



[11] Fenton D.M., 2011.Iron and Steel Scrap. U.S. Geological Survey, *Mineral Commodity Summaries January 2011*
[12] Upadhyaya, S., 2010. Compilation of Energy Statistics for Economic Analysis. *United Nations Industrial Development Organization* , p. 30

Examples of Energy Efficiencies Policies and Programs implemented in China[13]

Given the Chinese Government's control over State Owned Enterprises and therefore direct influence over much of industry, its policies in this space are more likely to be effectual and have proved to be in the past.[14]

Reasons as to why there was an overall decline in energy intensity and decline in growth of energy consumption since 1996 could possibly be explained by the effectiveness of the energy efficiency policies implemented by China historically. In 1981 China moved from an energy policy that focused primarily on energy supply to one that also took into account energy conservation. From that point on, China established departments and agencies dedicated to energy conservation. Programs and policies to promote energy efficiency such as low interest loans for energy conservation projects and tax breaks for energy efficient products were implemented. According to analysis, energy savings brought on by a reduction in energy intensity resulted in energy consumption being less than half of what it would have been in 1995 if energy intensity were stagnant at 1977 levels.[15]

A hallmark policy that has been deemed very successful in encouraging energy efficiency; is the National Development and Reform Commission's (NDRC's) Top-1000 Energy-Consuming Enterprises Program, which aims to reduce the energy consumption of the 1000 largest industrial enterprises in China. As part of the program, each enterprise was set energy targets for 2010.

As per Price *et al* (2008)[16]:

The industries included in the Top-1000 Energy-Consuming Enterprise program are large-scale enterprises in nine major energy-consuming industries that each consumed a minimum of 180,000 tce (5.3 PJ) in 2004: iron and steel, petroleum and petrochemicals, chemicals, electric power generation, non-ferrous metals, coal mining, construction materials, textiles, and pulp and paper.

The main objectives of the program are to improve energy efficiency amongst the participants; reduce unit energy consumption to domestic best practice level for all major products; have some enterprises attain either international best practice levels or sector best practice levels; improve the energy efficiency of each sector; and achieve energy savings of approximately 100 million tons of coal equivalent in the 11th Five-Year Plan period (2006-2011). All participating enterprises have signed energy conservation agreements with local governments, promising to reach the energy savings within the five year plan period.

The program has been considered highly successful, achieving, and even exceeding, the program goal of achieving energy savings of 100 mtce as set in the 11th five year plan. The program is thus expected to be expanded to the Top 10 000 program.[17] An effective program such as this could explain China's solid energy intensity decline rate as can be seen across each industrial sector in the figures above. Continued implementation of such policies along with the continued promotion of the development of energy-efficiency technology as set out in the 12th five year plan (came into effect in 2011) is likely to support continued energy intensity decline in China.

Policies implemented in the steel industry in China[18]

[13] Price, L., Wang, X., Yun, J., 2008.China's Top-1000 Energy Consuming Enterprises Program: Reducing Energy Consumption of the 1000 Largest Industrial Enterprises in China. *Ernest Orlando Lawrence Berkeley National Laboratory, Peking University, and China Energy Conservation Association.*

[14] 2009. Understanding Energy in China. *Asia Pacific Energy Research Centre*

[15] Price, L., Worrell, E., Sinton, J., Yun, J., 2000. Industrial Energy Efficiency Policy in China. *Lawrence Berkeley National Laboratory and China Energy Conservation Association*

[16] Price, L., Wang, X., Yun, J., 2008.China's Top-1000 Energy Consuming Enterprises Program: Reducing Energy Consumption of the 1000 Largest Industrial Enterprises in China. *Ernest Orlando Lawrence Berkeley National Laboratory, Peking University, and China Energy Conservation Association.*

[17] Reinaud, J., Goldberg, A., 2011.Insights into Industrial Energy Efficiency Policy Packages Sharing best practices from six countries. *Institute for Industrial Productivity*

[18] Tang, R., 2010. *China's Steel Industry and Its Impact on the United States: Issues for Congress.* Congressional Research Service (CRS), CRS Report for Congress

By industrial GDP, historically (1990-2009) the iron and steel industry has been one of the fastest growing industries in China with an annual average growth rate of nearly 14 per cent. Of course, since this is GDP and not actual production, this growth rate is heavily influenced by the sometimes fluctuating and speculative nature of steel prices. However, regardless of price, China is the world's largest steel producer. Because of its stronghold in the Chinese economy due to its sheer size as well as because most of the steel produced in China is consumed locally, the government has policies regarding efficiency targeted specifically to this industry. Over the past five years the Chinese Government has acknowledged its concern regarding overcapacity in the steel industry, which has become a sizeable problem since 2006. The reason for concern over this issue is the affect it will have on domestic steel prices and thus the profitability of local steel companies. To counter overcapacity, the central government has been working with provincial and municipal authorities to phase out obsolete capacity, usually by setting a target of total plant closures and applying it on a regional basis. In 2010 the Chinese Ministry of Finance and State Administration of Taxation essentially removed the export tax rebate (subsidy) for key commodities, including some steel exports. It is believed that this may control production overcapacity and encourage steel industry consolidation and restructuring, main goals of the Chinese Government.

In addition to the above, in 2009 China introduced a "Steel Industry Revitalization Plan" which aims to update steel production through technological improvements and innovation, and to control total output and cease obsolete capacity. To reach the aforementioned goals the Chinese Government is seeking mergers and acquisitions amongst steelmakers and increases in the industry concentration rate, with a goal to have 45 per cent of Chinese steel output come from the top five steelmakers.

Given, that as seen above (in Figure 1) the iron and steel industry will be one of the most energy intensive industries in China over the projection period, the introduction and effectiveness of such a plan and other energy efficiency related policies, along with structural change within the industrial sector aided by technological change, will be instrumental in ensuring improvement in the decline of energy intensity in this vital sector.

Limitations

Given that the model developed and used is generic as it was developed to apply to all 21 APEC economies, there are many limitations. One such limitation; is that as described above in the case of both the US and China the construction and for China also the textile and apparel industry contribute significantly to GDP, therefore it may be useful to break out these sectors and the other sectors from the 'other' industries category to model their projected energy consumption separately to better understand the likely energy consumption and energy intensity trends in the long term in these important sectors as well as other sectors that may prove to be high energy consumers in the projection period.

The price used in the model is the world price (for simplicity) therefore not taking into account local energy prices and local sensitivities to these price changes in terms of choice of energy inputs for industrial production.

As previously mentioned intensity is calculated based on industrial GDP market rates (i.e. $USD at 2005), if purchasing power of parity was used, China's energy intensity is likely to be much lower, given the USD's value and power to purchase in China. This raises the very important question as to how to accurately calculate energy intensity, i.e. what is the best method?[19]

Further work

Further work in terms of current modeling on long-term trends of the use of both processes to produce steel needs to be conducted in order to understand how it will affect energy intensity within the sector. A noteworthy question that could be raised in the analysis of the iron and steel sector is that if the comparison of energy intensities is based on primary energy, considering the fuel mix used to produce electricity rather than just total electricity, may affect the energy intensity gap, possibly causing it to disappear. Given that the US's steel production method is electricity intensive considering primary energy rather than final energy is highly likely to narrow the intensity gap between the two countries, as it will increase the energy consumption more in the US than it does in China. Further research needs to be conducted.

The next step in our work will be to consider the alternative case, this will involve considering other possible policies that may be implemented both in China and the US that have not already been legislated as well as the possibility for further

[19] Samuelson, D.R., 2011.The Unexpected Challenge of using Energy Intensity as a Policy Objective: Examining the Debate over the APEC Energy Intensity Goal. *Kyoto IAEE Conference*

technological change and thus structural change which will have significant effects on energy intensity, possibly reducing it further.

Conclusions

The main conclusions of the paper can be summarized as follows:

In general across the sectors energy intensity between China and the US can be seen to be rapidly converging in all sectors except for in the iron and steel industry as well as the “other” industries; driven by projected growth in construction, which in the past has been much more energy intensive in China than the US and also projected growth of the highly intensive textiles and apparel sector in China. Total energy intensity in the industrial sector follows the general trend of convergence, with the slight difference attributable to the aforementioned factors.

It is highly likely that convergence has been driven by the Chinese Government’s aggressive energy efficiency and energy intensity improvement policies. The Chinese Government’s “Steel Revitalization Plan” may prove instrumental in promoting technological improvements, elimination of obsolete capacity and a move to more energy efficient practices within the iron and steel sector. Such policy backing will be needed to further reduce energy intensity especially in sectors such as the iron and steel industry. Likewise increased attention to energy efficiency in the textiles and apparel sector in China may be necessary to improve energy intensity in this sector.

If the percentage of steel produced through oxygen blast furnaces remains at 90 per cent as in 2010 in China and continues to increase, convergence in this sector may remain unattainable for some time. Especially given that China continues to grow and arguably may not even reach full development by the end of our projection period, thus steel production and use will be vital to the continued economic growth of the nation. However, even though production of steel through the electric furnace process is very small, the continuing and maybe a rapid increase in its use from 2010 into the projection period may further reduce energy intensity in the sector. A limiting factor of the use of the electric furnace though is the availability of scrap metal which is difficult to come by in emerging economies as opposed to highly industrialized economies.

Calculations of energy intensity in the production of steel using primary energy consumption rather than final energy consumption could provide an alternative picture for energy intensity convergence in the iron and steel sector. Recalculating energy intensities using GDP at purchasing power parity could prove to produce different results across all sectors, lowering China’s energy intensity significantly.