Petroleum and Coal

Review **Open Access**

ANALYSIS OF THE METHANOL INDUSTRY AND ITS APPLICATION FROM ECONOMIC STANDPOINT

Laleh Shirazi[1,], Erfan Aghaei[2]*

[1] Gas Division, Research Institute of Petroleum Industry (RIPI), Tehran, Iran
[2] Young Researchers and Elite Club, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran

Received March 13, 2017; Accepted May 2, 2017

Abstract

The methanol industry is one of the most dynamic industries in the world and methanol is one of the three important products of chemical industry in the world. According to the foreseeable scarcity of energy resources in the future, the direct use of methanol as a clean fuel and produce hydrogen for a fuel cell is highly regarded.

Methanol is a key product to create added value from energy sources including natural gas and coal. In this work, methanol industry has been analyzed from an economic perspective, and future vision of methanol has been sketched in Iran and the world. The production and consumption of methanol in Iran and the world, methanol market in the world, supply and demand for methanol and other details about the methanol economy have been described. Also, the predictions of the future of methanol in Iran and the world is presented. Iran's methanol would be having a significant impact on the methanol industry and the global economy in the future.

Keywords: Methanol economy; Fuel; Supply and demand; Derivatives.

1. Introduction

Methanol is one of the three most important products of chemical industry in the world and many materials derived from it. Also, due to the lack of predictable future energy sources, direct use of methanol as a clean fuel and/or produce hydrogen for a fuel cell, is highly regarded. Methanol is one of the most important products of upstream petrochemical industry for numerous products that can replace with petroleum derivatives and use to produce a range of petrochemical products. Methanol is a key product to create added value from natural gas and coal. It has an important role in the global economy. Because of the importance of methanol in the country and the increasing demand for this product in the world, where necessary, the various aspects of methanol process & its economy are examined.

Due to abundant reserves of natural gas in our country, it is a major producer of methanol in the world. Also, due to low natural gas prices and profitability of the production of methanol from natural gas, extensive investments have been made in this area.

Also, a small part of methanol is consumed in downstream industries, and most methanol production is exported in raw form to other countries. The amount of methanol produced in the country in the future could effect on global markets of methanol. On the basis, in this research, the vision of methanol industry, final methanol vision in the country, economy and the global market for methanol and its derivatives at now and in the future have been investigated. As well as appropriate ways to deal with the drop in prices of methanol with a proper conversion of methanol to higher value-added products is provided.

2. Methanol industry vision

Methanol trade in the past years with several major changes has been met. Recently, the extensive growth in demand and production capacity of methanol in China has taken place, and this trend will continue as long as this process is economically feasible. An important factor in global demand for methanol is due to methanol conversion to olefins projects (MTO) in the future [2-3]. By increasing of application of derivatives of methanol and also use it as fuel in China and rest of the world, it is anticipated that methanol industry is expected to expand significantly in the coming years. The use of methanol as fuel and mixed with petrol creates a vision clearly in demand for methanol as a clean fuel in the coming years [7,10-11,18]. High capacity of methanol production in North America, this country will become an importer into an exporter of methanol. At the moment, East Asian countries and Europe are methanol important importer, and this trend will continue in the coming years. In Iran, because of the abundance and availability of natural gas, methanol production is considered to be special, and several methanol production units are under construction and commissioning.

3. Supply and demand for methanol

Supply and demand for methanol in the world since 2008 and forecast up to 2023 is shown in Figure 1. The trend of methanol production since 2008 up to now has had increasing so that there is always an excess of methanol in the world. According to this report, it had in 2013 the world's methanol production capacity of 98 million tons, the consumption of 59.5 million tons and the remaining of 38.5 million tons. Forecasts show that the empty capacity of methanol production in 2023 will be equal to 36.2 million tons. The expected production capacity of methanol in Iran 8.8 million tons is considered in 2023. However, despite plans being built in the country, methanol production capacity more than this amount and will be equal to 34.7 million tons in 2023.

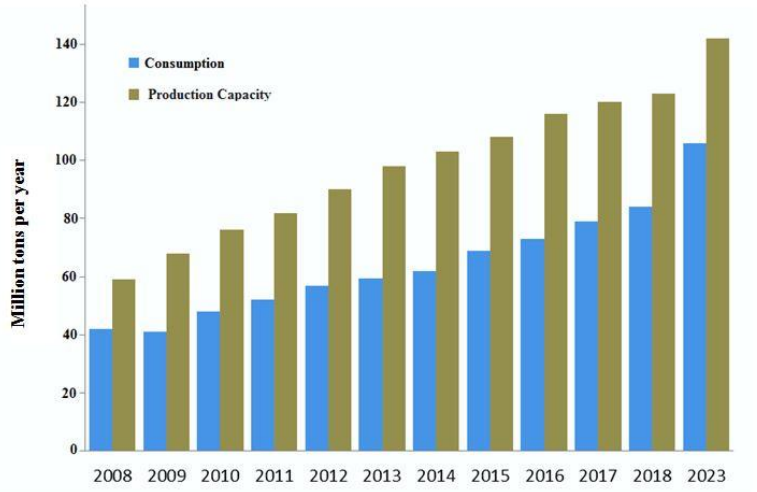

Fig. 1. The production, consumption and production capacity of methanol and predict the coming years in the world (IHS reported in 2013)

Due to the significant surplus of methanol in the world markets and also low growth demand for methanol of the main importer countries, it is expected that increasing of Iran's methanol production capacity to decline the world price of methanol in the future. On the other hand, if the continuity of low natural gas prices, due to low methanol prices in Iran, may not develop many of methanol production units in Europe and America. In this case methanol as a raw product with very low price with no economic justification and technical leaves the country.

In 2008 and 2009, global demand for methanol was low because of the recession and the progress was 4 and 2%, respectively. The research results of IHS Institute in 2013 show that

global demand for methanol in 2010 to 2012 grew about 23%. It is expected that methanol demand in the coming years has a growth rate of over 8% from 2012 to 2022. The countries of North East Asia, Europe, and North America were the largest importer of methanol areas in the world in 2012 that have about 80% of the world's methanol imports. North America up to 2022 will be a more balanced situation because high volumes of methanol production capacity in different areas are expanding.

In the decades 1980s and 1990s, America was largest consumer and exporter of methanol in the world. However, now China is in the first place in the world. Before the rise in natural gas price in the late 1990s, America had a production capacity of 10 million tons per year methanol. In late 2005, this capacity was 785 thousand tons per year, which led to most of the country's needs by supplying methanol imports. Natural gas price in America in 1999, was equal to 2$ per million BTU and up to 2005 rose about 8 dollars per million BTU. The increase in natural gas price led to a reduction in capacity in the country's methanol production. But this trend by the progress of science and technology and the possibility to withdraw from new sources has changed.

China is the world's largest producer of methanol which 54% of the world consumption capacity of methanol and 44% of the world production capacity of methanol (26.5 million tons per year) in 2013 related to this country. This country has specific plans to reduce imports of methanol and tries the major needs of the country's methanol, to be supplied through coal resources in the country. In 2013, about 99.5% produced methanol from coal is produced in China. This amount equal to 64% of the total produced methanol in this country.

Methanol industry in the world already reached to peak capacity expansion. Since 2007, the production capacity of methanol with a rate of 14.3% in the year is increased. Whereas, methanol demand's rate in the industry has 8.6% per year growth. The demand for methanol in Western Europe between 2011 and 2016 with an average annual growth rate 2.6% has increased. North America in 2011, has imported about 6-7 million tons of methanol and It is anticipated that by increasing domestic production of methanol in America, this value is declined. China has been expanding extensively in downstream units such as methanol to olefins, methanol-to-propylene, and methanol to dimethyl ether. These units are accounted the huge proportion of the country's methanol consumption of this country.

4. Methanol production and consumption in Iran

In 1338 Arabic countries of the Persian Gulf while increasing exploitation of the region's oil and gas resources, Iran started activities in the field of petrochemical with the construction of Shiraz petrochemical and production of urea. According to the Islamic Republic of Iran Customs, the average price of imported and exported goods of the petrochemical industry in the 1393 year were 2800 and 900 $ per ton, respectively, which these figures indicative raw retail of petrochemical products. These products enter the country by standing in value-added chain increase with several times prices. Despite a fifty-year history of the petrochemical industry in Iran, an export of low-value products is axis development of operational units. This has led to a disproportionate growth of production capacity of some low-value goods regardless of proper solutions for increasing value-added of them.

Iran with more than 33 trillion cubic meters of natural gas in the world is as one of the major poles of methanol production in the world. Now, there is 5 million tons of methanol production capacity in the country using natural gas feedstock that exported to world markets especially East Asia and Western Europe. In Table 1 methanol production units and production capacity in 2014 is presented. Methanol consumption in the country is less than 300 thousand tons per year, which amounts to only about 6% of methanol in the country and more than 94% methanol production of petrochemical units is exported as crude. China, Japan, the Republic of Azerbaijan, Slovenia, Afghanistan, Italy, Belgium, Thailand, Taiwan, South Korea, Sri Lanka, Iraq, Egypt, the Netherlands, and India are the most important consumers of methanol of Iran. Now, Iran is the largest exporter of methanol to China so that in 2010, 44% of China methanol market was supplied by Iran.

Table 1. Methanol production plants in Iran

Production plants	Annual production	Feedstock of plants	Location
Khark Methanol	660 thousand tons	Associated sour gasses feed extracted from the oil regions	Khark
Fanavaran Methanol	1 million tons	Surplus natural gas and carbon dioxide for Razi and Maroon Petrochemical	Petrochemical special economic zone
Zagros Methanol	1.65 million tons	South Pars refinery Phases	Pars special economic zone
Shiraz Methanol	85 thousand tons	The main gas line	Shiraz

However, so far effective and serious planning to increase the value added of crude methanol and prevent its sale has not taken place. However, the amount of produced methanol in the country has shown a rising trend. In addition to the existing methanol production units, several units are being built. Commissioning the units, more than 19.14 million tons per year of methanol production capacity will be added in the country.

Also, in addition to projects under construction, with commissioning other petrochemical units in different parts of the country, particularly Makran coast has agreed to produce methanol. With the commissioning of the petrochemical units, 10.6 million tons per year will be added to methanol capacity in the country. According to Figure 2, the total capacity of methanol in the country will be reached to 34.7 million tons per year up to next 10 years.

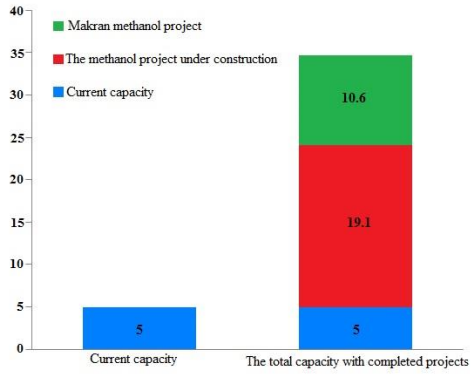

Figure 2. Iran's methanol production capacity now and in the future

According to reports published by the Institute of IHS, methanol consumption in the world in 2013, equal to 59.5 million tons and Iran's share in the supply of methanol is 8%. Now we can supply more than 38.5 million tons of methanol in the world and many parts of the world such as Europe and America, despite the higher production of methanol, a substantial portion of its requirements through imports supplying. Due to the oversupply of methanol and availability capacity of methanol production in the world, significant increases in the production of methanol by planning taking place in the country and exports huge quantities of methanol to other countries certainly significant decrease in the world price of methanol in the future.

In general, estimates show that due to the lack of natural gas feedstock in Saudi Arabia and Trinidad and Tobago, Iran in the future, with the advantage of gas reserves and production and use of new petrochemical complexes of methanol production can be used as a second largest producer of this petrochemical product in the world market. Iran's rival countries in the field of methanol production are one of the foremost countries and benefit from high technologies to produce chemicals and petrochemicals in the world. The use of these technologies is effective directly on the costs and quality of product and leads to a higher quality product with lower cost. However, the competitors have been built an industry of value-added products of methanol beside in the methanol production units, which have been able to reduce transportation costs and feed and reduce energy consumption, improve response time and interactions across the supply chain. Some of the products such as acetic acid and MTBE are currently being produced in the country, and in the near future with the abandonment of MTBE, there will be no market for it. The use of methanol as a fuel in the country is considered,

too. Also, one of the projects-studies in Iran is the conversion of methanol to olefins with a capacity of 3.3 million tons.

5. Supply and demand for methanol derivatives

Methanol derivatives are including formaldehyde, MTBE, to improve octane fuel, acetic acid, methyl-metacrylate, additives to plastics and so [4-6,9,14-15]. For China being at the center of global growth, fuel application is one of the primary reasons for methanol demand.

Tens of valuable materials can be produced from methanol, while very few of them are produced in Iran. This suggests the need for production of downstream products from methanol that with these products, considerable value-added will accrue to the country.

Methanol market divided into two segments Non-fuel (such as formaldehyde, olefin production such as ethylene and propylene, DMT, acetic acid, MMA, solvents and applications such as methylamine and methyl chloride synthesis which these materials used in various industries including adhesives, paints, melamine dishes, switches, acrylic used in neon signs and traffic signs, etc.) [4, 9, 15] and the fuel (including MTBE, DME, combined with gasoline and other applications fuel, including biodiesel, fuel cells for hydrogen production) [5, 7, 10, 14, 18].

Expected demand for methanol as a fuel increases from 5 million tons in 2012 to 11 million tons in 2022, indicating a 12% growth in this field. With combined ratio of methanol to fuel equal to 15% and slightly higher, methanol consumption in this area could increase to 15 million tons per year. In China, more than 7 million tons per year of methanol mixed to gasoline to produce fuel. Other potential uses for methanol is biodiesel production using methanol as a feedstock. In Europe and other countries seems to use this field is almost not possible because in these countries most of the agricultural production are used to produce biodiesel which is consistent with the policies of food production and agricultural development. Another field of use of methanol is converted to dimethyl ether. This way when the new rules to reduce sulfur in fuel are intensified, or enough low-sulfur fuel is not available, can be important.

Figure 3 shows the distribution of various products produced from methanol to 2013 and forecast up to 2017. It can be seen, the greatest amount of methanol consumption in recent years has been related to its use to produce chemical products. Forecasts show that this will continue in the future. It is also seen the greatest growth in the products from methanol is related to fuel and energy sector.

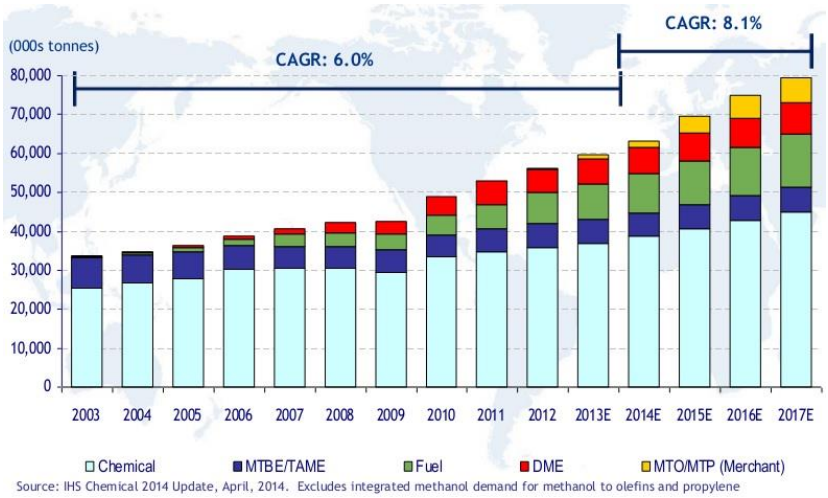

Fig. 3. Growth products from methanol [14]

Due to the volume of production and export of methanol in Iran, it seems that at least 10 million tons of methanol in the next 5 years there will be a surplus in the country. So many ways to convert methanol into high-value products such as propylene (MTP) [12], Dimethyl ether (DME) [17], gasoline (MTG) [13], olefin (MTO) [2-3], Polystal, methyl methacrylate and

Polymethyl methacrylate can be noted that with excess methanol in the future, has the technical and economic feasibility. The direct use of methanol as a fuel and fuel additives is a context for utilization of methanol. Surveys show that only 6% of produced methanol of country is consumed inside which mainly is converted to acetic acid and MTBE. According to Figure 4 can be seen that most of the methanol in the world in 2013 is converted to formaldehyde, dimethyl ether, fuel additive, acetic acid, MTBE and other products.

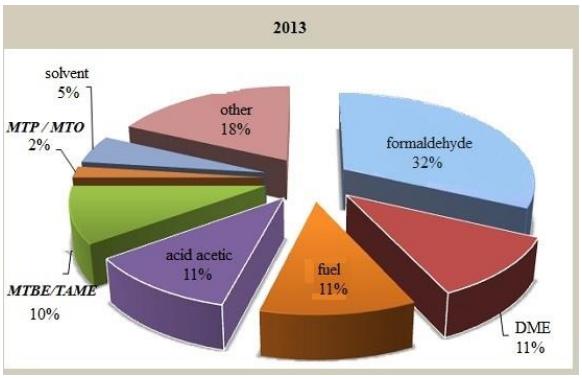

Figure 4. Status of products from Methanol in the world (According to HIS 2013)

Also, similar this trend is predicted for 2023. Hence the fund of converting methanol to the products that have a high proportion of demand in global markets seems economical. Macro policies in the country incline to increase the value added of methanol to use new processes such as MTO, MTP and convert methanol to fuel (methanol to gasoline). In 2013, the share of these processes for methanol conversion had been reported 2%. Forecasts show that the share of MTO and MTP processes of converting methanol and methanol as fuel will increase to 8% and 14%, respectively in 2023.

Among the main based petrochemical products are ethylene and propylene which consume in the production most of the products downstream petrochemical. Ethylene is obtained from produced ethane of naphtha cracking and other hydrocarbon products, mainly. However, the amount of produced propane of these units to propylene production is small and is produced mainly as a byproduct. So propylene due to different supply and demand situation needs more attention. The important derivatives of propylene include polypropylene, acrylonitrile, propylene oxide, phenol, oxo alcohol, acrylic acid, isopropyl alcohol, oligomers and other required intermediate materials for the electronics industry, automotive, construction, packaging and like it.

Currently, formaldehyde is the main product produced from methanol which in 2010, about 27%, and in 2013 about 32% of world demand for methanol is formaldehyde production. The greatest demand for formaldehyde is in the construction industry that it is used as a binder to prepare various products. In developed countries, by expanding the use of engineering products, demand for formaldehyde has increased. Formaldehyde is a need for the manufacture of composite products. For example, construction industry recession is reduced demand for formaldehyde.

It is expected that use of methanol as a fuel will be increased in the next years. The use of methanol as a fuel is containing MTBE, biodiesel, combined with gasoline and dimethyl ether. Methanol as a mixture with gasoline in China has been widely used. With the significant increase in the price of conventional energy sources (such as in 2009), use of methanol as fuel will further increase.

MTBE was allocated 11% of global methanol demand in 2013. In the previous years, MTBE as the second most widely used product was produced from methanol. MTBE domestic demand in the United States of America increased, by legislation for cleaner air in 1990. The use of oxygenated compounds in gasoline was required to prevent air pollution. In this country, MTBE was first oxygen compounds for use in new gasoline. However, due to MTBE leaks from underground tanks of gasoline, its use was challenged. In other regions of the world, especially in countries that still used from lead compounds to improve the octane number, MTBE consumption is likely to grow.

Acetic acid accounted 11% of methanol consumption in 2013, and the same trend is also expected to be maintained until 2018. Main consumption of acetic acid is production vinyl acetate monomer. Therefore the demand for acetic acid is highly dependent on the demand

for vinyl acetate. Acetic acid is also used as a solvent for the production of terephthalic acid. From 2013 to 2018, demand for acetic acid at the rate of 7/5% per year will grow which is less than its growth rate in the past five years (equal to 6.5%).

Methanol-to-olefin and propylene applications are growing, and it is expected between 2013 and 2018 with annual growth rate of 46.5% associated. The method used for the production of olefins and propylene from methanol now is exclusively in China which since 2011 has started and now is accounted for 2% of methanol consumption and with a capacity of 61 thousand tons per year of methanol is in operation. When the prices of natural gas compared to crude oil price are low, the process of converting methanol to light olefins particularly ethylene and propylene is economical. This process has high investment costs. For example, investment of a methanol-to-propylene conversion unit with the capacity of 450 thousand tons per year was about 850 million dollars (in 1393) [1]. Converting methanol to propylene plant is available in China, and use of this process in the Middle East is at the stage economies.

6. Methanol prices

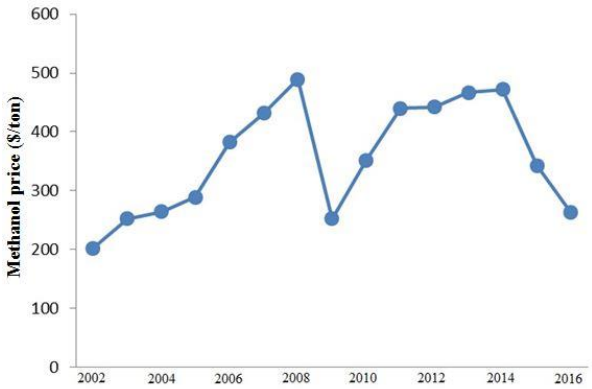

Figure 5) Asian methanol prices from 2002 to 2016 (Source: Methanex corporation report) [19]

The majority of the production costs of methanol from natural gas related to reforming and preparing the gas stages. Distribution costs for investment in different parts of the commissioning of a methanol unit are: Desulfurization (2%), reforming and cooling gas (32%), steam generation (14%), compression (24%), methanol synthesis (22%) and distillation (6%) [16]. Changes in methanol prices in the past years and forecasts up to 2018 are shown in Figure 5. It is observed that methanol prices fell sharply in the years 2008 to 2009 due to the global economic recession. Also, the price of methanol has increased from 2009 to 2014 and from $ 250 per ton in 2009 to $ 470 per ton in 2014 increased. Methanol price since 2014 up to now has continuously decreased. Methanol price fluctuations in recent years are due to an oversupply of methanol and are dependent on the ability of import and export of methanol and natural gas prices.

7. Conclusion

Methanol as an intermediate product plays an important role in increasing the value added of natural gas, the global economy, and energy. Over the past years, there has been surplus production capacity of methanol in the world and forecasts also show that this trend will continue in the future. So it will affect the global economy of methanol and the methanol industry strongly, and it will be more in the future with the significant increase of methanol production capacity of Iran and other countries. The results show that now methanol as raw with low-value currency exits from the country that this process is not economical and the review is essential. According to the supply and demand for methanol and methanol production capacity, development of downstream industries for increasing of value added of methanol seems essential. Forecasts show that the use of methanol in the field of fuel and energy in the future will assign a high share of global demand. Suitable areas of increasing the value added of produced methanol in Iran are its use as a fuel, fuel additives, fuel cell hydrogen production, conversion to acetic acid and formaldehyde and conversion to light olefins and gasoline.

References

[1] Aghaei E, Haghighi M. Enhancement of catalytic lifetime of nanostructured SAPO-34 in conversio of biomethanol to light olefins, Microporous and Mesoporous Materials, 2014; 196: 179-190.

[2] Aghaei E, Haghighi M, Pazhohniya Z, Aghamohammadi S. One-pot hydrothermal synthesis of nanostructured ZrAPSO-34 powder: Effect of Zr-loading on physico-chemical properties and catalytic performance in conversion of methanol to ethylene and propylene, Microporous and Mesoporous Materials, 2016; 226: 331-343.

[3] Yu EH, Scott K. Development of direct methanol alkaline fuel cells using anion exchange membranes, Journal of Power Sources, 2004; 137: 248-256.

[4] Hamnett A. Fuel Cells and Catalysis Mechanism and electrocatalysis in the direct methanol fuel cell, Catalysis Today, 1997; 38: 445-457.

[5] Liu S, Cuty Clemente ER, Hu T, Wei Y. Study of spark ignition engine fueled with methanol/gasoline fuel blends, Applied Thermal Engineering, 2007; 27: 1904-1910.

[6] Çelik MB, Özdalyan B, Alkan F. The use of pure methanol as fuel at high compression ratio in a single cylinder gasoline engine, Fuel, 2011; 90: 1591-1598.

[7] Yadav G.D., Kirthivasan N., Single-pot synthesis of methyl *tert*-butyl ether from *tert*-butyl alcohol and methanol: dodecatungstophosphoric acid supported on clay as an efficient catalyst, Journal of the Chemical Society, Chemical Communications, 1995; 203-204.

[8] Collignon F, Loenders R, Martens JA, Jacobs PA, Poncelet G. Liquid Phase Synthesis of MTBE from Methanol and Isobutene over Acid Zeolites and Amberlyst-15, Journal of Catalysis, 1999; 182: 302-312.

[9] Thiebaut DM, Vidalin KE. Methanol plant retrofit for manufacture of acetic acid, Patent No. WO 2001032594 B1, 2001.

[10] Torrence GP, Hendricks JD, Dickinson, DD, Aguilo A, Addition of hydrogen to carbon monoxide feed gas in producing acetic acid by carbonylation of methanol, CA 1299195 C, 1992.

[11] Fujimoto K, Omata K, Shikada T, Tominaga H. Vapor phase carbonylation of organic compounds over supported transition metal catalysts. 2. Synthesis of acetic acid and methyl acetate from methanol with nickel-active carbon catalyst, Industrial & Engineering Chemistry Product Research and Development, 1983; 22: 436-439.

[12] Chao HR, Lin TC, Chao MR, Chang FH, Huang CI. Chen C.-B., Effect of methanol-containing additive on the emission of carbonyl compounds from a heavy-duty diesel engine, Journal of Hazardous Materials, 2000; 73: 39-54.

[13] Bakraji EH, Salman N. Properties of wood–plastic composites: effect of inorganic additives, Radiation Physics and Chemistry, 2003; 66: 49-53.

[14] Excludes integrated methanol demand for methanol to olefins and propylene, in: IHS chemical 2014 update, April, 2014.

[15] Lee YJ, Kim YW, Viswanadham N, Jun KW, Bae JW. Novel aluminophosphate (AlPO) bound ZSM-5 extrudates with improved catalytic properties for methanol to propylene (MTP) reaction, Applied Catalysis A: General, 2010; 374: 18-25.

[16] Yaripour F, Baghaei F, Schmidt I, Perregaard J. Catalytic dehydration of methanol to dimethyl ether (DME) over solid-acid catalysts, Catalysis Communications, 2005; 6: 147-152.

[17] Sadeghi S, Haghighi M, Estifaee P. Methanol to clean gasoline over nanostructured CuO–ZnO/HZSM-5 catalyst: Influence of conventional and ultrasound assisted co-impregnation synthesis on catalytic properties and performance, Journal of Natural Gas Science and Engineering, 2015; 24: 302-310.

[18] Wender I. Reactions of synthesis gas, Fuel Processing Technology, 1996; 48: 189-297.

[19] https://www.methanex.com/our-business/pricing, in, 2016.

To whom correspondence should be addressed: shirazil@ripi.ir