Natural gas consumption in Croatian refineries 2013 - 2023

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PRESENTATION FROM SCIENTIFIC AND EXPERT GATHERINGS

Today, all energy entities, even the smallest local players, must carefully analyze technological and economic viability of their operations by taking into consideration the impacts such as: constraints in availability and accessibility of energy resources, trends and imposed measures for emission reduction, growing demand for energy due to civilisation advancements, sensitive supply and demand relationships, significant volatility of energy prices, challenges in securing funding for future purchase of energy sources, including cost of financing. Particularly, the above phenomena have strong influence on conventional energy sources which still account for 90% of total energy, while the share of oil and gas exceeds two thirds of total energy. Oil refineries are important for producing oil products and meeting the demand for these products. They continually upgrade their processes to remain competitive and sustainable. Refineries are confronted with the need to implement modernization projects and new technologies on one side and to find solutions for achieving competitive, i.e. relatively cheap production on the other side. Refineries in Croatia are influenced by the same problems and operating conditions, with the difference that the share of indigenously produced crude is only 10-15% of total demand. Refineries in Rijeka and Sisak have favourable geographic position, access to the existing and future oil and gas pipelines and sufficient supply of natural gas for their needs. Considering these advantages, they have real potential for current and future sustainability. The existing modernization programme implemented in the Croatian refineries by INA d.d. and its strategic partner MOL, is a well designed and harmonized development project. When realized it will ensure higher performance of the refineries in comparison with the existing and potential competitors in the region. It takes into account general trends in the industry and regional and local specific requirements, as well as existing constraints and advantages. Consequently, in respect of accessibility and availability of oil products, Croatia should have a reliable supply of high quality motor gasolines, diesel fuel and LPG in the decades to come.

According to the official modernization programme of INA's refineries in Rijeka and Sisak, natural gas is going to be used as a fuel for energy supply and for processing requirements, together with fuel gas, but also as a feedstock for hydrogen generation. Hydrogen is needed for a demanding treatment of gasoline and diesel, primarily sulphur recovery process. This paper analyzes foreseen consumption of natural gas in both refineries in the period 2013 - 2023 by taking into consideration specific type of modernization project and manner of its implementation, as well as the current and future regional demand for refined products in the above period. This specific forecast of natural gas consumption can be considered as a contribution to the forecast of total industry sector natural gas consumption, but also total natural gas consumption in Croatia. In addition, this forecast will represent a significant contribution to balancing specific low-emission air pollutants, and for the assessment of overall industry emissions.

Key words: natural gas, refinery energy supply, projection of energy consumption

1. Philosophy of INA's refineries modernization

The ten-year projection of natural gas consumption in INA's refineries is based on analyses of consumption of natural gas as a fuel for energy supply and processing requirements in each modernized refinery and foreseen supply of oil products to the existing and future markets. Foreseen supply of oil products to the markets is used as a base for estimation of necessary refining capacity and the respective natural gas consumption. Total consumption of oil products on the former and current markets of Croatia, Bosnia and Herzegovina, Slovenia, Serbia, Montenegro and the MED market is estimated on the basis of longterm projections of GDP in these countries as quoted by relevant national banks, and on the simulation of location, capacity, dynamics and quality of modernization of other regional refineries, including the share of INA's refined products in the respective markets.

The modernization of INA's refineries in Rijeka and Sisak involves the implementation of modern refining and residue upgrading technologies currently available in the market, which are implemented in over 90% of refinery modernization concepts around the world in the last two decades. Refining technologies are focused on high level purification of specific light, middle and heavy fractions by removal of non-hycrocarbon compounds from crude oil. Residue upgrading technologies are focused on maximizing distillate yields (gasoline, diesel and LPG), and at the same time minimizing low value-added products (fuel oil, hydrocarbon residues). They are installed for economic reasons, in order to upgrade performance of a refinery.

Implementation of state-of-the-art refining technologies of adequate capacity which is aligned with the existing refining units capacity, enables production of improved fuel quality - Euro5 grade gasoline and diesel (with less

Table 1. INA Refineries throughput 2012 - 2023, in million t/y

Ref. Capac. Mt/y	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Rijeka Refinery	3.4	3.6	3.8	4.0	4.2	4.4	4.5	4.5	4.5	4.5	4.5	4.5
Sisak Refinery	1.5	1.3	1.1	1.1	1.1	1.1	1.5	1.8	2.2	2.6	3.0	3.2
Total Ref. Capacity	4.9	4.9	4.9	5.1	5.3	5.5	6.0	6.3	6.7	7.1	7.5	7.7
	RS(FO+FG)	RS(FO+FG)	RS(FO+FG)	RS(FO+FG)	RS(FO+FG)	RS(FO+FG)	RS(FG+H_2)	RS(FG+H_2)	RS(FG+H_2)	RS(FG+H_2)	RS(FG+H_2)	RS(FG+H_2)

Note: RS = Refinery Sisak
FG = Fuel Gas
FO = Fuel Oil
H_2 = Hydrogen

than 10 ppm sulphur) and Euro5 grade heating oil (less than 1% sulphur). These technologies are based on catalytic-thermal treatment with hydrogen under high pressure which induces substitution of hetero-compounds in hydrocarbon structure with hydrogen and improves purity of hydrocarbons, while reduced hetero-compounds are further treated and mainly removed in elementary form. The best known and the most frequently applied hydrogen treatment processes are hydrocracking (HC) and hydrodesulphurization (HDS). As traditional gasoline reforming technology, as the only traditional process for hydrogen generation, cannot produce sufficient quantity of hydrogen for production of high quality Euro5 grade products, modern refineries must include additional hydrogen generation units, frequently based on natural gas (if available) as a feedstock or gasoline (in case natural gas is not available). The world renown first class licensers of commercial HC technologies are: Axens, Chevron Lummus Global LLC, Du Pont, Haldor Topsoe A/S, Shell Global, UOP, ExxonMobil. Licensers of HDS tehnology are: UOP, ExxonMobil, CDTECH, Chevron Lummus Global LLC, Du Pont, Haldor Topsoe A/S, GTC Technology. Well-known licensers of hydrogen production technology are: Technip, Uhde GmbH, Haldor Topsoe A/S, Air Products and Chemicals Inc., Foster Wheeler USA Corp., Davy Process Technology, ExxonMobil. These technologies are implemented primarily in order to reduce harmful emissions caused by use of refined products in consumers (automobiles, ships, locomotives, thermal power plants, heating plants and other).

Residue upgrading technologies at maximum capacity, depending on existing processing structure, installed capacity and the manner how various processing units are interconnected, can significantly improve yield of high quality gasoline and diesel components 5-15%, in some cases even more. The official modernization programme of INA's refineries opted for delayed coking technology (or alternative residue hydrocracking) which would enable improved yield of gasoline and diesel components by 11-12%. Well-known international licensers of delayed coking technology are: Foster Wheeler USA Corp., KBR, Lummus Technology and CB&I Co., ExxonMobil.

Emission reduction technologies (amine treatment of fuel gas, removal of elementary sulphur and other) directly reduce harmful emissions from the refining units or make them less harmful or fully acceptable. Well-known licensers of these technologies are: Air Products Co., Worley Parsons, Haldor Topsoe A/S, ExxonMobil, Belco Technologies Corp., Merichem Chemical & Refinery Services LLC.

2. Natural gas consumption balance in INA's modernized refineries

The official modernization plan foresees maximum refining capacity of 4.5 million t/year of the Rijeka refinery, and 3.2 million t/year of the Sisak refinery. Production of high quality derivatives in both refineries should enable regaining of formerly lost share in regional markets, at the beginning partially and in later stage completely. On the other hand, higher share of high-value and sought after products (motor gasoline, diesel fuel and LPG) should improve profitability and competitiveness of INA's refineries and enable expansion of the market, if necessary by offering durable, more attractive commercial terms to the buyers.

Table 1 shows planned INA refineries' (Rijeka and Sisak) throughput 2012 - 2023 in line with the above mentioned projection of regained market share, location advantage factor, and existing and new infrastructure.

As can be seen from the table, full refining capacity is to be achieved gradually in the forthcoming decade or 5 to 6 years after completed modernization.

At maximum planned capacity (4.5 million t/y), the Rijeka refinery daily heat requirement is estimated at 13 391 million kcal, out of which 8 389 million kcal/day would be met from available fuel gas - 714.5 t/day, while the remaining quantity of heat energy 5 002 million kcal/day would be met by natural gas supply from the grid - 430.8 t/day.

At maximum planned capacity (3.2 million t/year), the Sisak refinery daily heat requirement is estimated at 11 684 million kcal, out of which 6 755 million kcal/day would be met from available fuel gas - 616.8 t/day, while the remaining quantity of heat energy 4 929 million kcal/day would be met by natural gas supply from the grid - 424.5 t/day.

According to the refining model simulation and respective capacity in specified years, natural gas consumption is expected to move as presented in Table 2 (consumption in t/year).

Note: Rijeka refinery could finish planned modernization (second stage) after 2016 (coking or other residue processing technology) which would enable further increase in production of high quality white products by 11-12% and thus achieve planned profitability of the moderinization project.

Table 2. INA Downstream natural gas consumption 2013-2023 (based on INA's official Modernization Plan from 2008 and as revised in 2011 because of delays in implementation)

CONSUMER, t/y	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
INA Rijeka Ref. for fuel	126 684	131 611	138 538	145 465	152 392	155 855	155 855	155 855	155 856	155 855	155 855
INA Rijeka Ref. for H_2	125 794	132 782	139 771	146 759	153 748	157 242	157 242	157 242	157 242	157 242	157 242
INA Rijeka Ref, total	250 478	264 393	278 308	292 224	306 139	313 097	313 097	313 097	313 097	313 097	313 097
INA Sisak Ref. for fuel	62 945	53 261	53 261	53 261	53 261	72 629	87 155	106 523	125 891	145 259	154 943
INA Sisak Ref. for H_2	0	0	0	0	0	65 700	78 840	96 360	113 880	131 400	140 160
INA Sisak Ref. total	62 945	53 261	53 621	53 261	53 261	138 329	165 995	202 883	239 771	276 659	295 103
TOTAL INA (Ri+Si) Ref.	313 423	317 570	331 570	345 485	359 401	451 426	479 092	515 980	552 868	589 756	608 200

Note: Rijeka Refinery will finish modernization after 2016 (Coker or some other residual technology)
Sisak Refinery has not planned modernization in continue at all and yet has possibility to finish all planned activities after 2017 (Hydrocracker, HDS, Hydrogen production, Coker)
Sisak Refinery will spend natural gas for firing (with refinery gas) because fuel oil will be off spec after July 1, 2013.

Table 3. INA Downstream Natural Gas Consumption from 2013 to 2023 (based on official INA's Plan from 2008 and renewed 2011 because term delay)

CONSUMER, million m^3/y	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
INA Rijeka Ref. for firing	171.98	181.53	191.09	200.64	210.20	214.97	214.97	214.97	214.97	214.97	214.97
INA Rijeka Ref. for H_2	173.51	183.15	192.79	202.43	212.07	216.89	216.89	216.89	216.89	216.89	216.89
INA Rijeka Ref, total	345.49	364.68	383.87	403.07	422.26	431.86	431.86	431.86	431.86	431.86	431.86
INA Sisak Ref. for firing	86.82	73.46	73.46	73.46	73.46	100.18	121.20	146.93	173.64	200.36	213.71
INA Sisak Ref. for H_2	0.00	0.00	0.00	0.00	0.00	90.62	108.74	132.91	157.08	181.24	193.32
INA Sisak Ref. total	86.82	73.46	73.46	73.6	73.46	190.80	228.96	279.84	330.72	381.60	407.04
TOTAL INA (Ri+Si) Ref.	432.31	438.14	457.34	476.53	495.73	622.66	660.82	711.70	762.58	813.46	838.90

Note: Rijeka Refinery will be able to finish planned modernization after 2017 (Coker or some other residual technology)
Sisak Refinery has not planned modernization in continue at all and yet has possibility to finish all planned activities after 2017 (Hydrocracker, HDS, Hydrogen production, Coker)
Sisak Refinery will spend natural gas for firing (with refinery gas) because fuel oil will be off spec. (2.3% S) without modernization. If Sisak Refinery frontally start with planned modernization (HD, HDS, Coker) finish would be after 2017.

The first stage of the Rijeka refinery modernization is completed (HC, HDS and H_2 generation) and enables production of Euro 5 grade gasoline, diesel and heating oil.

The modernization of the Sisak refinery is in significant delay (1st and 2nd stage). With the introduction of more stringent emission reduction standards after 1 July 2013, the refinery will not be allowed to use heating oil above 1% S (currently it produces heating oil up to 2.3% S). Consequently it should use natural gas for energy needs.

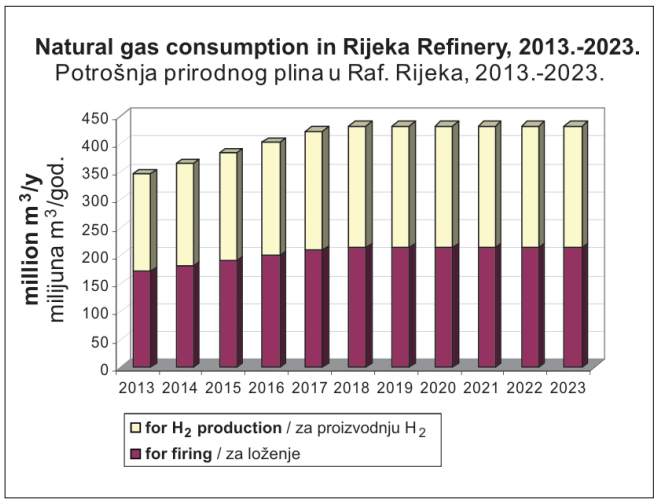
Key modernization processes in the Sisak refinery (HC, HDS, H_2 generation and coking) have not been even started by 2012. Planned realization of the modernization process would require immediate design and implementation of all key processes, which could be completed by 2018. Otherwise, the Sisak refinery will have to be closed down as a result of ecologically unacceptable and unprofitable production.

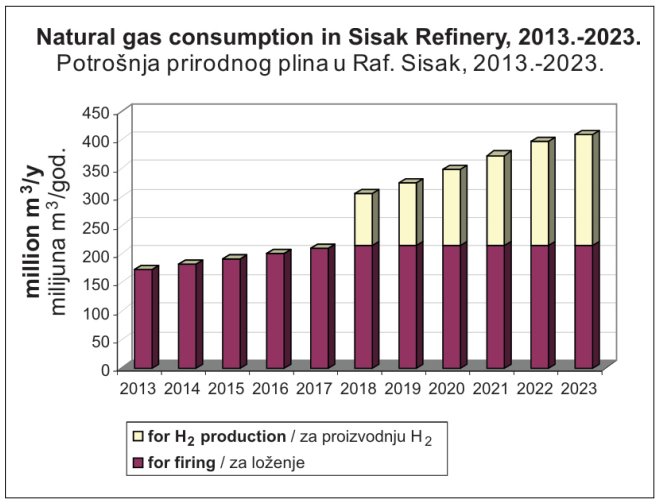
The same natural gas consumption movement is presented in Table 3, but expressed in million m^3/year.

The estimated natural gas consumption in the refineries Rijeka and Sisak is also presented in the charts (see next page).

As the starting date of coking unit construction in the Rijeka refinery is still under question, consequently, the completion date as well, it is reasonable to base the simulation on lower natural gas consumption for firing by 11%. In such a scenario the consumption of natural gas at maximum refining capacity would be at the level of 383.7 mt/day or 140 051 t/year.

As for the Sisak refinery, the start and completion of the construction of key modernization processing units, both refining (HC/HDS, hydrogen generation) and residue processing (coking) are still under question. However, there is an additional problem in case of the Sisak refinery: after 1 July 2013 the refinery will not be allowed to use heating oil with sulphur content above 1% (with the existing process technology the refinery can only produce heating oil up to 2.3% S). It could be substituted by import of Euro 5 grade heating oil (below 1% S), but technically it would be simpler to have natural gas supplied to the plant, moreover since pipeline connection is close to the refinery battery limit, than to import heating oil from the neighbouring countries or from the MED market.





3. Conclusion

1. Planned and realized modernization of INA's fuels refineries in Rijeka and Sisak caused significant changes in the refining production systems with some important consequences: higher quantity and improved quality of products (Euro5 grade), significant decrease of heating oil production, use of natural gas for energy and processing needs, including hydrogen generation, and what is most important - significant improvement of competitiveness and profitability.
2. The analysis indicates that the modernization projects in Rijeka and Sisak refineries will make them one of the largest natural gas consumers in the Republic of Croatia.
3. The analysis also indicates that it will be necessary to identify and coordinate participation of consumers in domestic natural gas supply, specifically from the aspect of quality of domestic natural gas versus quality of imported gas, by taking into consideration specific needs of consumers.
4. The projection of natural gas consumption in modernized refineries in Rijeka and Sisak, shows that they could become significant consumers. Accordingly, refineries would be second ranked among large industrial consumers in Croatia, immediately after HEP - Electricity company (future natural gas consumption for power generation will exceed the current 750 million m³/year by minimum 15%, so HEP will remain the largest consumer, followed by INA's refineries, while Petrokemija Kutina will fall to the third position).
5. When we take into account the consumption of the three largest natural gas consumers in Croatia (HEP, INA's refineries and Petrokemija Kutina), the consumption will gradually rise from the current 1.15 billion m³/year to over 2.15 billion m³/year in the forthcoming decade.
6. The above described optimal selection of natural gas as energy source and its use for substitution of heating oil by the two largest consumers in Croatia (HEP, INA), has huge advantage, because it eliminates the need for installation of carbon capture or other expensive emission reduction technologies which should be implemented in case of alternative energy sources (heating oil, coal). Natural gas is the best choice not only as substitution fuel, but also because it is available to consumers thanks to significant local production (northern Croatia and the North Adriatic) and the developed pipeline infrastructure.

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Acknowledgment

The analysis of natural gas consumption in modernized refineries was prepared by the authors, members of the Refining Section and Oil Business Economics Section, following the initiative of the Round Table entitled 'Natural Gas' organized by the Scientific Council for Oil and Gas of the Croatian Academy of Science and Arts in July 2012.

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