MGPB

The Mining-Geology-Petroleum Engineering Bulletin
UDC: 553.9
DOI: 10.17794/ rgn.2016.2.6

Izvorni znanstveni rad

# The characteristics of the production and processing of oil and natural gas in Croatia from 2000 to 2014

**Josipa Velić[1,2]; Katarina Kišić[1*] Dragan Krasić[3]**

[1]University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, 10 000 Zagreb, Pierottijeva 6, [*] Master of Science in Geology,
[2]Croatian geological summer school, 10 000 Zagreb, Pančićeva 5
[3]Ministry of Economy, 10 000 Zagreb, Ul. grada Vukovara 78

**Abstract**

This research analyzes the characteristics of the production and processing of oil, condensates and natural gas in the Republic of Croatia starting from 2000, until the end of 2014. Amounts of balance sheet (exploitable) reserves of oil and condensates ranges from 9330,92 × $10^3$ $m^3$ in 2005, to 13 471,08 × $10^3$ $m^3$ in 2013, while extracted amounts are gradually declining from 1332,61 × $10^3$ $m^3$ to 639,96 × $10^3$ $m^3$. The ratio of extracted amounts and reserves is gradually declining, meaning that a slight increase in reserves does not affect the extracted amounts. Exploitable reserves of natural gas during the observed period fluctuate greatly. Being peaked in 2007, at 40,919.70 × $10^6$ $m^3$, they reached a low in 2014, at 17,932.98 × $10^6$ $m^3$. Unlike liquid hydrocarbons, the ratio of extracted and exploitable amounts is growing and peaked in 2014. Overall energy demands for oil in Croatia (shown as total consumption of crude oil) amounted to 3032,8 × $10^3$ $m^3$ in 2013, while demands for natural gas amounted to 2809,90 × $10^6$ $m^3$. It is interesting to note that the consumption of oil is rapidly declining, which is a favorable trend from the standpoint of reducing emissions of greenhouse gases. While needs are partly covered by domestic exploitation, the dependence on imports of oil and natural gas is still evident and ranges from 75% to 84% for oil and 28% to 46% for natural gas, without major changes to the trend. The amounts of processed hydrocarbons are declining gradually, especially motor gasoline and fuel oil, while diesel fuel amounts remain mostly the same. Further research as well as development of the exploitation of oil and natural gas is of paramount importance, especially by investing in cadre education and new technologies.

**Key words**

Oil, natural gas, reserves, extraction, processing, Croatia.

## 1. Introduction

An increase in consumption of all forms of energy imposes solving the question of securing its supply in the future, especially of oil and natural gas as a particularly essential source of energy as well as an industrial raw material. Despite an increase in consumption, it is evident that even today over half of the world's energy needs (59,4%) are satisfied by the consumption of oil (60%) and natural gas (40%), and should remain so in the foreseeable future in regards to their supply. We have recently been witnessing a rising reliance on natural gas in overall energy consumption. In this sense, the planned construction of pipelines to supply natural gas into Europe named „South Stream" and „Nabucco" (**Sučić et al., 2011**) is of particular interest.

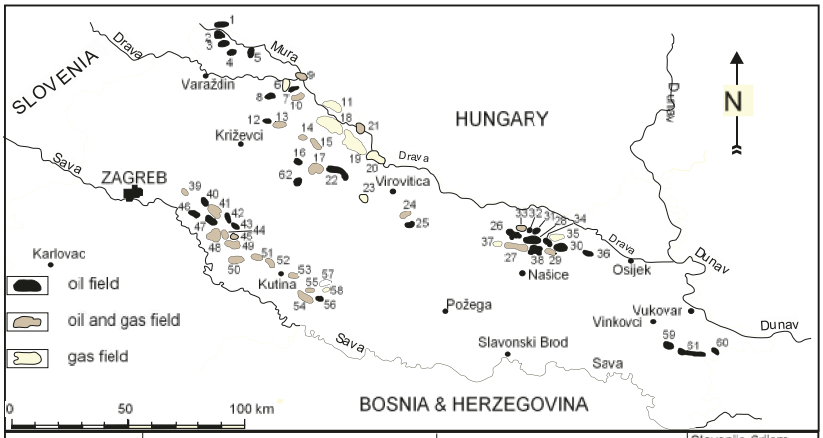
Therefore, supplies are increasing, and the so-called Hubert's peak (a theory claiming that petroleum production tends to follow a bell-shaped curve, reaching a maximum and then declining) keeps shifting into the future while recognizing that fossil fuels accrue over millions of years and are expended relatively quickly. For example, in 1939, oil sufficiency was estimated for a period of up to only 13 years, while in 1959 oil supplies (proven and probable) were at 159 × $10^9$ $m^3$ which was estimated as sufficient for the following few decades. By the latest available data (**BP, 2015**), oil reserves are sufficient for an additional 52 years of extraction, and natural gas for 54 more years.

Corresponding author: Josipa Velić
josipa.velic@rgn.hr

Therefore, oil and natural gas remain the main sources of energy in use until 2050, however in combination with coal, sun, sea, wave, sea flow as well as nuclear energy and others. While oil and gas exploitation still has an expiry date, it is important to ensure the rationality of their consumption and use.

The price of hydrocarbons is an important factor in their rational consumption. As hydrocarbon research becomes more complex and is undertaken in increasingly difficult conditions, its cost also rises. Oil and gas will therefore become more costly in the future although the price of crude oil has fallen drastically in the second half of 2015 to its lowest point in the last 12 years.

Croatia has a long and rich history of hydrocarbon exploitation (**Velić et al., 2010; Velić et. al., 2012).** The Croatian industry boasts with a tradition of 150 years and, while a drastic decrease of hydrocarbon supply can be presumed, due to its non-renewability, analysis of reserves and acquisitions has shown that reserves are regularly maintained, and are even increasing in volume. The eldest exploited field is Bujavica – the first natural gas field discovered in 1917 and active up until 1937. The first significant extraction of oil began in 1941 from the deposit of Gojlo field.




| Mura depression | Drava depression | | Sava depression | | Slavonija-Srijem. depression |
|---|---|---|---|---|---|
| 1. Mursko Središće | 10. Peteranec | 25. Cabuna | 39. Dugo Selo | 51. Voloder | 59. Privlaka |
| 2. Zebanec | 11. Gola-Ždala | 26. Crnac | 40. Lupoglav | 52. Mramor-Brdo | 60. Ilača |
| 3. Selnica | 12. Lepavina | 27. Bokšić | 41. Kloštar Ivanić | 53. Gojlo | 61. Đeletovci |
| 4. Mihovljan | 13. Jagnjedovac | 28. Beničanci | 42. Šumećani | 54. Lipovljani | |
| 5. Peklenica | 14. Mosti | 29. Obod | 43. Bunjani | 55. Jamarica | |
| 6. Veliki Otok | 15. Čepel.-Hampovica | 30. Števkovica | 44. Hrastilnica | 56. Kozarica | |
| 7. Kutnjak-Đelekovec | 16. Letičani | 31. Kučanci-Kapelna | 45. Vezišće | 57. Janja Lipa | |
| 8. Cvetkovec | 17. Šandrovac | 32. Krunoslavlje | 46. Ježevo | 58. Bujavica | |
| 9. Legrad | 18. Molve | 33. Ladislavci | 47. Ivanić | | |
| | 19. Kalinovac | 34. Obod-Lacić | 48. Žutica | | |
| | 20. Stari Gradac | 35. Sjeće | 49. Okoli | | |
| | 21. Ferdinandovac | 36. Bizovac | 50. Stružec | | |
| | 22. Bilogora | 37. Obradovci | | | |
| | 23. Gakovo | 38. Klokočevci | | | |
| | 24. Pepelana | 62. Galovac-Pavljani | | | |

**Figure 1:** Oil and gas fields in the Croatian part of the Pannonian Basin System (**Velić, 2007**)

Intense activities of research and oil and natural gas exploitation in Croatia have lasted for the last 70 years, and today on the territory of the Croatian part of the Panonnian Basin System (further in text – CPBS) (see **Figure 1**) hydrocarbons are being extracted from 33 oil fields, gas condensates from 9 gas-condensate fields and gas from 17 gas fields. Research of the Adriatic offshore has lasted over 40 years, and natural gas extraction has been conducted from 1999, from nine gas fields (see **Figure 2**).

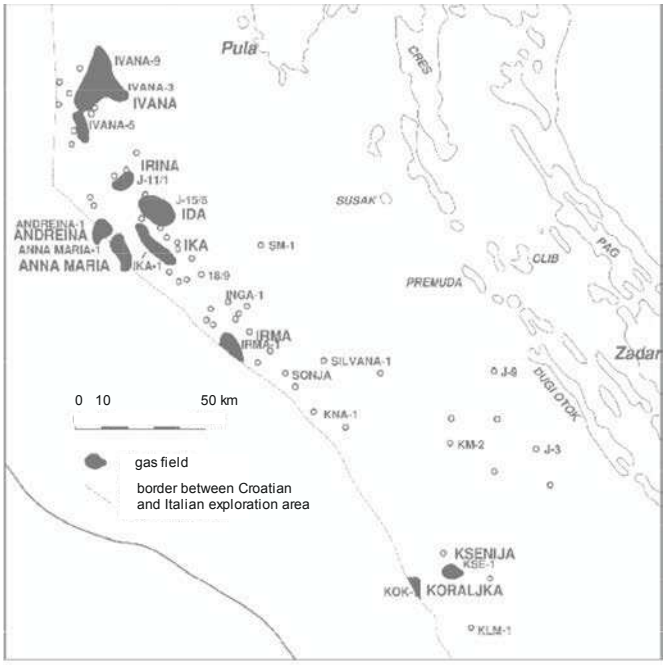



**Figure 2:** Gas field sites in the Adriatic offshore (**Velić, 2007**)

According to **Velić et al. (2010),** the sum of geological reserves equals 740 × $10^6$ $m^3$ of oil equivalents. Initial oil reserves are estimated at 112 $10^6$ $m^3$, condensates are estimated at 10.74 × $10^6$ $m^3$ and natural gas at 100.67 × $10^9$ $m^3$ (see **Table 1**). The differential between estimated starting reserves and the total extracted sums yields remaining reserves, which are also shown in **Table 1** where the amounts of condensates are marked in brackets. The remaining oil reserves amount to 8.01 × $10^6$ $m^3$ while natural gas reserves amount to 35.76 × $10^9$ $m^3$. Based on the remaining reserves, **Dobrova et al. (2003)** have ranked Croatia third amongst the states of Middle and Eastern Europe in 2002, although according to more recent data the remaining reserves are estimated at lower values (**Velić et. al., 2010; Malvić et al., 2011**). At the end of this introduction, an additional remark: according to data relevance, in **Tables 8 to 9**, and on **Figures 8, 12, 14 to 22**, the data shown is up to the year 2013.

**Table 1:** Croatian recoverable reserves, cumulative production and remaining hydrocarbon reserves (**Malvić et al., 2011**)

| **Dobrova et al. (2003)** | | | | | | **Velić et al. (2010)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Recoverable reserves* | | *Cumulative production* | | *Remaining reserves* | | *Recoverable reserves* | | *Cumulative production* | | *Remaining reserves* | |
| Oil | Gas | Oil | Gas | Oil | Gas | Oil | Gas | Oil | Gas | Oil | Gas |
| **141.18** | **108.11** | **109.70** | **26.16** | **31.48** | **81.95** | **112.06** **(10.73)** | **100.67** | **104.45** **(6.93)** | **64.91** | **8.01** **(3.80)** | **35.76** |
| Oil in $10^6$ $m^3$; Gas in $10^9$ $m^3$ | | | | | | | | | | | |

## 2. Reserves of oil, condensates and natural gas

Exploitable (balance sheet, commercial or proven reserves) reserves of oil, condensates and natural gas observed in the period from 2000 to 2014 in the Republic of Croatia are shown in **Tables 2 to 4** and **Figures 3 to 5 respectively.** In **Table 3** and on **Figure 3** oil and condensates are shown separately. The assessed quantities of oil, condensates and natural gas in a deposit that can be profitably exploited are classified as proven reserves.

Proven reserves of oil and condensates have been generally decreasing until 2004, when they were estimated at $9348{,}71 \times 10^3$ $m^{3,}$ which amounts to 80% of their value in 2000. Since 2006, reserves are increasing, especially in 2013, when they amounted to 13 $471{,}08 \times 10^3$ $m^3$. By comparing reserves separately for oil and condensates a disproportion is visible; namely oil reserves are growing while condensate reserves have fallen from $3468{,}82 \times 10^3$ $m^3$ in 2000, to only $1435{,}47 \times 10^3$ $m^3$ in 2014, a variation of 40%.

**Tables 2 and 5:** Proven reserves and produced volumes of oil and condensate, imported volumes and total consumption of crude oil in Croatia from 2000 to 2014

| | **Table 2** | | | **Table 5** | | |
|---|---|---|---|---|---|---|
| | According to the Annual report of mineral ores reserves, source: Ministry of Economy, Croatia | | | According to the Energy report 2003-2011 (Eurostat), Croatia; data labelled with a * Energy in Croatia, 2012-2013, Ministry of Economy (***3**) | | |
| **Year** | **Proven reserves of oil and condensate** [$10^3$ $m^3$] | **Produced volumes of oil and condensate** [$10^3$ $m^3$] | | **Imported volumes of crude oil** [$10^3$ $m^3$] | **Total consumption of crude oil** [$10^3$ $m^3$] | |
| | **A** | **B** | **B/A** | **C** | **D** | **C/D** |
| 2000 | 11,477.34 | 1,332.61 | 0.116 | - | - | - |
| 2001 | 10,564.45 | 1,262.16 | 0.119 | - | - | - |
| 2002 | 10,152.69 | 1,217.40 | 0.120 | - | - | - |
| 2003 | 10,356.13 | 1,152.48 | 0.111 | 3,814.20 | 5,096.60 | 0.75 |
| 2004 | 9,348.71 | 1,085.37 | 0.116 | 4,250.90 | 5,324.20 | 0.80 |
| 2005 | 9,330.92 | 1,005.19 | 0.108 | 4,049.50 | 5,113.50 | 0.79 |
| 2006 | 9,689.11 | 977.49 | 0.101 | 3,847.30 | 4,856.30 | 0.79 |
| 2007 | 11,719.10 | 930.10 | 0.079 | 4,251.60 | 5,177.00 | 0.82 |
| 2008 | 11,472.48 | 867.87 | 0.076 | 3,517.40 | 4,508.30 | 0.78 |
| 2009 | 10,823.58 | 807.45 | 0.075 | 4,119.00 | 4,919.20 | 0.84 |
| 2010 | 10,481.58 | 743.93 | 0.071 | 3,598.00 | 4,362.00 | 0.82 |
| 2011 | 11,554.00 | 697.50 | 0.060 | 2,894.70 | 3,444.20 | 0.84 |
| 2012 | 11,531.60 | 659.32 | 0.057 | 2,325.00* | 3,108.30* | 0.75 |
| 2013 | 13,471.08 | 636.78 | 0.047 | 2,461.80* | 3,032.80* | 0.81 |
| 2014 | 12,597.80 | 639.96 | 0.051 | - | - | - |

* in 1,000 tons

**Table 3:** Proven reserves and produced volumes of oil and condensate in Croatia from 2000 to 2014

| | **Proven reserves of oil and condensate** [$10^3$ $m^3$] | | **Produced volumes of oil and condensate** [$10^3$ $m^3$] | |
|---|---|---|---|---|
| Year | Oil | Condensate | Oil | Condensate |
| 2000 | 8,008.52 | 3,468.82 | 1,003.87 | 328.74 |
| 2001 | 7,040.30 | 3,524.15 | 934.35 | 327.81 |
| 2002 | 6,935.47 | 3,217.22 | 906.95 | 310.45 |
| 2003 | 7,435.20 | 2,920.93 | 853.00 | 299.48 |
| 2004 | 6,707.18 | 2,641.53 | 802.62 | 282.75 |
| 2005 | 6,152.09 | 3,178.83 | 745.59 | 259.60 |
| 2006 | 6,736.64 | 2,952.47 | 728.65 | 248.84 |
| 2007 | 8,949.30 | 2,769.80 | 702.19 | 227.91 |
| 2008 | 8,917.39 | 2,555.09 | 653.15 | 214.72 |
| 2009 | 8,454.81 | 2,368.77 | 619.65 | 187.80 |
| 2010 | 8,460.94 | 2,020.64 | 563.11 | 180.82 |
| 2011 | 9,199.24 | 2,354.76 | 528.45 | 169.05 |
| 2012 | 9,295.68 | 2,235.92 | 511.68 | 147.64 |
| 2013 | 11,370.71 | 2,100.37 | 499.51 | 137.27 |
| 2014 | 11,162.33 | 1,435.47 | 518.27 | 121.69 |

Regarding natural gas (see **Table 4** and **Figure 5)**, significant oscillations are visible. Reserves were at a peak in 2007 (40 919.70 × $10^6$ $m^3$) and have been decreasing steadily – to 17,932.98 × $10^6$ $m^3$. The grounds had a smaller investment in research while CPBS is considered to be well explored, and most deposits depleted. There are diverging standpoints on the matter, stated for instance in the work of **Velić (2007).** According to some research conducted for CPBS, 2 to 4 times more oil was generated than determined in existing deposits (**Malvić et al., 2011**). Even though the values might be overrated, a significant amount of hydrocarbon reserves can be obtained by increasing deposit utilization and discovering new ones. In this sense, it is relevant to quote the standpoint of **Velić et al. (2012)**, pointing to the fact that significant deposits can be expected in rocks underlying the Neogene deposits (under the EL-border "Tg", e.g. "PT", in the top of the Paleozoic magmatites and metamorphites and Mesozoic sedimentary rocks), at the edges of depressions or on rises in the paleorelief, as well as in stratigraphic traps inside Miocene deposits whereas they consist of diverse lithofacies from distinctly diverse sedimentary environments.

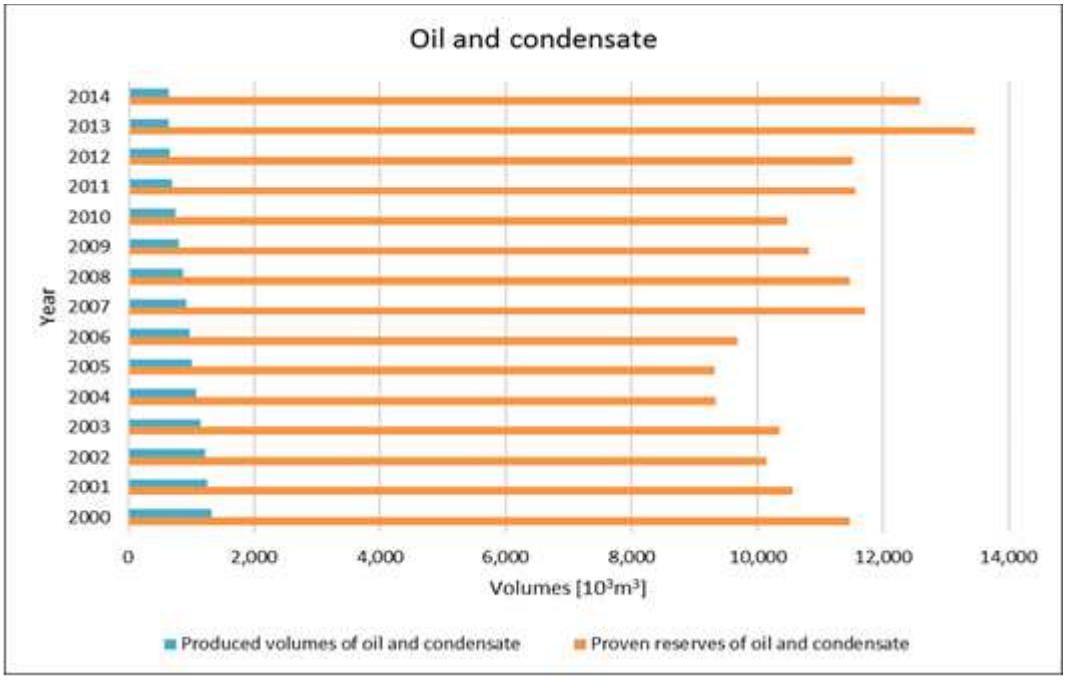



**Figure 3:** Proven reserves and produced volumes of oil and condensate in Croatia from 2000 to 2014

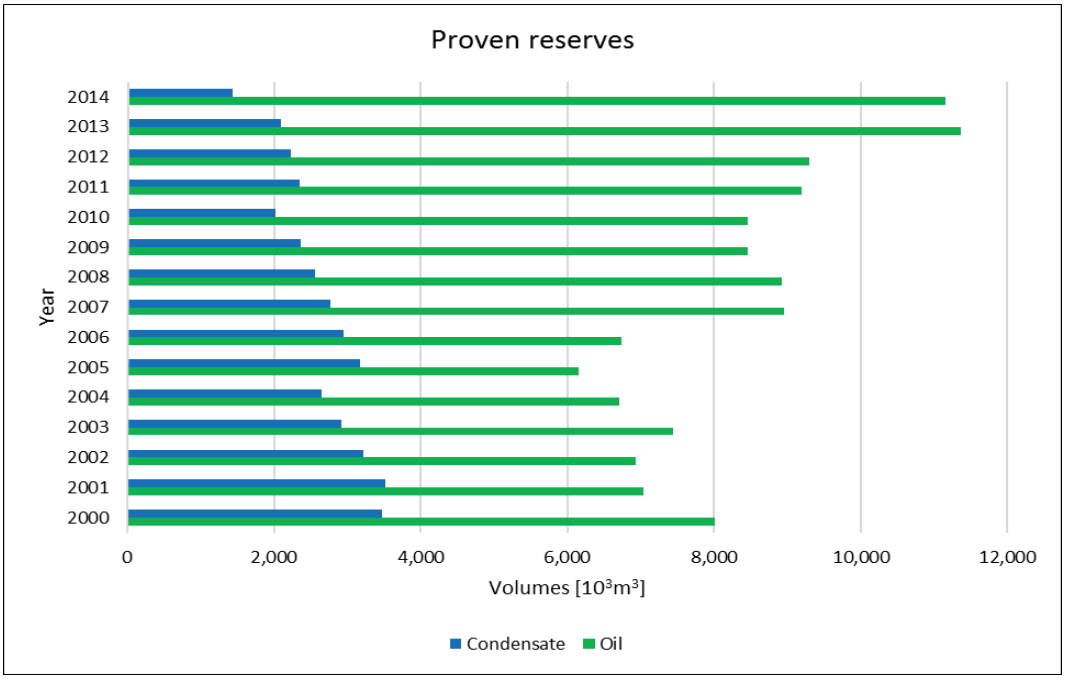



**Figure 4:** Proven reserves in Croatia from 2000 to 2014 shown separately for oil and condensate

**Tables 4 and 6:** Proven reserves and produced volumes of natural gas and imported volumes and total consumption of natural gas in Croatia from 2000 to 2014

| | **Table 4** | | | **Table 6** | | |
|---|---|---|---|---|---|---|
| | According to the Annual report of mineral ores reserves, source: Ministry of Economy, Croatia | | | According to the Energy report 2003.-2011. (Eurostat), Croatia; and data labelled with a * Energy in Croatia, 2012.-2013. Ministry of Economy (***3***) | | |
| Year | **Proven reserves of natural gas** $[10^6\ m^3]$ | **Produced volumes of natural gas** $[10^6\ m^3]$ | | **Imported volumes of natural gas** $[10^6\ m^3]$ | **Total consumption of natural gas** $[10^6\ m^3]$ | |
| | **A** | **B** | **B/A** | **C** | **D** | **C/D** |
| 2000 | 29,204.51 | 1,888.35 | 0.065 | - | - | - |
| 2001 | 33,203.17 | 2,851.87 | 0.086 | - | - | - |
| 2002 | 35,906.14 | 2,880.48 | 0.080 | - | - | - |
| 2003 | 28,150.91 | 2,278.40 | 0.081 | 827.40 | 2,095.80 | 0.39 |
| 2004 | 26,574.65 | 2,352.25 | 0.089 | 855.60 | 2,443.80 | 0.35 |
| 2005 | 30,358.60 | 2,432.42 | 0.080 | 921.00 | 2,363.10 | 0.39 |
| 2006 | 30,110.54 | 2,863.70 | 0.095 | 914.80 | 2,337.00 | 0.39 |
| 2007 | 40,919.70 | 3,001.04 | 0.073 | 856.80 | 2,685.30 | 0.32 |
| 2008 | 36,436.12 | 2,847.18 | 0.078 | 996.30 | 2,602.80 | 0.38 |
| 2009 | 34,500.20 | 2,819.07 | 0.082 | 848.00 | 2,403.30 | 0.35 |
| 2010 | 31,163.58 | 2,833.22 | 0.091 | 868.60 | 2,632.30 | 0.33 |
| 2011 | 23,959.91 | 2,571.46 | 0.107 | 711.50 | 2,570.20 | 0.28 |
| 2012 | 24,315.39 | 2,086.38 | 0.086 | 1,357.70* | 2,971.70* | 0.46 |
| 2013 | 21,368.61 | 1,963.32 | 0.092 | 1,270.40* | 2,809.90* | 0.45 |
| 2014 | 17,932.98 | 1,824.03 | 0.102 | - | - | - |

In Croatia, oil is recovered by primary, secondary and tertiary methods. The recovery ratio for some of the largest Croatian fields can be as low as 16% (Žutica), however it is significantly higher in most other fields like 31% in Kloštar, 39% in Stružec, and as high as 51% in the Beničanci.

The most common secondary method is water injection, however alternative solutions are explored such as carbon dioxide ($CO_2$) flooding whereby carbon dioxide is injected into an oil reservoir in order to increase output when extracting oil. Tests were conducted in INA's laboratories for fourteen fields (**Goričnik & Domitrović, 2003; Novak et al., 2013 a, b**), results were also analyzed by the Faculty of Mining, Geology and Petroleum Engineering of the University of Zagreb (**Vulin, 2010; Novak, 2015**). It is opportune to mention some opinions here on unconventional deposits of hydrocarbons and the methods of their evaluation, which is certainly relevant in reserve planning and acquisition (**Rusan, 2014**).

Quantities of acquired hydrocarbons sorted as oil and condensate (liquid hydrocarbons) and natural gas are shown in **Tables 2, 3 and 4** and on **Figures 3, 5 and 6**. It is evident that acquired quantities of oil and condensates are declining from an observed peak of $1332{,}61 \times 10^3\ m^3$ to only $639{,}96 \times 10^3\ m^3$ in 2014 (see **Table 2** and **Figure 3**). Certain

oscillations are the result of a field's development on oil fields, which contributed to the increase of oil extraction in 2014 by 3,7% in relation to 2013.

Quantities of natural gas oscillate readily (see **Table 4** and **Figure 5**). According to **Table 7,** it can be noticed that, at the beginning of the observed period, the leading role in the extraction of natural gas was held by the quantity from the CPBS deposit (relation 7:1). A reversal is noticed in 2009 and 2010, where a slightly larger quantity of extracted gas came from the Adriatic offshore, and at the very end of the observed period – in 2013, the relation stands at 1:1 (see **Figure 7**). A natural drop in natural gas extraction in 2014 from 6,4% in relation to 2013 is the consequence of the suspension of drilling activity in the Ika Field, the restoration project on the Anamaria field and on the contracted area „North Adriatic" as well as an increase in share of water in the contracted area „Aiza Laura".

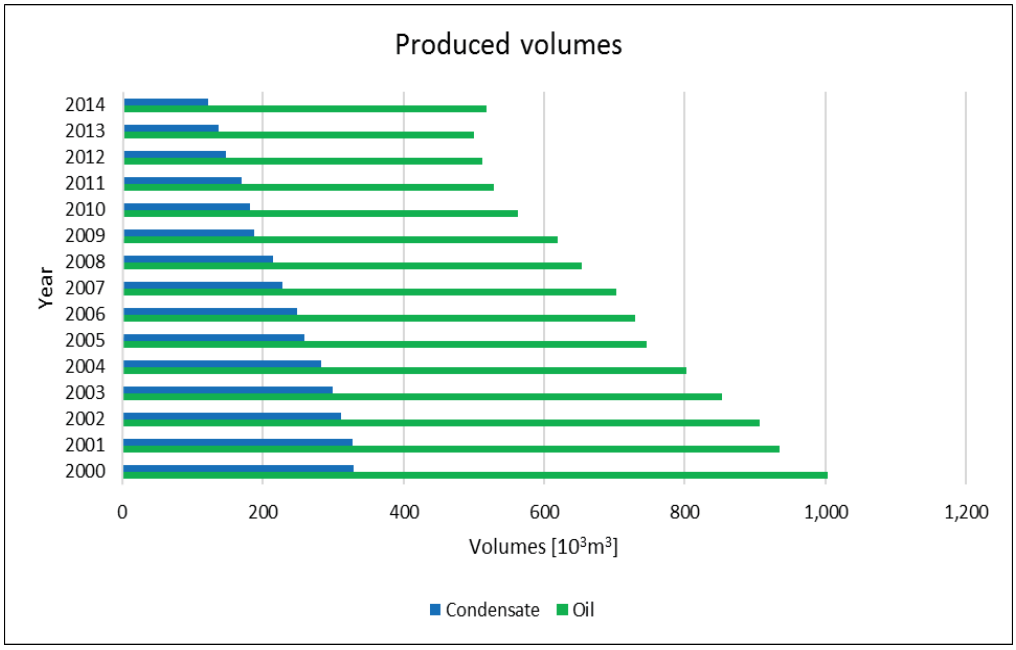



**Figure 5:** Produced volumes in Croatia from 2000 to 2014 shown separately for oil and condensate

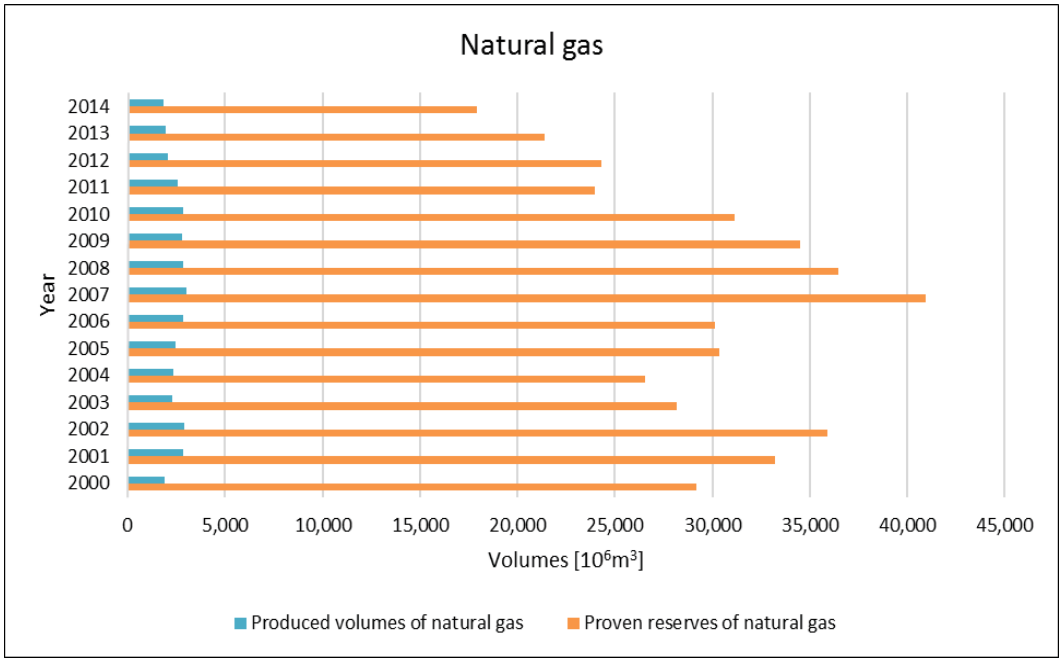



**Figure 6:** Proven reserves and produced volumes of natural gas in Croatia from 2000 to 2014

**Table 7:** Comparison of the produced volumes of natural gas from the CPBS and the Adriatic offshore

| **Production region** | **CPBS** | **Adriatic offshore** | **CPBS/Adriatic offshore ratio** |
|---|---|---|---|
| Year | Volumes A [$10^6$ m$^3$] | Volumes B [$10^6$ m$^3$] | A/B |
| 2000 | 1,654.15 | 234.19 | 7.06 |
| 2001 | 2,314.36 | 537.52 | 4.30 |
| 2002 | 2,199.17 | 681.31 | 3.23 |
| 2003 | 1,597.06 | 681.34 | 2.34 |
| 2004 | 1,678.01 | 712.55 | 2.35 |
| 2005 | 1,955.95 | 892.21 | 2.19 |
| 2006 | 1.747.38 | 1,386.16 | 1.26 |
| 2007 | 2,084.14 | 1,687.98 | 1.23 |
| 2008 | 1,930.95 | 1,601.35 | 1.20 |
| 2009 | 1,737.94 | 1,680.50 | 1.03 |
| 2010 | 1,577.08 | 1,803.82 | 0.87 |
| 2011 | 1,378.44 | 1,608.29 | 0.86 |
| 2012 | 1,145.20 | 1,227.86 | 0.93 |
| 2013 | 1,177.64 | 1,147.26 | 1.03 |

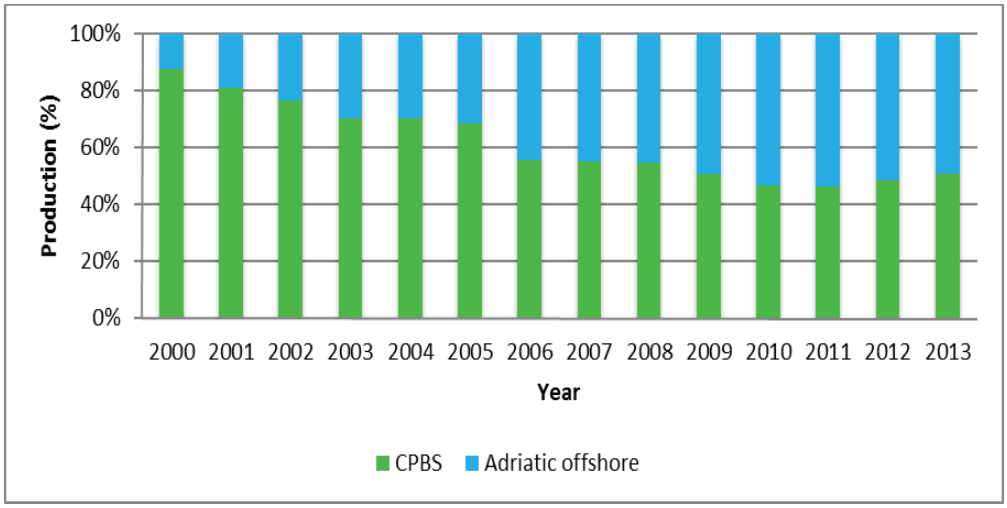



**Figure 7:** Ratio of natural gas recovered in Croatian part of the Pannonian Basin System and the Adriatic offshore from 2000 to 2013 **(Kišić, 2015)**

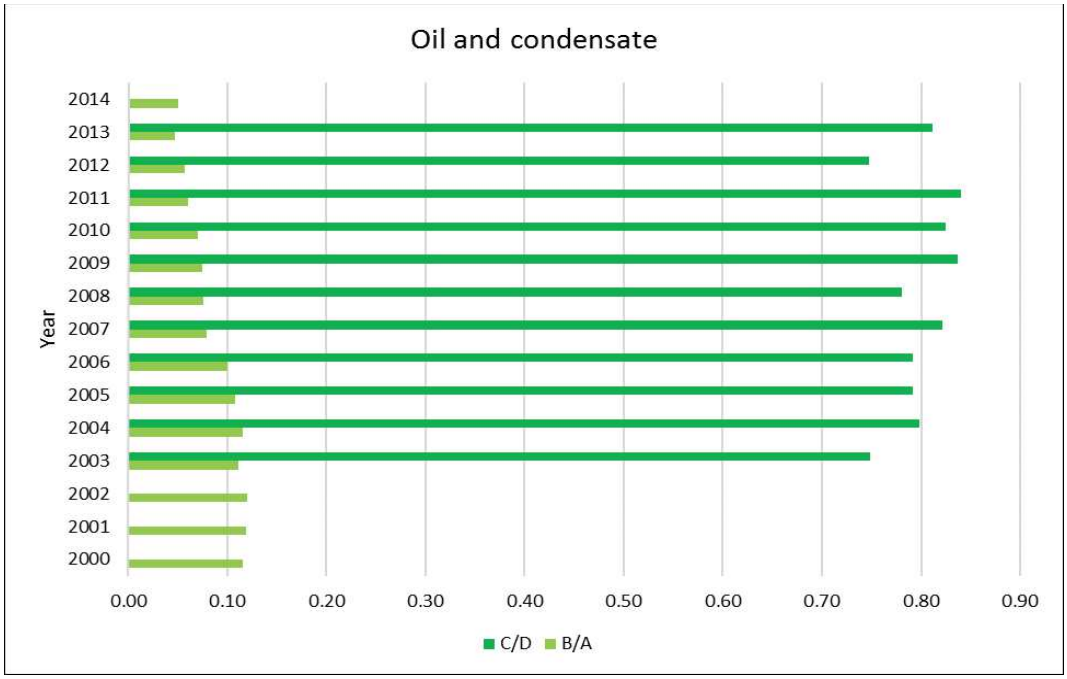



**Figure 8:** Volume ratio of proven reserves and produced volumes of oil and condensate (B/A) and ratio of imported volumes and total consumption of crude oil (C/D) in Croatia from 2000 to 2014 (B/A and C/D from **table 2**)

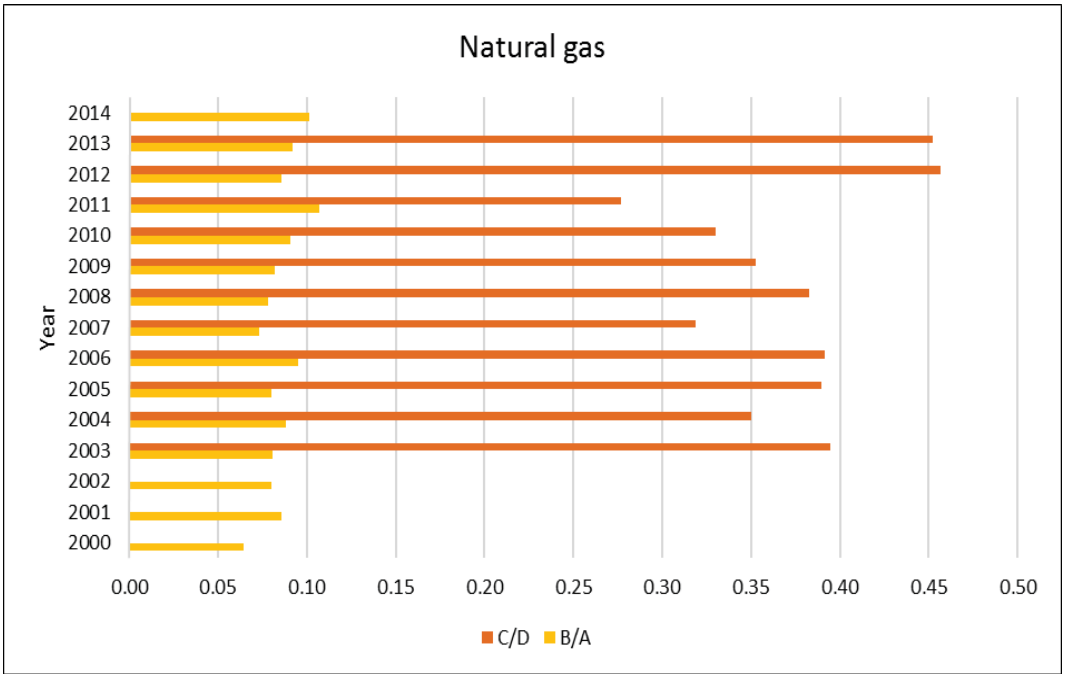



**Figure 9:** Volume ratio of proven reserves and produced volumes (B/A) and ratio of imported volumes and total consumption of natural gas (C/D) in Croatia from 2000 to 2014 (B/A and C/D from **table 4**)

In contemplating reserves and extraction, data on the ratio of total reserves and extraction is relevant, also by observed years (**Tables 2 and 4, Figures 9 and 10**). In general the ratio „extraction: proven reserves" for liquid hydrocarbons is gradually declining from 0,12 (2002.) to 0,051 in 2014, in other words, at the beginning of the observed period around

10% of the reserves were being extracted compared to 5% at the end of the period. It is unclear why oil and condensate extraction is declining yet reserves are regenerating.

With natural gas, the situation is different. Moving towards 2014, increasingly larger amounts are extracted in relation to reserves, from 6,5% at the beginning to 10% in 2014. One speculative conclusion is that perhaps oil is being preserved for the future, while natural gas as a cheaper energy-generating product is being increasingly exploited. The answer could also lie in INA's business policy.

## 4. Consumption and import of oil and natural gas in Croatia

The Republic of Croatia meets its hydrocarbon needs only partially by internal oil and gas extraction, meaning a larger share falls on import. During the observed period, from 2000 to 2014, the total quantity of imported crude oil amounted to 50, 360 × $10^3$ tons. Croatian needs for crude oil decreased by 40%, observing from 2003. Specifically, from 5096,60 $10^3m^3$ total consumption has dropped to 3032,80 × $10^3$ $m^3$ by 2013. Furthermore, from 2000 to 2014, quantities of imported oil have irregularly, but gradually decreased (see **Table 5**). The ratio of internal production to import however is relatively stable through the years and stands at 2:8 (see **Figures 10 and 11**). However, it can be noted that the imported quantity was significantly lower in the last three years (2325,00 × $10^3$ $m^3$) in relation to the largest ever imported quantity (4251,60 × $10^3$ $m^3$ in 2004 and 2007). Thereby the quantity of oil produced locally has a regular trend of decline. Total consumption of natural gas is steadily growing and has stood at 2810 × $10^6$ $m^3$ in 2013. To satisfy local needs, 1300 × $10^6$ $m^3$ is being imported, amounting to 40% of Croatian consumption (see **Table 6**, **Figures 9**, **12** and **13**).

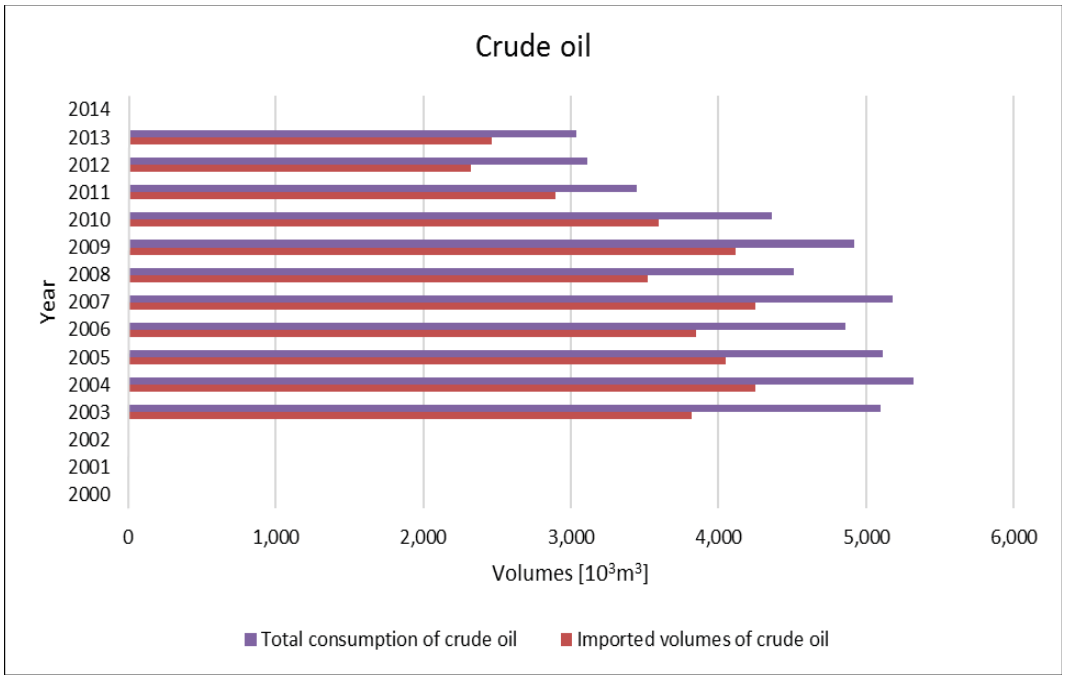



**Figure 10:** Total consumption and imported volumes of crude oil in Croatia from 2000 to 2014

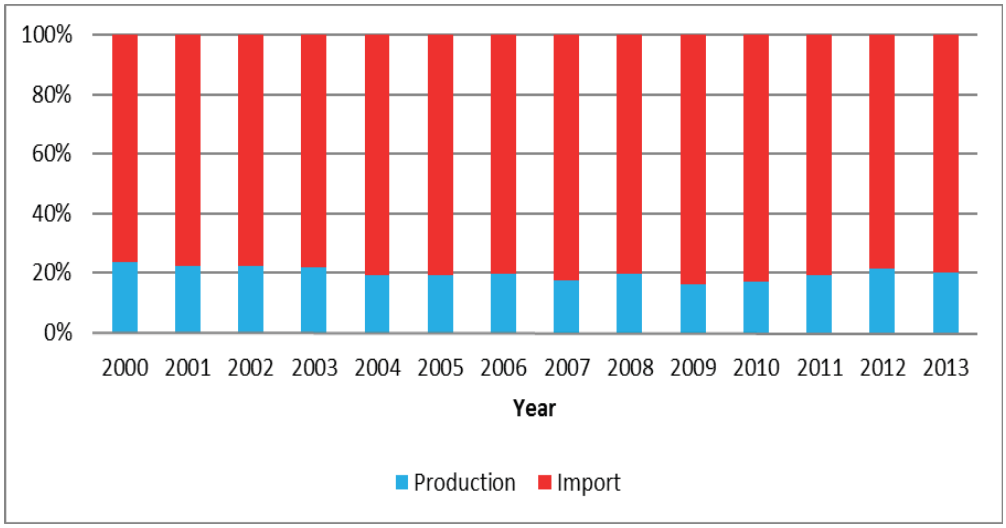



**Figure 11:** Ratio of domestic production and imported volumes of oil in Croatia from 2000 to 2013 (**Kišić, 2015**)

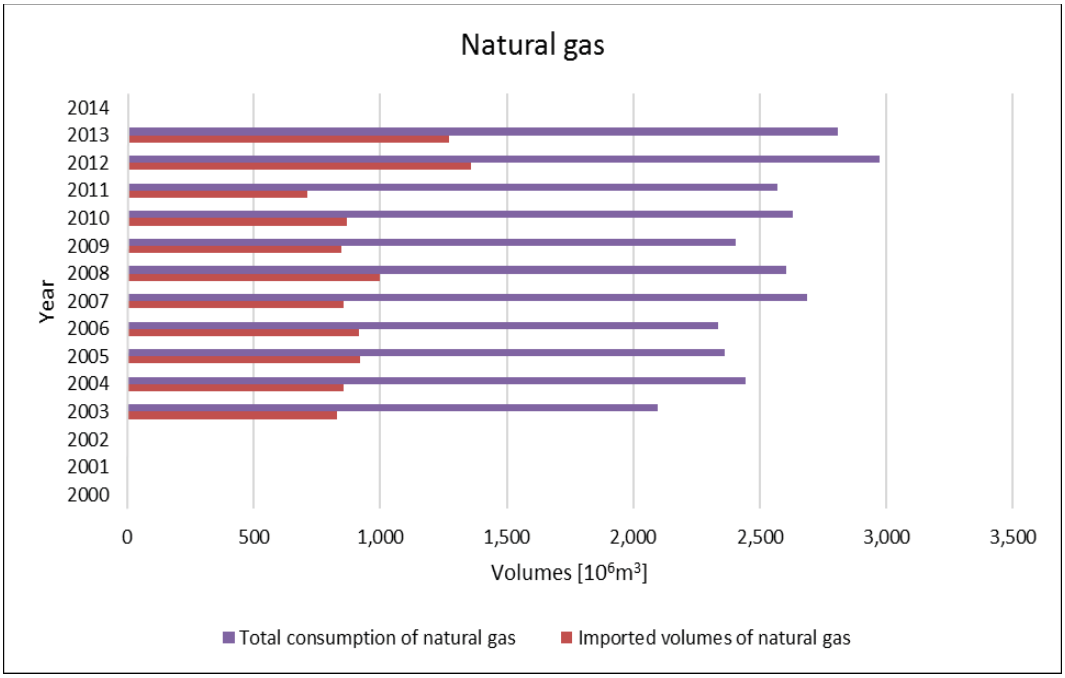



**Figure 12:** Total consumption and imported volumes of natural gas in Croatia from 2000 to 2014

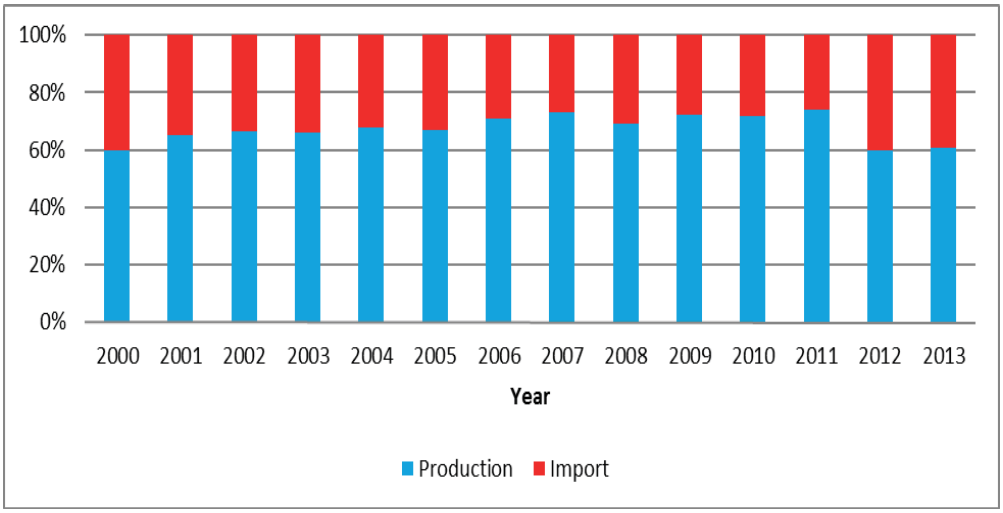



**Figure 13:** Ratio of domestic production and imported volumes of natural gas in Croatia from 2000 to 2013 **(Kišić, 2015)**

## 5. Processing

Since oil contains numerous types of hydrocarbons, which differ greatly in composition, vapor pressure and boiling point, oil cannot be directly used neither as an economical fuel, nor a chemical raw material. Usable oil products are gained only by processing. Oil is processed in refineries by separation, conversion and cleansing. Processes of separation are also called primary, and processes of conversion and cleansing secondary processes.

By its chemical composition, oil predominantly consists of hydrocarbons and, in a lesser part, of organic compounds with oxygen, nitrogen and sulfur, with traces of inorganic matter (e.g. metals in smaller quantities). The physicochemical properties of oil depend on its origin (chemical composition of oil).

According to **Sertić-Bionda (2006),** non-hydrocarbon components (sulfur, oxygen and nitrogen) are the properties highly influencing oil processing. The organic compounds sulfur, oxygen and nitrogen tend to concentrate in petroleum cuts with higher boiling points and thus irrespective of their initial content in crude oil significantly impede the processing of those fractions. The hydrocarbon-based part of oil mostly consists of paraffin, naphthene and aromatic organic compounds. Olefin and acetylene hydrocarbons are usually not present in crude oil.

Petroleum products are the products of the industrial processing of oil, in the first order products of atmospheric and vacuum fractional distillation that can be directly utilized as fuel or as a raw material for obtaining diverse organic compounds. The most important groups of petroleum products are petroleum gas, kerosene, motor gasoline, diesel fuel, rocket fuel, kerosene and petroleum for jet engines, fuel oil (light and heavy), lubricating oil, bitumen and petroleum coke, paraffin (wax) and olefin as well as aromatic hydrocarbons such as petrochemical raw materials, especially ethylene, propylene, benzene, toluene and xylene.

Refineries in Croatia have a long history and carry great importance in the economy. The processing of oil in Croatia takes part in refineries in Rijeka and Sisak and in the facility "Maziva" in Zagreb that are the property of INA, d.d. In **Table 9,** refinery products are listed. For the most part petroleum products that are created by oil processing come from imported crude oil. The quantity of crude oil entering refineries ranges from 5 million tons of oil at the beginning of the observed period (2000) to 3 million in 2013. Observing the available capacities of Croatian refineries (**Table 8**) it becomes evident that processing in the observed period was carried under much smaller capacity than was available. In total these refineries possess the capacity to process around 9 million tones yearly by atmospheric distillation. As stated before, in Croatia only $3 \times 10^6$ tons of crude oil was processed in 2013, with 2,4 million coming from import.

The largest quantities are related to fuel oil, diesel fuel and motor gasoline. Aside from refining plants and facilities for fuel and lubricant production, INA also utilizes the necessary networks for the distribution of oil and other products.

Delivery of oil to refineries is conducted by pipeline, and transportation of other products by sea, road and railroad while utilizing available storage capacities. Sale is organised through wholesale as well as a diversified retail network.

**Table 8**: Processing capacities of oil refineries in Croatia

| Processing capacities | Installed (1,000 tons/year) |
|---|---|
| **1. OIL RAFINERY RIJEKA (URINJ)** | |
| *atmospheric destilation* | 5,000 |
| *reforming* | 730 |
| *FCC* | 1,000 |
| *visbreaking* | 600 |
| *isomerization* | 250 |
| *gasoil desulphurization* | 1,040-560 |
| *hydrocracking* | 2,600 |
| **2. OIL RAFINERY SISAK** | |
| *atmospheric destilation* | 4,000 |
| *reforming* | 720 |
| *FCC* | 500 |
| *coking* | 240 |
| *vacuum destilation* | 800 |
| *bitumen* | 350 |
| **3. LUBE REFINERY ZAGREB** | |
| *lubricants* | 60 |

The largest share in the total energy consumption in Croatia falls to liquid fuels. Their share was 43,4% in 2008 and decreased to 33,7% by 2013. Aside from liquid fuel shares, shares of liquid gas and imported electrical energy also decreased in 2013.

The total quantity of petroleum products produced in Croatia has progressively declined since 2008, while imported quantities remain unchanged. Congruently, the consumption curve is declining. The gas consumption curve also points to a gradual decline (see **Figure 20**) with marked variations in the quantity of gas for energy transformation (see **Figure 21**).

**Table 9:** Oil refinery products in Croatia (**1, 2*,3**)

| *Year/1,000 t)* | 2000 | 2005 | 2010 | 2013 |
|---|---|---|---|---|
| *oil refinery products– total production* | 5,280 | 5,139 | 4,232 | 3,357 |
| *liquefied petroleum gas* | 284 | 291 | 246 | 209 |
| *motor gasoline* | 1,330 | 1,168 | 1,094 | 928 |
| *kerosene and jet fuel* | 88 | 99 | 95 | 109 |
| *diesel oil* | 1,064 | 1,081 | 1,079 | 1,072 |
| *light fuel oil* | 603 | 522 | 228 | 169 |
| *fuel oil* | 1,111 | 1,160 | 868 | 514 |
| *naphtha* | 103 | 177 | 66 | 30 |
| *bitumen* | 177 | 181 | 67 | 36 |
| *refinery gas* | 262 | 241 | 162 | 175 |
| *other products* | 259 | 221 | 328 | 113 |

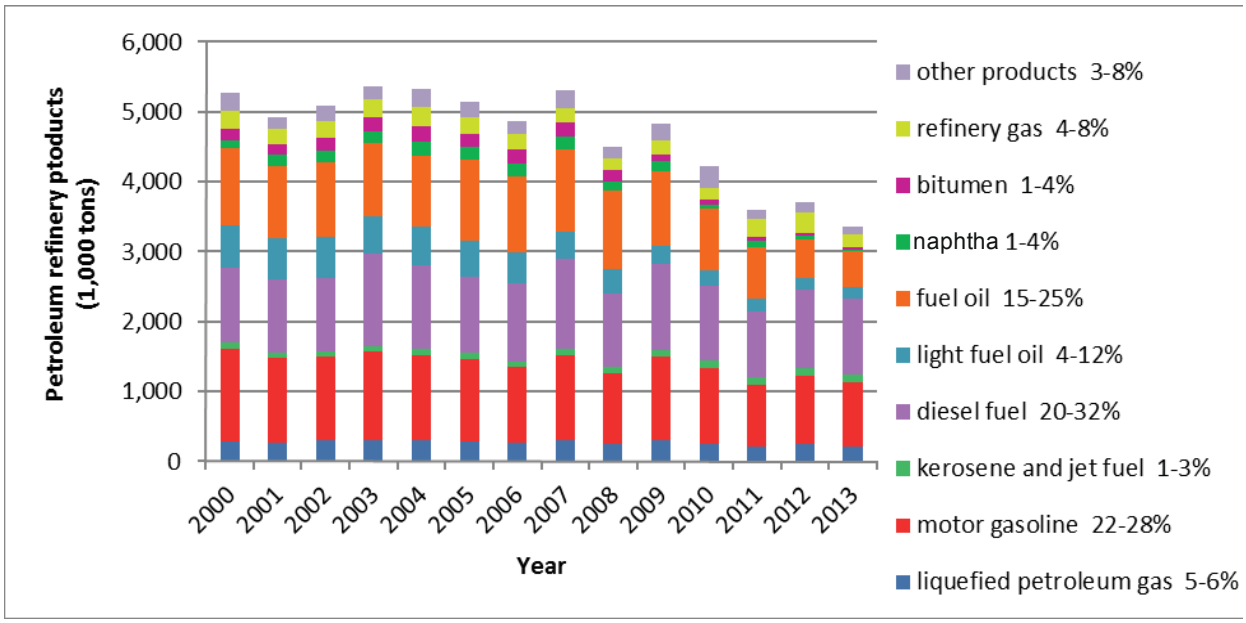



**Figure 14:** Petroleum refinery products in Croatia from 2000 to 2013 in % (**Kišić, 2015**)

Production decline of motor gasoline and fuel oil is evident, while produced quantities of diesel fuel have remained mostly unchanged in the observed period. On **Figure 14,** the same trend in decline can be observed for the remaining refinery products.

In the observed period, a change in the structure of energy consumption in transportation transpired (see **Figure 15**) where the share of diesel fuel and jet fuel consumption increased, while the share of motor gasoline consumption

decreased (see **Figures 16 to 18**). Due to changes in the structure of liquid fuel consumption in transportation, diesel and jet fuel have maintained virtually the same value in production (or have increased slightly) for the entire observation period.

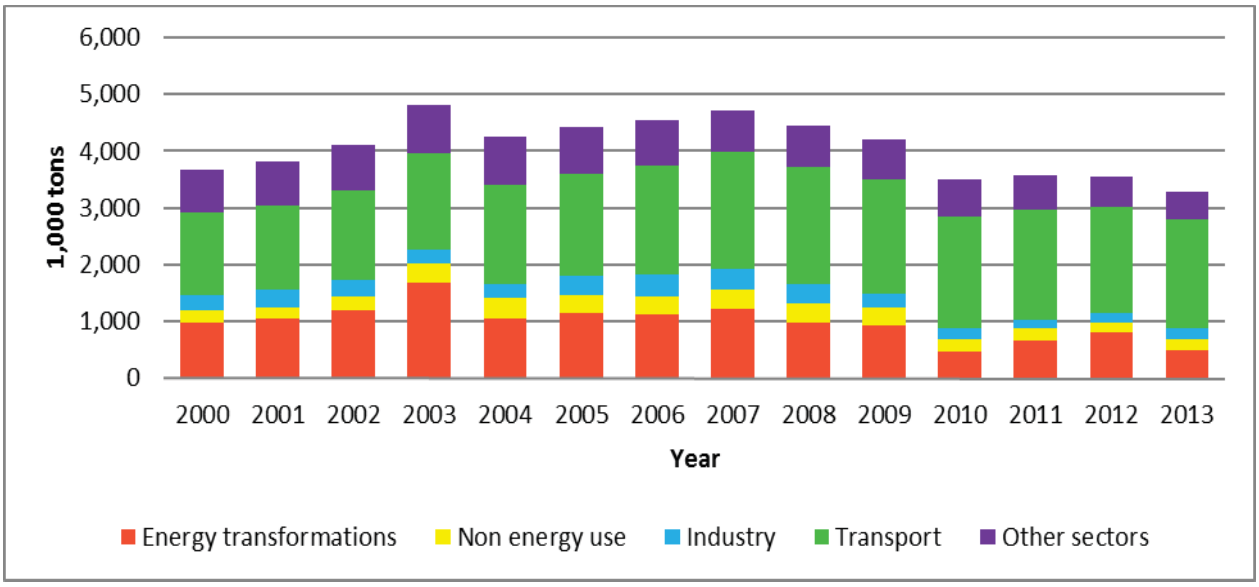



**Figure 15:** The consumption of oil products per sectors in Croatia from 2000 to 2013 (**Kišić, 2015**)

Today's energy consumption is less than it was in 1988. Aside from direct and indirect damages caused during the Homeland War (1991-1995), Croatian manufacturers have partially changed the market. Traditional economic, primarily manufacturing branches are changing, leading to the restructuring of the economy, with gradual dominance of the services and trade sector. These trends reflect upon the consumption. The largest growth in consumption was experienced in 2007, followed by the decline.

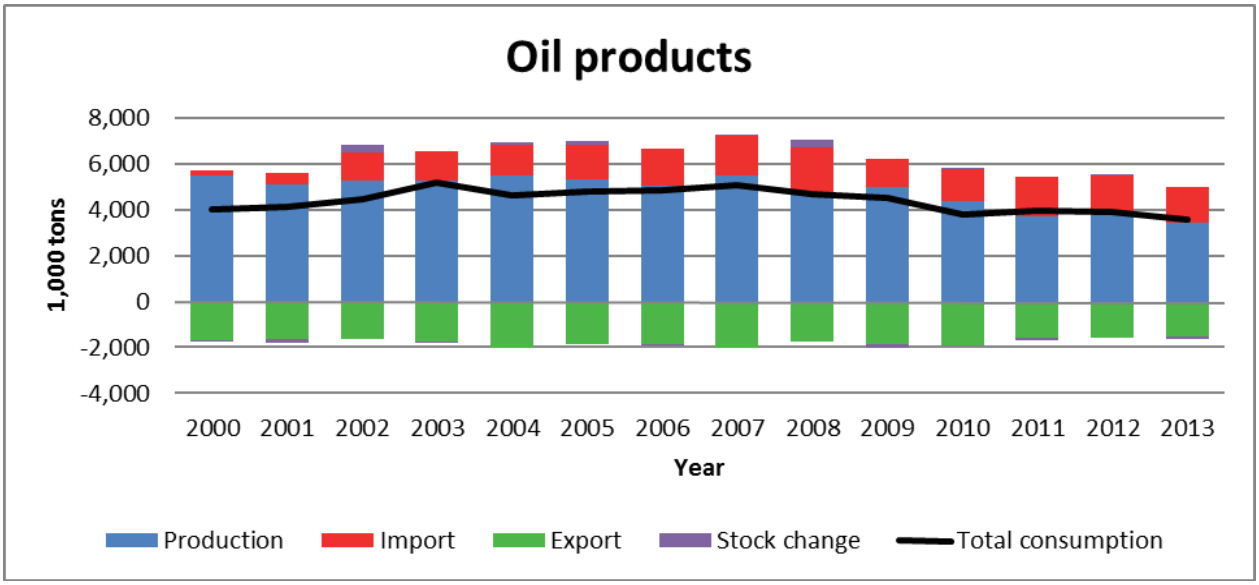



**Figure 16:** The total amount of oil products produced in Croatia, imported and exported amounts from 2000 to 2013 and the curve of total consumption (**Kišić, 2015**)

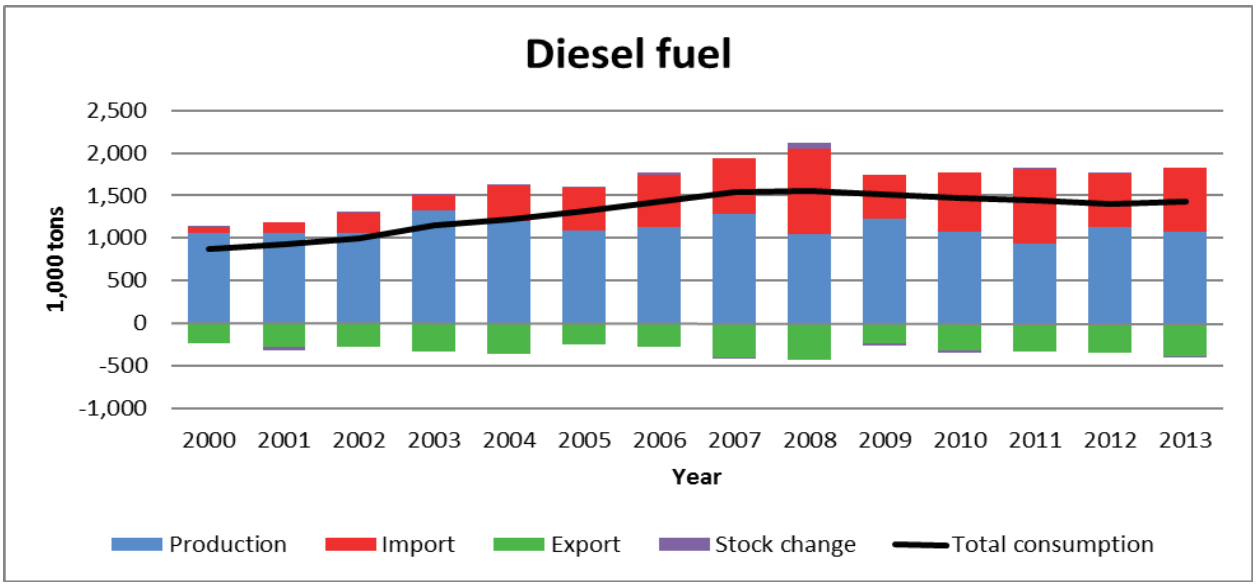



**Figure 17:** The total amount of diesel fuel produced in Croatia, imported and exported amounts from 2000 to 2013 and the curve of total consumption (**Kišić, 2015**)

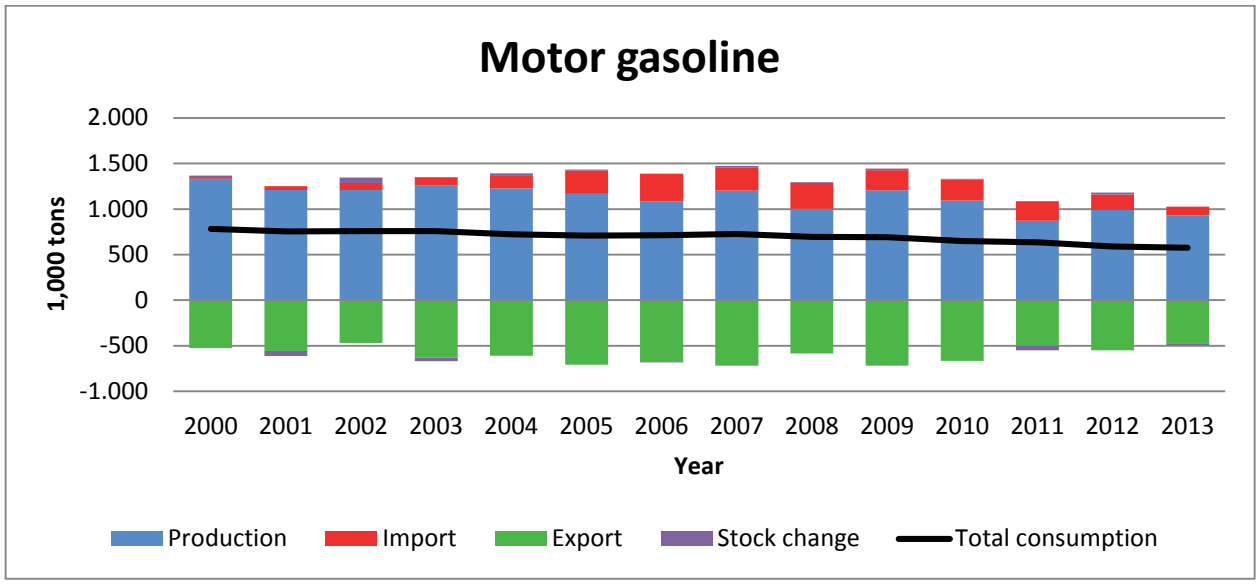



**Figure 18:** The total amount of motor gasoline produced in Croatia, imported and exported amounts from 2000 to 2013 and the curve of total consumption (**Kišić, 2015**)

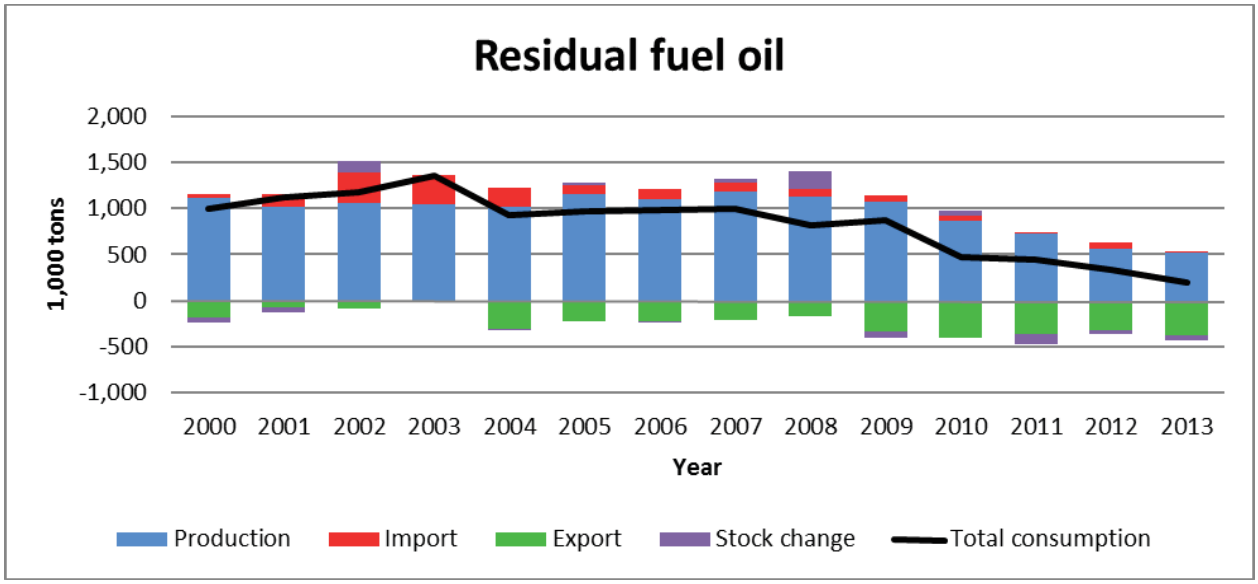



**Figure 19:** The total amount of residual fuel oil produced in Croatia, imported and exported amounts from 2000 to 2013 and the curve of total consumption (**Kišić, 2015**)

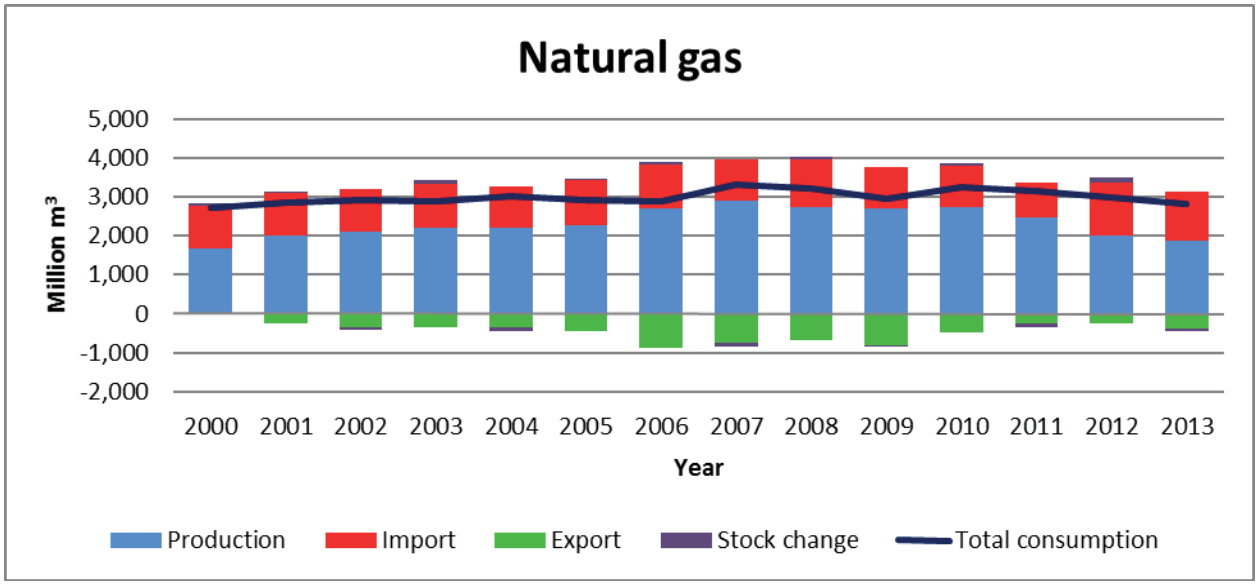



**Figure 20:** The total amount of natural gas produced in Croatia, imported and exported amounts from 2000 to 2013 and the curve of total consumption (**Kišić, 2015**)

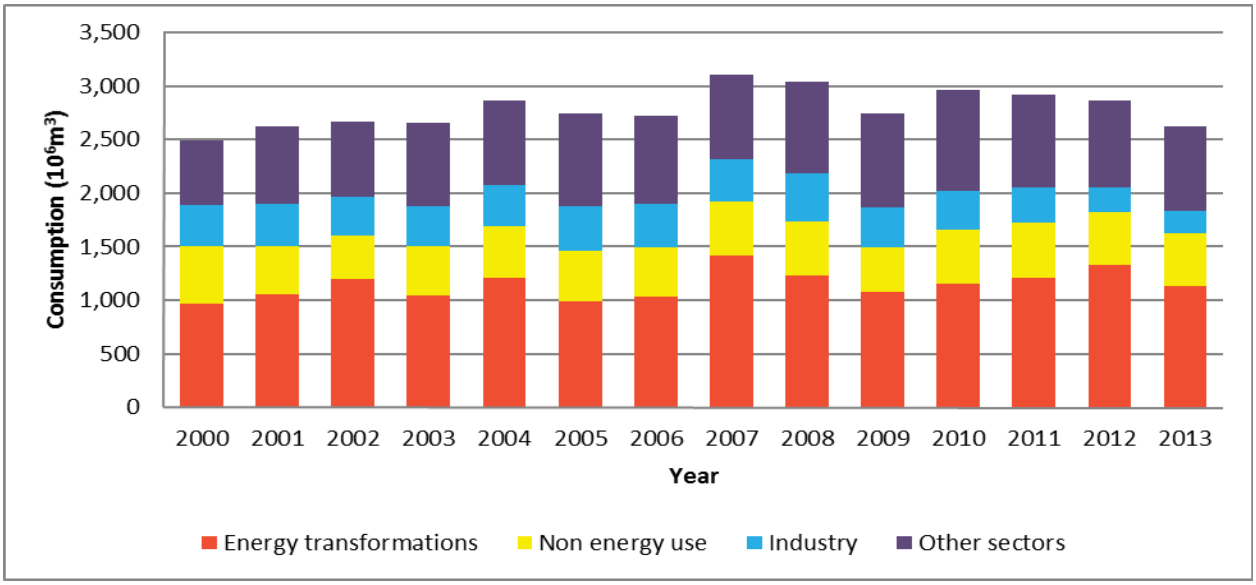



**Figure 21:** The consumption of natural gas per sectors in Croatia from 2000 to 2013 (**Kišić, 2015**)

## 6. Discussion

**Karasalihović-Sedlar et al. (2009)** assess that the role of liquid fuels in the energy consumption in Croatia will remain significant and their share would not decrease significantly in the period from 2020 reaching to 2030. A rise in direct liquid fuel consumption of around 2% is expected in the period up to 2030.

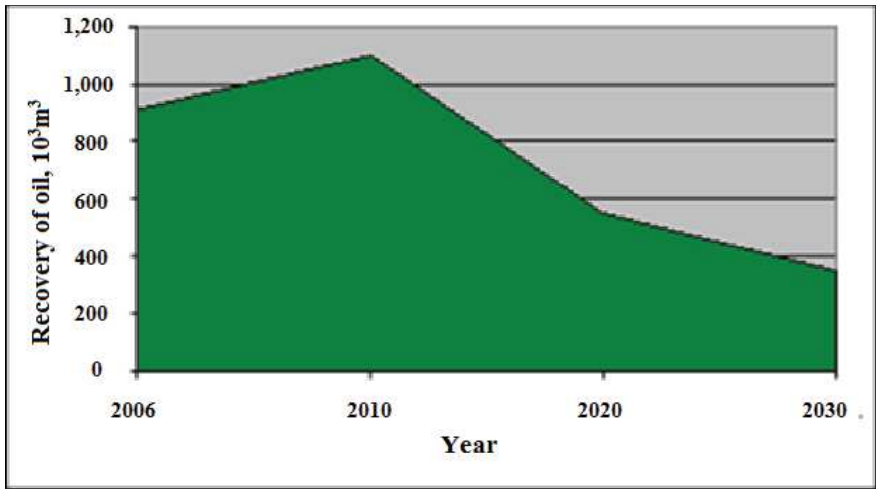



**Figure 22:** The projection of oil recovery in Croatia (**Karasalihović et al., 2009**)

**Figure 22** shows a projection of oil and condensates in Croatia (according to **Karasalihović et al., 2009).** During the drafting of the projection for the period up to 2020, the future extraction of oil and condensates from existing local exploitation fields as well as the use of new technologies and methods for increasing recovery (EOR-*Enhanced Oil Recovery)* was taken into consideration. Based on the data from this scientific work, the decline in recovery is somewhat slower. Dependence on imported oil is expected to increase, ranging at around 80% for the last few years (see **Figure 11**), and rising to around 90% of total oil needs in Croatia by 2020. After 2020, the inclusion of the energy infrastructure in the infrastructure of the immediate and wider environment is of particular importance, as well as the diversification of

supply with new sources and ensuring new import routes, thus empowering the energy sector in Croatia. To enable development of strategic supplies of oil, it is necessary to ensure additional storage capacities.

For the last two decades, consumption of natural gas is steadily growing (see **Table 6 and Figure 12**), and natural gas is gaining an increasingly strategic role. It is predicted that the share of natural gas consumption in world energy consumption will rise from 23% today to almost 45% by 2050. In Croatia, according to **Hrnčević et al. (2008),** direct consumption of natural gas is expected to rise by 4,2% annually.

An assessment of future extraction of natural gas in The Republic of Croatia, in the period reaching to 2030, is shown on **Figure 23**. It is visible that natural gas extraction will decline in the future. According to assessments, import of natural gas will satisfy 50% of local needs in 2015, and up to 65% by 2020. It should be noted that these assessments are relatively accurate, since import accounted for 45% of the necessary quantities of natural gas in 2013, therefore somewhat less than anticipated (see **Figure 13**).

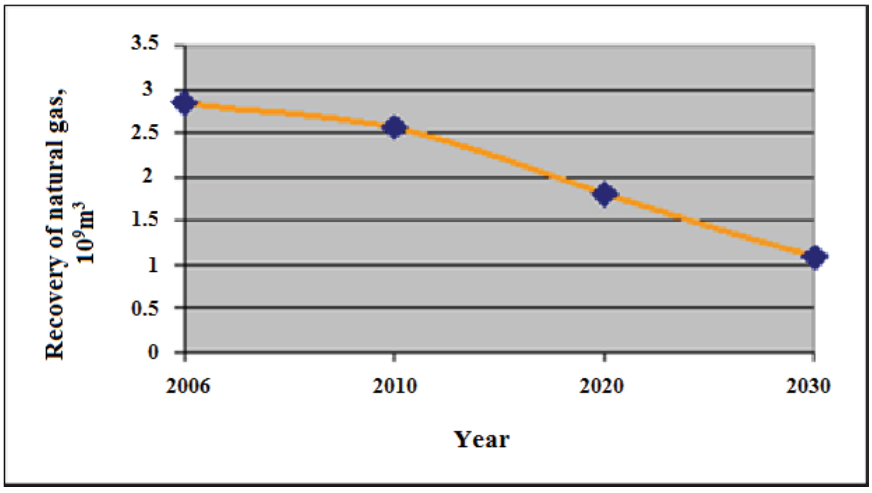



**Figure 23:** Evaluation of domestic recovery of natural gas in the period up to 2030 (**Hrnčević at al., 2008**)

By following the recorded trend of decreased extraction, by 2030, supply with locally extracted primary energy in Croatia will amount to somewhere between 21 and 23%. Considering the aforementioned estimations, it is evident that Croatia will be increasingly dependent on the import of energy.

## 7. Conclusion

The Republic of Croatia has a rich history in oil and natural gas extraction and processing. Currently around 60% of the needs for gas and 20% of the needs for oil are covered by local extraction.

Local extraction in Croatia is in decline, and in regards to expectations of increasing demand in the future, it will become necessary to import larger quantities. In the Croatian consumption balance sheet of primary energy, oil and petroleum products make up the largest share. That should certainly not change significantly in the following few decades. Only changes in the structure of petroleum products consumption are expected, with natural gas consumption shares on the rise. In regards to this state of affairs, Croatia should decrease its energy dependence on imported energy. It is necessary to construct an efficient energy infrastructure, which would guarantee the safety of supply, for which surely there are numerous solutions.

Extraction of oil and natural gas will continue to decline due to deposit depletion. Therefore, investment into new research is mandatory, as well as further development with secondary and tertiary methods. The Croatian segment of the Pannonian Basin System is a well-researched territory, however so-called residual hydrocarbons and satellite deposits are bound to exist, and numerous conducted research papers endorse their existence.

In the Northern Adriatic offshore, additional deposits of natural gas can also be expected, especially in parts that were not explored thoroughly. Considering the fact that import, as well as extraction from local deposit fields, is following consumption trends, it can be concluded that the situation in local extraction is not overly pessimistic.

Refinery operation is a pronouncedly complex process influenced by numerous factors, particularly the market. In order for our refineries to operate successfully, they must meet the demands of a constantly changing market. INA's refineries are in the process of technological restructuring, which should accomplish an increase in product quality and market price reflecting changes in the structure of petroleum product consumption.

Croatia can withstand the challenges of energy dependency by improving the efficiency of energy use, as well as by using alternative forms of energy such as renewable sources, which should increase in importance in total consumption. It is also important to ensure the diversity of import routes and storage capabilities of oil and natural gas, to ensure safety in delivery under hazardous conditions.

## 8. References

**Published papers:**

Dobrova, H., Kolly, E. & Schmitz, U. (2003): *E&P Ventures in the Eastern-Central Europe Transformation States after 1989 - a Review of Expectations and Results*. Oil Gas European Magazine, 4, 172-182.

Goričnik, B. & Domitrović, D. (2003): *Laboratory analyses of $CO_2$ process applicability in oil fields of Republic of Croatia.* Naftaplin, 1, 5-12.

Hrnčević, L., Dekanić, I., Karasalihović Sedlar, D. (2008): *Analiza sigurnosti opskrbe prirodnim plinom u Republici Hrvatskoj*. Energija: časopis Hrvatske elektroprivrede, 57, 6, 600-609.

Karasalihović Sedlar, D., Dekanić, I., Hrnčević, L. (2009): *Sigurnost opskrbe naftom u Hrvatskoj*. Energija: časopis Hrvatske elektroprivrede 58/1, 6-13.

Kišić, K. (2015): *Analiza pridobivanja i preradbe nafte i plina u Hrvatskoj od 2000. do 2013. godine (Analysis of oil and gas recovery and processing in Croatia 2000-2013)*. Graduate thesis, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, 77 p. (in Croatian)

Malvić, T., Velić, J., Cvetković, M. (2011): *Quantification of Production Variables in Sandstone Hydrocarbon Reservoirs versus other Lithologies in Croatia*. U: Prva međunarodna konferencija i izložba o naftno-plinskom gospodarstvu u središnjoj i istočnoj Europi: Zbornik radova (1st international conference adn exhibition on oil-gas economy in Central and Eastern Europe), Siófok, Hungary, 14-16. 9. 2011., Naftaplin, 2011, 19-25.

Novak, K. (2015): *Modeliranje površinskog transporta i geološki aspekti skladištenja ugljikova dioksida u neogenska pješčenjačka ležišta Sjeverne Hrvatske na primjeru polja Ivanić.* Doctoral thesis, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, 185 p.

Novak, K., Malvić. T., Simon, K. (2013): *Increased hydrocarbon recovery and $CO_2$ managment, a Croatian example.* Environmental Earth Sciences, 84, 6, 1187-1197.

Novak, K., Malvić. T., Velić, J., Simon, K. (2013): *Increased hydrocarbon recovery and $CO_2$ managment, PVT relations and volumes, a Croatian example.* Part II. Environmental Earth Sciences, 71, 8, 3641-3653.

Rusan, I. (2014): *Razlika u pristupu ekonomskoj procjeni konvencionalnih i nekonvencionalnih ležišta (s naglaskom na konvencionalna ležišta)*. Rudarsko-geološko-naftni zbornik, 28, 1, 1-7.

Sertić-Bionda, K. (2006): *Procesi prerade nafte*; Internal handouts, Faculty of chemical engineering and technology, University of Zagreb, 136 p.

Sučić, D., Karasalihović-Sedlar, D., Hrnčević, L (2011): *Analiza značaja projekata dobave prirodnog plina za Europu-Južni tok i Nabucco (Analysis of significance of natural gas import for Europe – South Stream and Nabucco)*. Rudarsko-geološko-naftni zbornik, 23, 1, 15-24. (in Croatian)

Velić, J. (2007): *Geologija ležišta nafte i plina (Geology of Oil and Gas)*. Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, 342 p. (in Croatian)

Velić, J., Malvić, T., Cvetković, M., Vrbanac, B. (2010): *Characteristics of Hydrocarbon Fields in the Croatian Part of the Pannonian Basin*. OIL GAS European Magazine, 36, 3, 146-147.

Velić, J., Malvić, T., Cvetković, M., Vrbanac, B., (2012): *Reservoir geology, hydrocarbon reserves and production in the Croatian part of the Pannonian Basin System.* Geologia Croatica, 65, 1, 91-101.

Vulin, D. (2010): *Modeliranje termodinamičkih i petrofizičkih parametara za geološko skladištenje ugljičnog dioksida (Modeling Thermodynamic and Petrophysical Parameters for Geological Storage of Carbon Dioxide)*. Doctoral thesis, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, 120 p. (in Croatian)

**1* Energy in Croatia 2010: annual energy review. Ministry of Economy, Republic of Croatia, 2010.

**2* Energy in Croatia 2013: annual energy review. Ministry of Economy, Republic of Croatia, 2013.

**3* Energy in Croatia 2005: annual energy review. Ministry of Economy, Republic of Croatia, 2005.

**Internet sources**:

BP., *Statistical Review of World Energy June 2015*

URL: http://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf (accessed January 22th 2015)