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FORECASTS AND/OR SCENARIOS, INCLUDING QUANTIFICATION OF THE DISTANCE, TIMING AND COSTS

PROGNOZY I/LUB ICH SCENARIUSZE, W TYM KWANTYFIKACJA OBSZARU PROGNOZOWANIA, CZASU I KOSZTÓW

The paper addresses the problem of the forecasting and possible development of gas production from unconventional plays in Poland. As authors underline the potential of Polish shale gas is quite similar to US shales. Due to geological conditions, stage of development, size and location in more urban areas some experts compare Polish shale plays to Marcellus even. Document stated that from geographical and infrastructural points of view one can identify five different directions for export of natural gas surplus from Poland. It is important to notice that currently none of those routes physically exists – it means, that at present there are no infrastructure (or access to such infrastructure) for exporting of the Polish natural gas.

Keywords: unconventional gas, shale gas, forecast, environmental impact, gas resources, Poland, infrastructure

Dokument adresuje problemy prognozowania i możliwości rozwoju produkcji gazu ze złóż niekonwencjonalnych w Polsce. Autorzy konstatują, że potencjał polskiego gazu łupkowego wydaje się być bardzo podobny do amerykańskiego. Ze względu na warunki geologiczne, etap rozwoju, wielkości i lokalizacje złóż w obszarach bardziej miejskich, niektórzy eksperci porównują polski gaz z łupków nawet do amerykańskiego złoża Marcellus. W artykule stwierdzono, że biorąc pod uwagę warunki geograficzne i infrastrukturalne można zidentyfikować do pięciu różnych ewentualnych kierunków eksportu nadwyżek gazu z Polski. Zauważono, że obecnie żadna z opisanych dróg nie istnieje fizycznie – oznacza to, że obecnie nie ma infrastruktury (a nawet dostępu) do takiej infrastruktury) dla ewentualnego eksportu polskiego gazu ziemnego.

Słowa kluczowe: gaz ze złóż niekonwencjonalnych, gaz z łupków, gaz łupkowy, prognoza, zasoby gazu ziemnego, Polska, infrastruktura

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1. Future shale gas production in Poland

Initial estimation of risked technically recoverable shale gas resources were announced at the level of 48.3 TCF or 1.37 TCM (Wood Mackenzie, 2009), 66 TCF or 1.87 TCM (Kuhn & Umbach, 2011), 100 TCF or 2.83 TCM (Kuuskraa & Stevens, 2009) and finally 187 TCF or 5.3 TCM (EIA, 2011).

TABLE 1

Estimation of risked technically recoverable shale gas resources in various studies

Data Source	TCF	TCM
Wood Mackenzie Unconventional Gas Service Analysis „Poland/Silurian Shales", August 2009	48.3	1.37
M. Kuhn, F. Umbach EUCERS Strategic Perspectives of Unconventional Gas "A Game Changer with Implication for the EU's Energy Security", May 2011	66.0	1.87
Vello A. Kuuskraa, Scott H. Stevens, Advanced Resources International „Worldwide Gas Shales and Unconventional Gas: A Status Report, December 2009	100.0	2.83
EIA, World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, April 2011	187	5.30
Państwowy Instytut Geologiczny: „Ocena zasobów wydobywalnych gazu ziemnego i ropy naftowej w formacjach łupkowych dolnego Palezoiku w Polsce (BASEN BAŁTYCKO – PODLASKO -LUBELSKI)".	12-26,8	0,34-0,76

Source: Own data base – various company reports.

Conventional natural gas reserves are equal to 4.94 TCF or 0.14 TCM (Nawrocki, 2010) with current production of 416 MMCFD or 4.3 BCM/year which gives R/P index at the level of 34.6 – one of the highest in the Europe. Assuming similar R/P ratio for unconventional natural gas production we obtain huge, as for Poland, volumes of produced natural gas: from 3.82 BCFD (39.5 BCM/year) for Wood Mackenzie estimation, then 5.23 BCFD (54.0 BCM/year) for EUCERS assessment, 7.92 BCFD (81.9 BCM/year) for ARI forecast and finally 14.81 BCFD (153.1 BCM/year) for recent EIA estimation. Such volumes will be, however, possible to achieve in 15-20 years' time horizon only if all geological, technical, environmental, financial and commercial conditions for full shale gas development are met.

For more precise evaluation of shale gas production potential in Poland we need to refer to estimation of US shale plays production taking into consideration geological and operational (i.e. land accessibility) differences.

As we can see (Table 1) potential of Polish shale gas is quite similar to US shales. Due to geological conditions, stage of development, size and location in more urban areas some experts compare Polish shale plays to Marcellus. Estimated R/P ratio for Marcellus is also considerably higher than for Fayetteville or Haynesville plays: 60-45 in the 2020-2030 period comparing to 30-25 for Fayetteville and 25-15 for Haynesville, and thus similar to Polish conditions.

Therefore we decided to adopt estimated Marcellus production profile as well as Wood Mackenzie, EUCERS, Advanced Resources International (ARI) and EIA resources estimations as the base for assessment of Polish shale production. As a result we received four scenarios starting from the level of 24-26 BCM of annual production (2.3-2.5 BCFD) in 15-20 years (full

TABLE 2

Comparison of data foe the Gas Shale Plays in United States and Poland

Shale play	Area km^2	Resource Potential TCF	Depth range m	Shale thickness m	Porosity	Production MMCFD	Expected Rf	GIIP TDF estimated	Total organic carbon TOC	Thermal maturity Ro
Barnett	8840	21	1980-2700	30-183	4-6%	5100	25%	238	2-7%	0.7-3.0
Fayetteville	10350	36	450-2000	6-61	4-8%	2100	36%	253	4.5-9.5%	1.5-4.5
Haynesville	14164	89	3200-3962	61-91	9-12%	3300	25%	650	4%	2.2-3.0
Marcellus NE	105356	113	1500-2590	38	6-7%	640	8%	1628	2-10%	1.0-2.0
Marcellus SW	124519	82	1500-2590	38	6-7%	620	34%	310	2-10%	1.0-3.0
Poland Shale	23816 -29360	48.1-187	1750-5000	30-300	N/D	0	17% -24%	792-844	1.5% -7.0%	1.0-4.0

Source: Various company reports, Wood MacKenzie, Deutsche Bank, CERA, EIA, EUCERS

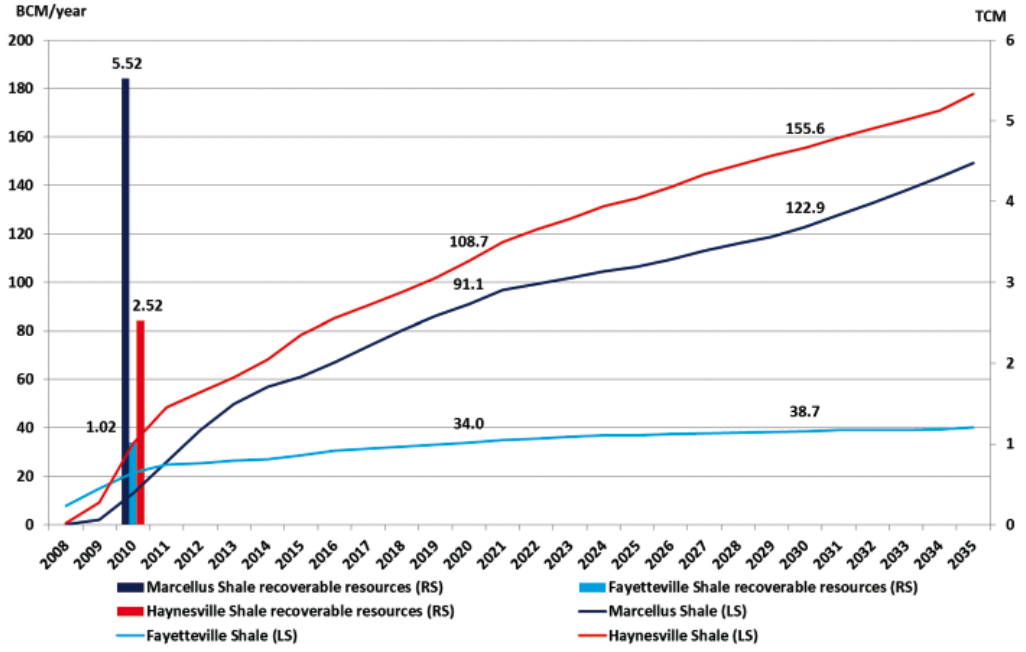

Fig. 1. Estimation of US shale production from Marcellus, Fayetteville and Haynesville plays.
Source: Own calculation based on EIA, EUCERS and CERA data

development stage) for Wood Mackenzie resources estimation, then 30-36 BCM/year (2.9-3.5 BCFD) for EUCERS, 47-55 BCM/year (4.5-5.3 BCFD) for ARI and huge 87-102 BCM/year (8.4-9.9 BCFD) for EIA assessment. Scenario based on Wood Mackenzie estimation seems to be too low and on the other hand scenario referred to EIA evaluation appears to be definitely too high, so lower range of our shale gas production forecast is set by EUCERS estimate and upper range by ARI assessment.

In order to obtain total gas supplies we need to add estimation of conventional gas production: 4.6 BCM/year for entire period and import volumes: 8.9-10.5 BCM/year from Russia up to 2022 (end of current Yamal contract) and then decreasing by 2-3 BCM/year up to 2024-2025 (spot or yearly contracts), 1.0-1.6 BCM from Germany up 2016 and 1.4 BCM since 2015 up to 2035 via LNG terminal in Świnoujście (Qatar Gas contract).

Estimation of total natural gas supplies for Polish market is presented on Fig. 3. Within ten years total volume of natural gas available for Polish customers can double or even triple comparing to current level (36-46 BCM vs. 14-15 BCM). In 20 years' time total volume of gas supplies could be 3-4 times larger than today, even though forecasted import will be almost entirely reduced (See also Siemek & Nagy, 2012).

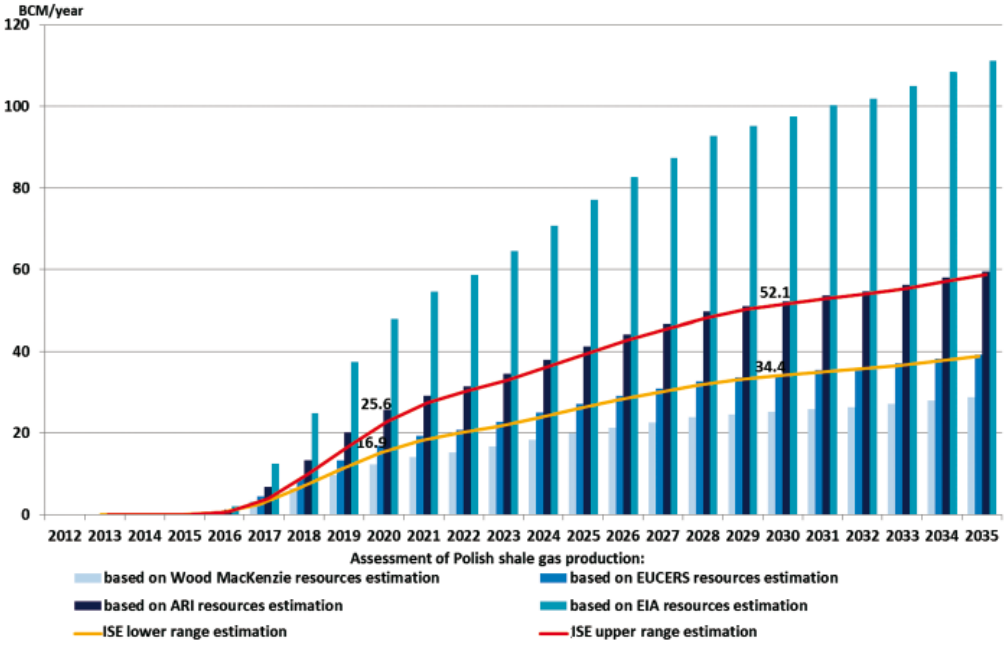

Fig. 2. Estimation of Polish shale production based on Marcellus production profile and as Wood Mackenzie, EUCERS, Advanced Resources International (ARI) and EIA resources estimations.
Source: Own calculation based on Wood Mackenzie, ARI, EIA, EUCERS and CERA data

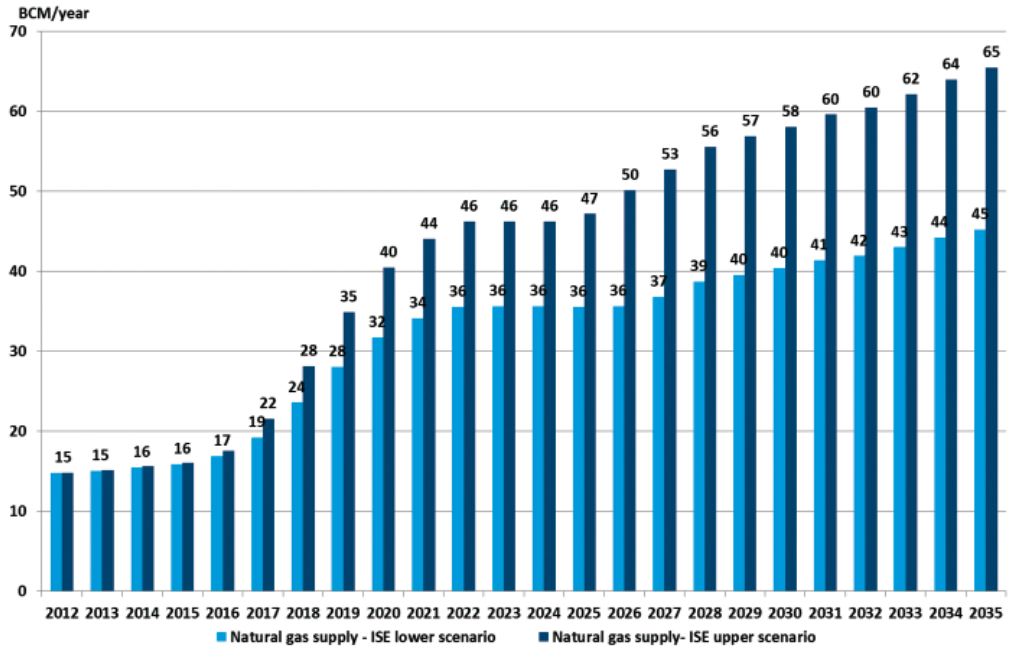

Fig. 3. Estimation of total natural gas supplies for Polish market.
Source: Own calculation based on ARI, EUCERS and CERA data

2. Potential areas of natural gas demand growth

Talking about natural gas consumption in Poland it is worth to differentiate between consumption of gas as a fuel and as a raw material for further processing, e.g. in the chemical industry.

Such differentiation you may find in a Table 3.

The first column presents total energy consumption converted into equivalent of high methane natural gas, second column its real consumption of natural gas in Poland. As you see the share of natural gas in power and heat generation sector is almost meaningless. This is a result of strong coal lobby in Poland and a lack of large natural gas resources. Polish power sector has always utilized hard coal and lignite as main fuels, and today, although production of steam coal dropped much below 100 million tons (from almost 200 million tons in 1980s coal lobby still has strong support, putting high pressure on the energy security.

However in case that large natural gas reserves are located in Poland, power security could be also built on domestic resources of natural gas. Considering its huge environmental advantage, natural gas can (and we believe it will) have a great future in Poland. Other sectors of industry utilize gas as a fuel in significantly larger amount, both in relative as in real numbers (for details – see tables 4). And there is still huge real and potential demand from dispersed customers – mainly households and services which could increases in pace with the transmission and distribution networks growth.

TABLE 3

Consumption of natural gas and other fuels in particular sectors of Polish economy and households

In MMCM of high methane gas equivalent, 36 MJ/CM [967 BTU/CF])	Total demand for fuel and energy carriers (baseline 2009)*	Natural gas consumption in 2009	Natural gas share in total consumption (%)
Energy sector – power and heat generation (utilities companies)	45 244	1 329	2.9%
Manufacturing industry (fuel purposes)	10 857	4 165	38.4%
Non fuel generation purposes (chemistry)	1 835	1 835	100.0%
Other sectors of the economy	942	544	57.8%
Dispersed customers including households**	19 582	5 725	29.2%
Natural gas industry own consumption	551	551	100.0%
TOTAL	**79 010**	**14 149**	**17.9%**

* Excluding all fuels (gasoline, diesel oil, jet-fuel, LPG and bunker oil) for trucking purposes, coking coal, coke, coke oven gas, blast furnace gas and other gaseous waste fuels for coke oven products industry and basic metal production industry, refinery fuel and heavy fuel oil (residue) for refinery industry

** without the heat from heat and power generation plants

Source: Own calculation on the basis of Central Statistical Office data.

Let us now turn attention to a special category of demand for natural gas, which is a production of hydrogen for chemical and petrochemical reactions. The chemical industry, to be more precise, fertilizers manufacturing, uses gas as a raw material to produce ammonia, which is subsequently used for nitrogen fertilizers production. This sector is the main consumer of gas for non-fuel purposes (Table 5).

In Poland there are five large ammonia plants:

- Zakłady Azotowe Puławy (ZA Puławy),
- Zakłady Chemiczne Police (Zch Police),
- Anwil,
- Zakłady Azotowe Kędzierzyn (ZAK),
- Azoty Tarnów.

Ammonia production in all Polish plants is based on natural gas steam reforming technology. Average natural gas consumption for ammonia production in Polish plants is equal to 29.5-32 GJ/ton of NH_3. Currently[1] domestic capacity of existing ammonia plants is equal to 2.83 million tons of NH_3 per year (8500 tons of NH_3 per day). In 2010 and earlier, it was 2.66 million tons of NH_3 per year (8000 tons of NH_3 per day). Capacity utilization was at the level of 89% in 2007, then dropped to 83% in 2008, 75% in 2009 and 77% in 2010. Due to economic problems of ZCh Police and high natural gas prices comparing to Western Europe (and Eastern Europe) plants, we expect that capacity utilization will remain at the level of 75%-80% in next years, which means 1.83-1.95 BCM of natural gas demand for ammonia production only and 2.1-2.2 BCM of total natural gas consumption in five, above mentioned plants.

[1] After Zakłady Azotowe Puławy expansion in April 2010 from 960 th. tons to 1130 th. tons per year.

TABLE 4

Natural gas as a fuel in particular sectors of Polish economy (2009 yearly data)

Segment/section/industry	Steam coal, coking coal, lignite, coke in TJ	Biogas, biomass and wastes fuelsin TJ	LPG in TJ	Light fuel oil in TJ	Heavy fuel oil in TJ	Peat and wood in TJ	Coke oven gas, blast furnace gas, refinery gas and gaseous waste fuels in TJ	Natural gas in TJ	Fuels together in TJ	Natural gas share in %	Natural gas in MMCM	Other fuels in MMCM
1	2	3	4	5	6	7	8	9	10	11	12	13
Households segment	235 120	0	20 812	13 121	0	102 500	0	134 822	506 375	26,6%	**3 745 056**	10 320 917
Other consumers segment (administration, public utility, small business, services)	29 620	0	3 216	16 005	0	6 746	0	69 710	125 297	55,6%	**1 936 389**	1 544 083
Non-metallic mineral products industry	35 651	12 368	601	729	2 003	69	1 246	41 434	94 101	44,0%	**1 150 944**	1 462 972
Refining industry	135	1 359	6 368	5 902	46 251	0	44 653	28 020	132 688	21,1%	**778 333**	2 907 444
Basic metal production industry	78 612	0	123	78	163	8	21 214	22 763	122 961	18,5%	**632 306**	2 783 278
Oil&gas upstream and gas processing and transportation section	0	37	102	18	0	0	0	19 826	19 983	99,2%	**550 722**	4 361
Food industry	28 941	118	1 095	2 428	1 270	73	0	16 909	50 834	33,3%	**469 694**	942 361
Transport segment*	2 355	0	0	727	0	9	2	15 039	18 132	82,9%	**417 750**	85 917
Chemicals industry**	53 999	3 152	164	245	1 398	12	4 434	9 174	72 578	12,6%	**254 833**	1 761 222
Paper industry	10 559	17 979	157	232	1 627	7 113	155	5 233	43 055	12,2%	**145 361**	1 050 611
Wooden products industry	3 819	7 367	135	53	669	5 953	0	4 141	22 137	18,7%	**115 028**	499 889
Beverages industry	1 267	89	145	189	191	31	0	3 765	5 677	66,3%	**104 583**	53 111
Fabricated metal products industry	1 176	0	304	330	1	17	0	3 741	5 569	67,2%	**103 917**	50 778
Motor vehicles industry	719	0	90	89	0	0	0	3 447	4 345	79,3%	**95 750**	24 944
Rubber and plastics industry	3 911	0	212	283	203	10	0	2 592	7 211	35,9%	**72 000**	128 306

TABLE 4. continued

1	2	3	4	5	6	7	8	9	10	11	12	13
Electric equipment industry	147	0	48	51	6	0	0	2 345	2 597	90,3%	**65 139**	7 000
Construction segment	1 349	27	133	2 446	397	10	0	1 921	6 283	30,6%	**53 361**	121 167
Agriculture segment	44 926	31	2 129	4 375	1 251	19 000	0	1 577	73 289	2,2%	**43 806**	1 992 000
Other machinery and equipment industry	1 119	22	130	192	6	3	39	1 449	2 960	49,0%	**40 250**	41 972
Mining segment	9 147	21	149	198	1	87	126	1 193	10 922	10,9%	**33 139**	270 250
Textiles industry	782	0	43	84	0	0	0	1 083	1 992	54,4%	**30 083**	25 250
Pharmaceutical industry	35	0	4	67	0	0	0	995	1 101	90,4%	**27 639**	2 944
Sewerage section	2 601	1 421	16	123	13	204	0	825	5 203	15,9%	**22 917**	121 611
Water collection treatment and supply section	698	830	13	96	0	109	0	612	2 358	26,0%	**17 000**	48 500
Tobacco industry	130	0	0	94	0	0	0	528	752	70,2%	**14 667**	6 222
Other transport equipment industry	502	4	25	107	0	0	0	485	1 123	43,2%	**13 472**	17 722
Printing and reproduction industry	9	0	23	10	0	0	0	433	475	91,2%	**12 028**	1 167
Computer, electronic and optical products industry	96	0	6	22	0	3	0	350	477	73,4%	**9 722**	3 528
Wearing apparel industry	135	0	22	160	42	0	0	324	683	47,4%	**9 000**	9 972
Leather products industry	155	0	5	59	0	0	0	217	436	49,8%	**6 028**	6 083
Furniture industry	224	1 412	78	124	0	979	0	217	3 034	7,2%	**6 028**	78 250
Repair and installation of machinery and equipment	409	1	25	95	0	5	0	206	741	27,8%	**5 722**	14 861
Other manufacturing industry	164	0	5	39	0	7	0	134	349	38,4%	**3 722**	5 972
Coke oven products industry***	2 655	0	37	3	0	0	34 388	8	37 091	0,0%	**222**	1 030 083
TOTAL	551 167	46 238	36 415	48 774	55 492	142 948	106 257	395 518	1 382 809	28,6%	**10 986 611**	27 424 750

* Excluding LPG (trucking purposes) and bunker oil
** Excluding coking coal
*** Excluding natural gas as feedstock (non-fuel purposes)

Source: Own calculations based on Energy Statistics 2008, 2009 published by Central Statistical Office.

TABLE 5

Consumption of natural gas as a feedstock for non-fuel purposes

Consumption of natural gas for non-energy purposes:		2007	2008	2009
Total for industry	MMCM/year	2300	2312	1835
	MMCFD	222	224	177
Chemical industry	MMCM/year	2229	2286	1822
	MMCFD	216	221	176
Chemical industry share	%	96.9%	98.9%	99.3%
Ammonia (and nitrogen fertilizer) production share	%	90.0%	83.2%	94.9%

Source: Own calculations based on Energy Statistics 2008, 2009 published by Central Statistical Office and Annual Report for 2009 of Polish Chamber of Chemical Industry.

TABLE 6

Ammonia plants in Poland: ammonia production capacity and production volume in 2008-2010.

Plant	Ammonia production capacity in thousand tonnes/year	Theoretical gas consumption for NH_3 in MMCM	Ammonia production in 2010 in thousand tonnes	Ammonia production in 2009 in thousand tonnes	Ammonia production in 2008 in thousand tonnes
Zakłady Azotowe Puławy	1130	927	811	835	680
Zakłady Chemiczne Police	560	498	293	247	470
Anwil	520	455	373	407	502
Zakłady Azotowe Kędzierzyn	384	342	391	333	367
Azoty Tarnów	240	214	191	179	191
TOTAL	2834	2435	2059	2001	2210

Source: Company data, ISE estimations

Except of ZA Puławy we do not expect any major investments in a chemical segment in Poland. In fact, it is quite probable that ammonia plant in Police will be closed or reduced capacity to 280 th. tons per year[2].

While the mineral fertilizer (NPK[3]) consumption in Poland per 1 ha of cultivated area amounts to 132.6 kg (comparing with 140 kg in Germany, 200 kg in Netherlands, 115 kg in Czech Republic potential on the domestic market is not impressive and other large volume chemical and petrochemical production in Poland is based mainly on crude oil products as feedstock. Thus, it is rather unlikely that the demand for natural gas as feedstock from chemical industry will soar, the optimistic scenario assumes comeback to 2006-2008 level of consumption. Therefore we see a potential annual consumption growth of approx. 400-500 MMCM [39-48 MMCFD] for natural gas as feedstock for chemical production.

Potential growth of natural gas demand in Poland should be a consequence of two phenomena. First – appearance of new gas consumers; second – acquisition of existing customers, who – at the moment – consume other fuels.

[2] Due to economic downturn and reduced demand for fertilizers in mid-2009 management board of Police decided to temporary closed one unit of ammonia plant in Police (280 th. tons capacity). This unit was reopened in mid-2010.

[3] NPK – nitrogen, phosphorus and potassium.

Let us elaborate on the first group.

The largest potential for a consumption growth is in the energy sector.

At the moment natural gas accounts for only 2.9% of total electric energy and heat generation. And according to Polish Energy Policy this situation will not change radically, because Poland is seeking its security of supply in domestic resources of coal. This way of thinking is additionally supported by a very strong coal mining lobby in the Ministry of Economy and Polish Parliament. What could happen though, if natural gas is a "domestic" as well?

TABLE 7

Fuels structure in Polish power and heat generation segment in 2009

Energy sector	Total in TJ	Total in th. TOE	Total in MMCM	Structure
Steam coal	997 421	23 823	27 706	61.2%
Lignite	494 694	11 816	13 742	30.4%
Natural gas	47 843	1 143	1 329	2.9%
Peat and wood	24 268	580	674	1.5%
Biogas, biomass and wastes fuels	24 171	577	671	1.5%
Coke oven gas, blast furnace gas, refinery gas and gaseous waste fuels	18 971	453	527	1.2%
Wind and hydro energy	12 421	297	345	0.8%
Crude oil products	8 674	207	241	0.5%
Other	314	7	9	0.0%
TOTAL	1 628 777	38 903	45 244	100%
100% substitution	1 580 934	37 760	43 915	97.1%

Source: Own calculations based on Energy Statistics 2008, 2009 published by Central Statistical Office.

TABLE 8

Forecast of Electric energy generation in Poland by fuels (2015-2030)

Energy production (TWh)	2015	2020	2025	2030
Hard coal	62.9	62.7	58.4	71.8
Lignite	51.1	40	48.4	42.3
Natural gas	5.0	8.4	11.4	13.4
Oil	2.5	2.8	2.9	3.0
Nuclear energy	0.0	10.5	21.1	31.6
Renewables	17.0	30.1	36.5	38
Hydro	1.0	1.0	1.0	1.0
Wastes	0.6	0.6	0.7	0.7
TOTAL	**140.1**	**156.1**	**180.3**	**201.8**
Natural gas share in total electric generation	*3.6%*	*5.4%*	*6.3%*	*6.6%*

Source: Polish Energy Policy 2030

In Table 9 you will find plans of the modernization of Polish base-load energy generation.

TABLE 9

Modernization plans in the Polish power industry (2010-2030; only base-load)

Planned close-down of base load power plants (MW)	**2011-2015**	**2016-2020**	**2021-2025**	**2026-2030**	**Total**
Hard coal	1 825	2 785	2 805	4 527	**11 942**
Lignite	240	1 073	1 340	0	**2 653**
Planned new capacities of base load power plants (MW)					
Hard coal	1 380	2 600	0	0	**3 980**
Lignite	1 380	0	0	0	**1 380**
Natural gas	200	400	0	0	**600**
Nuclear energy	0	0	3 000	3 000	**6 000**

Source: Polish Energy Policy 2030. www.mg.gov.pl

As you can see Poland plans to close down approx. 14.5 GW (out of 35 GW, end of 2010) of existing generating capacity in base load power plants by 2030. Surprisingly, according to Polish Energy Policy natural gas is to replace only 600 MW. However taking into consideration probable influence of CO_2 emission costs gas fired energy generation should be cheaper than coal fired. Therefore we would expect significant growth of natural gas based generation (even replacement of one of the nuclear power plants with a gas fired one).

It is also worth to mention that PEP assumes increase of wind power generation from 173 MW in 2006 to 7 879 MW in 2030. While we expect this prognosis to be far too optimistic (Poland does not even have enough area suitable for such amount of wind farms), it is worth to mention, that wind energy must be balanced by peak power plants. And peak power should mean gas-fired plants, which gives additional incentive for a development of gas fired energy.

What kind of barriers may occur in a development of gas-fired power generation?

In our opinion there may be two such obstacles.

First, decisions regarding the configuration of future power plants should be made today or in the near future, based on today available data and documented primary energy sources. Economically viable shale gas in Poland is so far only a hypothesis, based on strong premises but still hypothesis. Other "secure", domestic gas sources, i.e. conventional gas deposits do not provide enough fuel for large-scale investments in power generation.

Second, price relations between particular fuel types and especially the future level of CO_2 emission fees are a substantial risk factor. Depending on whether the EU climate policy is continued in the same shape or smoothened, natural gas will become very competitive against alternative fuels, especially coal, or will remain too expensive.

Therefore the future scenario could assume a maximum increase of annual natural gas consumption in the energy sector of approx. 6-8 BCM [580-770 MMCFD] by the year 2020. More realistically (probable two-three year delay in construction of last two units) we see the potential of 4-6 BCM/year [390-580 MMCFD] increase in natural gas consumption in the energy sector by 2020.

After 2020 there is a possibility to increase that volume to the level of 9-11 BCM/year [870-1060 MMCFD], however it will depend on the development of shale gas production in Poland and economic outcomes of EU policy on CO_2 emissions implementation.

Let us now turn attention to a potential growth of natural gas consumption in the processing industry.

TABLE 10

Fuel and other energy carriers consumption in 2009 in manufacturing industry excluding consumption for non-fuel purposes[4]

Total manufacturing industry	Total in TJ	Total in th. TOE	Total in MMCM	Structure
Steam coal, coking coal, lignite, coke	153 722	3 672	4 270	39.3%
Natural gas	149 950	3 581	4 165	38.4%
Biogas, biomass and wastes fuels	43 870	1 048	1 219	11.2%
Crude oil products	29 090	695	808	7.4%
Peat and wood	8 331	199	231	2.1%
Coke oven gas, blast furnace gas, refinery gas and gaseous waste fuels	5 873	140	163	1.5%
TOTAL	390 836	9 335	10 857	100.0%
100% substitution	240 886	5 753	6 691	61.6%

Source: Own calculations based on Energy Statistics 2008, 2009 published by Central Statistical Office.

The data presented in Table 10 show the consumption of fuel and energy carriers in manufacturing industry for energy generation purposes. Contrary to the case of power generation industry, the manufacturing industry has already started to use gas as a fuel. The share of natural gas in manufacturing industry, accounted for 38.4% of total energy carriers used for energy generation, being almost equal to consumption of coal and lignite. That is why the future growth potential for gas demand is much smaller in this area in comparison to the energy sector.

While it is not possible to include in this document all calculations that we have taken into consideration analyzing a potential increase of annual gas consumption in the manufacturing industry[5], we only inform that we assess it in a range of 1-1.5 BCM [98-145 MMCFD] within the next 10-years, provided introduction of new economic incentives (positive such as tax reliefs and European Union surcharges or negative: taxes and fees for CO_2 emission), which will accelerate a substitution of cheaper, but less environmentally friendly, hard coal.

Assuming maintaining a legal status quo it is safe to predict increase of annual gas demand by approx. 400-500 mcm, substituting liquid fuels based on oil and imported LPG which are substantially less competitive than natural gas.

[4] Also excluding coke and coking coal for coke production, heavy fuel oil (residue) and refinery gas in refining industry, cocking coal, coke and blast furnace gas in metallurgy, wood in wood industry as well as heat and electricity in all branches.

[5] ISE has been analyzing this issue in details and we may provide such analysis, if necessary.

The breakeven price for emission of CO_2, which makes natural gas and coal equally competitive, is in the range from 31 to 40 €/ton, assuming average prices for gas and coal in Poland on the basis of International Energy Agency[6] data for the first half of 2009[7].

We also assumed the difference in emissions amounting to 4 tons of CO_2 when burning of 1000 cm of natural gas with calorific value of 36 MJ/CM and its energy equivalent in hard coal. In case of largest consumers, with annual consumption above 150 thousand toe, the breakeven price is lower and amounts approximately 22-23 € per ton of CO_2 emission.

There are however other barriers for larger substitution besides the price factor, which is availability of the raw material and security of supply. For the natural gas a monopolistic structure of the market and dominant position of POGC and its subsidiaries gives no choice to current and potential customers and forces them to accept unfavorable provisions in the gas sales agreement.

The appearance of large volumes of gas (considering Polish conditions) delivered by independent gas companies will definitely be a huge incentive to accelerate the process of Polish economy gasification. The crucial factor deciding about fuel substitution in a particular establishment will be the profitability analysis, which will be hugely influenced by the future shape of European climate policy and costs of CO_2 emissions (See also Siemek & Nagy, 2012).

Table 11 shows gas and alternative energy carriers consumption in "other" sectors of the economy such as: mining (coal and metal ores excavation), construction, sewerage, water collection treatment and supply, transport (only heating purposes) as well as oil&gas upstream and gas processing and transportation (natural gas industry self-consumption).

TABLE 11

Fuel and energy carriers consumption in 2009 in other sectors of the economy*

Other sectors and segments	Total in TJ	Total in th. TOE	Total in MMCM	Structure
Steam coal, coking coal, lignite, coke	7 003	167	195	20.7%
Natural gas	19 590	468	544	57.8%
Biogas, biomass and wastes fuels	2 336	56	65	6.9%
Crude oil products	4 432	106	123	13.1%
Peat and wood	419	10	12	1.2%
Coke oven gas, blast furnace gas, refinery gas and gaseous waste fuels	128	3	4	0.4%
TOTAL	33 908	810	942	100.0%
100% substitution	14 318	342	398	42.2%

* Excluding coal and lignite in mining industry

Source: Own calculations based on Energy Statistics 2008, 2009 published by Central Statistical Office.

Applying the same methodology as for manufacturing industries we received theoretical potential of fuel substitution for natural gas in other segments. However it is not substantial in comparison to energy generation – "only" 398 MMCM/year (38.5 MMCFD) in case of 100% substitution. More realistic scenario (limited switching) gives considerably lower amounts

[6] Energy Prices & Taxes, Quarterly statistics, Third Quarter 2009.

[7] We will conclude with the same result, when taking the average annual values for gas and coal from 2001-2008 period.

– 96 MMCM/year (9.3 MMCFD) in all other segments of economy, out of which construction segment stands for 66 MMCM/year (6.4 MMCFD).

The remaining groups of so called "dispersed" customers consist mainly of small entities (considering volume of gas consumption), often dispersed, so efficient gas delivery to these customers will require an active participation of gas distribution companies. Among them the largest group of natural gas consumers is "households", which are, by definition, the most dispersed group, however with substantial share in total gas consumption. Apart from households in this group we have also public administration, public buildings (schools, hospitals and so on) and small business – so called commercial segment as well as agriculture.

TABLE 12

Fuel and energy carriers consumption in 2009 in "dispersed" customers segments of the economy

Dispersed customers segments	Total in TJ	Total in th. TOE	Total in MMCM	Structure
Steam coal, coking coal, lignite, coke	309 666	7 396	8 602	43.9%
Natural gas	206 109	4 923	5 725	29.2%
Biogas, biomass and wastes fuels	31	1	1	0.0%
Crude oil products	60 909	1 455	1 692	8.6%
Peat and wood	128 246	3 063	3 562	18.2%
Coke oven gas, blast furnace gas, refinery gas and gaseous waste fuels	0	0	0	0.0%
TOTAL	704 961	16 838	19 582	100%
100% substitution	498 852	11 915	13 857	70.8%

Source: Own calculations based on Energy Statistics 2008, 2009 published by Central Statistical Office.

Natural gas accounts currently for 29% fuel and energy carriers consumption for heating purposes in dispersed customers segments (Table 12), but there are large differences between segments: natural gas constitutes only 2% of total fuel consumption in agriculture, 27% in households and 56% in commercial sector. Theoretically the largest possible volume of new demand for natural gas due to fuel switching comes from households segment – 10.3 BCM/year (998 MMCFD). Next sector is agriculture 1.99 BCM/year (193 MMCFD), mostly due to very low natural gas share – so far only 2.15%. Commercial segment, although much larger in terms of fuels and total energy consumption, is also more "gasified" – thus conversion potential is lower and equals 1.54 BCM/year (149 MMCFD). Therefore, there is a possibility of even three times increase of gas consumption in these segments[8]). Certainly, it is only theory, as such increase requires substantial investment outlays both from end users (new boilers) and gas companies (development of transmission and distribution networks), which may not be always profitable due to dispersed location of the customers in some areas. Besides investments, the end customers will also have to approve higher bills compared to earlier used coal or wood.

[8] ISE has been analyzing this issue in details and we may provide such analysis, if necessary.

3. Summarizing

According to our estimations, on the basis of abovementioned assumptions we see a potential of additional natural gas demand on the Polish market by 2020 on the level of (2009 baseline):

- 4.0-6.0 BCM/year [390-580 MMCFD] in power and heat generation sector,
- 1.0-1.5 BCM/year [98-145 MMCFD] in the manufacturing industry,
- 0.4-0.5 BCM [39-48 MMCFD] as feedstock for chemical production (in fertilizers production),
- approx. 2.0 BCM [193 MMCFD] in dispersed customers segments (mainly households and commercial clients),
- 0.1 BCM/year [9.7 MMCFD] in other sectors of economy.

Therefore total annual consumption of natural gas in Poland may grow by approx. 7.5 BCM/year [725 MMCFD] (lower scenario) – 10.1 BCM/year [977 MMCFD] (upper scenario) by 2020. However, we would like to point out that these predictions don't include effect of new gas discoveries.

For longer period – by 2030 we predict potential increase of natural gas demand in Poland on the level of (2009 baseline):

- 9.0-11.0 BCM/year [870-1063 MMCFD] in power and heat generation sector,
- 1.9 BCM/year [184 MMCFD] in the manufacturing industry,
- 0.4-0.5 BCM/year [39-48 MMCFD] as feedstock for chemical production (in fertilizers production) – no increase to 2020 level,
- 3.9-4.0 BCM/year [378-387 MMCFD] in dispersed customers segments (mainly households and commercial clients),
- 0.1 BCM/year [9.7 MMCFD] in other sectors of economy – no increase to 2020 level.

At the end of 2030 we see potential increase of demand to the level of 15.3 BCM/year [1480 MMCFD] (lower scenario) – 17.5 BCM/year [1692 MMCFD] (upper scenario).

Adding current level to potential increase[9] of demand we obtain forecast of demand for natural gas in Poland – lower and upper scenarios (Fig. 4) and thus potential natural gas surplus and export requirements (Fig. 5).

Lower scenario of supply and demand predicts about 10 BCM/year [967 MMCFD] surplus of natural gas on Polish market in years 2020-2030 and such volumes need to be exported to neighboring European countries. For upper scenario total volume of surplus (and export requirements) doubles from almost 16 BCM/year [1530 MMCFD] in 2020 to 32 BCM [3090 MMCFD].

4. Export of the gas surplus – directions, routes, amount and physical destination points

From geographical and infrastructural points of view we can identify five different directions for export of natural gas surplus from Poland. It is important to notice that currently none of those routes physically exists – it means, that at present there are no infrastructure (or access to such infrastructure) for exporting even one cu. m of Polish natural gas.

[9] Including proportional to growing demand increase in own consumption.

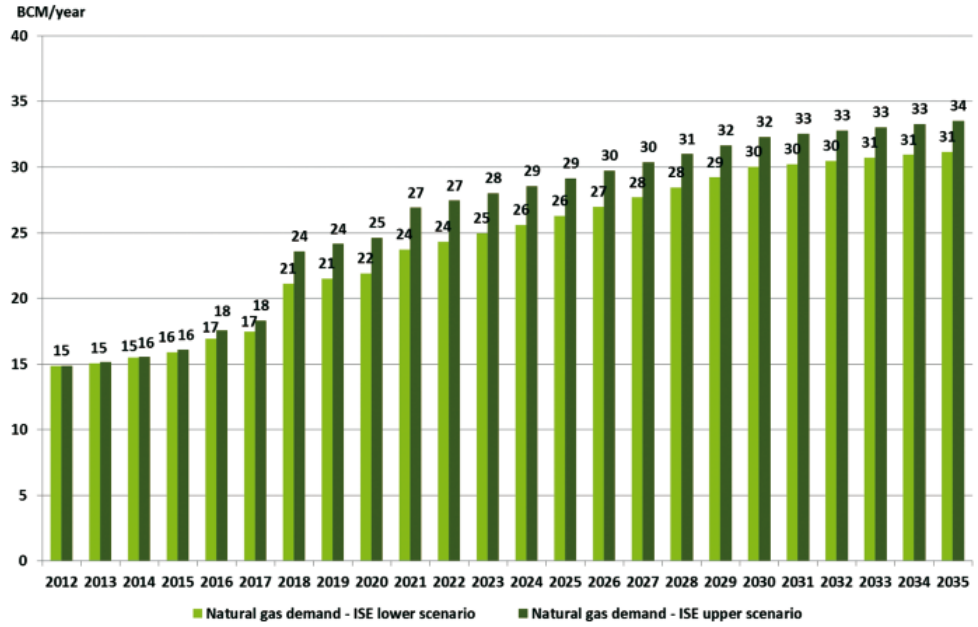

Fig. 4. Estimation of total natural gas demand on Polish market.
Source: Own calculation based on above mentioned assumptions

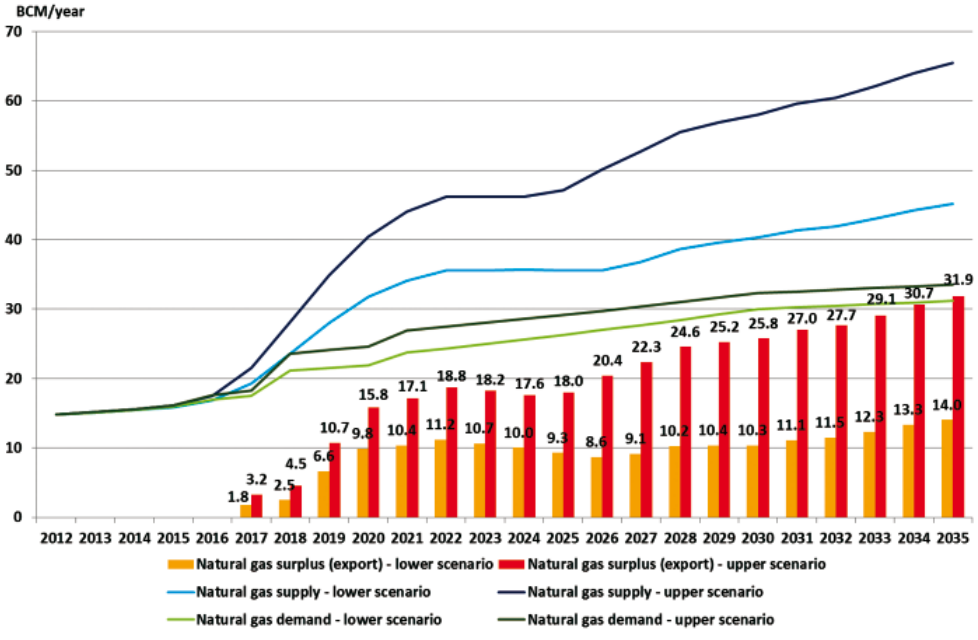

Fig. 5. Estimation of potential natural gas surplus (export requirements) on Polish market
Source: Own calculation based on ARI, EUCERS, CERA and data above mentioned assumptions

Nevertheless, in future we see possibility to export natural gas from Poland to:

- Germany and other Western Europe countries (directly or indirectly via Czech Republic),
- Southern and Central Europe countries: Slovakia, Czech Republic, Hungary and Austria (via Baumgarten hub) with potential extension to Italy and Balkan countries (Serbia, Croatia, Slovenia, Romania),
- Baltic countries: Lithuania, Latvia and Estonia,
- Scandinavia: Denmark with potential extension to Sweden,
- Former Soviet Union countries in Eastern Europe: Belarus and Ukraine.

Each route has different demand volume, structure and projections, infrastructure investment requirements as well as political and economic conditions thus different probability of success for implementation.

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