20th International INFORUM Conference

2 – 9 September 2012

Florence, Italy

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Modeling the impact of possible shale gas extraction in Poland

INSTITUTE OF ECONOMETRICS

Plan of the presentation

- What this presentation is about
- The energy of today
- The energy of tomorrow
- Scenarios of shale gas development up to 2035
- Conclusion and future work

What this presentation is about

Project financed by National Scientific Center:

The prospect of exploitation of shale gas deposits in Poland in light of the "resource curse" concept.

The presentation

- **include**: first part of introductory study to the project
- **does not include**: second part more about modelling. Not ready yet. No information about specificity of Poland (in future work)

Sources estimates and forecasts base on publications by:

- ARI - Advanced Resources Agency Inc
- EIA - US Energy Information Administration
- IEA – International Energy Agency (OECD)

The energy of today

Determinants of primary energy consumption - demand side

$$En = \frac{En}{GDP} \cdot \frac{GDP}{pop} \cdot Pop = ei \cdot wth \cdot Pop$$

where

En – energy use

GDP – Gross Domestic Product

Pop – **population**

ei – **energy intensity**

wth – **wealth** (GDP per capita)

The energy of today

Determinants of primary energy consumption – supply side

$$En = (Coal + Oil + Gas) + Nuc + Ren = NonR + Nuc + Ren$$

Problems of non-renevables

- **depletion** of fossil fuels deposits

  Types of reserves (according to the level of confidence of estimates)
  - *proven* (proved)
  - *recoverable*
  - *probable* (indicated)
  - *possible*

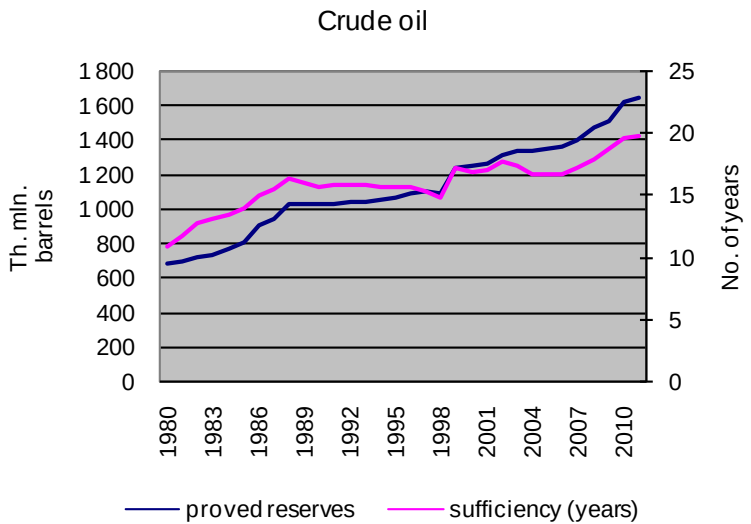
- **pollution** related to use of fossil fuels

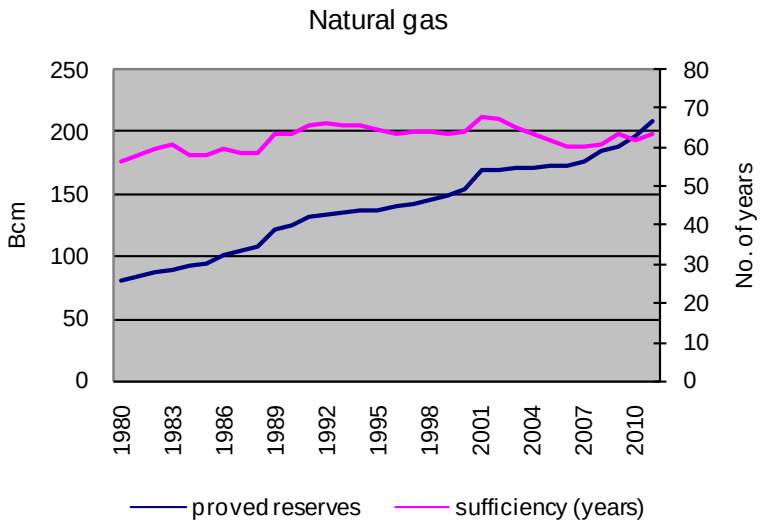
  emission coefficients
  - gas (1)
  - oil (1.40)
  - coal(1.78)

The energy of today

Determinants of primary energy consumption - supply side

Reserves of natural gas and oil

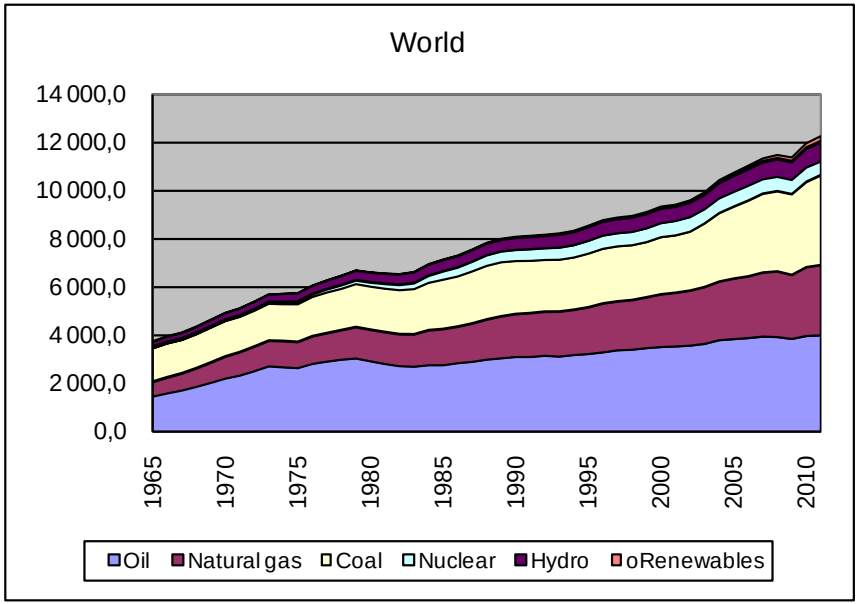


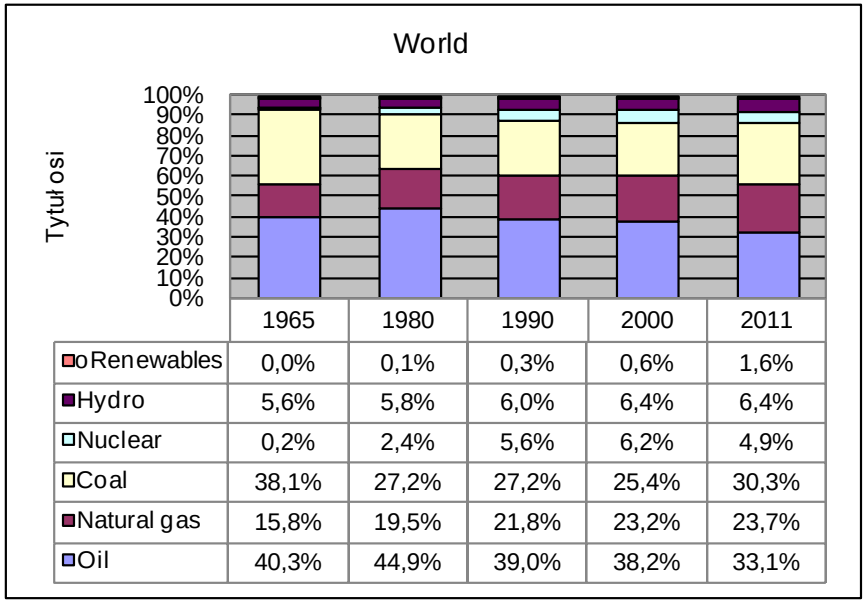


Source: Author's elaboration based on BP report

The energy of today

Level and structure of primary energy demand



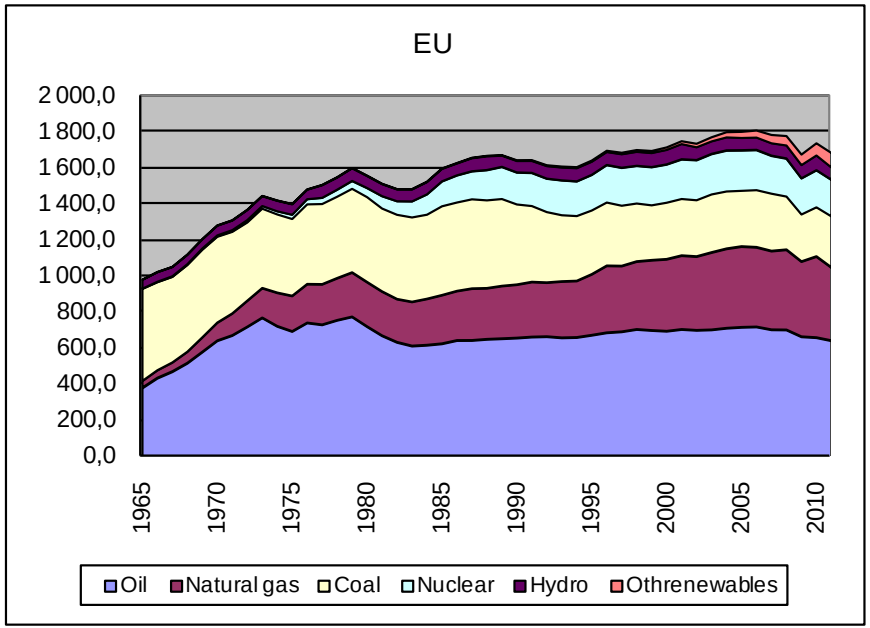


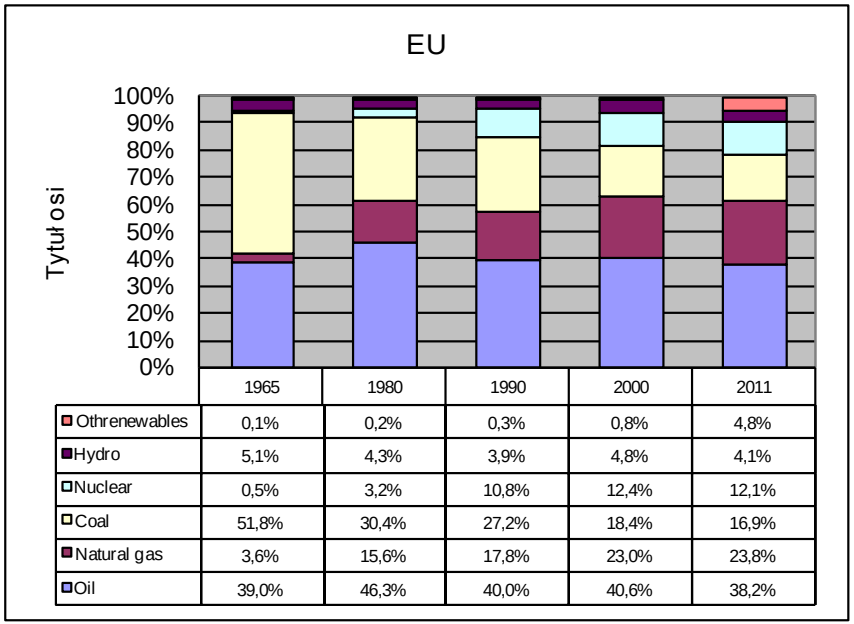
	1965	1980	1990	2000	2011
oRenewables	0,0%	0,1%	0,3%	0,6%	1,6%
Hydro	5,6%	5,8%	6,0%	6,4%	6,4%
Nuclear	0,2%	2,4%	5,6%	6,2%	4,9%
Coal	38,1%	27,2%	27,2%	25,4%	30,3%
Natural gas	15,8%	19,5%	21,8%	23,2%	23,7%
Oil	40,3%	44,9%	39,0%	38,2%	33,1%

Source: Author's elaboration based on BP report

The energy of today

Level and structure of primary energy demand



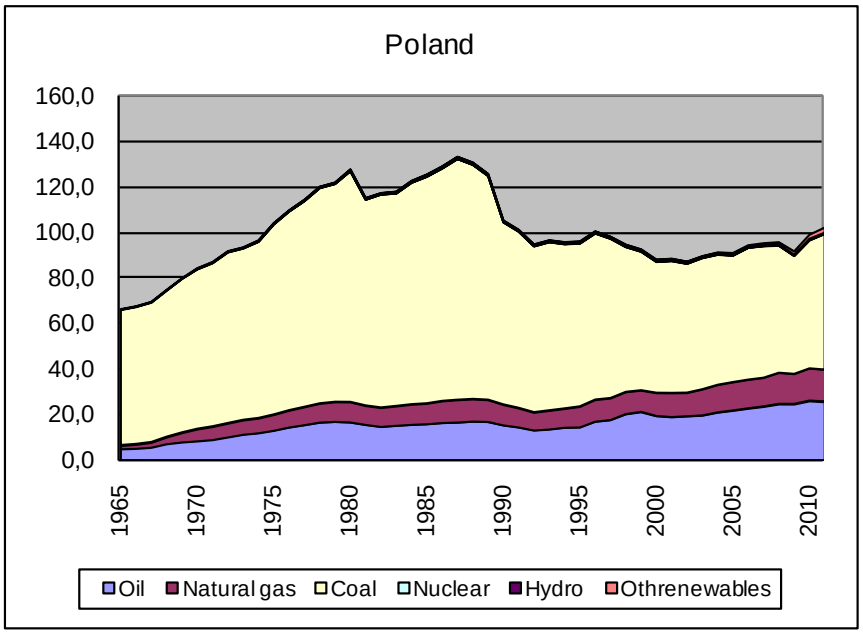


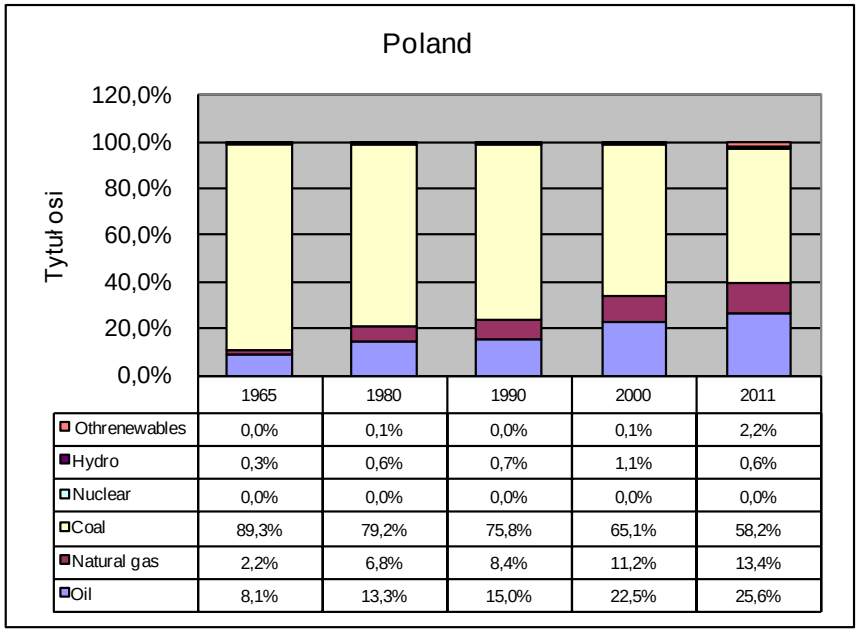
	1965	1980	1990	2000	2011
Othrenewables	0,1%	0,2%	0,3%	0,8%	4,8%
Hydro	5,1%	4,3%	3,9%	4,8%	4,1%
Nuclear	0,5%	3,2%	10,8%	12,4%	12,1%
Coal	51,8%	30,4%	27,2%	18,4%	16,9%
Natural gas	3,6%	15,6%	17,8%	23,0%	23,8%
Oil	39,0%	46,3%	40,0%	40,6%	38,2%

Source: Author's elaboration based on BP report

The energy of today

Level and structure of primary energy demand





	1965	1980	1990	2000	2011
Othrenewables	0,0%	0,1%	0,0%	0,1%	2,2%
Hydro	0,3%	0,6%	0,7%	1,1%	0,6%
Nuclear	0,0%	0,0%	0,0%	0,0%	0,0%
Coal	89,3%	79,2%	75,8%	65,1%	58,2%
Natural gas	2,2%	6,8%	8,4%	11,2%	13,4%
Oil	8,1%	13,3%	15,0%	22,5%	25,6%

Source: Author's elaboration based on BP report

Fossil or not fossil: That is the question

The energy of tomorrow

A golden age of gas - why gas?

Why gas?

- high calorific value
- easy of combustion
- ease adjustment of fuel flow
- relatively small carbon emissions
- easy of transport

The energy of tomorrow

A golden age of gas – gas reserves

Estimated shale gas technically recoverable resources for selected basins in 32 countries, compared to existing reported reserves, production and consumption during 2009, sufficiency of reserves

		2009 Natural Gas Market			Proved NG Reserves	Technically Recoverable Shale Gas Resources (Ru)		Sufficiency of reserves (ceteris paribus)			
		Prodction (P)	Consum-ption (C)	(C-P)/C				Exporters (years of production)		Importers (years of	
		Bcm	Bcm	%	Bcm	Bcm	% of total	Rc/P	(Rc+Ru)/P	Rc/C	(Rc+Ru)/C
Europe	France	0.0	49.0	98%	0	5 097	2.7%	-	-	0	104
	Germany	14.4	92.6	84%	176	227	0.1%	-	-	2	4
	Netherlands	79.0	48.7	-62%	1 388	481	0.3%	18	24	-	-
	Norway	103.4	4.5	-2156%	2 039	2 350	1.3%	20	42	-	-
	U.K.	59.2	88.1	33%	255	566	0.3%	-	-	3	9
	Denmark	8.5	4.5	-91%	59	651	0.3%	7	84	-	-
	Sweden	0.0	1.1	100%	0	1 161	0.6%	-	-	0	1025
	Poland	5.9	16.4	64%	164	5 295	2.8%	-	-	10	332
	Turkey	0.8	35.1	98%	6	425	0.2%	-	-	0	12
	Ukraine	20.4	44.2	54%	1 104	1 189	0.6%	-	-	25	52
	Lithuania	0.0	2.8	100%	0	113	0.1%	-	-	0	40
	Other	13.6	26.9	50%	77	538	0.3%	-	-	3	23
North America	US	583.3	645.6	10%	7 716	24 409	13.0%	-	-	12	50
	Canada	159.4	85.2	-87%	1 756	10 987	5.9%	11	80	-	-
	Mexico	50.1	60.9	18%	340	19 284	10.3%	-	-	6	322
Total of the above area		1 503.6	1 557.4	-3%	28 345	**187 514**	100.0%	19	144	-	-
Total world		3 015.7	3 021.4	0%	**187 146**			-	-	-	-

Source: EIA 2011and own calculations

The energy of tomorrow

A golden age of gas – gas reserves (cont.)

Estimated shale gas technically recoverable resources for selected basins in 32 countries, compared to existing reported reserves, production and consumption during 2009, sufficiency of reserves

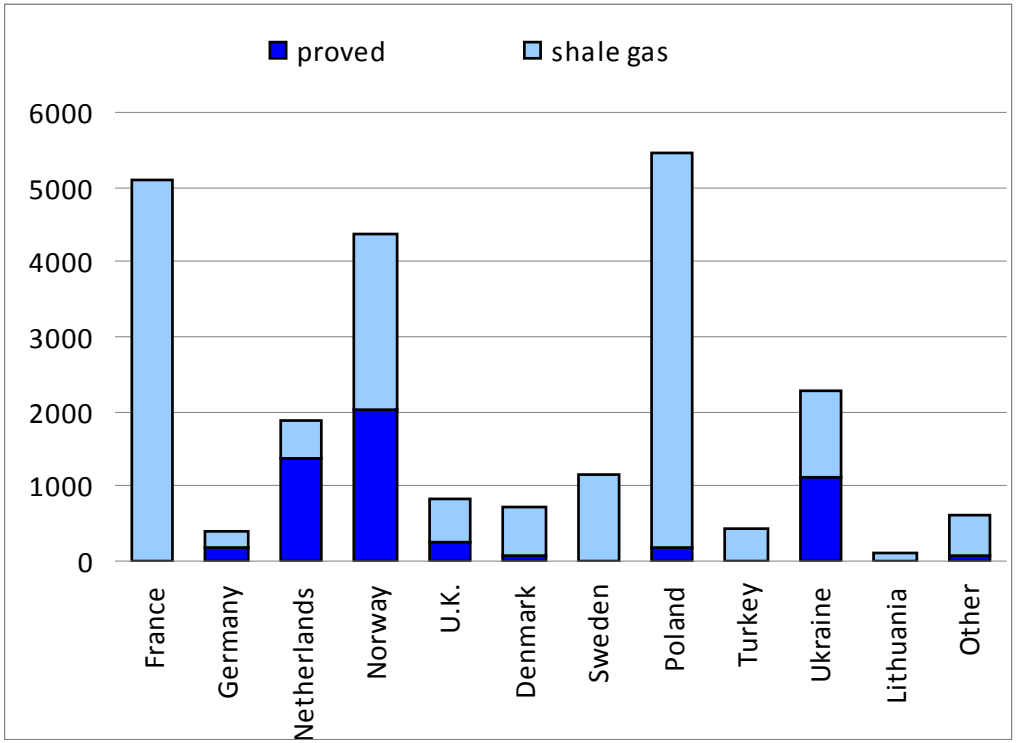
		2009 Natural Gas Market			Proved NG Reserves	Technically Recoverable Shale Gas Resources (Ru)		Sufficiency of reserves (ceteris paribus)			
		Prodction (P)	Consum-ption (C)	(C-P)/C				Exporters (years of production)		Importers (years of	
		Bcm	Bcm	%	Bcm	Bcm	% of total	Rc/P	(Rc+Ru)/P	Rc/C	(Rc+Ru)/C
Asia	China	83.0	87.2	5%	3 030	36 104	19.3%	-	-	35	449
	India	40.5	53.0	24%	1 073	1 784	1.0%	-	-	20	54
	Pakistan	38.5	38.5	0.0	841	1 444	0.8%	-	-	-	
Australia		47.3	30.9	-52%	3 115	11 213	6.0%	66	303	-	
Africa	South Arfrica	2.0	5.4	63%	0	13 734	7.3%	-	-	0	2553
	Libya	15.9	5.9	-165%	1 549	8 212	4.4%	98	616	-	
	Tunisia	3.7	4.8	26%	65	510	0.3%	-	-	14	119
	Algeria	81.6	28.9	-183%	4 502	6 541	3.5%	55	135	-	
	Morocco	0.0	0.6	90%	3	311	0.2%	-	-	5	555
	Western Sahara	0.0	0.0	0.0	0	198	0.1%	-	-	-	
	Mauritania	0.0	0.0	0.0	28	0	0.0%	-	-	-	
South America	Venezuela	18.4	20.1	9%	5 066	311	0.2%	-	-	252	267
	Colombia	10.5	8.8	-21%	113	538	0.3%	11	62	-	
	Argentina	41.3	43.0	4%	379	21 917	11.7%	-	-	9	518
	Brazil	10.2	18.7	45%	365	6 400	3.4%	-	-	20	362
	Chile	1.4	2.8	52%	99	1 812	1.0%	-	-	35	675
	Uruguay	0.0	0.0		0	595	0.3%	-	-	-	
	Paraguay	0.0	0.0		0	1 756	0.9%	-	-	-	
	Bolivia	12.7	2.8	-346%	750	1 359	0.7%	59	166	-	
Total of the above area		1 503.6	1 557.4	-3%	28 345	**187 514**	100.0%	19	144	-	
Total world		3 015.7	3 021.4	0%	**187 146**			-	-	-	

Source: EIA 2011and own calculations

The energy of tomorrow

A golden age of gas – reserves of gas in Europe

Reserves of gas in Europe



Source: Author's elaboration based on EIA 2011

The energy of tomorrow

A golden age of gas – recoverable reserves of gas?

Remaining technically recoverable resources of gas by type and region, end 2011 (tcm)

	Total	Conven-tional	Unconventional				Unconv share (%)
				Tight	Shale	Coalbed	
E. Europe/Eurasia	174	131	43	10	12	20	24.7
Middle East	137	125	12	8	4	-	8.8
Asia/Pacific	128	35	93	20	57	16	72.7
OECD Americas	122	45	77	12	56	9	63.1
Africa	74	37	37	7	30	0	50.0
Latin America	71	23	48	15	33	-	67.6
OECD Europe	45	24	21	3	16	2	46.7
World	752	421	331	76	208	47	44.0

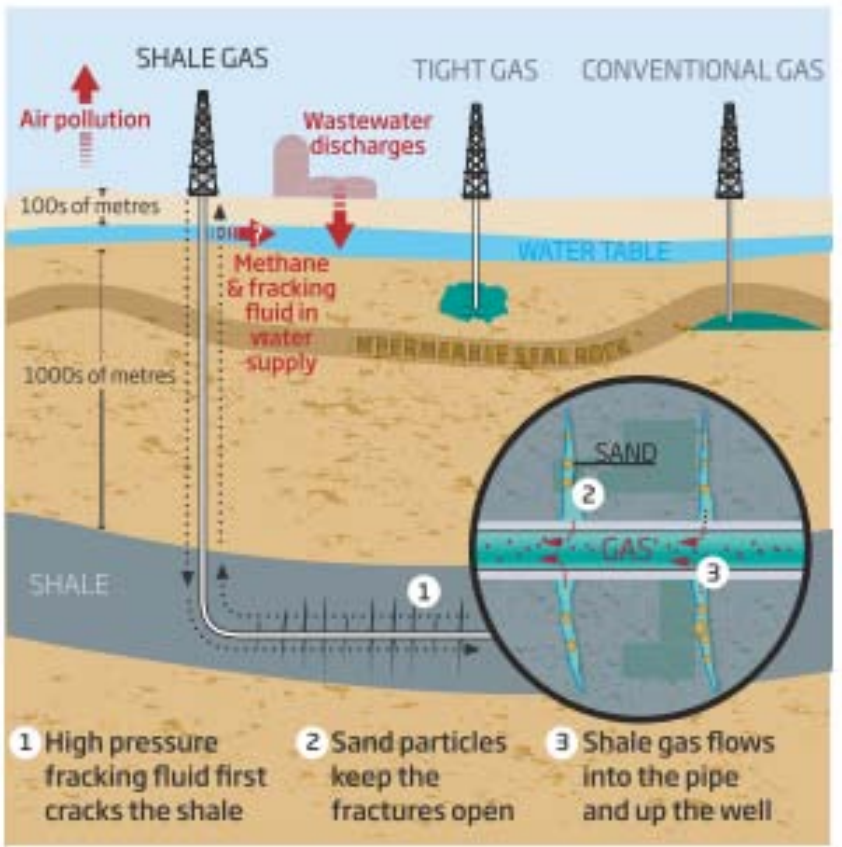
Source: IEA 2012

The energy of tomorrow

A golden age of gas – methods of extraction of shale gas

Technical innovations that led to breakthroughs in shale gas extraction
- horizontal drilling
- hydraulic fracturing

Shale gas production techniques and possible environmental hazards



Source: Aldhous 2012

The energy of tomorrow

A golden age of gas – risks of the possible revolution

Business risks

- resource size and structure
- access to resources
- the fiscal and regulatory framework
- availability of expertise and technology
- existing infrastructure access to it
- market and pricing
- water availability

Risks of adverse impact

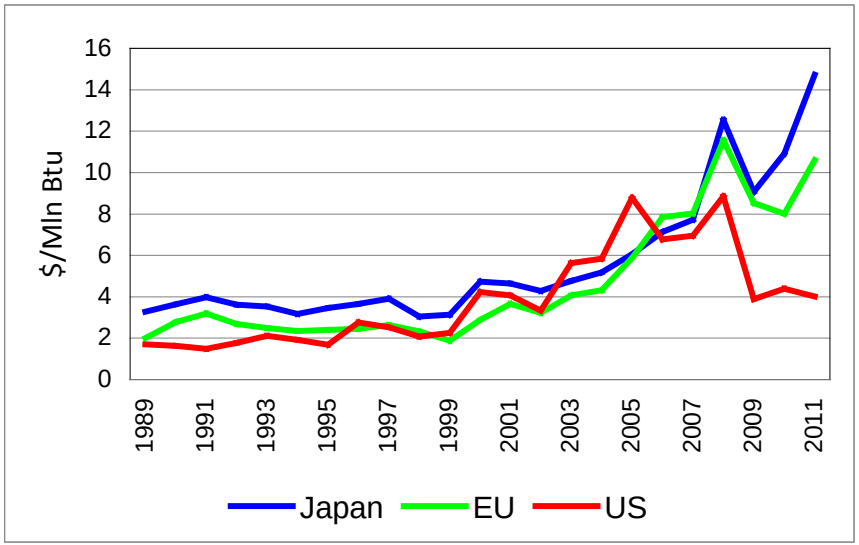
- emissions
- excessive water use
- water contamination
- more noise
- adverce social impact
- …….

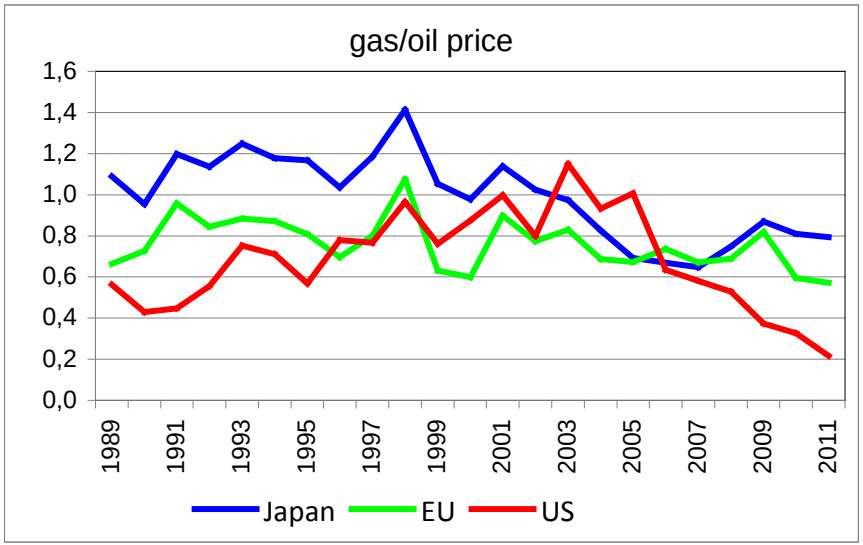
The energy of tomorrow

A golden age of gas – political risks

Eksporters will defend their positions in energy markets

Prices of gas and gas/oil prices in Japan, EU and US





Source: Author's elaboration based on BP report

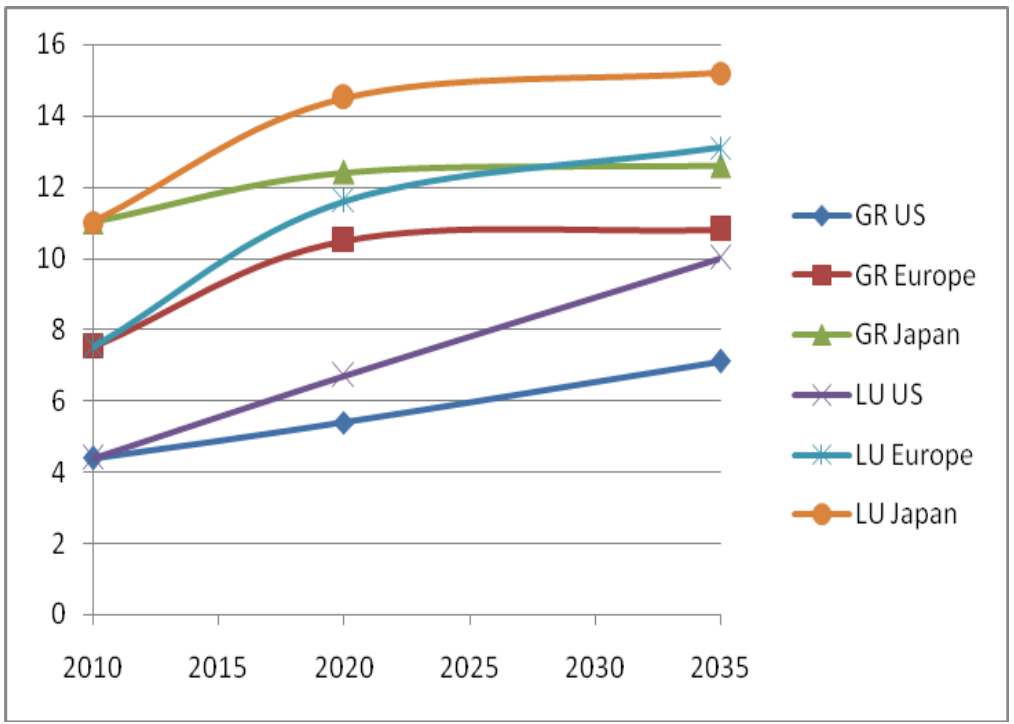
Scenarios of shale gas development up to 2035

Assumptions

Scenarios of development of world energy sector by 2035

- Golden Rules (GR
- Low Unconventional (LU)

Natural gas price assumption (2010 dollars per 1 Mbtu)



Source: Author's elaboration based on IEA 2012

Scenarios of shale gas development up to 2035

Assumptions

Natural gas price assumption by case

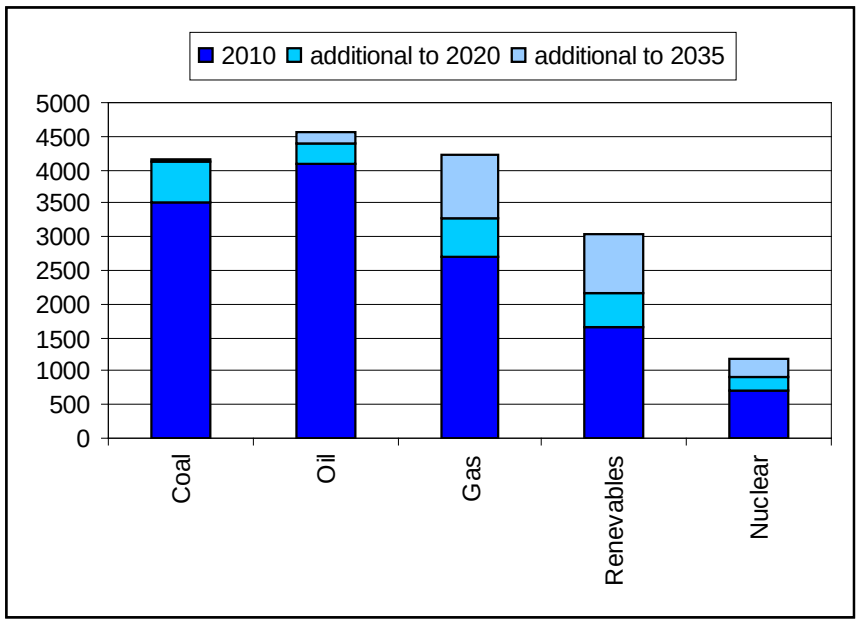
		2010 US dollars per Mbtu			2010=1	GR=1	US=1	
		2010	2020	2035		2035	2010	2035
Unted States	GR	4.4	5.4	7.1	1.61	1.41	1.00	1.00
	LU	4.4	6.7	10	2.27			1.00
Europe	GR	7.5	10.5	10.8	1.44	1.21	1.70	1.52
	LU	7.5	11.6	13.1	1.75			1.31
Japan	GR	11.0	12.4	12.6	1.15	1.21	2.50	1.77
	LU	11.0	14.5	15.2	1.38			1.52

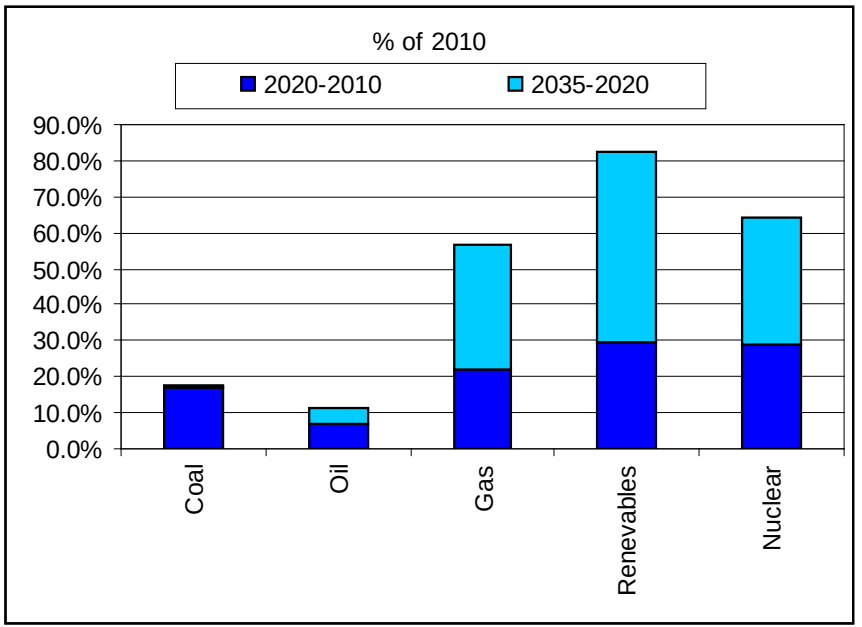
Source: Author's elaboration based on IEA 2012

Scenarios of shale gas development up to 2035

Results

World primary energy demand by fuel in the Golden Rules Case (Mtoe)





Source: IEA 2012

Scenarios of shale gas development up to 2035

Assumptions

Natural gas production by region in GR scenario (bcm)

	2010		2020		2035		2010-2035**
	Total	Share of unconv*	Total	Share of unconv*	Total	Share of unconv*	
E.Europe/Eurasia	**826**	**3%**	**922**	**3%**	**1 123**	**6%**	**1.2%**
Russia	637	3%	718	4%	784	6%	0.8%
Asia	**431**	**3%**	**643**	**20%**	**984**	**56%**	**3.4%**
China	97	12%	246	45%	473	83%	6.6%
India	51	2%	75	21%	111	80%	3.2%
Indonesia	88	0%	106	2%	153	37%	2.2%
Middle East	**474**	**0%**	**581**	**1%**	**776**	**2%**	**2.0%**
Africa	202	1%	264	1%	397	5%	2.7%
Algeria	79	0%	101	1%	135	8%	2.2%
Latin America	**159**	**2%**	**226**	**4%**	**286**	**22%**	**2.4%**
Argentina	42	9%	53	9%	72	48%	2.1%
World	**3 276**	**14%**	**3 982**	**21%**	**5 112**	**32%**	**1.8%**
EU	**201**	**1%**	**160**	**7%**	**165**	**47%**	**-0.8%**
Poland (share in total of EU	3.0%		5.6%		20.6%		

Source: IEA 2012

Scenarios of shale gas development up to 2035

Results

Natural gas production by region in GR scenario (bcm)

	2010		2020		2035		2010-2035**
	Total	Share of unconv*	Total	Share of unconv*	Total	Share of unconv*	
OECD	**1 183**	**36%**	**1 347**	**49%**	**1 546**	**60%**	**1.1%**
Americas	**821**	**51%**	**954**	**62%**	**1 089**	**68%**	**1.1%**
Canada	160	39%	174	57%	177	67%	0.4%
Mexico	50	3%	52	12%	87	43%	2.2%
United States	609	59%	726	67%	821	71%	1.2%
Europe	**304**	**0%**	**272**	**4%**	**285**	**27%**	**-0.3%**
Poland	6	11%	9	37%	34	90%	7.1%
Asia Oceania	**58**	**9%**	**121**	**49%**	**172**	**64%**	**4.5%**
Australia	49	11%	115	51%	170	65%	5.1%
Non-OECD	**2 094**	**2%**	**2 635**	**7%**	**3 567**	**20%**	**2.2%**
World	**3 276**	**14%**	**3 982**	**21%**	**5 112**	**32%**	**1.8%**
EU	**201**	**1%**	**160**	**7%**	**165**	**47%**	**-0.8%**
Poland (share in total of EU	3.0%		5.6%		20.6%		

Source: IEA 2012

Scenarios of shale gas development up to 2035

Results

Natural gas indicators in the European Union by case

	Golden Rules			Low conventional		GR-LO
	2010	2020	2035	2020	2035	
Concumption (bcm)	547	592	645	562	594	51
Production (bcm)	201	160	165	139	84	81
Unconventional	1	11	77	0	0	77
Unconv. share	1%	7%	47%	0%	0%	47%
Cumulative investment in upstream gas		434		235		199
Unconventional		181				181
Net imports (bcm)	346	432	480	423	510	-30
Imports as a share of demand	63%	73%	74%	75%	86%	-11%
Share of gas in the energy mix	26%	28%	30%	26%	28%	2%
Total energy related to CO2 emissions (millions tonnes)	3633	3413	2889	3414	2873	16

* Difference between the Golden Rules Case and the Low Unconventional Case.

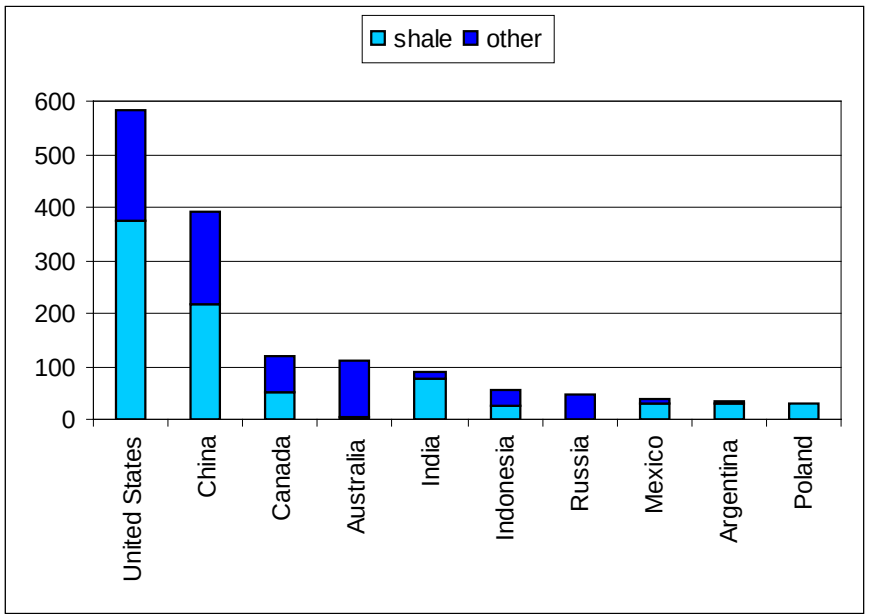
** Investment figures arein billions of year-2010 dollars.

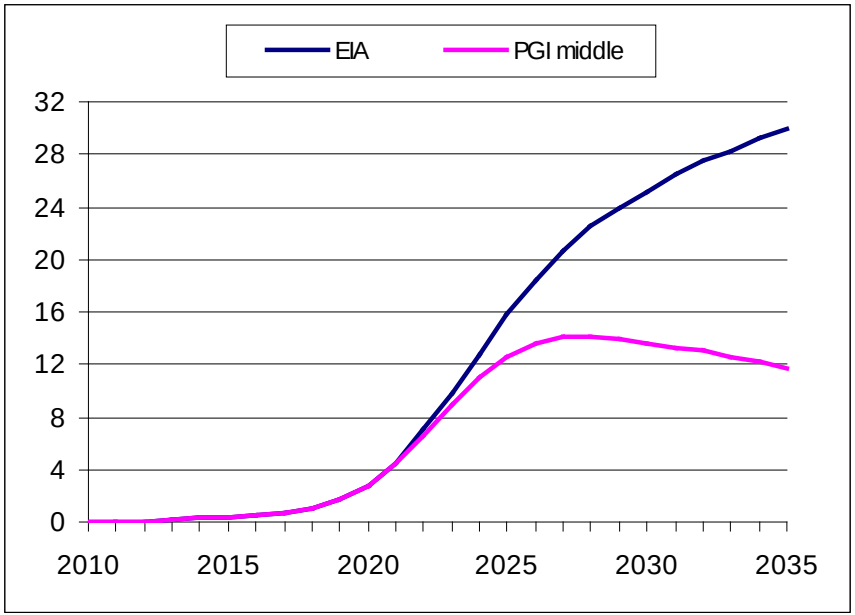
Source: IEA 2012

Scenarios of shale gas development up to 2035

Results

Ten largest unconventional gas producer in the GR scenario and impact of different resource assessments on projected shale gas production in Poland (production in bcm)





Source : IEA 2012

Conclusions and future work

- Fossil fuels are the fundament of the energy sector in the world, but their resources are depleting.
- For the next few decades the greatest hope is associated with natural gas from unconventional resources, paricularly shale gas.
- Extracting of shale gas is connected with some threats
- If optimistic assumptions are met, Poland around 2030 will become a net exporter of of gas.
- To assess possible consequaences of shale gas extraction in Poland IMPEC model should be revised. A new branch should be explicitelly put into the io table by adding the row and the oolumn.
- Detailed scenarios for investment outlays should be prepared.