Brandenburg
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Prospects for Shale Gas Exploration in Europe

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Contents:

Unconventional wisdom

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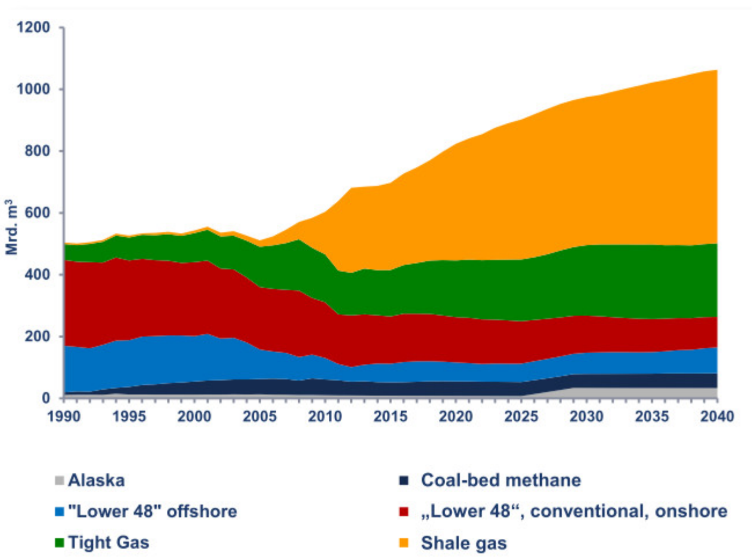
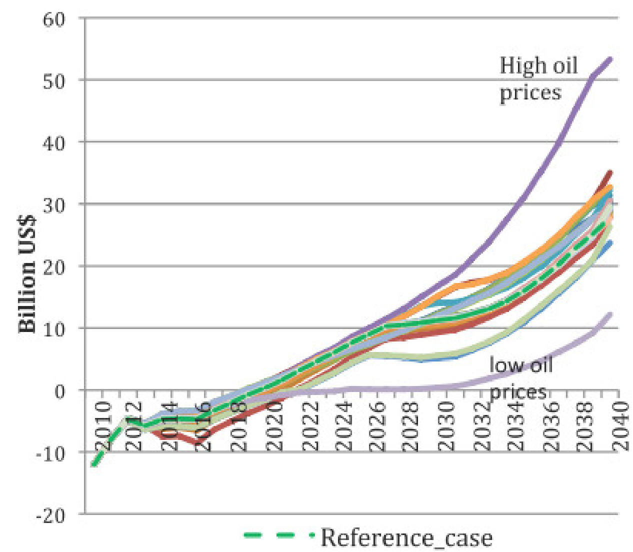


- ✓ In 2012 US produced 290 bcm of unconventional natural gas
- ✓ Wellhead prices for US natural gas had a sharp drop from 8 USD/Mbtu (2008) to 4 USD/Mbtu (2013)

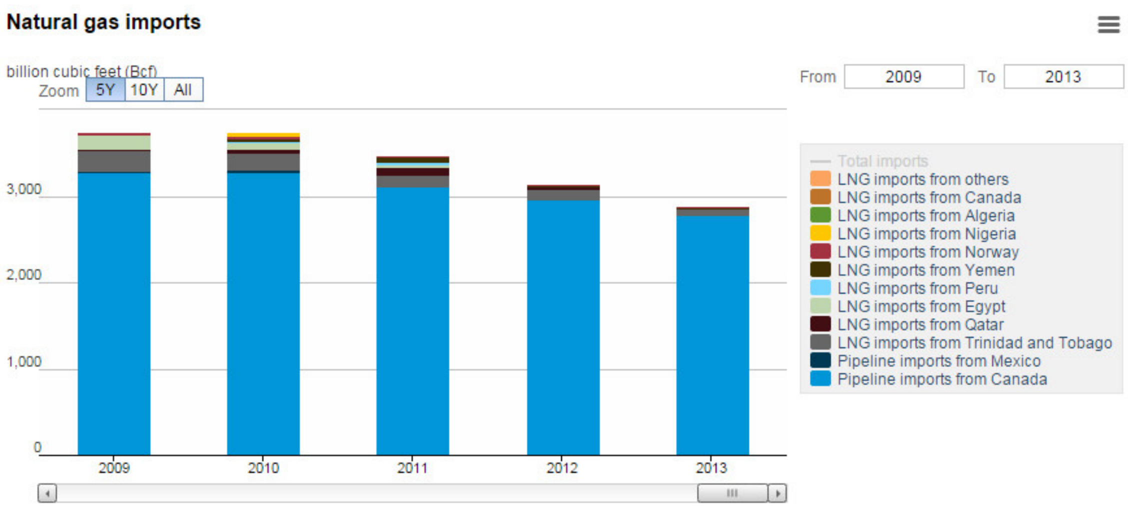


US natural gas trade balance forecasts (Spencer et al., 2013):

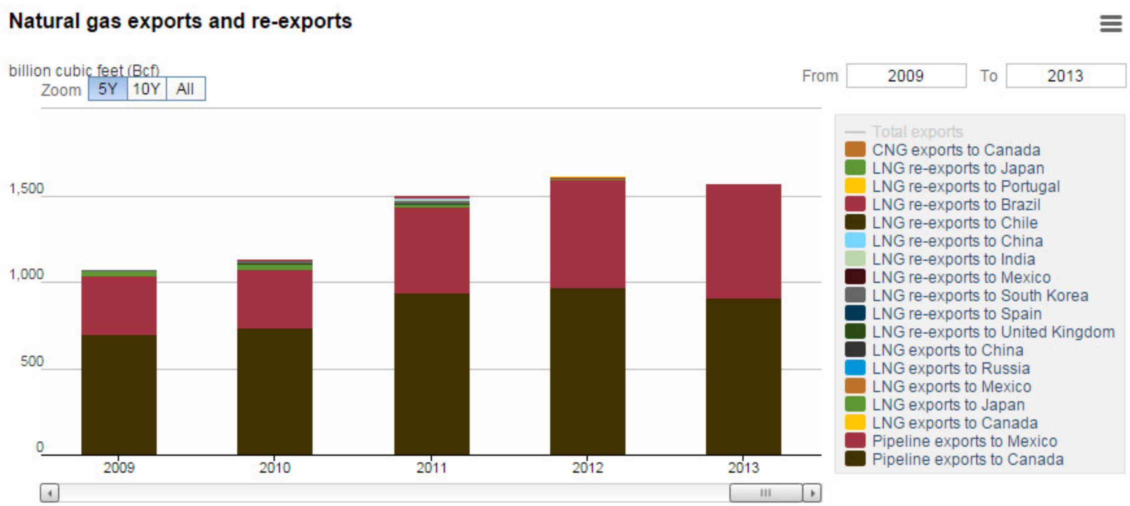
- ✓ In perspective US to become the biggest natural gas producer in the world and to change soon net status from “importer” to “exporter”

Unconventional wisdom

- ✓ LNG imports decreased by 45% from the 2012 level to 97 Bcf in 2013, the lowest level since 1998

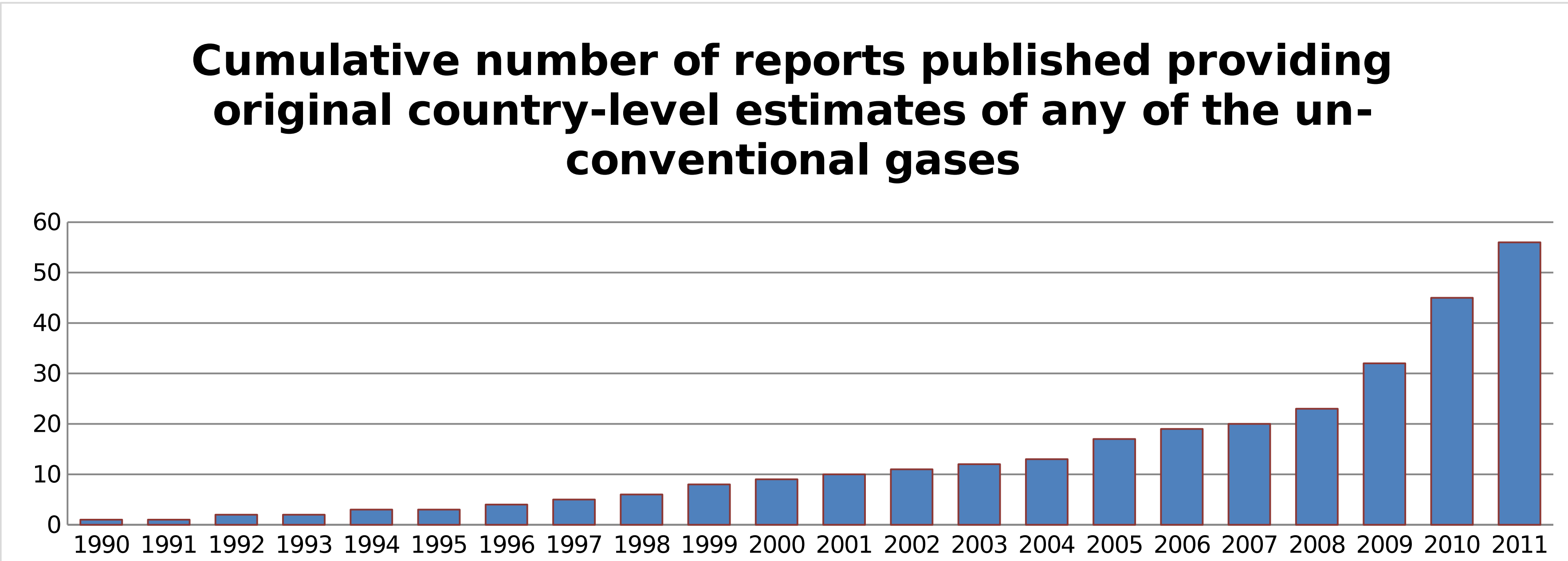


- ✓ Pipeline exports to Mexico rose by 6% to 658 Bcf (a record level).



US EIA

Rising interest all around the world



- The focus is on *original* estimates of OGIP, TRR or ERR
- “Original estimate” is the one from a source that has either *developed* the estimate itself using recognized methodologies, or *adapted* the estimate from existing sources

Pearson et al., JRC EC (2012)

Objective and questions to answer

- The objective of the study is to estimate a potential for shale gas exploration in Europe and consequent impact on natural gas market.

To what extent can shale gas production influence energy security concerns of EU (or certain member states) by

- compensating the drop of European indigenous conventional gas production?
- substituting natural gas imports?

Contents:

Major European sedimentary basins with shale gas potential

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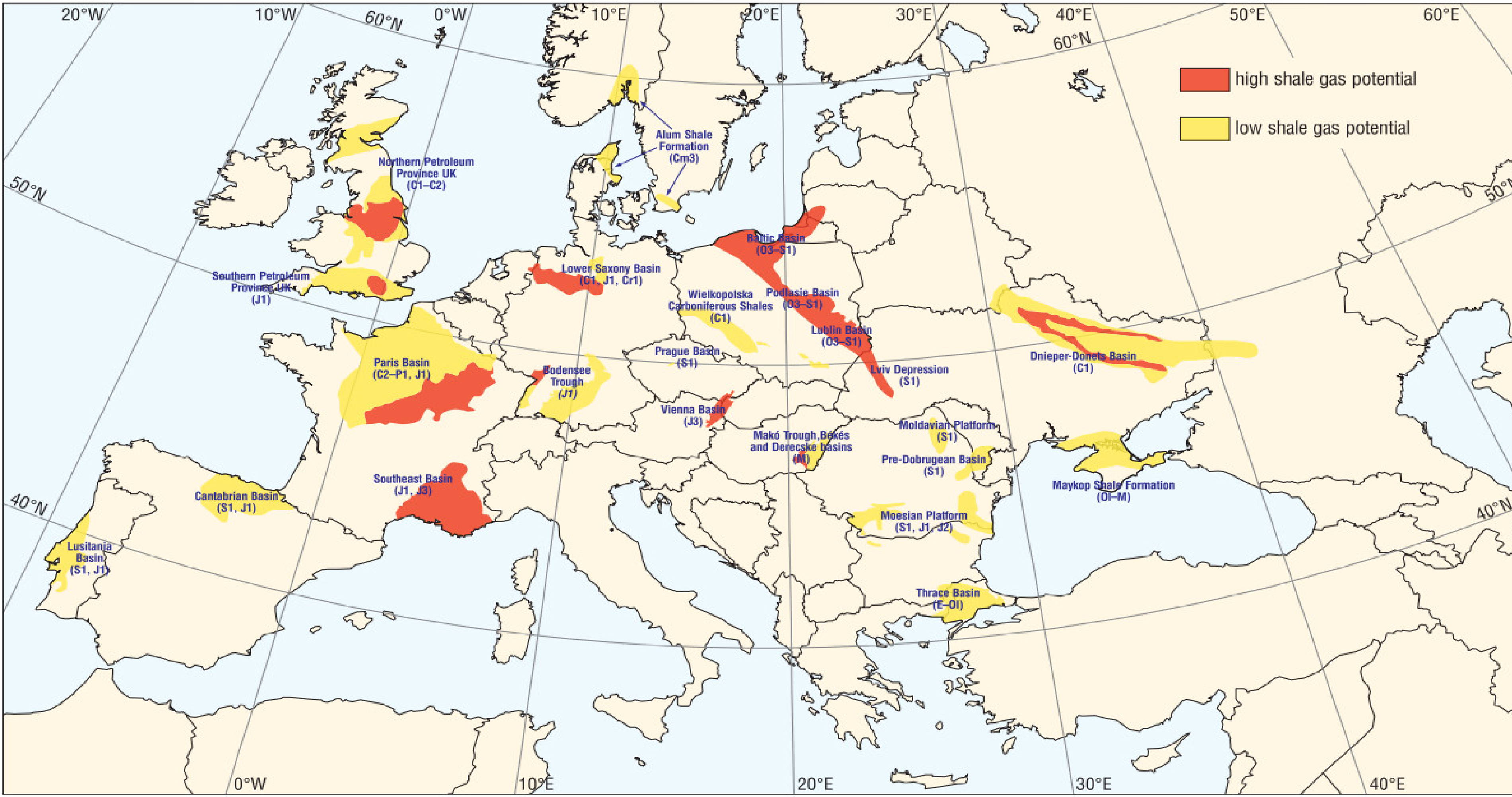
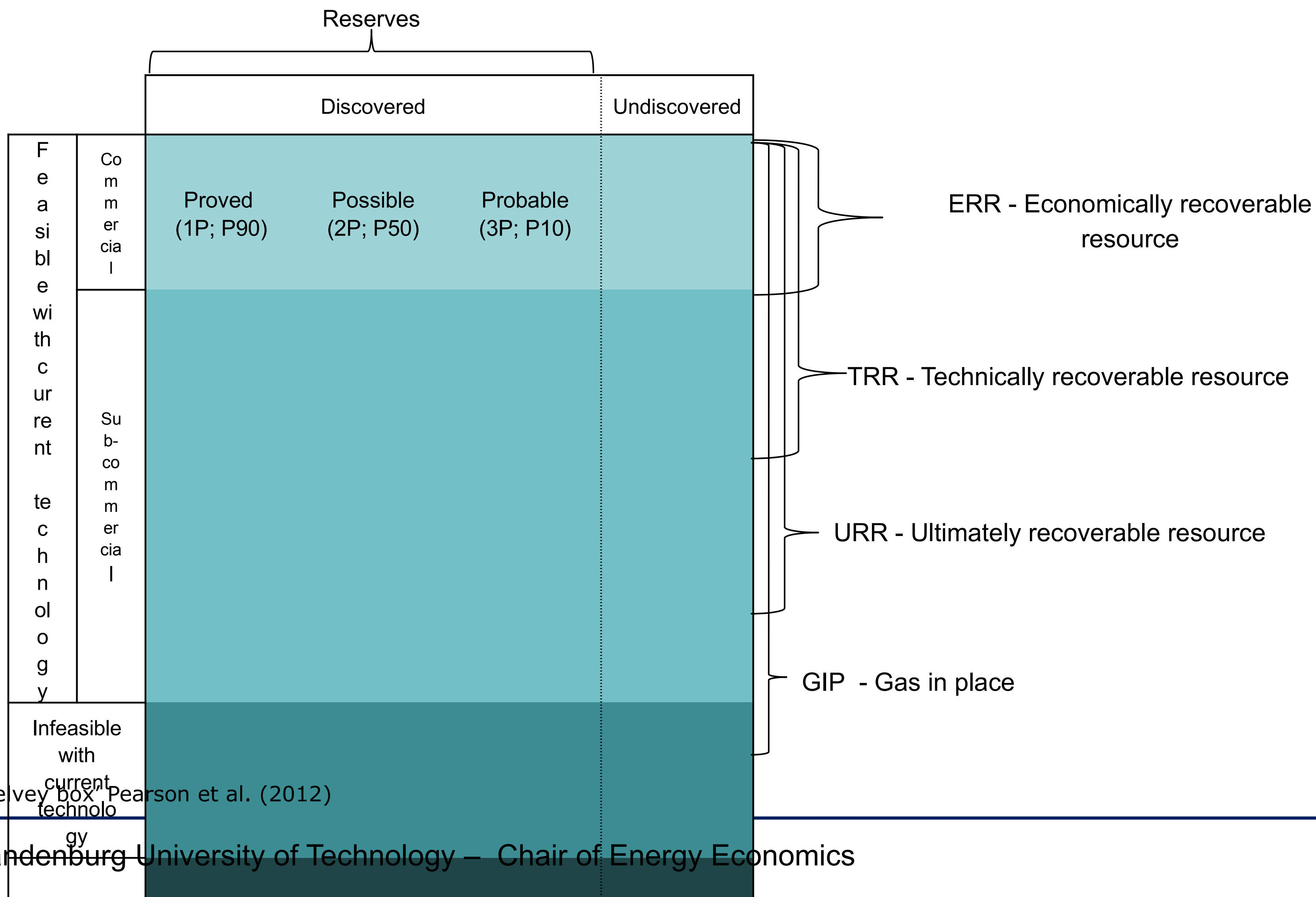


P. Karcz et al.: Compilation based on Szalay & Koncz (1993), Poprawa (2010b), Schulz et al. (2010), Kuuskraa et al. (2011), BGR (2012)

Resources and reserves



'McKelvey box' Pearson et al. (2012)

Set of basic geological parameters characterizing European shale rocks

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<table>
<tr><th>State</th><th>Basin</th><th colspan="2">Depth (m)</th><th colspan="6">TRR (TCM)</th></tr>
<tr><td rowspan="4">Poland</td><td>Baltic</td><td>1000 - 4500 [1,2]</td><td>1900 - 4800 [4]</td><td>3,65 [1]</td><td rowspan="3">0,34 -0,76 [5]</td><td colspan="2" rowspan="3">0 - 0,11 [2]</td><td>2,98 [4]</td><td rowspan="4">0,0257 [6]</td></tr>
<tr><td>Podlasie</td><td>500 - 5000 [1,2]</td><td>1820 - 4800 [4]</td><td>0,4 [1]</td><td>0,29 [4]</td></tr>
<tr><td>Lublin</td><td>1000 - 4000 [1,2]</td><td>3350 [4]</td><td>1,25 [1]</td><td>0,26 [4]</td></tr>
<tr><td>Fore Sudetic</td><td colspan="2">2400 - 4900 [4]</td><td colspan="4">n.d.</td><td>0,6 [4]</td></tr>
<tr><td>Lithuania</td><td>Baltic</td><td>1950 - 2120 [1,2]</td><td></td><td colspan="6">0,11 [1]</td></tr>
<tr><td rowspan="3">Ukraine</td><td>Lviv Depression</td><td>1000 - 1500 [1,2]</td><td></td><td colspan="3" rowspan="2">1,2 [1]</td><td colspan="3">n.d.</td></tr>
<tr><td>Dnieper-donets</td><td colspan="2">1000 - 5000 [4]</td><td colspan="3">2,15 [5]</td></tr>
<tr><td>Maykop Shales</td><td colspan="2">n.d.</td><td colspan="6">n.d.</td></tr>
<tr><td rowspan="3">Romania</td><td>Pannonian</td><td colspan="2">n.d.</td><td colspan="2" rowspan="5">0,54 [1]</td><td colspan="4">n.d.</td></tr>
<tr><td>Moldavian/ Scythian Platform</td><td colspan="2">n.d.</td><td colspan="4">0,1579 [4]</td></tr>
<tr><td>Moesian Platform</td><td rowspan="2">1800 - 4400 [1,2]</td><td rowspan="2">1500 - 5000 [4]</td><td colspan="2" rowspan="2">1,32 [4]</td><td colspan="2">n.d.</td></tr>
<tr><td>Bulgaria</td><td>Moesian Platform</td><td colspan="2">n.d.</td></tr>
<tr><td>Hungary</td><td>Pannonian</td><td colspan="2">n.d.</td><td colspan="4">n.d.</td></tr>
<tr><td>Austria</td><td>Vienna</td><td colspan="2">2000 - 8500 [1,2]</td><td colspan="6">0,425 [4]</td></tr>
<tr><td>Turkey</td><td>Thrace</td><td colspan="2">n.d.</td><td colspan="6">0,17 [1]</td></tr>
<tr><td rowspan="2">United Kingdom</td><td>North UK</td><td colspan="2">1500 - 4000 [4]</td><td colspan="6">0,71 [4]</td></tr>
<tr><td>South UK</td><td colspan="2">1200 - 1830 [4]</td><td colspan="6">0,017 [4]</td></tr>
<tr><td rowspan="2">Spain</td><td>Basque-Cantabrian</td><td colspan="2">2400 - 4420 [4]</td><td colspan="3">0,24 [4]</td><td colspan="3">1,084 [5]</td></tr>
<tr><td>Others</td><td colspan="2">n.d.</td><td colspan="6">0,893 [5]</td></tr>
<tr><td rowspan="2">France</td><td>Paris</td><td colspan="2">1200 - 5000 [4]</td><td colspan="6">3,66 [4]</td></tr>
<tr><td>South -East</td><td colspan="2">2500 - 5000 [4]</td><td colspan="3">0,21 [4]</td><td colspan="3"></td></tr>
<tr><td>Germany</td><td>Lower Saxony</td><td colspan="2">1000 - 5000 [4]</td><td colspan="3">0,48 [4]</td><td colspan="3">1,3 [5]</td></tr>
<tr><td>Netherlands</td><td>West Netherlands</td><td colspan="2">1000 - 5000 [4]</td><td colspan="3">0,73 [4]</td><td colspan="3">2,39 [5]</td></tr>
<tr><td>Sweden</td><td>Alum Shale</td><td colspan="2">1000 - 2150 [4]</td><td colspan="6">0,28 [4]</td></tr>
<tr><td>Denmark</td><td>Alum Shale</td><td colspan="2">3300 - 4600 [4]</td><td colspan="3">0,9 [4]</td><td colspan="3">0,2061 [5]</td></tr>
</table>

1. P. Karcz et al. (2011); 2. Gautier et al. (2012); 3-4. ARI (2-11, 2013); 5. National Reports*; 6. U.S. Geological Survey (2012)

TRR by country: comparison

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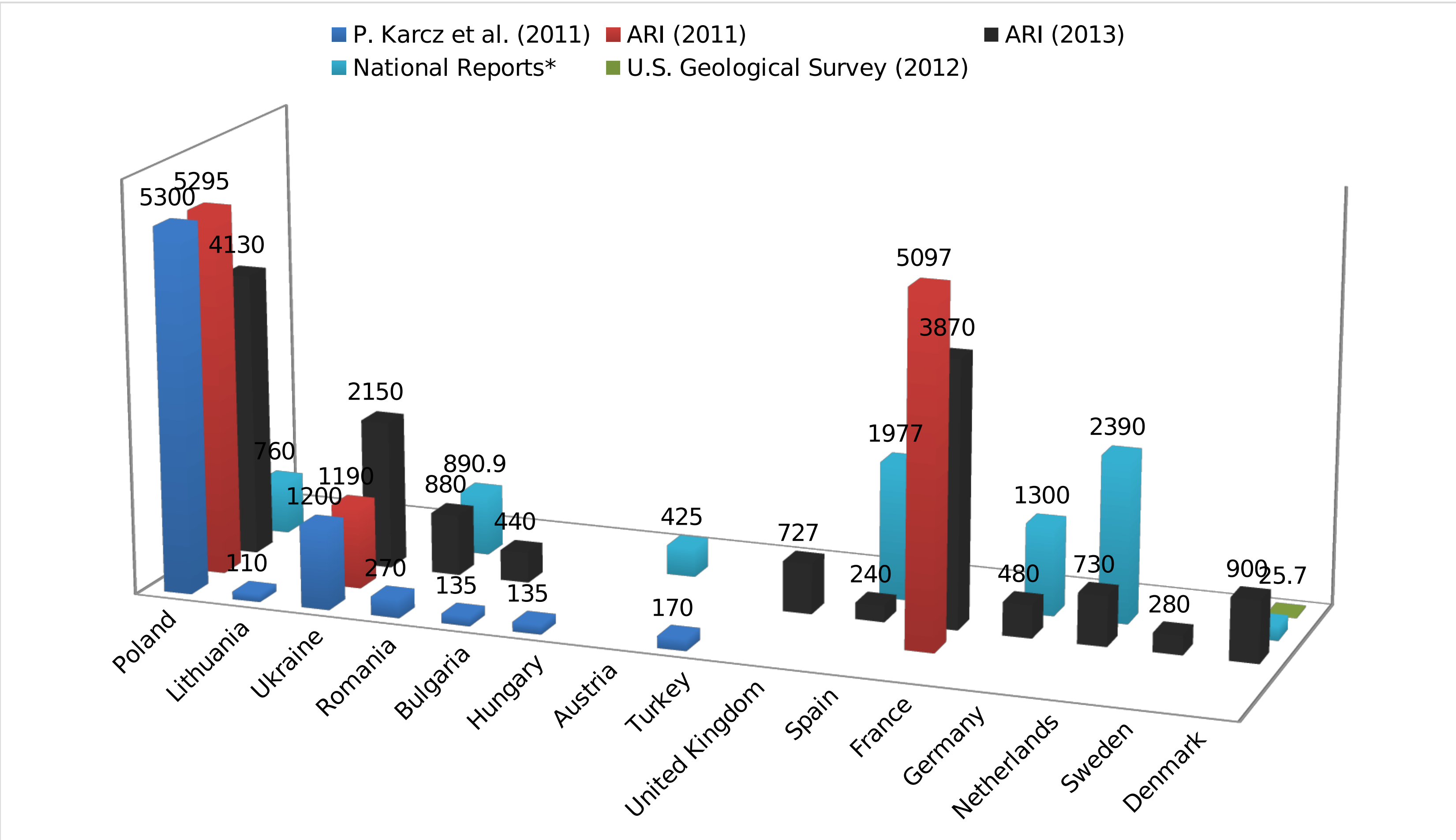

* Spain: ACIEP (2013), Germany: BGR (2012a), Netherlands: TNO (2009), Denmark: Gautier et al. (2013), Austria: OMV (2012), Poland: PIG-PIB (2012)

Countries included in a model and costs assumption

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State	Basin	Depth (m)		Costs* ($/tcm)		
				Conservative	Reference	Optimistic
				EUR 20 mcm	EUR 40 mcm	EUR 60 mcm
Poland	Baltic	1000 - 4500 [1,2]	1900 - 4800 [4]	731	365	241
	Podlasie	500 - 5000 [1,2]	1820 - 4800 [4]			
	Lublin	1000 - 4000 [1,2]	3350 [4]			
	Fore Sudetic	2400 - 4900 [4]				
Ukraine	Lviv Depression	1000 - 1500 [1,2]		562	281	185
	Dnieper-donets	1000 - 5000 [4]				
	Maykop Shales	n.d.				
Romania	Pannonian	n.d.		646	323	213
	Moldavian Scythian Platform	n.d.				
	Moesian Platform	1800 - 4400 [1,2]	1500 - 5000 [4]			
Bulgaria	Moesian Platform			646	323	213
United Kingdom	North UK	1500 - 4000 [4]		539	270	178
	South UK	1200 - 1830 [4]				
France	Paris	1200 - 5000 [4]		562	281	185
	South -East	2500 - 5000 [4]				
Germany	Lower Saxony	1500 - 5000 [4]		577	289	190

*G. Thonhauser, JRC EC (2012)

Contents:

Design of employed natural gas market model

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Model focus

- The model simulates operation and future developments of European gas sector for a middle- and long time periods

Model scope

- European, FSU, North Africa and Middle East countries
- Natural gas pipeline infrastructure
- LNG liquefaction and regasification terminals
- Storage facilities

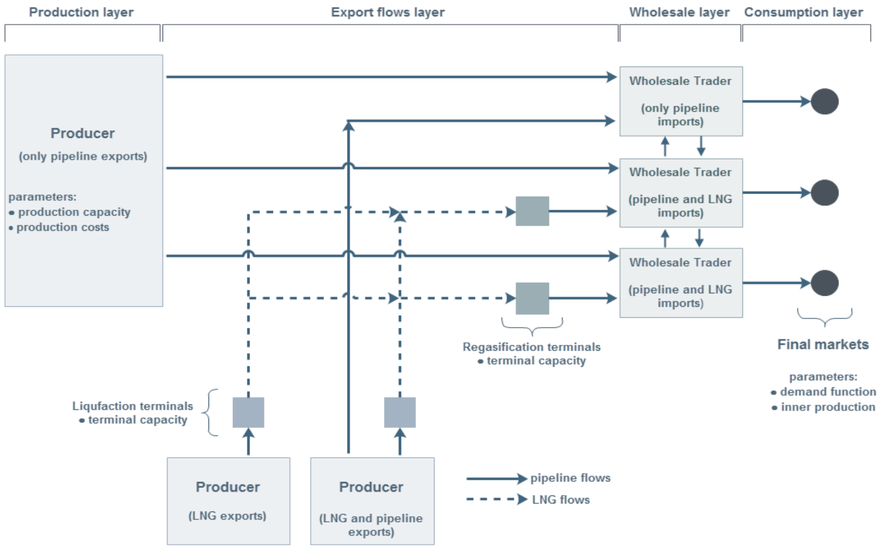
Model output

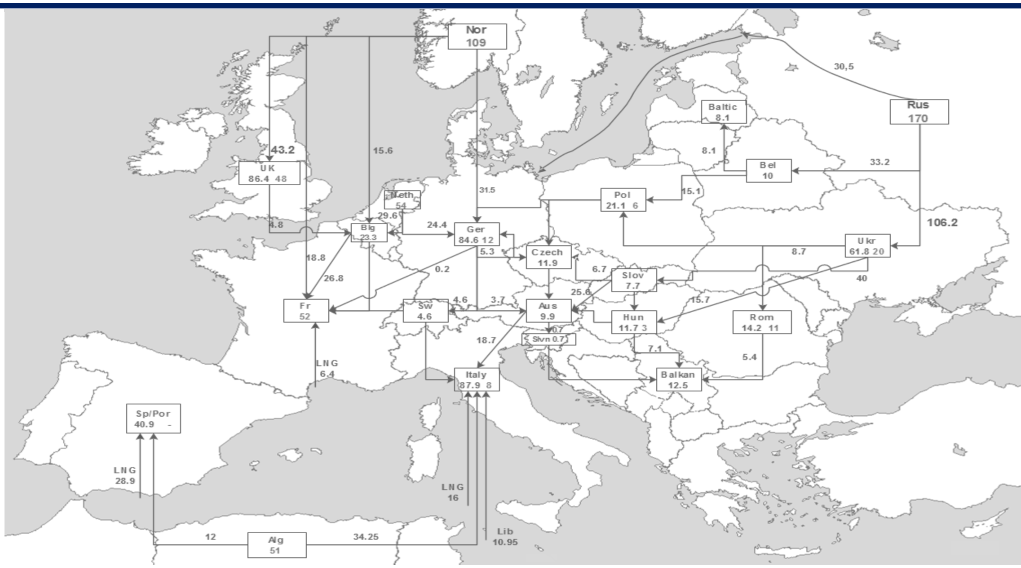
- Production&Consumption volumes
- Gas traded volumes
- Physical gas flow volumes
- Price levels for natural gas
- Seasonal storage dispatch

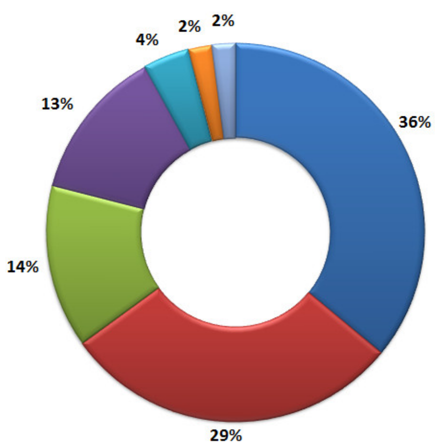
Model approach

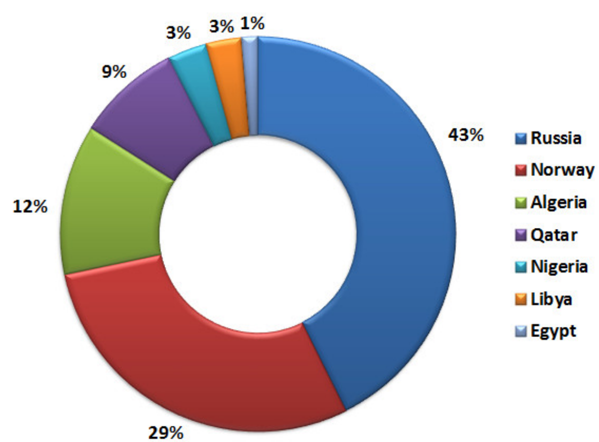
- Model formulated as a mixed complementarity problem (MCP)
- Solved in GAMS

Design of employed natural gas market model









Left-top: Model scheme

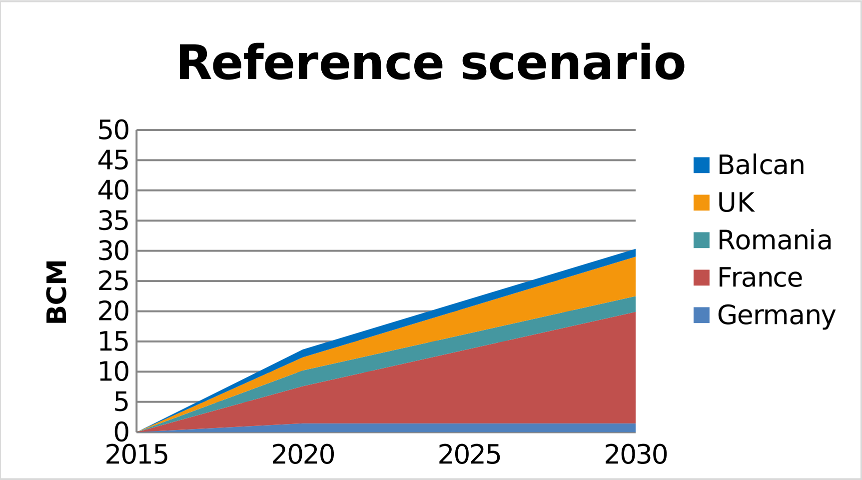
Right-top: Model output data

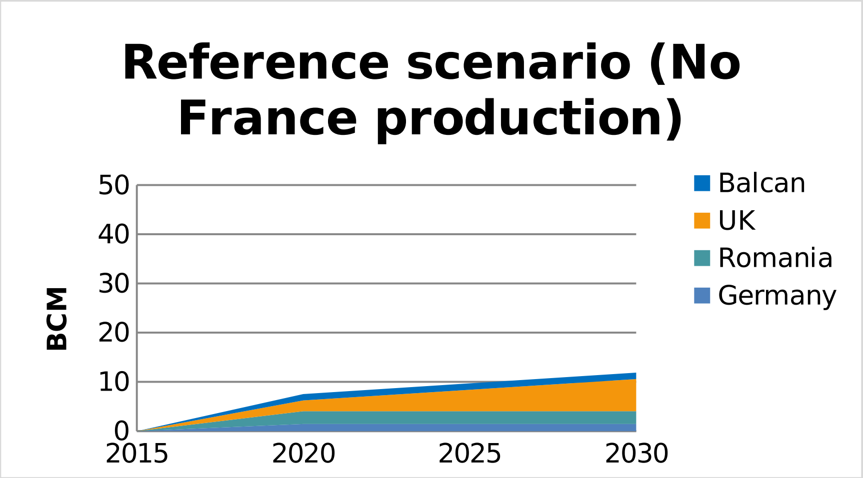
Bottom: European imports mix validation
(Left – reference data for 2013;

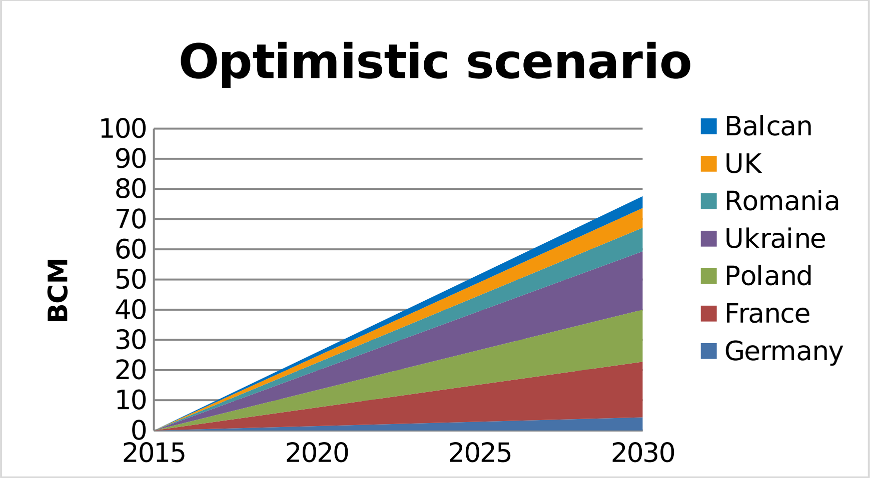
Right – model output for 2013)

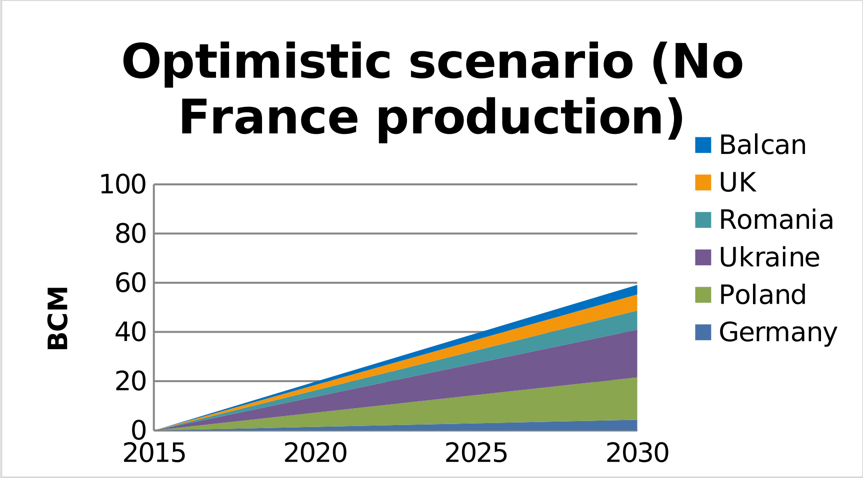
Contents:

Investments in shale gas









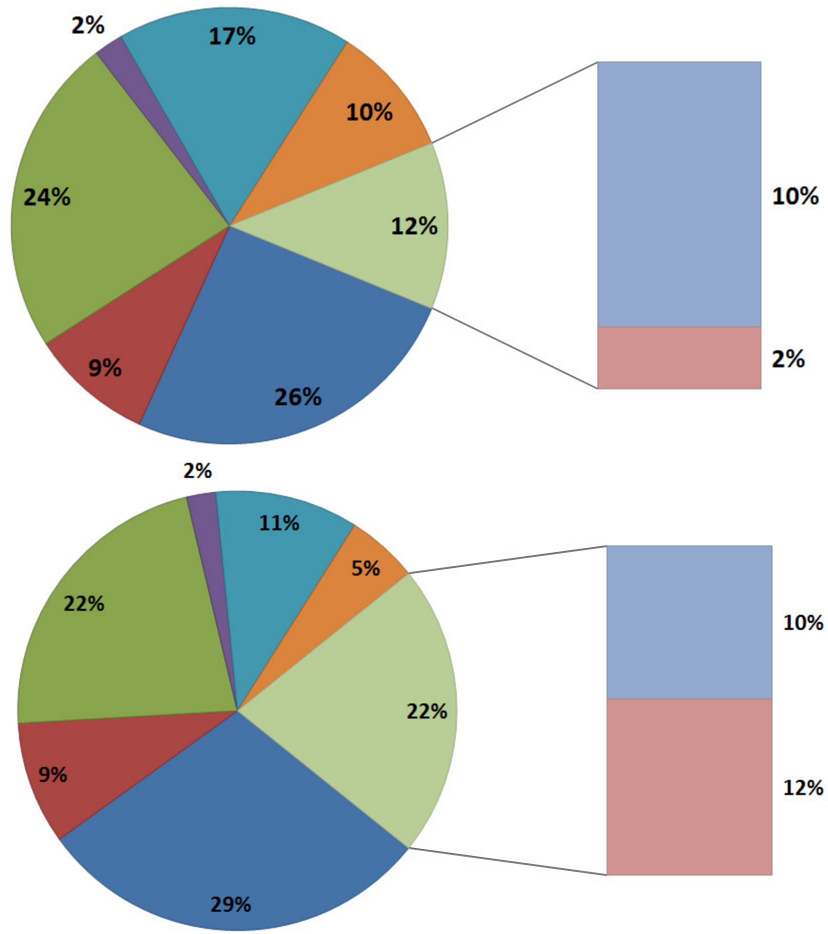
European supply mix for year 2030

Reference scenario:

Consumption: 526.2 BCM
Shale gas: 11.9 BCM*

Optimistic scenario:

Consumption: 530.4 BCM
Shale gas: 59.1 BCM*



*Excluding production in France

Natural gas self sufficiency for selected countries

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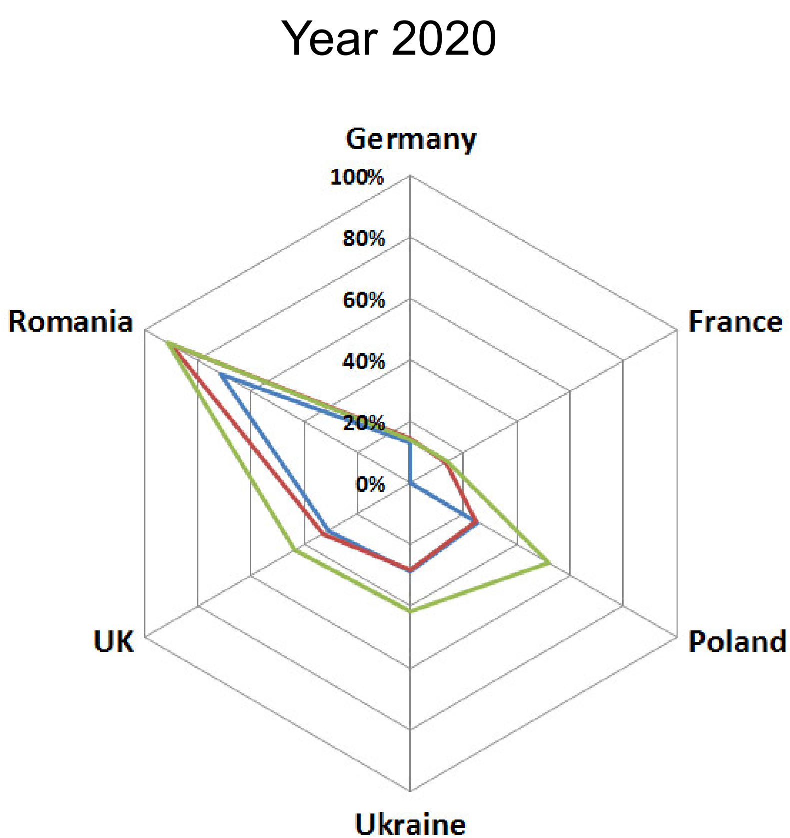

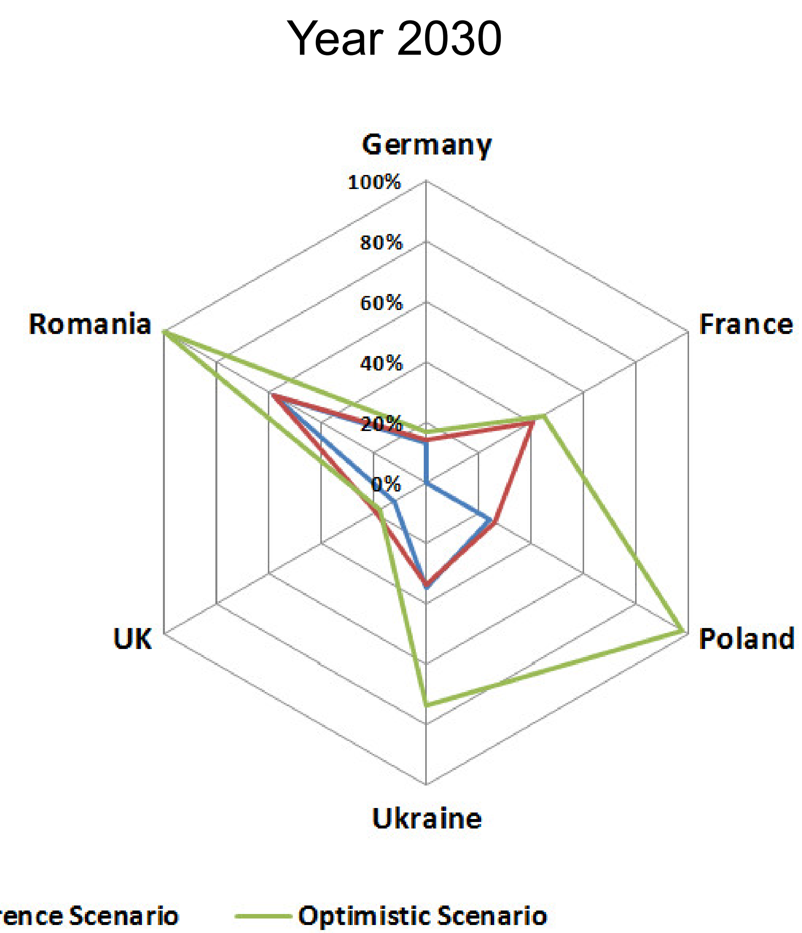

Conclusions

- ✓ Shale gas in *itself* should not be perceived as a solution to European energy security concerns
- ✓ Under a reference scenario shale gas will not provide any significant contribution to European supply mix by 2030
- ✓ The shale gas production, though, can have a positive influence on a market situation in particular European countries by reducing their import dependence.
- ✓ The analysis examines only the *economic potential* of shale gas exploration and should be seen together with the associated reports addressing *regulatory, environmental, technical and social* issues.

THANK YOU!

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This presentation is based on a joined research with Felix Müsgens

Appendix A: Approaches used by reports providing country-level shale gas resource estimates

- Bottom-up analysis of geological parameters
- Literature review
- Extrapolation of production experience
- Expert judgement
- Method not stated

Pearson et al., JRC EC (2012)

Appendix B: European shale gas potential estimates

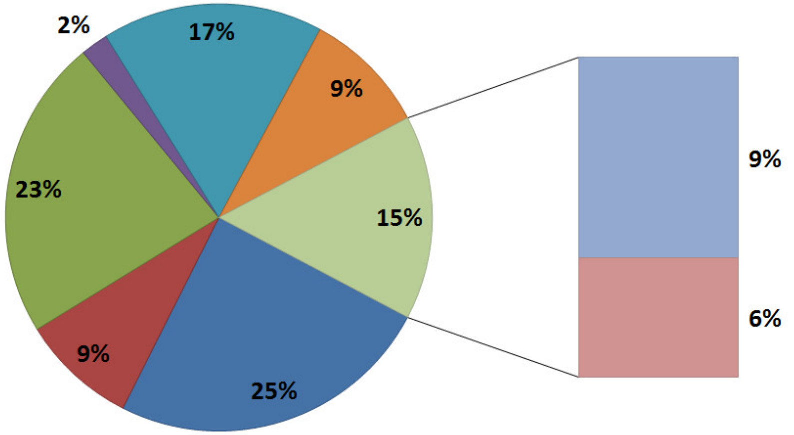
Study	Cost Assumption	Projected EU shale gas production in 2035	NG import dependence in 2035 (63% in 2011)
JRC 2012	5-12 USD/Mbtu	1 to 2.1 tcm cumulatively to 2035	57% (high scen.) 72% (low scen.)
IEA WEO 2013	-	20 bcm in 2035	81%
Poryry and Cambridge Econometrics study for IA of Oil and Gas Producers, 2013)	9 USD/Mbtu	60 to 150 bcm in the high scenario	63% (high scen.) 80% (low scen.)
BP WEO 2013	-	37 bcm in 2035	C.a. 75%
EIA 2013	-	79 bcm in 2035 (figures for OECD Europe, not the EU)	75%

T. Spencer et al. (2014)

Appendix C: European supply mix (with France) 2030

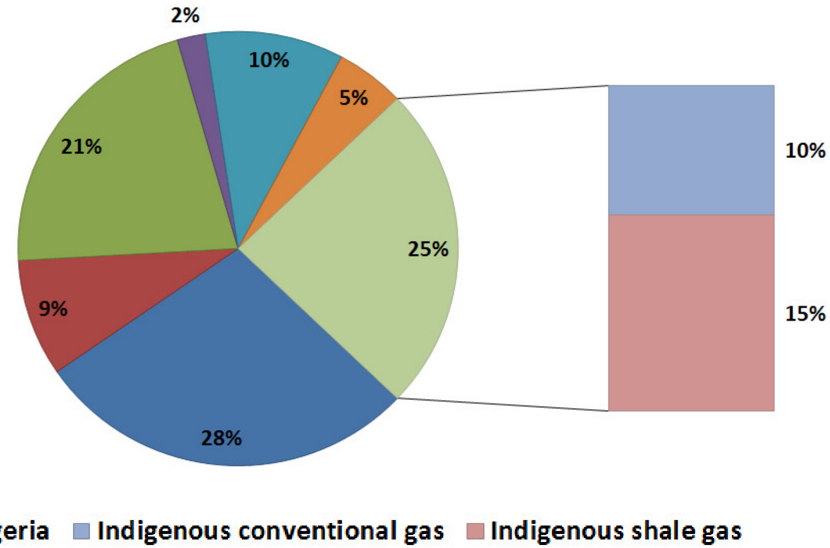
Reference scenario:

Consumption: 526.2 BCM
Shale gas: 30.33 BCM*



Optimistic scenario:

Consumption: 530.4 BCM
Shale gas: 77.6 BCM*



*Including production in France