European Commission

A spatially resolved agent-based analysis of potential shale gas development in Poland

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Research question:
Impacts of a future development of unconventional gas on job creation ad additional infrastructures (case of Poland).

Choice of the modeling approach: considering Input-Output and GCE.

- modelling exercise should generate a tool for policy support. A scenario generator for exploring determinants, barriers and impacts of the development of shale gas projects. Aimed at investigate what-if scenarios: agent based modelling (ABM)
- Main difference from a pure optimization approach: we should be ablo to reproduce failures, out-of equilibrium situations.
- «*What should be*» (optimization) versus «*What it could be if…*» (agent based modelling).

- Agent-Based Models: is a family of computational models. Used in the field(s) of theory of consumer behavior, game theory, complex systems, computational sociology. Entities (agents) with a set of goals and behavioral rules.
- Usually very simplified rules, driving (at a micro level) actions and interaction of agents, generate (at a macro level) complex and not intuitive patterns.

- Advantage and disadvantages
  - KISS (A/D)
  - Explicitly representing different phases of projects
  - Integration of monetary and non monetary factors
  - Heterogeneity of agents
  - Interactions (context)
  - Time dynamic

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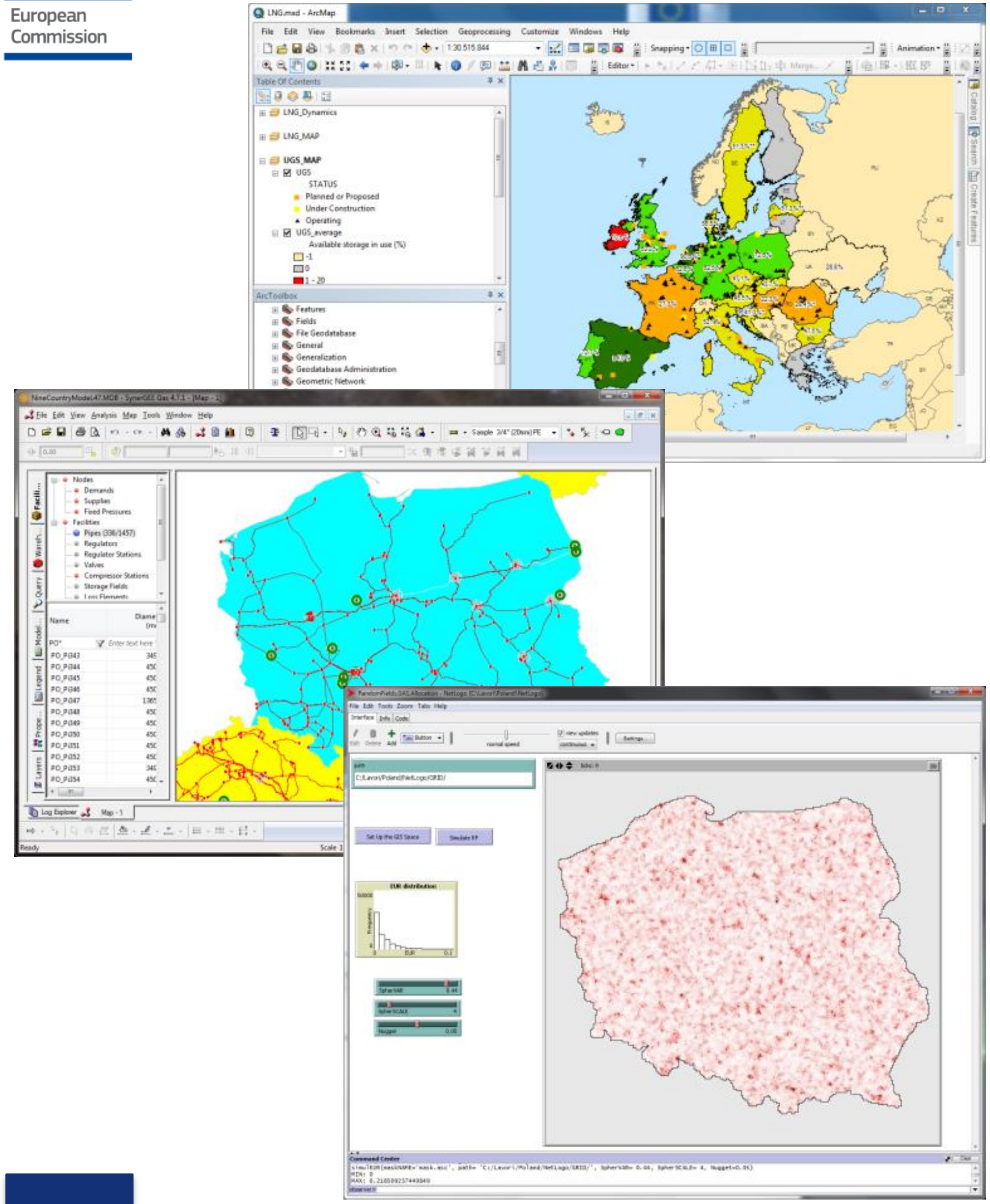
- **Spatial modelling**
  - *ESRI ArcGIS Desktop*

- **Hydraulic modelling**
  - ***GL Noble Denton Synergee GAS***

- **Agent Based Modelling**
  - ***NetLogo***



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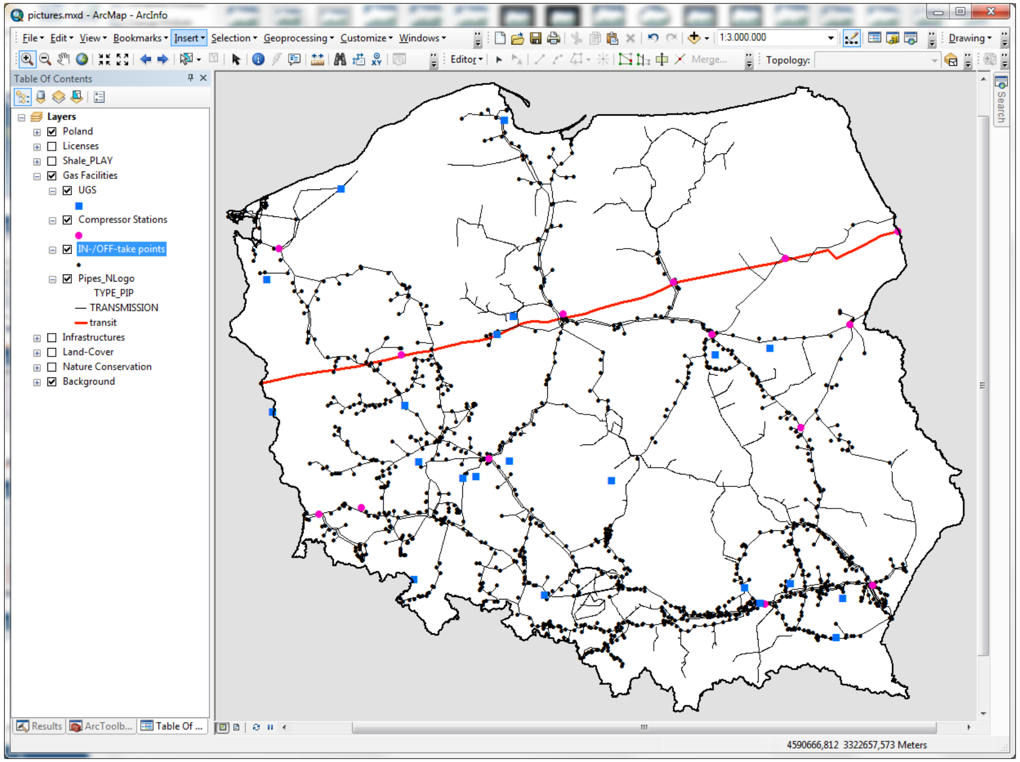
Spatial modelling

National Gas Transmission System (from TSO):

- Pipelines (transit and transmission);
- In-/Off-take points;
- Compressor Stations and UGS.



Necessary to:

- Gas infrastructure accessibility
- NGTS spare capacity

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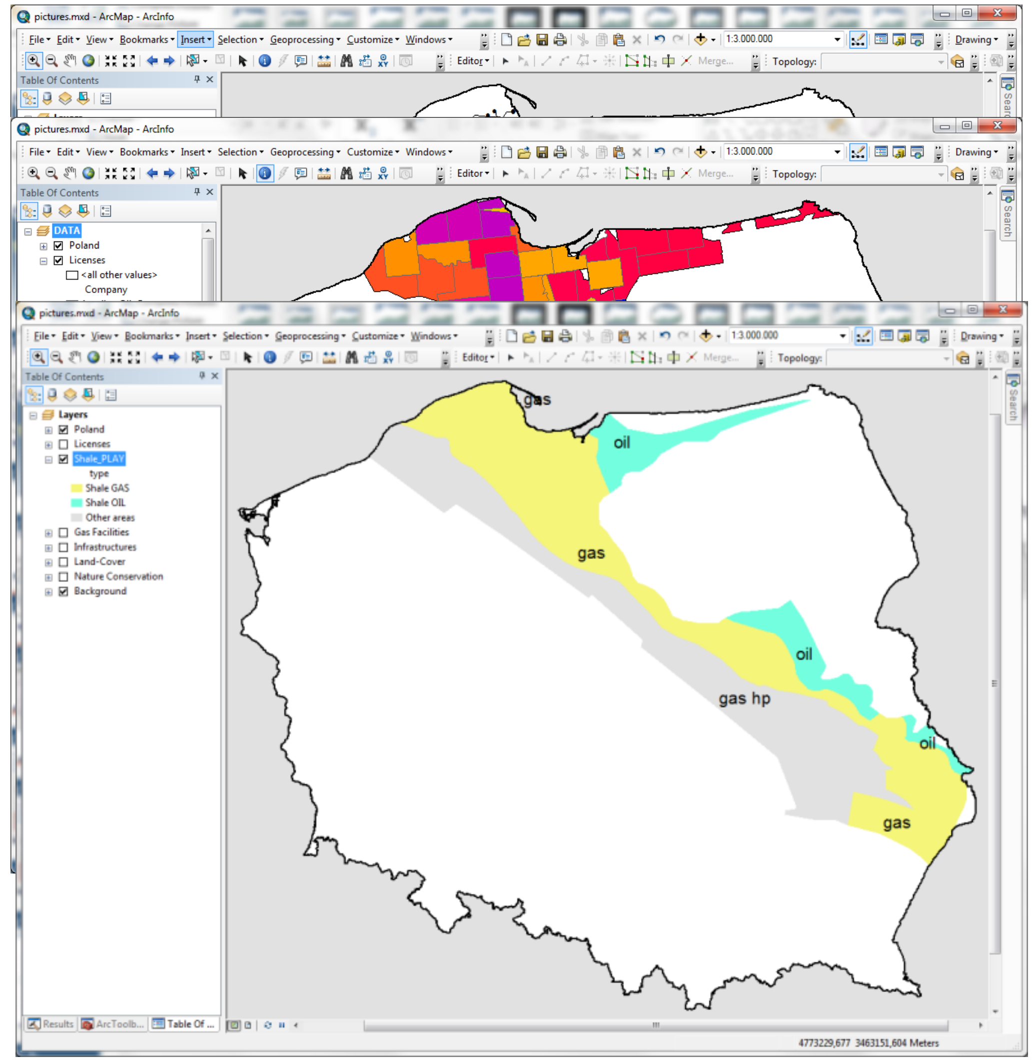
Spatial modelling

National Gas Transmission System (from TSO):

- Pipelines (transit and transmission);
- In-/Off-take points;
- CS and UGS.

Drilling Licenses (at 01.01.2014) from the Ministry of Environment.

Shale gas basin (Lower Paleozoic) from the PGI



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Spatial modelling

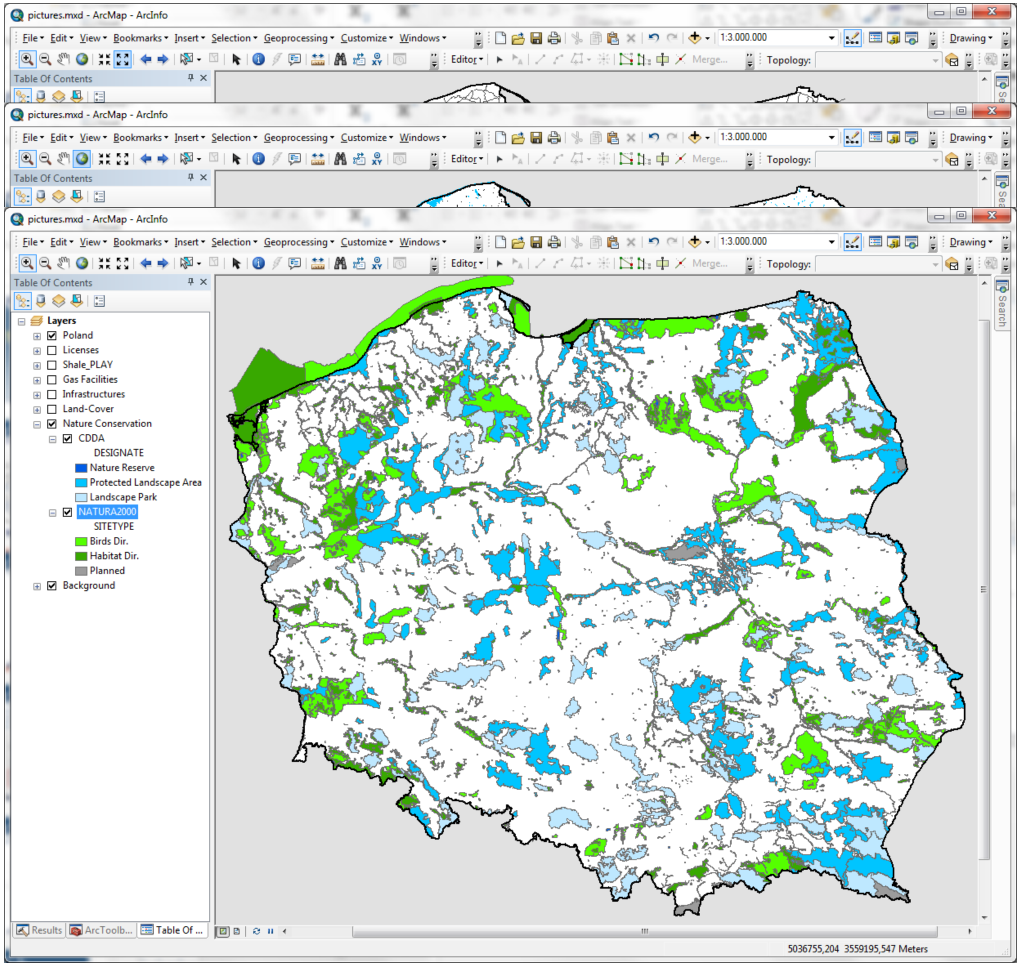
National transport system (from GISCO):

- main roads;
- railroads.

Urban areas and Inland Water Bodies (from CORINE LandCover)

Natural Protected Areas:

- National Parks and Reserves (Min. Env.);
- NATURA 2000 (EEA).



Spatial modelling

Reference Grid for NetLogo world

- 3x3 km squares for each well pad;
- enlarged for boundary conditions;
- define the grain of the analysis.

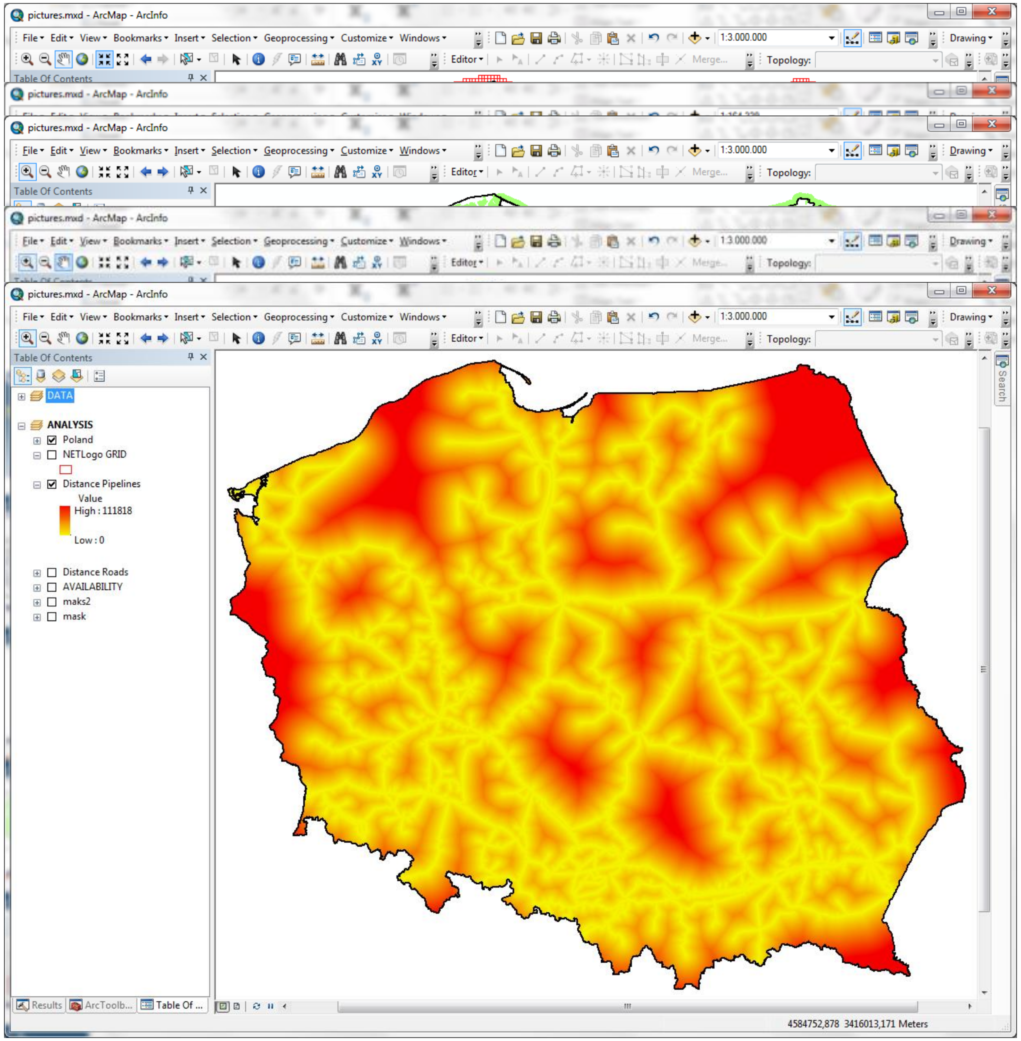
From previous base data we derive:

Land availability (no legal constraints) with buffers

Distance and Density of roads

Distance and Density of Pipelines

Distance to Industrial areas



Gas allocation

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Polish Geological Survey

Polish Hydrogeological Survey

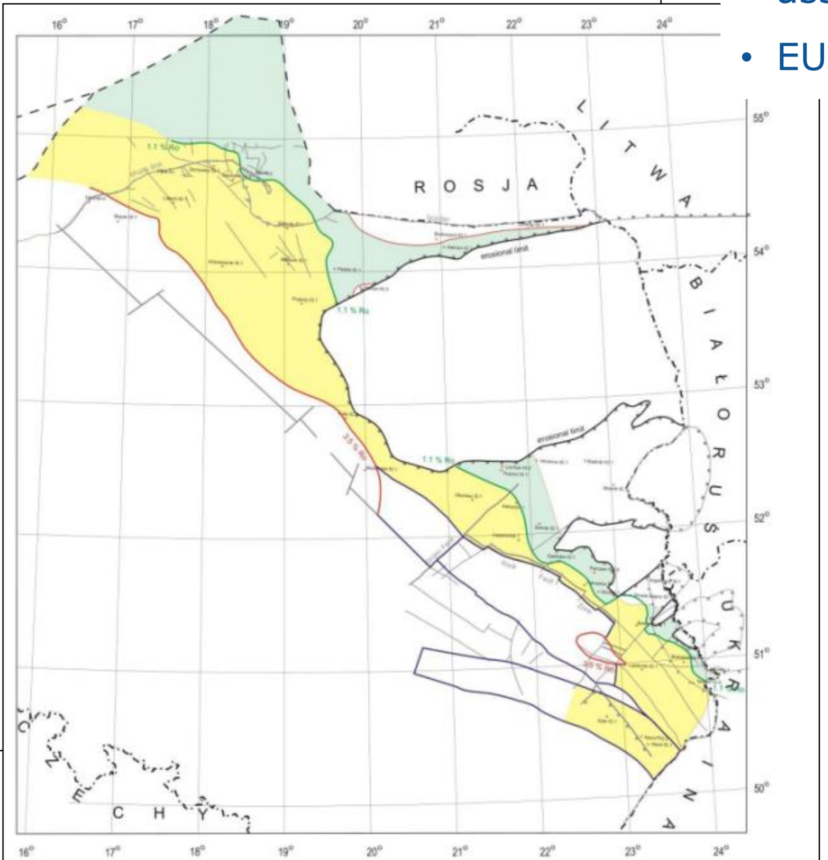


Figure 14.
The acreage incorporated into assessment units and qualified into calculation of resources of shale gas (yellow color) and shale oil (green color) in a model with maximum thickness of shale intervals with TOC contents > 2 % wt on the basis of 39 exploratory drillings from 1950-1990

The report of 2012 is based on:

- historical data (39 expl. drillings from 1950 to 1990);
- assumptions on TOC and other variables;
- EUR and average acreage drainaged by wells from US.

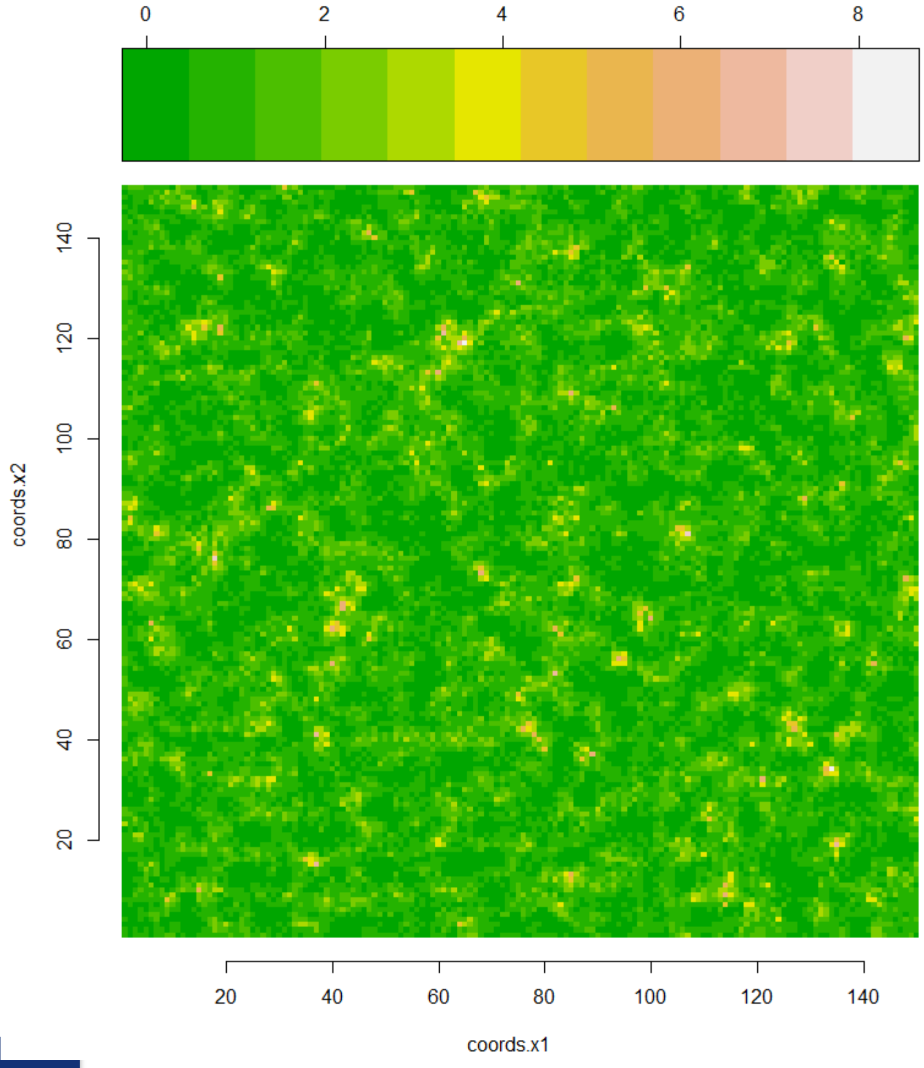
Table 1
Recoverable resources of shale gas in the Lower Paleozoic basin. Bcf – billion cubic feet. Bcm – billion cubic meters. EUR – Estimated Ultimate Recovery.

	EUR minimum 0.04 Bcf = 1,13 MMcm),	EUR optimum (0,4 Bcf = 11,3 MMcm)	EUR maximum (1 Bcf = 28,3 MMcm),
offshore acreage max. 7 952,4 km^2	14,8 Bcm	148,4 Bcm	371,1 Bcm
offshore acreage min. 6 192,4 km^2	11,6 Bcm	115,6 Bcm	289,0 Bcm
onshore basin acreage max. 33 183,3km^2	61,9 Bcm	619,4 Bcm	1 548,6 Bcm
onshore basin acreage min. 12 347,3km^2	23,0 Bcm	230,5 Bcm	576,2 Bcm

The EUR spatial distribution is modeled as a random field.

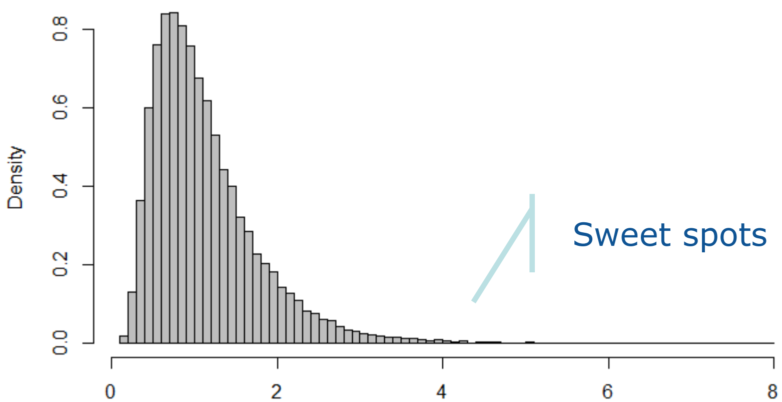
Random field is a list of random numbers whose values are mapped onto a space and are spatially correlated.

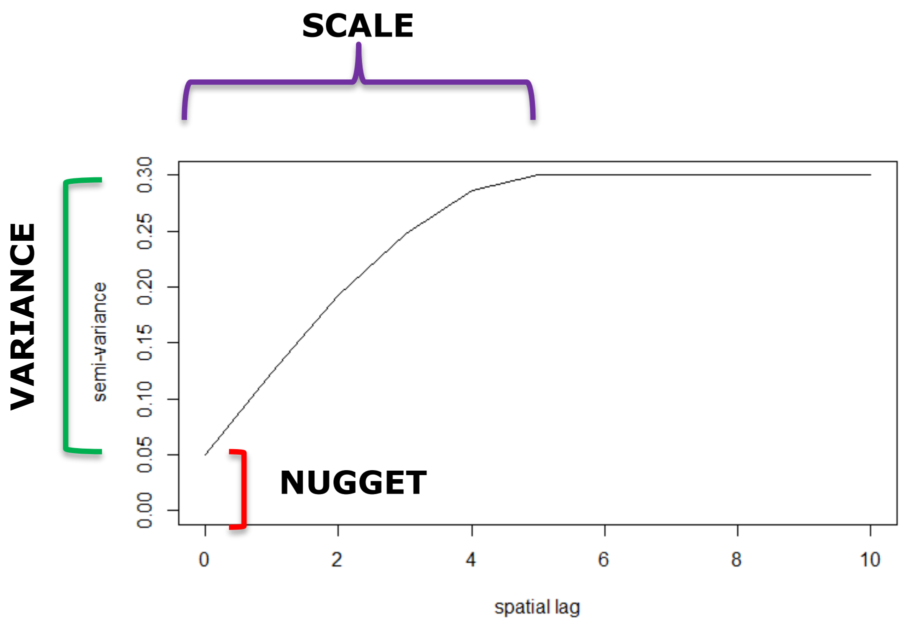
In its most basic form this might mean that that nearby values are more similar than far-apart values.



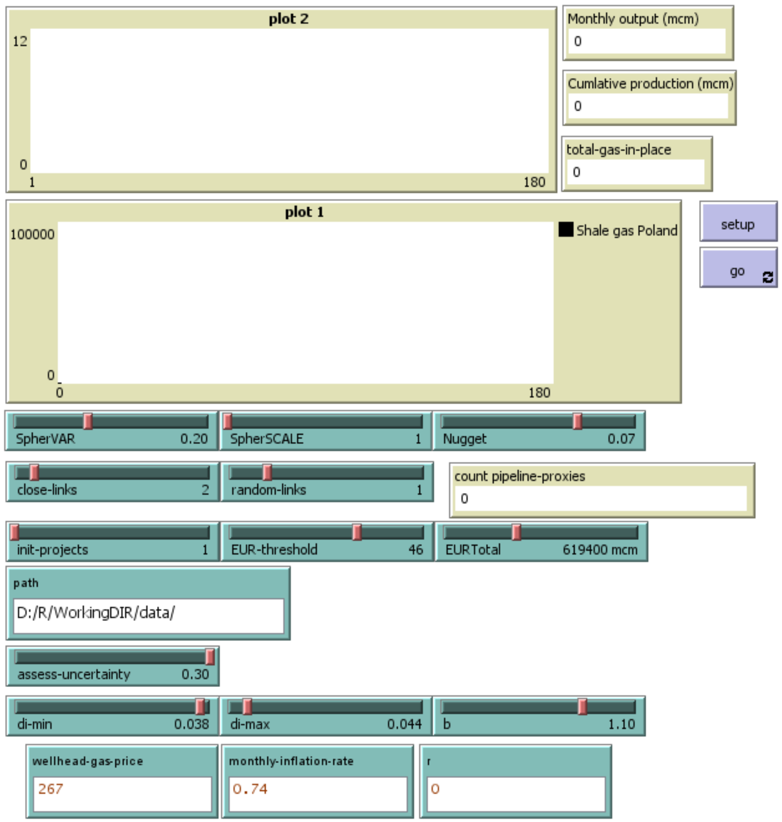
The EUR spatial distribution is modeled as a random filed with:

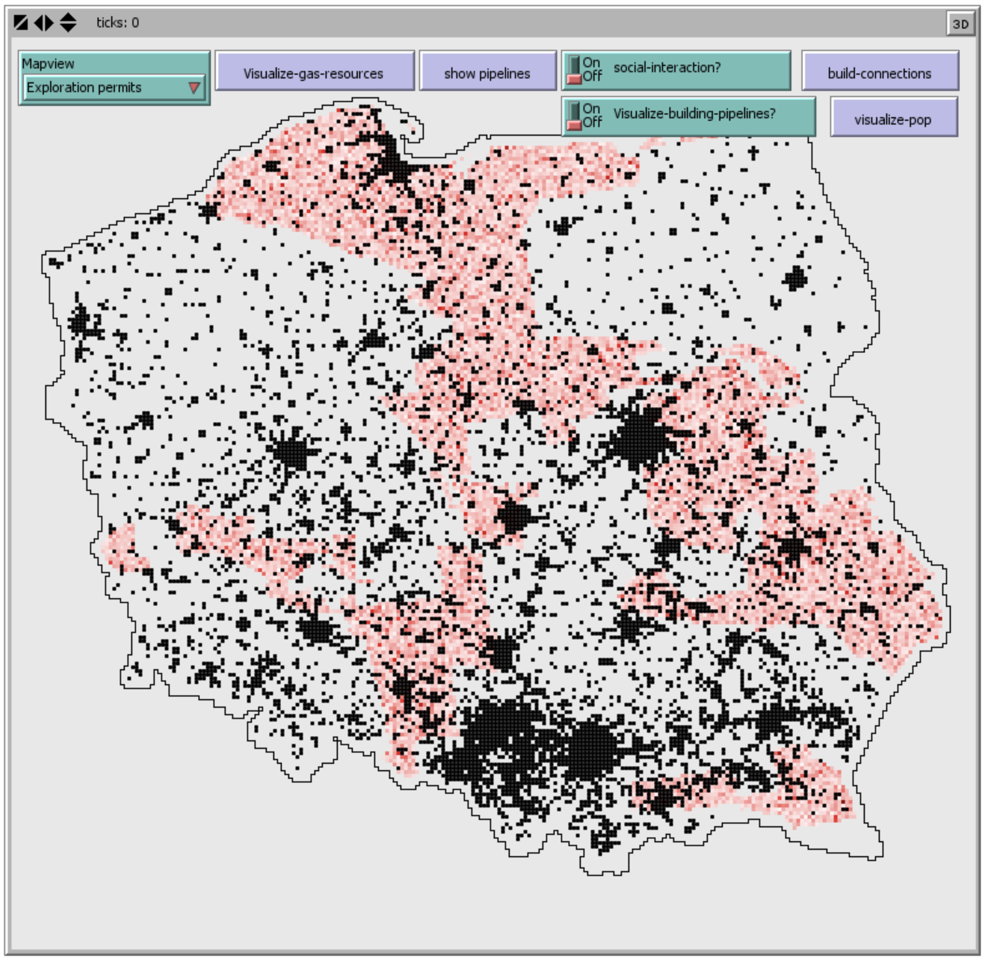
- identical distributed random variables following a lognormal distribution;
- a spherical semi-variogram model (nugget, variance, scale);
- a stationary and isotropic process.





The interface





WHITE low values

DARK RED high values

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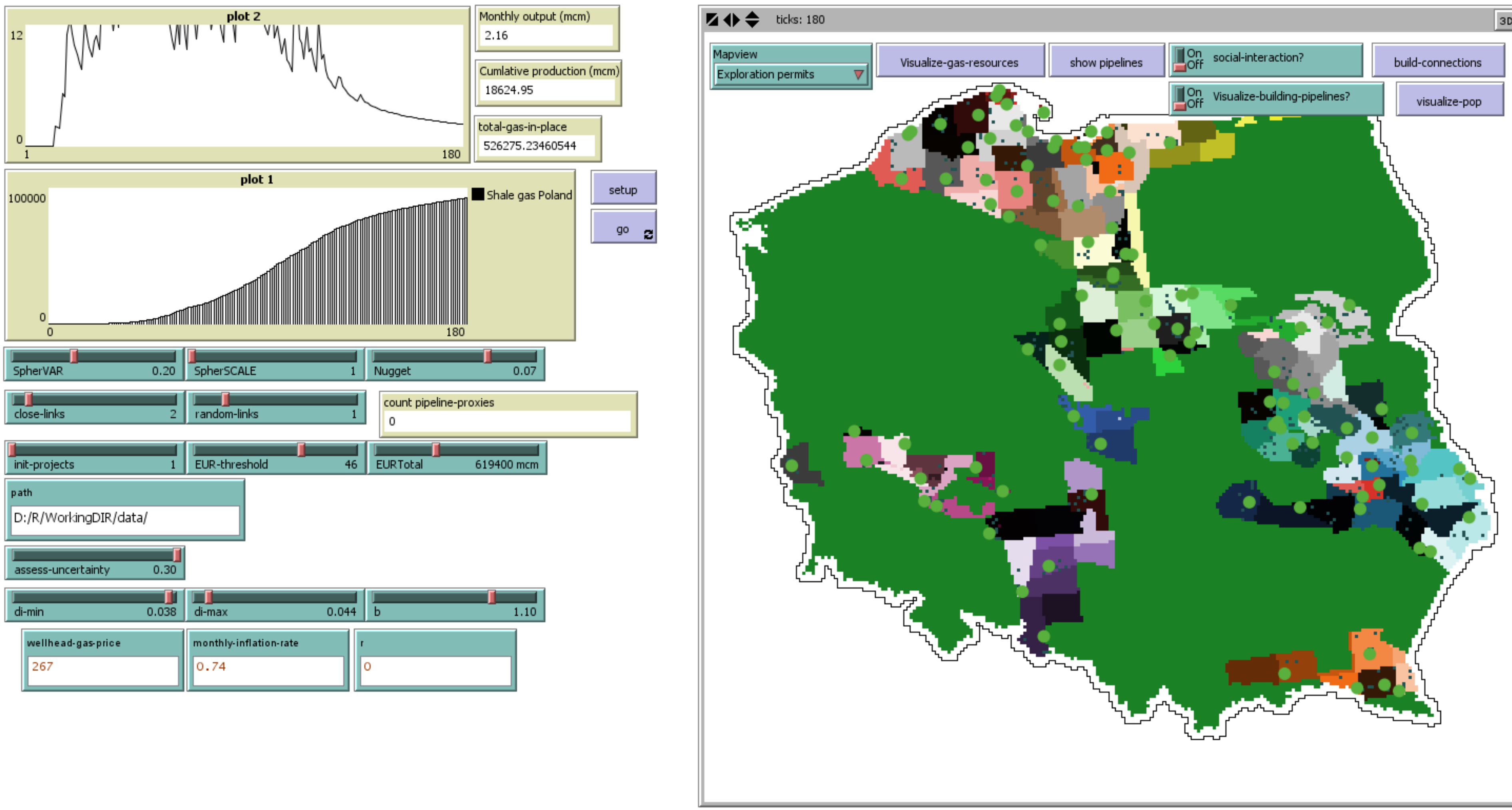

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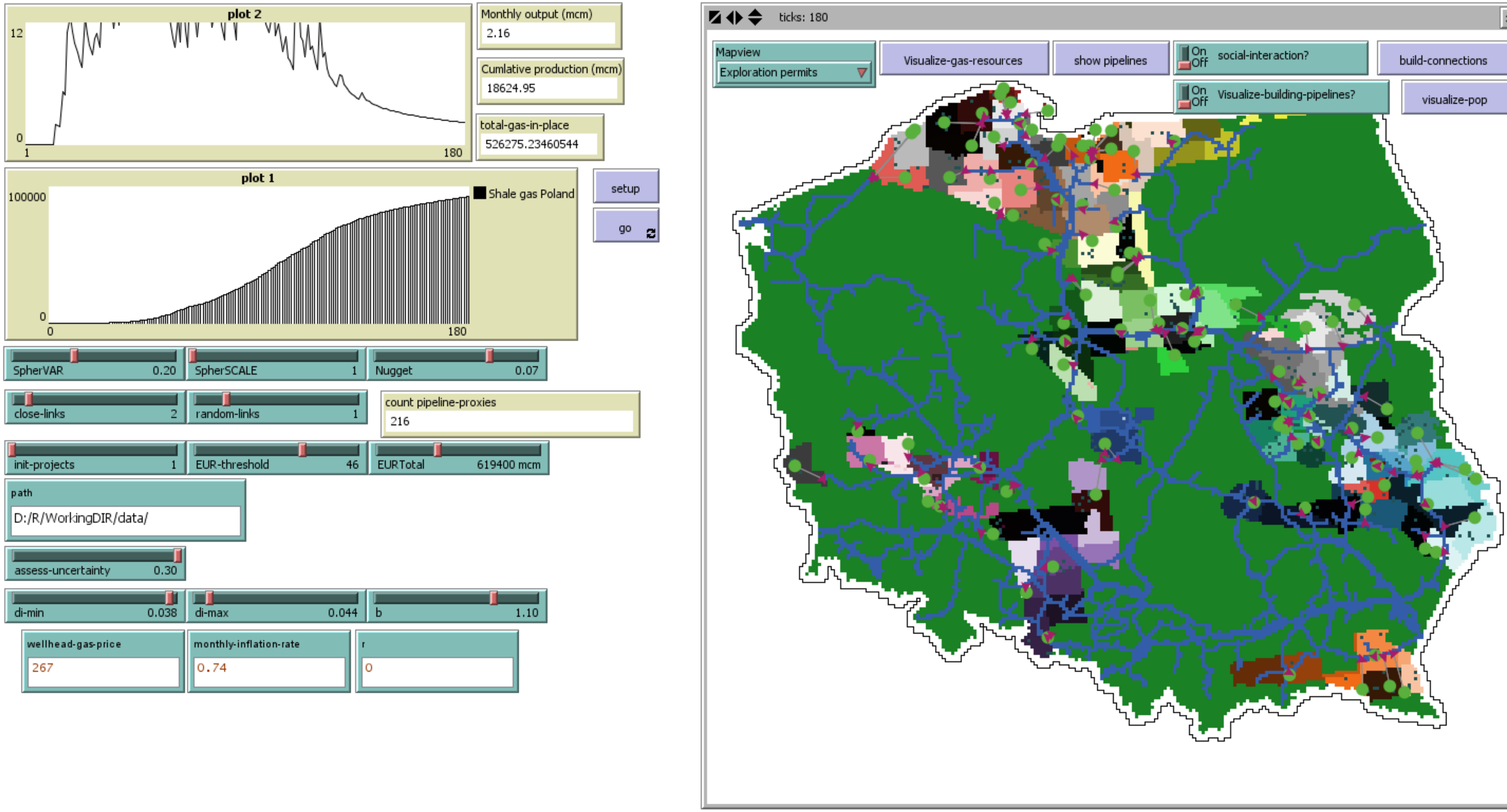
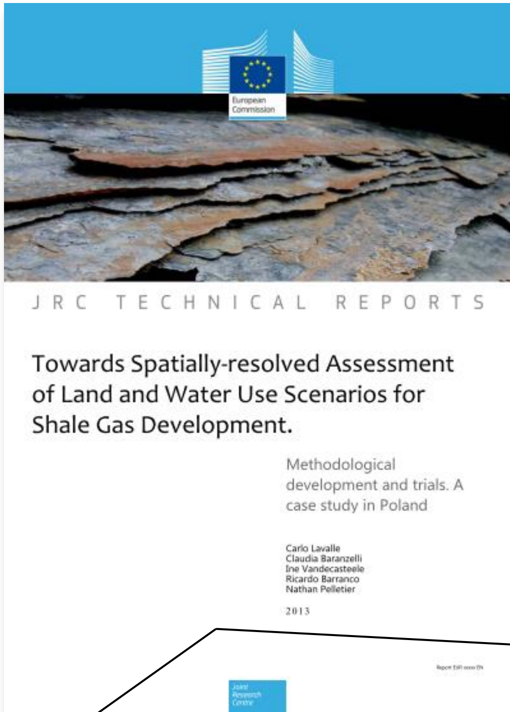


Overlapping the dimensions


JRC TECHNICAL REPORTS

Towards Spatially-resolved Assessment of Land and Water Use Scenarios for Shale Gas Development.

Methodological development and trials. A case study in Poland

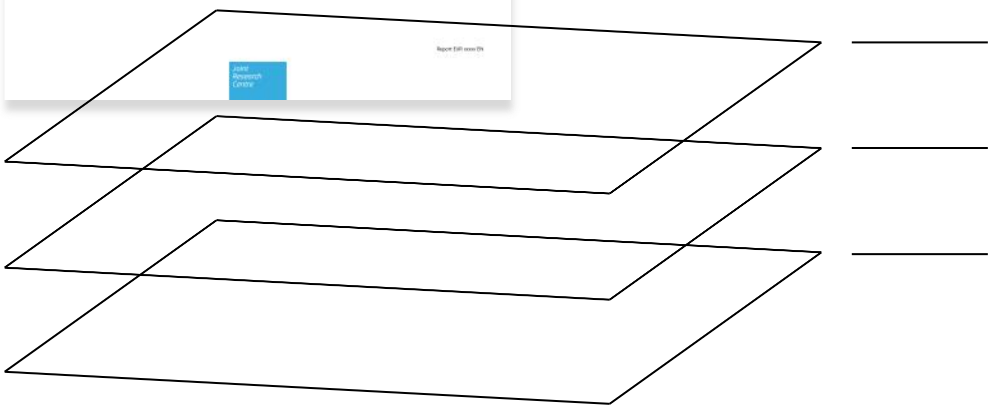
Carlo Lavalle
Claudia Baranzelli
Ine Vandecasteele
Ricardo Barranco
Nathan Pelletier

2013

Assess impact on water;

Spatially resolved;

No economic assumptions.



Financial/Economic space (investment decisions, technology, …)

Physical space (geology, infrastructures, …)

Societal actors (residents, institutions, organizations, …)

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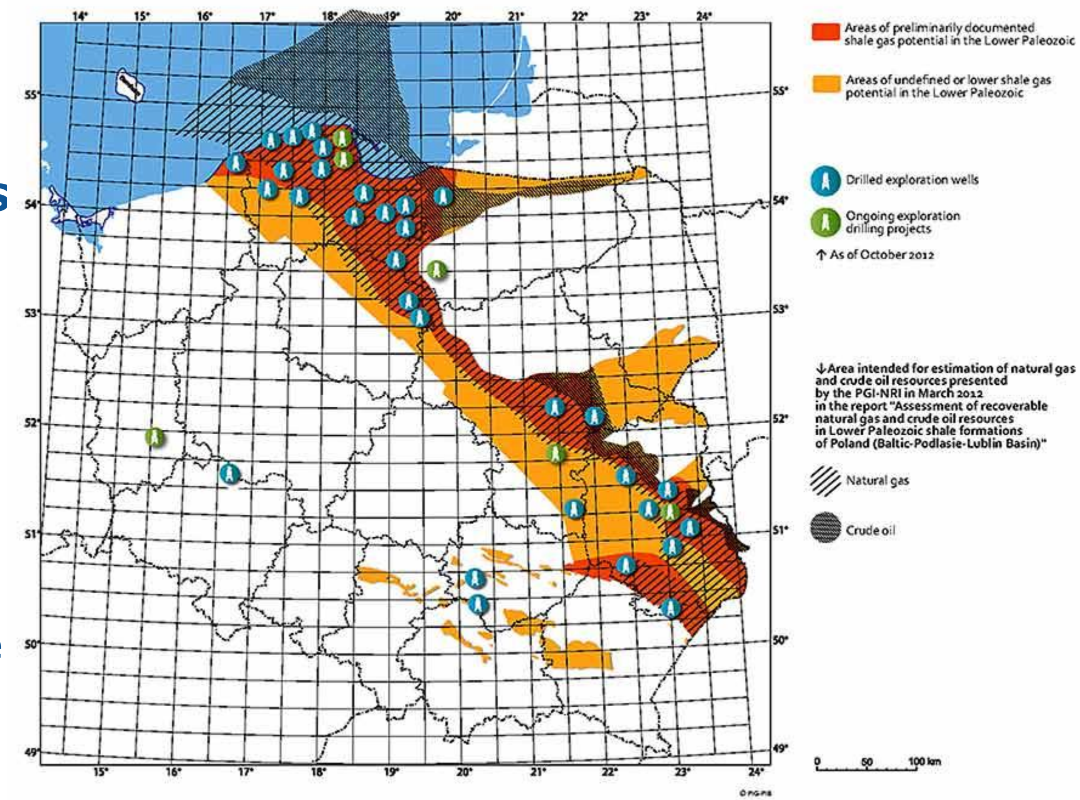
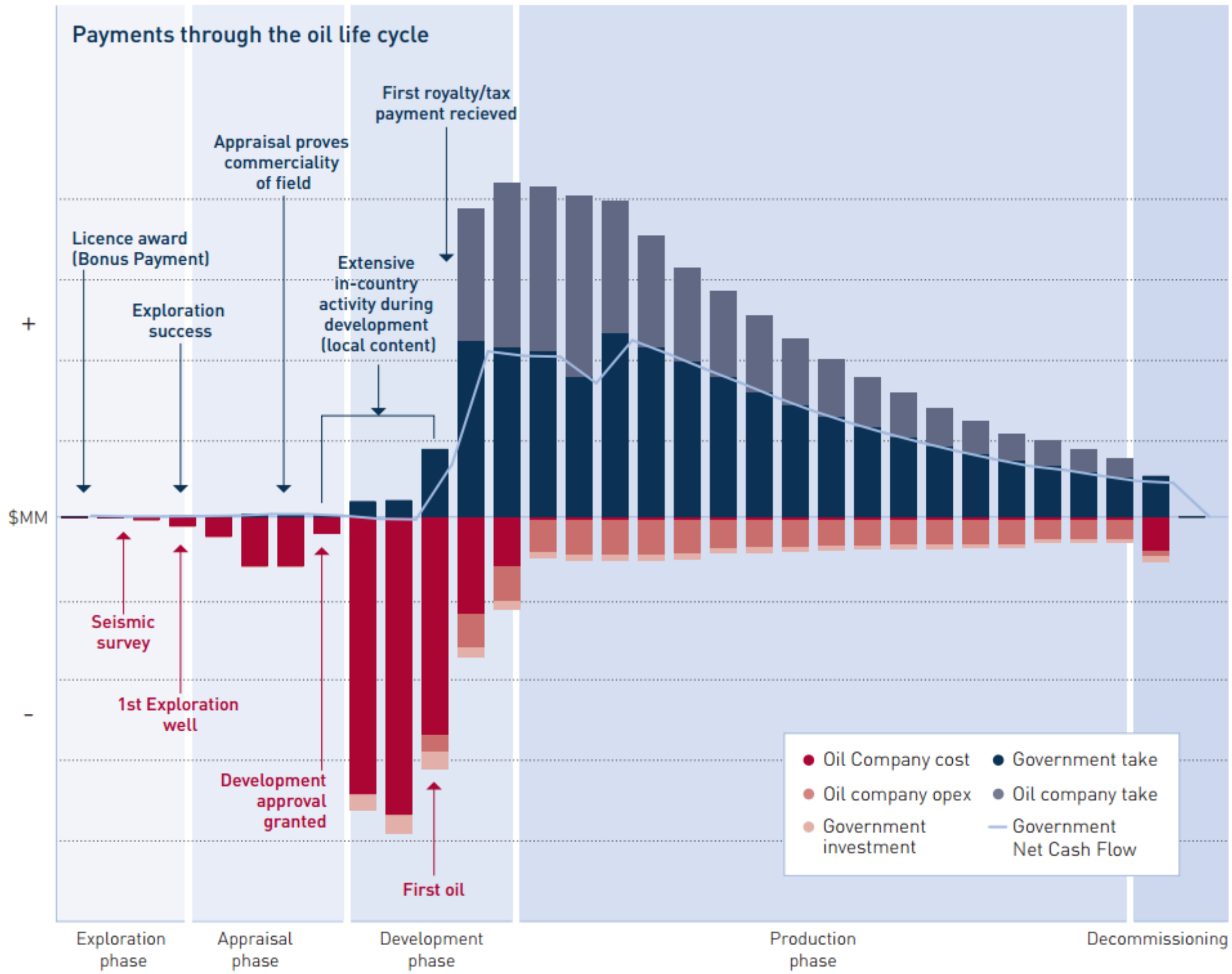
Agents: projects or companies?

3Legs Resources, BNK Petroleum, CalEnergy, Chevron, CNOOC, ConocoPhillips, Cuadrilla Resources, Dart Energy, DPVSErvice, ENI, ExxonMobil, HuttonEnergy, LNG Energy, LOTOS MacOil, Marathon oil, Mitsui, PKN Orlen, Petrolinvest, PGNiG, RAG, San Leon Energy, Sorgenia, Stena, Total, Wiswnt Oil&Gas



In order to empirically inform the simulation, some indicators related to **the level of capitalization**, debt situation, diversification of activity are to be introduced as agents' attributes.

Different companies are assumed to have access to the same set of technologies.



Local cost components expenditures
For building road, power, gas connections are site specific.

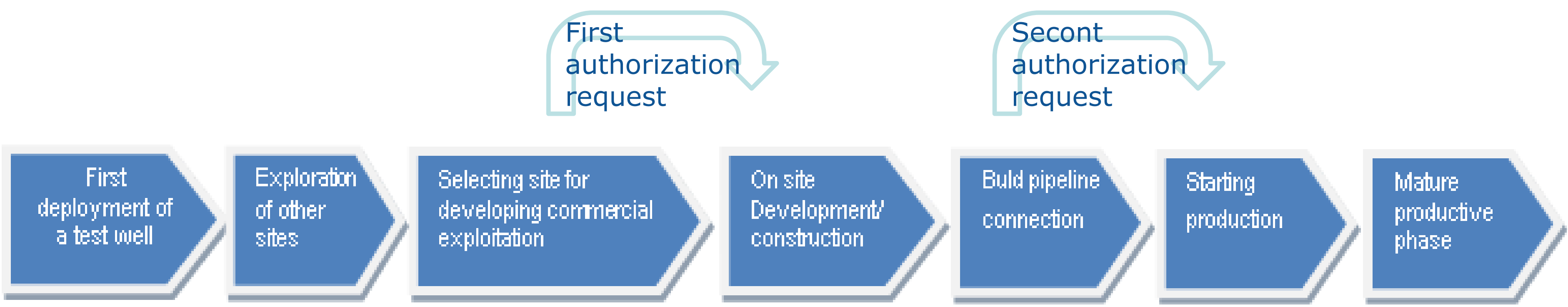
Institutionally driven cost components timing of the authorization process

Global, or not site specific cost components
Expenditures for drilling, fracking and water waste treatments

In the actual version of the model, companies interact with central governmental institutions in the form of authorization requests:

- a first between the exploration and the development phase
- a second in between the development and the production

The agent (agency) takes a definite number of time steps to assess each single application, so the waiting time is defined by the number of concurrent applicants.



How much…
(where and when?)

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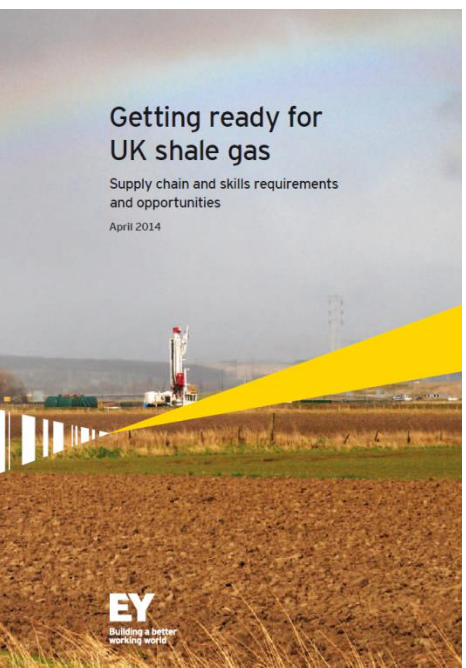
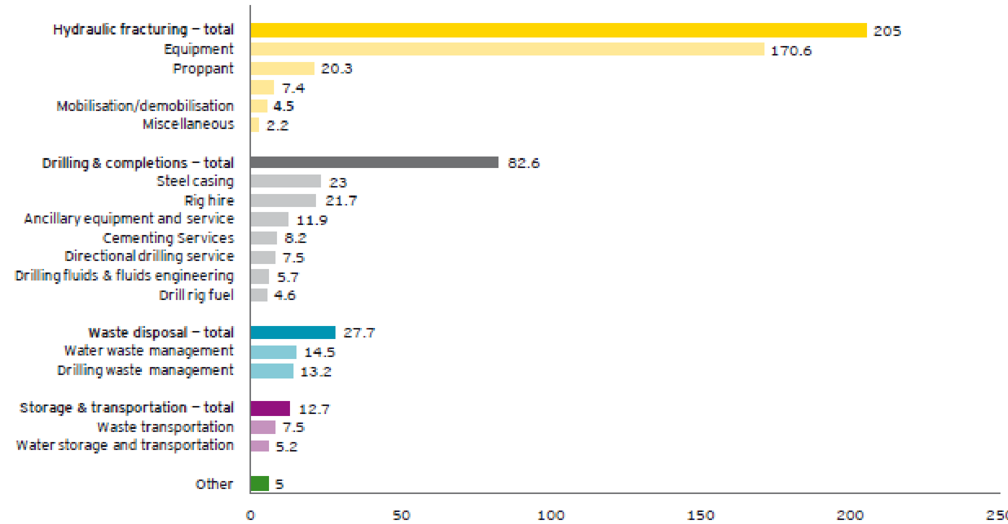
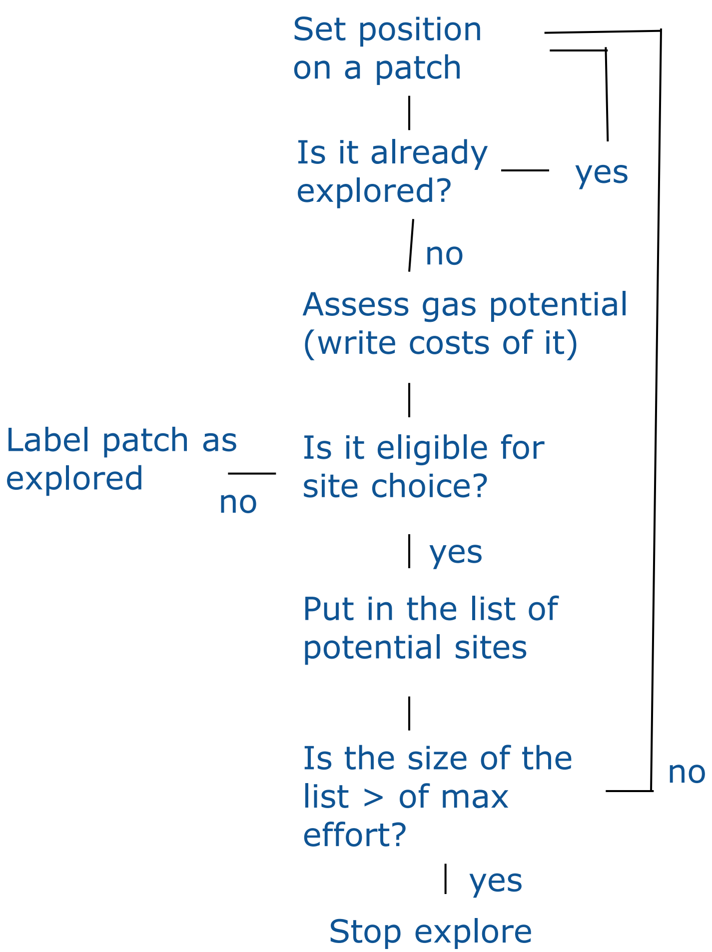
The essential information we are actually implementing to structure the DCF is the allocation of costs across the lifecycle of the investment.



Breakdown of spend £m categories for a single pad (10 vertical wells, 40 lateral wells)



Reshape DCF



The basic rule for financial investor is to compute the project value as a sum of discounted flows. All the financial costs written at each round in the project accounts are compared to a baseline reference series of cash flow (to be found…) according to the formula:

$$\Delta NPV = \sum_{year=1}^{t} \frac{(R_a - C_a)}{(1+r)^t} - \sum_{year=1}^{t} \frac{(R_{ref} - C_{ref})}{(1+r)^t}$$

The tick (time unit) of the simulation is monthly, while the financial check is done every 12 ticks.

The actual implementation of the model performs NPV calculation, and the behavioral rules for adjusting decision are still to be designed (this should follow feedbacks and collaboration from E&P companies.

If the surplus is negative, the company can go to debt funding without changing the baseline profile, or adjusting her discount rate. The firms can risk financial failures, opting for increasing their expectation in terms of gas production.

The adjustment of the baseline expectation is an attempt to model a process of learning of firms working on an innovative playing field with high uncertainty and imperfect foresight.

Exploration

Financial expenditures :

- Acquisition of acreage
- Seismic data collection
- Exploration

The early exploration effort is quantified (random distribution 2.5 - 5 M€) for each patch (3x3 km).

The assessed gas content for each patch is revealed to the explorer as:

$$g_a = g_e + \varepsilon$$

g_a is the assessed gas amount (TRR). we need to pass from URR to TRR through a recovery factor.
g_e is the actual presence of gas (parameter `ge` of patches in NetLogo)
epsilon an error, dependent from g_e ,
normal distributed with mu = 0 and s.d. = x % of g_e (parameter `ge`).
The company explores groups of patches. A threshold can be adopted as criteria to consider the patches as potentially suitable for drilling a test well $g_a > g_{min}$
The size of the group of patches explored (parameter `max-effort`) varies according to the capitalization level of the company (which determines the potential capacity of financial exposure).

A set of possible locations is built making a list of patches with $g_a > g_{min}$.

Site choice

Exploration (cont'd)

After having defined a list of patches eligible well drilling (`eligible` attribute of patches), the company should choose one site. Two possible ways have been considered

- Lexicographic preferences: choosing the site with the highest value of gas assessed g_a
- Multiattribute choice: the assessed gas potential remaining the leading factor, some other issue can also have an influence on the probability to chose one of the set of explored. We can adopt the specification of the deterministic component of multinomial processes (McFadden, 1973) that is usually employed for modelling qualitative choice behaviours . The probability of preferring the patch i among the j alternatives is accordingly defined as a function of the attributes of i, and the other j attributes over the entire choice set.

$$P(i|J) = \frac{\exp(\beta_1 x_{i1} + \beta_2 x_{i2} + \beta_{...} x_{...} + \beta_{in} x_{in})}{\sum_{j=1}^{J} \exp(\beta_1 x_{i1} + \beta_2 x_{i2} + \beta_{...} x_{...} + \beta_{in} x_{in})}$$

Possible attributes:

- Distances from other ongoing gas extraction activities (`B_neighbors_wells`)
- Accessibility (proximity) to existing gas pipelines, load points (`B_grid_proximity`)
- ….

Government

Permitting explorations

Permitting production

Setting taxes (corporate, royalties and production)

Gas market regulation (spot or contract)

presence and stability of a regulatory framework drive investment decision of **Gas companies.**

Gas companies

DCF for
- Exploration
- Development
- Production

Environmental constraints and resource drive many capital and operating costs.
Government actions induce cost variations, time lags etc.

Social actors

Acceptance

Job creation

Driven by **Gas companies**
(+) by job creation
(-) by environmental externalities

Depending from social interactions

General perception of the technology affects **Central government**

Environment

Accessibility to gas resources

Accessibility to transport services

Existing gas pipelines

Gas companies activities induce externalities, perceived by residents.

Development and production

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Drilling, site completion

GIS data allows to specify, for each development site, the cost for connecting the site to the road network (to be input as `road-cost`)

Production
Once the stock of gas is quantified (`ge`) the time dynamic of the extraction activity can assumed to follow a decline curve.

Here we assume the hyperbolic type, based on the evidence based works on the US wells (alternatively the exponential form is suitable).
We introduce hererogeneity on b and D

$$f_n = f_i(1+bDt)^{-b}$$

Where
f_n is the gas production in year n
fi is the strarting flow in the first year
a is a negative fraction expressing the decline in production

Two key issues:
Construction of a power generator on the site, to be connected to the existing electricity grid

Construction of the connection to the existing pipeline (according to real constraints in term of transport capacities)

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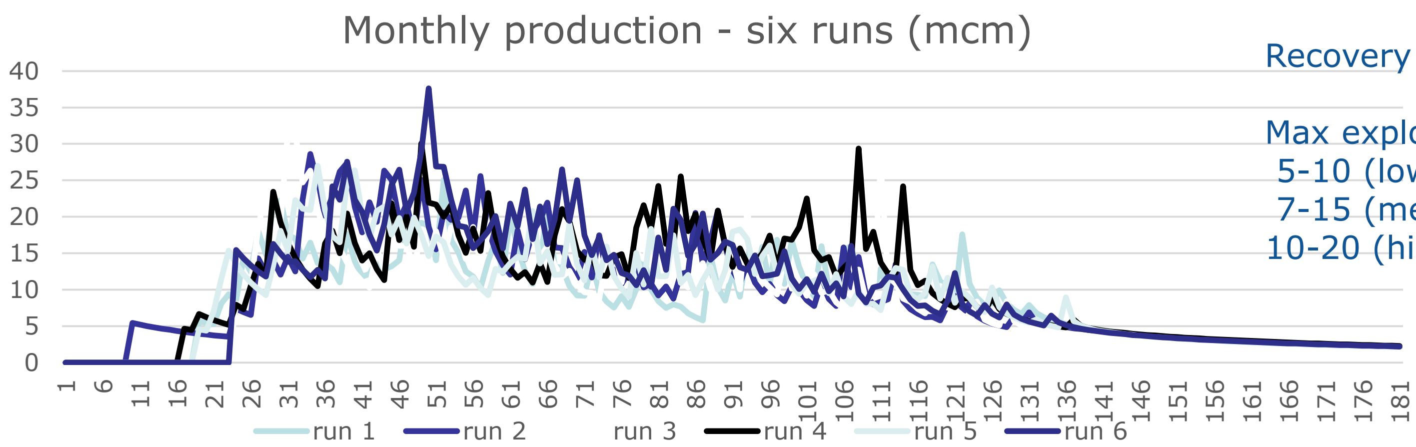
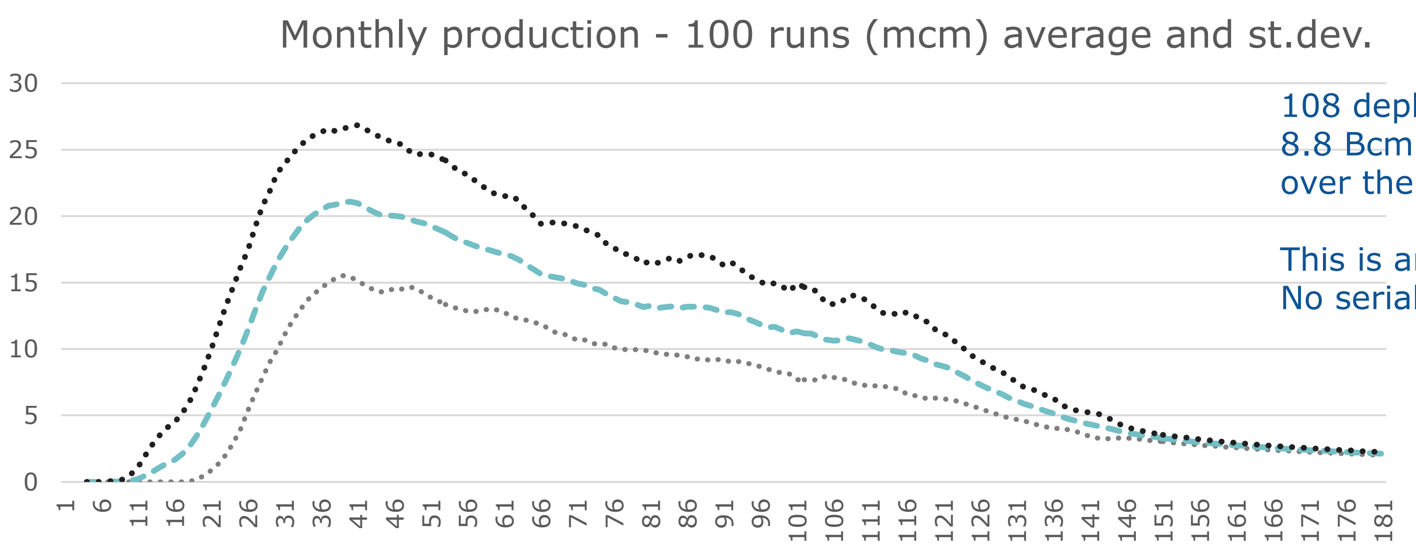
131 pilot wells with TRR below the threshold (20 mcm)

Recovery factor u.d. 10-25%

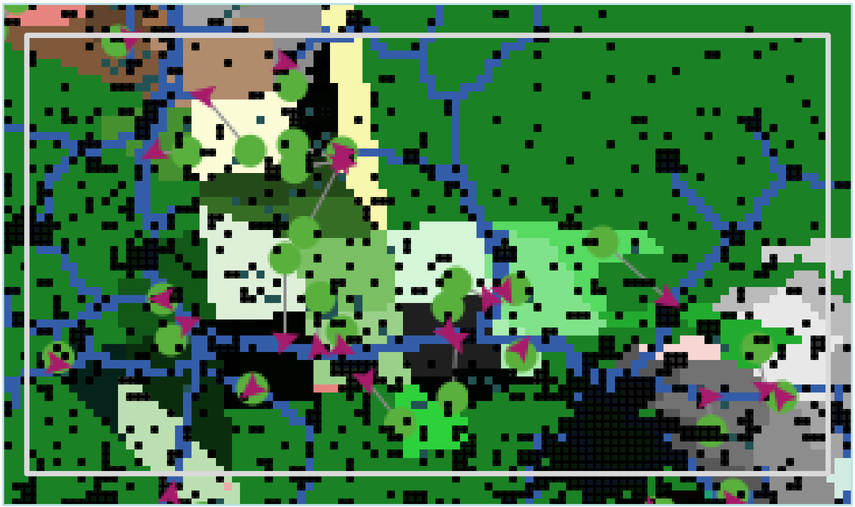
Max exploration effort
5-10 (low capital. level)
7-15 (medium capital. level)
10-20 (high capital. level)





108 deployed projects
8.8 Bcm of cumulative production over the whole time period

This is an illustrative run.
No serial drilling activity



Results: length and location of additional pipelines to deliver the gas to the existing grid

Need to assess the spare capacity of the NGTS to formulate hypothesis on infrastructure improvements.

Assumption:

- Average winter demand
- Average flow of last 5 years
- Average production
- Average level of storage (5 years)