Geothermal energy and support schemes in The Netherlands

The Guarantee Fund & Exploitation subsidy scheme

- Harmen Mijnlieff, TNO
- Paul Ramsak, NL Agency

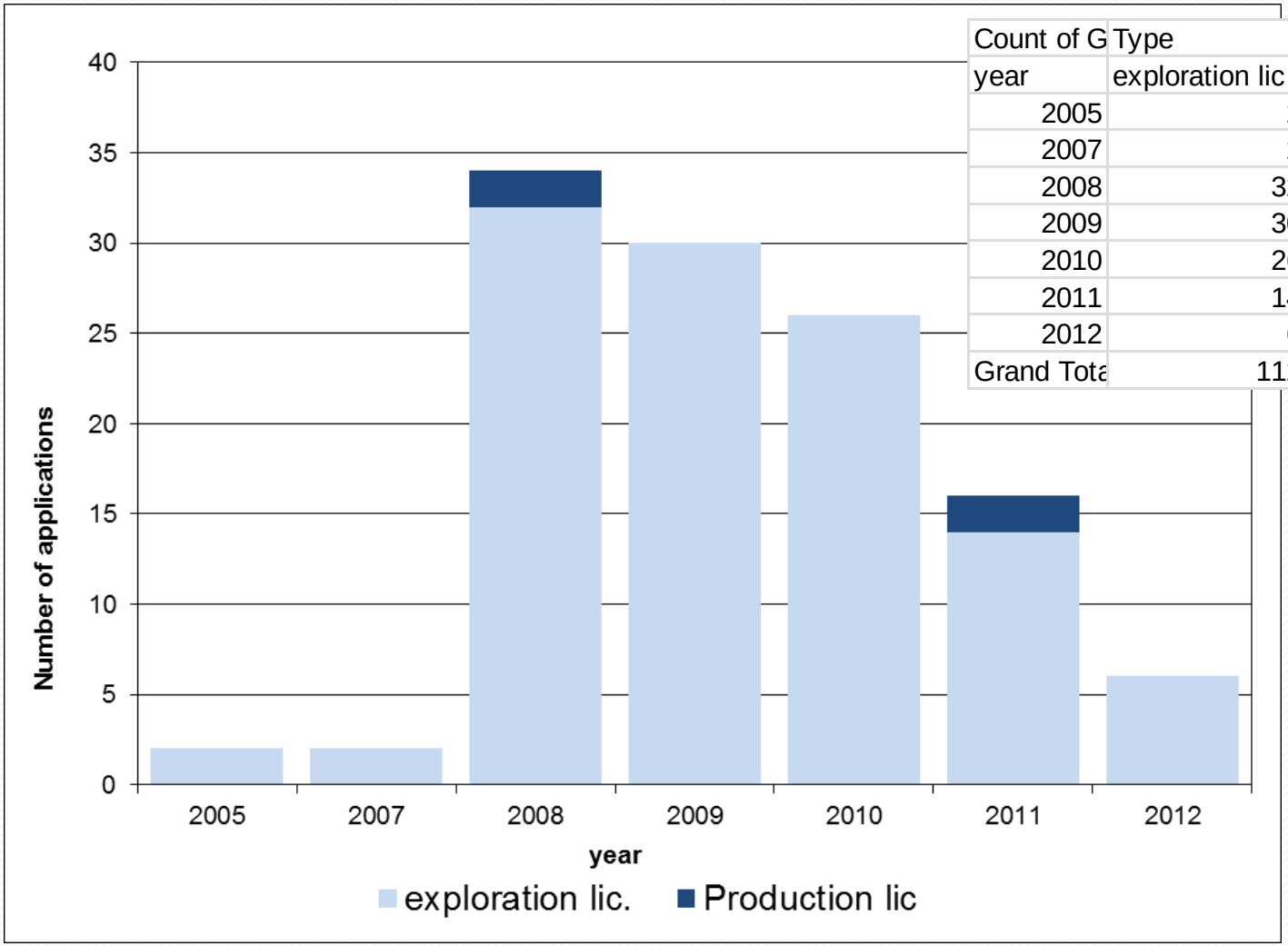
- Paul Lako, ECN
- Bart in 't Groen, DNV KEMA
- Jules Smeets, DNV KEMA
- Hans Veldkamp, TNO

Support scheme stakeholders

- Ministry of Economic affairs (MEA) => owner
- Agency NL => execution of schemes, support policy conception
- TNO-AGE => support in execution and conception
- ECN => support policy conception of SDE+
- DNV-KEMA => support policy conception of SDE+

- Participation: Joint operators, consultants

Geothermal license applications



Count of G	Type		
year	exploration lic.	Production	Grand Tota
2005	2		2
2007	2		2
2008	32	2	34
2009	30		30
2010	26		26
2011	14	2	16
2012	6		6
Grand Tota	112	4	116

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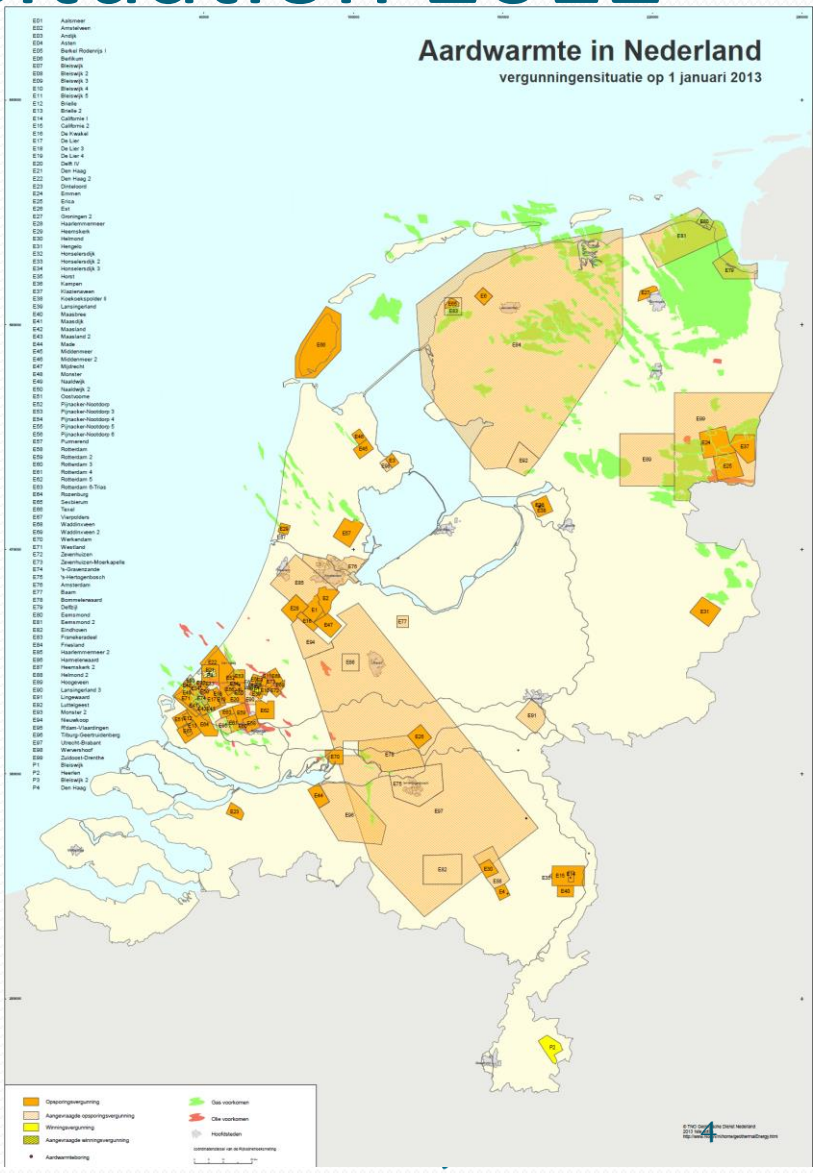
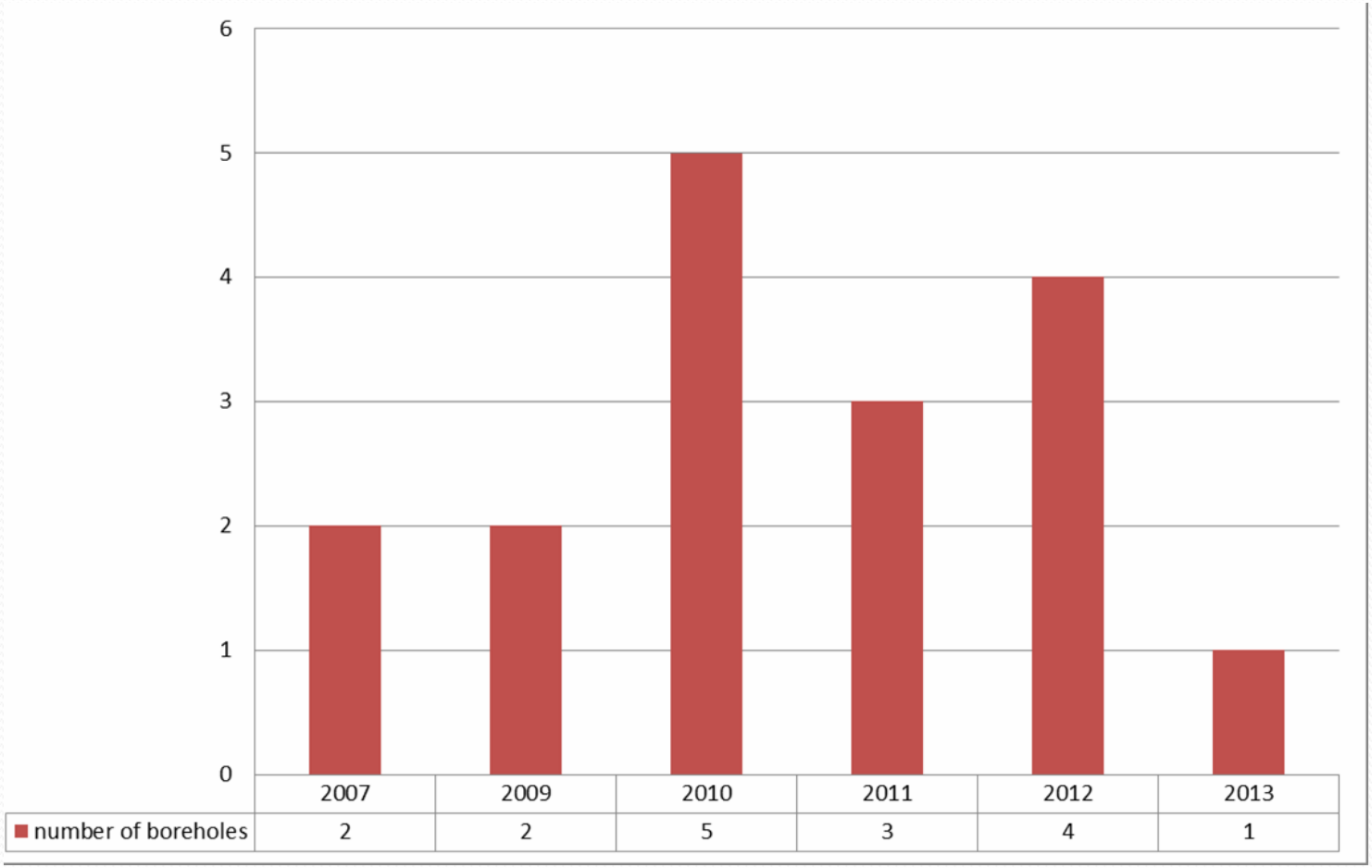
Geothermal licence situation 2012

- Exploration licences (73)
- Production licences (2)



Geothermal wells drilled



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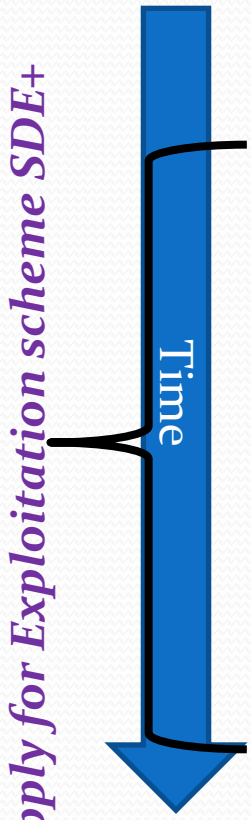
From Plan to Production of a Geothermal project



Apply for Exploitation scheme SDE+

1) Quickscan geothermal potential evaluation
2) Apply for exploration license
3) Location specific research
   - ***<= Apply for Guarantee fund?***
4) File drilling plan to State Supervision on Mining
5) Drill 1st well
6) Test?
7) Drill 2nd well
8) Test?
9) Apply production license
10) Production

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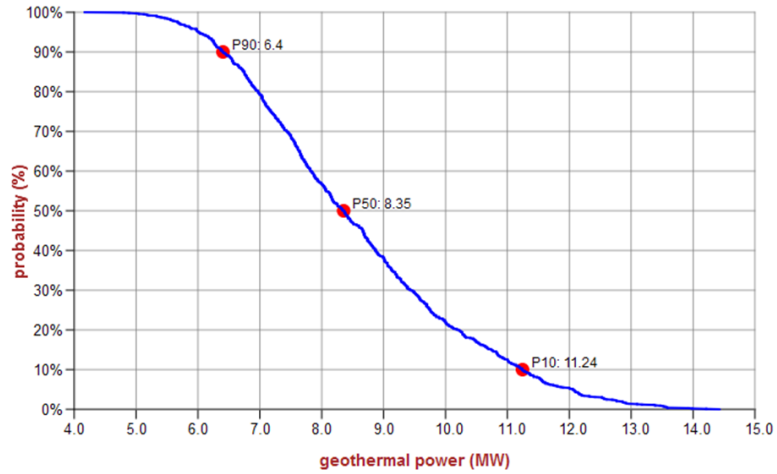
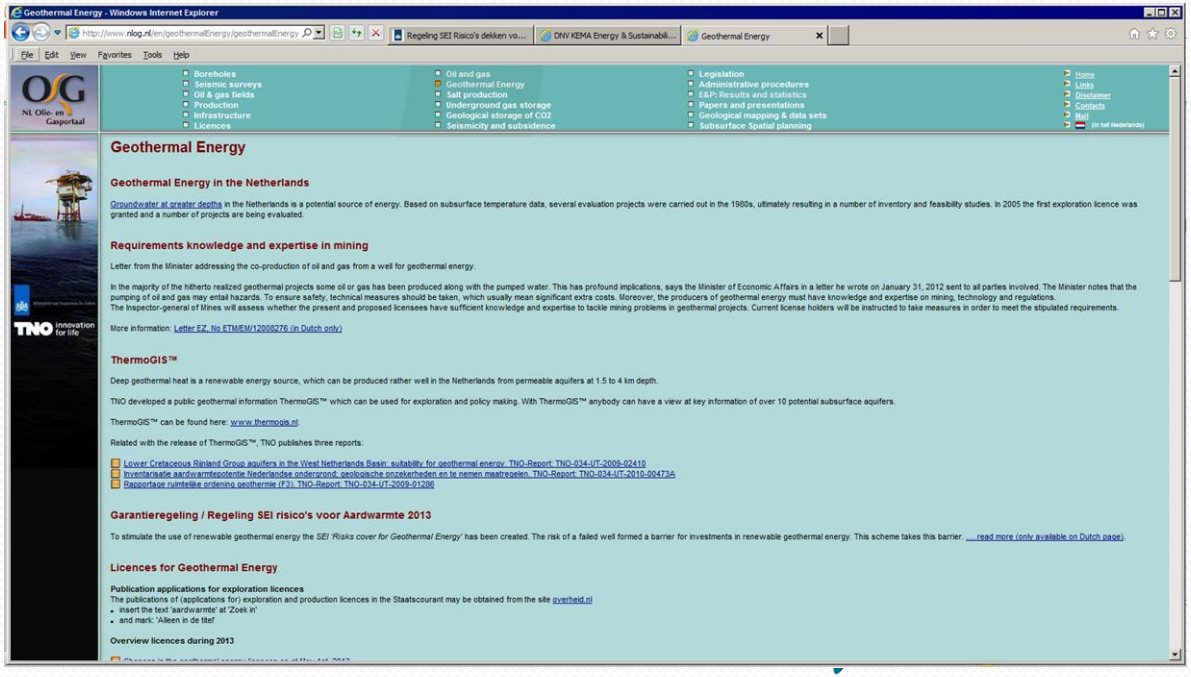
Subsurface Geology ⇔ Uncertainty

- Calculation geothermal potential = f (flow, temperature)
  - Flow = f(k, H, N/G, salinity)
  - Temperature = f (geothermal gradient, depth)
- Pre-drill estimation of geological/aquifer parameters
  - Tricky => estimation including uncertainty range
- Best expressed as a range of possible outcomes with an equal likelihood of realization



Aquifer evaluation => Subsurface Data and geological information

- **www.NLOG.nl ⇔ Public domain data**
  - "raw" subsurface data: well data, seismic data, production data
  - Interpreted subsurface data: regional mapping, ThermoGis
  - Publications



Subsurface uncertainty: e.g. aquifer thickness

Thickness 2 m

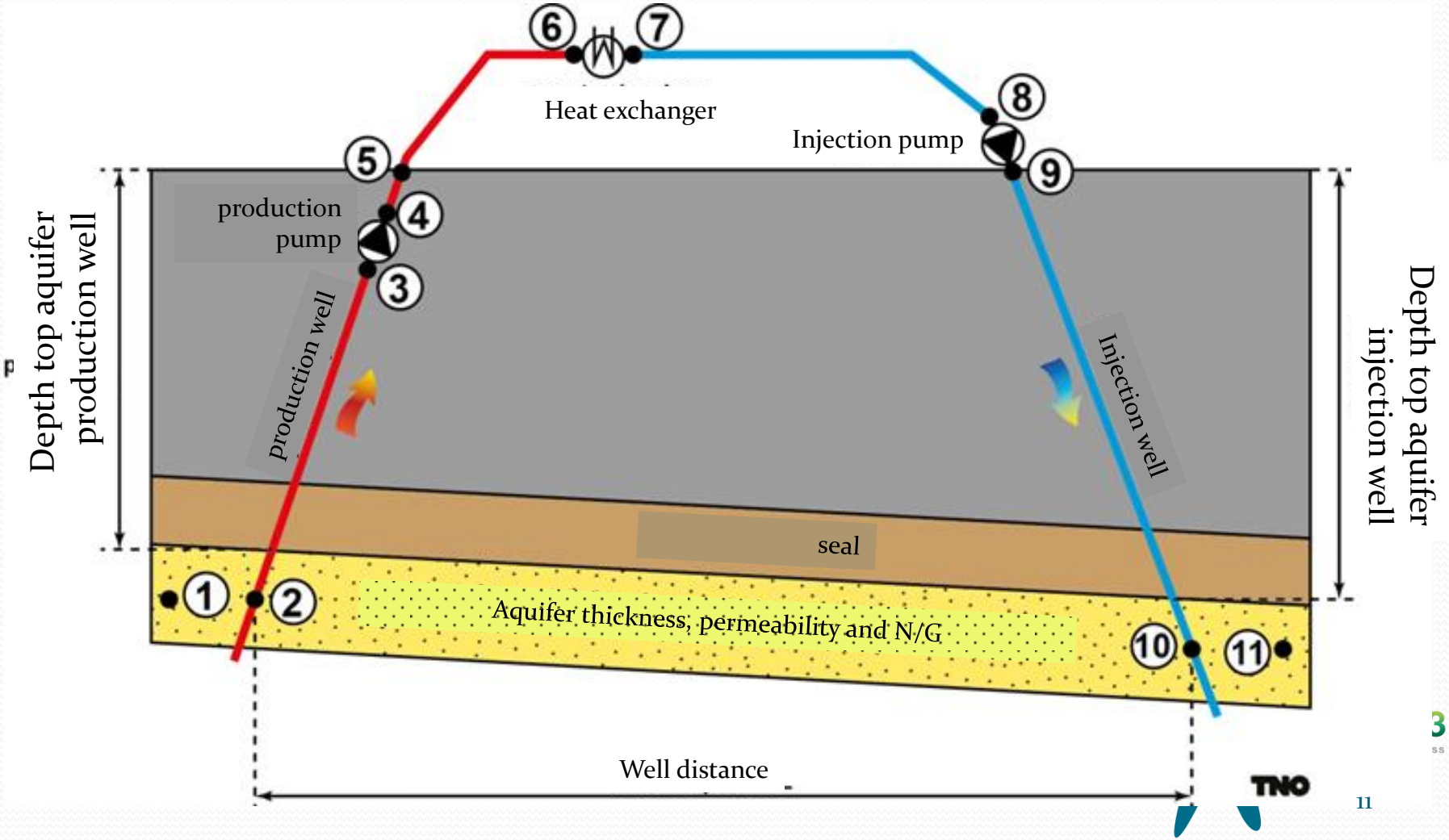
← Ca 2500m →

Thickness 30 m

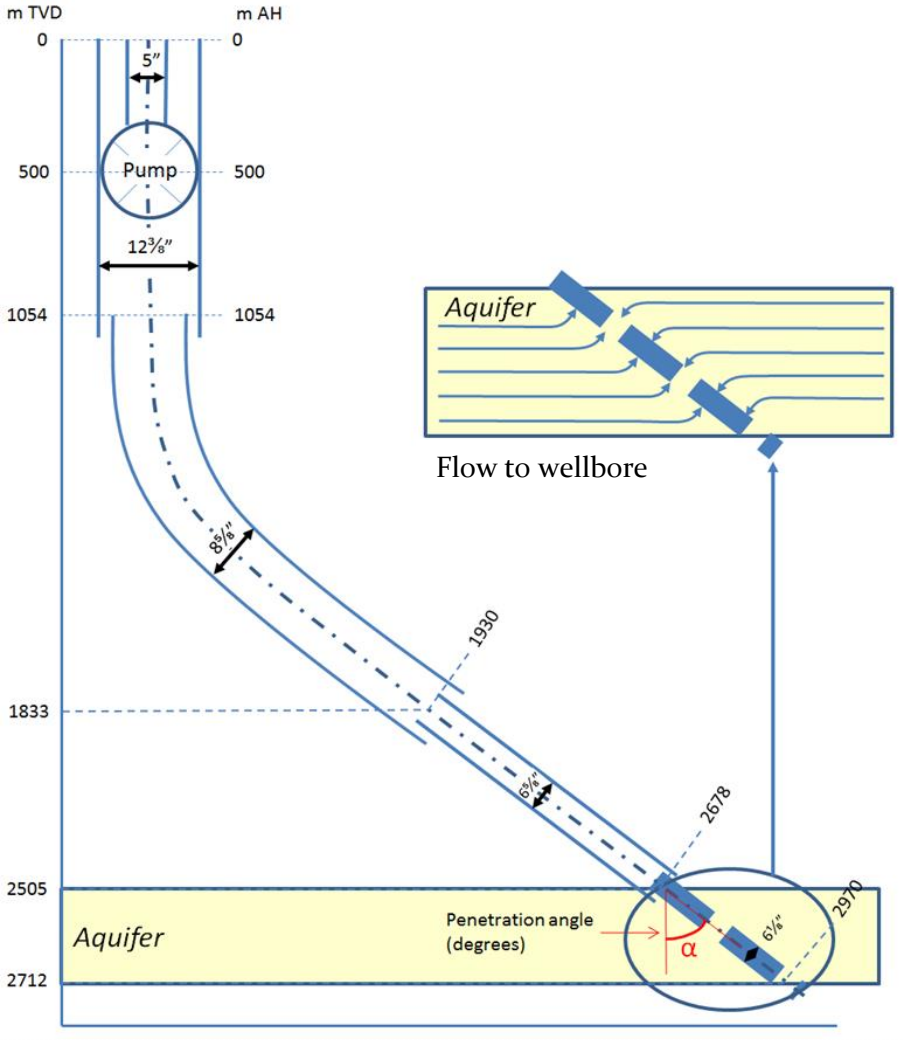
Calculation Indicative Pre-drill Geothermal Power →DoubletCalc

- DoubletCalc: a dedicated program which calculates the potential geothermal power of a doublet, on a basic set of geological, installation and operational parameters
- Geological input parameters are given in uncertainty ranges
- Geothermal power is stochastically calculated
- Output => P_{90}, P_{50}, P_{mean} & P_{10} geothermal power

DoubletCalc model



Installation parameters

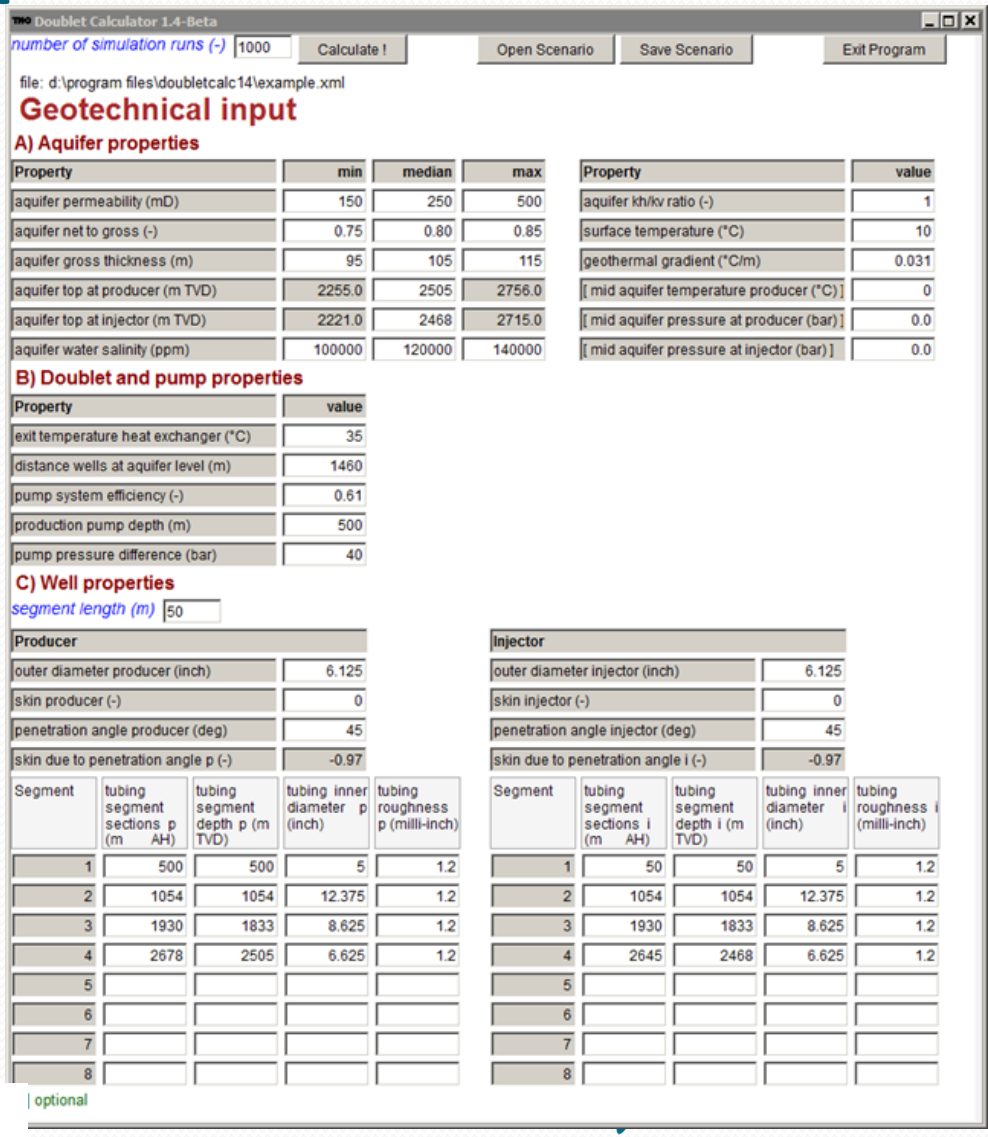


DoubletCalc: Input screen

Aquifer properties => range

Installation properties => single

Well properties => single



Doublet Calculator 1.4-Beta

number of simulation runs (-) 1000 | Calculate ! | Open Scenario | Save Scenario | Exit Program

file: d:\program files\doubletcalc14\example.xml

Geotechnical input

A) Aquifer properties

Property	min	median	max
aquifer permeability (mD)	150	250	500
aquifer net to gross (-)	0.75	0.80	0.85
aquifer gross thickness (m)	95	105	115
aquifer top at producer (m TVD)	2255.0	2505	2756.0
aquifer top at injector (m TVD)	2221.0	2468	2715.0
aquifer water salinity (ppm)	100000	120000	140000

Property	value
aquifer kh/kv ratio (-)	1
surface temperature (°C)	10
geothermal gradient (°C/m)	0.031
[mid aquifer temperature producer (°C)]	0
[mid aquifer pressure at producer (bar)]	0.0
[mid aquifer pressure at injector (bar)]	0.0

B) Doublet and pump properties

Property	value
exit temperature heat exchanger (°C)	35
distance wells at aquifer level (m)	1460
pump system efficiency (-)	0.61
production pump depth (m)	500
pump pressure difference (bar)	40

C) Well properties

segment length (m) 50

Producer	
outer diameter producer (inch)	6.125
skin producer (-)	0
penetration angle producer (deg)	45
skin due to penetration angle p (-)	-0.97

Segment	tubing segment sections p (m AH)	tubing segment depth p (m TVD)	tubing inner diameter p (inch)	tubing roughness p (milli-inch)
1	500	500	5	1.2
2	1054	1054	12.375	1.2
3	1930	1833	8.625	1.2
4	2678	2505	6.625	1.2
5				
6				
7				
8				

Injector	
outer diameter injector (inch)	6.125
skin injector (-)	0
penetration angle injector (deg)	45
skin due to penetration angle i (-)	-0.97

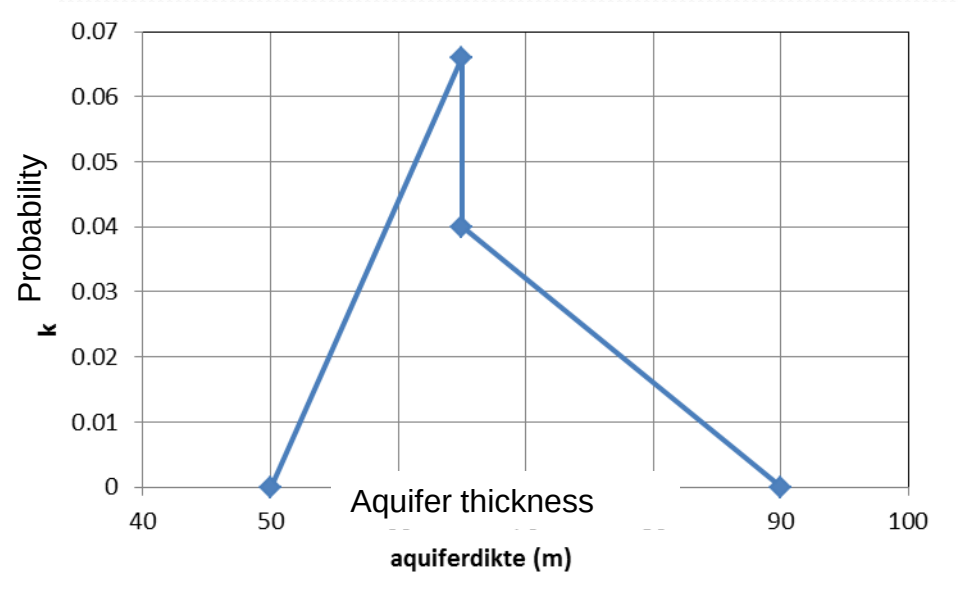
Segment	tubing segment sections i (m AH)	tubing segment depth i (m TVD)	tubing inner diameter i (inch)	tubing roughness i (milli-inch)
1	50	50	5	1.2
2	1054	1054	12.375	1.2
3	1930	1833	8.625	1.2
4	2645	2468	6.625	1.2
5				
6				
7				
8				

optional

http://www.nlog.nl/nl/geothermalEnergy/geothermalEnergy.html

Stochastic simulation:

- Uncertainty ranges expressed as a double triangle
- Analytical model



$$Q_m = constant$$

$$Q_v = \frac{Q_m}{\rho}$$

$$\Delta p_{w,aq} = p_w - p_{aq} = Q_v \frac{\mu}{2\pi k H R_{ntg}} \left(\ln\left(\frac{L}{r_{out,w}} \right) + S \right)$$

$$p_{stat,p} + \sum_{k=1}^{N-1} \Delta p_{k+1,k} - p_{stat,i} = 0$$

$$q_{w,put} = \frac{4\pi k_{t,g} (T_c - T_{gt})}{\ln\left(\frac{4\alpha_{t,g} t}{\sigma r_c^{\,2}} \right)}$$

$$\rho_{fw} = 1 + 10^{-6}(-80T - 3.3T^2 + 0.00175T^3 + 489p - 2Tp$$
$$+ 0.16T^2 p - 1.3 \cdot 10^{-5} T^3 p - 0.333p^2 - 0.002Tp^2)$$

DoubletCalc Output screens

Doublet Calculator 1.4-Beta Result Table

probabilistic plots | fingerprinting | export base case details

file: d:\program files\doubletcalc14\example.xml

Geotechnics (Input)

Geotechnics (Output)

Property	min	median	max
aquifer permeability (mD)	150.0	250.0	500.0
aquifer net to gross (-)	0.75	0.8	0.85
aquifer gross thickness (m)	95.0	105.0	115.0
aquifer top at producer (m TVD)	2255.0	2505.0	2756.0
aquifer top at injector (m TVD)	2221.0	2468.0	2715.0
aquifer water salinity (ppm)	100000.0	120000.0	140000.0

Monte Carlo cases (stochastic inputs)	P90	P50	P10
aquifer kH net (Dm)	16.4	21.3	32.52
mass flow (kg/s)	35.16	43.79	58.29
pump volume flow (m³/h)	119.8	149.1	198.5
required pump power (kW)	218.3	271.6	361.5
geothermal power (MW)	6.42	8.33	11.23
COP (kW/kW)	28.0	30.4	32.8

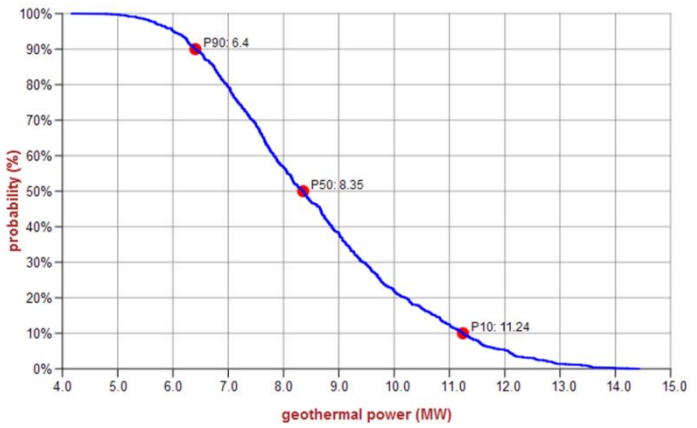
Property	value
number of simulation runs (-)	1000.0
aquifer kh/kv ratio (-)	1.0
surface temperature (°C)	10.0
geothermal gradient (°C/m)	0.031
[mid aquifer temperature producer (°C)]	0.0
[mid aquifer pressure at producer (bar)]	0.0
[mid aquifer pressure at injector (bar)]	0.0
exit temperature heat exchanger (°C)	35.0
distance wells at aquifer level (m)	1460.0
pump system efficiency (-)	0.61
production pump depth (m)	500.0
pump pressure difference (bar)	40.0
outer diameter producer (inch)	6.13
skin producer (-)	0.0
skin due to penetration angle p (-)	-0.97
tubing segment sections p (m AH)	500.0,1054.0,1930.0,2678.0
tubing segment depth p (m TVD)	500.0,1054.0,1833.0,2505.0
tubing inner diameter p (inch)	5.0,12.38,8.62,6.62
tubing roughness p (milli-inch)	1.2,1.2,1.2,1.2
outer diameter injector (inch)	6.13
skin injector (-)	0.0
skin due to penetration angle i (-)	-0.97
tubing segment sections i (m AH)	50.0,1054.0,1930.0,2645.0
tubing segment depth i (m TVD)	50.0,1054.0,1833.0,2468.0
tubing inner diameter i (inch)	5.0,12.38,8.62,6.62
tubing roughness i (milli-inch)	1.2,1.2,1.2,1.2

base case (median value inputs)	value
aquifer kH net (Dm)	21.0
mass flow (kg/s)	43.05
pump volume flow (m³/h)	146.6
required pump power (kW)	267.1
geothermal power (MW)	8.12
COP (kW/kW)	30.4
Aquifer Pressure at producer (bar) *	255.08
Aquifer Pressure at Injector (bar) *	251.18
Pressure difference at producer (bar) *	13.78
Pressure difference at Injector (bar) *	25.81
Aquifer temperature at producer (°C) *	89.28
Temperature at heat exchanger (°C)	86.51

* @ mid aquifer depth

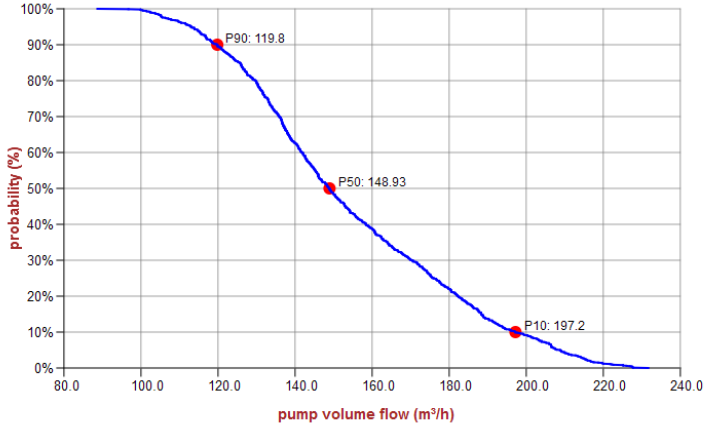
Doublet Calculator 1.4 Probabilistic Plots

geothermal power (MW) | export CSV file

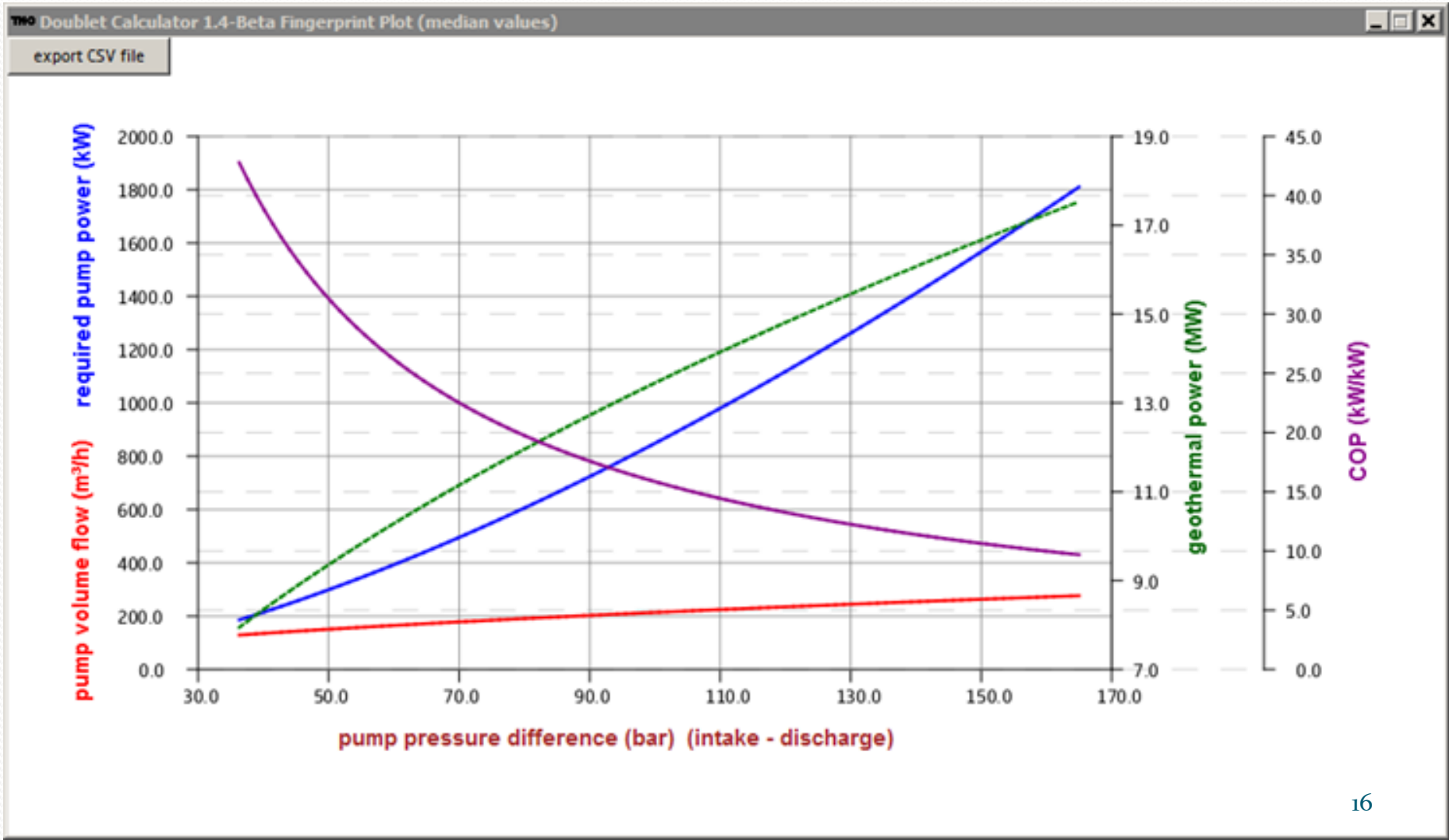


Doublet Calculator 1.4 Probabilistic Plots

pump volume flow (m³/h) | export CSV file



DoubletCalc output screen



Geothermal Guarantee Scheme

www.agentschapnl.nl/aardwarmte

- **Risk-mitigation** scheme for geothermal projects
- Insurance on disappointing realised performance of a geothermal doublet due to **geological risks**
- Insurance on difference: pre-drill $P_{estimated/insured}$ (max. P90 estimated Geothermal power) vs. $P_{realised}$ (realised Geothermal power)

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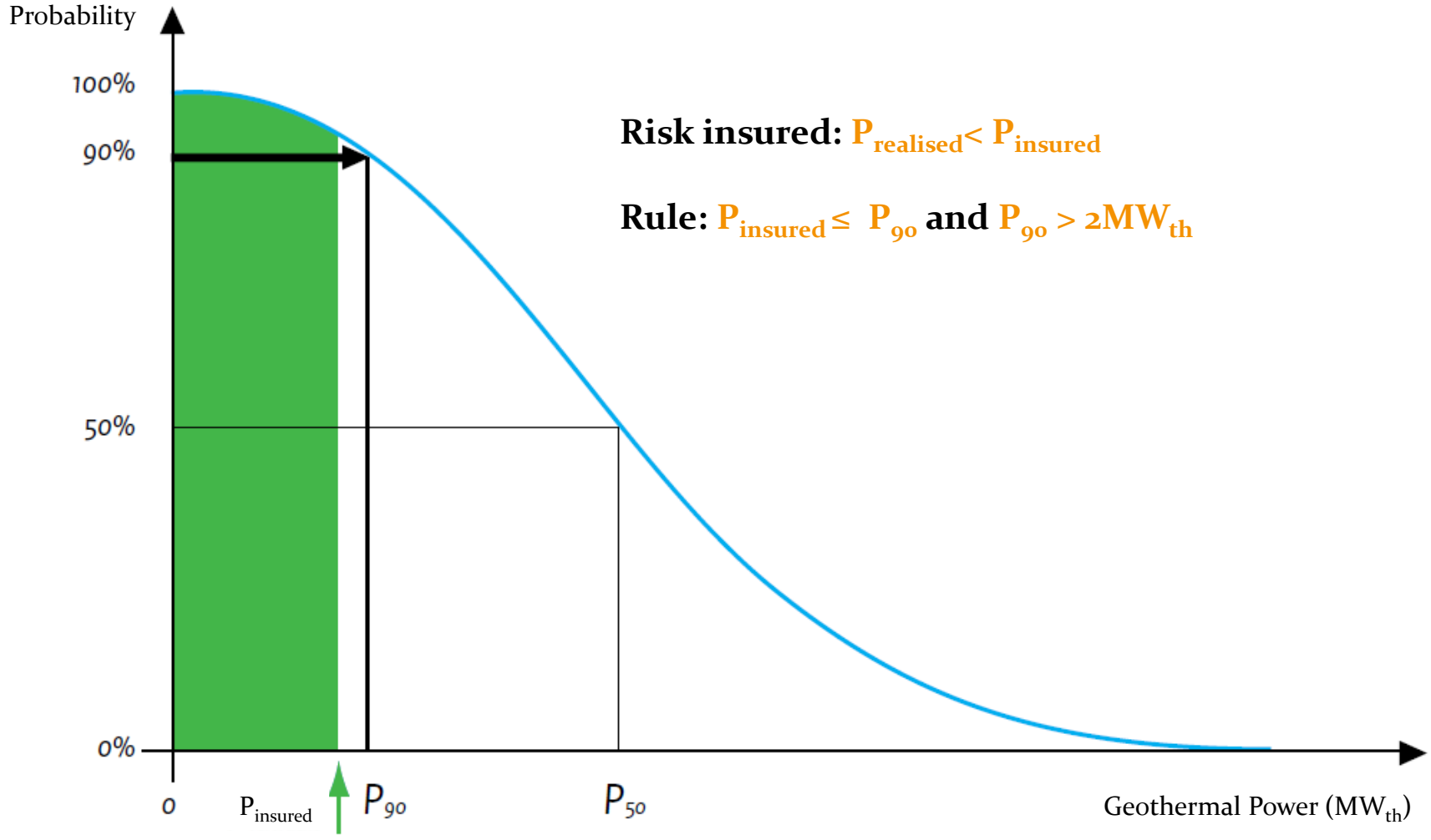
P90 pre-drill geothermal power



Risk insured: $P_{realised} < P_{insured}$

Rule: $P_{insured} \leq P_{90}$ **and** $P_{90} > 2MW_{th}$

Application procedure

Action Applicant

- 1. Contact government (NL Agency)
- 2. File an application

Audit & processing application by government (NL Agency)

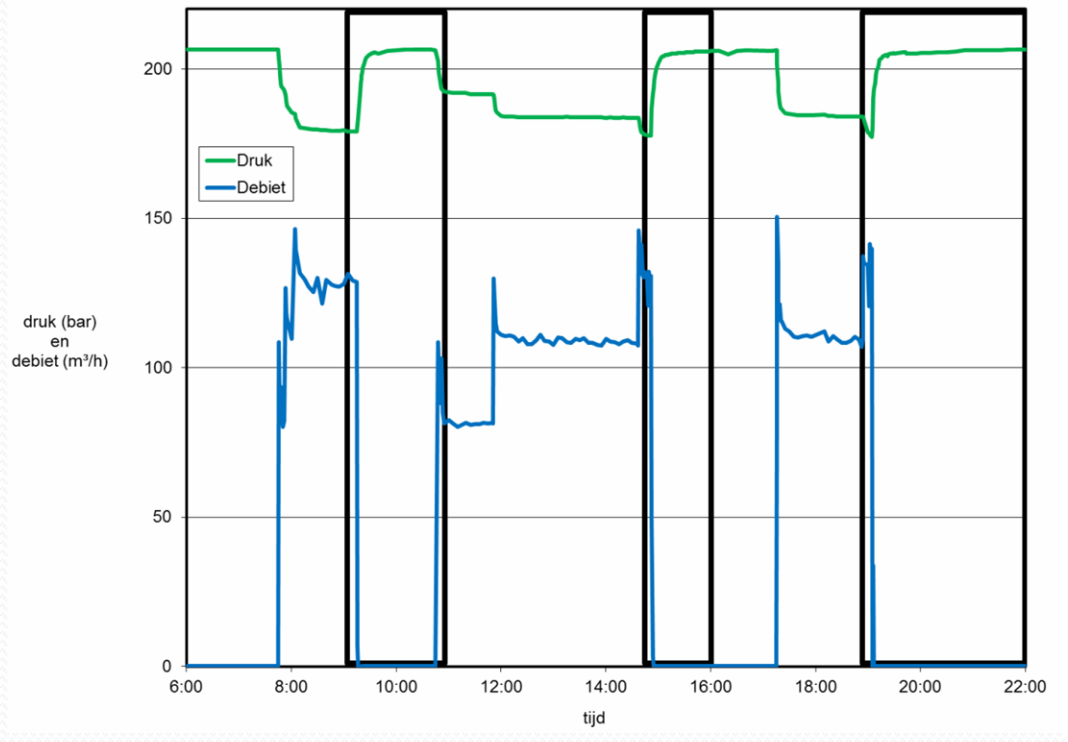
- 3. Is the application complete?
- 4. Audit on content:
  - geologic audit *(TNO review P90 GT-power)*
  - audit of economic, financial, technical, organizational and planning aspects *(NL Agency)*
- 5. Grant or denial (NL Agency)

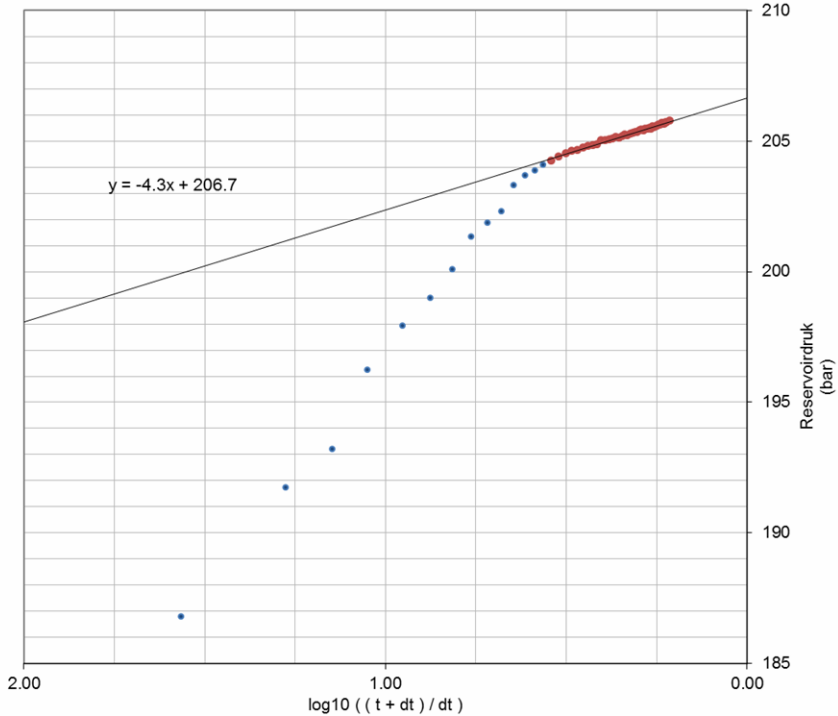
Action applicant

- 6. Payment of "insurance" premium

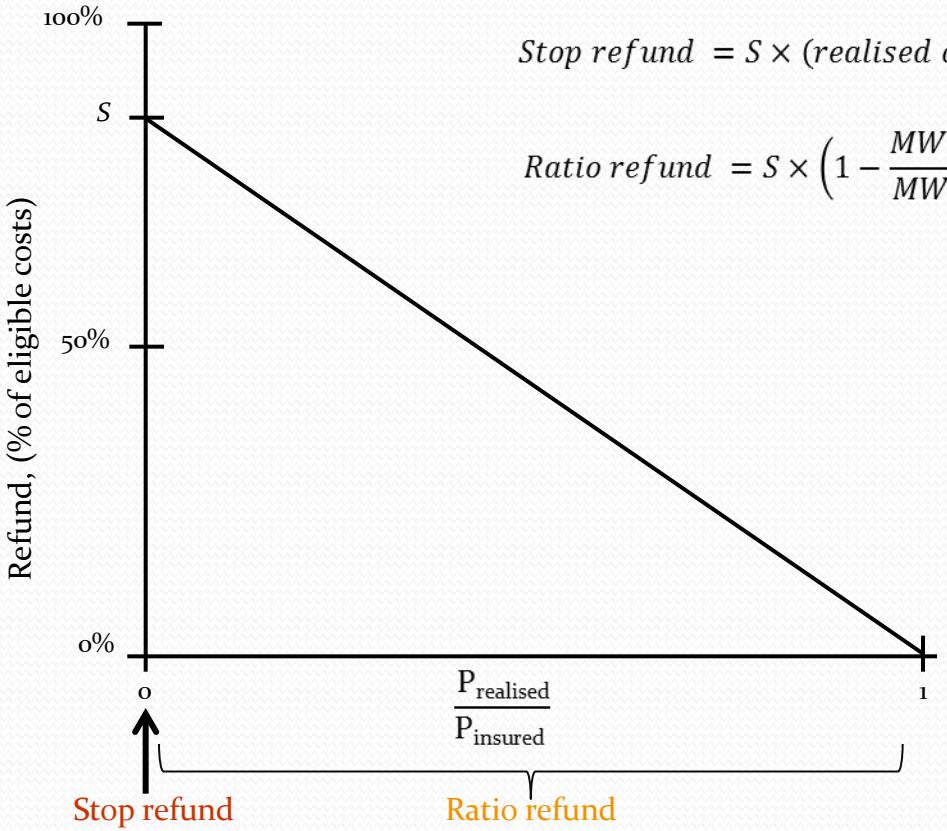
Realised performance: Well test

- Well test => Determination of: transmissivity, permeability and skin
- Calculation realised geothermal power ($P_{realised}$)





Refund strategy



$$Stop\ refund\ = S \times (realised\ costs\ - rest\ value)$$

$$Ratio\ refund\ = S \times \left(1 - \frac{MW_{realised}}{MW_{insured}}\right) \times realised\ costs$$

improvement or alternative use possible

Refund scenario's for a project

- 1st well

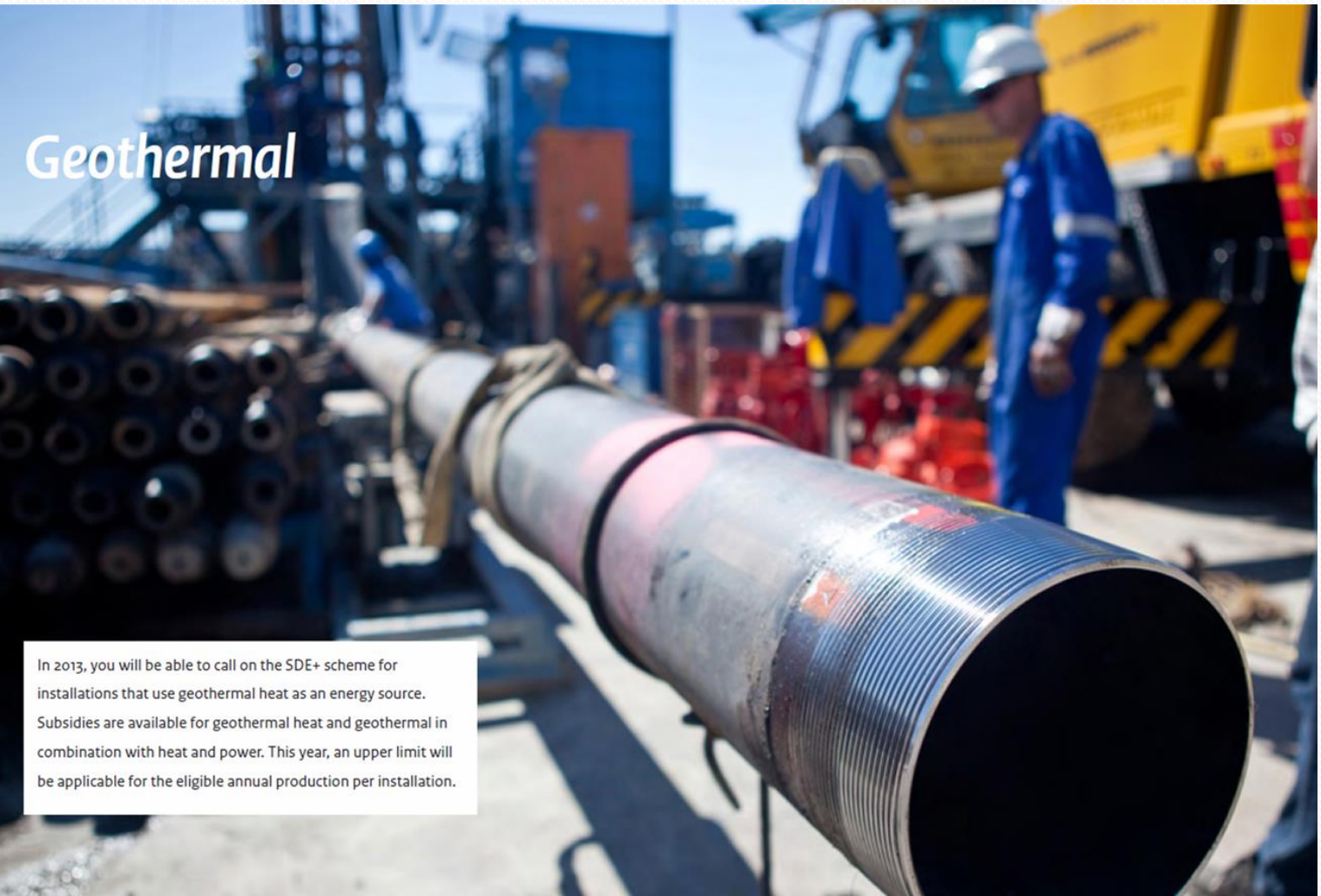
1st well doublet	> 75%	→ 2nd well obligatory
	> 50%< MW_{th}< 75%	→ Choice: 2nd well or stop refund
	< 50%	→ stop obligatory → stop refund
1st well half doublet	> 75%	→ 2nd well obligatory
	<75%	→ Choice: 2nd well or stop refund

- 2nd well

2nd well doublet	> 100%	→ Project successful → no refund
	<100%	→ Suboptimal project → ratio refund

Exploitation Subsidy: SDE+

www.agentschapnl.nl/sde



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SDE+

- Feed-in premium for renewables
- SDE+ levels cost price of renewables to fossiles
- one pot + auction
  (max. base amount increased per phase; 6 phases in 2013)
- renewable **heat** included **since 2012**

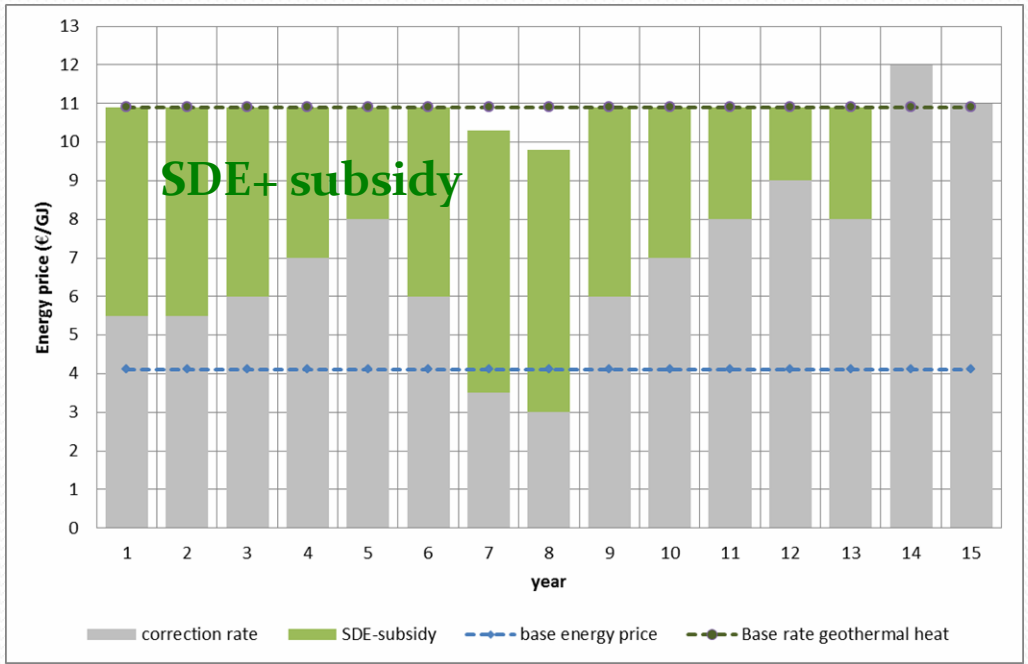
- **Geothermal energy**
  - Max. subsidy duration = 15 yr
  - Max. full load hours = 5500 hrs/yr (4158 hrs/yr for cogen.)
  - Leadtime start up installation= 4 yr

SDE+ figures

- **Base rate** is fixed (= cost price geothermal energy)
- **Correction amount** determined yearly (= cost price fossile energy)
- **Base-energy price** = lower limit "correction amount"
- **SDE+-subsidy** = (Base rate – correction amount) € /GJ

Base rate >

BEP >



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Calculation of base rate

- Based on **reference cases** (advice: ECN / DNV KEMA)
- Costs
  - Drilling
  - Separation of Hydrocarbons
  - Installation

Drilling depth	Unit	Net drilling costs	Reserve for separation of hydrocarbons	Drilling costs including separation of hydrocarbons
2300 m	[M€]	5.7	1.0	6.7
3000 m	[M€]	11.0	1.0	12.0
4000 m	[M€]	16.5	1.0	17.5

		Reference case 2300m – target depth 500 – 2700 m			**Reference case 3000m – target depth > 2700 m**		
		Variant Doublet	Variant 'Sweet spot'	Variant Triplet	Variant Doublet	Variant 'Sweet spot'	Variant 'Triplet
Flow rate	[m^3/h]	137	180	2x137	133	180	2 x 133
Geothermal capacity	[MW_{th}]	6.2	8.1	12.4	9.0	12.15	18.0
Full-load hours	[h/a]	5,500	5,500	5,500	5,500	5,500	5,500
Investment cost	[€/kW_{th}]	1,527	1,261	1,132	1,743	1,381	1,321
Fixed O&M cost	[€/kWth]	30	25	23	35	28	26
Variable O&M cost	[€/GJ]	2.2	2.2	2.2	1.85	1.85	1.85
Base rate	**[€/GJ]**	**11.8**	10.3	9.5	**12.8**	10.6	10.2

SDE+ 2013 rates

Geothermal Energy SDE+ 2013	max. base amount (€/GJ)	preliminary correction amount 2013 (€/GJ)	preliminary SDE+ amount 2013 (€/GJ)	max. full load hours per year	*max. 15y subsidy at prel. 2013 corr.rate / (power)*
Geothermal Heat > 500m max. 245,520 GJ/year	11.8	5.7 (BEP=€3.7)	**6.1** (0-8.1)	5500	*€ 22,465,080 / (12,4 MWth)*
Geothermal Heat > 2700m max. 356,400 GJ/year	12.8	5.7 (BEP=€3.7)	**7.1** (0-9.1)	5500	*€ 37,956,600 / (18 MWth)*
Geothermal Heat+Electricity max. 178,129 GJ/year	24	7.1 (BEP=€5.5)	**16.9** (0-18.5)	4158	*€ 45,155,702 / (12 MW*)*

BEP = Base Energy Price

* nominal power for Geothermal H+E = nominal Heat Power + nominal Electrical Power (not neccesarily at same time)

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SDE+2013, 6 phases

April 4	May 13	June 17	Sep 2	Sep 30	Nov 4
0.07	0.08	0.09	0.11	0.13	0.015
€ct/kWh	€ct/kWh	€ct/kWh	€ct/kWh	€ct/kWh	€ct/kWh
19.444	22.222	25.000	30.556	36.111	41.667
€/GJ	€/GJ	€/GJ	€/GJ	€/GJ	€/GJ

3. Phasing and rates for Geothermal

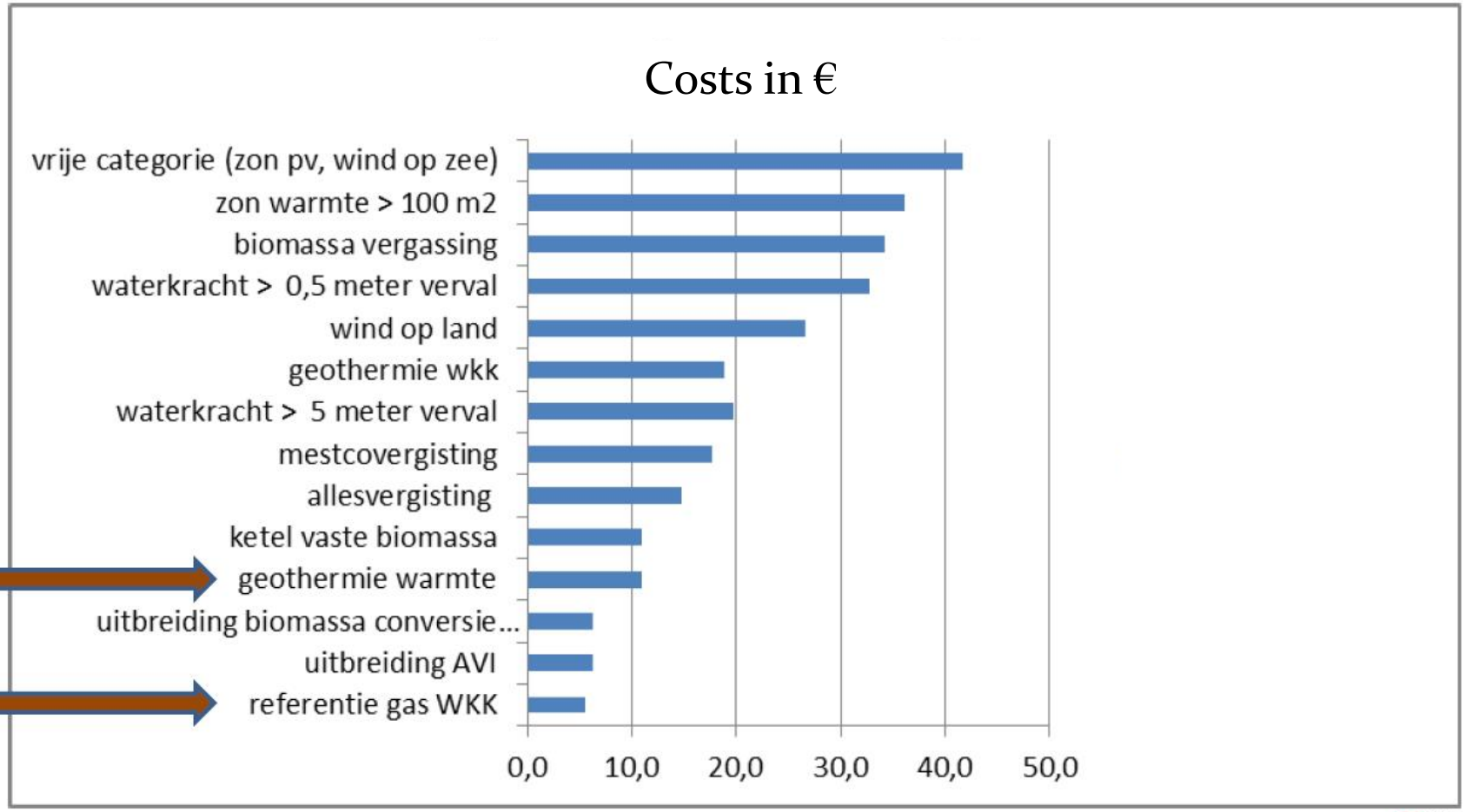
	Phase 1 4 Apr 9.00 to 13 May 17.00	Phase 2 13 May 17.00 to 17 Jun 17.00	Phase 3 17 Jun 17.00 to 2 Sep 17.00	Phase 4 2 Sep 17.00 to 30 Sep 17.00	Phase 5 30 Sep 17.00 to 4 Nov 17.00	Phase 6 4 Nov 17.00 to 19 Dec 17.00	Base energy price	Preliminary correction amount for 2013	Max. full load hours per year	Max. subsidy period (years)	Latest term for operation
Geothermal	Base amount per phase (€ / GJ)						(€ / GJ)				
Geothermal CHP • ≥ 500 m deep, max 178,129 GJ/year	19.444	22.222	24.0	24.0	24.0	24.0	5.5	7.1	4158	15	4
Geothermal heat • ≥ 500 m deep, max 245,520 GJ/year • ≥ 2700 m deep, max 356,400 GJ/year	11.8 12.8	11.8 12.8	11.8 12.8	11.8 12.8	11.8 12.8	11.8 12.8	3.7 3.7	5.7 5.7	5500 5500	15 15	4 4

4. Geothermal calculation example

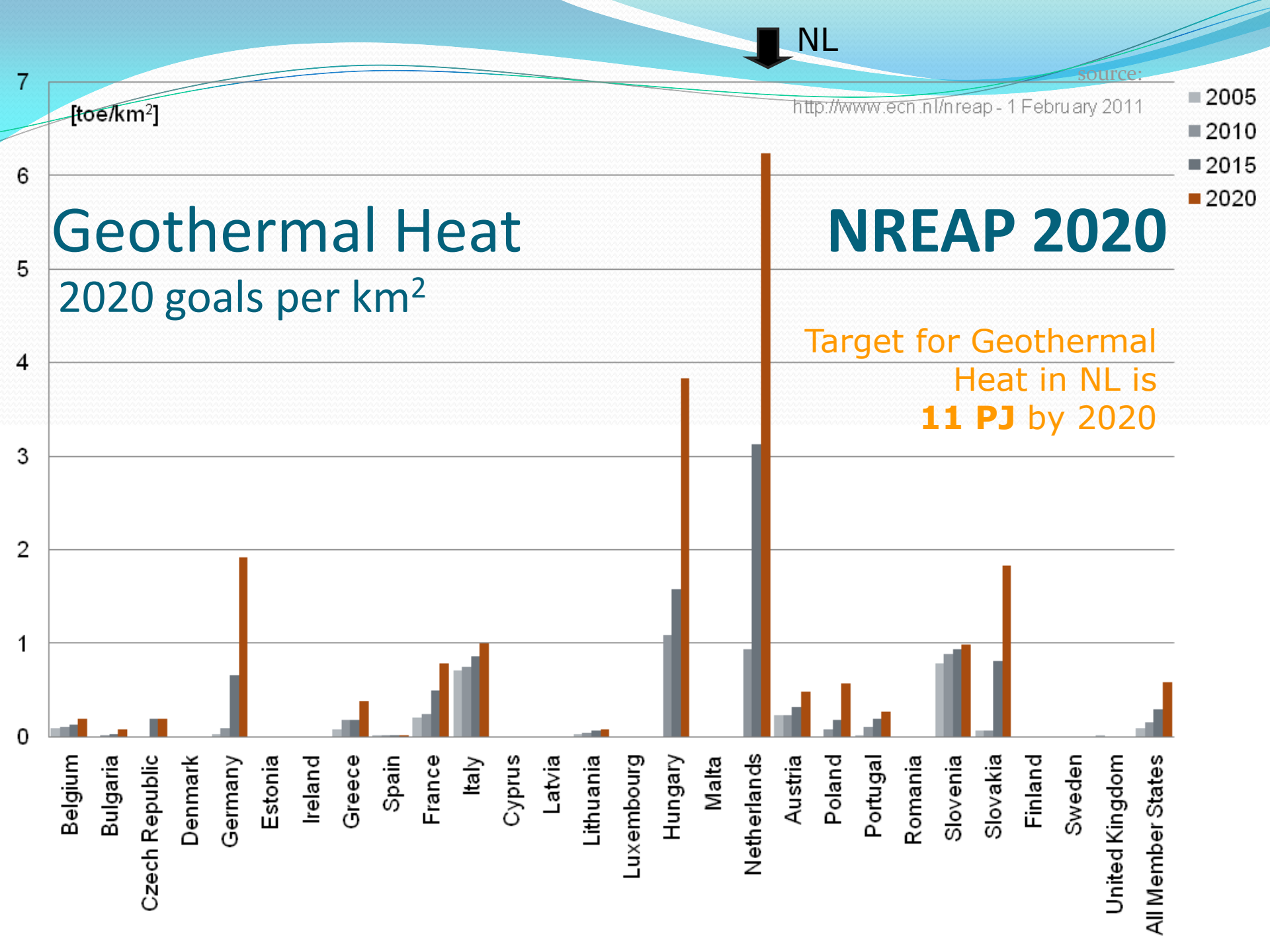
Calculation example SDE+ contribution – Geothermal deeper than 2700 metres (heat)

Base amount from phase 1	12.8 €/GJ
Preliminary correction amount for 2013	5.7 €/GJ
Preliminary SDE+ contribution for 2013 from phase 1	12.8 – 5.7 = 7.1 € / GJ
Maximum number of eligible full load hours	5,500
Maximum eligible annual production at an installation with a capacity of 10 MW	10 * 5,500 = 55,000 MWh (corresponds with) 198,000 GJ
Maximum eligible annual production per production installation for the geothermal category deeper than 2700 metres	356,400 GJ
Annual production for which you are applying for a subsidy: 198,000 GJ. In this case, the subsidy is granted for a maximum of 198,000 GJ/year.	
Preliminary SDE+ contribution for 2013 when applied from phase 1	**7.1 * 198,000 = € 1,405,800,-**

SDE+ 2012 base rates



Source: www.geothermie.nl


NL
source:
http://www.ecn.nl/nreap - 1 February 2011
[toe/km²]
2005
2010
2015
2020
Geothermal Heat
2020 goals per km²
NREAP 2020
Target for Geothermal Heat in NL is 11 PJ by 2020
0
1
2
3
4
5
6
7
Belgium
Bulgaria
Czech Republic
Denmark
Germany
Estonia
Ireland
Greece
Spain
France
Italy
Cyprus
Latvia
Lithuania
Luxembourg
Hungary
Malta
Netherlands
Austria
Poland
Portugal
Romania
Slovenia
Slovakia
Finland
Sweden
United Kingdom
All Member States

Summary

2012 SDE+ (incl. renewable heat)
total budget allocation 1700 M€
*30 **geothermal heat projects** > 829 M€ allocated*
*> maximum 121 PJ (in 15 years) = **max. 8 PJ /year***

2013 SDE+
total budget allocation 3000 M€
*opened **april 4th 2013***

2013 Geothermal Guarantee scheme (renewed, 3rd opening)
available budget 43 M€
*opened **march 18th 2013***
new/innovative: possibility for deep project > 3500 m, half doublet, etc.

Geothermal in NL
ready for take off…

EGC 2013
European Geothermal Congress

Conclusion

- Support schemes are propelling geothermal in NL to a next phase
- The main issues are the uncertainties in the pre-drill geothermal power estimation, and in the investment costs
- DoubletCalc software efficiently calculates an indicative geothermal power range
- Regular amendments are carried out to meet new requirements and incorporate new insights

***Support Schemes** are a crucial element for the **breakthrough of geothermal** in NL*

Thank you for your attention

source: www.vleestomaat.nl

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