

Hydrogeologie · Geothermie

Deep Geothermal energy in Munich (and Bavaria) – progress to date

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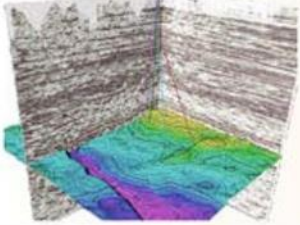
- ❖ Introduction
- ❖ Geothermal Development in Bavaria – Brief Overview
- ❖ Reasons for Success
- ❖ Stadwerke München (SWM)
- ❖ Template for further Regions and Cities?

Introduction



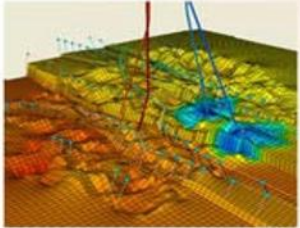
Geology & Geophysics

Geological Exploration
Geological Models
Well Site Geology
Borehole Geophysics



Reservoir Engineering

Reservoir Models
Simulation & Targeting
Risk Assessment
Well Test Analysis



Drilling Engineering

Well Design and Drilling Program
Well Site Design
Supervision
Drilling Data Analysis & Drilling Performance Analysis



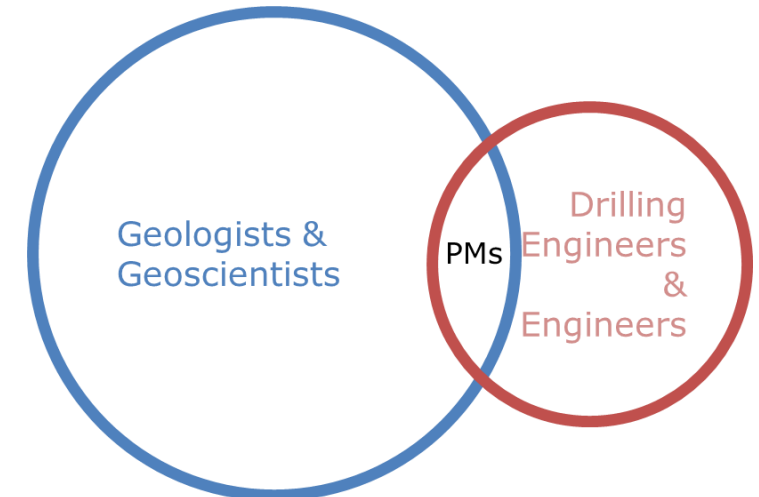
Production Engineering

Completion Design
Well Test Design
Artificial Lift Systems
Stimulation Design

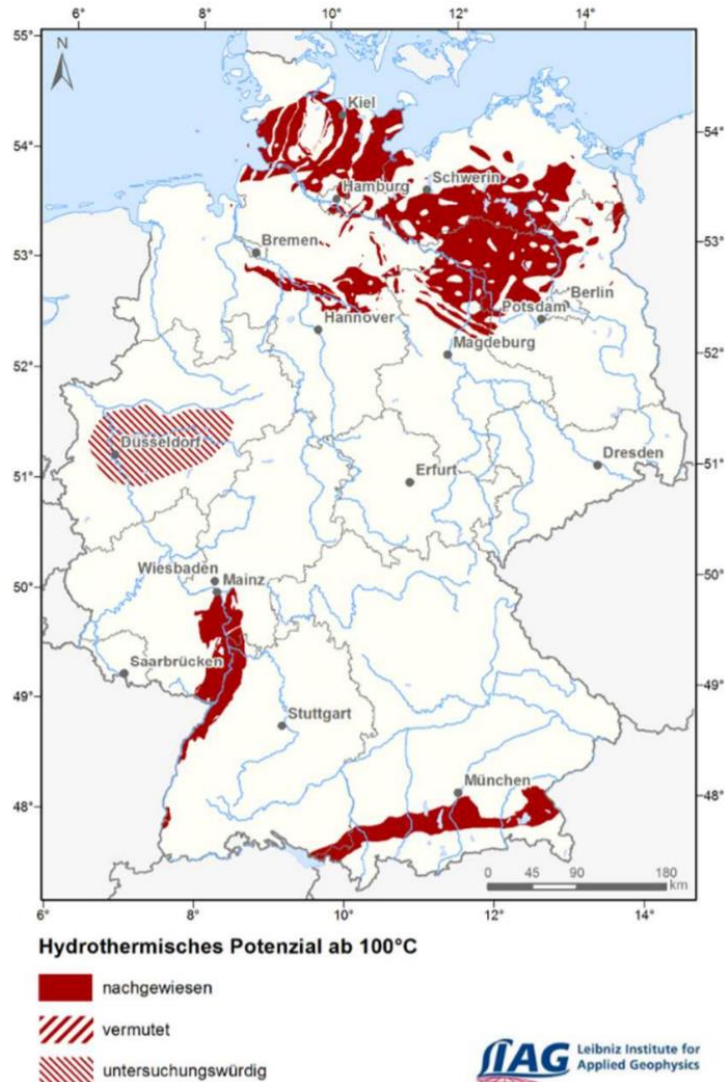


Project Management, Permits and Tenders

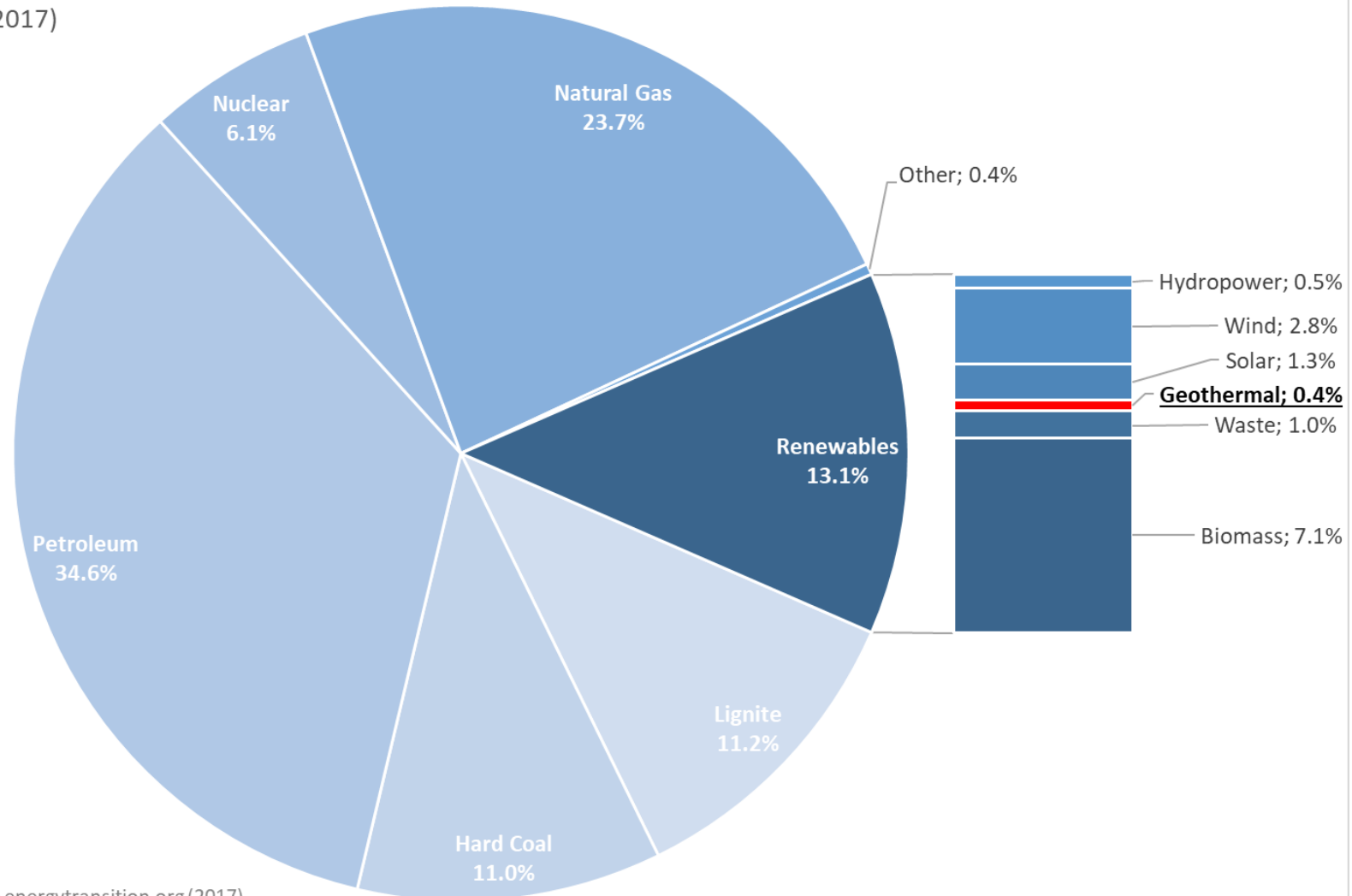
Project Management
Bidding Procedures
Approval Procedures



Introduction

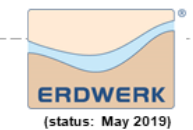
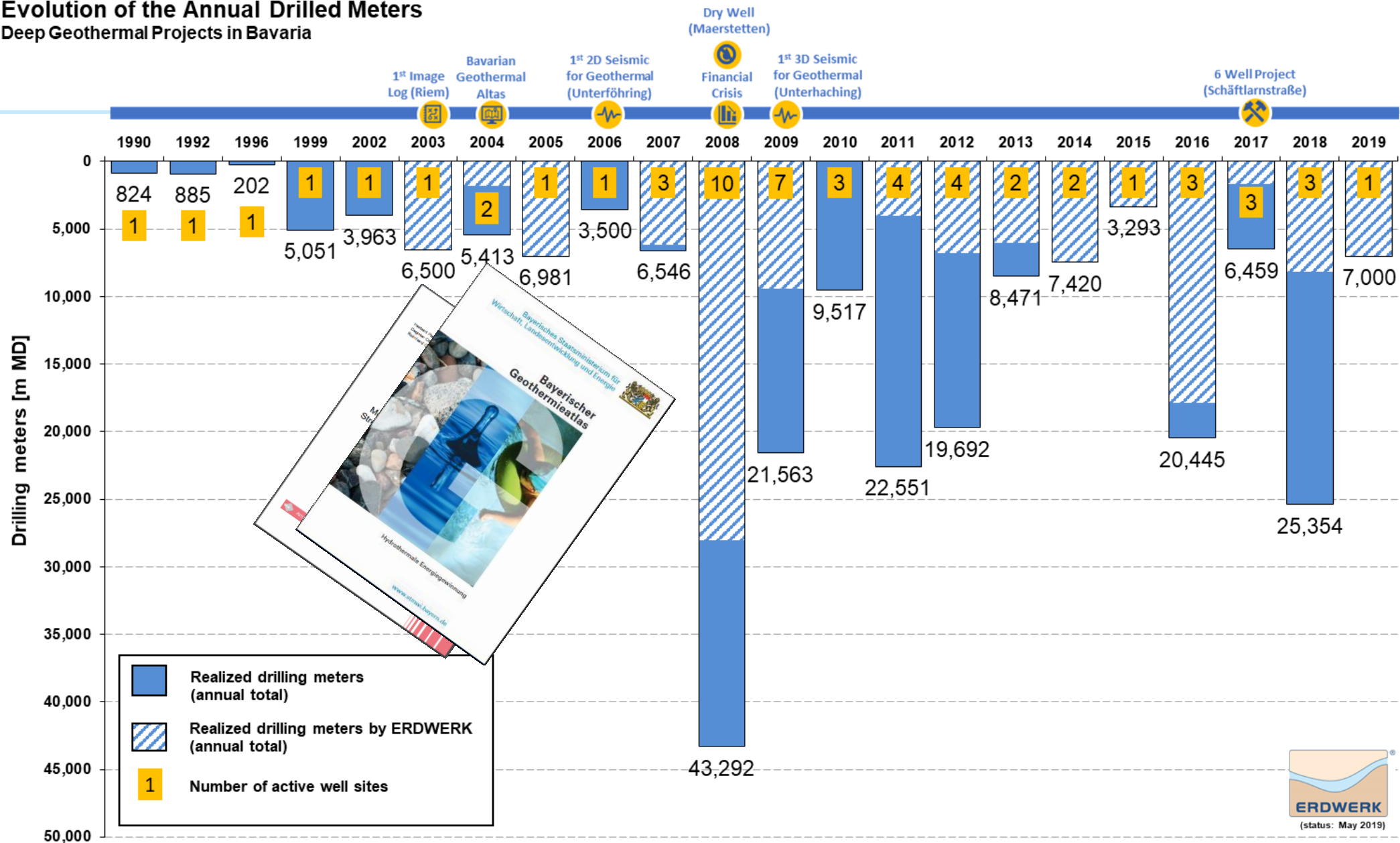


Primary Consumption Energy Mix
Germany (2017)

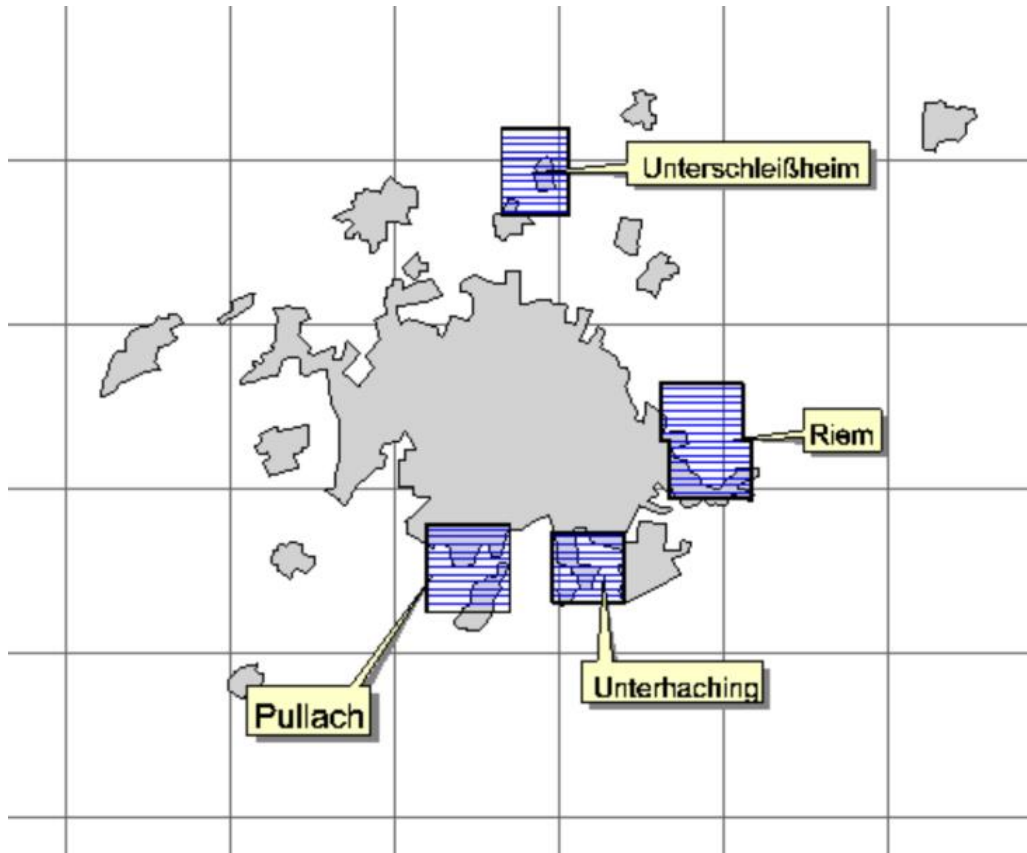


Adapted from energytransition.org (2017)

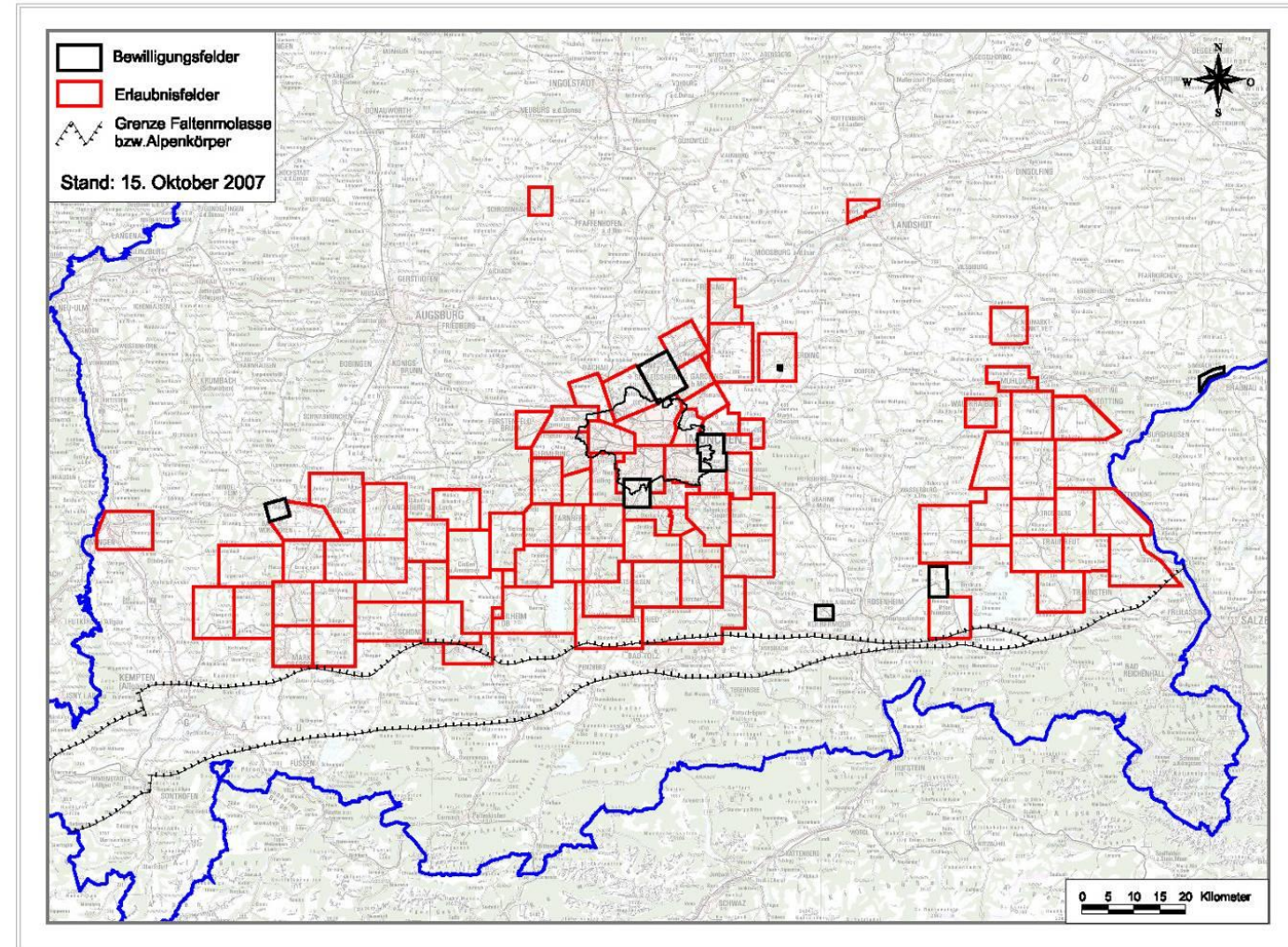
Evolution of the Annual Drilled Meters Deep Geothermal Projects in Bavaria



Geothermal Development in Bavaria – Brief Overview

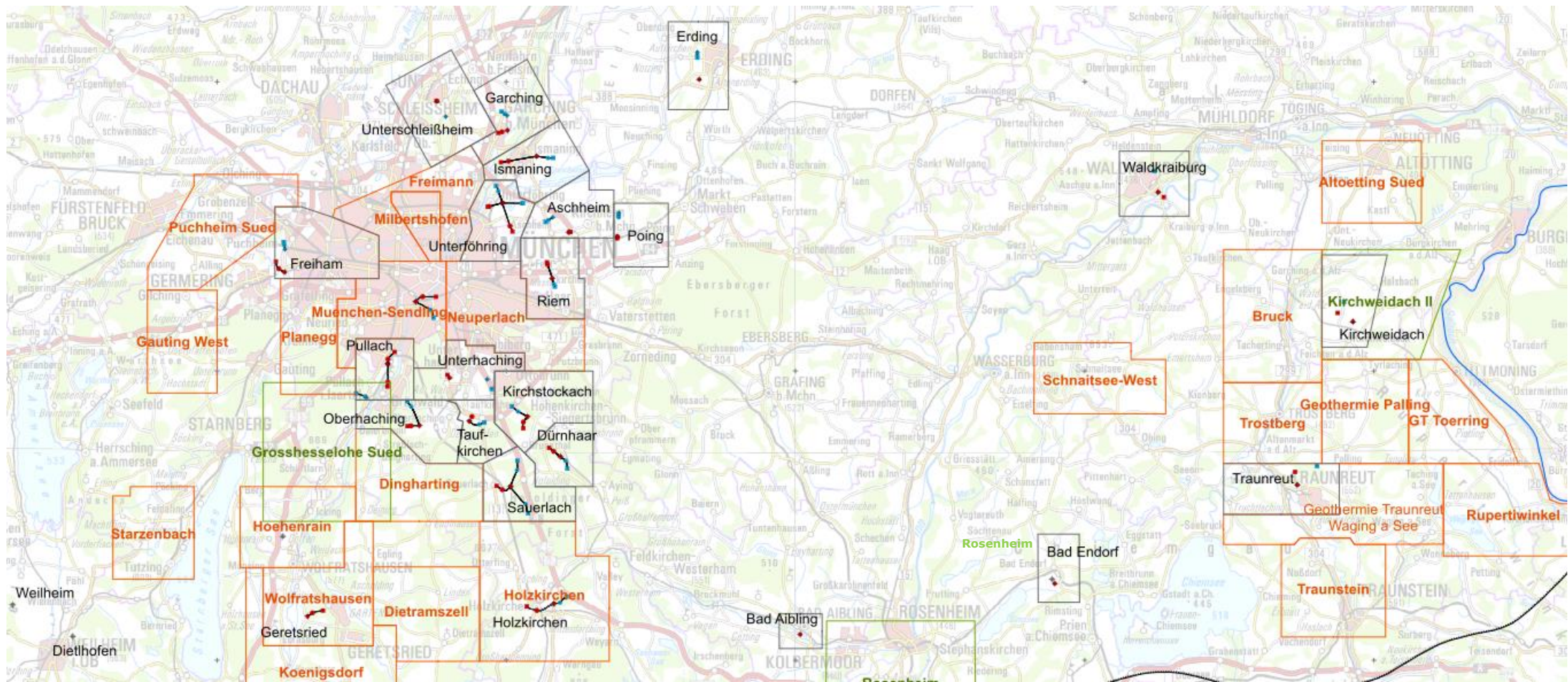
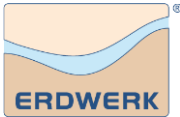


2002



2007

Geothermal Development in Bavaria – Brief Overview



Geothermal Concession Fields

- Production Permit
- Exploration Permit
- Large-Scale Permit

Geothermal Wells

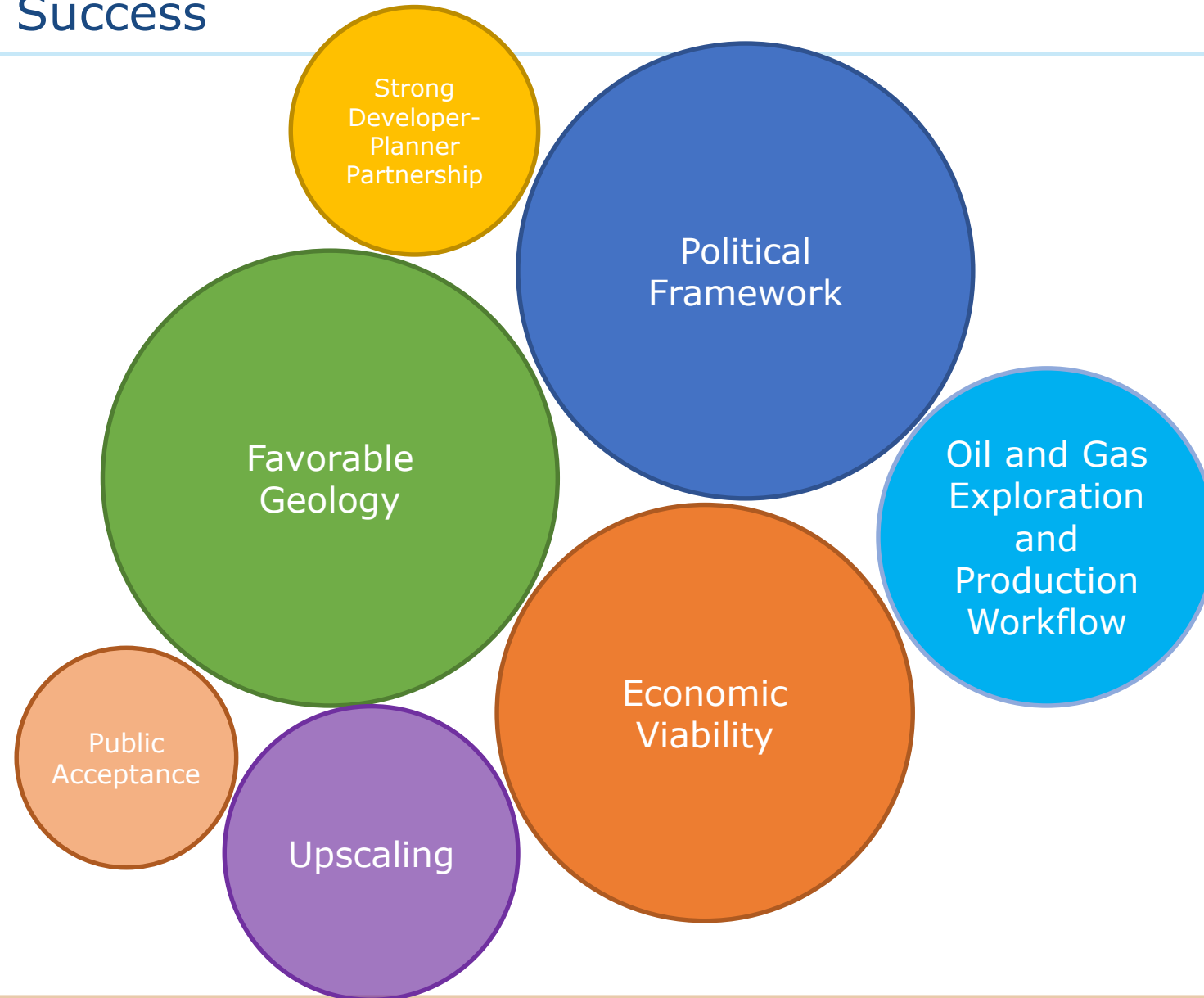
- Production Well
- Injection Well

Development of the Concessions Fields in Bavaria

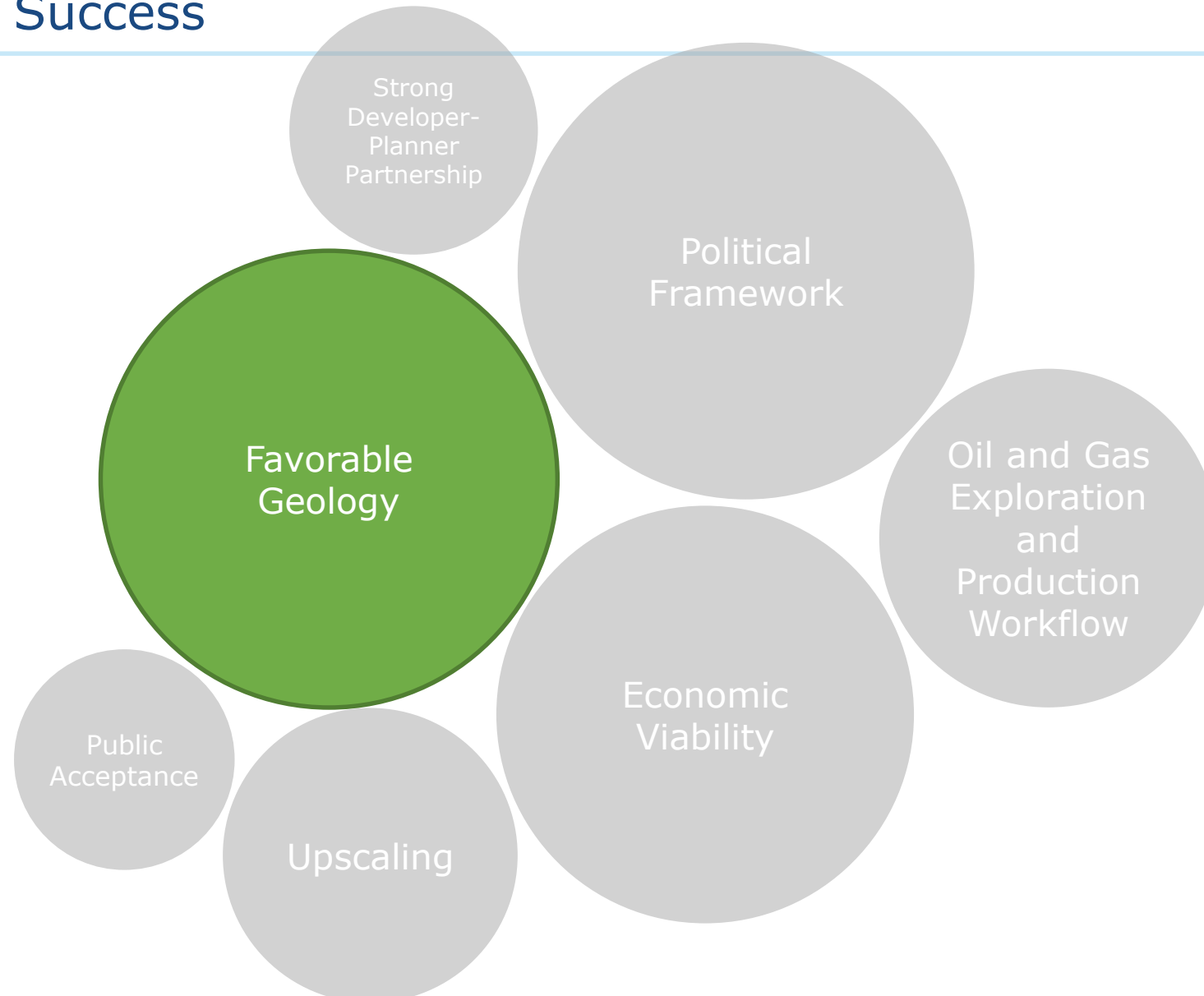
Year	Concessions
2002	4
2004	>40
2013	>80
heute	ca. 50

Stand: 02/2019

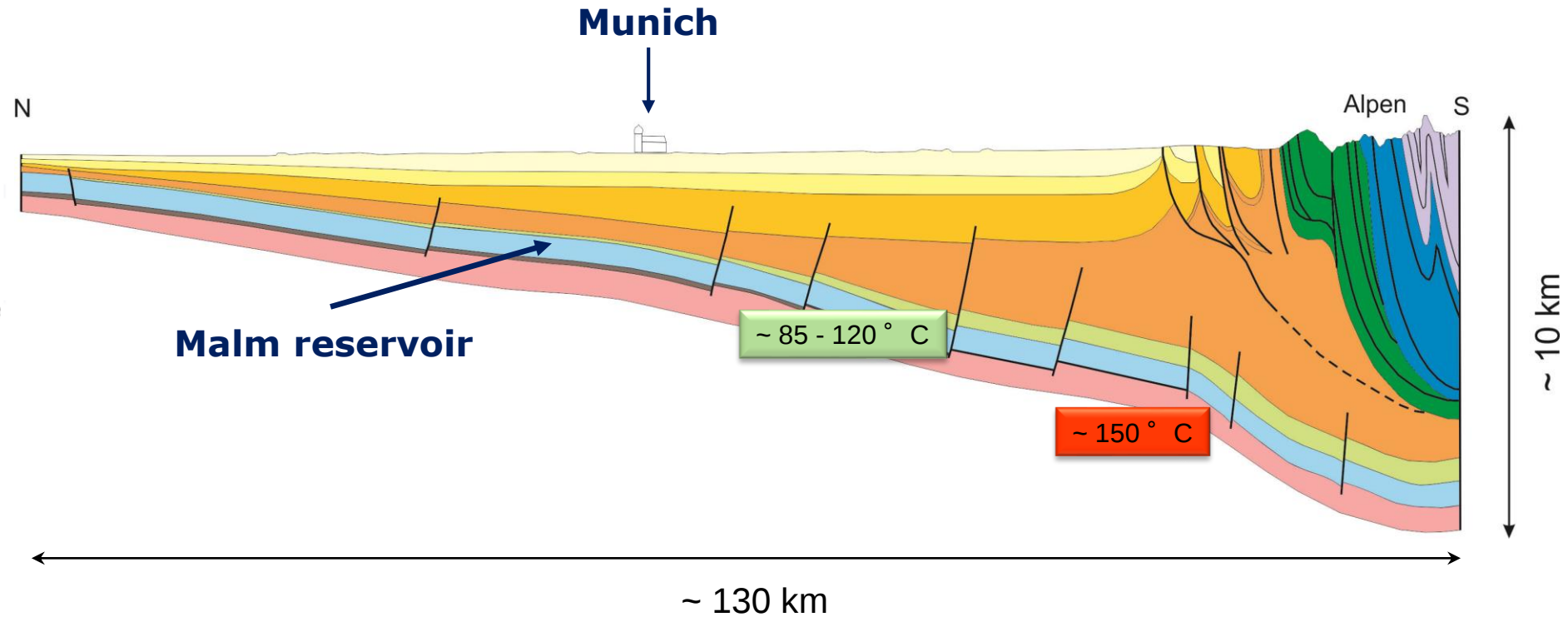
Reasons for Success



Reasons for Success

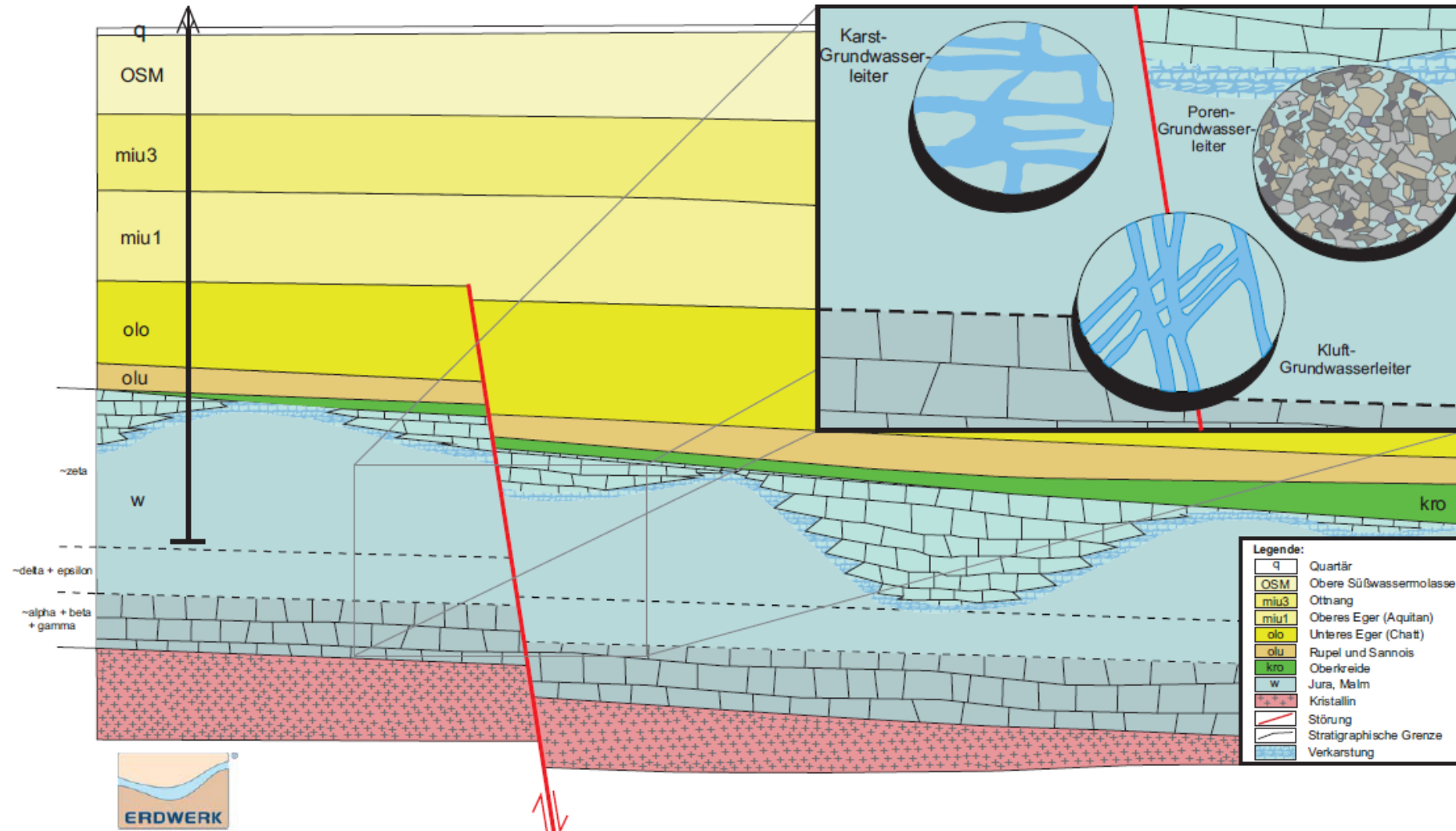


Reasons for Success: Favourable Geology



After: „Geologische Karte von Bayern 1:50000“, Bayerisches Geologisches Landesamt, 1996

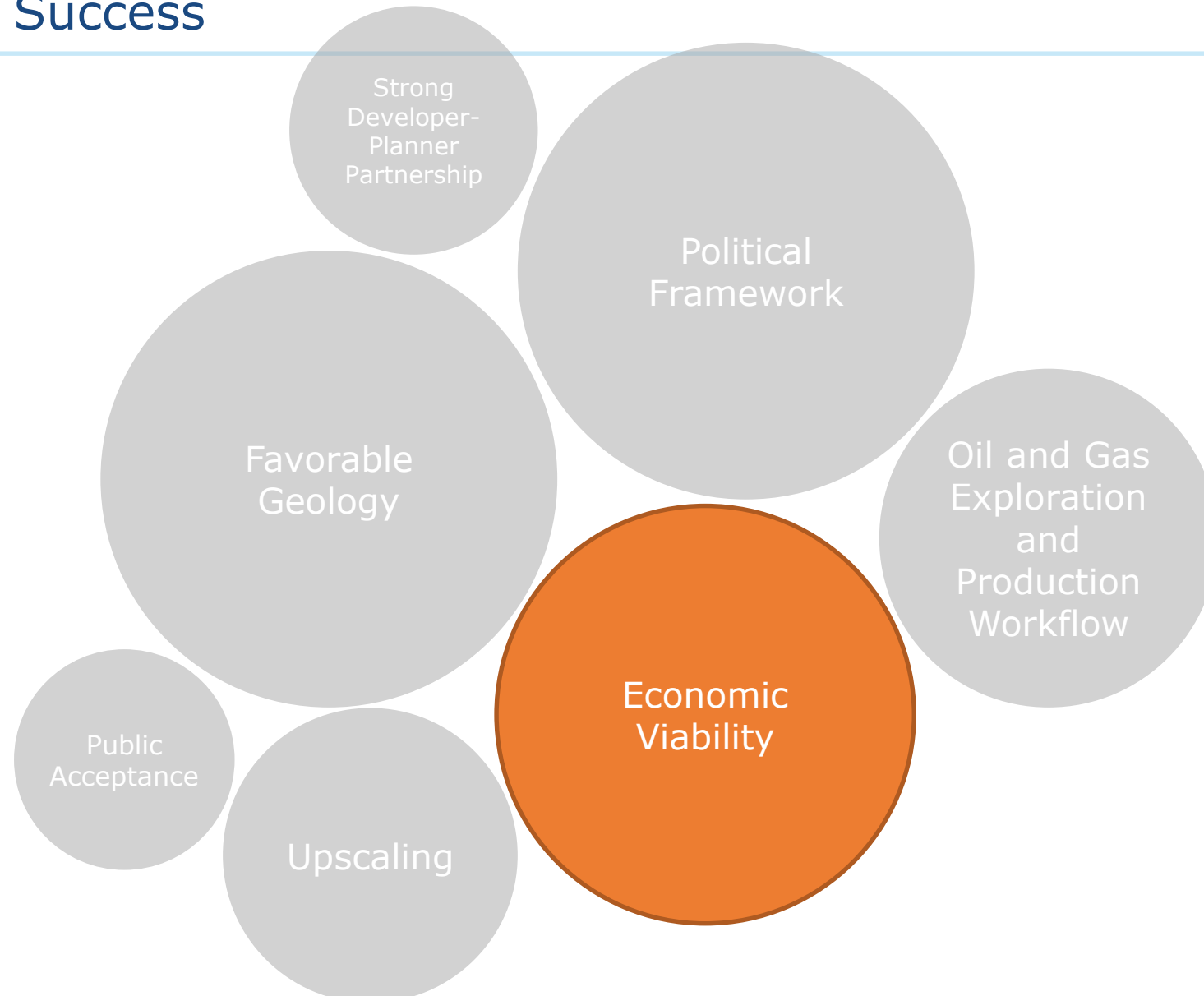
Reasons for Success: Favourable Geology



Reasons for Success: Favourable Geology

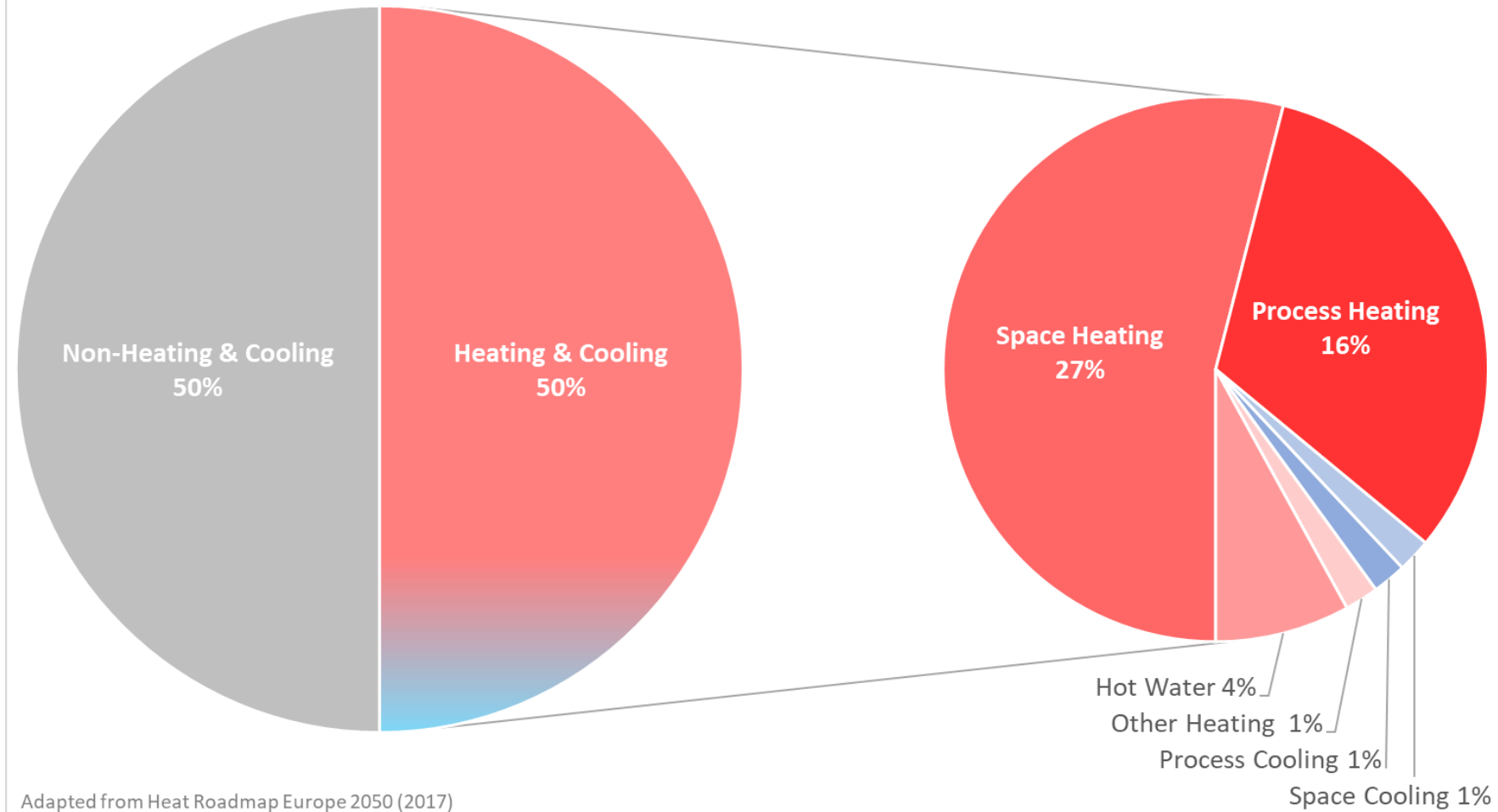
	Dinantian	Malm	+/-
Age	c. 300 Ma (Lower Carboniferous)	c. 150 Ma (Upper Jurassic)	-
Climate	Tropical, warm		+
Depositional Environment	Epicontinental – Shallow Marine		+
Lithology	Carbonates (Limestone, Dolomite, Marls)		+
Diagenesis	Partial Dolomitization?	Dolomitization	+/-
Post-depositional Structural Setting	Foreland basin		+
Formation Fluid	High Salinity (radioactive)	Low Salinity (almost fresh)	-
Geothermal Gradient	30 – 40 ° C/km (Some high temp anomalies)		+
Porosity (deep)	(Intergranular) (Karstic) Fractures	Intergranular Karstic (Fractures)	+/-

Reasons for Success



Reasons for Success: Economic Viability - Heat Demand

EU28 Energy Demand(2015)
(Household and Industry)



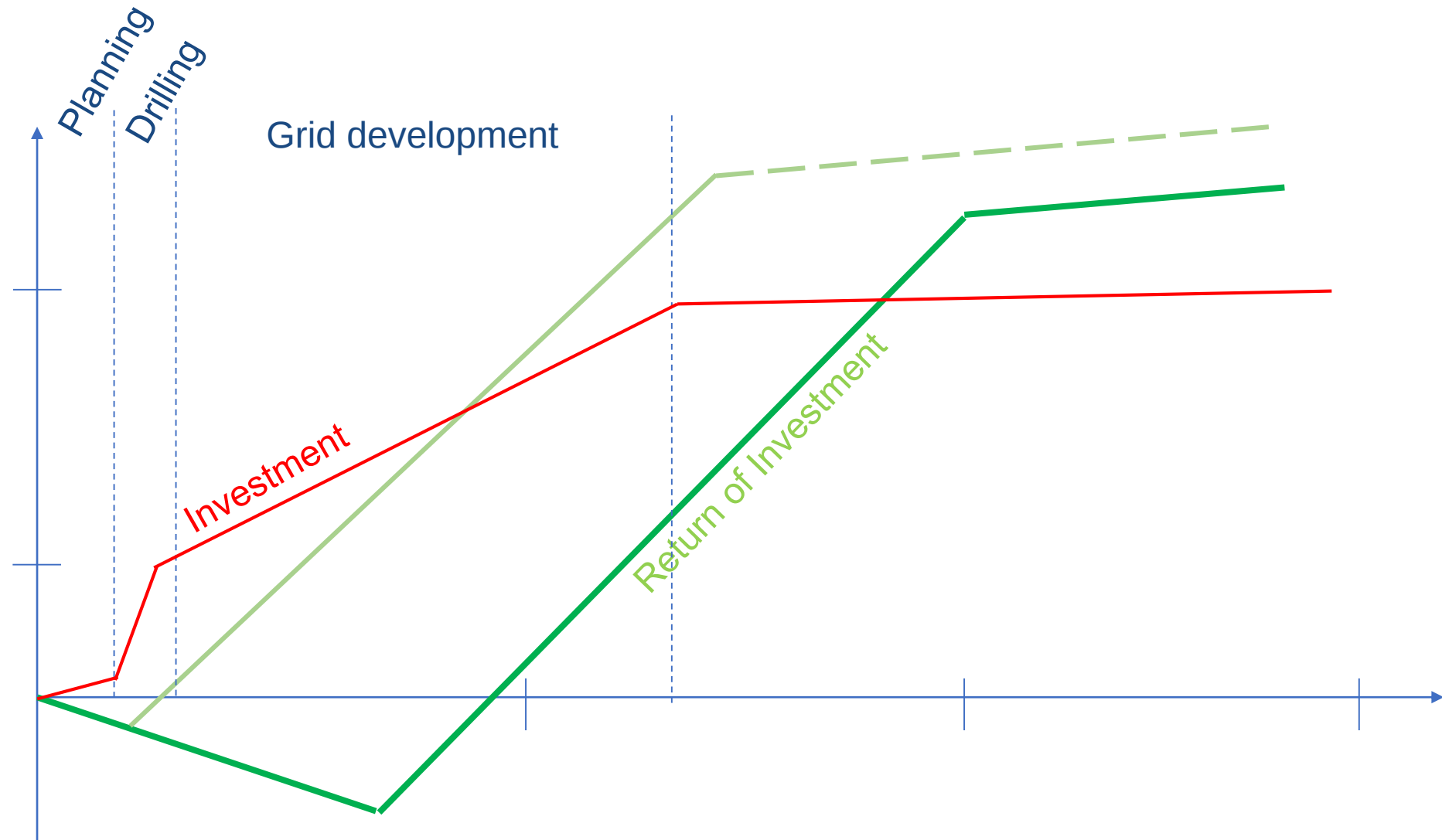
Adapted from Heat Roadmap Europe 2050 (2017)

Reasons for Success: Economic Viability - Heat Demand

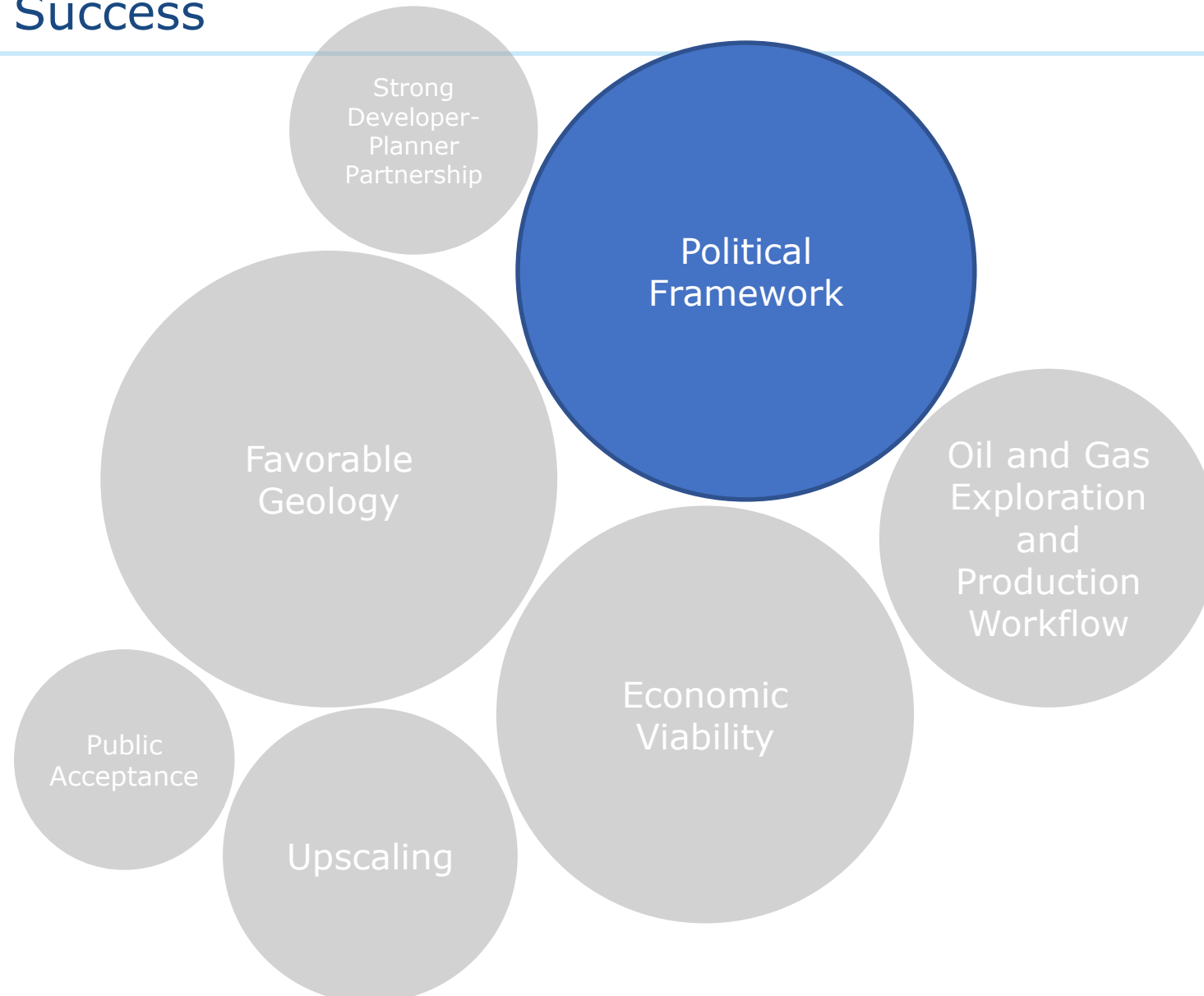
• Wells	10.8 Mio. Euro (Th1a/Th2) 7.3 Mio. Euro (Th3)
• Energy Center	3.7 Mio. Euro
• DHN Pt1	ca. 16.8 Mio. Euro
• DHN Pt2	ca. 28.0 Mio. Euro
• Extension of Energy Center	ca. 2.9 Mio. Euro
• Reinjection Pipework	ca. 2.9 Mio. Euro
• Total Investment to 2054	ca. 76.0 Mio. Euro

Quelle:  IEOP
INNOVATIVE ENERGY OPERATIONS

Reasons for Success: Economic Viability - Heat Demand



Reasons for Success

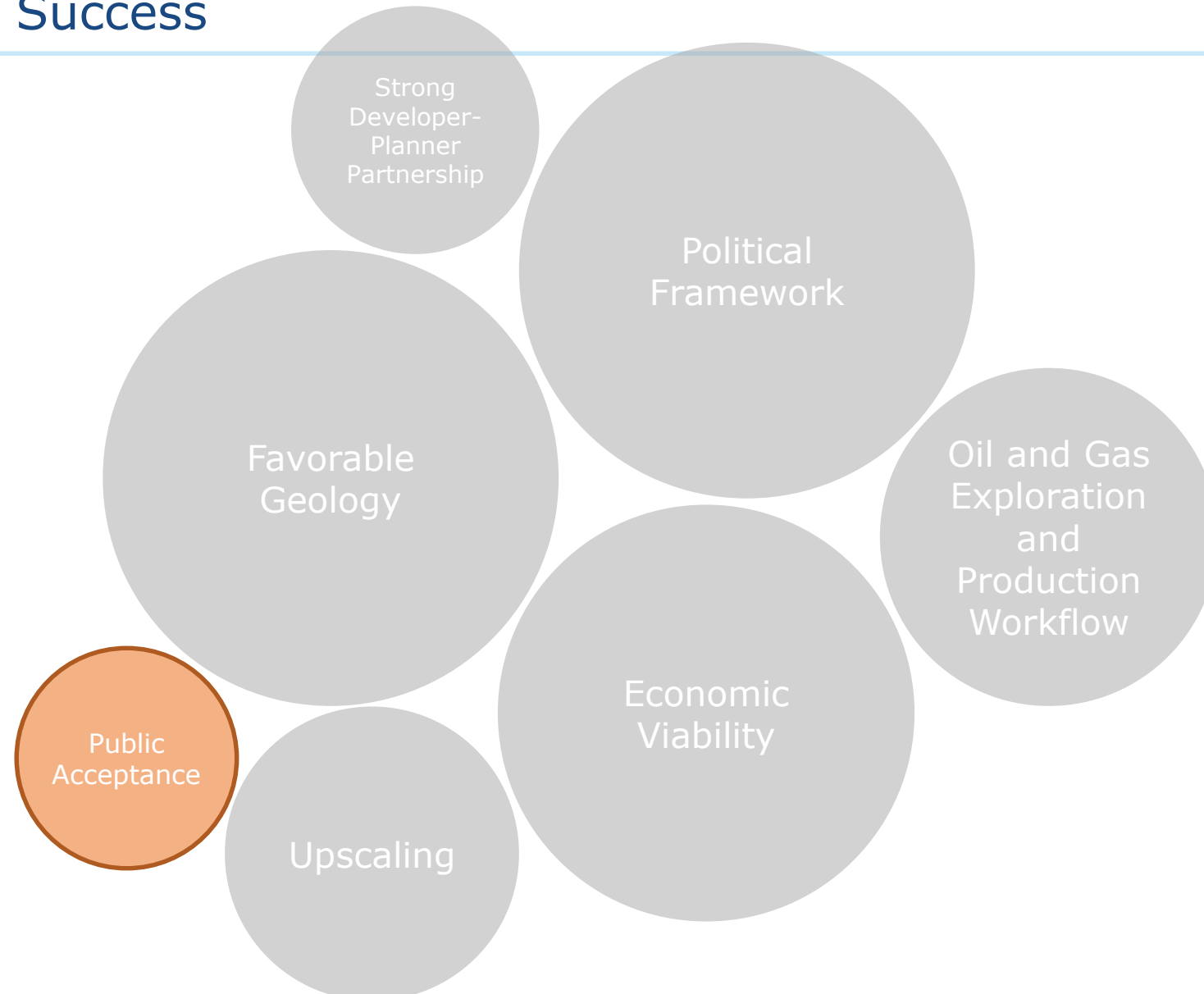


Reasons for Success: Political Framework

National Subsidies (Kreditanstalt für Wiederaufbau (KfW))			
Plant Subsidies	200 €/kW ^(nominal heat output) Max. €2 million		
Deep Geothermal Wells (heat)	400 m to 1,000 m TVD: 375 €/m TVD	1,000 m to 2,500 m TVD: 500 €/m TVD	>2,500 m TVD: 750 €/m TVD
	Max €5 million per doublet Additional work due to unforeseen technical risks, up to 50% of costs, max €1.25 million per well-		
District Heating Network (DHN)	60 €/m (new sections) Max €1.5 million Repayment Subsidies: €1,800 per household connection		
Bavarian Subsidies (LfA Förderbank Bayern)			
District Heating Network (DHN)	Max €0.5 million per project from the LfA Förderbank		
Municipal Infrastructure Projects	loans at reduced interest rates granted by LfA Förderbank		

However, there is no exploration insurance!

Reasons for Success



Reasons for Success: Public Acceptance

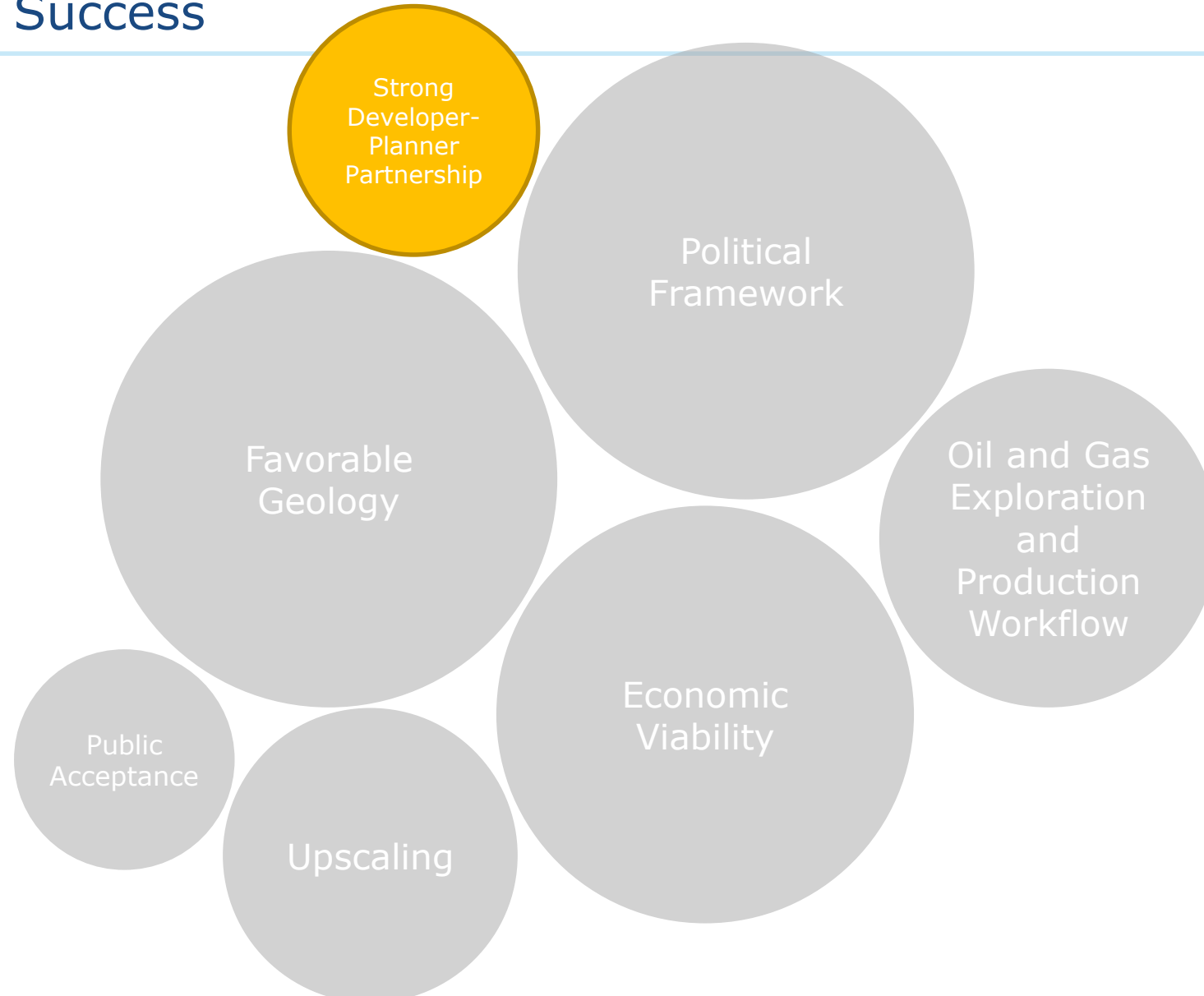
- 93% of German citizens support the development of green energy*
- Project Success = Positive Reporting
- Transparent approach of Municipal Projects
- PR work & Education
- Accept that sometime there isn't a fit.



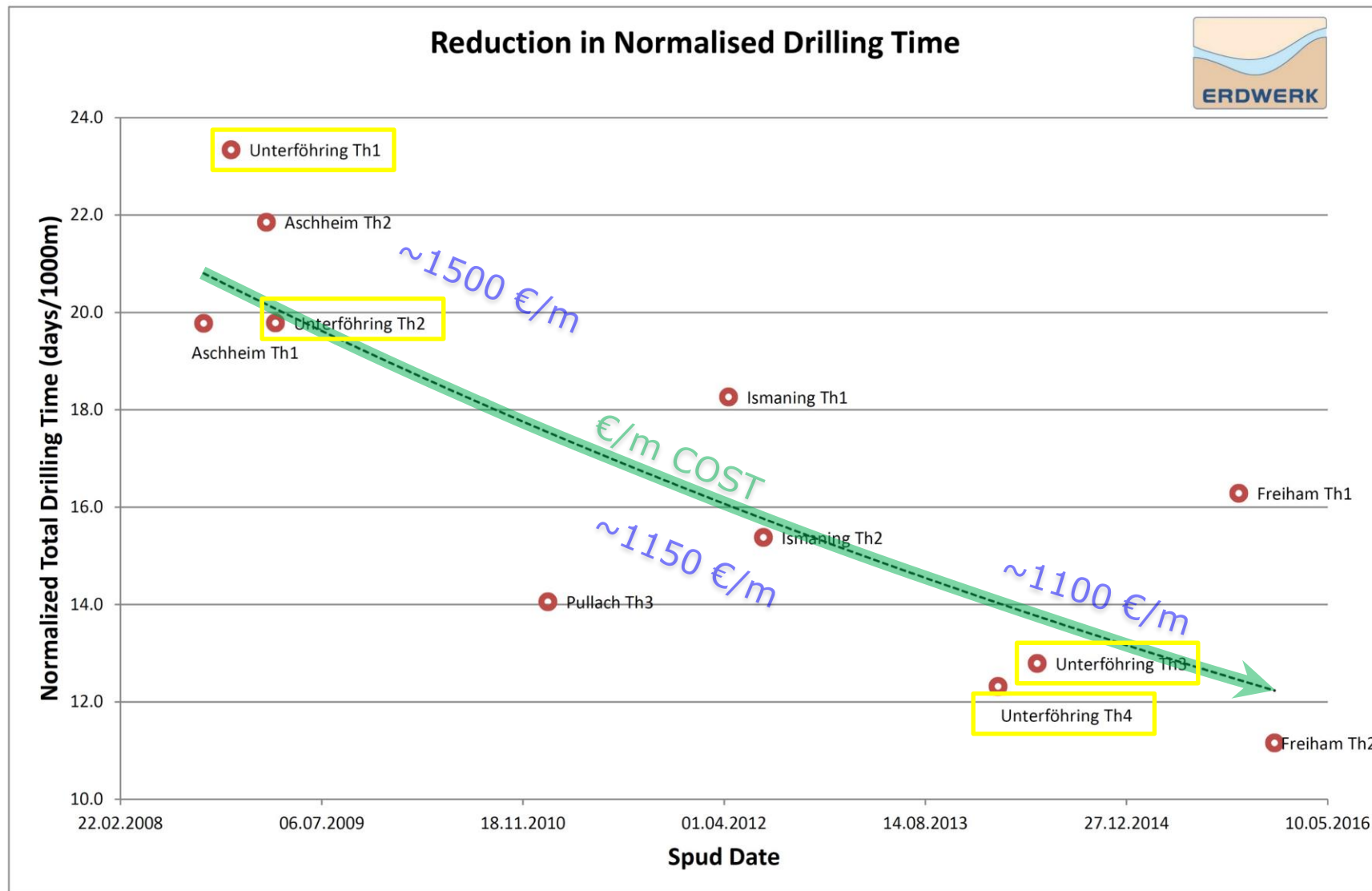
Site	First detection	Strongest event / Event number	Description
Unterhaching (UH)	10.02.2008	M_L 2.4 / 657	27 events $M_L \geq 1.0$, six events $M_L \geq 2.0$, near inj. well, decreasing
Taufkirchen (TK)	19.07.2012	M_L 0.3 / 11	During circulation test at inj. well
Kirchstockach (KS)	23.08.2012	M_L 0.8 / 33	30 microseismic events $M_L \leq 0.8$ near inj. well
Sauerlach (S)	19.06.2014	M_L 1.2 / 2	M_L 0.7 and M_L 1.2, big location error
Pullach (Pu)	21.02.2015	M_L -0.4 / 1	Near inj. well
Oberhaching (OH)	01.02.2016	M_L 0.5 / 3	Near inj. well
Duermhaar (DH)	31.07.2016	M_L 1.3 / 10	Big location error
Poing (PO)	19.11.2016	M_L 2.1 / 21	18 microseismic events, two events $M_L = 2.1$, near inj. well

*Agentur für Erneubare Energien, 2018

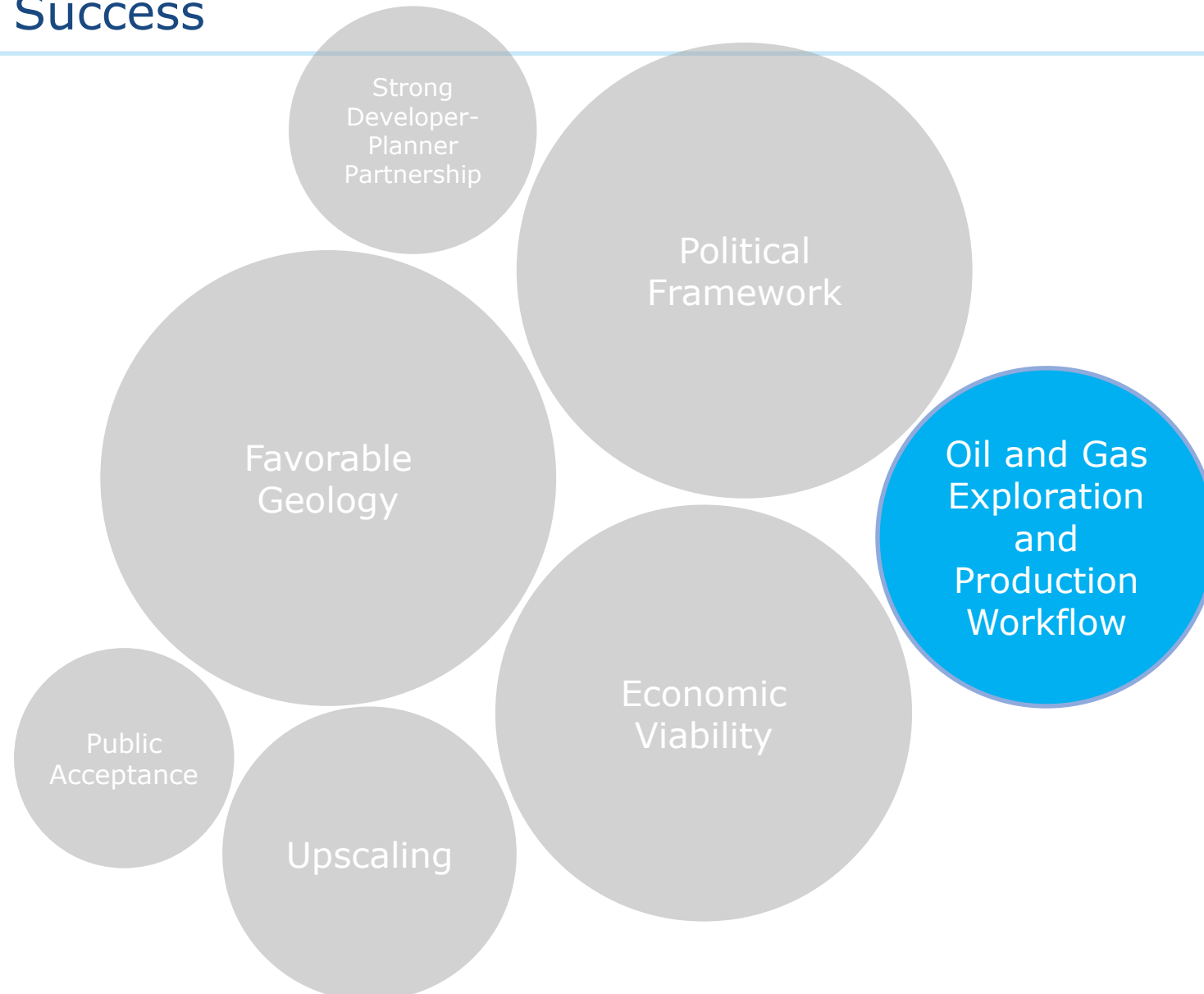
Reasons for Success



Reasons for Success: Strong Developer – Planner Partnership



Reasons for Success



- Technology
 - Seismic Profiles 2D to 3D
 - Petrel & Eclipse
 - RSS & Multilateral
- HSE
 - More than just water wells
- Human Resources
- Industry Cross Over
- Large Operator Approach
- Upscaling

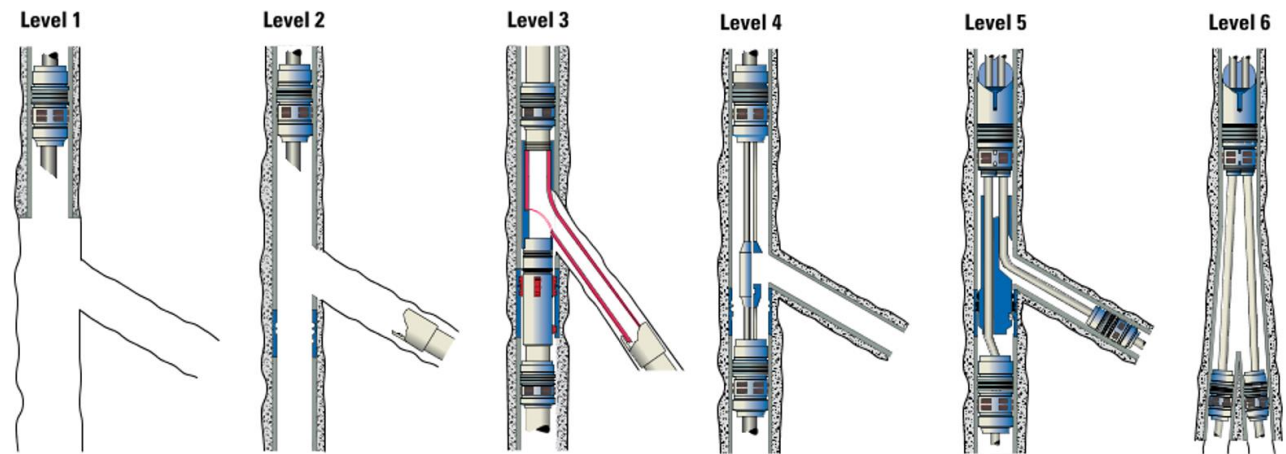
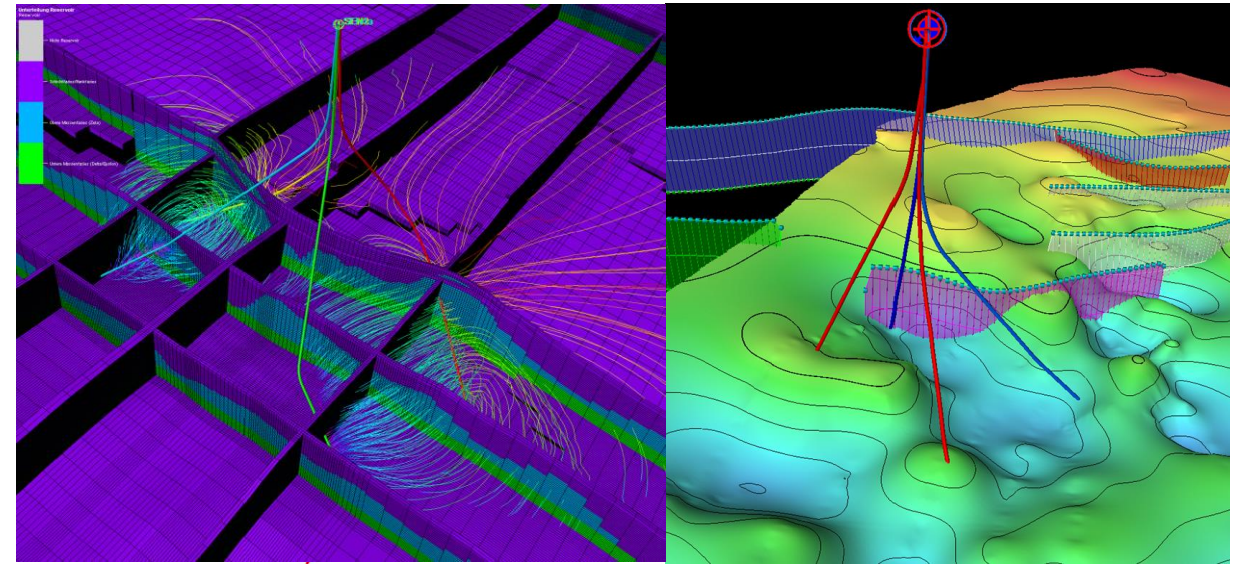
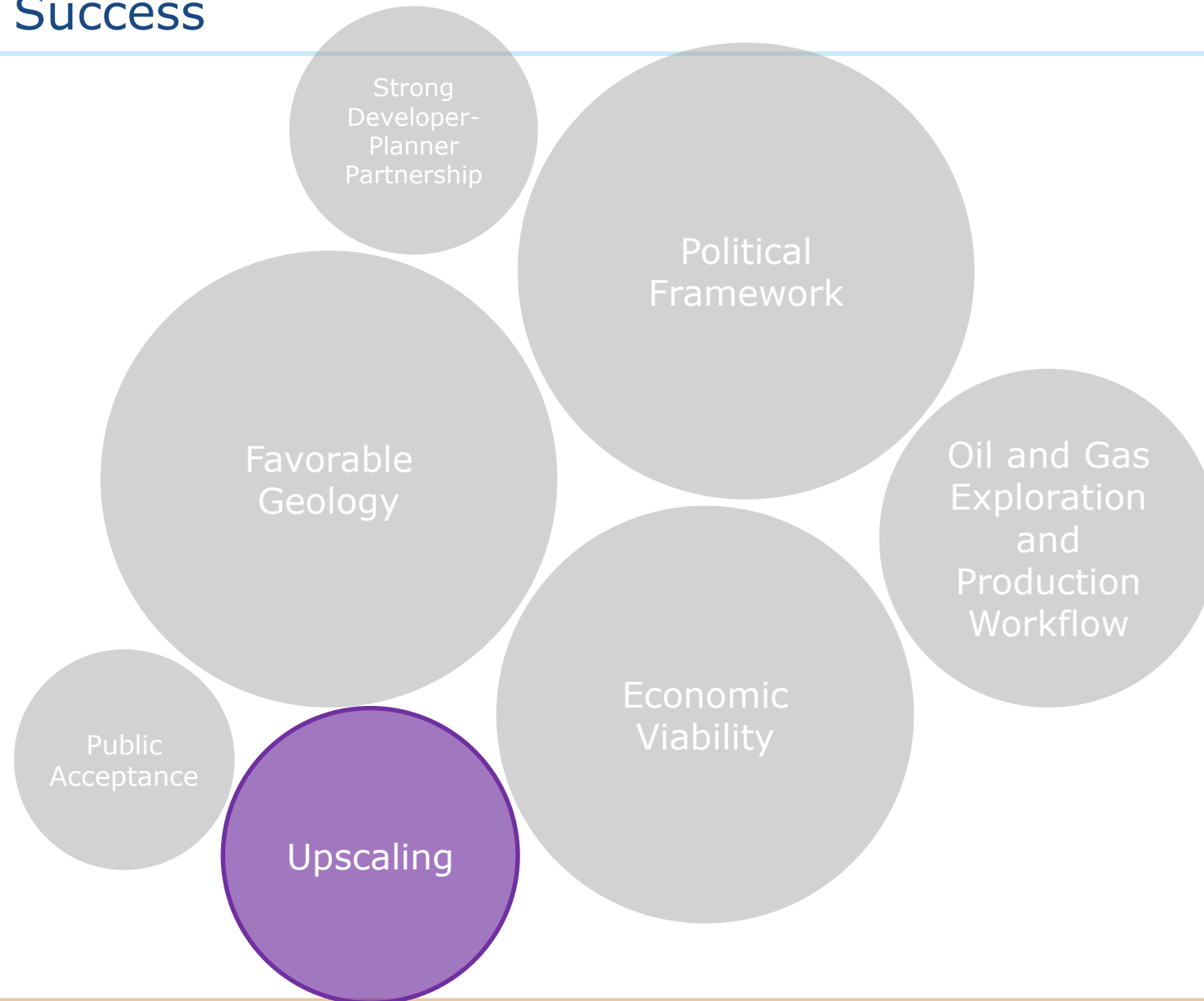


Figure 1: Junction Classification. Source: New Aspects of Multilateral Well Construction, Fraija et al (2002)

Reasons for Success



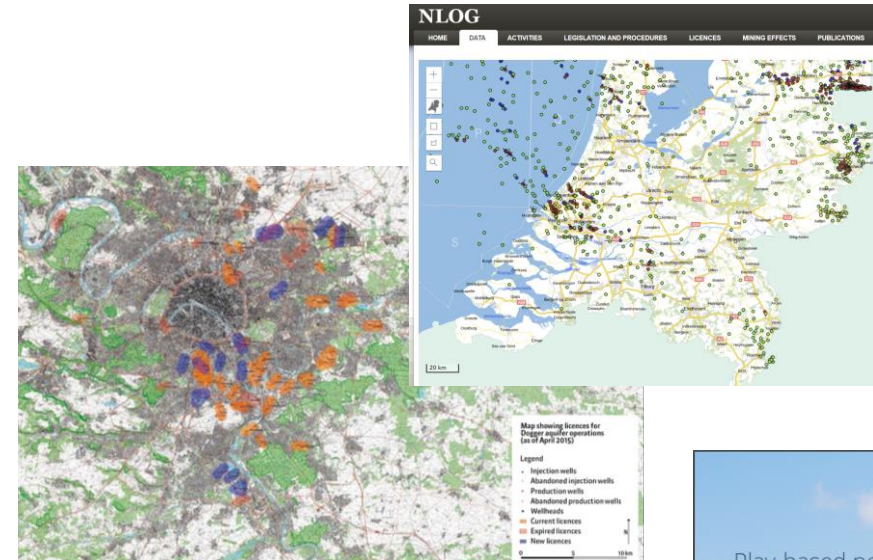
Reasons for Success: Upscaling

Exploration without Exploration

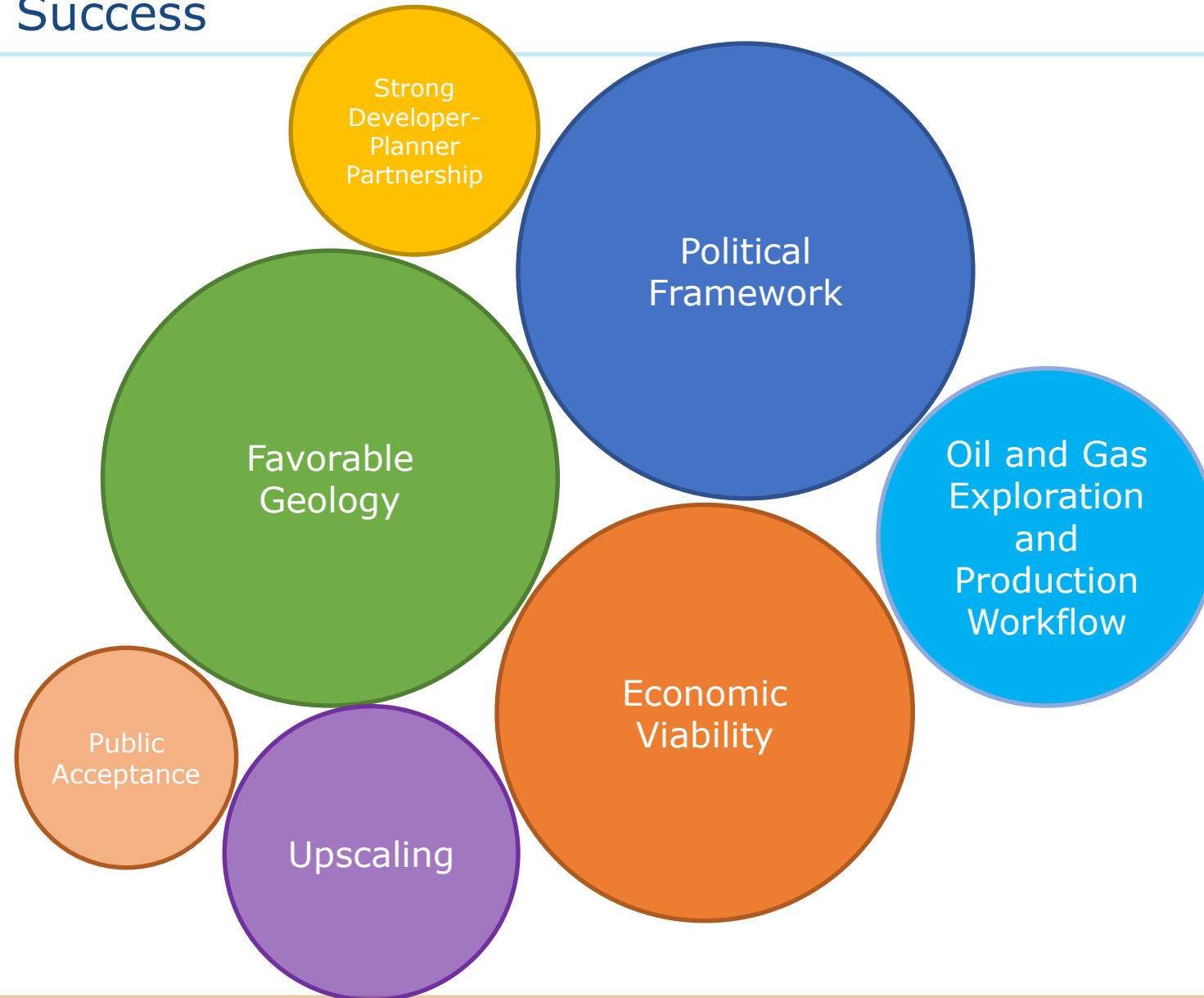
- Experienced planner with extensive inhouse project performance data.
- Opensource centrally held information
- NLOG, Paris Dogger Database

Play based Exploration

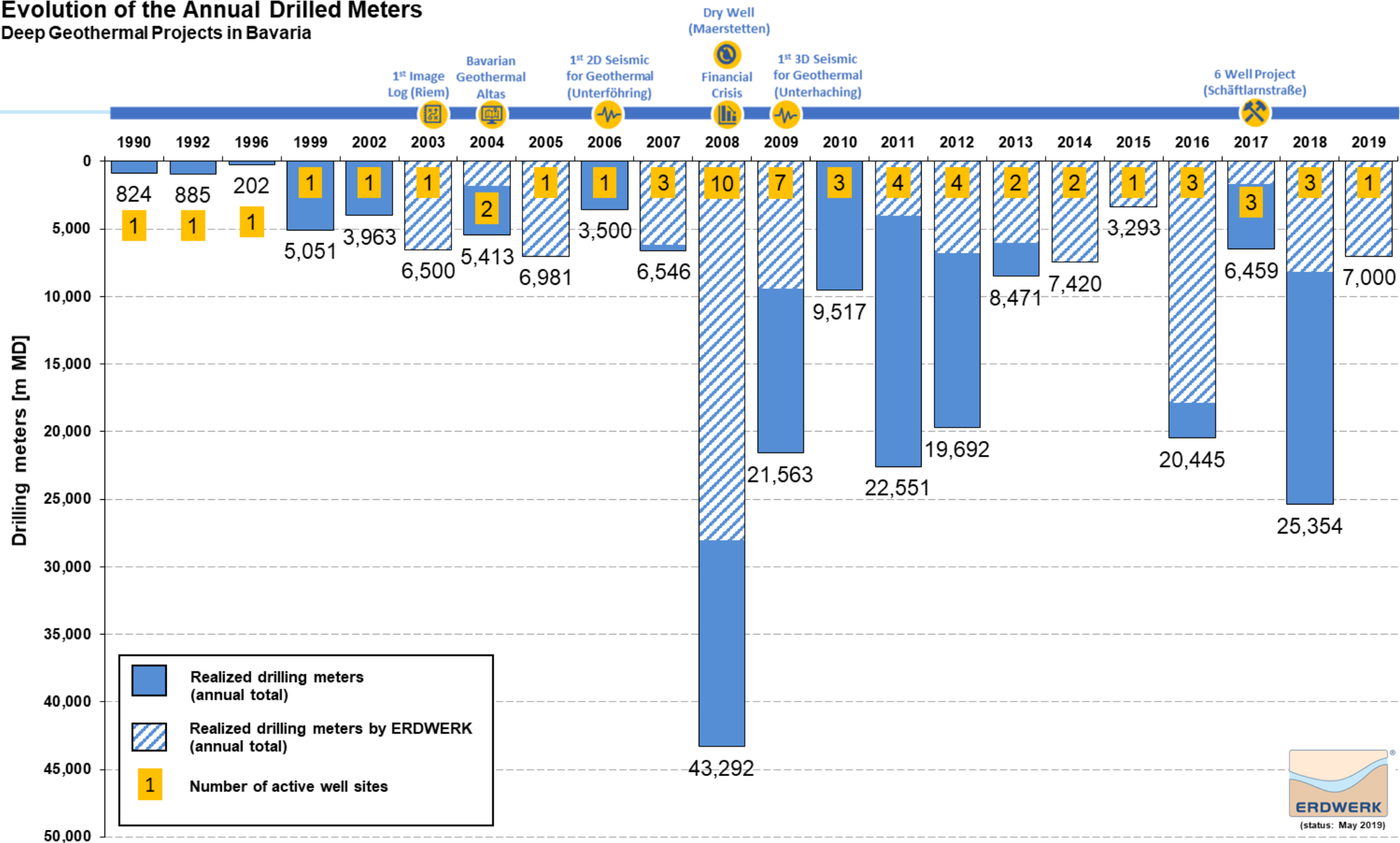
- Economies of Scale
- SWM-Munich



Reasons for Success



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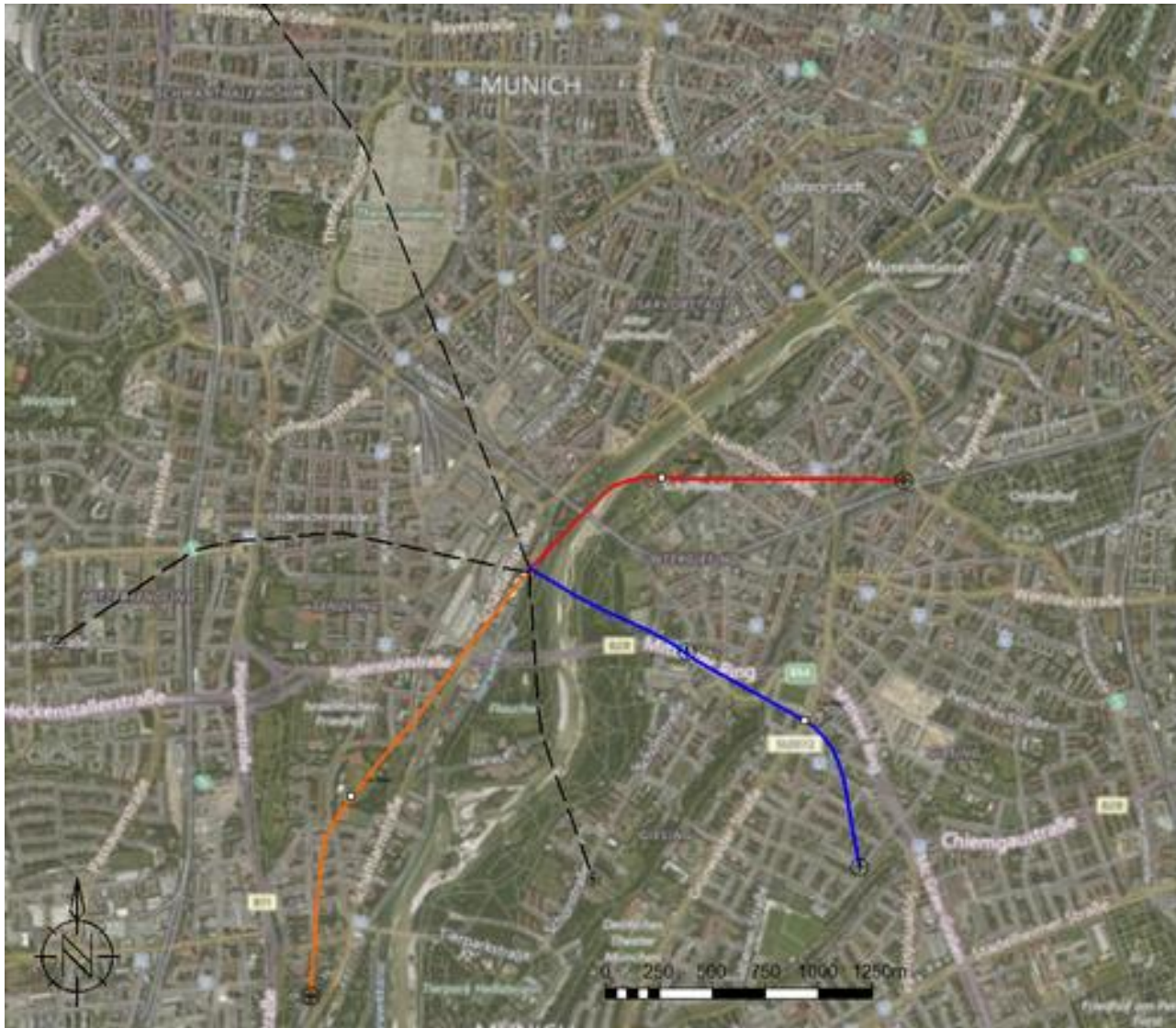
The Present and the Future







The Present and the Future



Project Schäftlarnstraße

1. Th1: 3860m MD / 2804m TVD
2. Th2: 4060m MD / 3043m TVD
3. Th6: 4179m MD / 3141m TVD
4. Th4: 3741m MD / 2947m TVD
5. Th5: 4105m MD / 2688m TVD
6. Th3: Oct/Nov 2019

Avg. Temperature: $>100^{\circ}\text{C}$

Avg. Production rate: $>100\text{ l/s}$

The Present and the Future



Template for Further Regions and Cities?



Problems	Drivers	Solutions

Thank You