SCCER SoE

SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Risk assessment and mitigation for the energy sector

(Task 4.1 und NFP70 project 'Risk Governance')

Stefan Wiemer
ETH Zürich

In cooperation with the CTI

Energy funding programme
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

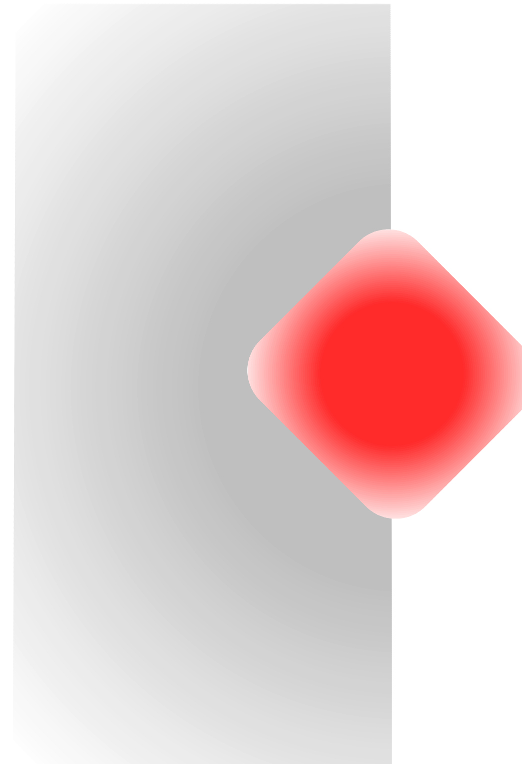
Swiss Confederation

Commission for Technology and Innovation CTI

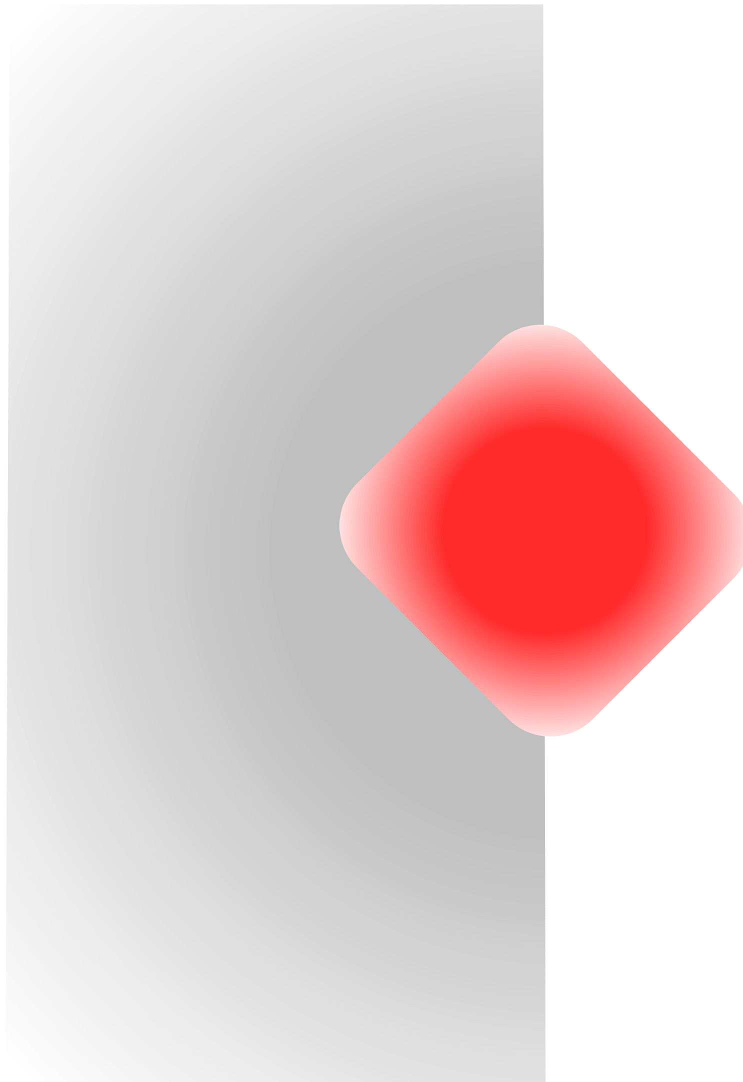
Risk Governance of GeoEnergies and HydroPower

We adopt/develop a **holistic concept of risk governance and community resilience** advocating a broad picture of risk:

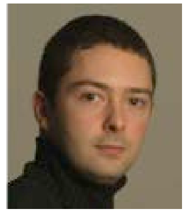
- not only does it include '**risk management**' and **'risk analysis**',
- It also looks at how **risk-related decision-making** unfolds when a range of actors is involved.

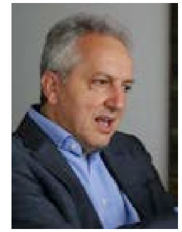


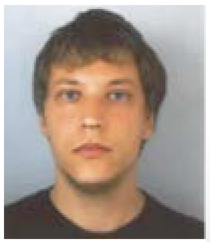
Risk requires interdisciplinary thinking!

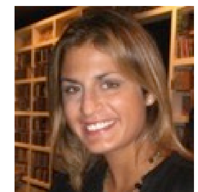
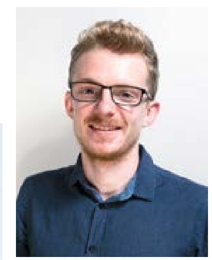


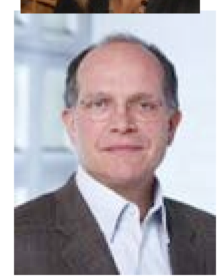
Risk requires an interdisciplinary team!

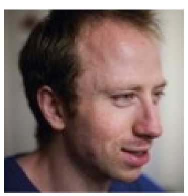












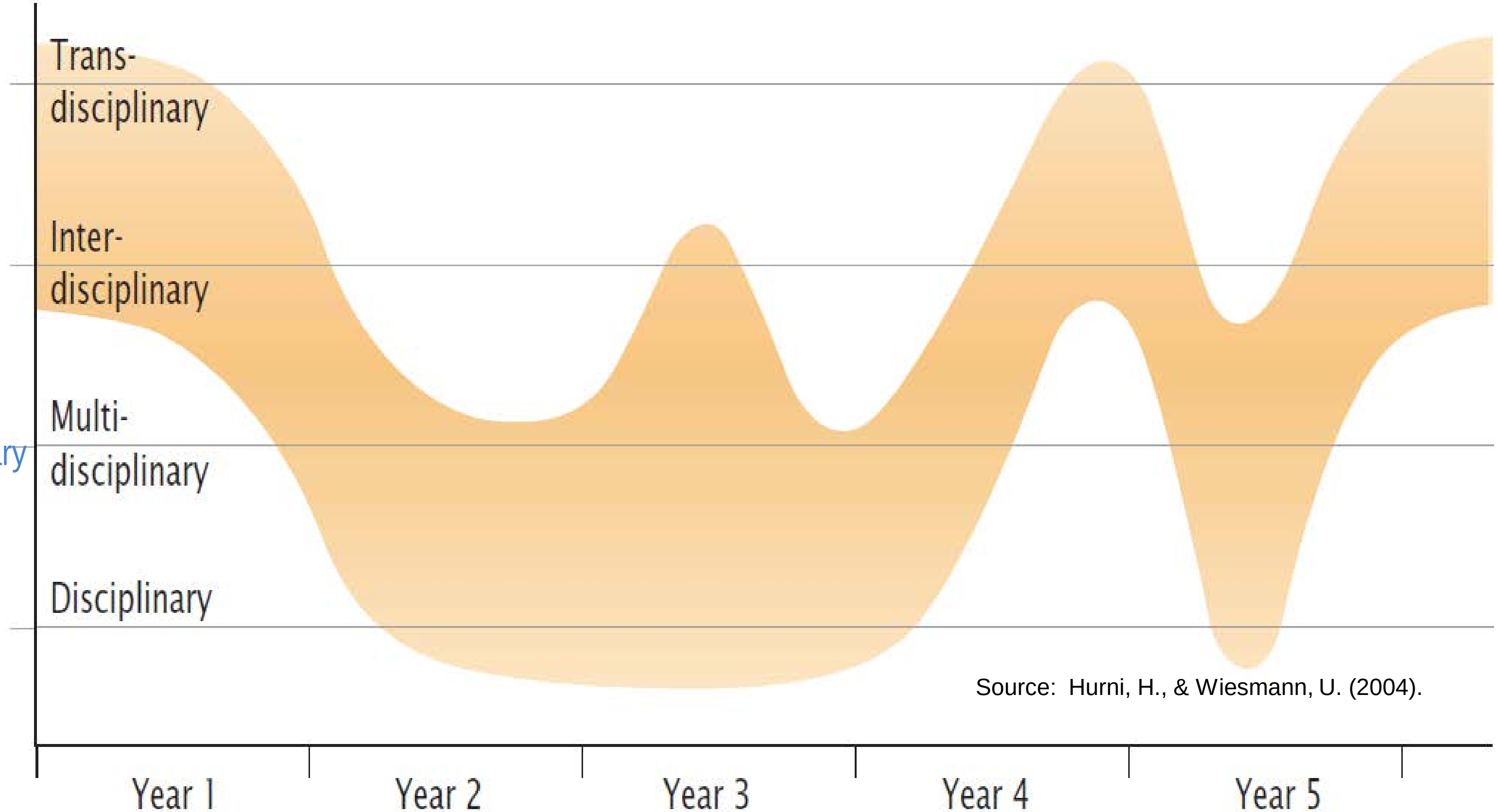



Interdisciplinary research: A dynamic process

(i.e. science-society)

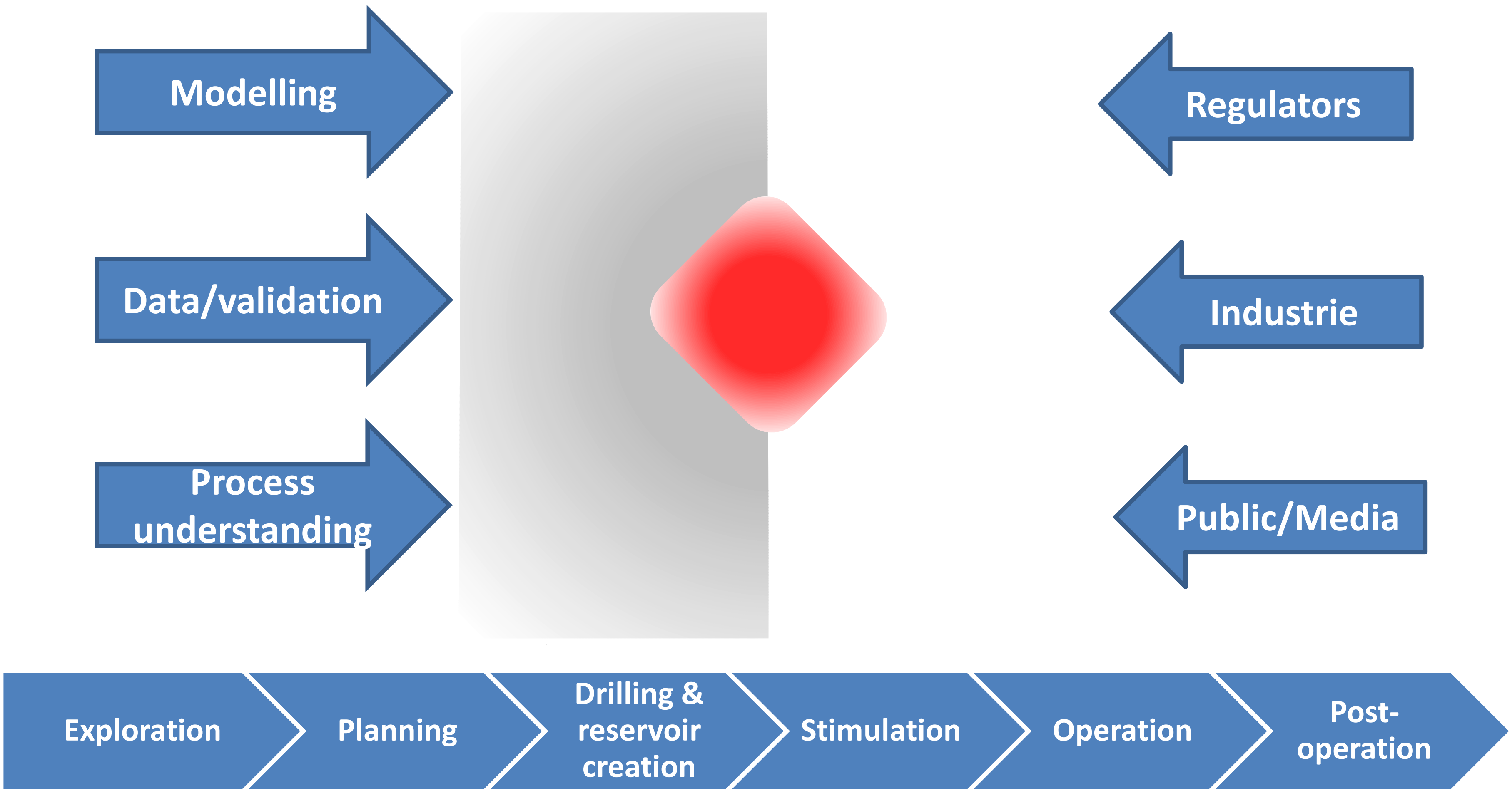
(i.e. joint goal, integrated outcomes)

(i.e. common topic, disciplinary outcomes)



Risk governance requires interfaces!

Risk Governance: A highly integrative SCCER-SoE activity, please see the 14 posters!



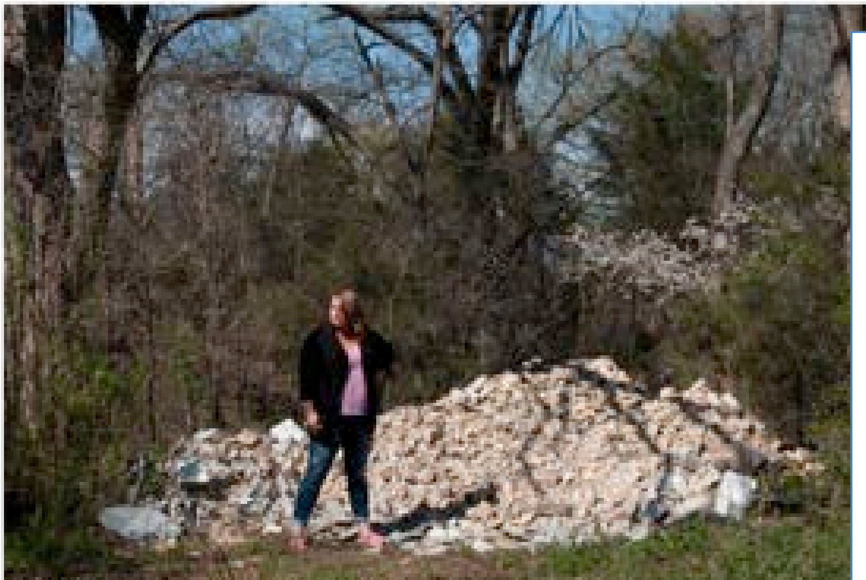
An international perspective

U.S.

380 COMMENTS

As Quakes Rattle Oklahoma, Fingers Point to Oil and Gas Industry

By RICHARD A. OPPEL Jr. and MICHAEL WINES APRIL 3, 2015



INSIGHTS | *PERSPECTIVES*

GEOPHYSICS

Coping with earthquakes induced by fluid injection

Hazard may be reduced by managing injection activities

By **A. McGarr,[1*] B. Bekins,[2] N. Burkardt,[3] J. Dewey,[4] P. Earle,[4] W. Ellsworth,[1] S. Ge,[5] S. Hickman,[1] A. Holland,[6] E. Majer,[7] J. Rubinstein,[1] A. Sheehan[5]**

SHARE

as of the United States long

are so many disposal wells that this cont utes significantly to the total seismic ard, at least in the mid-continent (*1*, 2 EOR has been associated with earthqua as large as *M*4.5, but felt earthquakes rare (*7*). For the most part, fracking indu

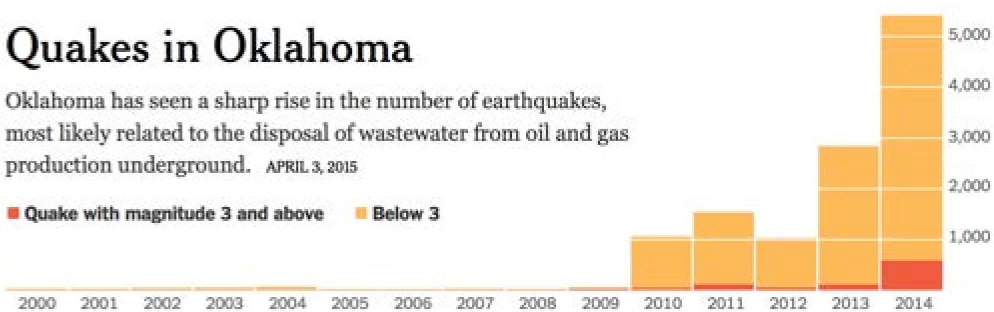
Science, Feb. 2015

U.S.

Quakes in Oklahoma

Oklahoma has seen a sharp rise in the number of earthquakes, most likely related to the disposal of wastewater from oil and gas production underground. APRIL 3, 2015

■ Quake with magnitude 3 and above ■ Below 3



Outreach Highlights: TA Swiss study and Schatzalp workshop on induced seismicity

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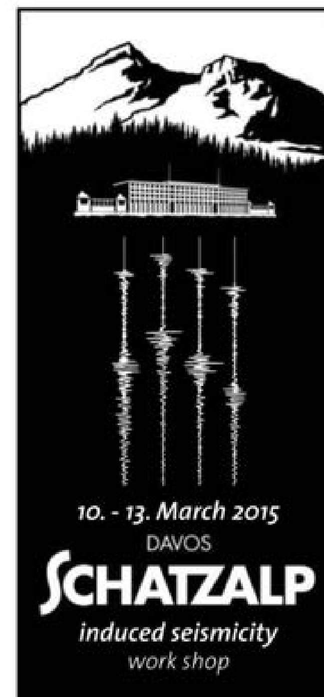


Non-technical aspects of risk governance

for hydropower and deep geothermal energy

SCCER SoE
USYS TdLab
ETH Zürich

Context

Society plays an important role in shaping the future of hydropower and deep geothermal energy and their risk governance

Activities

- Non-technical aspects of induced seismicity risk governance
- Retrospective assessment of the St. Gallen geothermal project
- Research-informed risk communication (including low probability-high consequence events) for hydropower and geothermal
- Media analysis at local and national scales
- Public and stakeholder engagement

M. Stauffacher et al. / Technological Forecasting & Social Change 98 (2015) 60–70

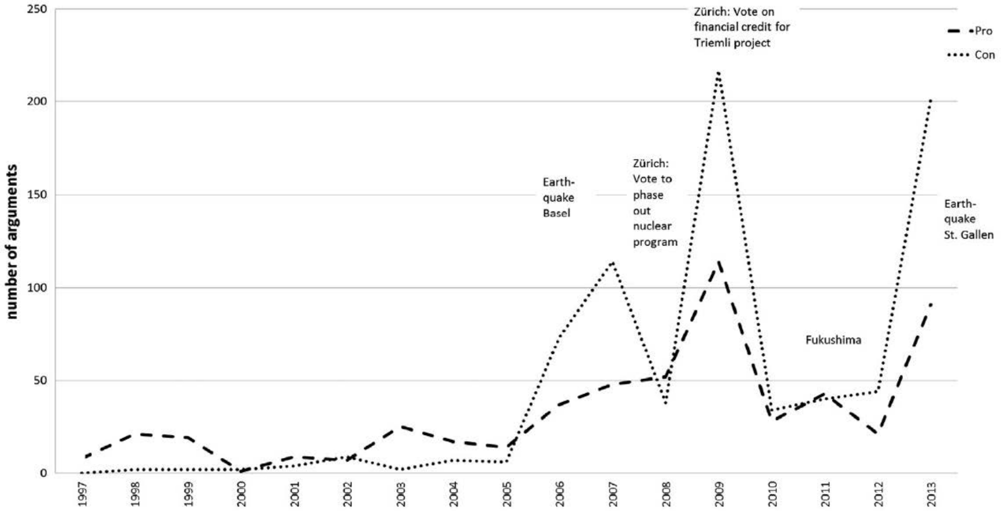


Fig. 2. Frequency of pro and con arguments in TA and NZZ over time ($N = 1350$ arguments; based on the filtered sample 2, $N = 193$ articles).

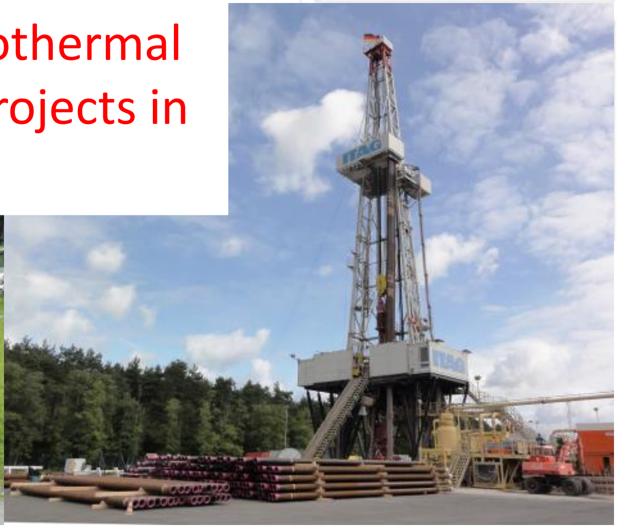
Transdisciplinary Case Study 2015 «Deep Geothermal Energy: the St. Gallen project»

- Elective teaching course for ETH MSc Environmental Sciences
  - 7 ECTS (approx. 210 hrs.)
  - Spring semester 2015
- Lecturers
  - Dr. Michael Stauffacher & Prof. Stefan Wiemer (SED, D-ERDW)
  - Dr. Evelina Trutnevyte (& others for specific inputs)
- http://www.tdlab.usys.ethz.ch/education/tdcs/current.html

St. Gallen as success story and blueprint for other projects?

Guiding question

What can we learn from the geothermal project in St. Gallen for future projects in Switzerland?



Multi-risk

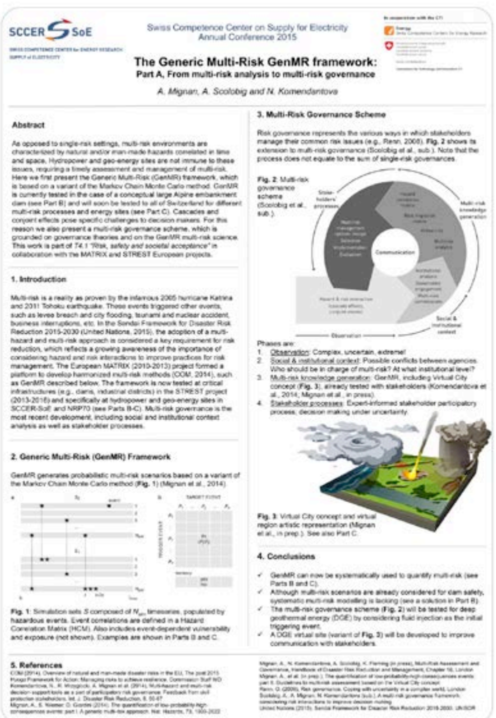
By A. Mignan (ETH Zurich) and colleagues

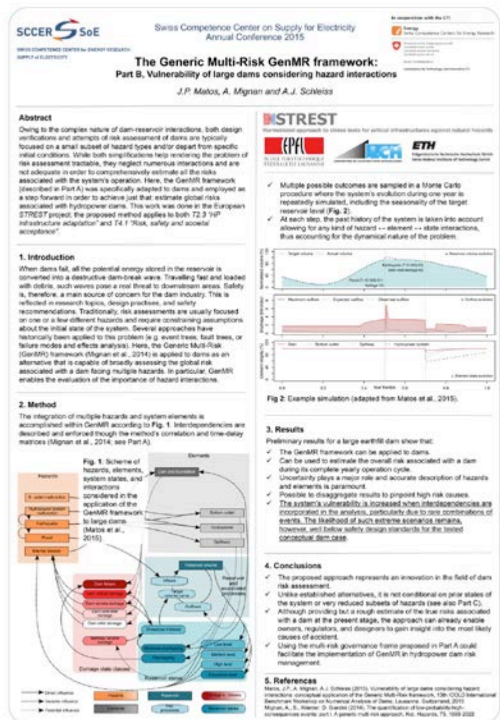
Multi-risk = All dynamic processes in the risk chain, i.e., hazard interactions, damage-dependent vulnerability, etc.

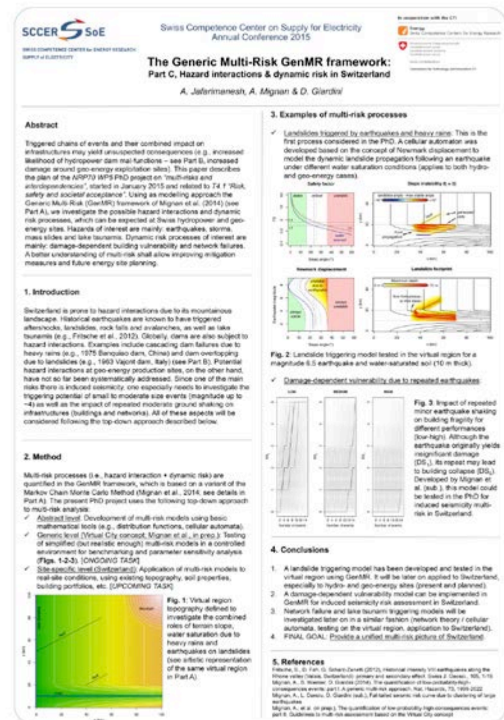
Activities

- Multi-risk analysis and multi-risk **governance** (in collaboration with ETH Zurich Climate Policy Group)
- Multi-risk analysis of **hydropower dams** (in collaboration with EPFL, A. Schleiss' group)
- Multi-risk analysis in **Switzerland** (NRP70 PhD WP5, A. Jafarimanesh)
- Upcoming: application of multi-risk to **Deep Geothermal Energy**

To learn more, don't miss the **multi-risk triptych in the poster area**.







Risk Assessment of Hydropower in Switzerland with focus on dams (PSI)

SCCER SoE

- PhD at PSI co-supervised between the Technology Assessment group at the Paul Scherrer Institut (PSI) and Prof. Bruno Sudret from the Chair of Risk, Safety and Uncertainty Quantification at ETHZ.

- The PhD project investigates accident risks of hydropower dams using an integrated approach that considers available historical experience and models selected dam failure scenarios and their potential consequences

- The main focus of the research is the quantification of the uncertainties in the modeling of dam break consequences

Research plan

Phase 1: Historical dam failures

- Update of hydropower accidents in PSI's Energy-related Severe Accident Database (ENSAD)
- Probabilistic analysis of historical data

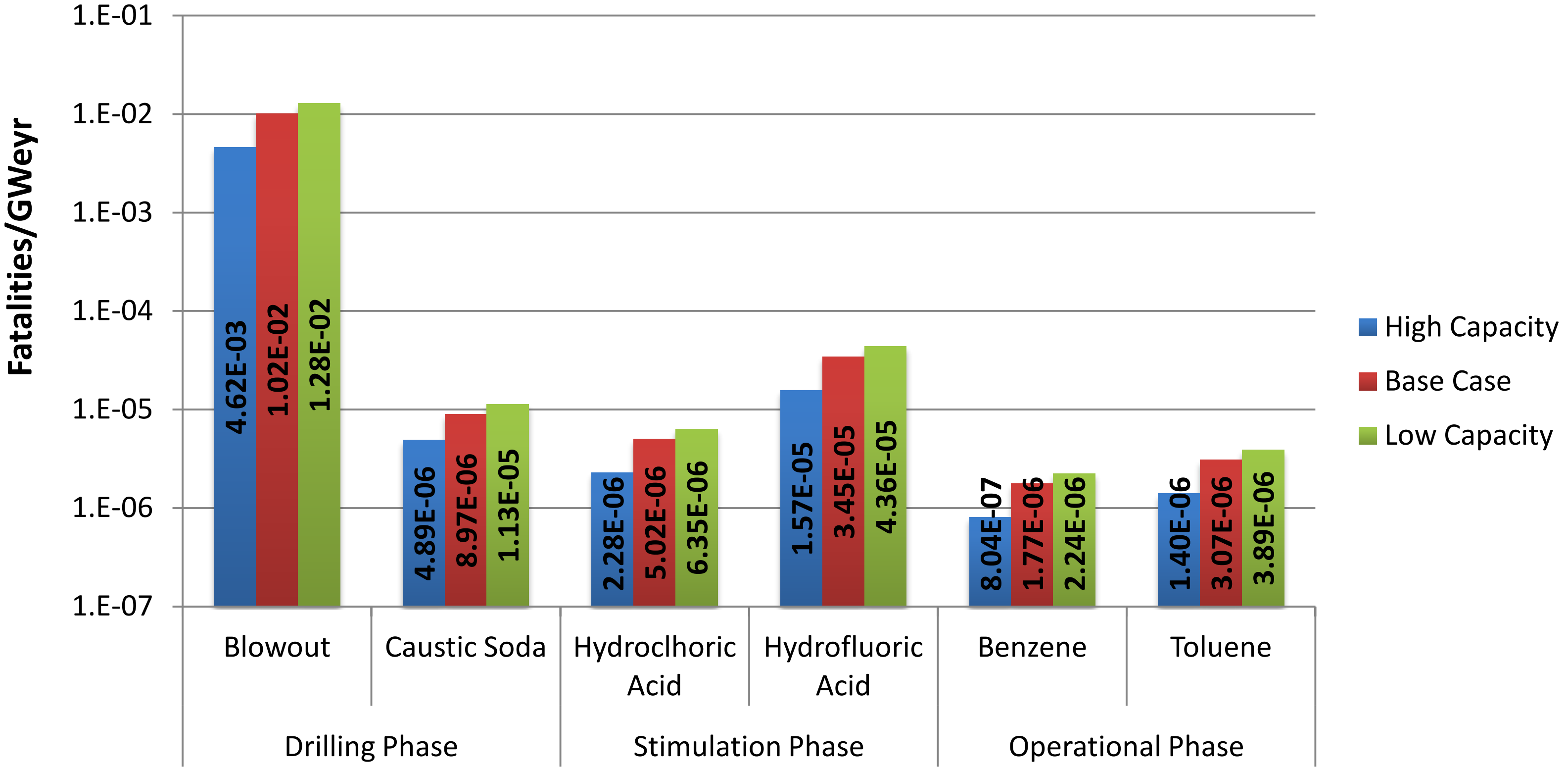
Phase 2: Scenario modeling

- Modelling of dam-break flood
- Modelling of dam-break consequences

Phase 3: Uncertainty and sensitivity analysis

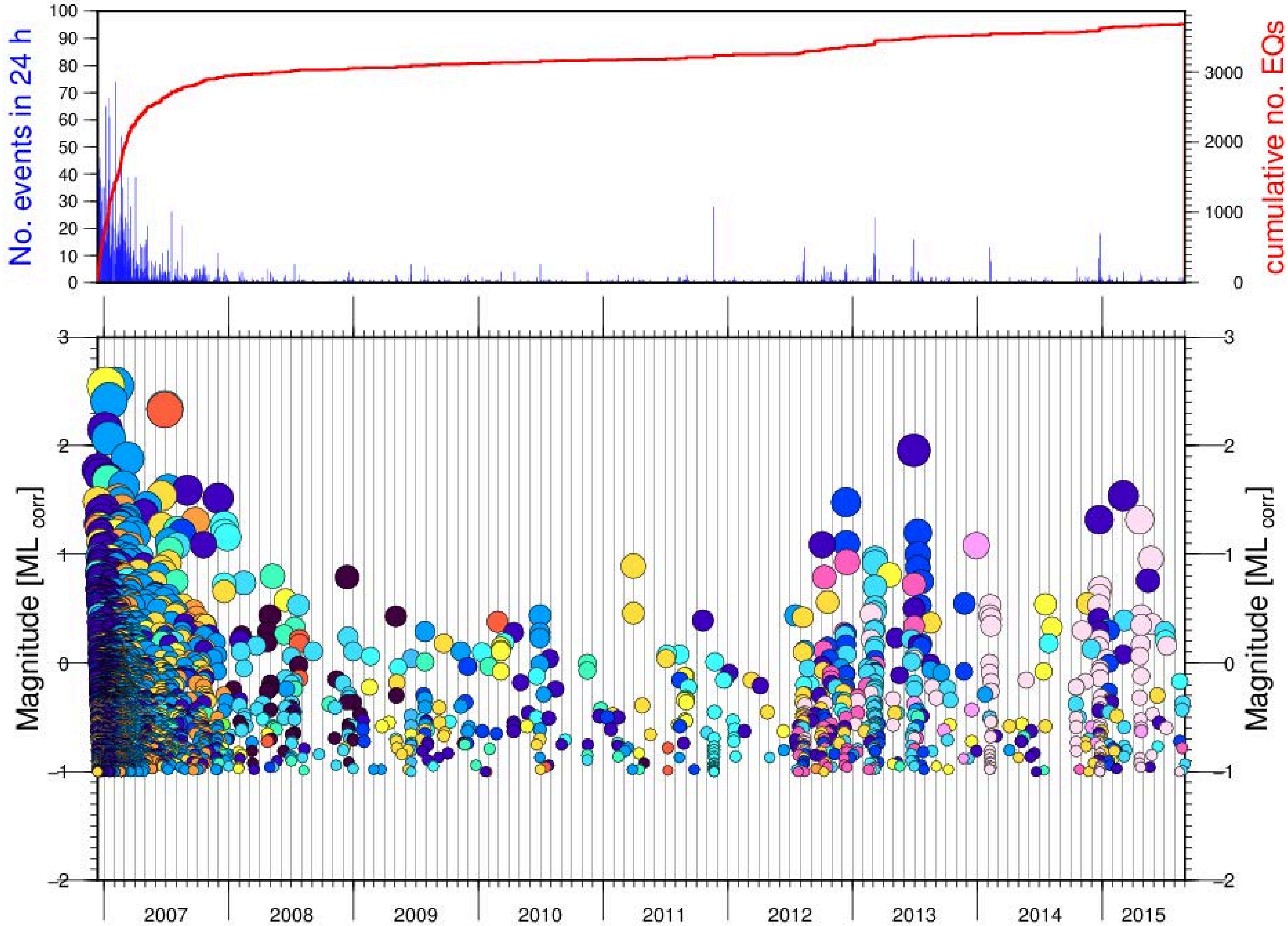
- Modelling of uncertainties and sensitivities for dam-break consequences
- Swiss case study

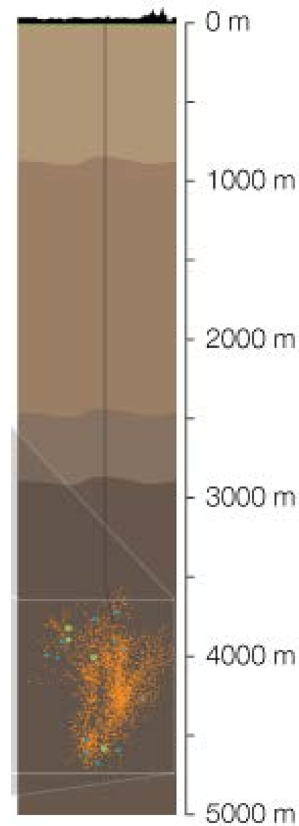
Accident Risk for Deep Geothermal Energy Systems (PSI)



- Risk indicators for three geothermal plant capacity cases for Switzerland based on the same assumptions used in Life Cycle Assessment and Cost Assessment.
- Fatality rates are estimated as the ratio between the aggregated number of fatalities in the period 1990-2013 and the unit of energy production weighted by a factor dependent on, for example, number of wells, for each substance and blowout.

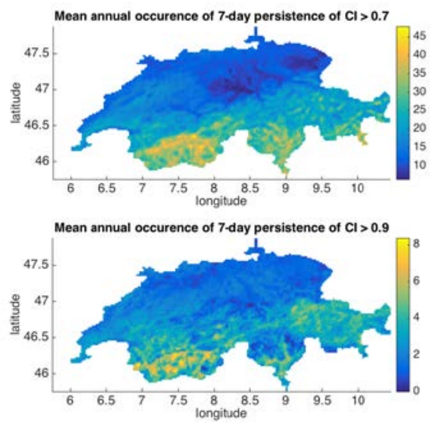
Earthquake Template matching: 10-100 times more information (ETH/SED)



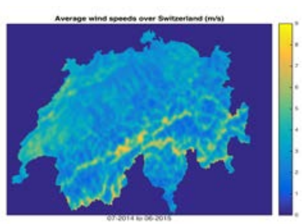


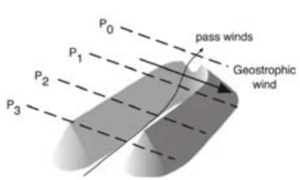
Swiss Renewable Energy Risk Analysis and Optimization (EPFL)

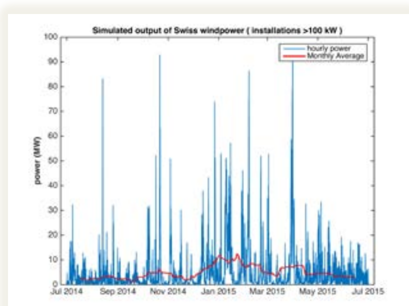
Extreme value statistics of Swiss Solar energy resource



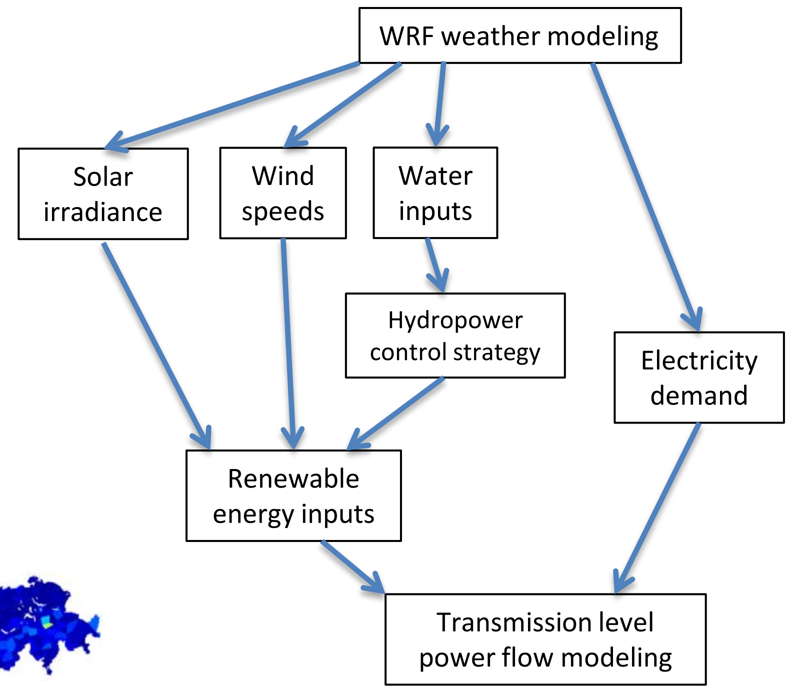
Risks and Opportunities for Wind Energy in the Swiss Alps

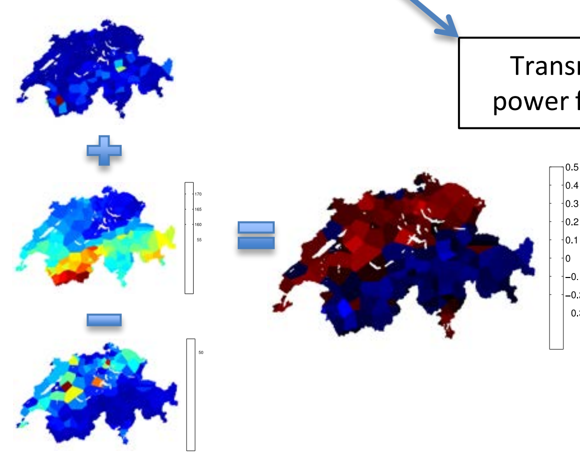






Extreme event analysis and optimisation of a fully renewable Swiss power system





Ambizione Energy project by E.Trutnevyte

SCCER SoE

RIsk GOveRnance of electricity pOrtfolioS (RIGOROuS): Cross-technology and spatial tradeoffs of multiple risks

Aims:

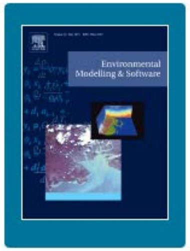
- Examine cross-technology and spatial ***risk tradeoffs in the whole Swiss electricity portfolio*** (not only individual technologies)
- Adopt a more open view to risk, including uncertain outcomes, likelihoods, and uneven knowledge robustness
- Build two interactive tools RISKMETERS by linking electricity portfolio model with the risk information
- Measure expert, stakeholder, and public preferences concerning these risk tradeoffs

ETH Zürich

USYS TdLab

Carnegie Mellon University

International Risk Governance Council

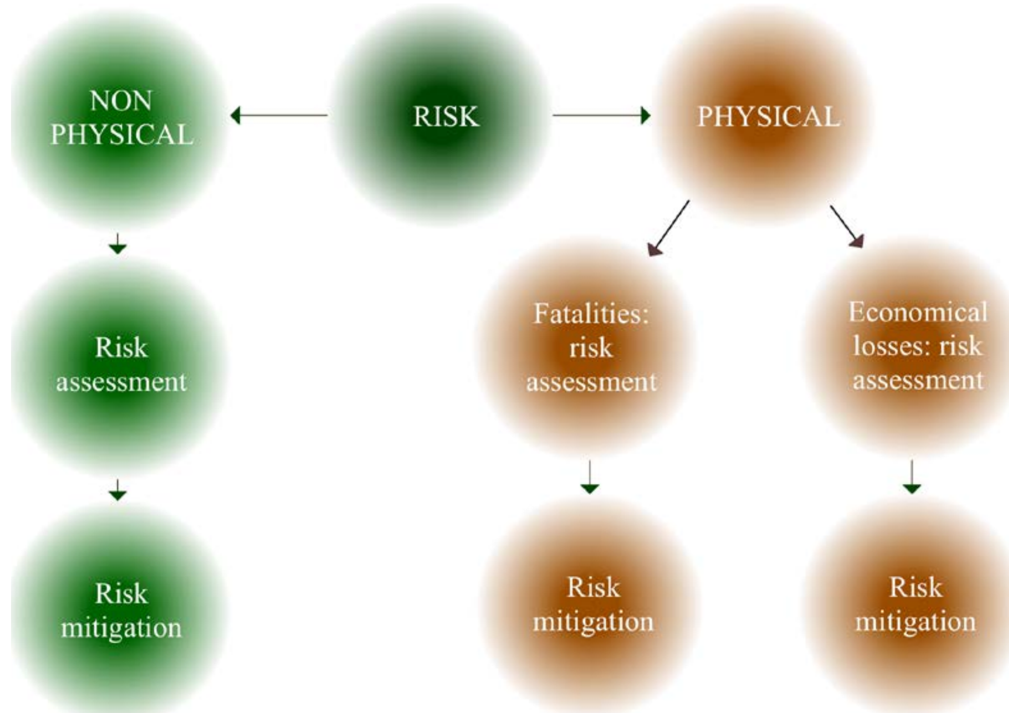


Environmental Modelling & Software

Special Issue on uncertainty modeling and visualization, interactive techniques

Exposure and risk assessment Swiss building stock for low intensity vibrations (ETHZ/BAUG)

Risk classification

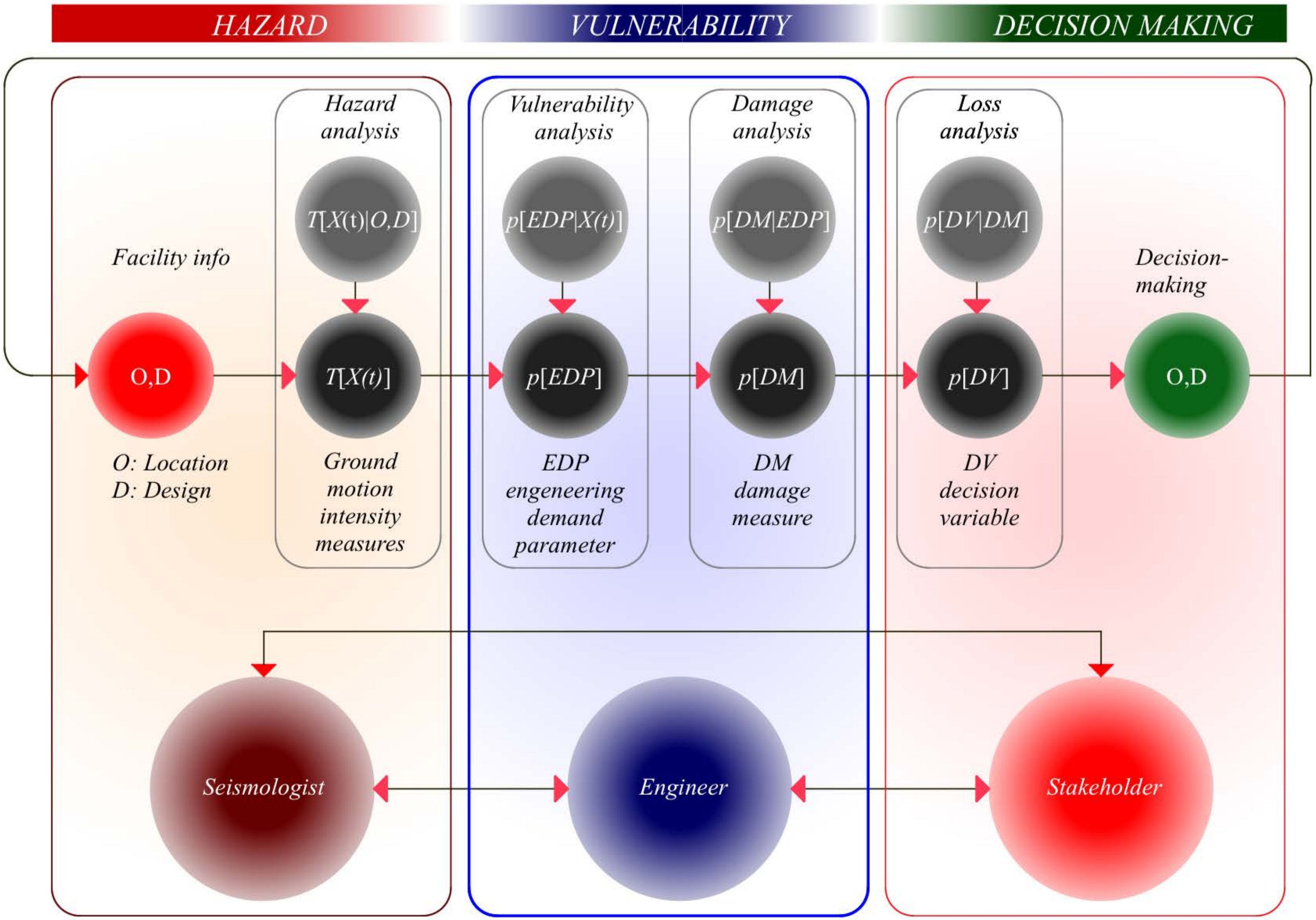


Challenges for the vulnerability model

- Which approach? Risk assessment and/or risk mitigation
- Which risk metrics to use for:
  - Fatalities
  - Monetary loss
  - Iconic loss, etc.

- Fragility function computed for macro seismicity not suitable for low intensity event
- Tail sensitivity of fragility functions
- Scale effect and spatial correlation
- Pure data driven models

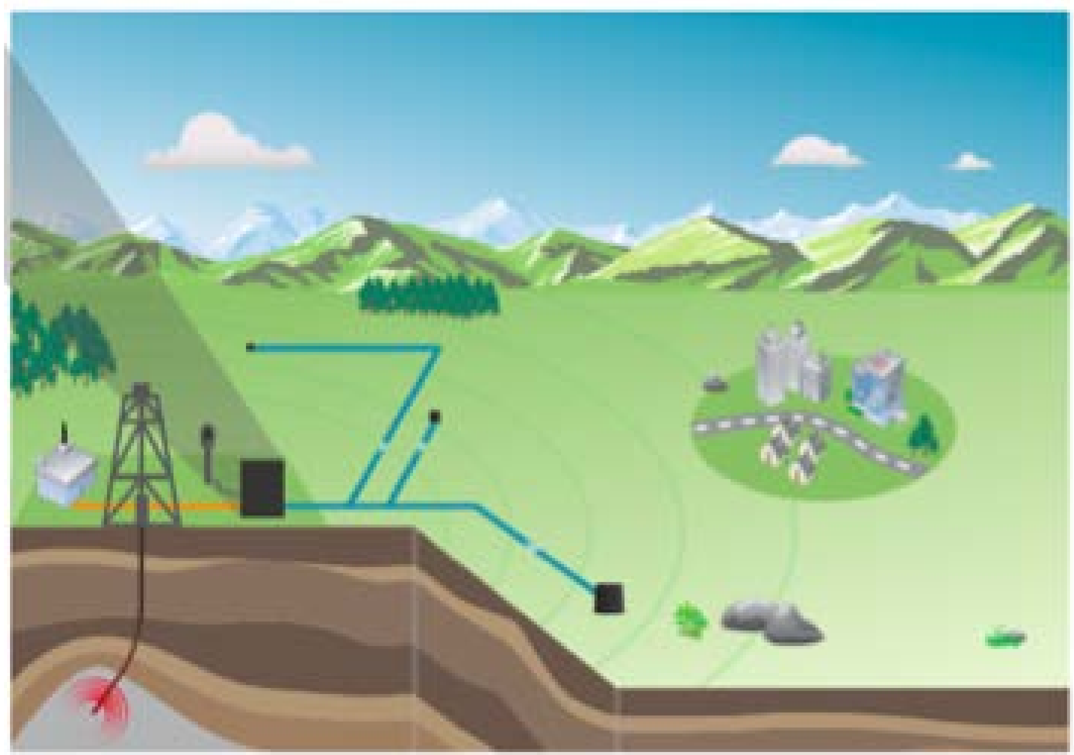
Exposure and risk assessment Swiss building stock for low intensity vibrations (ETHZ/BAUG)



Framework, PEER formula

Hazard, risk, mitigation and society

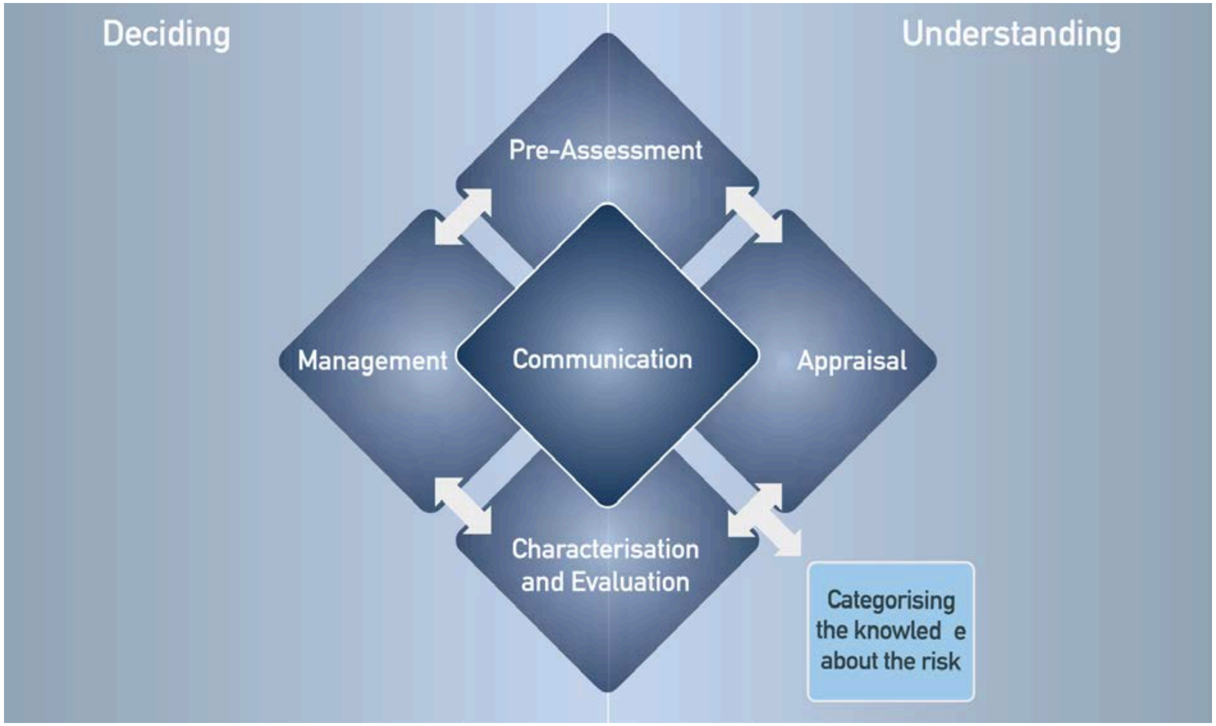
Society

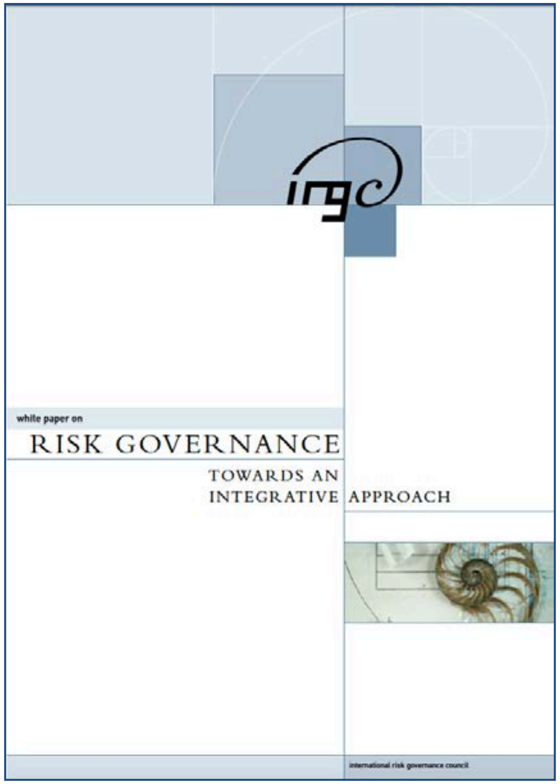


Risk
(exposure & vulnerability)

Hazard

Adopting the General framework of the International Risk Governance Council for Geothermal Projects

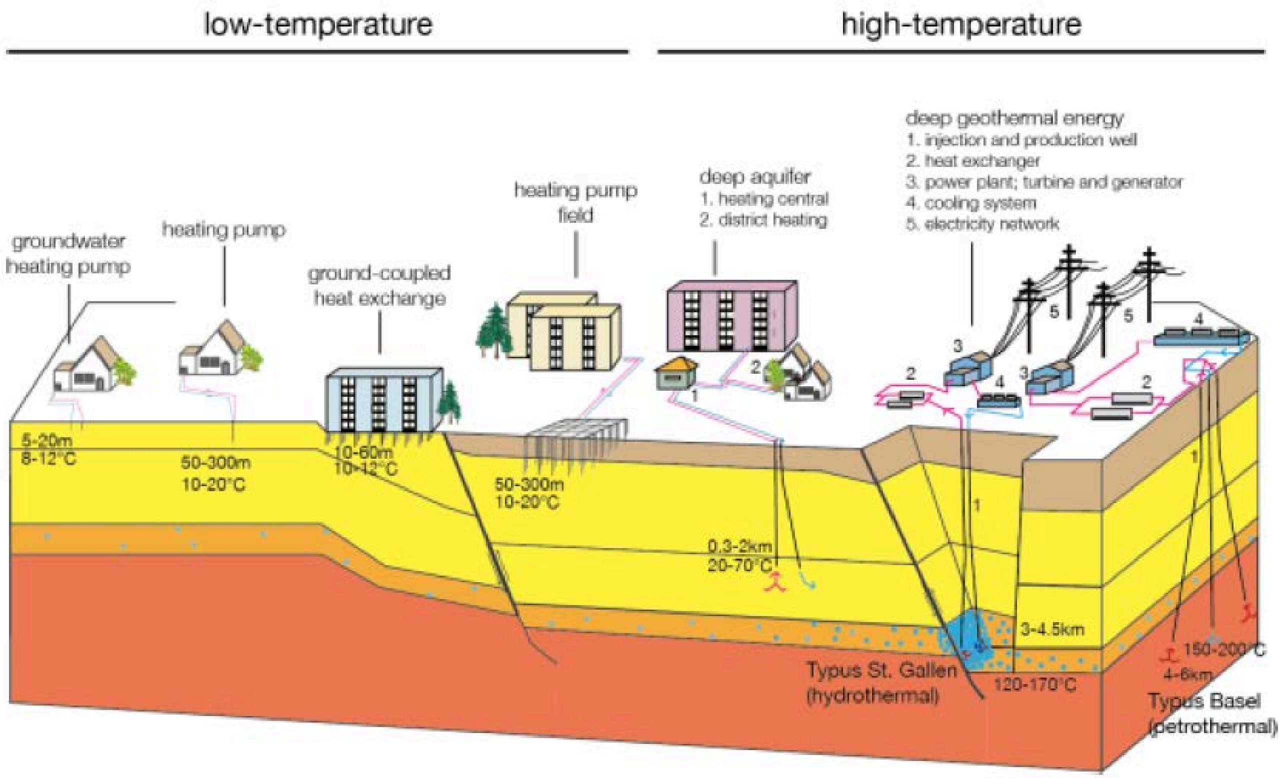




➔ How should it be translated and tailored to induced seismicity risk governance?

Categorizing Risk Profiles

- The (seismic) risk profiles of a deep heat pump, a hydrothermal project, a EGS, in an rural or urban environment etc. varies greatly.
- **Risk Governance workflows** must adopt, one size does not fit all.



GRID score

(Geothermal Risk of Induced seismicity Diagnosis)

Hazard concern

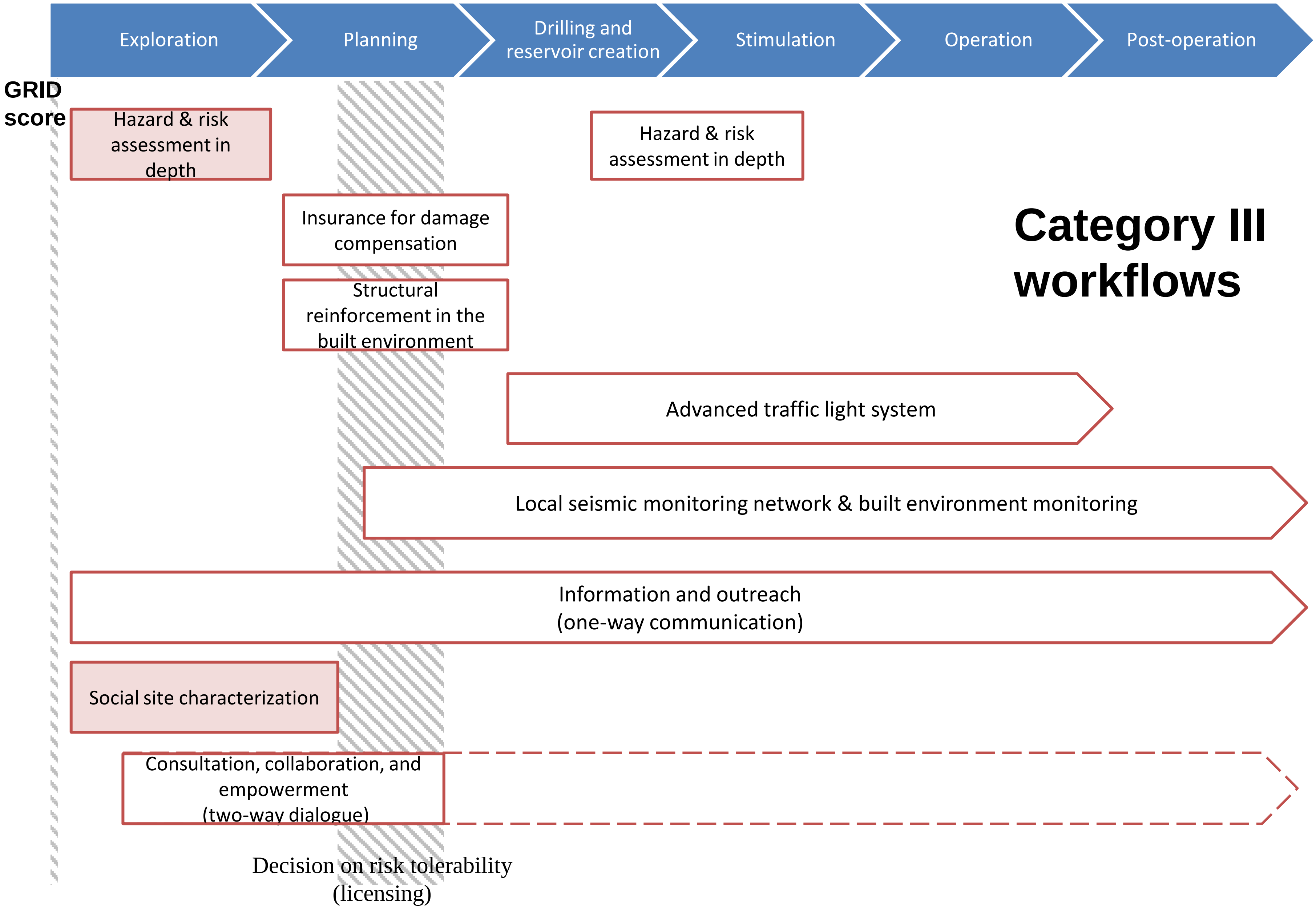
Social concern

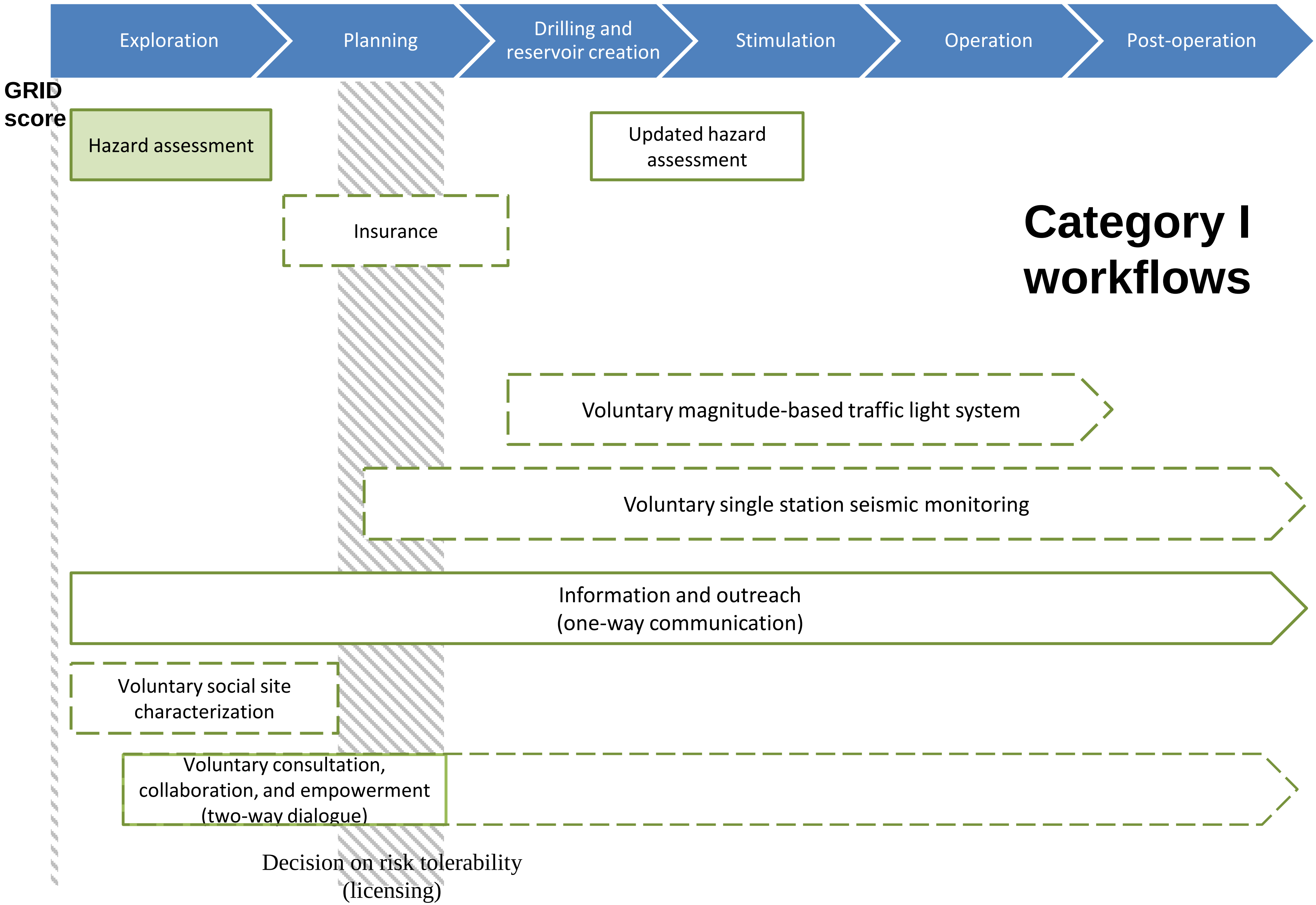
$$GRID\ score = \frac{\sum_{i=1}^{11} a_i^{hazard}}{22} + \frac{\sum_{j=1}^{5} a_j^{risk}}{10} + \frac{\sum_{k=1}^{5} a_k^{social}}{10};$$

Risk concern

Category 0 if GRID <33%
Category I if GRID 33-50%:
Category II if GRID 50-66%
Category III if GRID >66%

Category III workflows




Exploration
Planning
Drilling and reservoir creation
Stimulation
Operation
Post-operation
GRID score
Hazard assessment
Updated hazard assessment
Category I workflows
Insurance
Voluntary magnitude-based traffic light system
Voluntary single station seismic monitoring
Information and outreach (one-way communication)
Voluntary social site characterization
Voluntary consultation, collaboration, and empowerment (two-way dialogue)
Decision on risk tolerability (licensing)

Advanced traffic light system: Workflow

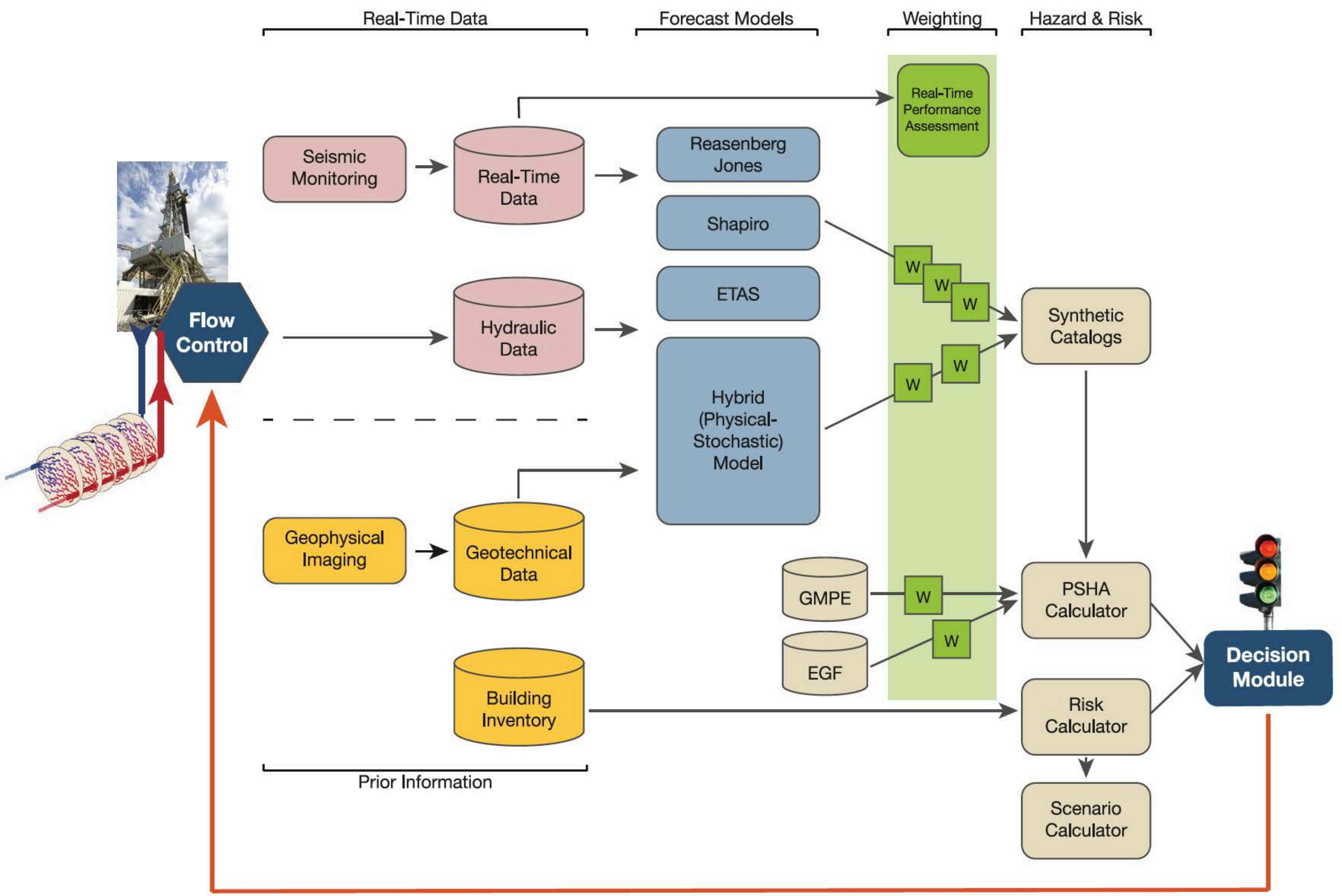
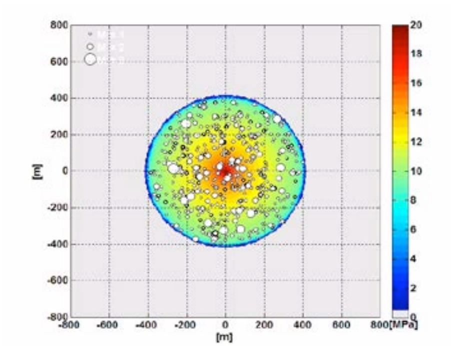


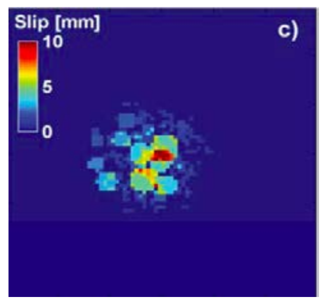
Figure: TA Swiss 2014

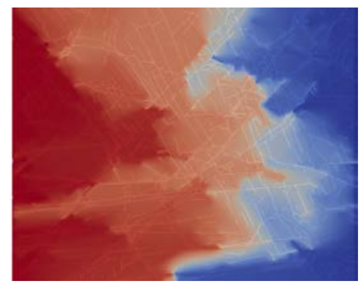
SED/SCCER
Modellig Efforts

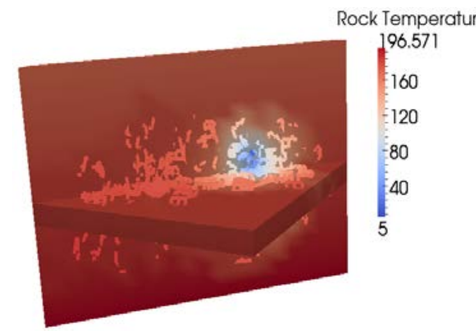
Model Complexity

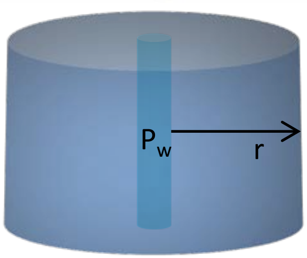
2012 | 2013a | 2013b | 2014a | ...



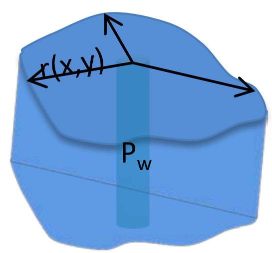




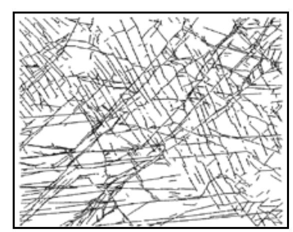




COMSOL



SUTRA



HFR-Sim

HFR-Sim+

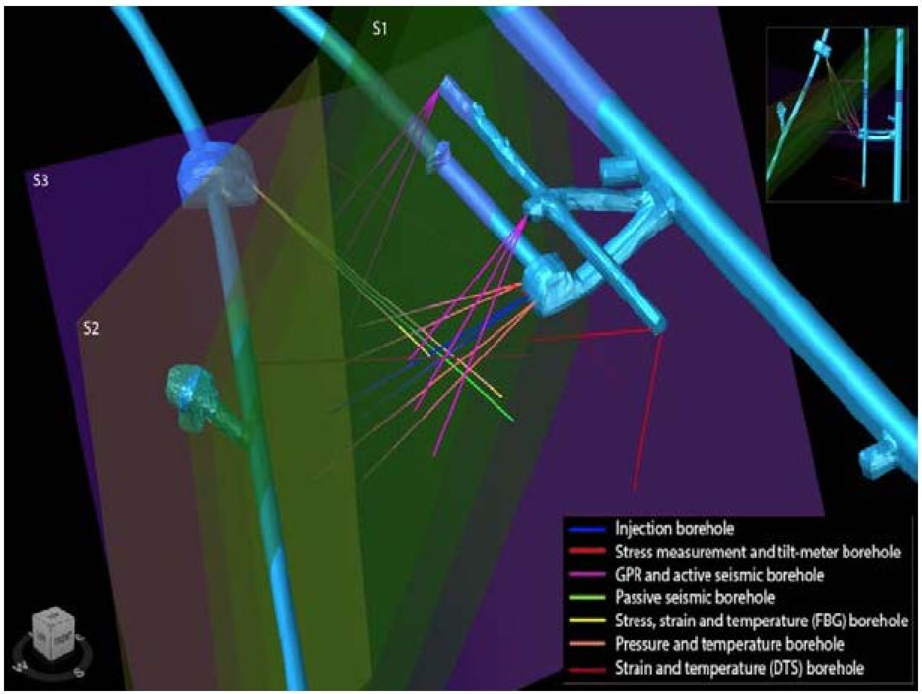
Gischig & Wiemer, 2013
Goertz-Allmann & Wiemer, 2013

Gischig et al, 2014

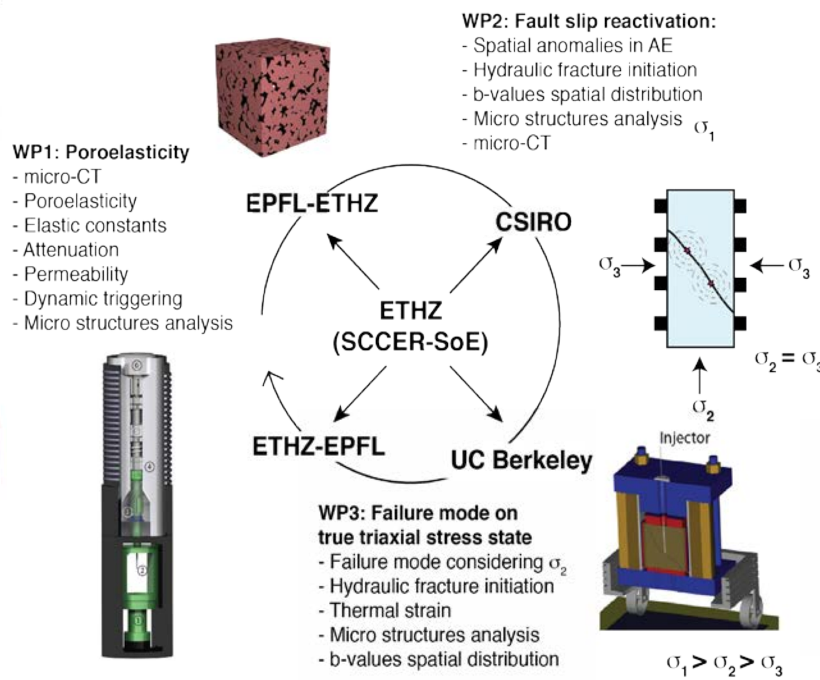
Karvounis et al., 2013

Karvounis and Wiemer, 2015

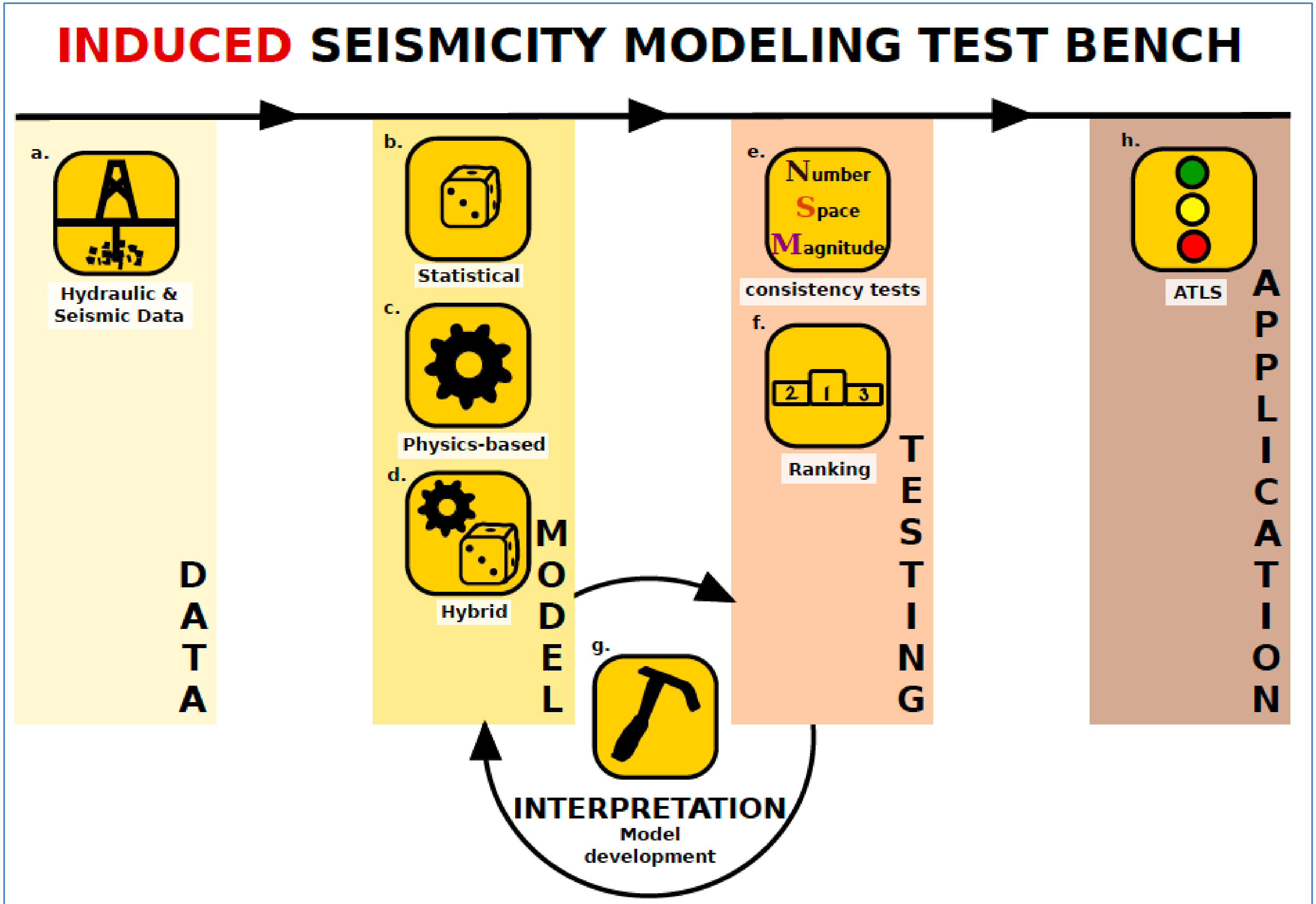
Lab Scale: Model development, calibration and validation



Amann, 2015



Madonna, 2015



→ Kiraly et al., 2015

Project Haute-Sorne as a test case

SCCER SoE

The project at a glance:

- est. power: 5 MW_{el}
- type: EGS (enhanced geothermal)
- plant type: ORC (Organic Rankine Cycle)
- source rock: crystalline
- depth range: 3.5km-5km
- estim. temperature: ~150°C - 180°C
- Stimulation method: multi-stage hydro-shearing

Safety and mitigation measures:

- risk studies (continuously updated)
  - ✓ naturally occurring seismicity
  - ✓ deterministic study
  - ✓ probabilistic study
  - ✓ logic tree risk analysis (link-up study)
- stimulation test
- traffic light system
- advanced (forecasting) traffic light system
- micro-seismic monitoring
- conservation of evidence (e.g. fissure protocols)

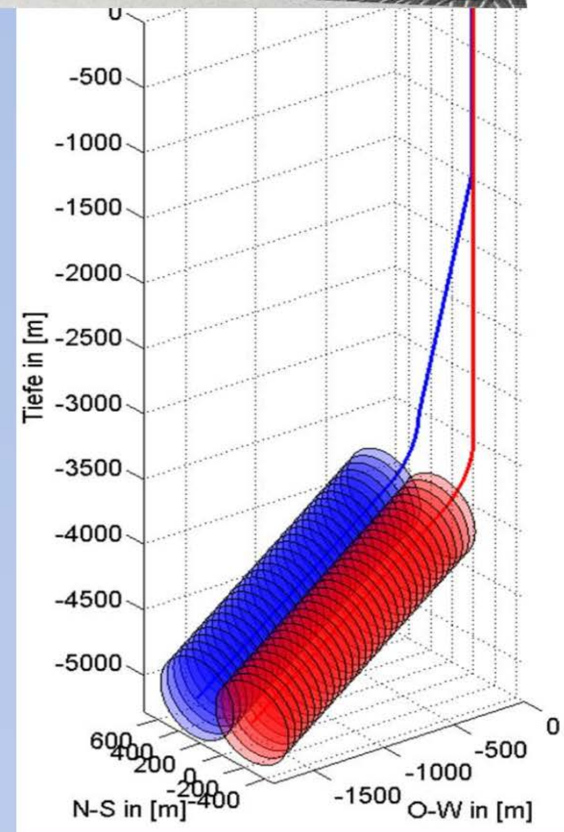
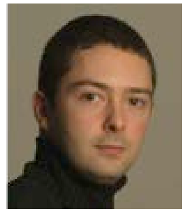
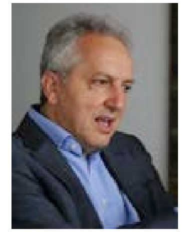
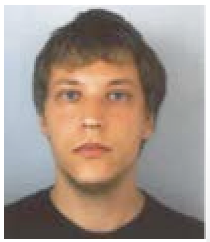


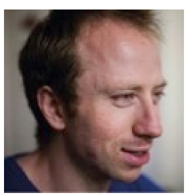
Figure 1: schematic view of the power plant and heat exchanger (not to scale)

Thank you!



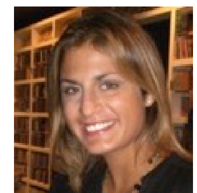
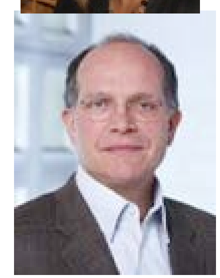
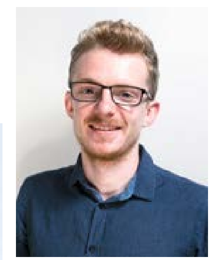









Hazard score

	0 (no concern)	1 (medium concern)	2 (high concern)
Depth	< 1 km	1 - 3 km	> 3 km
Injection volume during stimulation	<1'000m^3	1'000-10'000m^3	>10'000m^3
Injection volume during operation	<1'000m^3/day	1'000-10'000m^3/day	>10'000m^3/day
Extraction volume during operation	<10'000m^3/day	10'000-100'000m^3/day	>100'000m^3/day
Rock type	sediments	near crystaline basement	crystaline
Separation between background and induced seismicity	low activity	medium activity	high activity
Pore pressure perturbation	<0.1MPa	0.1-1MPa	>1MPa
Distance to critically pre-stressed extended fault	>5 km	2 - 5 km	<2km
Differential stress	litostatic	medium stress	high stress
Local soil amplification	predominately hard rock	mix	predominately soft rock
Susceptibility to secondary hazards (rock falls etc.)	none	does exist	high

Risk score (exposure and vulnerability)

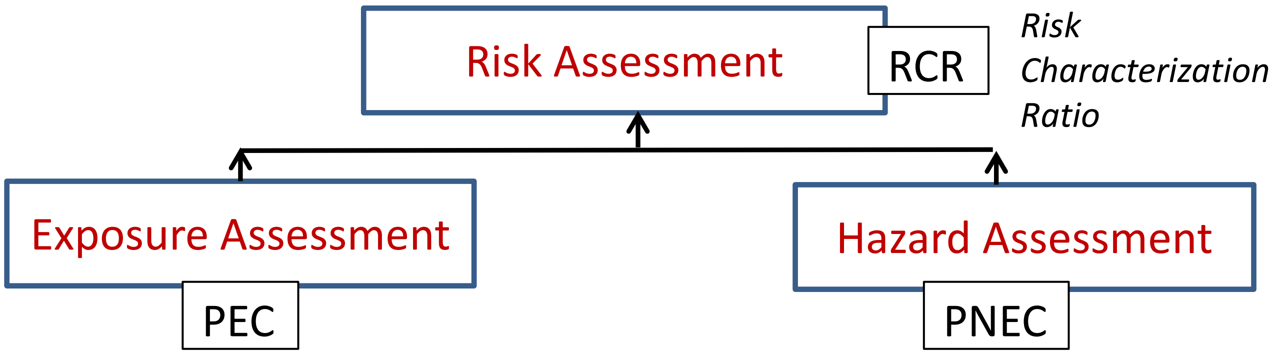
	0 (no concern)	1 (medium concern)	2 (high concern)
Population density	remote	rural	urban
Industrial or commercial activity	none or small	does exist	high
Buildings with structural damage potential	none	does exist	high
Critical infrastructures	none	does exist	high
Sensitive cultural heritage	none	does exist	high

Social concern score

	0 (no concern)	1 (medium concern)	2 (high concern)
High public concern potential	none	does exist	high
Highly vulnerable or opposing stakeholders	none	does exist	high
Previous negative experiences	none	does exist	high
Lack of trust in the project developers or authorities	none	does exist	high
Benefits to the local community	direct benefits	compensation only	none

Accident Risk for Deep Geothermal Energy Systems – Work in Progress

Environmental and Human Health Risk Assessment on the use of Chemicals in Deep Geothermal Energy systems



- Collect information for all the chemicals used in geothermal systems in drilling, stimulation and operational phase, including information about quantity (if possible).
- Assess the most commonly used chemicals in the different phases in geothermal energy systems.
- Environmental and human health risk assessment following the standardized European Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) methodology:
  - Collection of the Predicted No Effect Concentrations (PNEC) values for the chemicals under interest based on a literature survey;
  - Definition of the Predicted Environmental Concentrations (PEC) based on possible accidents scenarios;
  - Estimation of the risk based on the comparison between the PEC and PNEC.