

Electricity sector transition and the changing risks to human health, safety, natural and built environment

Evelina Trutnevyte, ETH Zurich

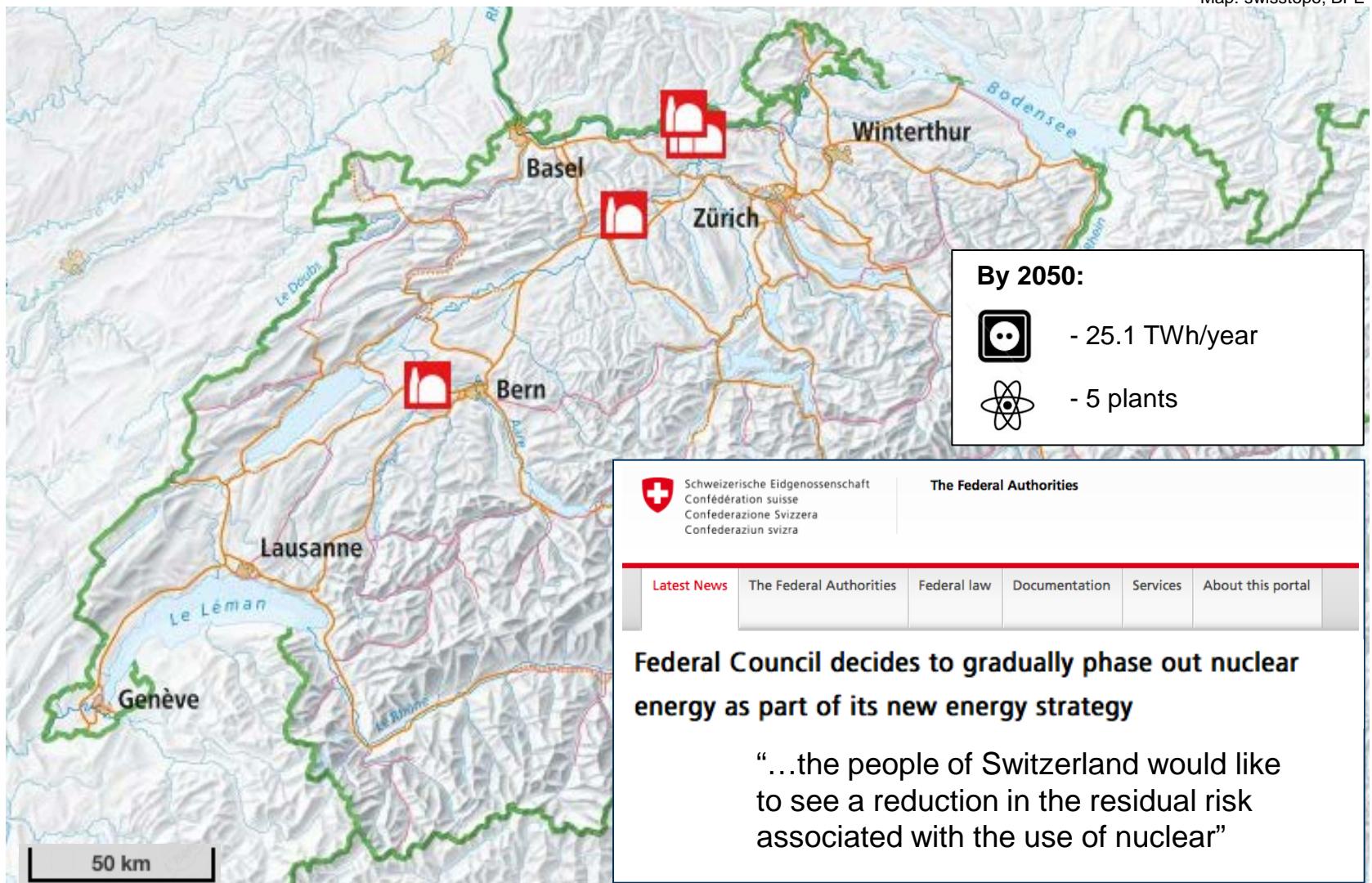
Fondazione Eni Enrico Mattei, Milan, 6 October 2016





Swiss Energy Strategy 2050

Map: swisstopo, BFE





< Protective measures

Staying indoors

Taking iodine tablets

Agricultural measures



Taking iodine tablets

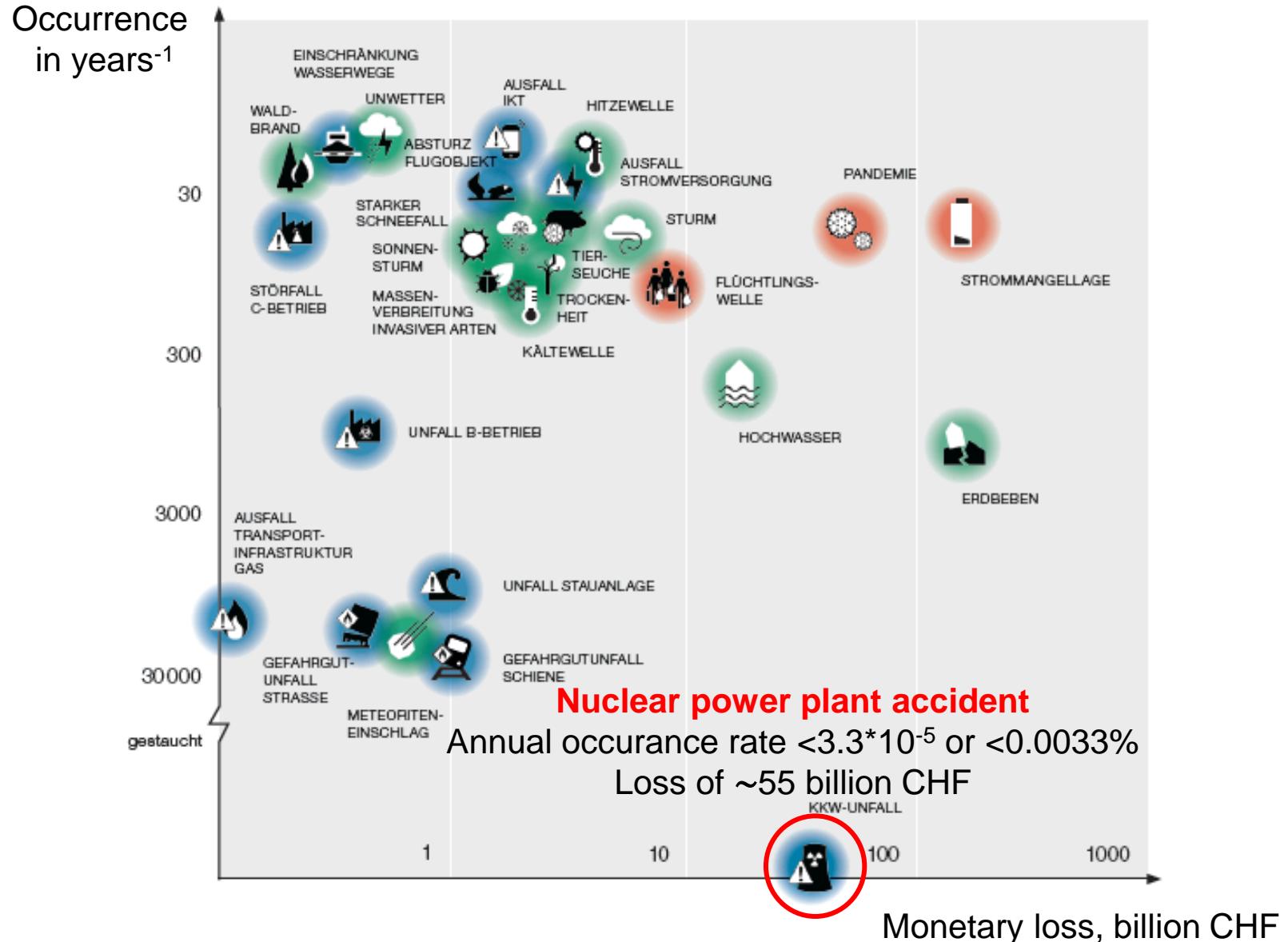
Potassium iodide tablets, taken at the appropriate time and according to official instructions, can prevent radioactive iodine in the air becoming enriched in the thyroid gland through inhalation. In this way, the radioactive load on the thyroid can be significantly reduced.

However, it should be noted that while potassium iodide tablets offer protection from radioactive iodine, they do not protect against radiation from external sources that affect the body and airways. This is why the authorities issue instructions on additional protective measures to be taken in conjunction with the tablets, such as staying indoors, or taking cover in a cellar or protective shelter.



Figures: kaliumiodid.ch

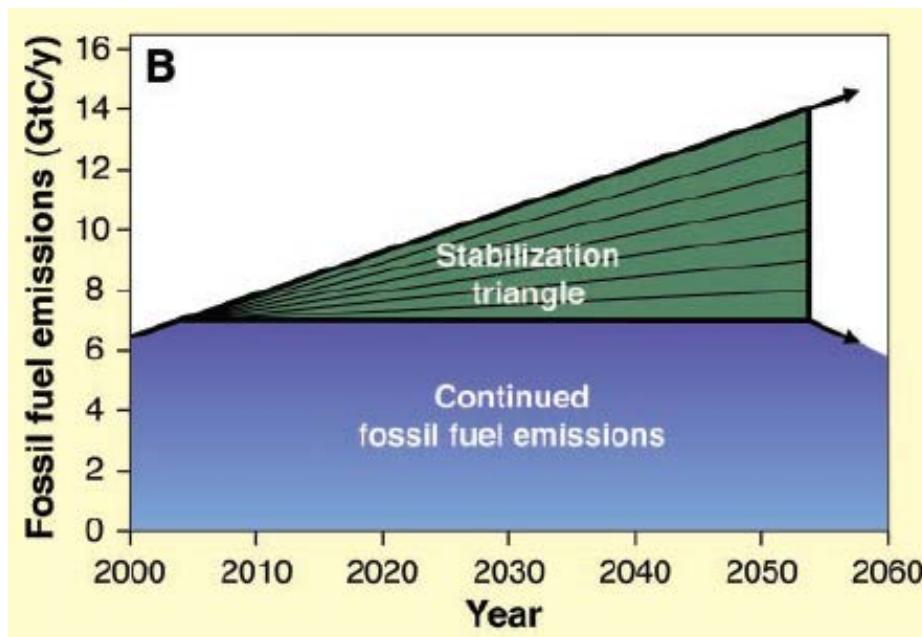
Nuclear accident risk



Low-carbon electricity supply requires a portfolio of technologies

Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies

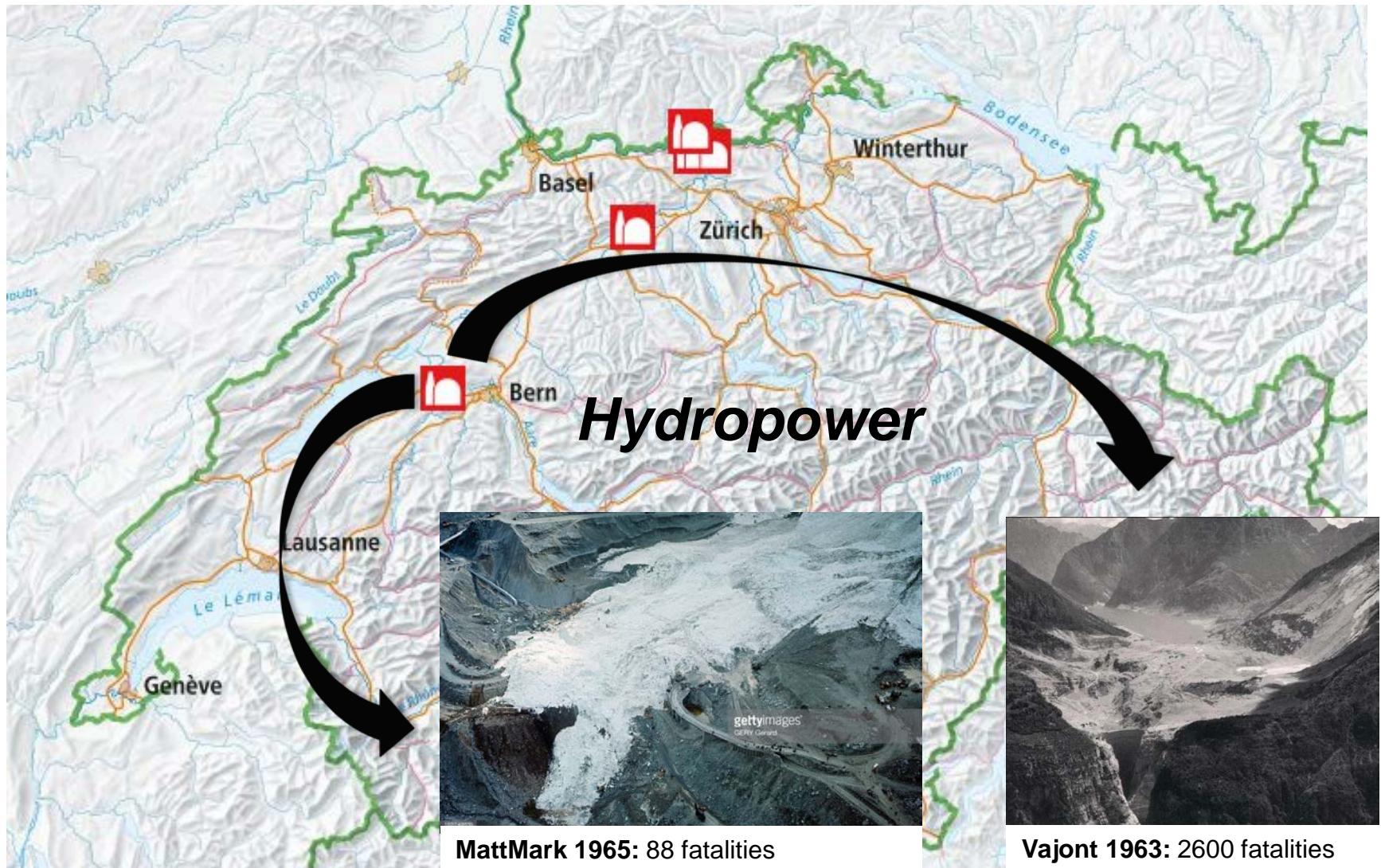
S. Pacala^{1*} and R. Socolow^{2*}
2004



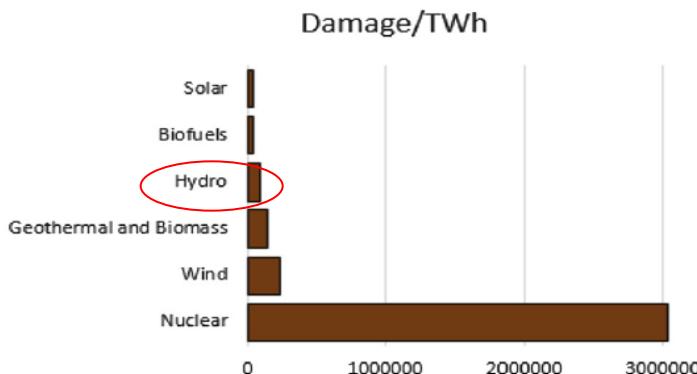
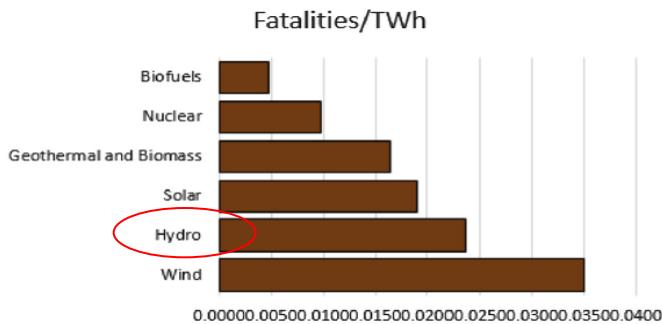
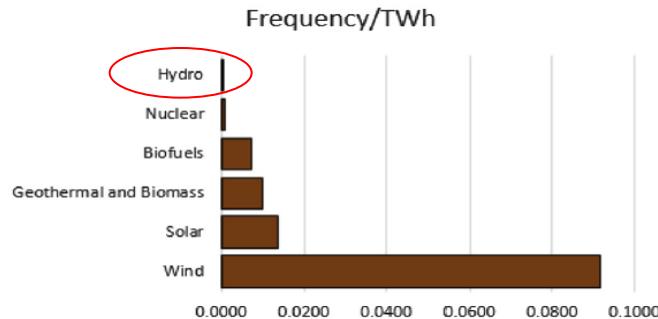
- Economy-wide carbon-intensity reduction (emissions/\$GDP)
- 1. Efficient vehicles
- 2. Reduced use of vehicles
- 3. Efficient buildings
- 4. Efficient baseload coal plants
- 5. Gas baseload power for coal baseload power
- 6. Capture CO₂ at baseload power plant
- 7. Capture CO₂ at H₂ plant
- 8. Capture CO₂ at coal-to-synfuels plant
- Geological storage
- 9. Nuclear power for coal power
- 10. Wind power for coal power
- 11. PV power for coal power
- 12. Wind H₂ in fuel-cell car for gasoline in hybrid car
- 13. Biomass fuel for fossil fuel

Cross-technology and spatial risk transfers

Map: map.geo.admin.ch



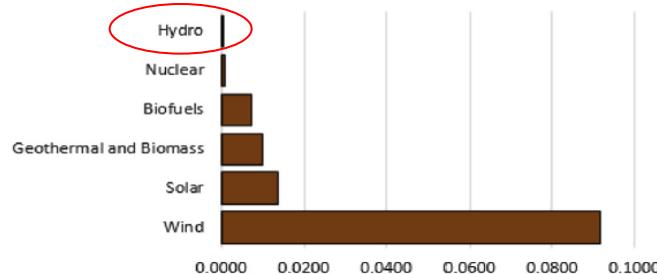
Hydropower accidents



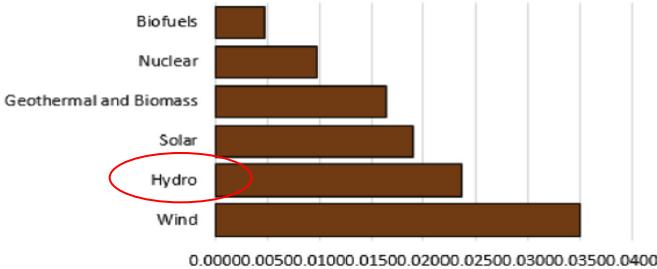
Sovacool et al. (2016)

Hydropower accidents

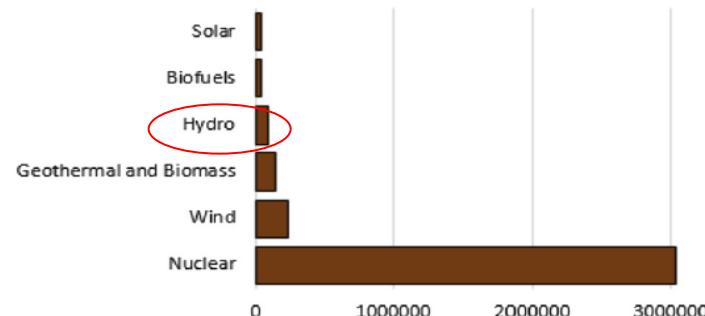
Frequency/TWh



Fatalities/TWh

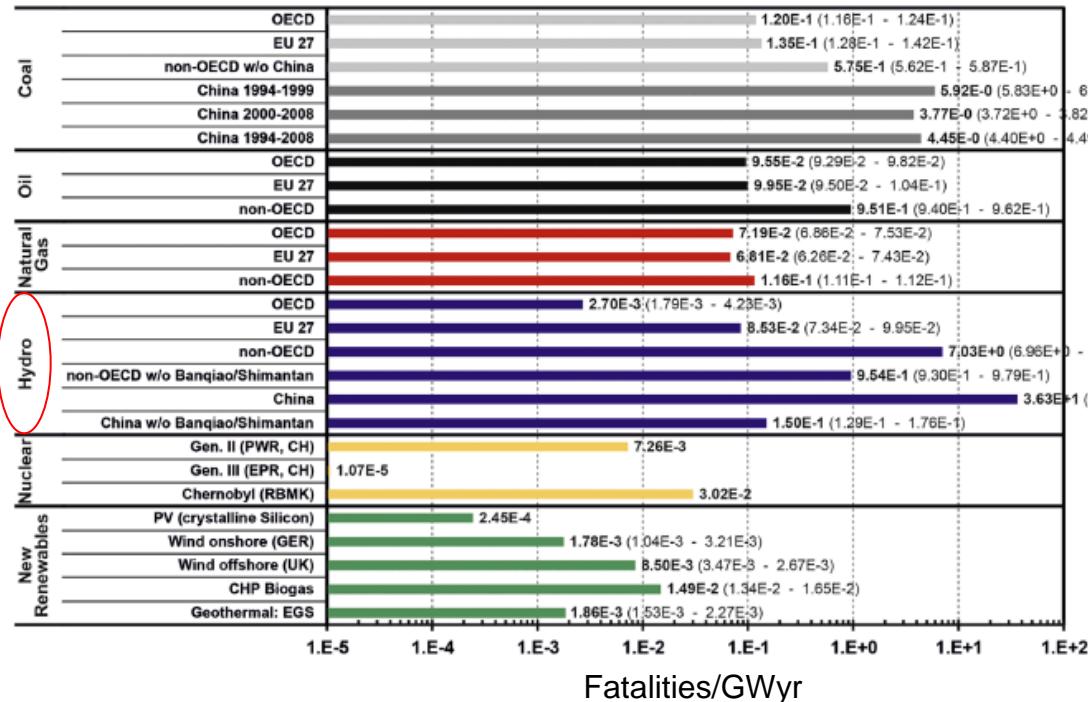


Damage/TWh



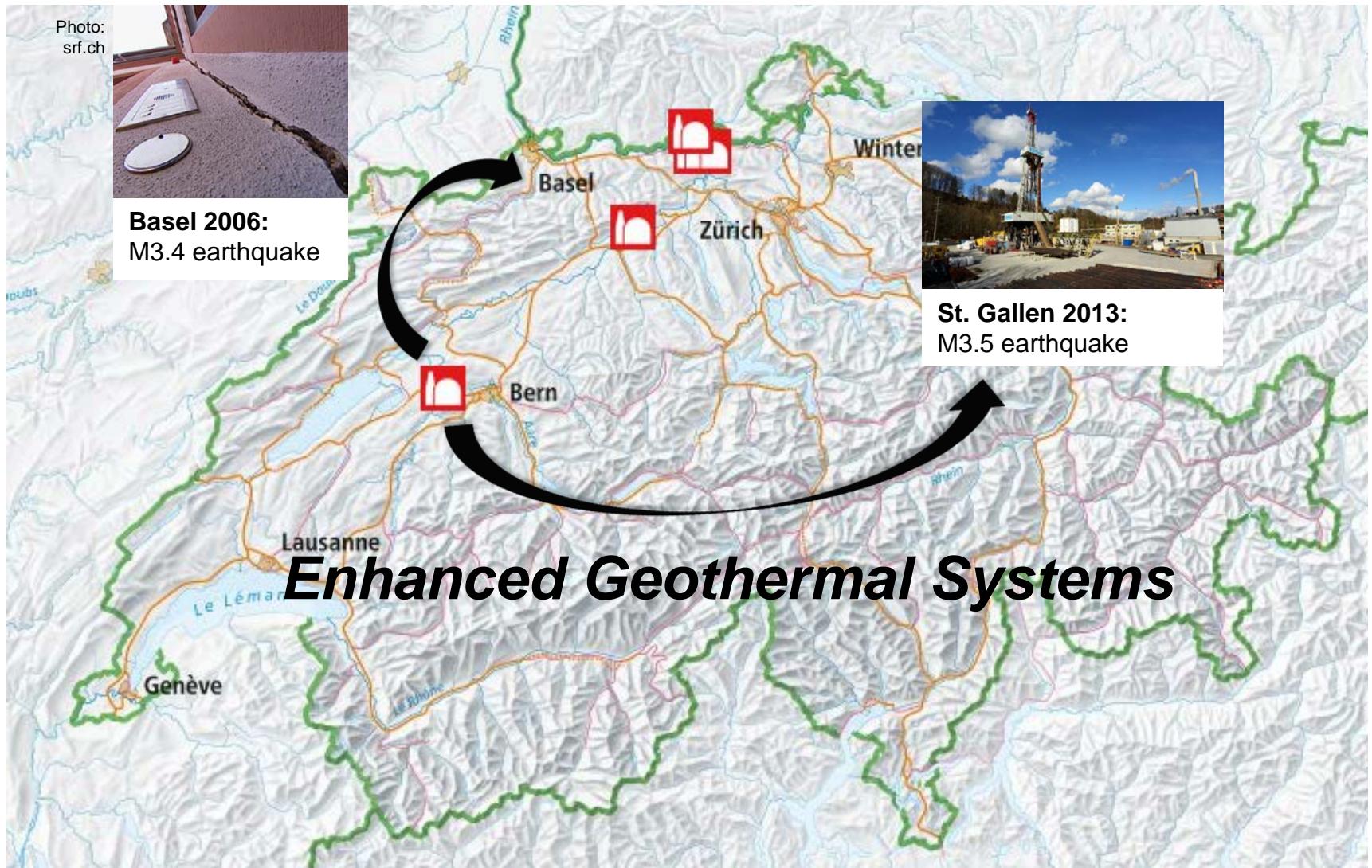
Sovacool et al. (2016)

Burgherr and Hirschberg (2014)



Cross-technology and spatial risk transfers

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Induced seismicity of Enhanced Geothermal Systems

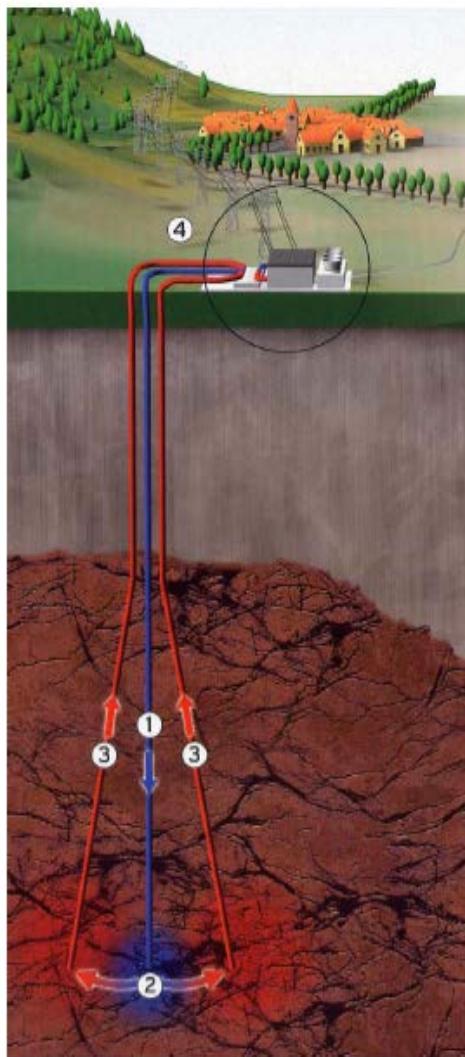
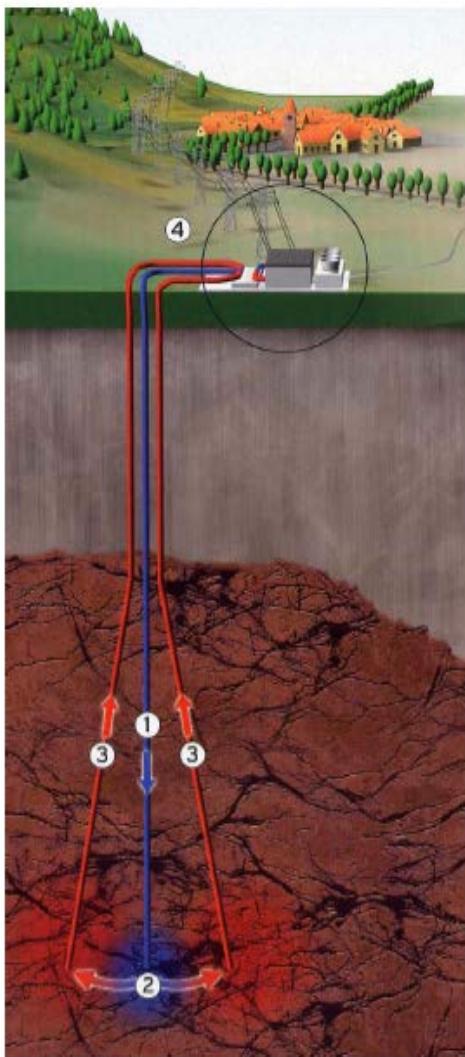
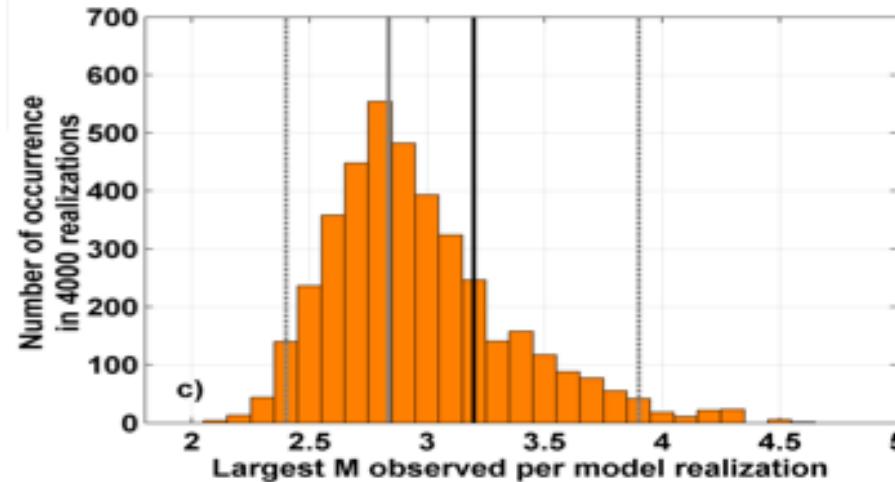


Figure: SCCER-SoE

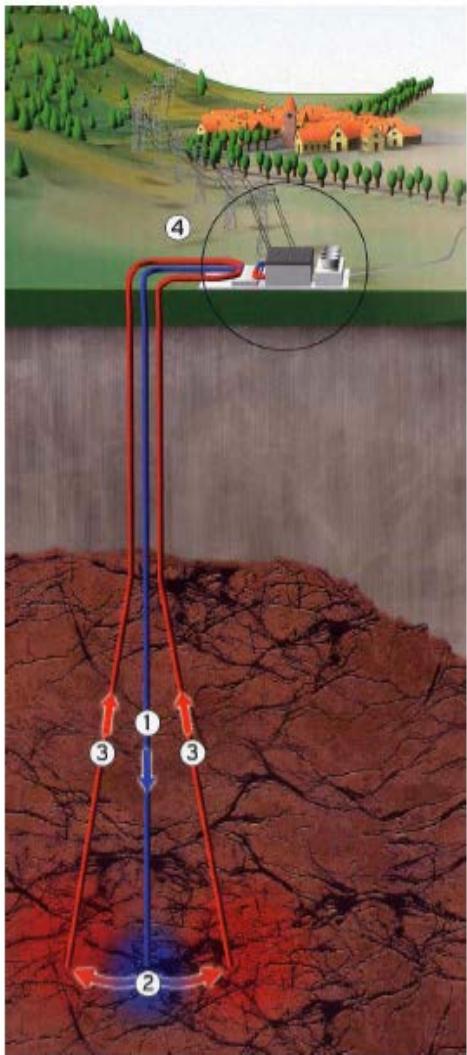
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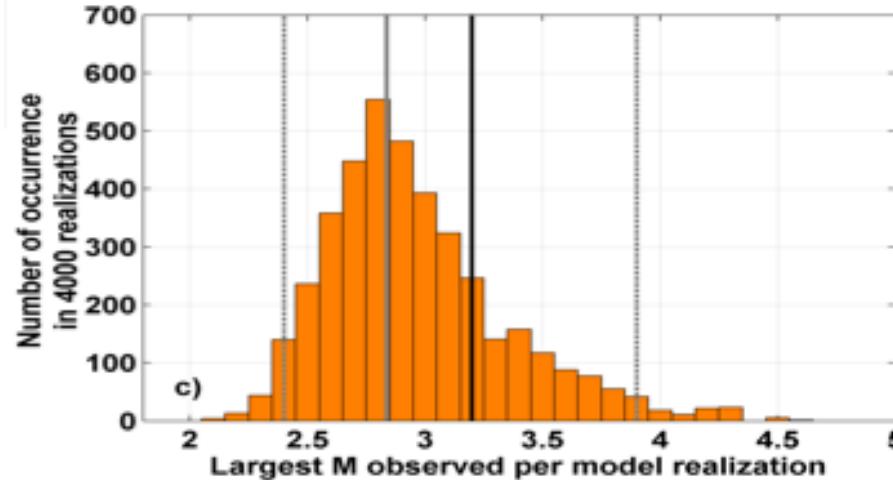
Probabilistic hazard assessment (Gischig & Wiemer, 2013)



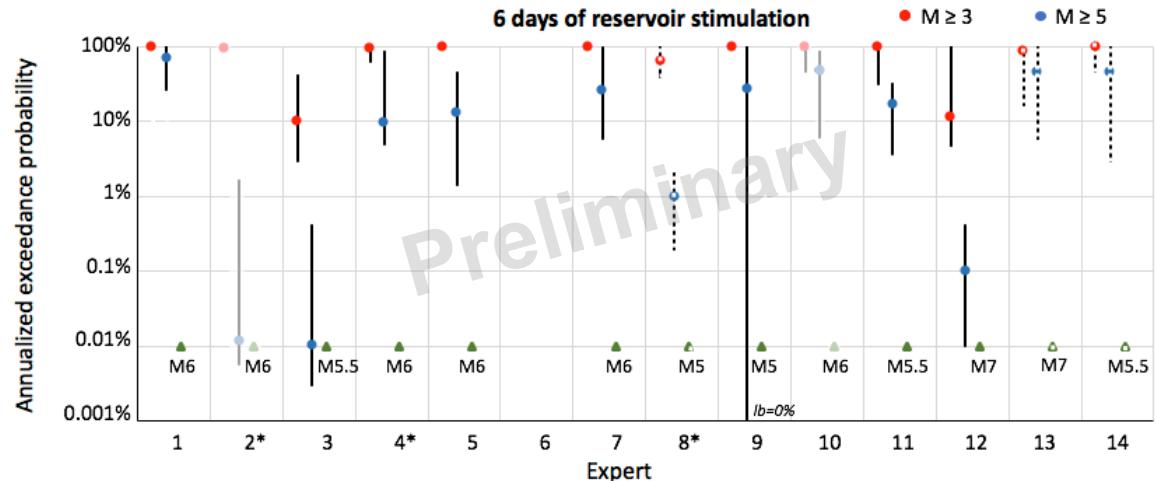
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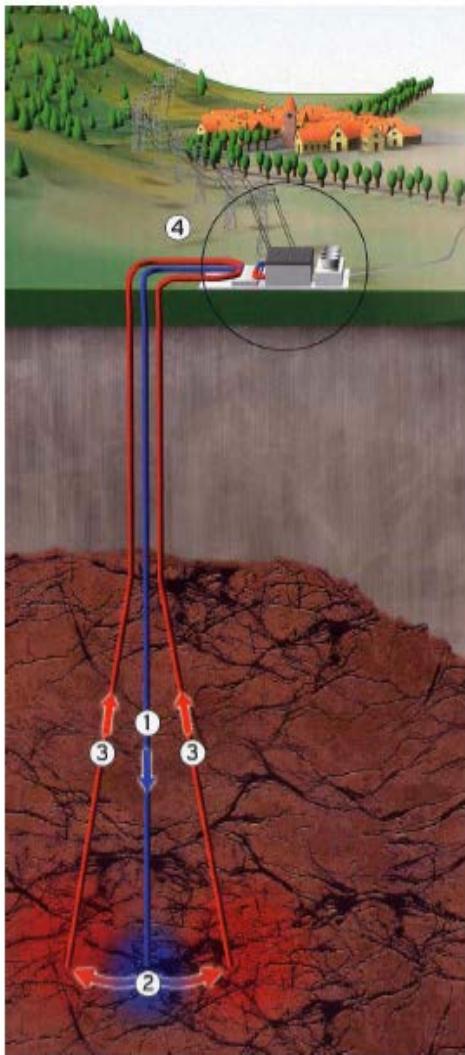
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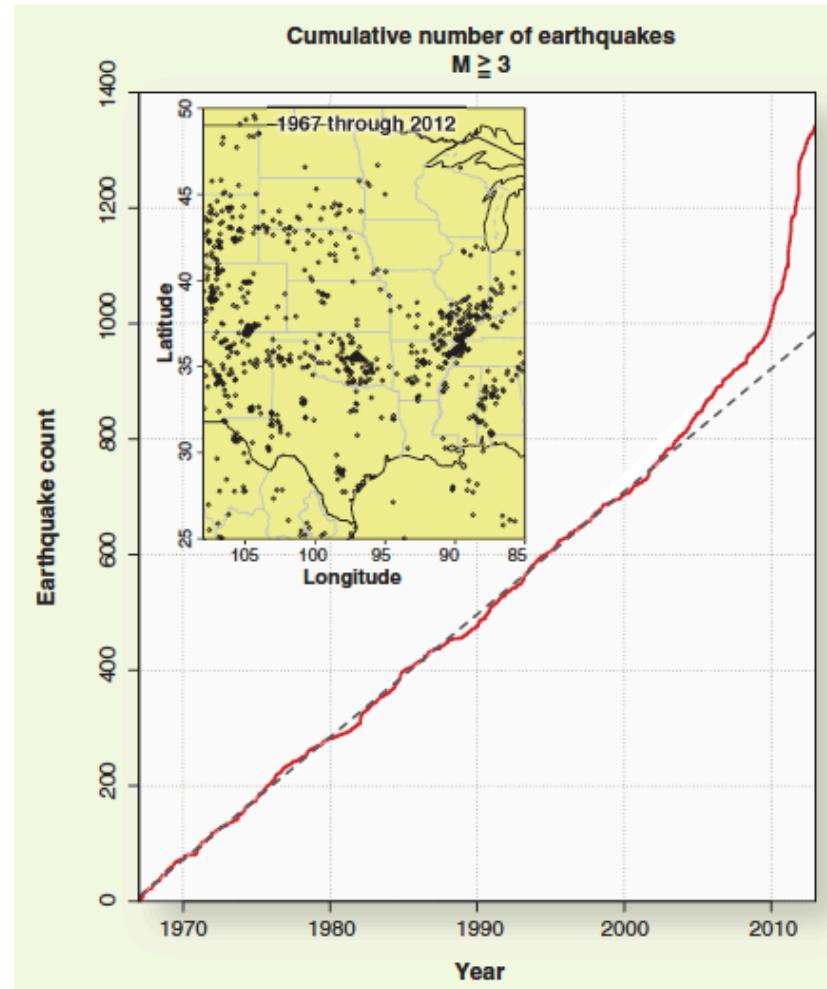
Expert elicitation (Trutnevyyte & Azevedo, 2016)



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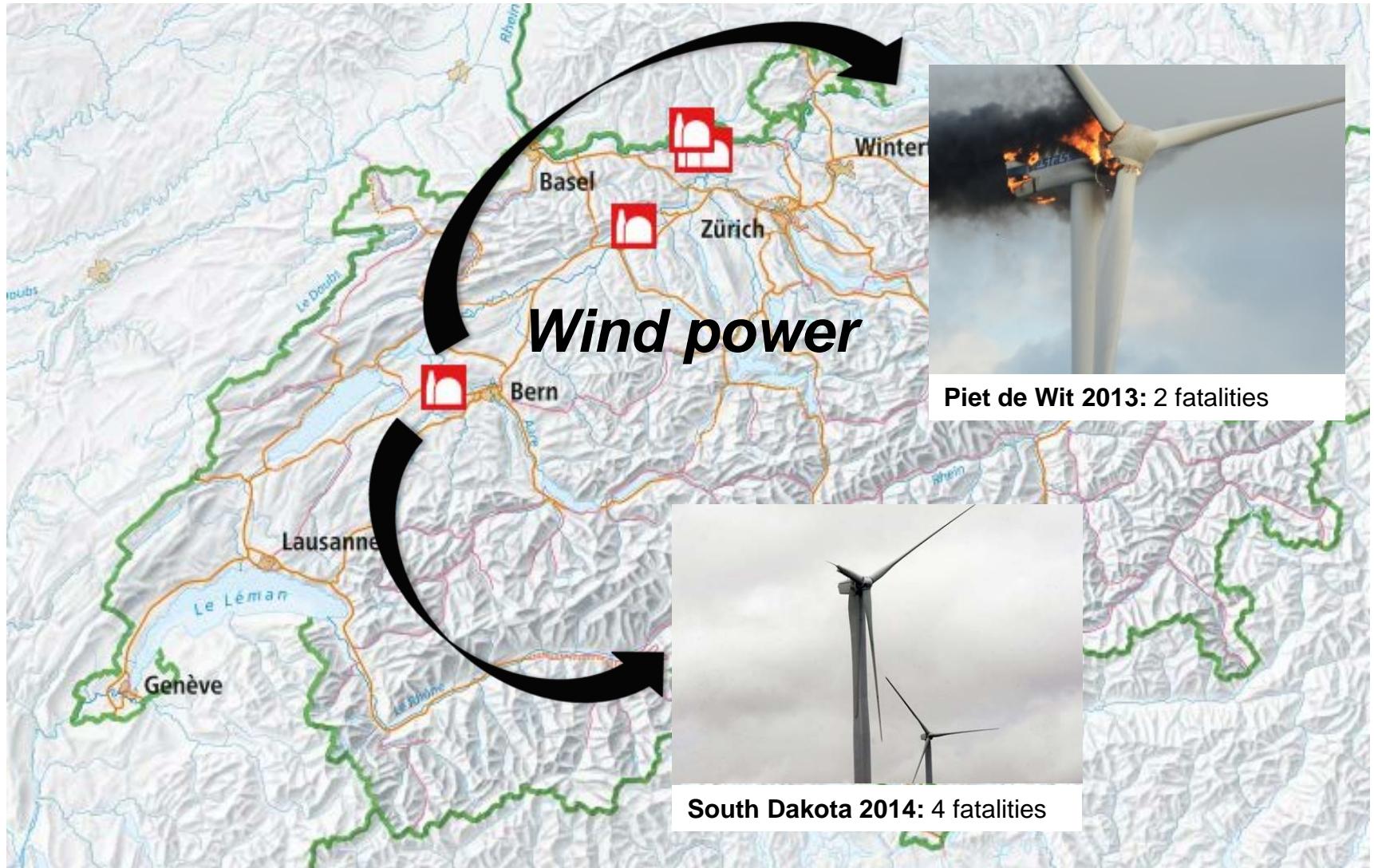


Earthquakes in central and eastern US (Ellsworth 2013)



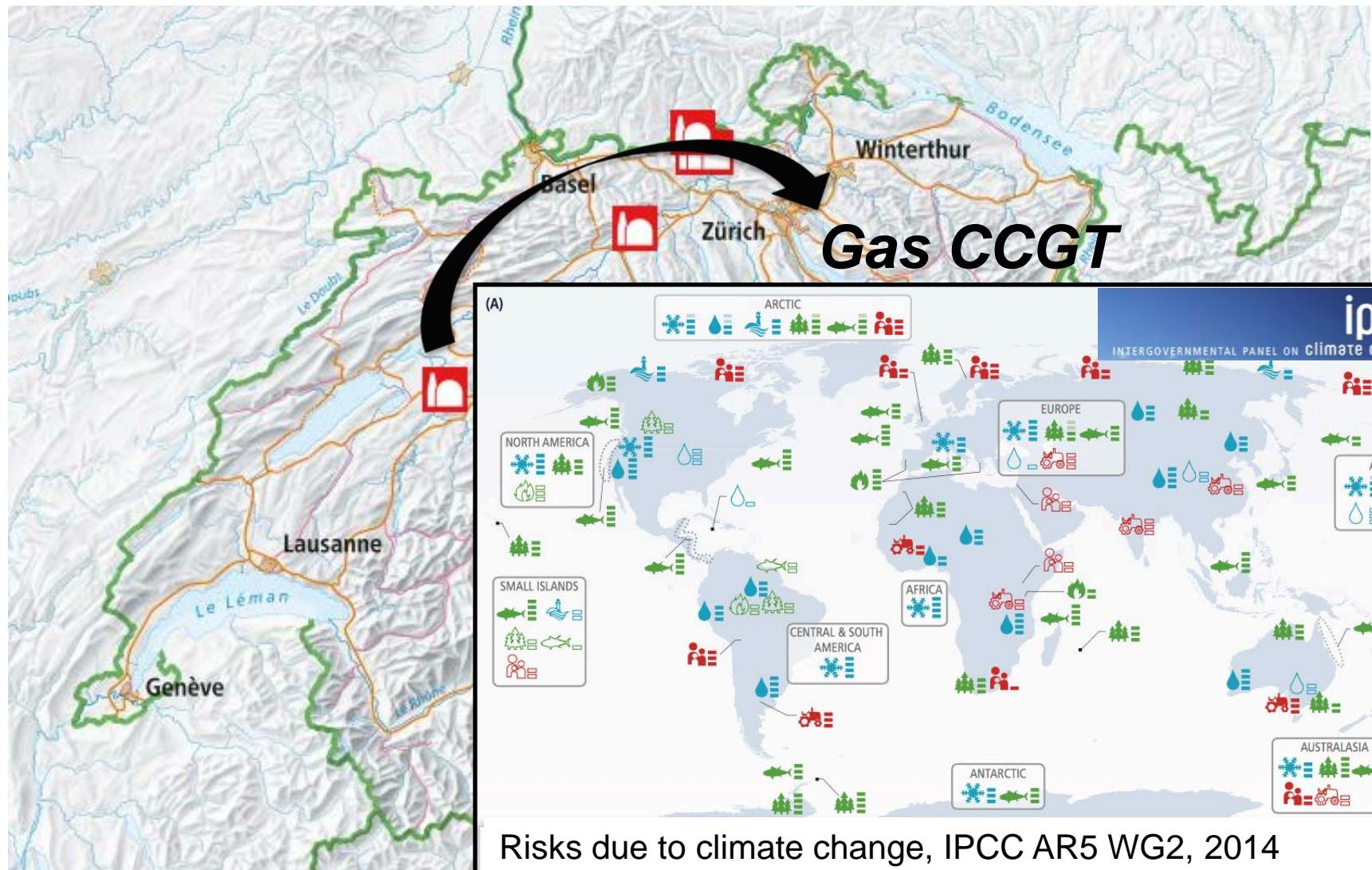
Cross-technology and spatial risk transfers

Map: map.geo.admin.ch

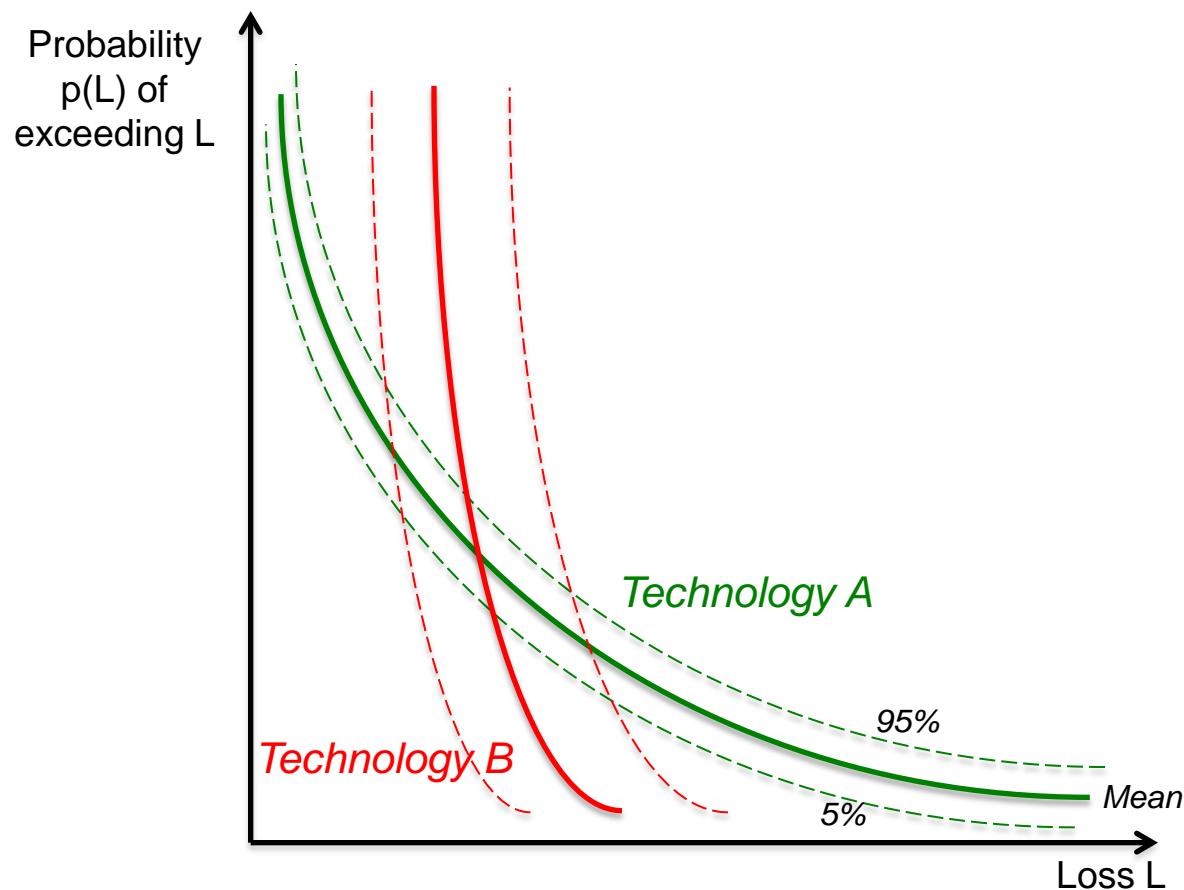


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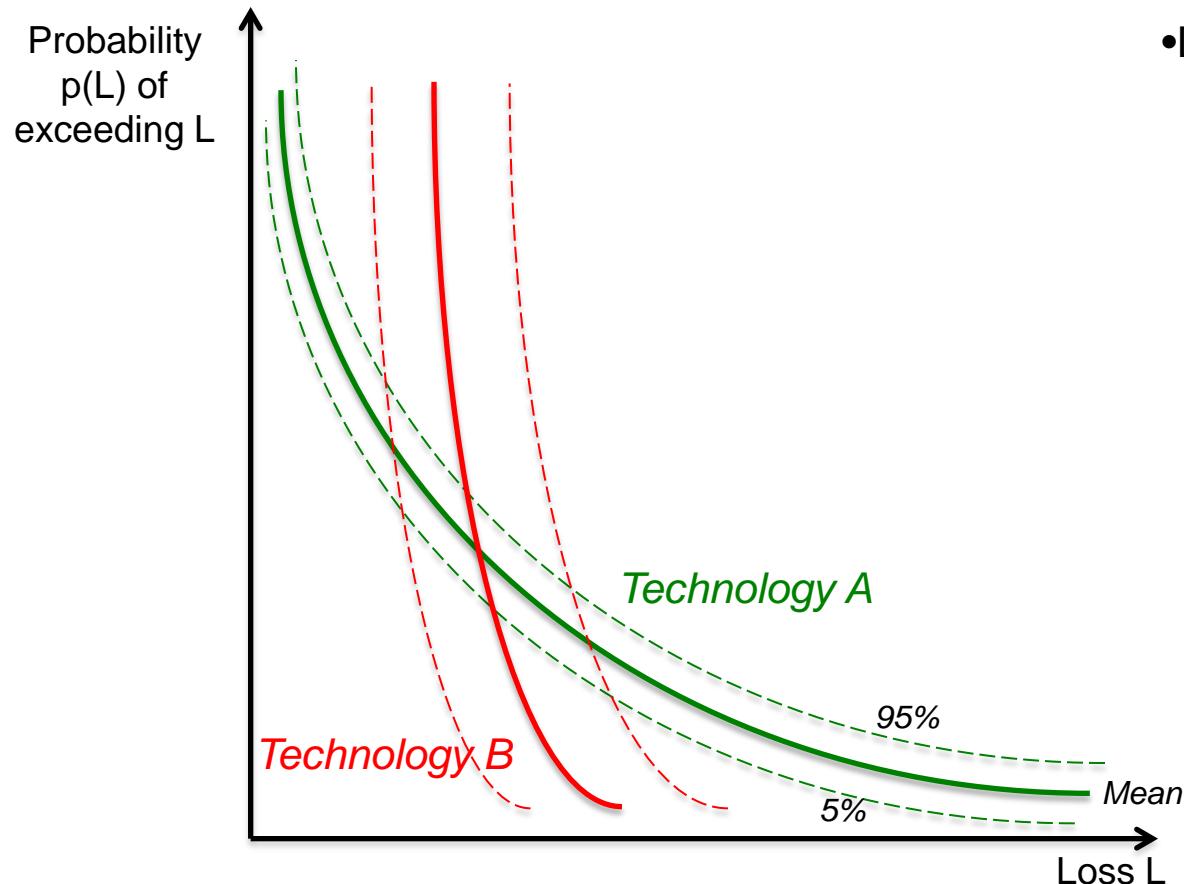
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Cross-technology risk tradeoffs



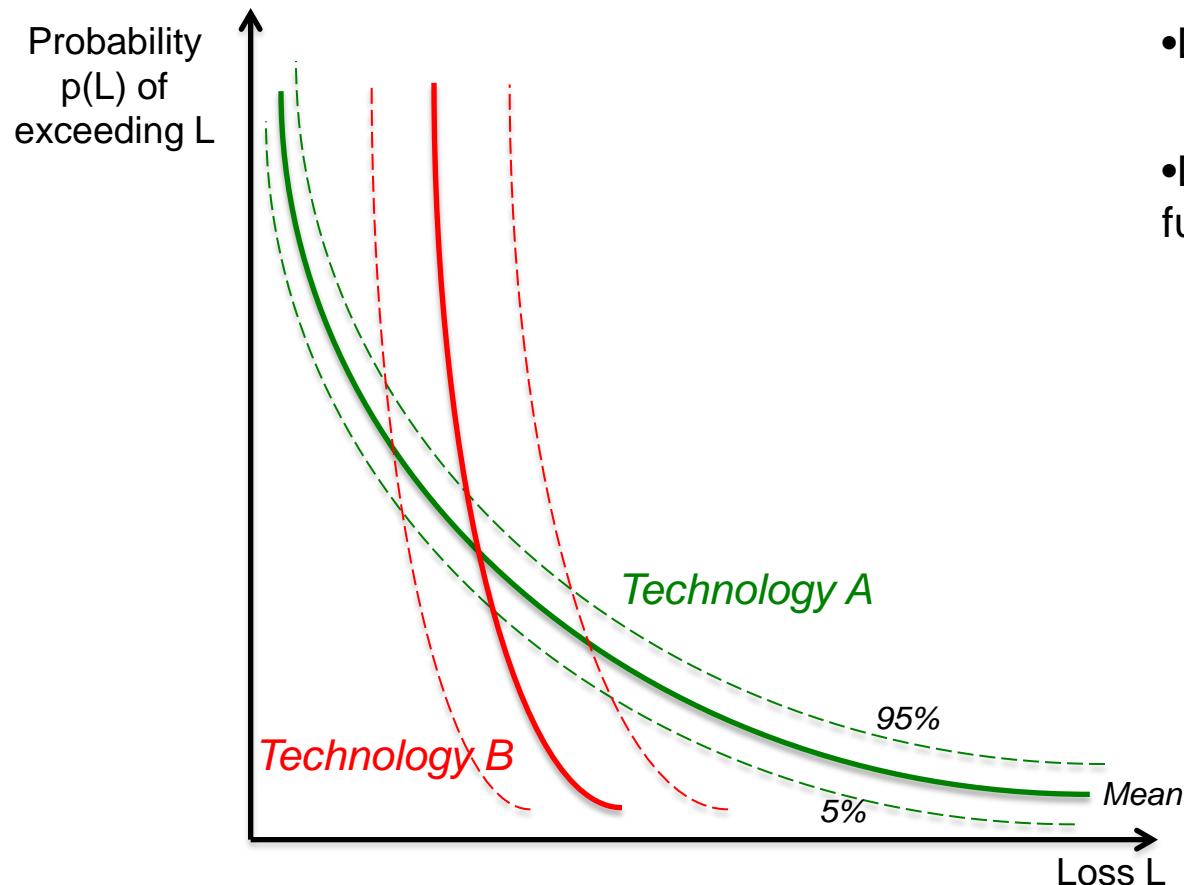
Cross-technology risk tradeoffs



Evidence and confidence:

- Decades of historic data
(e.g. gas plants)

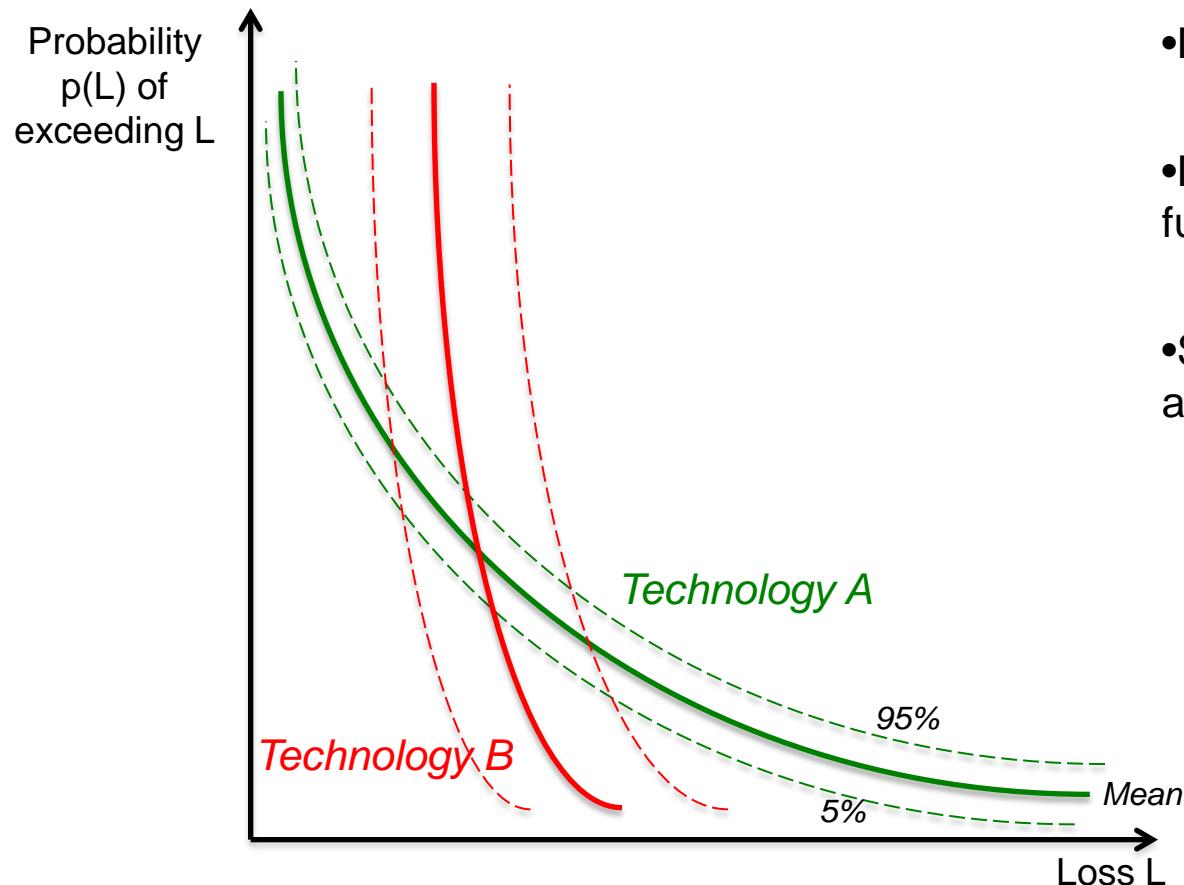
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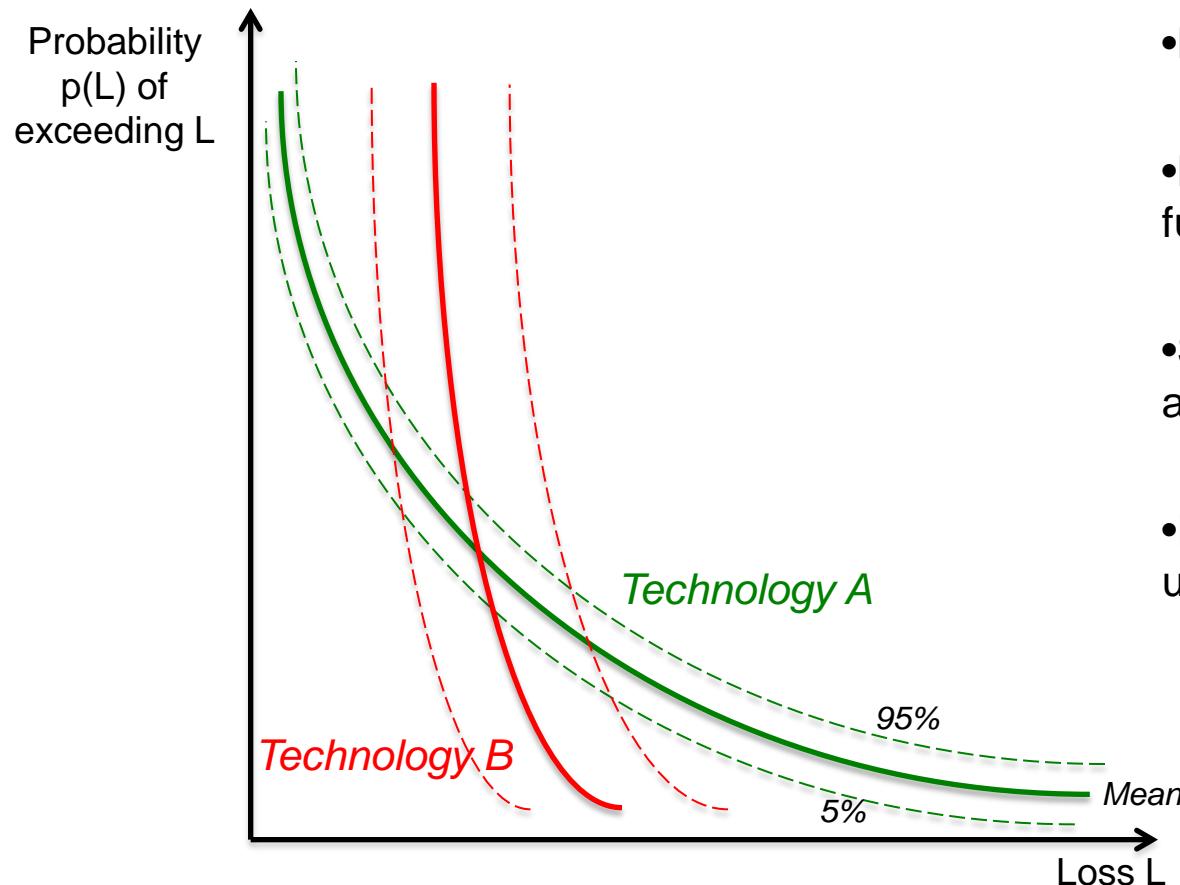
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Cross-technology risk tradeoffs



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- Decades of historic data, but future uncertainty
(e.g. hydropower under climate change)
- Several low probability events and probabilistic modeling
(e.g. nuclear)
- Emerging risks with deep uncertainties
(e.g. geothermal)

Aims of the RIGOROUS project

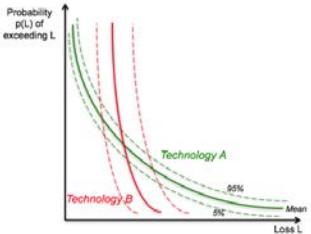


- Map cross-technology and spatial **risk tradeoffs** to human health, safety, natural and built environment posed by the whole Swiss **electricity portfolio**

Aims of the RIGOROUS project



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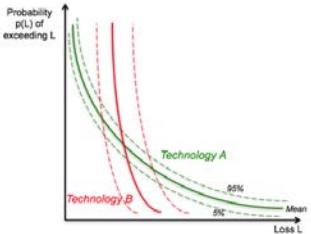


- Take a **more open view to risk**, including known and uncertain probabilities, consequences, and expert confidence

Aims of the RIGOROUS project



- Map cross-technology and spatial **risk tradeoffs** to human health, safety, natural and built environment posed by the whole Swiss **electricity portfolio**



- Take a **more open view to risk**, including known and uncertain probabilities, consequences, and expert confidence



- Using an interactive tool Riskmeter, elicit **public, stakeholder, and expert preferences** for risk tradeoffs

Three studies

- ◆ **Study I:** Modelling electricity generation portfolios for Riskmeter
- ◆ **Study II:** “Strategic listening” to the lay users of Riskmeter
- ◆ **Study III:** Empirically testing how laypeople interpret risk information

Study I: Background

- ◆ What are the alternative Swiss electricity generation portfolios in 2035 to choose from in Riskmeter?

Study I: Background

- ◆ What are the alternative Swiss electricity generation portfolios in 2035 to choose from in Riskmeter?
- ◆ Do existing Swiss scenarios cover a vast enough range of alternatives?

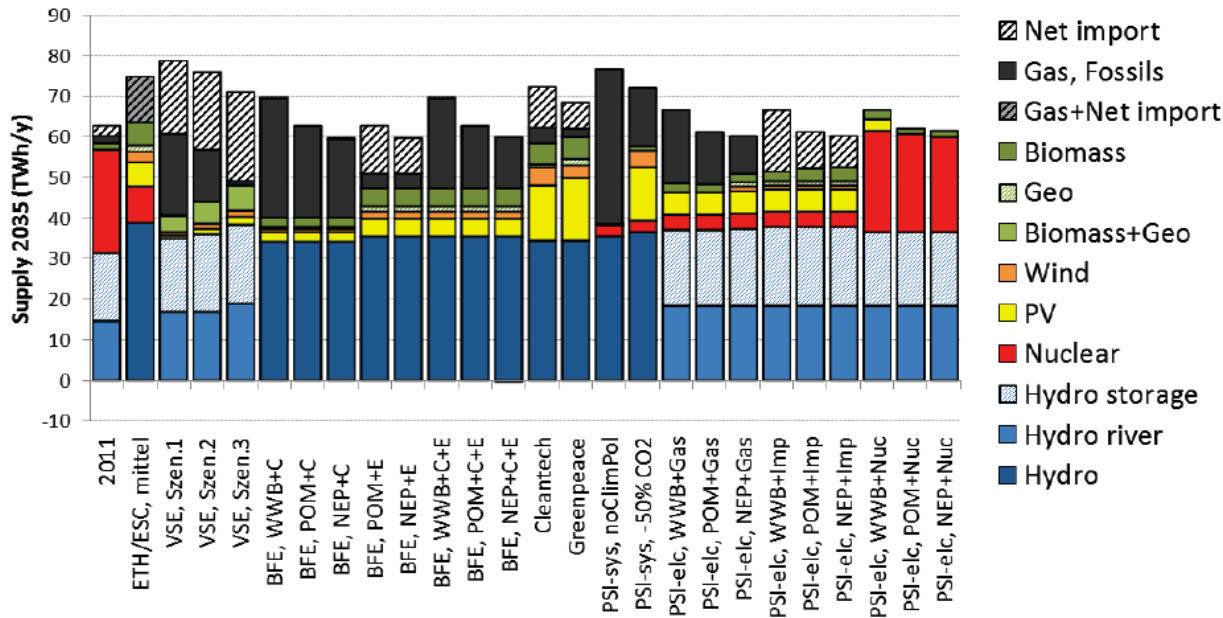


Figure: Densing et al. (2014)

Study I: Method

EXPANSE model

(EXploration of PAtterns in Near-optimal energy ScEnarios)

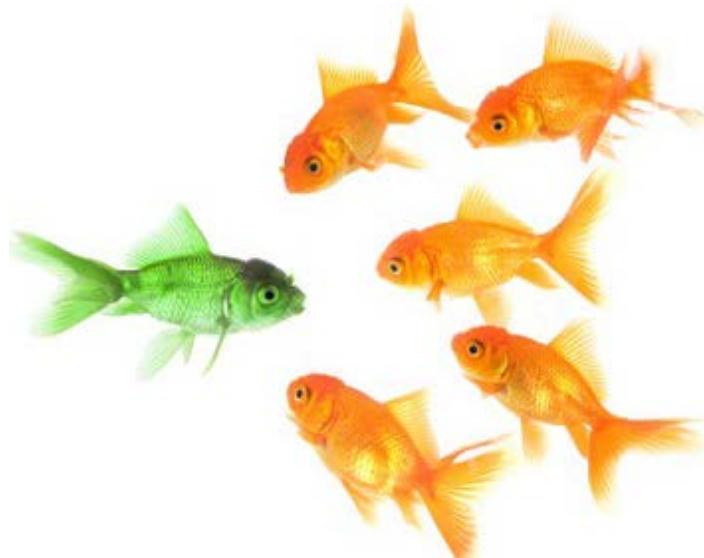
- ◆ Bottom-up, technology-rich energy system model

Study I: Method

EXPANSE model

(EXploration of PAtterns in Near-optimal energy ScEnarios)

- ◆ Bottom-up, technology-rich energy system model
- ◆ Near-optimal scenarios / Modelling to Generate Alternatives (MGA)
new!
- ◆ [Monte Carlo technique for parametric uncertainty]



Study I: Results

Why Modelling to Generate Alternatives (MGA) or near-optimal scenarios?

Retrospective modelling of the UK electricity supply (1990-2014):

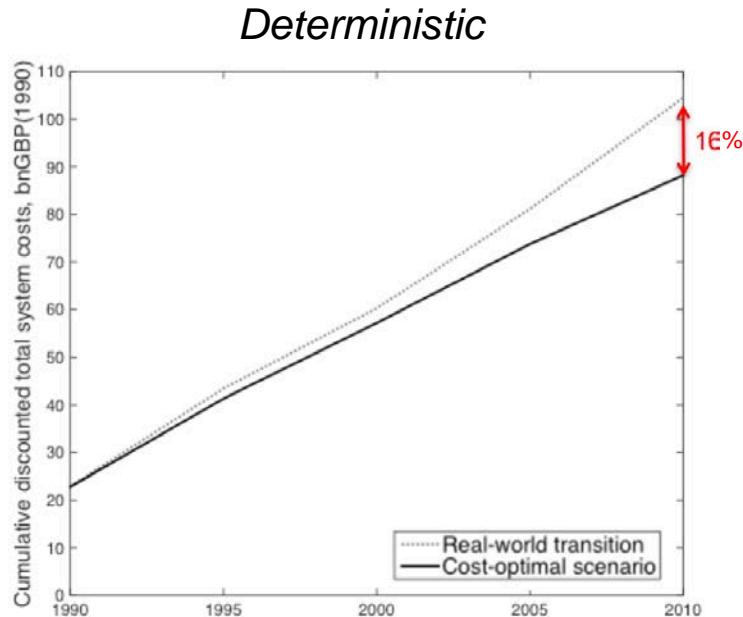
- Model generation mix, when demand is given exogenously
- Data on actual demand, plant retirement, technology costs etc.

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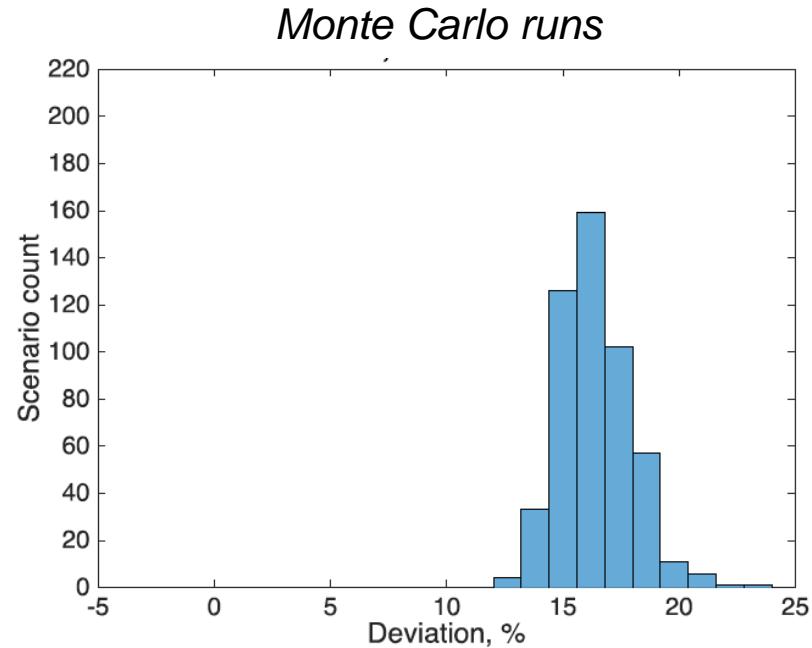
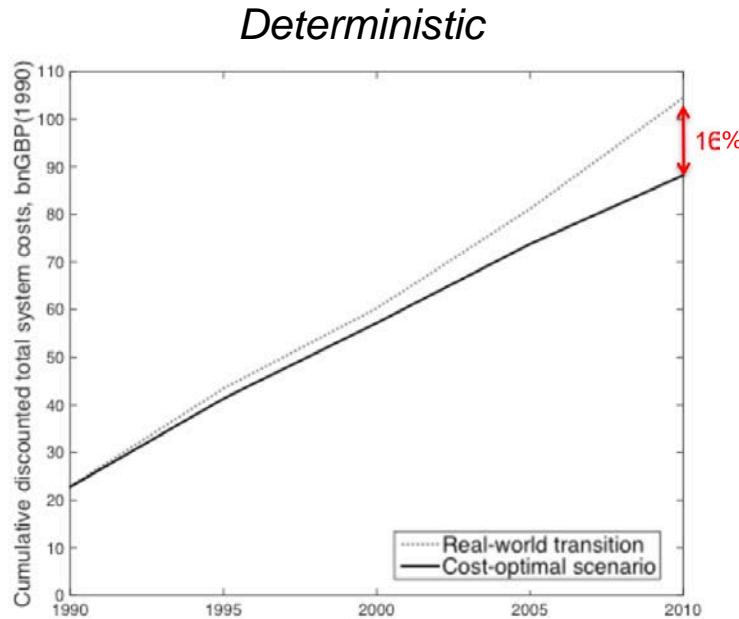


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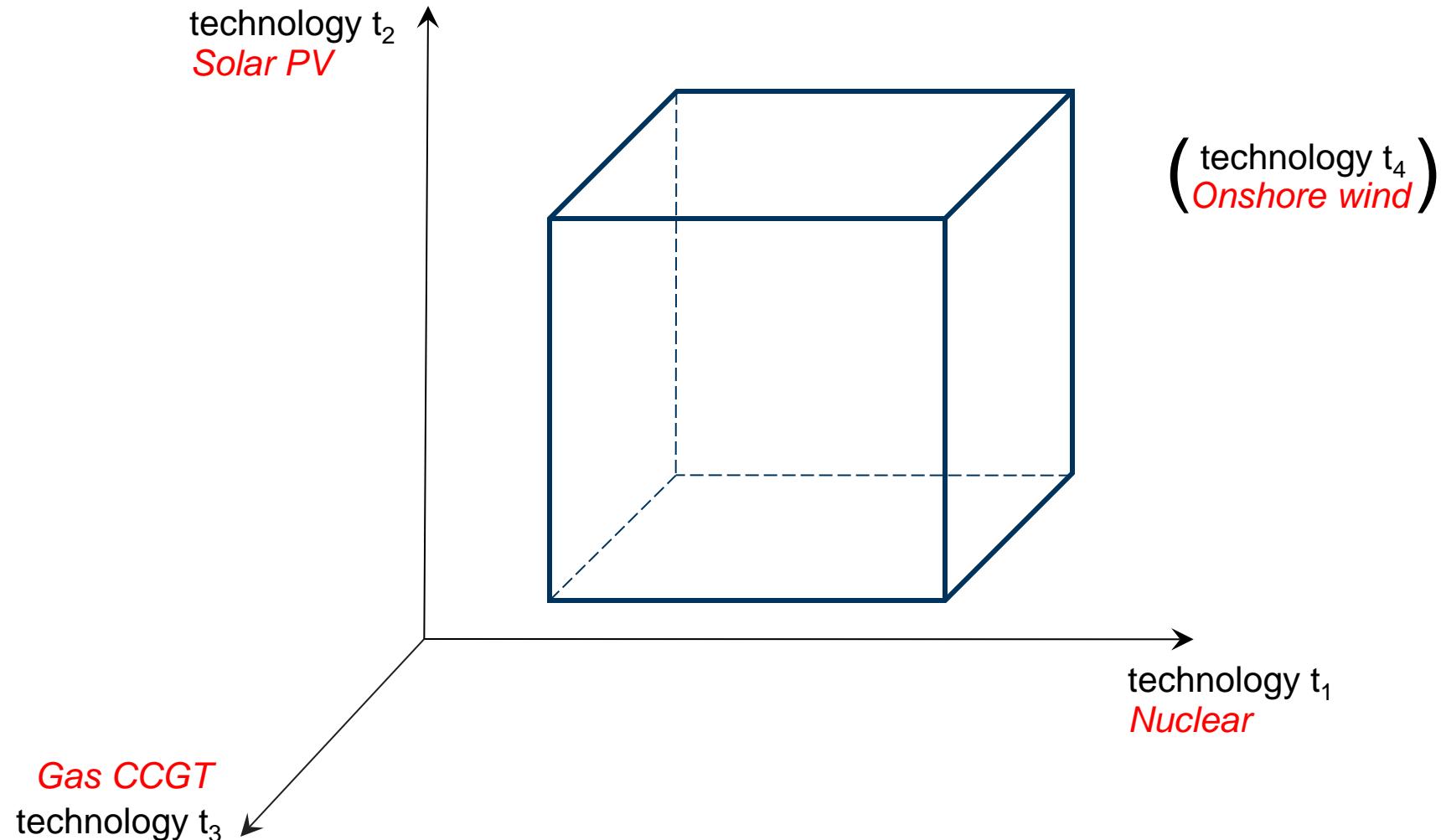
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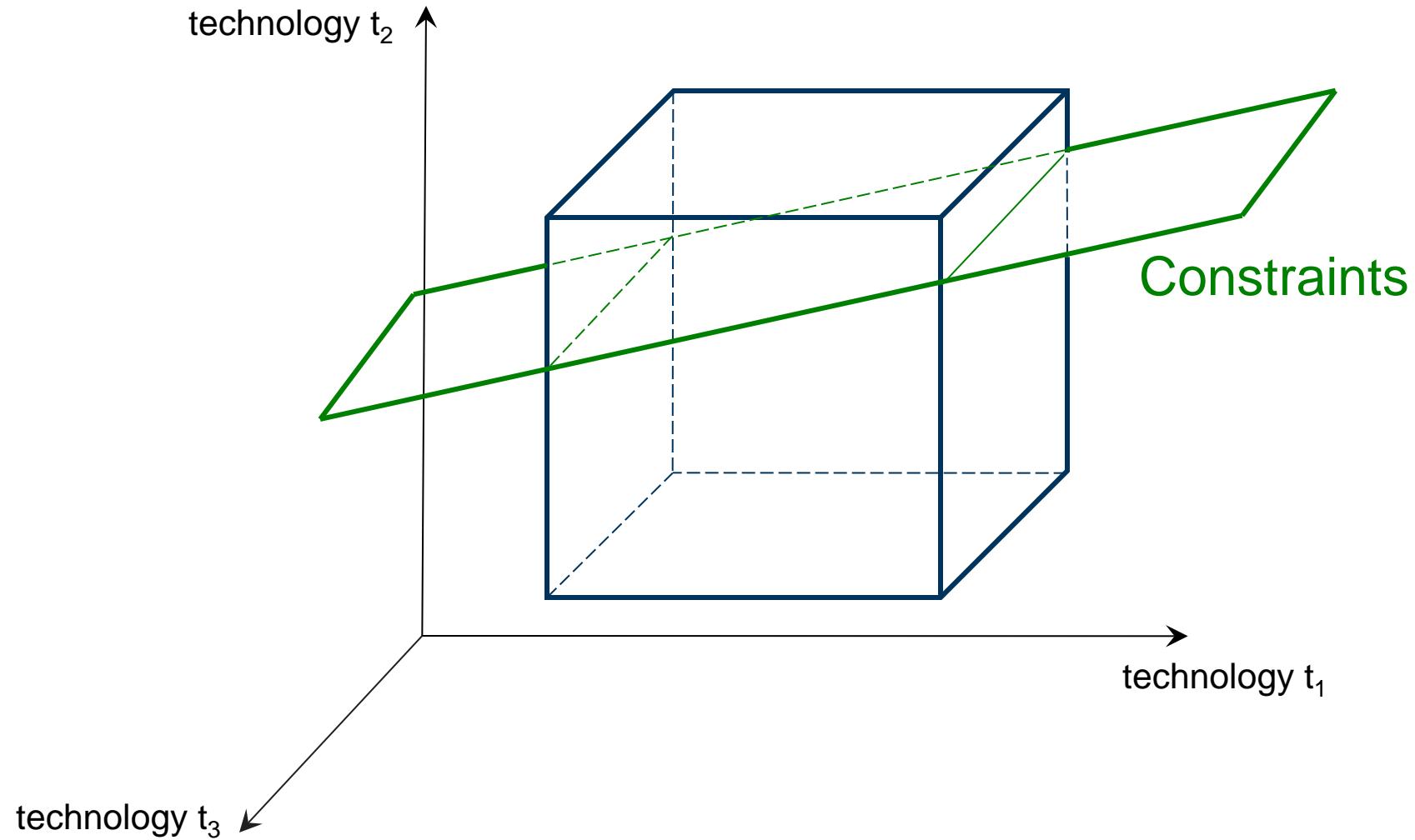
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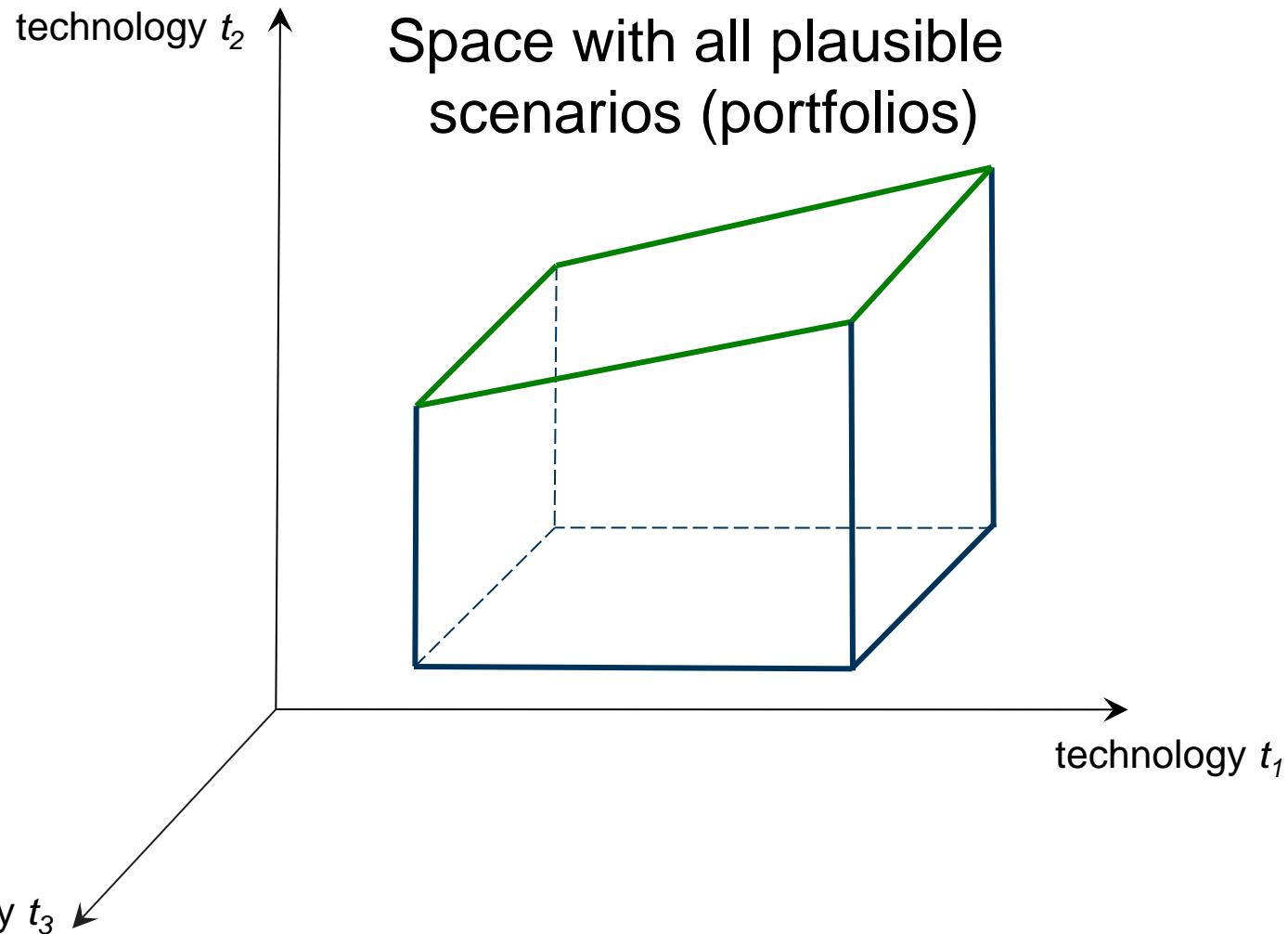
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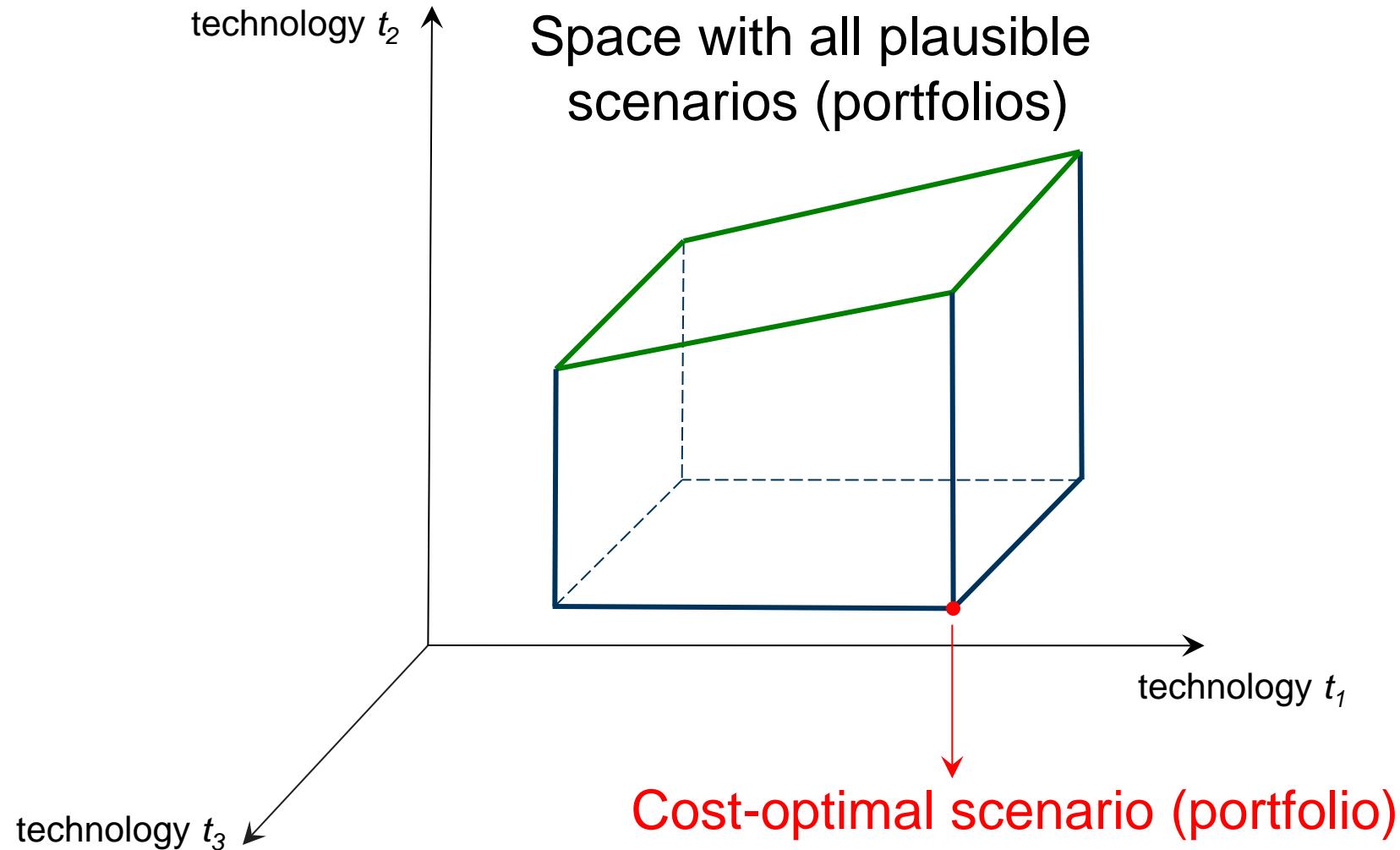
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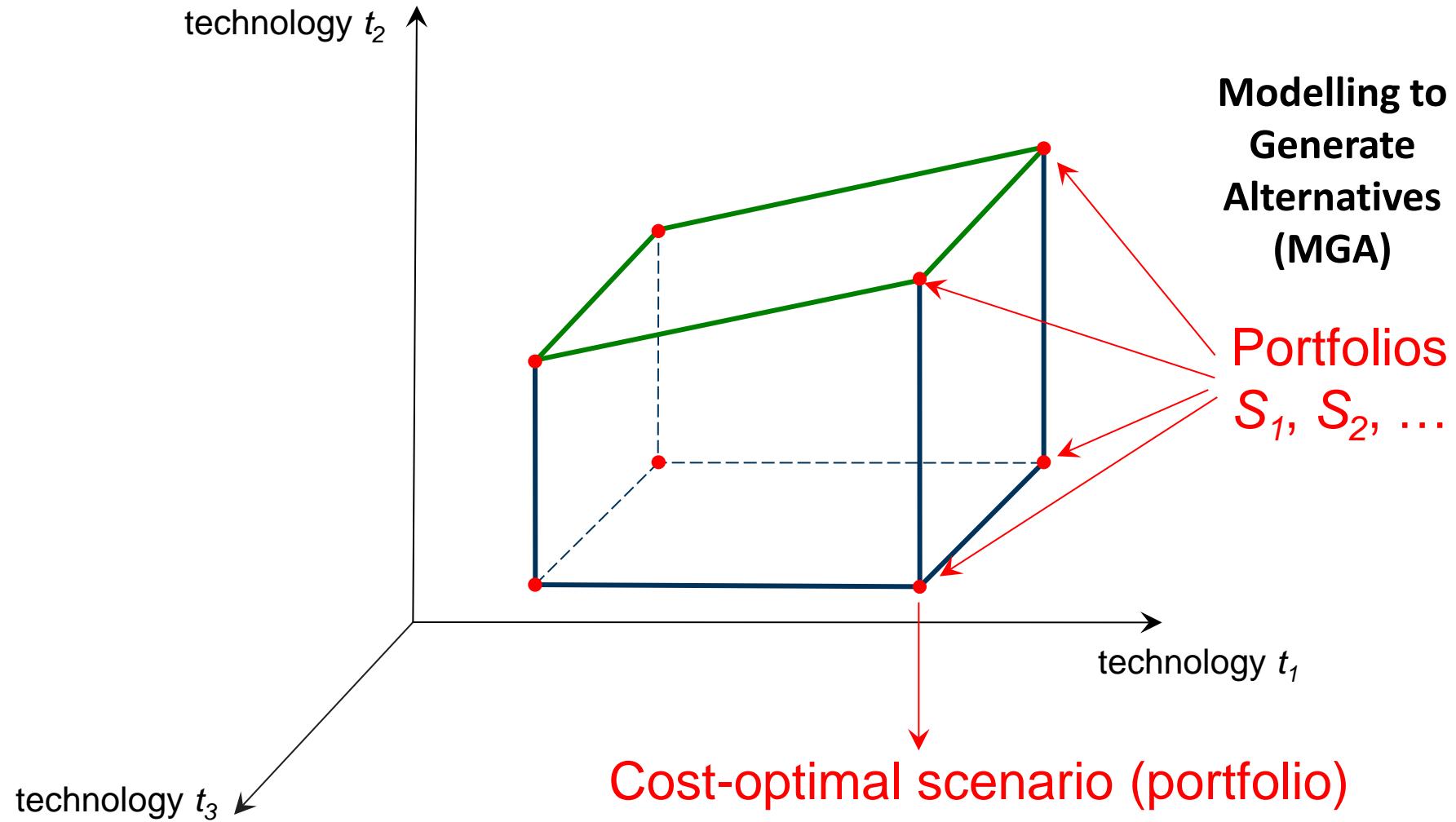
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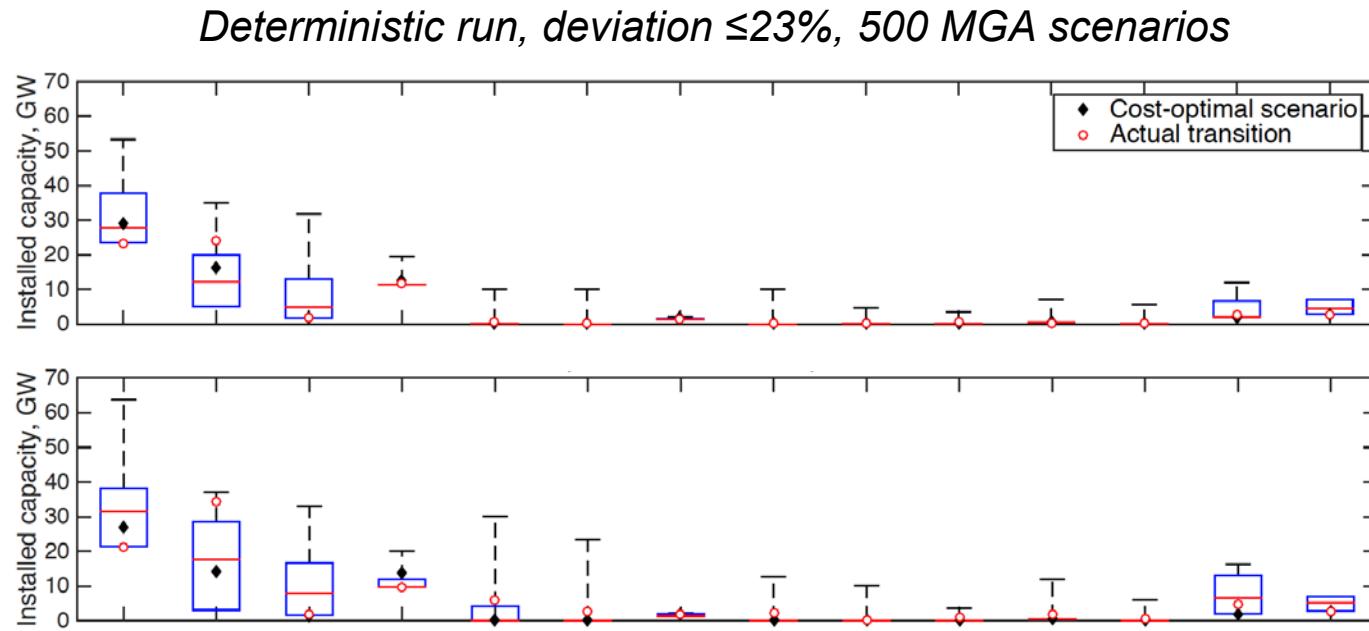
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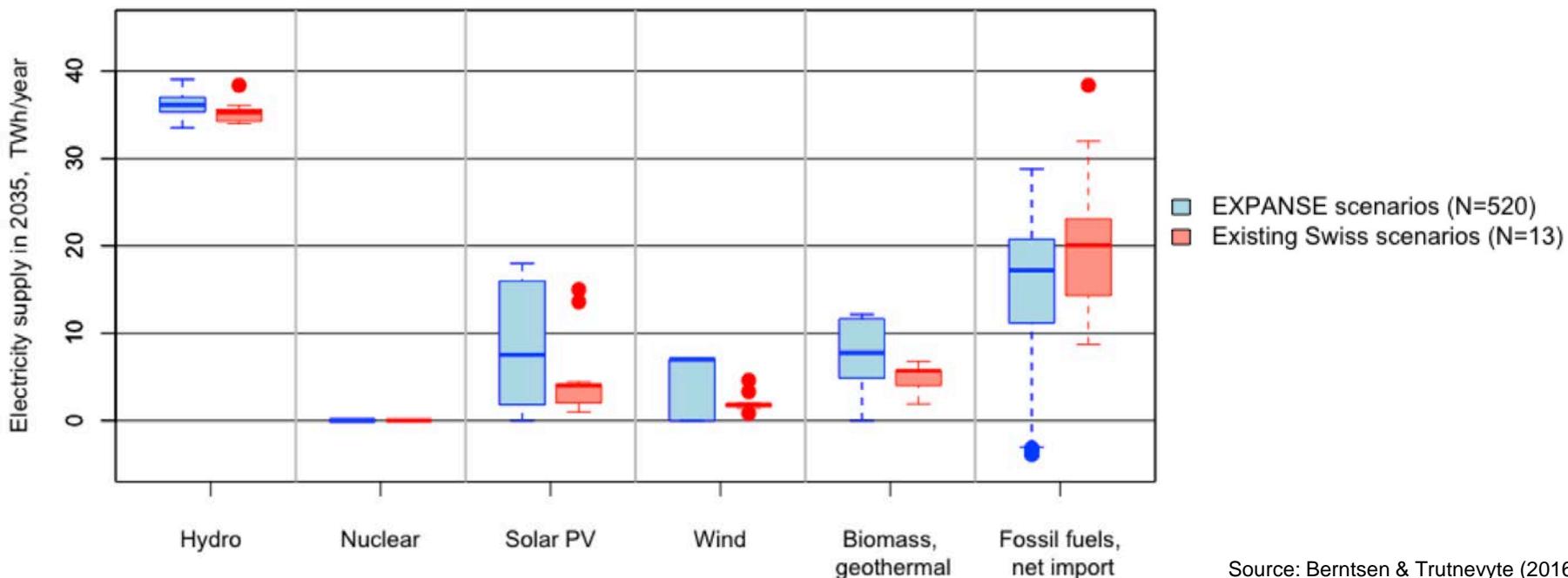
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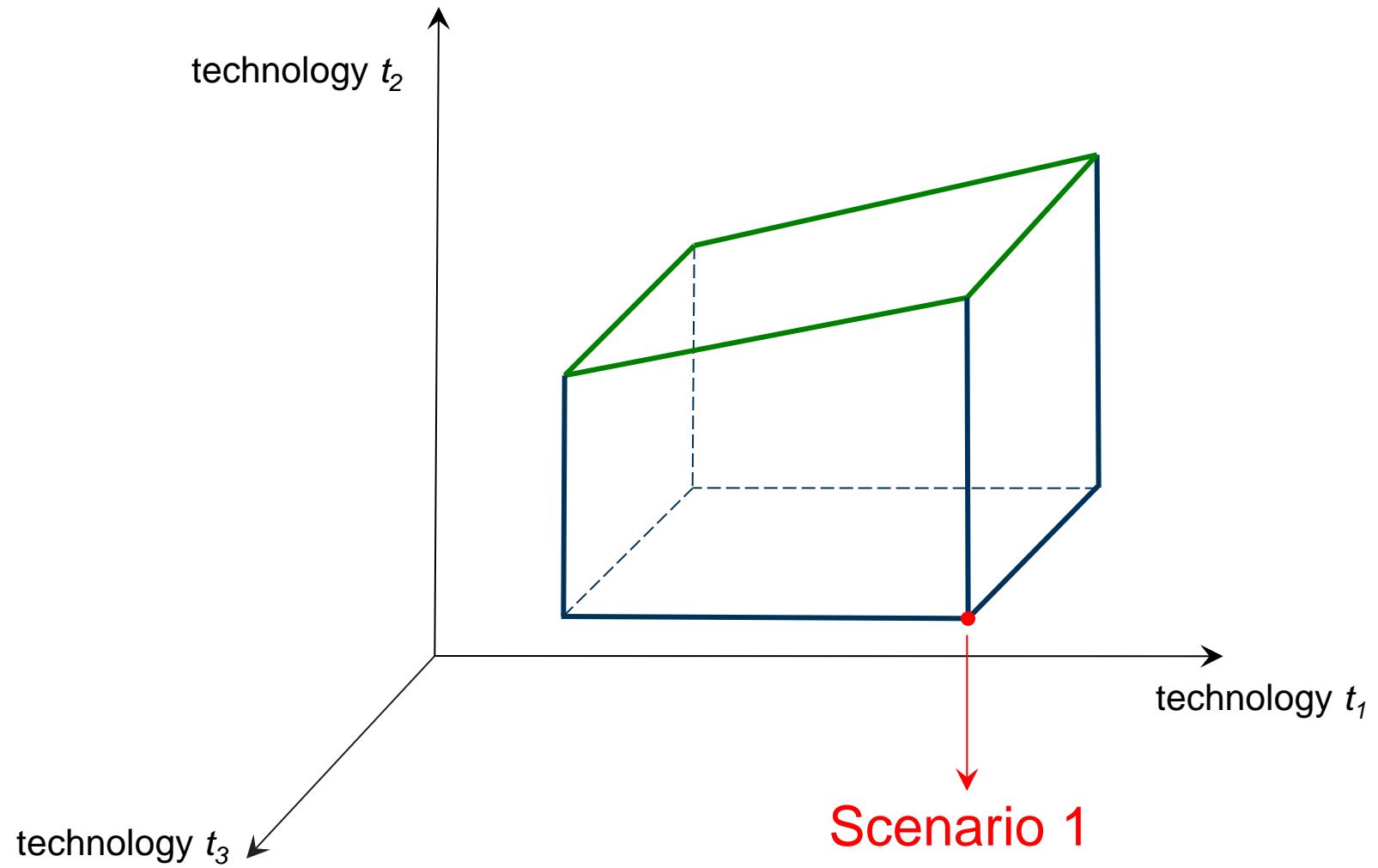


Study I: Results

Swiss EXPANSE model:

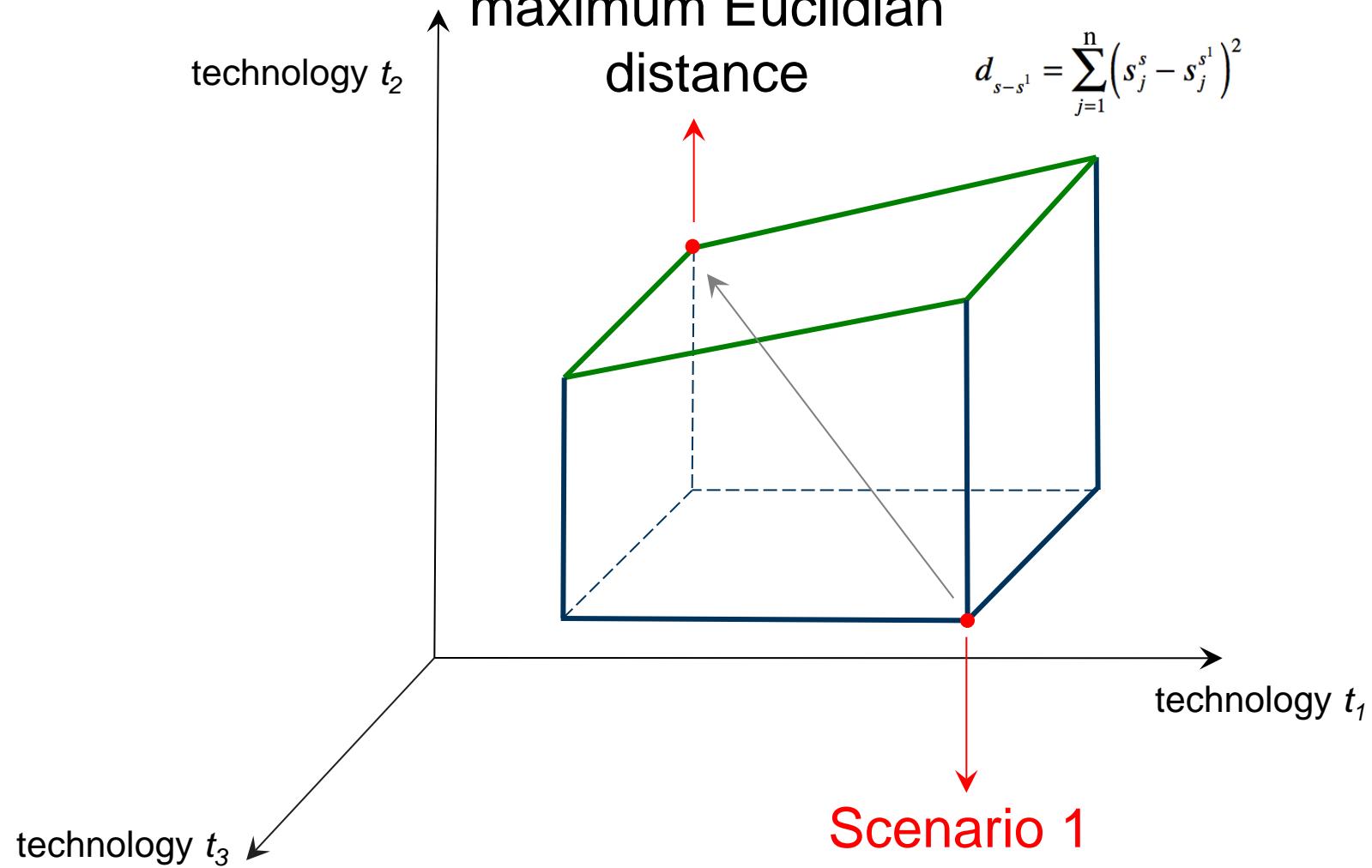
- 2015, 2035, 2050
- Electricity generation portfolio only, 1-hour dispatch
- Exogenously given demand (13 existing demand assumptions)
- Technical feasibility constraints only, no cost constraints or objectives
- 520 portfolios generated in total (40 MGA x 13 demand assumptions)





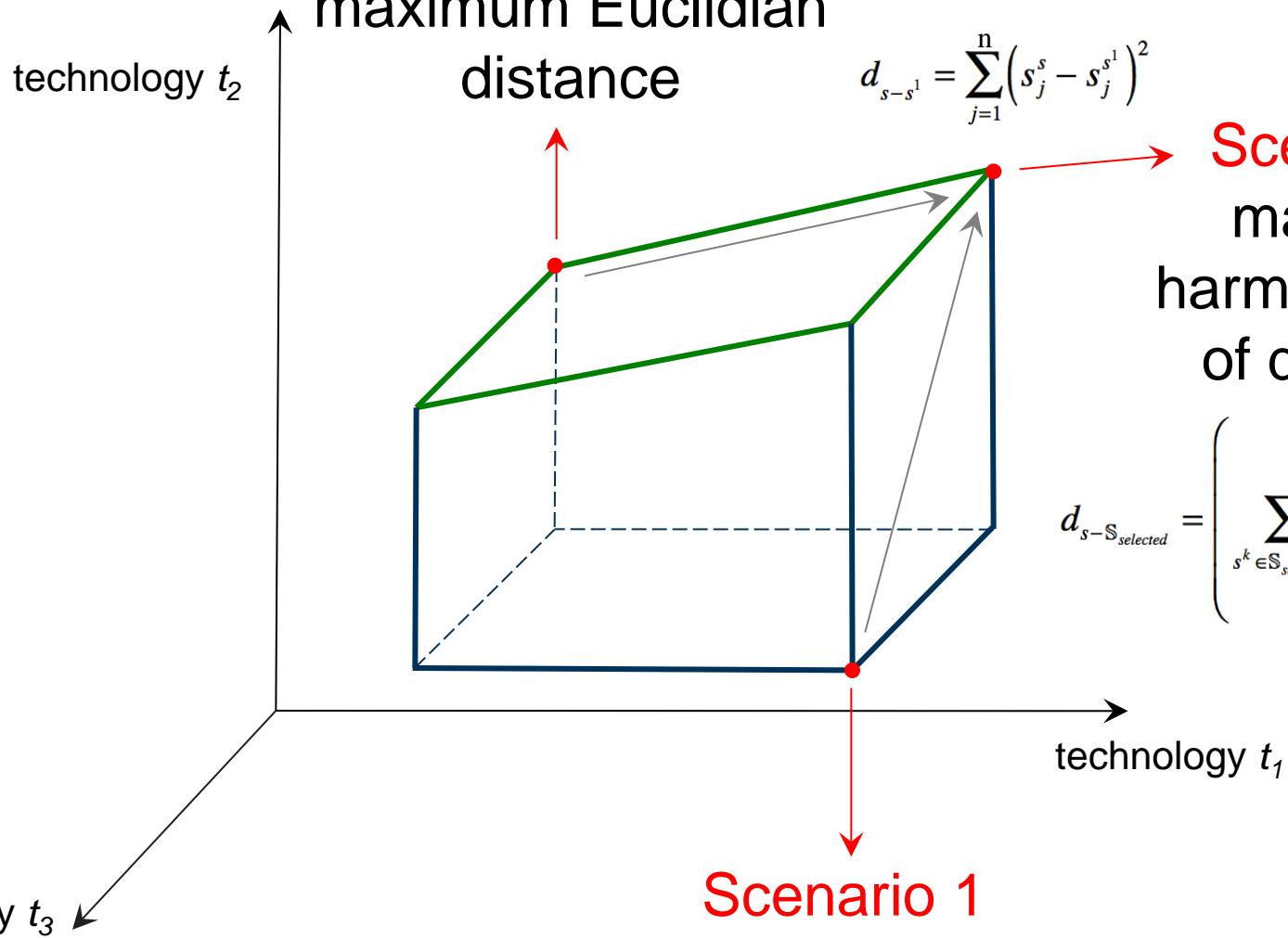
Scenario 2: maximum Euclidian distance

$$d_{s-s^1} = \sum_{j=1}^n (s_j^s - s_j^{s^1})^2$$



Scenario 1

Scenario 2: maximum Euclidian distance



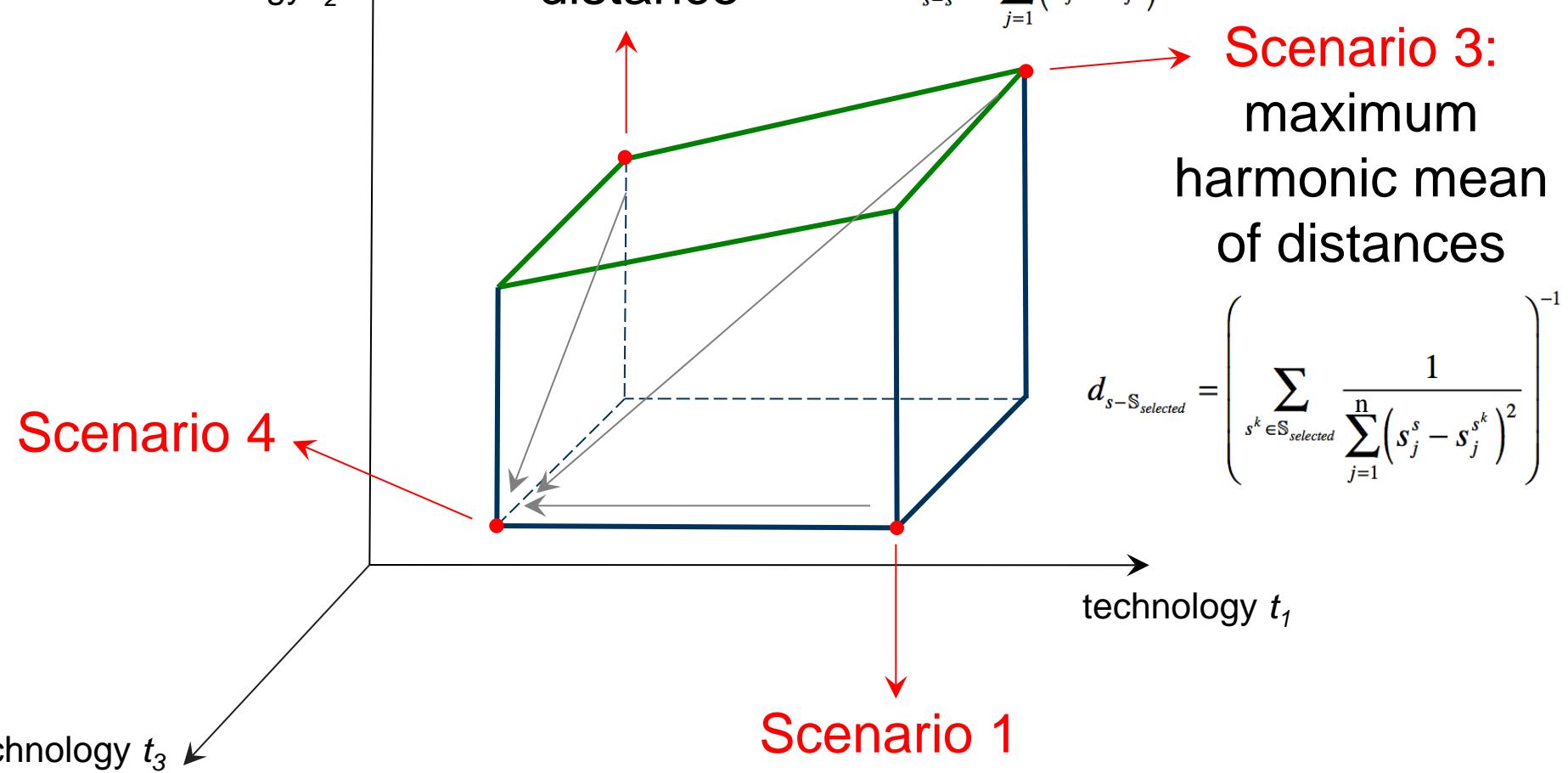
$$d_{s-s^1} = \sum_{j=1}^n (s_j^s - s_j^{s^1})^2$$

Scenario 3: maximum harmonic mean of distances

$$d_{s-\mathbb{S}_{selected}} = \left(\sum_{s^k \in \mathbb{S}_{selected}} \frac{1}{\sum_{j=1}^n (s_j^s - s_j^{s^k})^2} \right)^{-1}$$

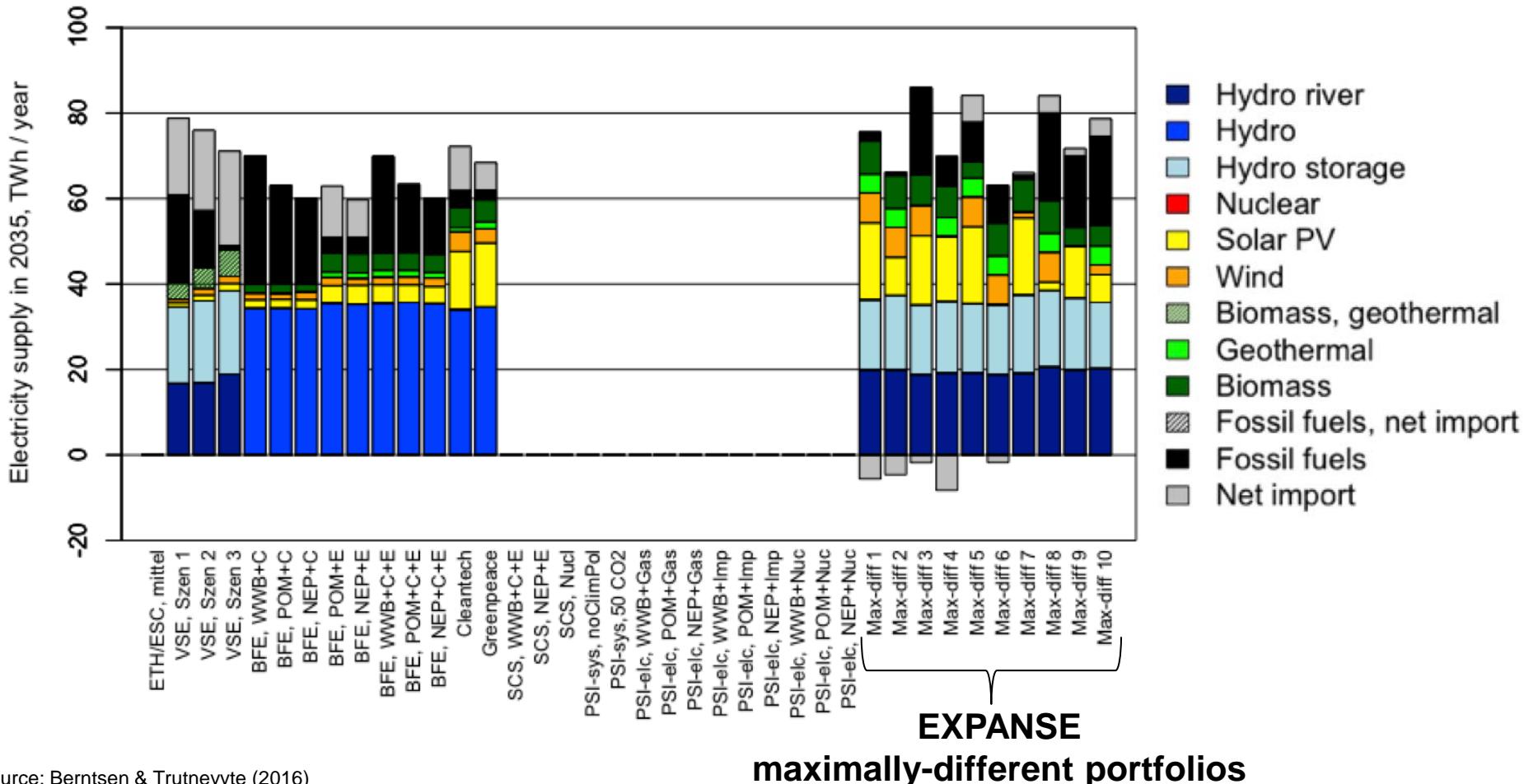
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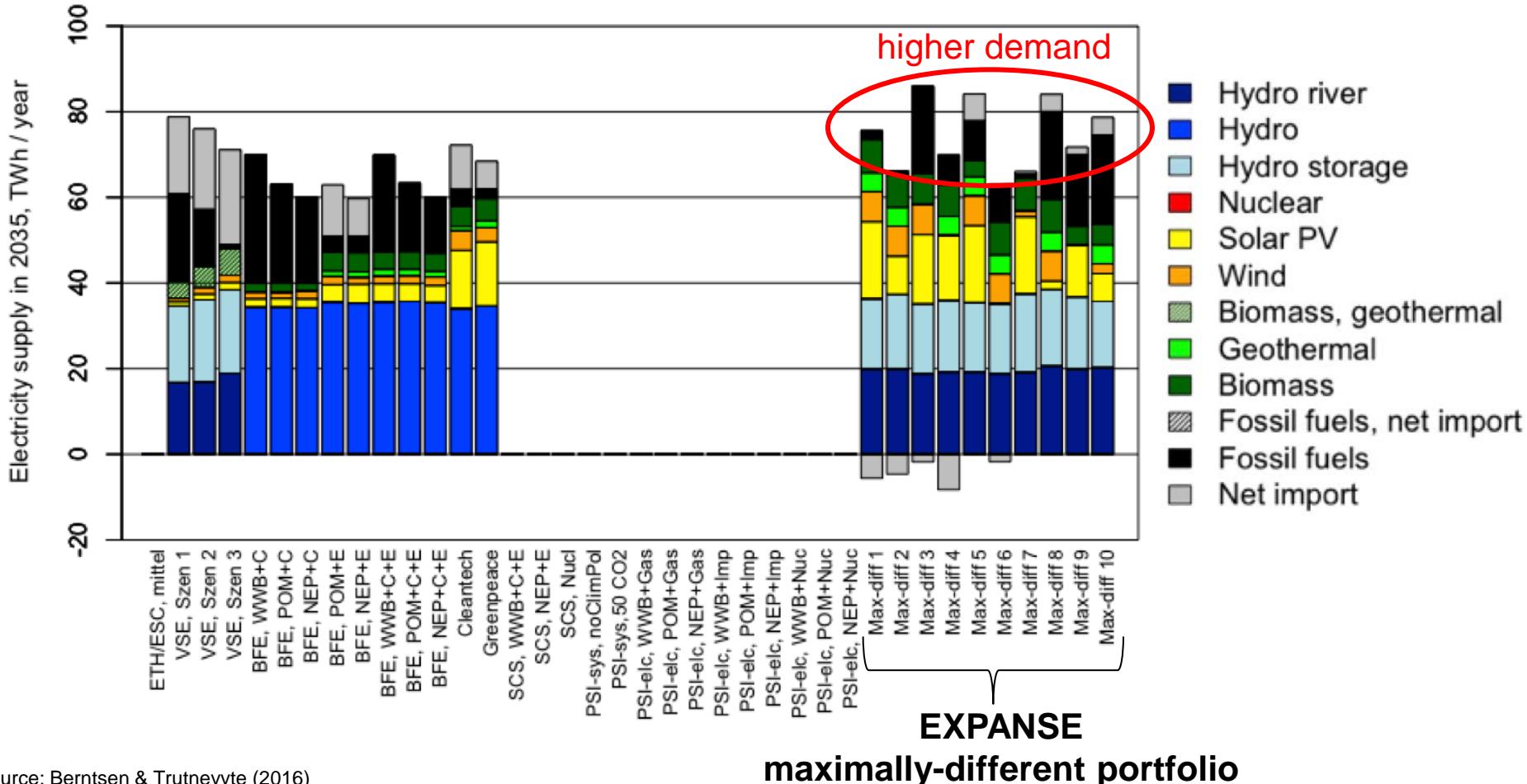
Study I: Results

EXPANSE portfolios that are maximally different from the existing Swiss scenarios



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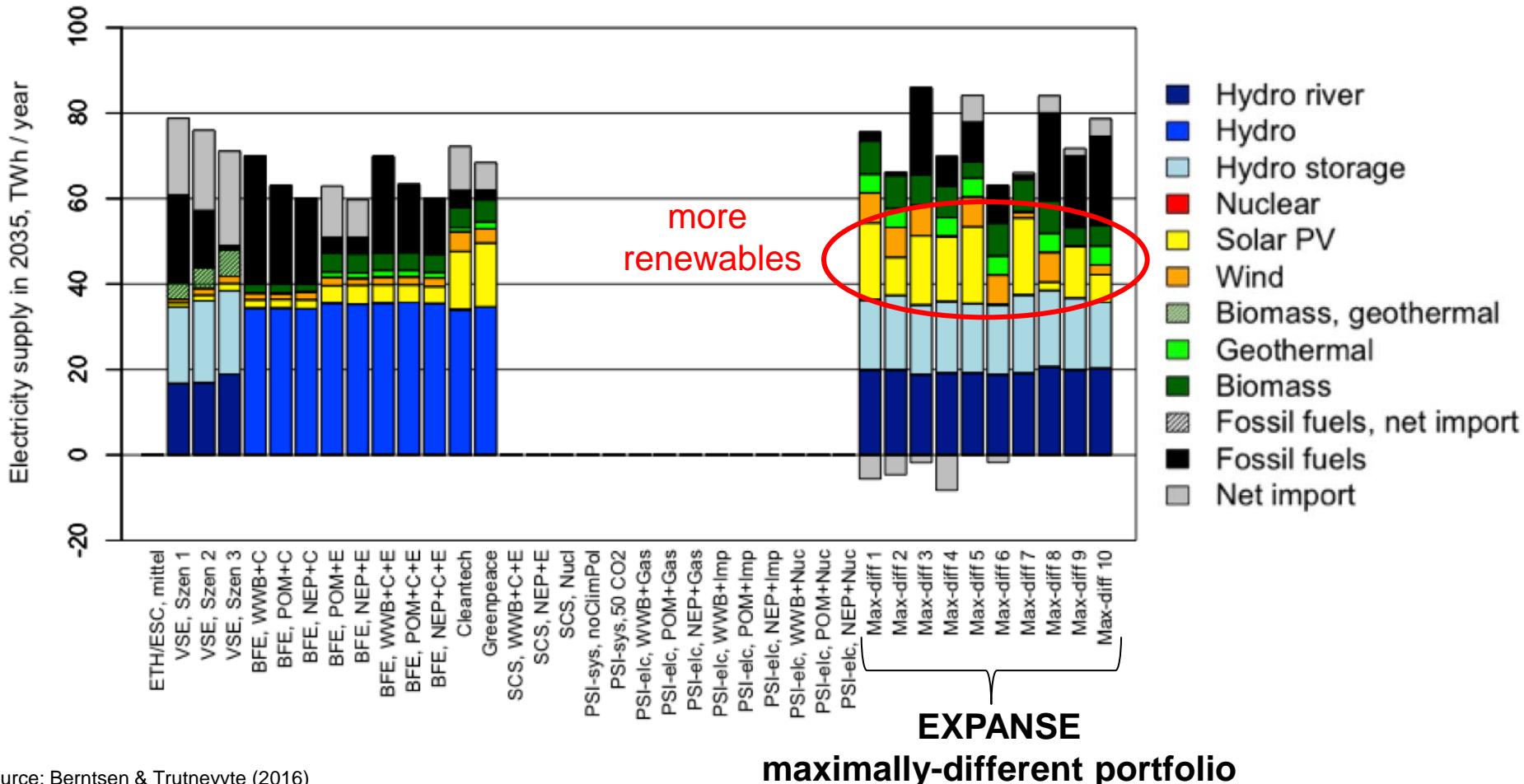
EXPANSE portfolios that are maximally different from the existing Swiss scenarios



Source: Berntsen & Trutnevyyte (2016)

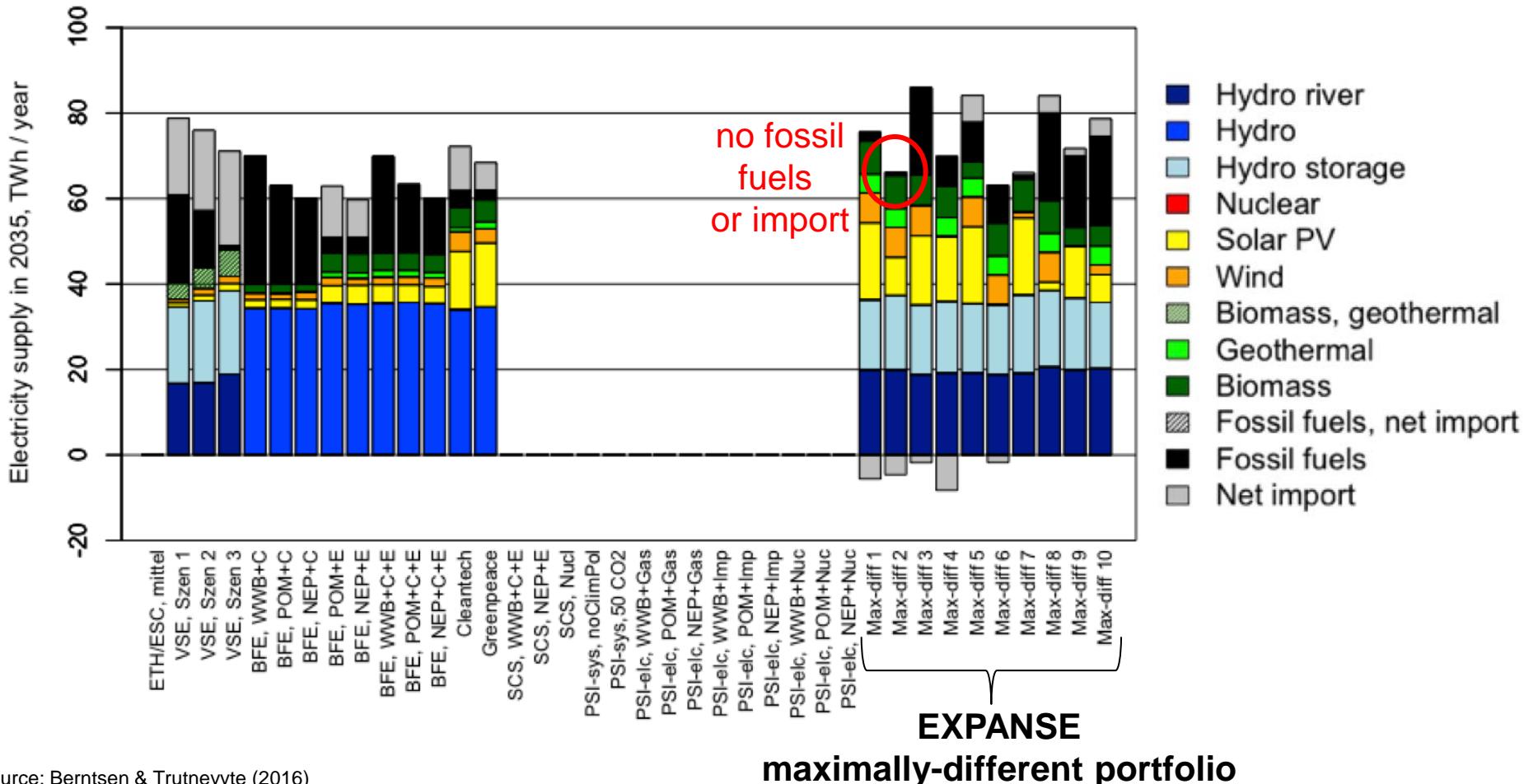
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Study I: Summary

- ◆ MGA-based EXPANSE covers various existing perspectives in Switzerland, including Swiss Federal Office of Energy, ETH Zurich, or Greenpeace
- ◆ Several perspectives were underrepresented in existing scenarios, especially the combinations of:
 - high demand and high renewables simultaneously
 - very low fossil fuel-based generation and low import simultaneously

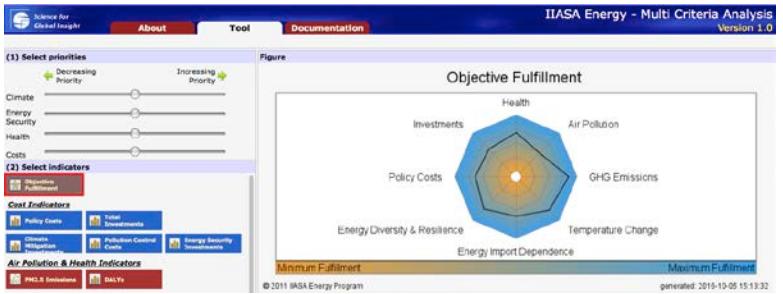
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Study II: Background

- ◆ How could the “usability gap” to the intended users of Riskmeter be closed?

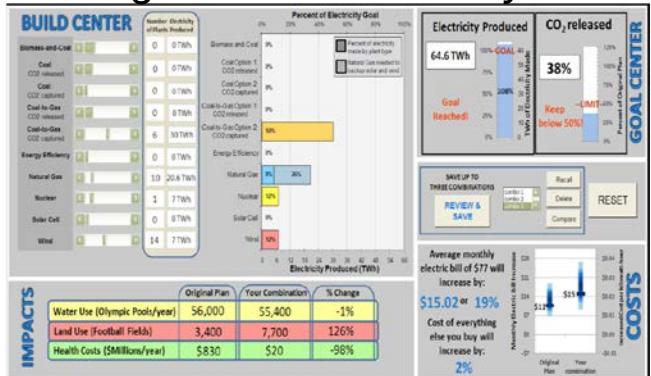
IIASA Multi-Criteria Analysis tool



UK DECC 2050 Calculator



Carnegie Mellon University's tool



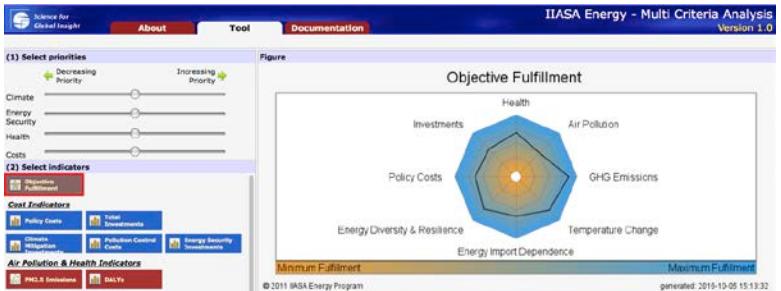
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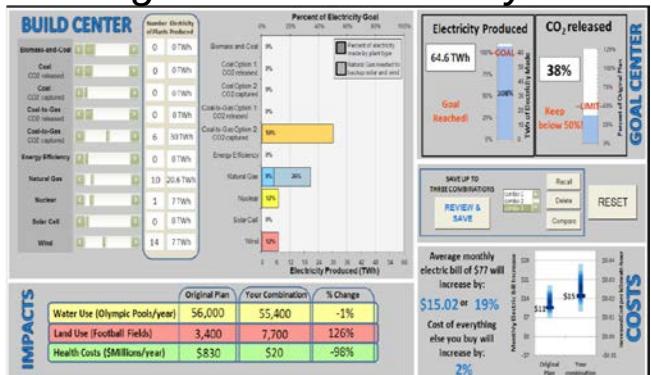
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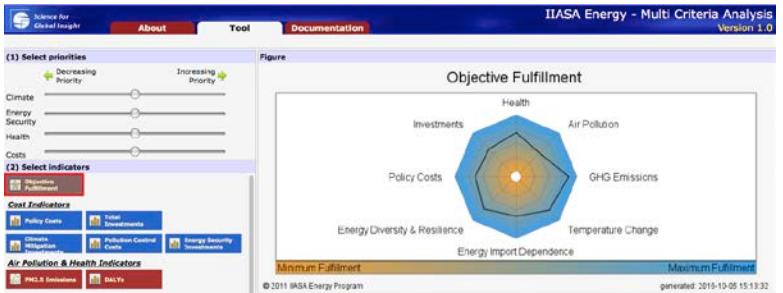
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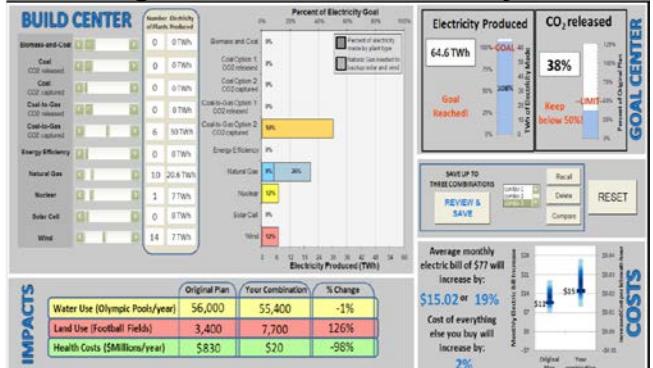
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Study II: Method

- ◆ 12 semi-structured laypeople interviews
- ◆ Interviewees of different age, gender, education, rural/urban groups
- ◆ Transcribed and coded for analysis

**Familiarity
with the
energy topic**

**Knowledge
and
awareness of
power plants**

**Knowledge
and
awareness of
risks**

**Trust,
concern,
acceptance
and trade-offs**

Study II: Results

First thoughts about the topic?



[ID_1] "Ehm, **Wasserkraft**....weil das ist... fach sympathischer als **Atomkraft**, **hydropower**"

[ID_10] "Unsere **Wasserkraftwerke**...Und an **Solar** denke ich...und dass es **lebenswichtig** ist."

[ID_4] "Ehm, die ganze Geschichte mit den **Atomkraftwerken**...nicht so dafür, dass man diese weiter laufen lassen", **hydropower**

[ID_9] „**Wasserkraft**...wird ja diskutiert. Also **Atomkraftwerke**, ja, nein? Ehm, beziehungsweise Alternativen. **Klimaerwärmung**....**Fukushima**..."



[ID_6] "Kühlturm und **Wasser**..."

[ID_7] „**Wasserkraftwerke**...Der **Umwelt** also wie, in der **Zukunft**, man das handhaben soll. Wie der **Konsum** zunimmt, wie man ihn decken kann.“



[ID_8] „Ja gut. Jetzt denke ich an die vielen. weißt du, die auf den Dächern sind. (Das) denke ich sei noch etwas gutes. **Solar**. ...Und das andere sind da diese **Atomkraftwerke**, die einem halt nicht gefallen.“

Study II: Results

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[ID_10] "Unsere **Wasserkraftwerke**...Und an **Solar** denke ich... **nuclear** **lebenswichtig** ist."

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nuclear”



[ID_6] “**Kühlturm und Wasser**...”

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[ID_8] „Ja gut. Jetzt denke ich an die vielen. weißt du, die auf den Dächern sind. (Das) denke ich sei noch etwas gutes. **Solar**. ...Und das andere sind da diese **Atomkraftwerke**, die einem halt nicht gefallen.“



Study II: Results

First thoughts about the topic?

-
- [ID_1] "Ehm, **Wasserkraft**....weil das ist... fach sympathischer als **Atomkraft**, **hydropower**"
- [ID_10] "Unsere **Wasserkraftwerke**...Und an **Solar** denke ich... **nuclear** **hydropower** **lebenswichtig** ist."
- [ID_4] "Ende die ganze Geschichte mit **Atomkraftwerken**. Weil... nicht so dafür, dass man diese weiter laufen. **hydropower**"
- [ID_9] „**Wasserkraft**...wird ja diskutiert. Also **Atomkraftwerke**, ja, nein? Ehm, beziehungsweise Alternativen. **Klimaerwärmung**....**Fukushima**... **nuclear** **nuclear** **nuclear** **hydropower** **solar**"
- [ID_6] "Kühlturm und **Wasser**..." **hydropower**
- [ID_7] „**Wasserkraftwerke**...Der... also wie, in der **Zukunft**, man das handhaben soll. Wie der **Konsum** zunimmt, wie man ihn decken kann.” **solar**
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Study II: Results

First thoughts about the topic?



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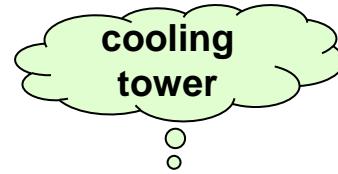
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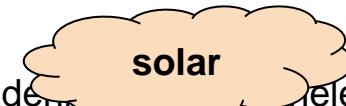
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nuclear **climate change** **nuclear**



[ID_6] "Kühlturm und **Wasser**..."



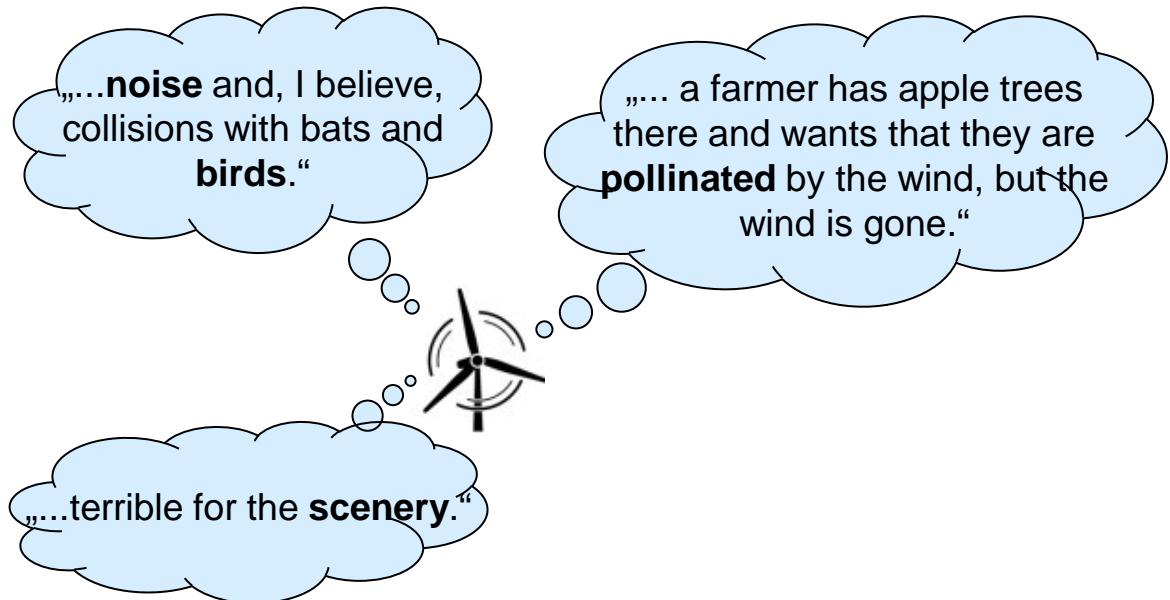
aftwerke...Der **Umwelt** Zukunft, man das handhaben soll. Wie der **Konsüm** zunimmt, wie man ihn decken kann."



[ID_8] „Ja gut. Jetzt denken wir mal wieder. weißt du, die auf den Dächern sind. (Das) denke ich sei noch etwas gutes. **Solar**. ...Und das andere sind da diese **Atomkraftwerke**, die einem halt nicht gefallen.“



Study II: Results



Study II: Results

„...**noise** and, I believe, collisions with bats and birds.“

„.... a farmer has apple trees there and wants that they are **pollinated** by the wind, but the wind is gone.“

„Clear, it is not nice to **look at**. It spoils the building a little.“

„...terrible for the **scenery**.“



„.... I am not a fan of them, because I do not know... when they are not working anymore, how do you **dispose** them.“



Study II: Results

„...noise and, I believe, collisions with bats and birds.“

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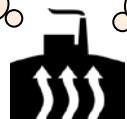
„...terrible for the **scenery**.“

„.... I am not a fan of them, because I do not know... when they are not working anymore, how do you **dispose** them.“



„.... they had to stop somewhere because the buildings got **cracks**.“

„The heat is extracted from the ground. And then one day there are **no more trees**.“



„It is apparently terribly **noisy**.“

„.... yes, it could lead to a small **vulcanic eruption**.“

Study II: Results

„...noise and, I believe, collisions with bats and birds.“



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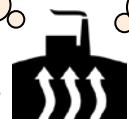
„Fish... and all the aquatic animals.“

„.... they had to stop somewhere because the buildings got **cracks**.“

„The heat is extracted from the ground. And then one day there are **no more trees**.“

„Mattmark, such a **catastrophe**...“

„It is apparently terribly **noisy**.“



„.... yes, it could lead to a small **vulcanic eruption**.“

„One could **blow up** the dam. Imagine, when such a lake spills.“

Study II: Results

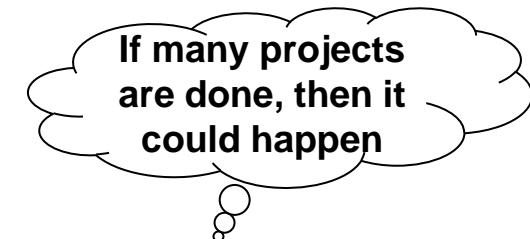
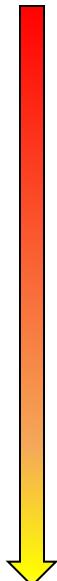
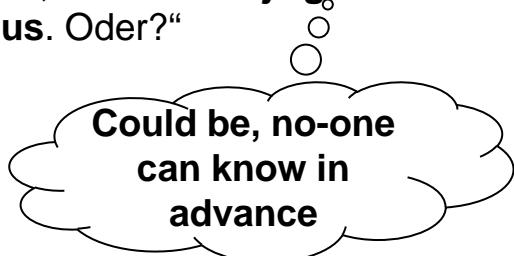
How likely do you think it is that deep geothermal projects induce earthquakes?



100 %

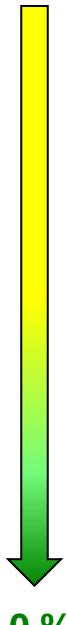
[ID_4 – 01:02:13] „Also ich bin **ganz sicher**, dass es wieder gibt...An sehr **vielen Orten** wo sie gebohrt haben, hat es nachher Erdbeben gegeben.“

[ID_10 – 00:45:30] „Das **kann sein**, ja. Klar. Aber ob. Das weiss niemand oder. Oder weiss das jemand? Was dort unten passiert? Was man da auslöst, ...**das kann ja gar niemand wissen im Voraus**. Oder?“



[ID_8 – 00:45:45] „Dass es der Grund dafür. Ja, wenn es zu viel. Ich denke **so ein einzelnes wahrscheinlich schon nicht, aber wenn das zu viel gemacht würde, ja**, dass es irgendwie einmal eine Reaktion käme, ja.“

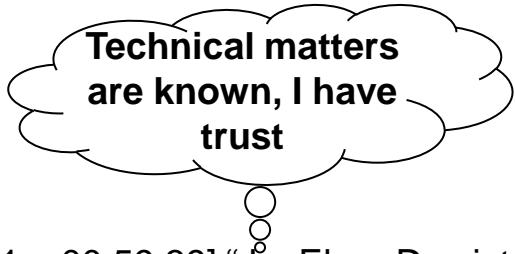
[ID_1 – 00:51:14] “Das ist wahrscheinlich eine Ausnahme gewesen. Weil sonst **hört** man eigentlich nichts von dem. Ich denke es ist **eine Ausnahme** gewesen, weil es einfach dort der Boden sq gewesen ist. Nehme ich an.“



Source: Volken et al. (2016)

Study II: Results

Confidence in experts (example of geothermal)

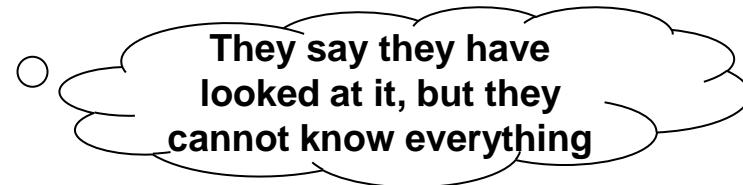


[ID_1 – 00:59:39] „Ja. Ehm. Das ist schwierig. Ich glaube, das verstehen sie sicher besser als ich, aber gefeit vor diesen Gefahren sind sie ja auch nicht. Also jetzt gerade so ein **Terroranschlag**. Das **weiss niemand**. Aber sonst von der Technik her, denke ich, die verstehen das schon. Da habe ich eigentlich noch **Zutrauen**.“

[ID_10 – 00:54:52.9] „Ich meine, wie gesagt, **es gibt nichts dass es nicht gibt**. **Die sagen**, „Ja, nein, wir haben da schon geschaut, dass da unten nichts ist“. **Aber das, wissen die ja nicht alles**. Das glaub ich auch nicht“ „**Wahrscheinlich prüfen sie es schon vorher, aber nichts ist sicher**.“ „...also da (Geothermie) können sie sicher nicht alles wissen.“



„....Also ich denke, gerade diese Sachen, die es **noch nicht so lange** gibt. Wie die ...Geothermie...ich denke, gewisse Sachen sind noch **zu wenig erforscht**. ...Staudämme, die gibt es ja **schon ewig**. Und die werden auch immer wieder **angeschaut und aufgebessert** und verändert...also mehr angeschaut wird oder schon mehr **Erfahrung** gemacht worden ist...“



Study II: Summary

- ◆ Before using the Riskmeter, a much more basic information to the lay users is needed

Study II: Summary

- ◆ Before using the Riskmeter, a much more basic information to the lay users is needed
- ◆ We are thus choosing the approach of technology fact sheets (under development)

DRUG FACTS
ABILIFY (aripiprazole) for adults with major depression that persists on antidepressants

What is this drug for? To reduce symptoms of major depression—nearly everyday feelings of extreme sadness, or hopelessness.

Who might consider taking it? Adults with major depression that persists after one or more 8-week courses of an anti-depressant.

How long has the drug been used? First approved in 2002 for schizophrenia; in 2007 for persistent depression (based on studies of about 1,000 people). As with all drugs, rare but serious side effects may emerge when more people use it for a new purpose.

What precautions should I take? Use caution driving or operating machinery because ABILIFY may impair judgment, thinking or motor skills. Do not drink alcohol or breastfeed. Check blood tests if you've had low white blood cell count or high sugar levels.

What other choices are there? Cognitive behavioral psychotherapy, exercise, switch to a different anti-depressant, add another anti-depressant, or electroconvulsive therapy.

Bottom line
Adding ABILIFY to an antidepressant is a tradeoff: some people's depression will improve but more will experience a serious side effect – akathisia. And some will gain a substantial amount of weight.
The 2 FDA-approval studies combined below had nearly identical findings about how much the drug helped over 6 weeks. This makes the numbers in the table more believable. Benefits and side effects over a longer time are more uncertain.
Like all anti-psychotic drugs, Abilify can cause a number of uncommon serious or life-threatening side effects including Tardive Dyskinesia, a potentially irreversible movement disorder with uncontrollable, jerky movements of the face or body.
The FDA reviewer was concerned that side effects like weight gain, sedation and serious movement disorders may be worse or more common when Abilify is combined with antidepressants.

STUDY FINDINGS (combined results of 2 identical trials)

741 people – ages 19 to 67 years – with major depression that persisted after 8 weeks of an anti-depressant were randomized to have either ABILIFY or PLACEBO added for 6 weeks. Here's what happened:

Anti-depressant + ABILIFY (10 mg each day)	vs.	Anti-depressant + PLACEBO (No drug)
9 points better	vs.	6 points better

What difference did ABILIFY make?

How did ABILIFY help?

Depression scores improved by 3 points more than placebo (on a scale from 0 to 60).

11% more people had important response and were no longer considered to have major depression

Functioning scores improved by 0.5 points more than placebo (on a scale from 0 to 10).

What were ABILIFY's side effects?

Serious side effects

21% more people developed akathisia - severe restlessness that is hard to keep still

3% more people developed movement disorders -like Parkinson's

Symptom side effects

6% more people had insomnia

5% more had blurred vision

4% more had substantial weight gain

4% more had fatigue

3% more had constipation

WARNINGS ABOUT UNCOMMON LIFE-THREATENING AND VERY SIDE EFFECTS

Young adults using anti-depressants for major depression have a high risk of suicide.

Elderly patients with dementia-related psychosis should not use anti-psychotic drugs.

Antipsychotic drugs cause: Neuroleptic Malignant Syndrome (very high fever, uncontrollable facial / body movements), Dangerous Heart Rhythms, Aspiration Pneumonia, Diabetes, Low Blood Pressure, Trouble Regulating Temperature.

Schwartz & Woloshin (2013)

Traditional Coal Plants



The Armstrong traditional coal plant in Pennsylvania. Source: www.industry.com/renewable.htm

Option 1: CO₂ is released into air

How it Works: Traditional coal plants burn coal to make steam. The steam is used as fuel in a type of engine, called a "turbine". This turbine runs a generator to make electricity.

When coal is burned, CO₂ is released by the plant. In **Option 1**, this CO₂ escapes into the air because no equipment is added to capture the CO₂.

MORE INFORMATION (ABOUT TRADITIONAL COAL PLANTS)

Cost* Traditional coal plants make cheaper electricity than advanced coal plants. Yet, it is more expensive to add CO₂ capture equipment to traditional coal plants.*

CO₂ released* Traditional coal plants release CO₂ to the air.*

Other Pollution/Waste * While these plants are much cleaner than in the past, they still release CO₂, nitrogen oxides, sulfur dioxide, mercury and particulates to the air. These pollutants can cause people to have many different health problems.*
Traditional coal plants produce a lot of ash that contain hazardous chemicals. Some ash can be recycled, for example, to make concrete. The leftover solid waste is usually put in a landfill near the plant.
Traditional coal plants use a lot of water to cool the plant's equipment. The water comes from wells, lakes, rivers or oceans. Some of it will evaporate after use. The rest is returned to its source. Since it is hot, the water may disturb plants and animals living in the water source.

Availability Experts say that the U.S. has enough coal to meet its needs for at least 100 years.

Reliability Coal can provide steady and dependable electricity.

Limits of use Traditional coal plants release a lot of CO₂. They cannot make all of the electricity that is needed in PA if we want to reduce CO₂. Other types of plants must also be built.

Noise These plants are about as loud as average street traffic.

Land use and ecology Coal mining near the surface disturbs the land, plants and animals. It also disrupts and pollutes streams. Underground mining can cause acidic water to leak into streams. If the mine collapses, it can also cause the ground to sink or shift.

Safety These plants are quite safe for operators. Coal mining is dangerous for the miners.

Lifecycle The lifetime of any plant is uncertain. But, a new traditional coal plant built today would likely make electricity for at least 50 years.

Current Use There are more than 1,000 of these plants working in the U.S. today.

*More cost and pollution information is available in 'Cost Comparison' and 'Pollution Comparison' sheets in Envelope #3.

Three studies

- ◆ Study I: Modelling electricity generation portfolios for Riskmeter
- ◆ Study II: “Strategic listening” to the lay users of Riskmeter
- ◆ **Study III: Empirically testing how laypeople interpret risk information**

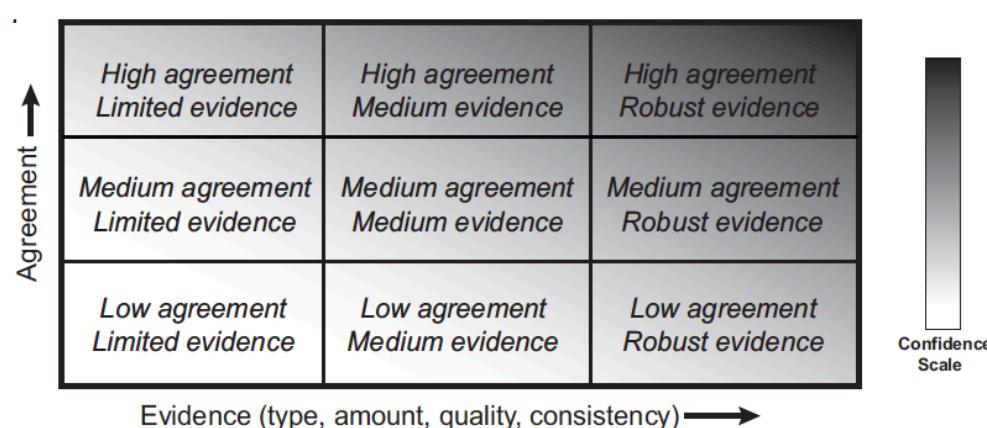
Study III: Background

- ◆ What is a good way to inform laypeople about risks of energy technologies, e.g. low-probability high-consequences induced seismicity?

Study III: Background

- ◆ What is a good way to inform laypeople about risks of energy technologies, e.g. low-probability high-consequences induced seismicity?
 - Quantitative or qualitative probabilities?
 - With risk comparison?
 - Acknowledging uncertainty and low confidence of experts?

Term*	Likelihood of the Outcome
<i>Virtually certain</i>	99-100% probability
<i>Very likely</i>	90-100% probability
<i>Likely</i>	66-100% probability
<i>About as likely as not</i>	33 to 66% probability
<i>Unlikely</i>	0-33% probability
<i>Very unlikely</i>	0-10% probability
<i>Exceptionally unlikely</i>	0-1% probability



Study III: Method

- ◆ Focus: low-probability high-consequence induced seismicity
- ◆ An online survey, N=590, split in 12 groups
- ◆ M=43.74 years old (SD=13.96 years)
- ◆ 299 female (50.7%)
- ◆ Slightly more educated than the Swiss average

Different risk information formats		
	No confidence statement	Confidence statement
Qualitative only	vignette 1	vignette 2
Qualitative and quantitative	vignette 3	vignette 4
Qualitative and quantitative with risk comparison	vignette 5	vignette 6



Perception of information
understandability
trust
concern
exactness
liking of information
perceived risk

Study III: Method

Enhanced Geothermal System (EGS)

Im Erdmantel ist Wärme gespeichert. Die Nutzung dieser Wärme nennt man Geothermie. Die Tiefengeothermie nutzt Wärme in circa 3-5 km Tiefe und ermöglicht neben Heizungsanwendungen in vielen Fällen die Produktion von Strom (Abbildung, rechter Teil). Im Gegensatz dazu nutzt die oberflächennahe Geothermie Wärme in einigen hundert Metern Tiefe und speist Heizungs- oder Warmwasseranwendungen (Abbildung, linker Teil). In dieser Studie geht es um Tiefengeothermie (Abbildung, rechter Teil).

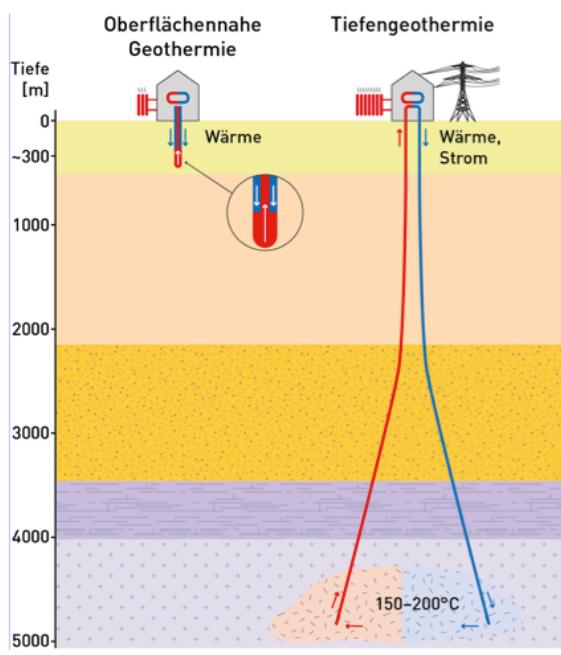


Abbildung: Oberflächennahe Geothermie und Tiefengeothermie*

Shale gas

Schiefergas ist ein im Erdmantel gelagerte fossiler Brennstoff, der zur Wärme- und Stromproduktion verwendet werden kann. Schiefergas bleibt in kleinen Bläschen im Gestein gefangen (Abbildung, rechter Teil). Um Schiefergas fördern zu können, wird dieses Gestein aufgebrochen. Dies bezeichnet man als **fracking**. Der Unterschied zu herkömmlichem Erdgas liegt in der Lagerung (siehe Abbildung): Herkömmliches Erdgas sammelt sich an bestimmten Lagerstätten, die zur Förderung angezapft werden (Abbildung, linker Teil). In dieser Studie geht es um die Schiefergasgewinnung durch Fracking.

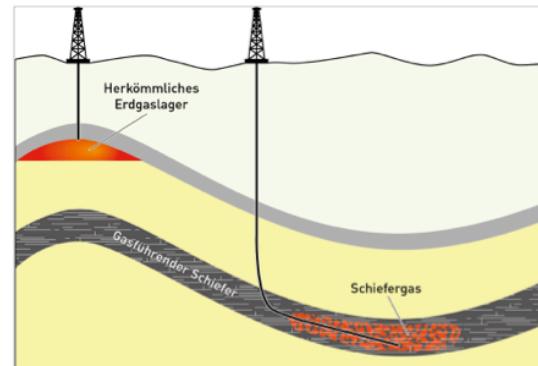


Abbildung: Schematische Darstellung von herkömmlichem Gas und Schiefergas*

Study III: Method

Vignette 1: Qualitative only

According to the risk assessment:

- Micro-earthquakes are **virtually certain**. These micro-earthquakes will be too small for humans to be felt.
- An earthquake that is lightly noticeable for humans is **unlikely**.
- An earthquake that is strongly felt and can cause slight damage (e.g. hair-line cracks or falling of small pieces of plaster) is **exceptionally unlikely**.
- An earthquake that is severely felt and can cause serious structural damage to average houses (e.g. large cracks in walls, falling of gable parts) is even more unlikely, thus also **exceptionally unlikely**.

Study III: Method

Vignette 1: Qualitative with confidence statement

According to the risk assessment:

- Micro-earthquakes are **virtually certain**. These micro-earthquakes will be too small for humans to be felt.
- An earthquake that is lightly noticeable for humans is **unlikely**.
- An earthquake that is strongly felt and can cause slight damage (e.g. hair-line cracks or falling of small pieces of plaster) is **exceptionally unlikely**.
- An earthquake that is severely felt and can cause serious structural damage to average houses (e.g. large cracks in walls, falling of gable parts) is even more unlikely, thus also **exceptionally unlikely**.

The risk assessment is based on best available methods. Due to unpredictable reactions in the subsoil, such risk assessments carry **uncertainty**. Therefore, experts can disagree on the exact probabilities and the largest possible earthquake.

Study III: Method

Vignette 3: Qualitative and quantitative

According to the risk assessment:

- Micro-earthquakes are **virtually certain**. These micro-earthquakes will be too small for humans to be felt.
- An earthquake of magnitude 3 on the Richter scale that is lightly noticeable for humans is **less probable than 5%** during drilling and construction works.
- An earthquake of magnitude 5 on the Richter scale that is strongly felt and can cause slight damage (e.g. hair-line cracks or falling of small pieces of plaster) is **exceptionally unlikely**. **It is less probable than 0.01%**.
- An earthquake of magnitude 6 on the Richter scale that is severely felt and can cause serious structural damage to average houses (e.g. large cracks in walls, falling of gable parts) is) is even more unlikely, thus also **exceptionally unlikely**. **It is less probable than 0.001%**.

Study III: Method

Vignette 5: Qualitative, quantitative and risk comparison

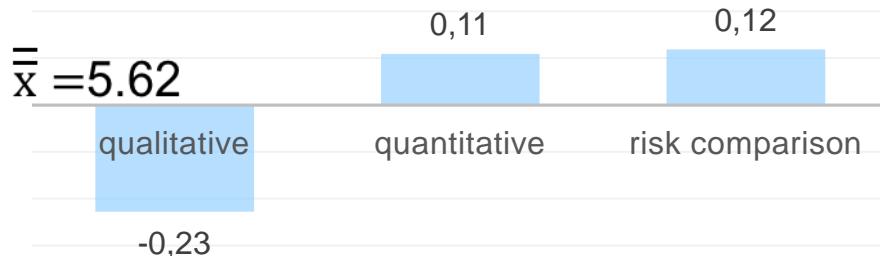
According to the risk assessment:

- Micro-earthquakes are **virtually certain**. These micro-earthquakes will be too small for humans to be felt.
- An earthquake of magnitude 3 on the Richter scale that is lightly noticeable for humans is **less probable than 5%** during drilling and construction works. **It is as unlikely as a lightning strike in your neighborhood in a week.**
- An earthquake of magnitude 5 on the Richter scale that is strongly felt and can cause slight damage (e.g. hair-line cracks or falling of small pieces of plaster) is **exceptionally unlikely**. It is **less probable than 0.01%**. **It is as unlikely as a tornado in your neighborhood in a week.**
- An earthquake of magnitude 6 on the Richter scale that is severely felt and can cause serious structural damage to average houses (e.g. large cracks in walls, falling of gable parts) is) is even more unlikely, thus also **exceptionally unlikely**. It is **less probable than 0.001%**. **It is as unlikely as a plane crash in your neighborhood in a week.**

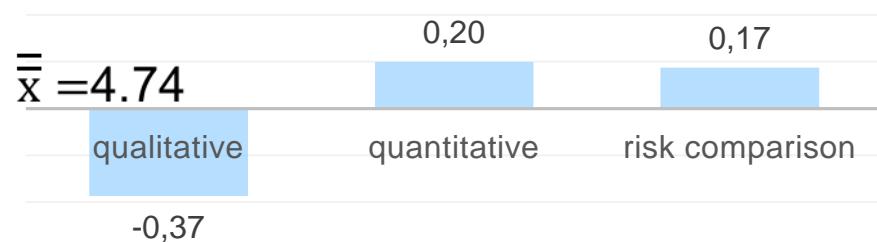
Study III: Results

Qualitative vs. quantitative vs. risk comparison

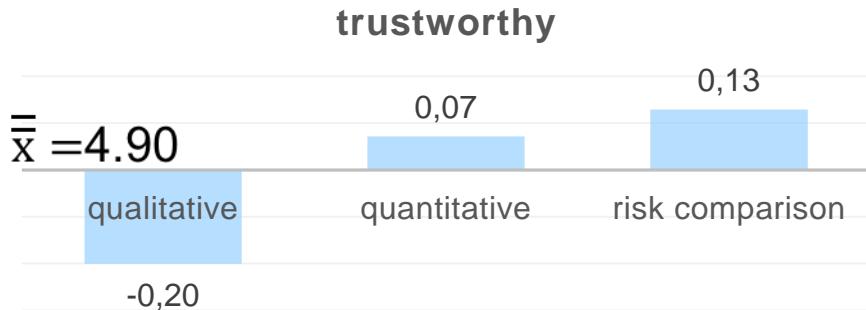
clear and easy to understand*



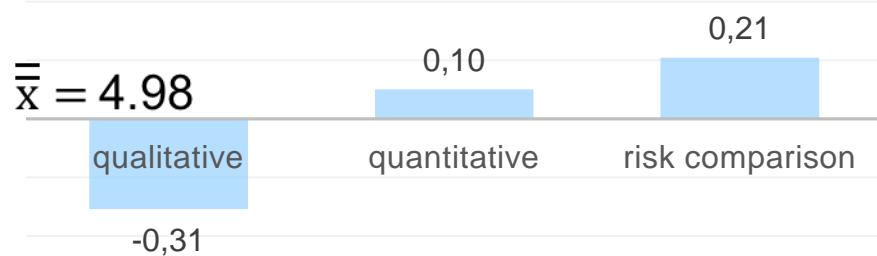
exact **



trustworthy

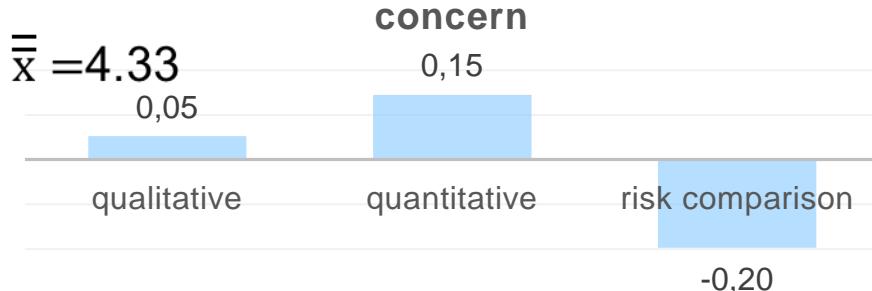


liking of information ***



\bar{x} - grand mean

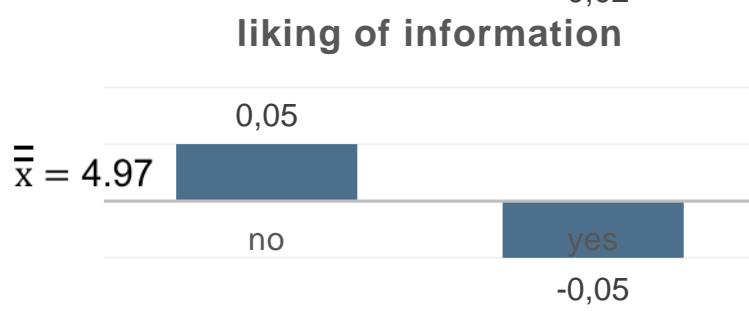
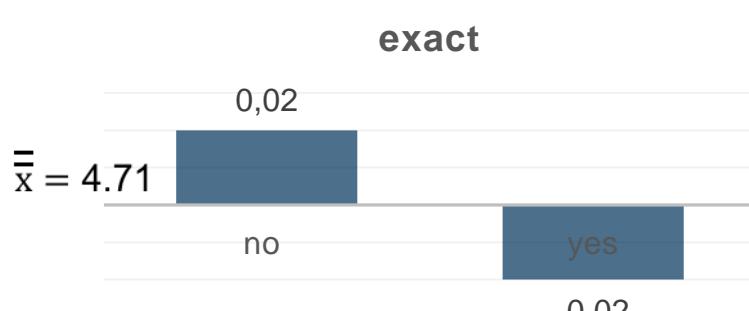
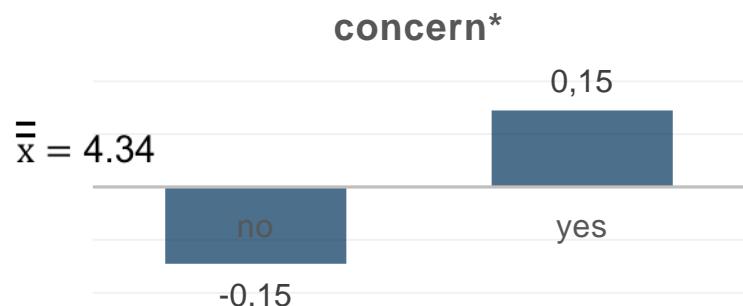
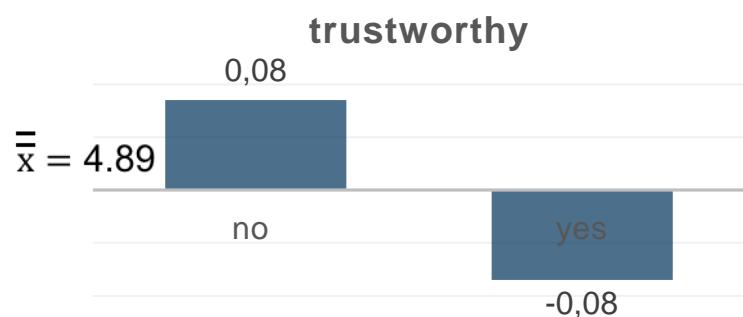
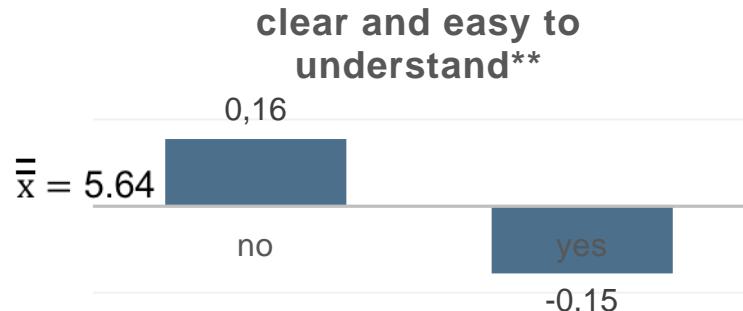
7-point Likert scale
1="totally disagree"
7="totally agree"



* p=0.054, ** p=0.01, *** p=0.001

Study III: Results

Without vs. with expert confidence



\bar{x} - grand mean

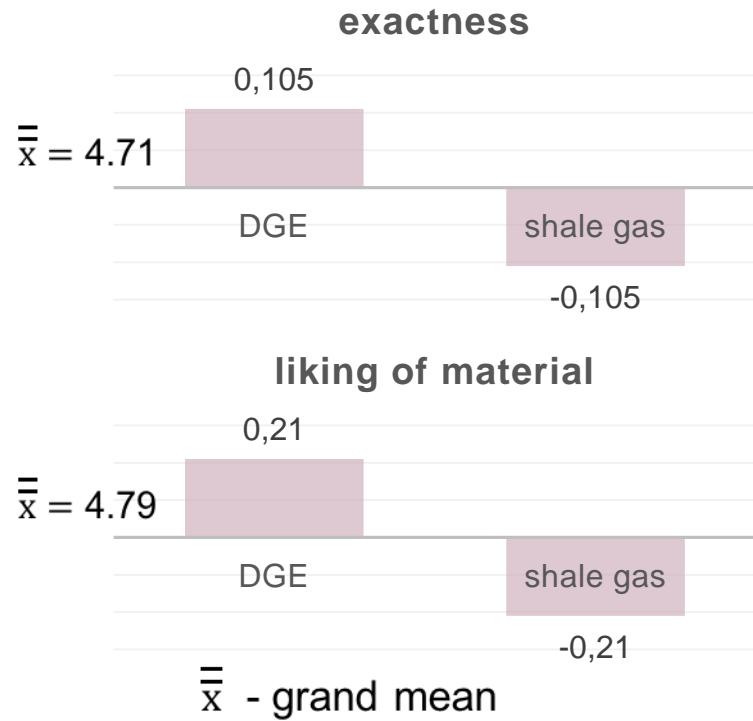
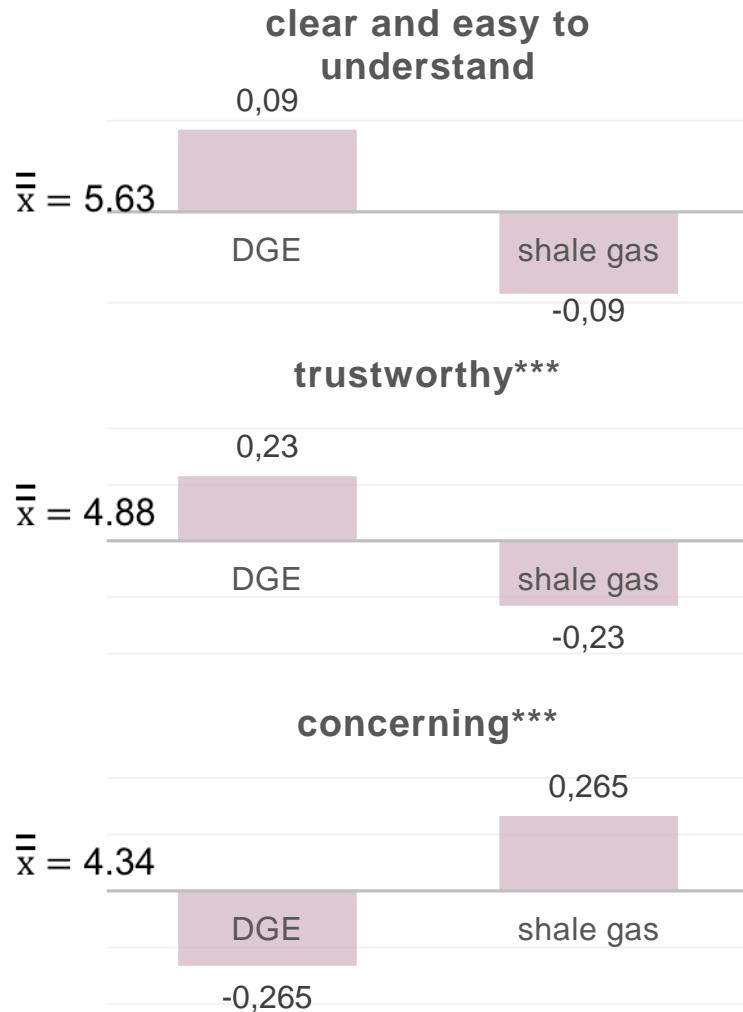
7-point Likert scale
1="totally disagree"
7="totally agree"

* p=0.05; ** p= 0.01

Source: Knoblauch et al. (2016)

Study III: Results

Geothermal vs. shale gas



\bar{x} - grand mean

7-point Likert scale
1="totally disagree"
7="totally agree"

*** p=0.001

Source: Knoblauch et al. (2016)

Study III: Summary

- ◆ Format matters to how risk information is perceived by the lay audience:
 - Quantitative probabilities increase clarity and liking of information
 - Risk comparisons increase liking of information
 - A statement about uncertainties and lack of expert confidence decreases clarity and increases concern
- ◆ Pre-existing views on technology also shape how risk information is perceived:
 - For less accepted shale gas, identical risk information is perceived more concerning and less trustworthy

Overall summary

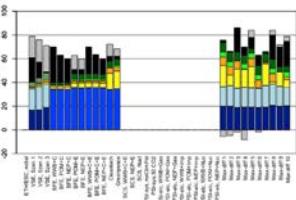


- ◆ Due to the nuclear phaseout, risks to human health, safety, natural and built environment posed by the Swiss electricity portfolio are changing

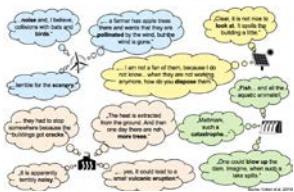
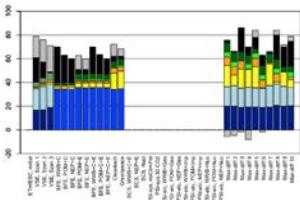
Overall summary



- ◆ Due to the nuclear phaseout, risks to human health, safety, natural and built environment posed by the Swiss electricity portfolio are changing
- ◆ Study I: MGA-based EXPANSE could generate future electricity portfolios that represent existing stakeholder views as well as missing perspectives



Overall summary

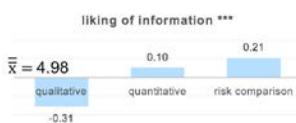
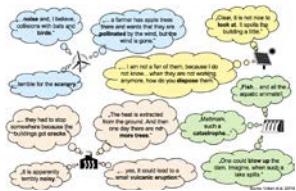


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Overall summary



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- ◆ Study III: Identical risk information can be perceived differently, especially if negative attitudes pre-exist or if experts acknowledge lack of confidence



Please get in touch with questions and comments!

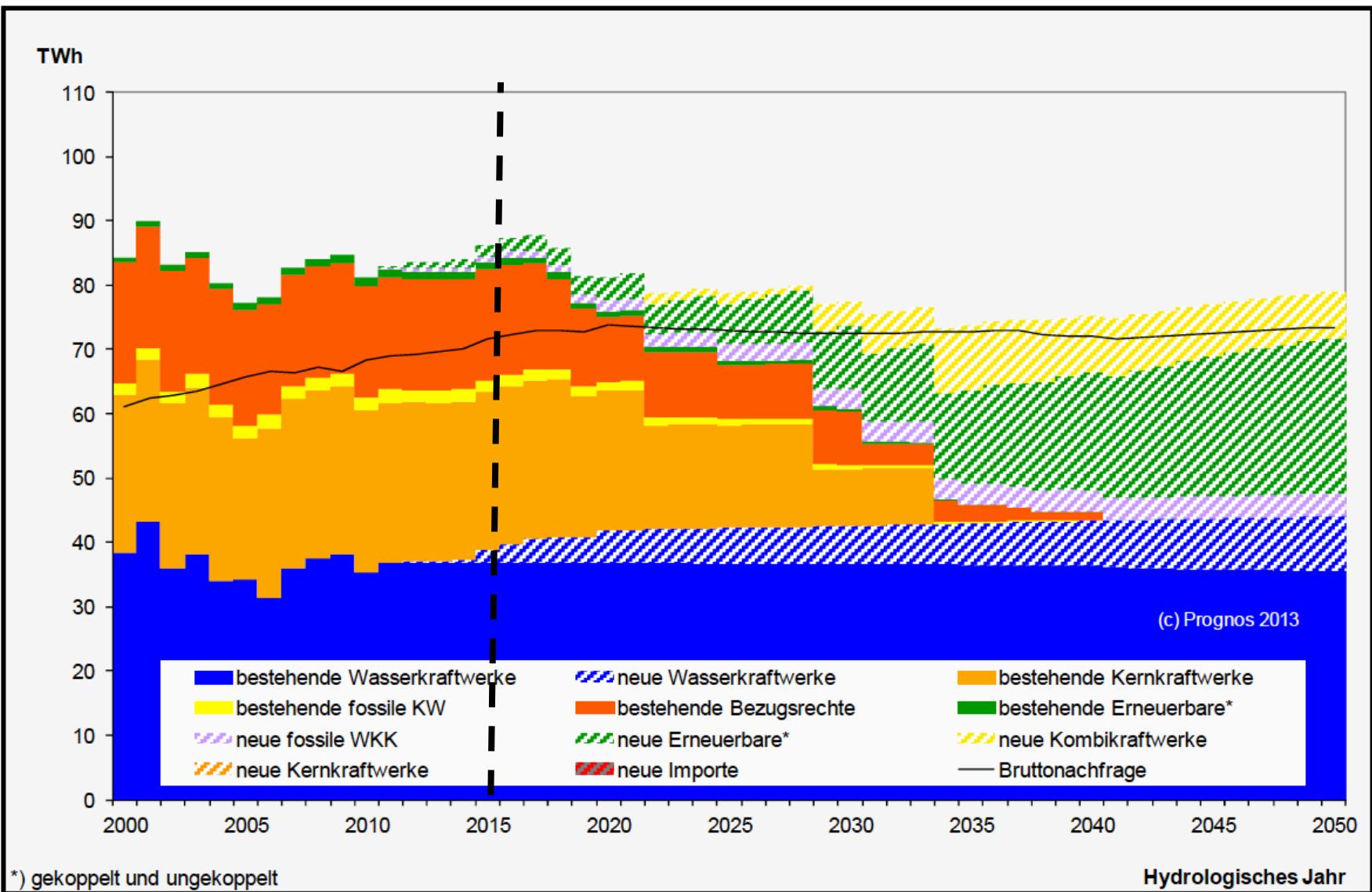
Evelina Trutnevyte

Email: tevelina@ethz.ch

Group: <http://www.tdlab.usys.ethz.ch/research/rigorous.html>



Swiss Energy Strategy 2050



Study II: Results

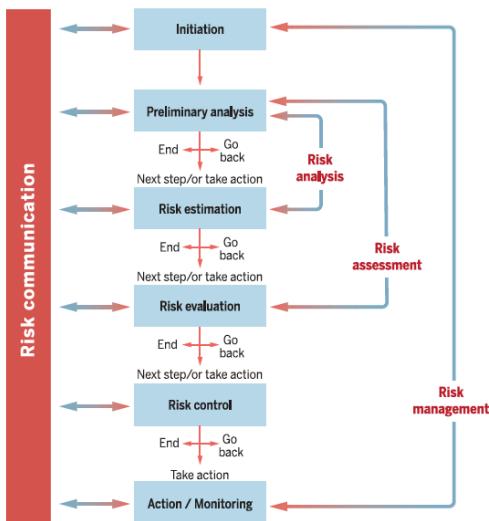
Which plants are present in your community of living or working?

Nuclear	No	No	No	No	No	No	No	No	No	Yes
(Pumped) storage hydro	No	Yes	No	No	Yes	No	Yes	Don't know	No	No
Run-of-river hydro	No	Don't know	No	No	Yes	No	Yes	Don't know	Yes	Yes
Natural gas	No	No	No	No	Don't know	No	No	Don't know	No	Don't know
Deep geothermal	No	No	No	No	Don't know	No	No	Don't know	No	Don't know
Photovoltaic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wind	No	No	No	No	No	No	Don't know	Yes	No	Yes
Biogas	No	Yes	No	Don't know.	Yes	No	Yes	Don't know	Yes	Yes

Source: Volken et al. (2016)

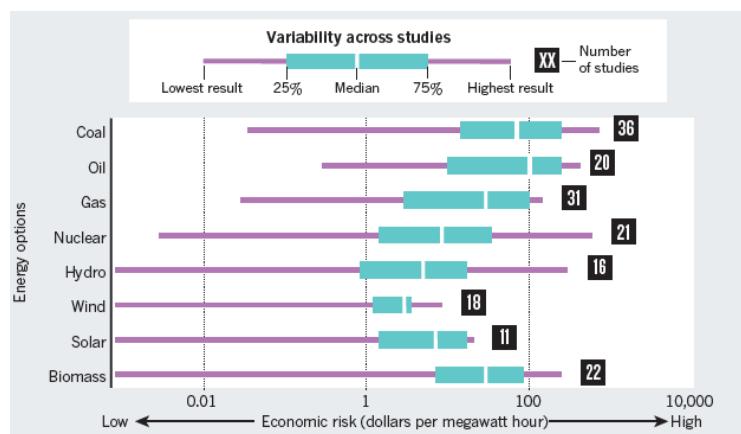
Frameworks for understanding the risk

Analytic-deliberative approach



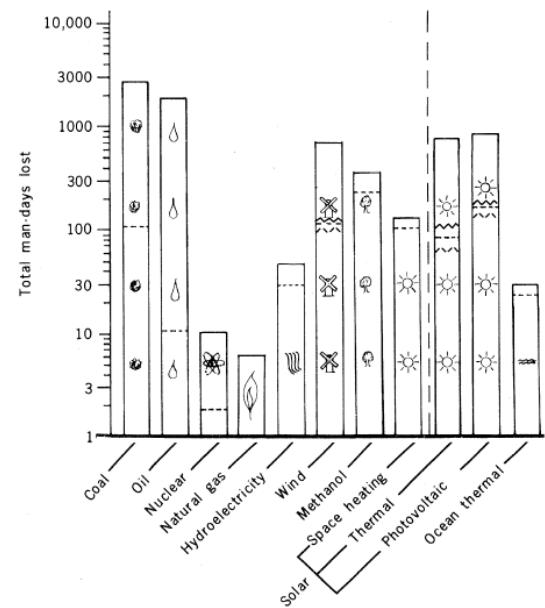
Fischhoff (2015) Science

Multi-criteria mapping



Stirling (2010) Nature

Comparative indicators



Inhaber (1979) Science

Simplification and loss of risk knowledge

Ability to compare multiple technologies

Swiss Energy Strategy 2050

Difference by 2050, TWh/year	- 25.1	+ 4.3	+ 4.4	+ 11.1	+ 8.6
Number of new or retired plants by 2050	- 5	+ 2'700	+ 95	+ 0.5 million	+ 200 (822 total)
Per canton	-	100	4	20'000	8
Distance to the next plant, km	-	2.5	12	0.2	8 (4 for all)