ETH Zurich Department of Architecture
ARCHITECTURE OF TERRITORY
Chair of Architecture
and Territorial Planning
Professor Milica Topalović

Kraftwerk Schweiz
Spring 2024

Nuclear

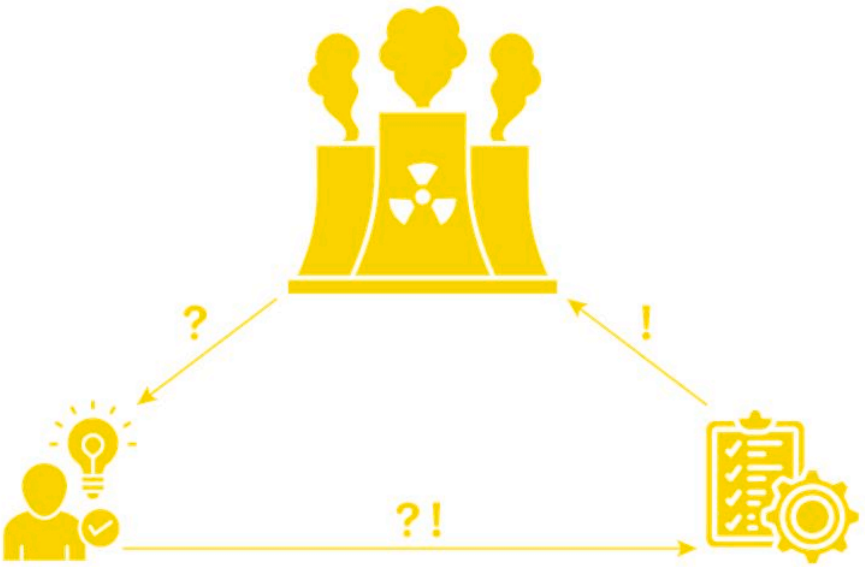
Atomic Crossroads: The Complexities of Nuclear Power and Its Waste

Eeva Rosenqvist, Tabea Brochier, and Andrei Zündel



As the global community tackles sustainable energy challenges, nuclear power remains divisive. This project examines nuclear power from a global perspective down to Switzerland's local context. We investigate nuclear waste and its proposed storage site, analyze related case studies, and apply these findings to Stadel, integrating territory and culture. Finally, we return to the global stage to underscore the project's significance, concluding with a profound reflection on the climate crisis.

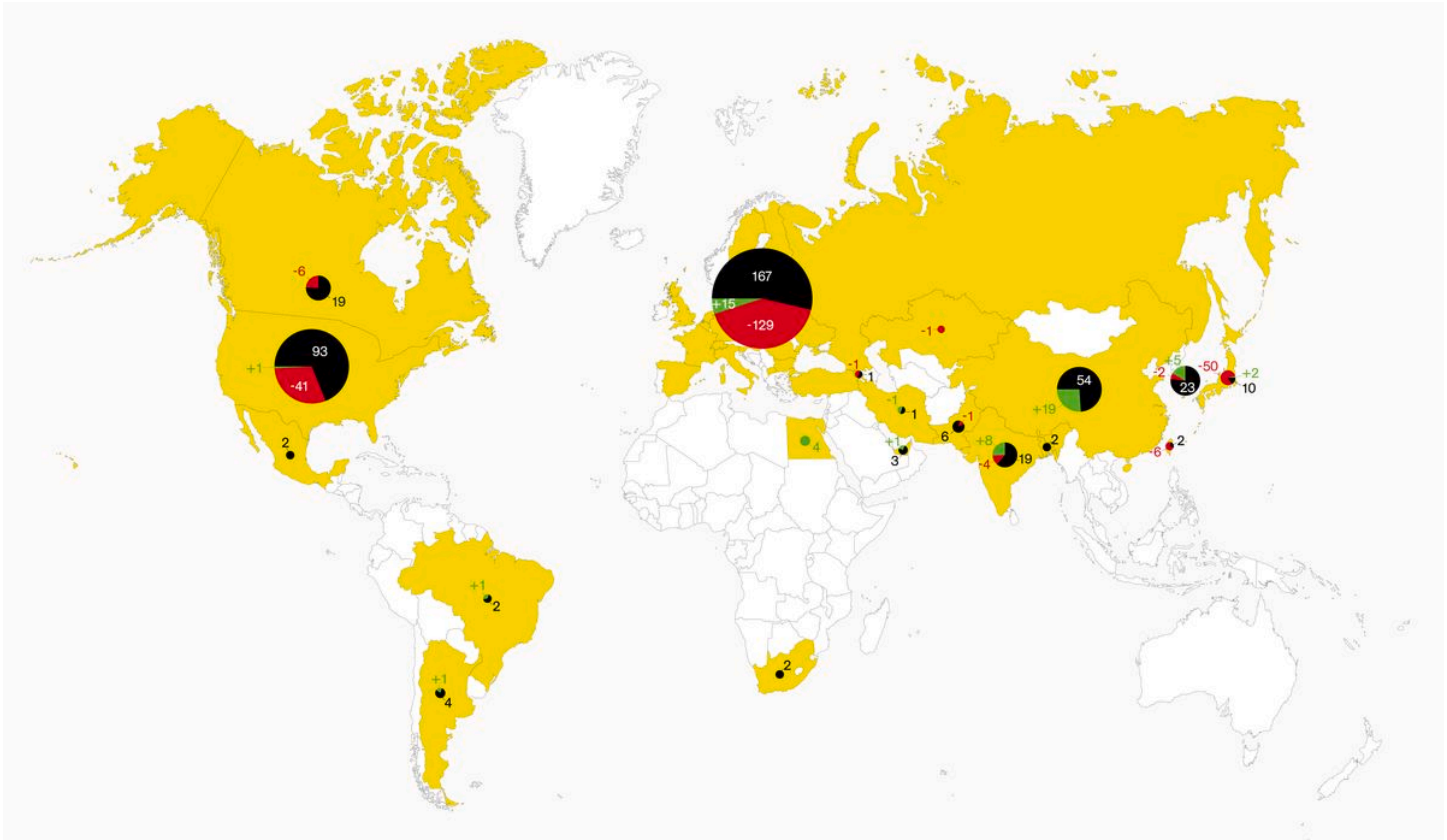
Radioactive Legacy: Understanding and Managing Nuclear Power



Nuclear power is a contentious issue globally. On one hand, it represents an energy source with low CO2 emissions; on the other, it inexorably generates hazardous waste that poses a significant threat to life. As some nations consider building even more new power plants, others opt to decommission them entirely.

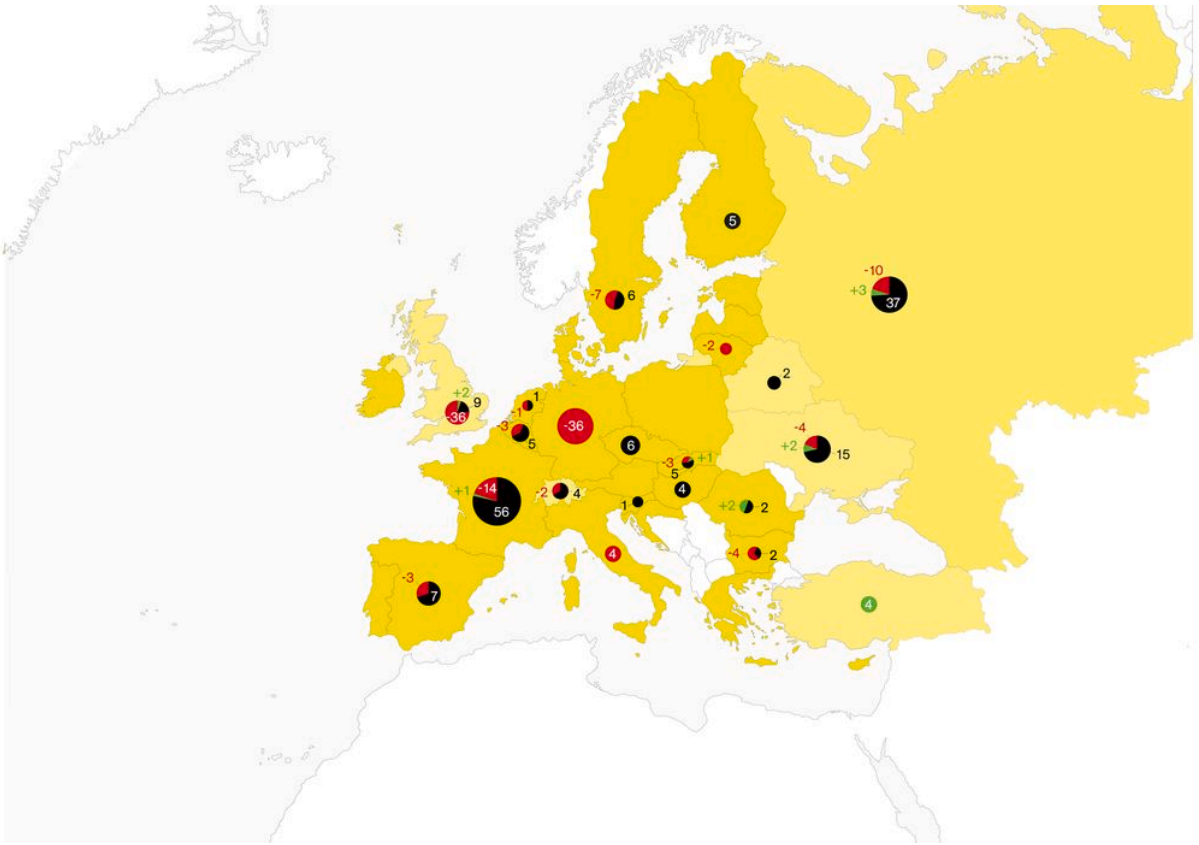


VIDEO PART I IS TALKING ABOUT THE NUCLEAR POWER PLANTS IN SWITZERLAND
https://youtu.be/sfQwb7mkL24



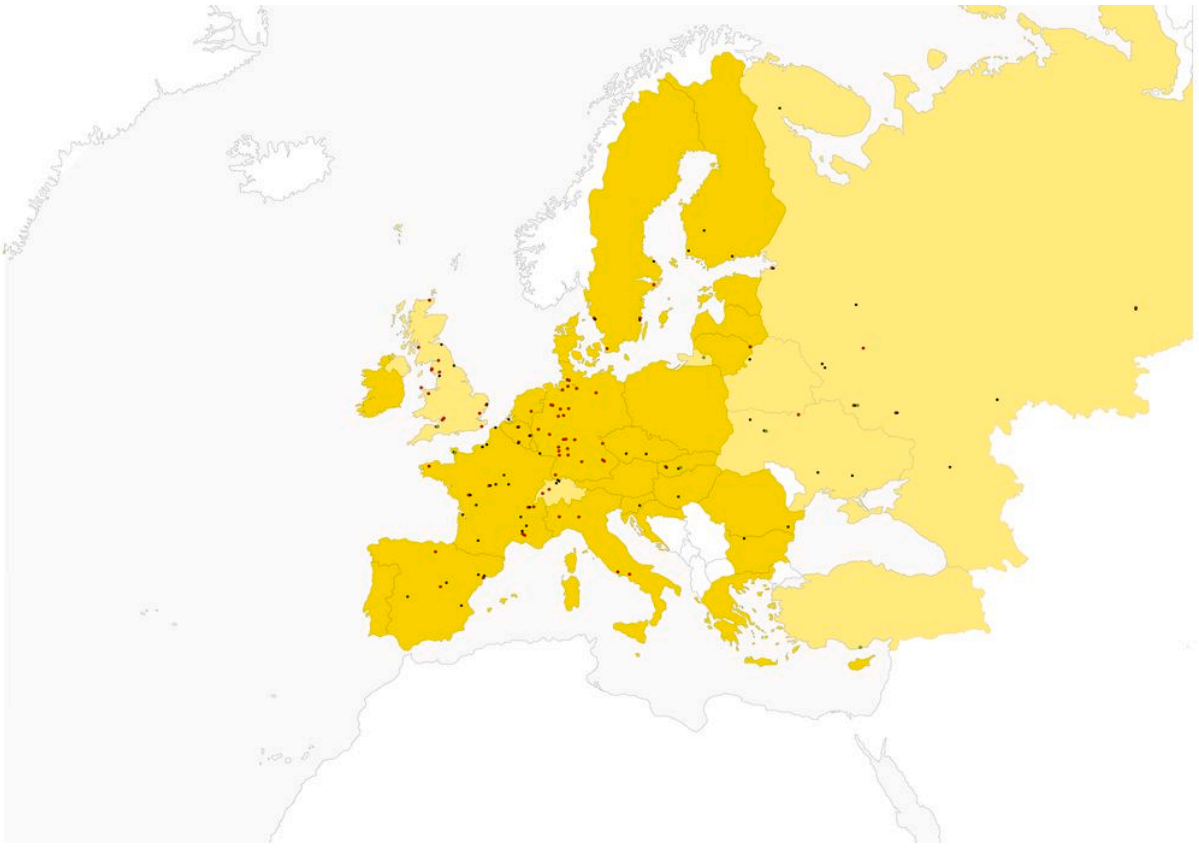
WORLD MAP NUCLEAR POWER PLANTS
(Source: Wikipedia, Liste der Kernkraftwerke)

- NUMBER OF ACTIVE POWER PLANTS: Europe 167; Asia 121; North America 114; South America 6; Africa 2; Australia 0
- NUMBER OF NUCLEAR POWER PLANTS BEING BUILT: Europe 15; Asia 36; North America 1; South America 2; Africa 4; Australia 0
- NUMBER OF DECOMMISSIONED NUCLEAR POWER PLANTS: Europe 129; Asia 65; North America 47; South America 0; Africa 0; Australia 0
- COUNTRIES WITH NUCLEAR POWER PLANTS
- COUNTRIES WITHOUT NUCLEAR POWER PLANTS



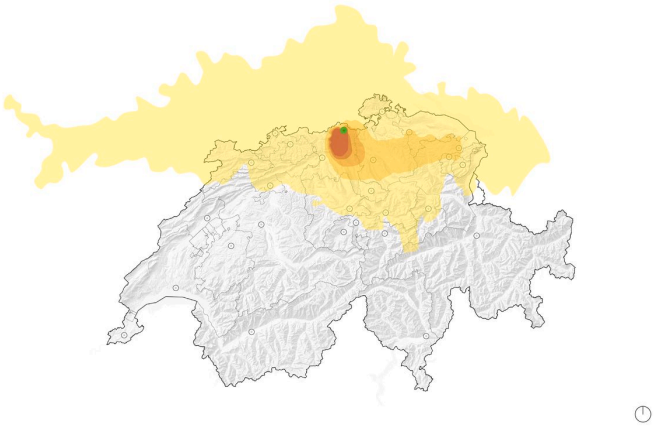
EUROPE MAP NUCLEAR POWER PLANTS
(Source: Wikipedia, Liste der Kernkraftwerke)

- Number of active nuclear power plants
- Number of nuclear power plants being built
- Number of decommissioned nuclear power plants
- Countries that belong to EU
- Countries that have nuclear power plants

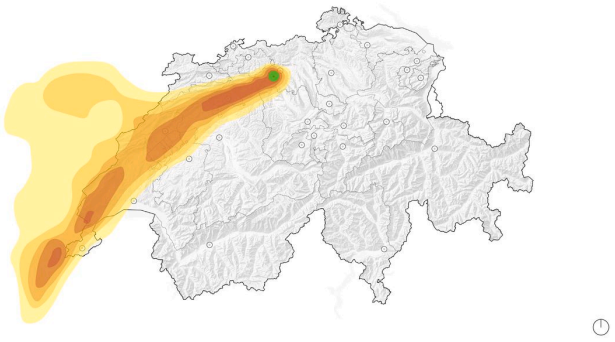


EUROPE MAP NUCLEAR POWER PLANTS LOCATION

- Number of active nuclear power plants
- Number of nuclear power plants being built
- Number of decommissioned nuclear power plants
- Countries that belong to EU
- Countries that have nuclear power plants



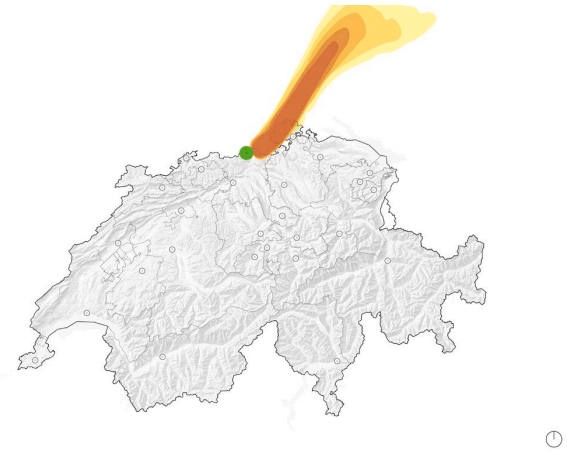
RADIOACTIVE CLOUD BEZNAU I & II



GÖSGEN

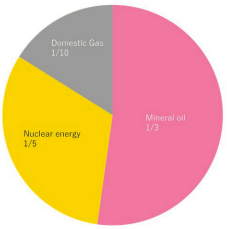
- 100mSv/year area is unhabitable for several centuries
- 50mSv/year area should be evacuated
- 20mSv/year area is habitable under certain conditions
- 6mSv/year area releases radioactivity slightly above the recommendation of 4 mSv/year
- 1 mSv area is safe to habit
- Location Nuclear Power Plant
- Water

(Source: Energiestiftung Schweiz)

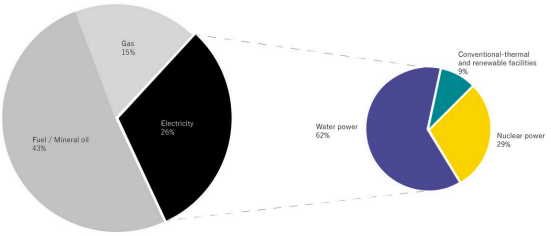


LEIBSTADT

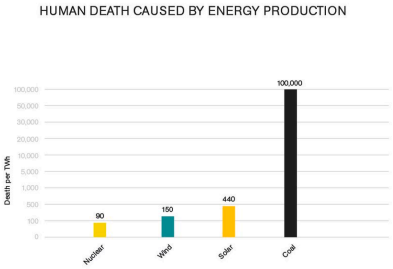
Switzerland made the decision to phase out nuclear power in 2017 following the Fukushima accident in 2011. The plan is to operate them as long as the power plants are deemed safe, which currently means up to 60 years, but extending this to 80 years is under investigation. A nuclear accident at even a single power plant could result in numerous cities suffering from toxic contamination for several years. The decision of exit will, however, imply a significant shift in Switzerland's energy landscape. Currently, nuclear power accounts for 29% of Switzerland's electricity generation.



NON-RENEWABLE ENERGY MIX IN SWITZERLAND



ENERGY USE IN SWITZERLAND



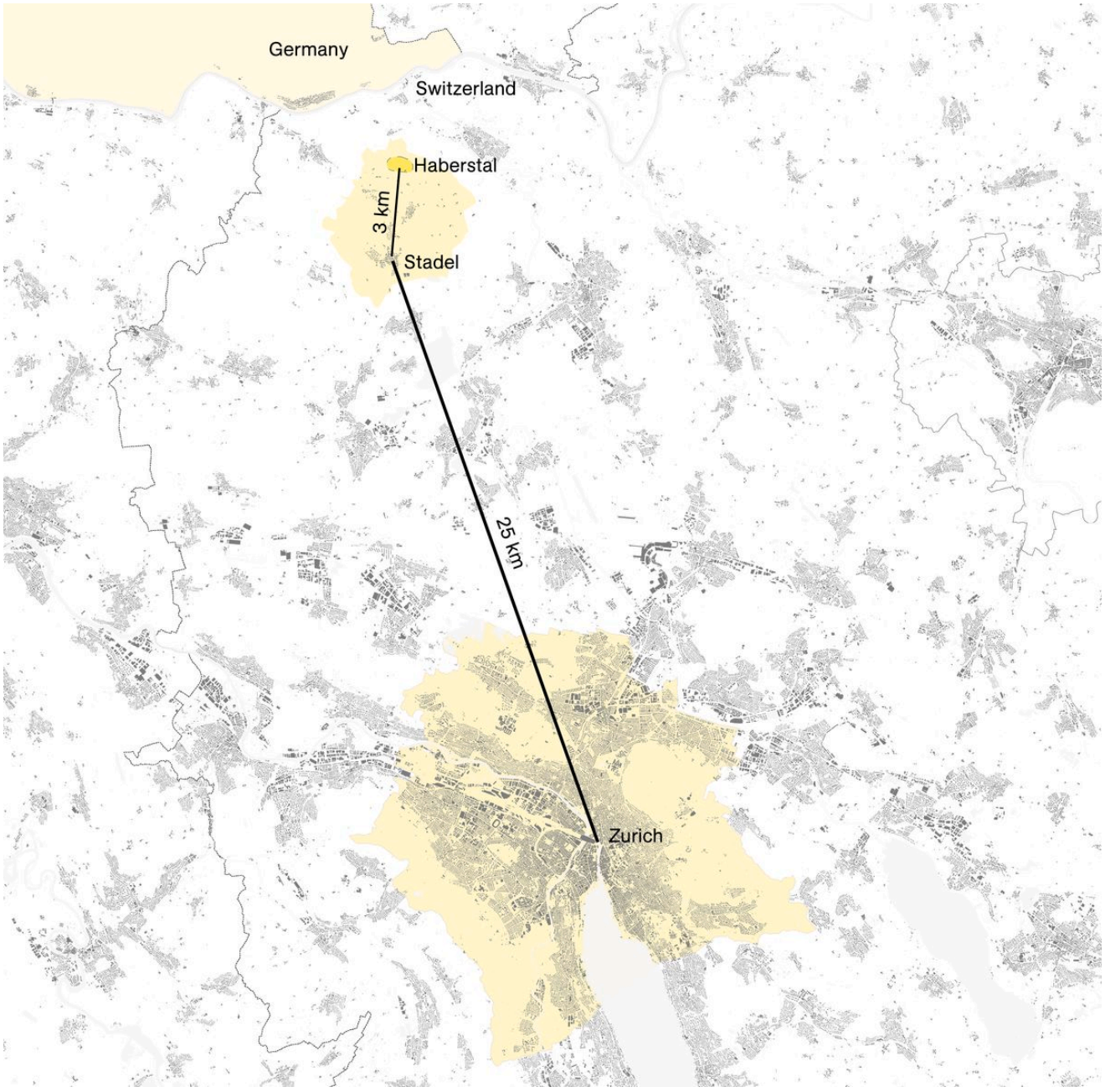
HUMAN DEATH CAUSED BY ENERGY PRODUCTION



TIMELINE: RADIOTOXICITY VS. HUMAN BUILDINGS
(Source: bfe.admin.ch)

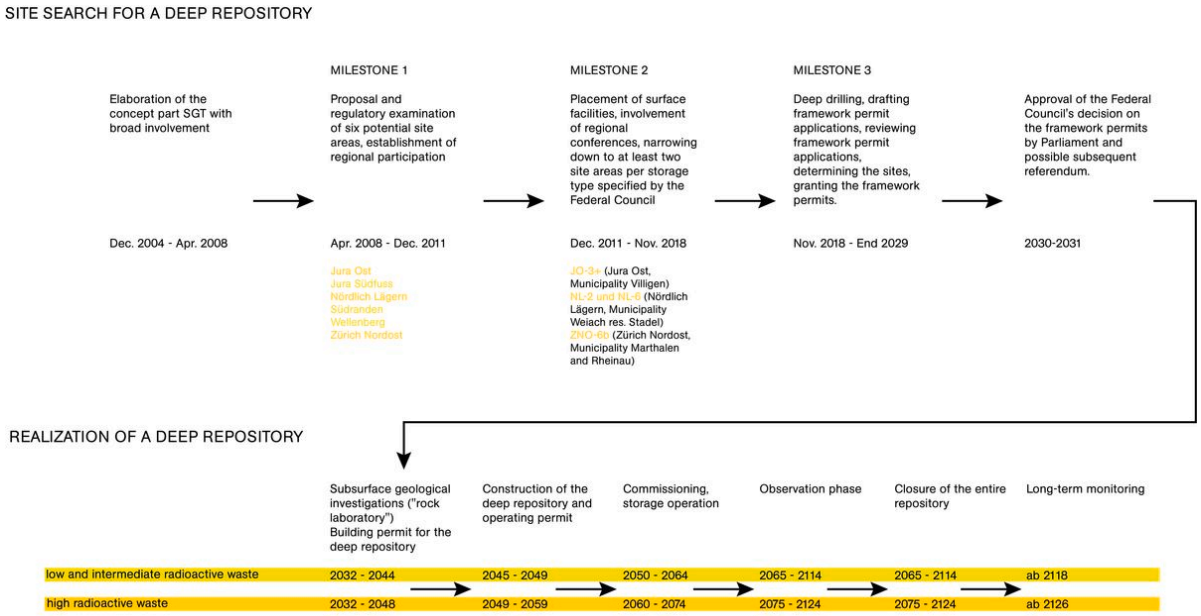
https://youtu.be/qP89-Sw7Cak

Burying the Issue: Political Battles over Nuclear Waste Repository Locations

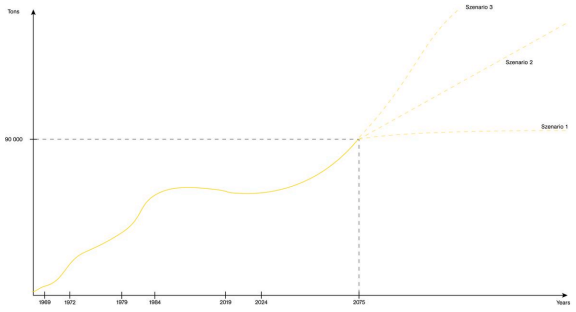


Regardless of the polemics and scenarios surrounding nuclear power, one fact is evident: the waste is already generated and it must be managed safely. The whole world is, hence, looking for a solution to locate repositories. Switzerland, as one of the few leading countries, has decided the siting of the high level radioactive waste repository.

After long deliberation, Nördlich Lägern, located approximately 30 km from Zurich, has been chosen as the high level nuclear waste repository site of Switzerland. The selection was based on criteria ensuring minimal impact on groundwater during waste placement in Opalinus clay. Additionally, the site offers good transport logistics and ample land for the repository. The waste will be transported to Nördlich Lägern from the temporary repositories of Switzerland, which are currently located near the nuclear power plants.

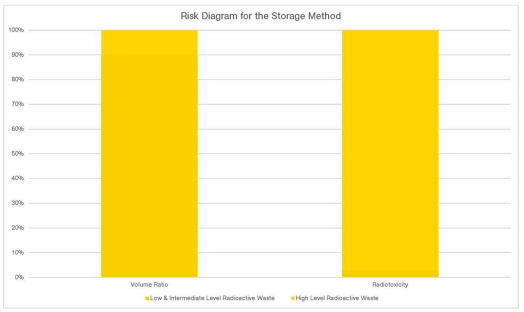


MILESTONES DEEP REPOSITORY SWITZERLAND
(Source: Sachplan geologisches Tiefenlager)

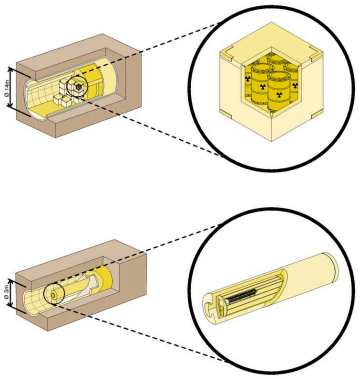


RADIOACTIVE WASTE
SCENARIOS OF SWITZERLAND

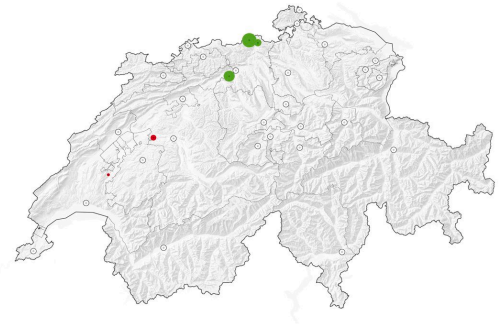
SCENARIO 1: Shutdown of all Power Plants
SCENARIO 2: Continuation of existing Power Plants
SCENARIO 3: Continuation and newly constructed Power Plants
(Source: bfe.admin.ch)



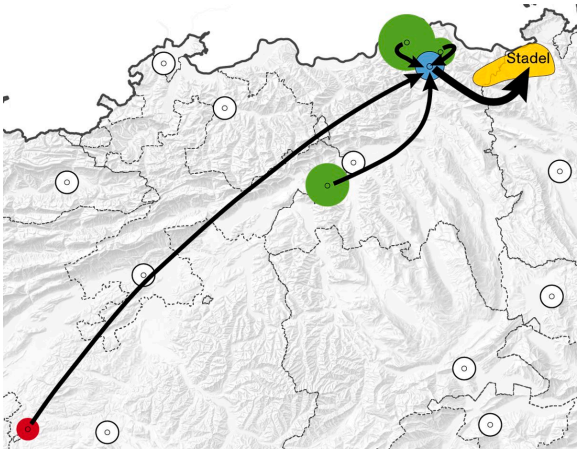
RISK DIAGRAM OF RADIOACTIVE WASTE
(Source: bfe.admin.ch)



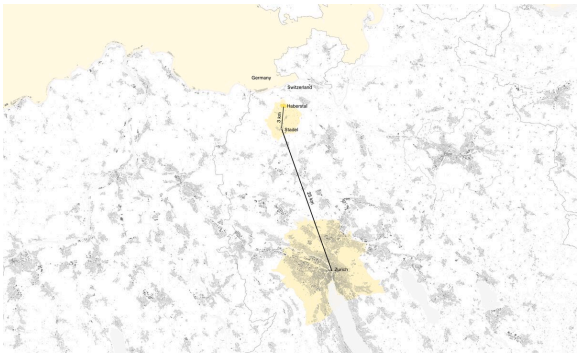
TOP: Low and Intermediate Level Radioactive Waste Storing Method
BOTTOM: High Level Radioactive Waste Storing Method
(Source: NAGRA)



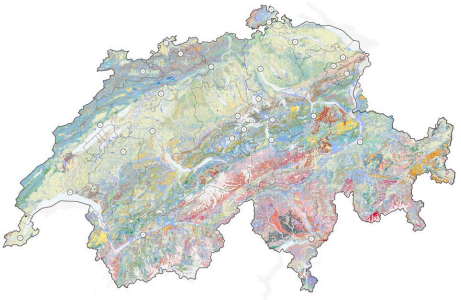
Nuclear Power Plants Switzerland



Transportation System - Radioactive Waste



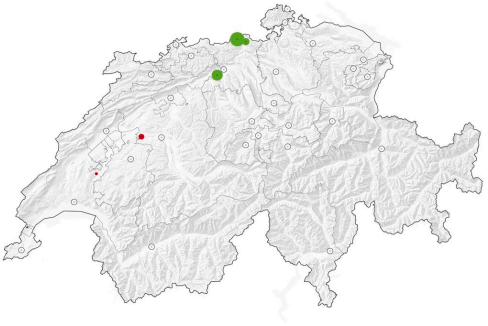
ZoomIn Stadel-Zurich



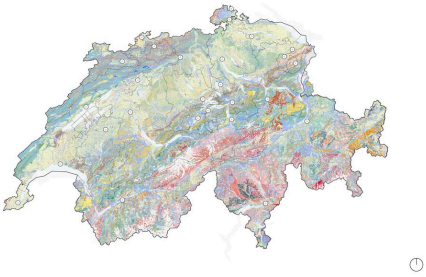
Geology Switzerland



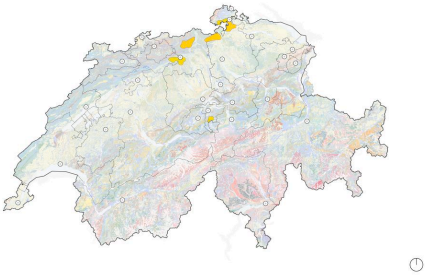
Possible Repository Locations



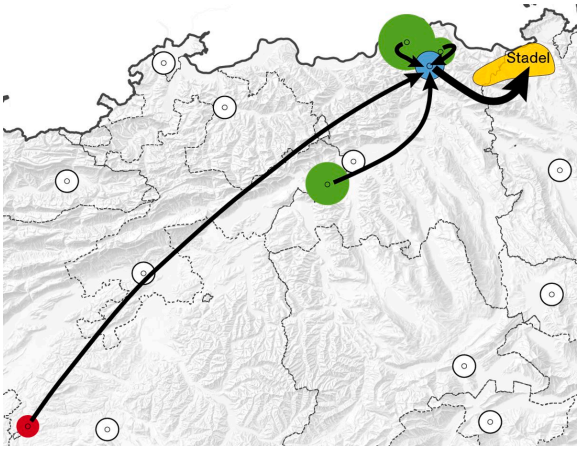
Nuclear Power Plants Switzerland



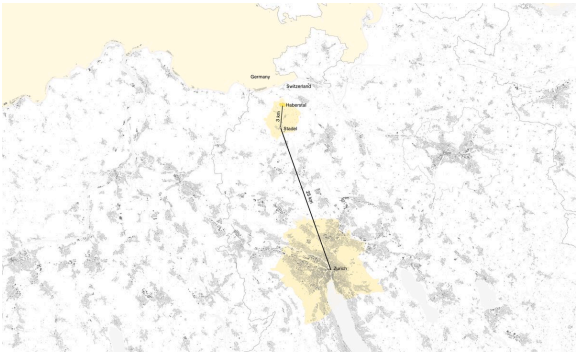
Geology



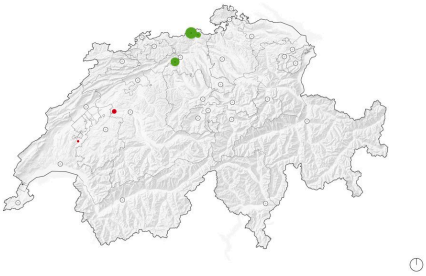
Possible Repository Locations



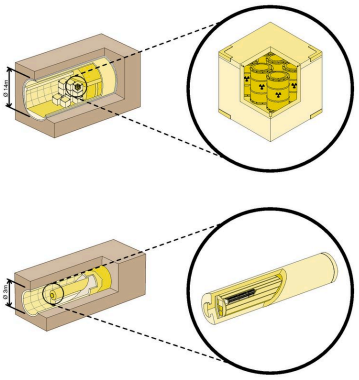
Transportation System Radioactive Waste



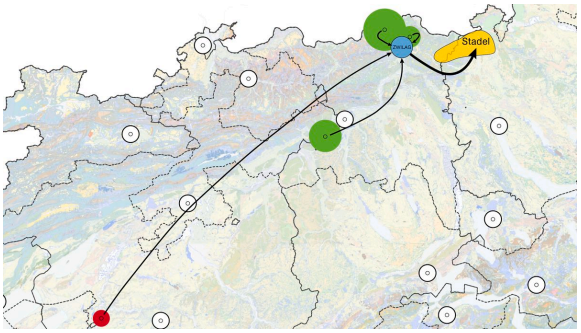
ZoomIn Stadel Zurich



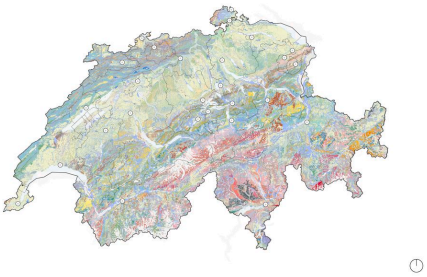
NUCLEAR POWER PLANTS SWITZERLAND



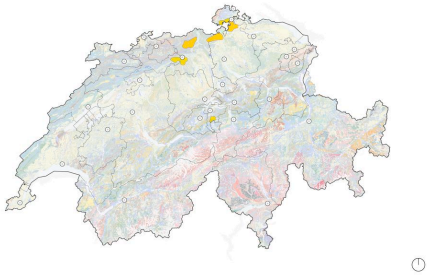
Top: Low and Intermediate Level Radioactive Waste Storing Method
Bottom: High Level Radioactive Waste Storing Method



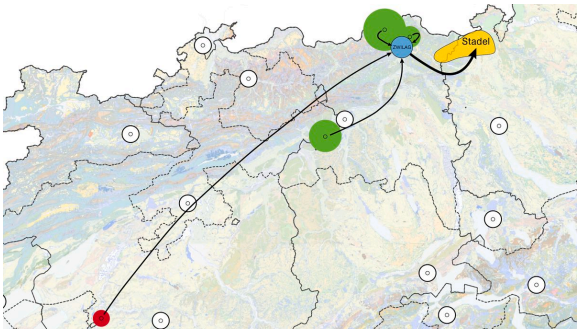
Transportation System Radioactive Waste



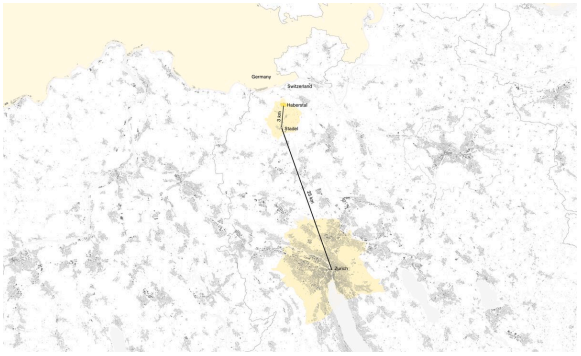
GEOLOGY
(Source: map.geoadmin.ch)



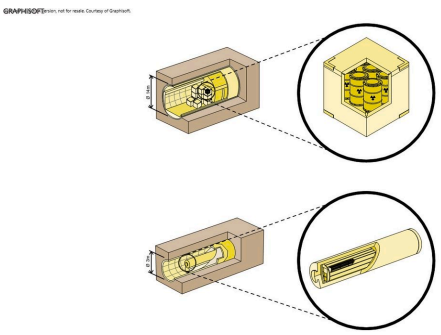
POSSIBLE REPOSITORY LOCATIONS
(Source: map.geoadmin.ch, NAGRA)



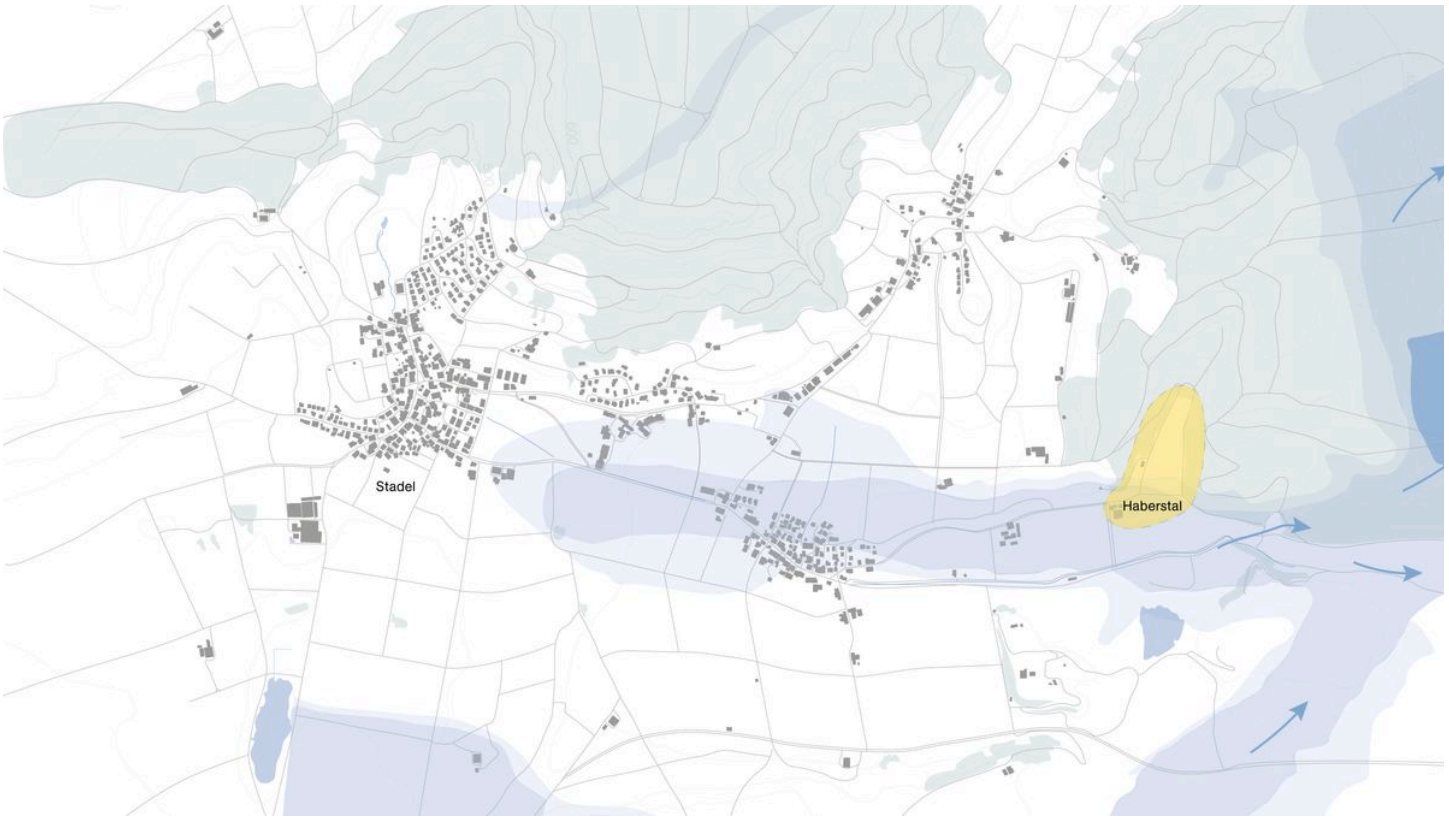
TRANSPORTATION SYSTEM
RADIOACTUVE WASTE



ZOOMIN STADEL - ZURICH



Top: Low and Intermediate Level
Radioactive Waste Storing Method
Bottom: High Level Radioactive Waste Storing
Method



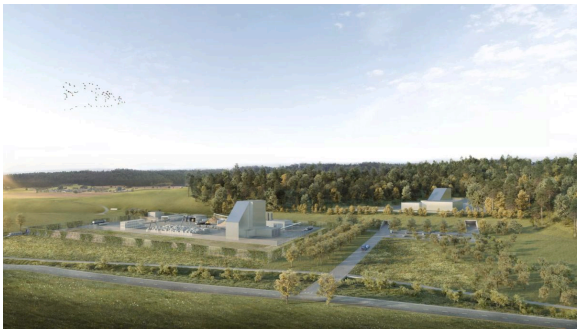
GROUNDWATER FLOW AROUND STADEL
(Source: tiefenlager-zuerich.ch)

- Surface facility site selected by Nagra (main entrance to waste disposal)
- Buildings
- Streets
- Contour Lines
- Forest
- Water
- The Flow Direction of Groudwater
- Shallow Groundwater Resource (<2m)
- Deep Broundwater Resource
- Groundwater Protection Area



VIDEO PART II IS TALKING ABOUT THE REPOSITORY IN SWITZERLAND
https://youtu.be/0-tihmlFF3A

NAGRAs Vision of the Repository Stadel



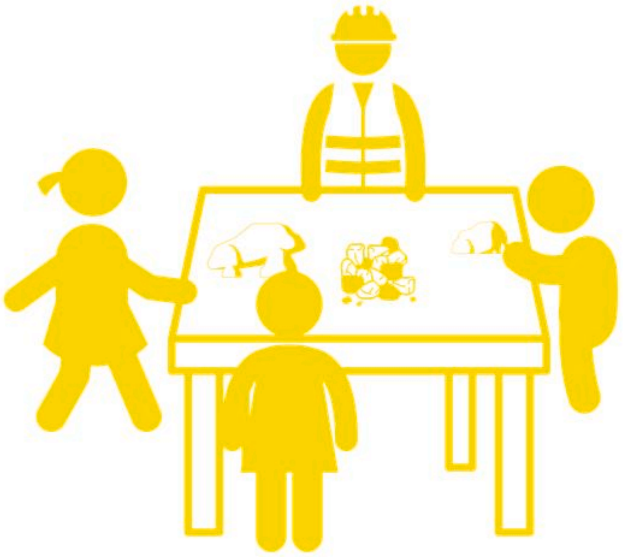
ORIGINAL RENDERING OF NUCLEAR REPOSITORY (Source: NAGRA)



EYE-LEVEL RENDERING OF REPOSITORY (Source: NAGRA)

The construction site of the repository will conquer the landscape of Stadel for years. Eventually after being finished, it will be a permanent mark on the scenery. The repository will lead to the demolition of some compensated farms and create an enclosed area indefinitely, from a human-life perspective. Acknowledging Nagra's renderings, it is important to note that the construction will bring noise, both permanent and temporary labor, and other hazards to a small town currently considered the peaceful heart of agriculture.

Project of the Century: A Ground Breaking Innovation



The repository construction will be one of the largest construction projects of Switzerland of the century. We chose to juxtapose it to the project of the longest tunnel in Switzerland, the Gotthardtunnel, to illustrate the effects on a concrete level.

The Gotthardtunnel project can be used to mirror the impact of Nördlich Lägern's infrastructure scheme on its surrounding region. While the tunnel transformed the area, it also significantly bolstered the economy by generating employment opportunities in the construction sector, which in turn benefited other industries. By excavation material measurement, the Gotthardtunnel was six times larger than the aforementioned project, symbolizing accommodations for 1,128,000 single-family homes for workers.



Drilling Maschine to create the Tunnel
Source: Swissinfo, Das Leben der Bauarbeiter im Gotthard-Tunnel



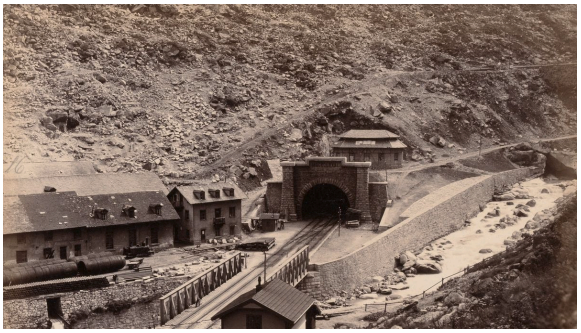
Workers village Gotthardtunnel
Source: Swissinfo, Das Leben der Bauarbeiter im Gotthard-Tunnel



Midnight Meal in the Container
behind the Drilling Head
Source: Swissinfo, Das Leben der Bauarbeiter im Gotthard-Tunnel



Entrance Göschenen around 1889
Source: Wikipedia, Gotthardtunnel



ENTRANCE GÖSCHENEN AROUND 1889
(Source: Wikipedia, Gotthardtunnel)



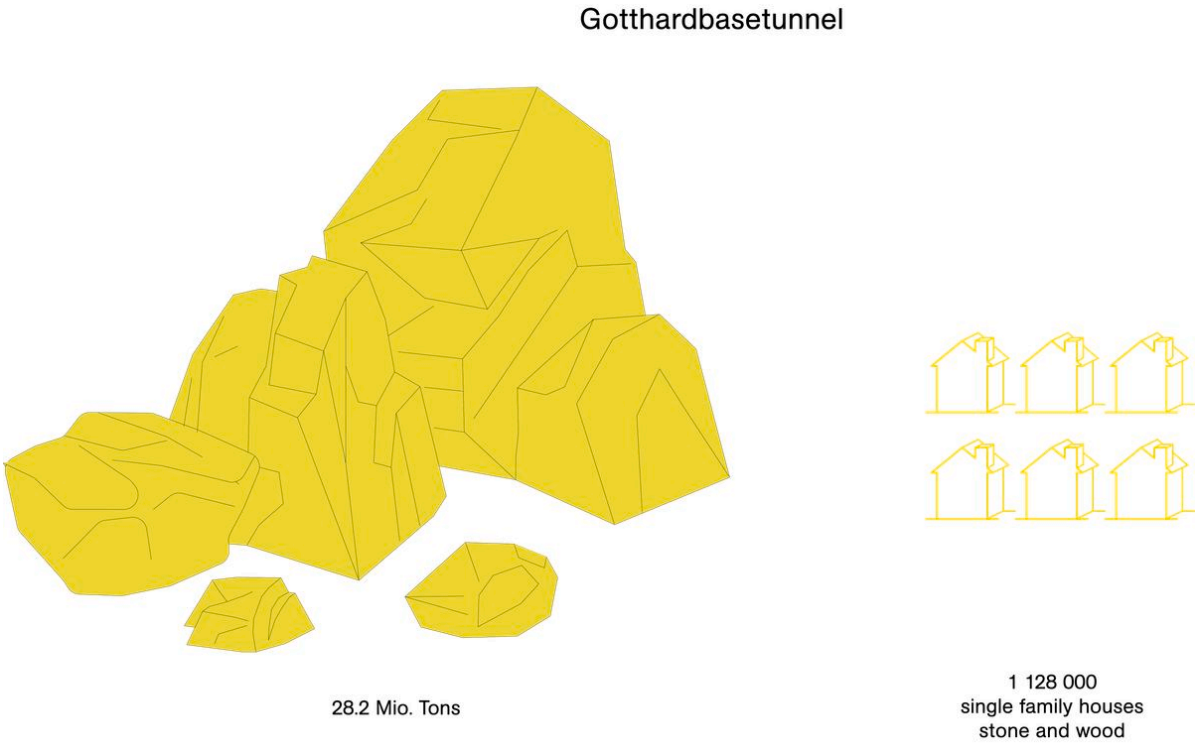
DRILLING MASCHINE TO CREAT THE TUNNEL
(Source: Swissinfo, Das Leben der Bauarbeiter im Gotthard-Tunnel)



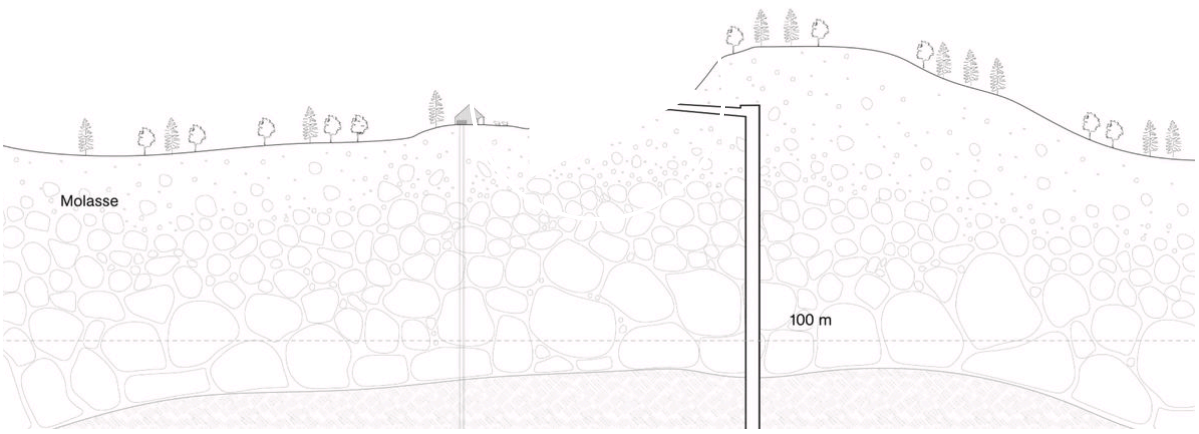
WORKERS VILLAGE GOTTHARDTUNNEL
(Source: Swissinfo, Das Leben der Bauarbeiter im Gotthard-Tunnel)



MIDNIGHT MEAL IN THE CONTAINER BEHIND THE DRILLING HEAD
(Source: Swissinfo, Das Leben der Bauarbeiter im Gotthard-Tunnel)



Excavation Material Gotthardtunnel



SECTION OF THE REPOSITORY

https://youtu.be/oP0l9cGhWeA

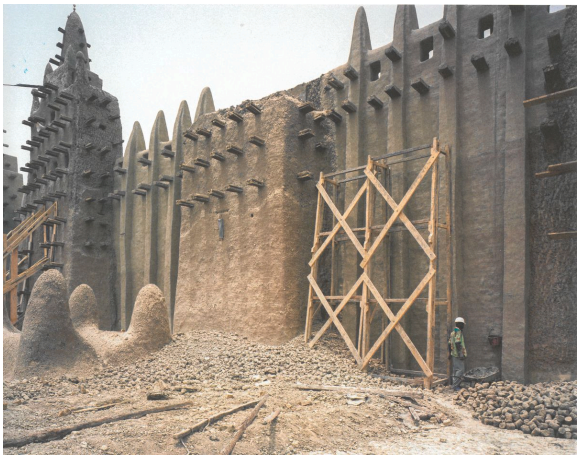
Shifting Future Landscapes: Pioneering Traditions



Stadel, as a neighboring city of repository placement, has encountered both acceptance and objection of high level waste repository. While the toxicity of the waste is a major concern, the main objection centers on the repository’s impact on the community.

Clay Mosque Dienne, Mali

The point of reference we suggest can be found from Djenne, Mali in the project of Clay Mosque. It has been kept up for 600 years without it being destroyed or forgotten.











LOCAL WORKERS ARE
MAINTAINING THE MOSQUE
(Source: ARCH+ 253, The Great Repair, Page 80-83)



CONSTRUCTION SITE ALREADY MAINTAINED
(Source: ARCH+ 253, The Great Repair, Page 80-83)



CONSTRUCTION SITE HAS TO BE MAINTAINED
(Source: ARCH+ 253, The Great Repair, Page 80-83)



LOCAL WORKERS ARE MAINTAINING THE MOSQUE
(Source: ARCH+ 253, The Great Repair, Page 80-83)

Materiality and It's Maintainance

Regardless of whether the impact at the microscale leans towards positivity or negativity, it is indisputable that the region will undergo significant changes. To address these changes, we propose a tradition of maintenance and retrievability to ensure ongoing awareness and cultural preservation across generations.

In Stadel, the materiality of the region could provide a point of view for keeping up a culture of knowledge. The materials fostered could include the knowledge surrounding Quartz, Granite and Opalinus Clay, which would also promote pride among the workers and residents of Stadel.



Quartz



Granit



Opalinus Clay







QUARTZ





OPALINUS CLAY



GRANITE





GRAVEL PIT STADEL
(Source: kibag.ch, der Kies rollt im Kieswerk Stadel)



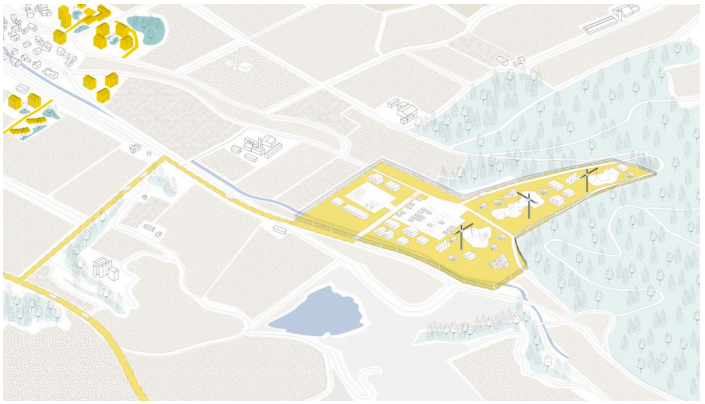


Development Before During and After the Construction of the Repository in Stadel (Our Vision)



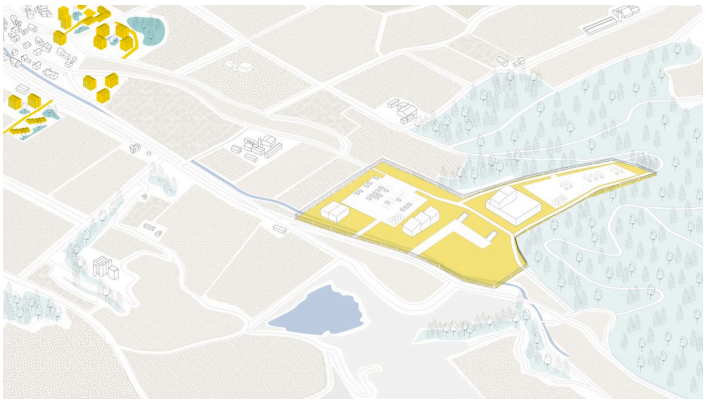
STADEL TODAY

Buildings under the threat of demolishment



STADEL DURING REPOSITORY CONSTRUCTION

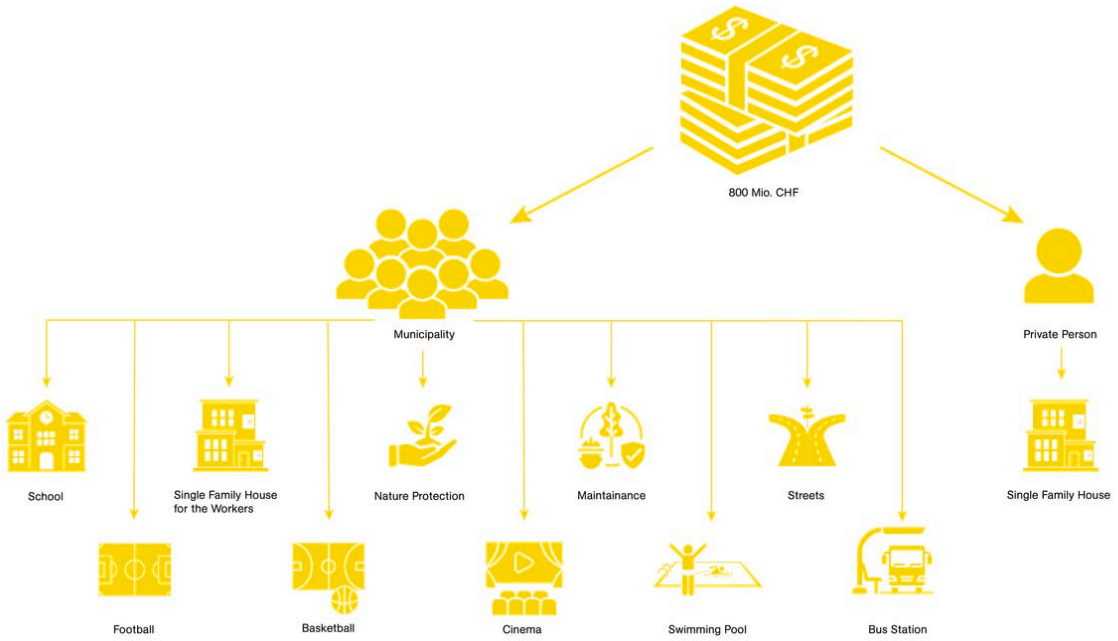
Areas of change



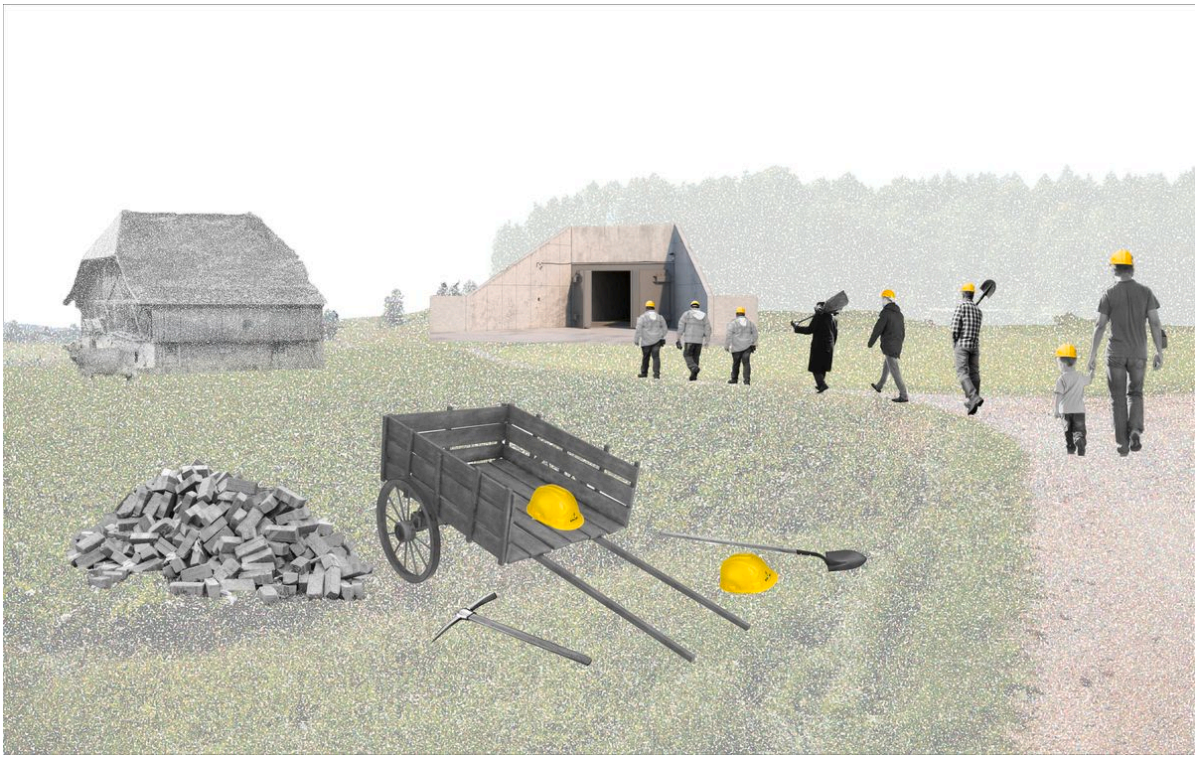
STADEL WITH THE FINISHED REPOSITORY SITE AND NEW HOUSING

Financial Reimbursement for the Municipality Stadel

The repository is anticipated to bring more than just its own presence; it will likely introduce various developments such as employment opportunities, residential complexes, educational institutions, transportation enhancements, and more to the municipality of Stadel. Moreover, the region is slated to receive 800 million francs in funding. While farmers are expected to receive compensation for their fields, the allocation of these funds within the municipality remains a complex political issue. Possible areas for funding allocation include education, housing, transportation, infrastructure improvement, and environmental conservation efforts.



FINANCIAL REIMBURSEMENT FOR THE MUNICIPALITY STADEL
(Proposal for different Usages)

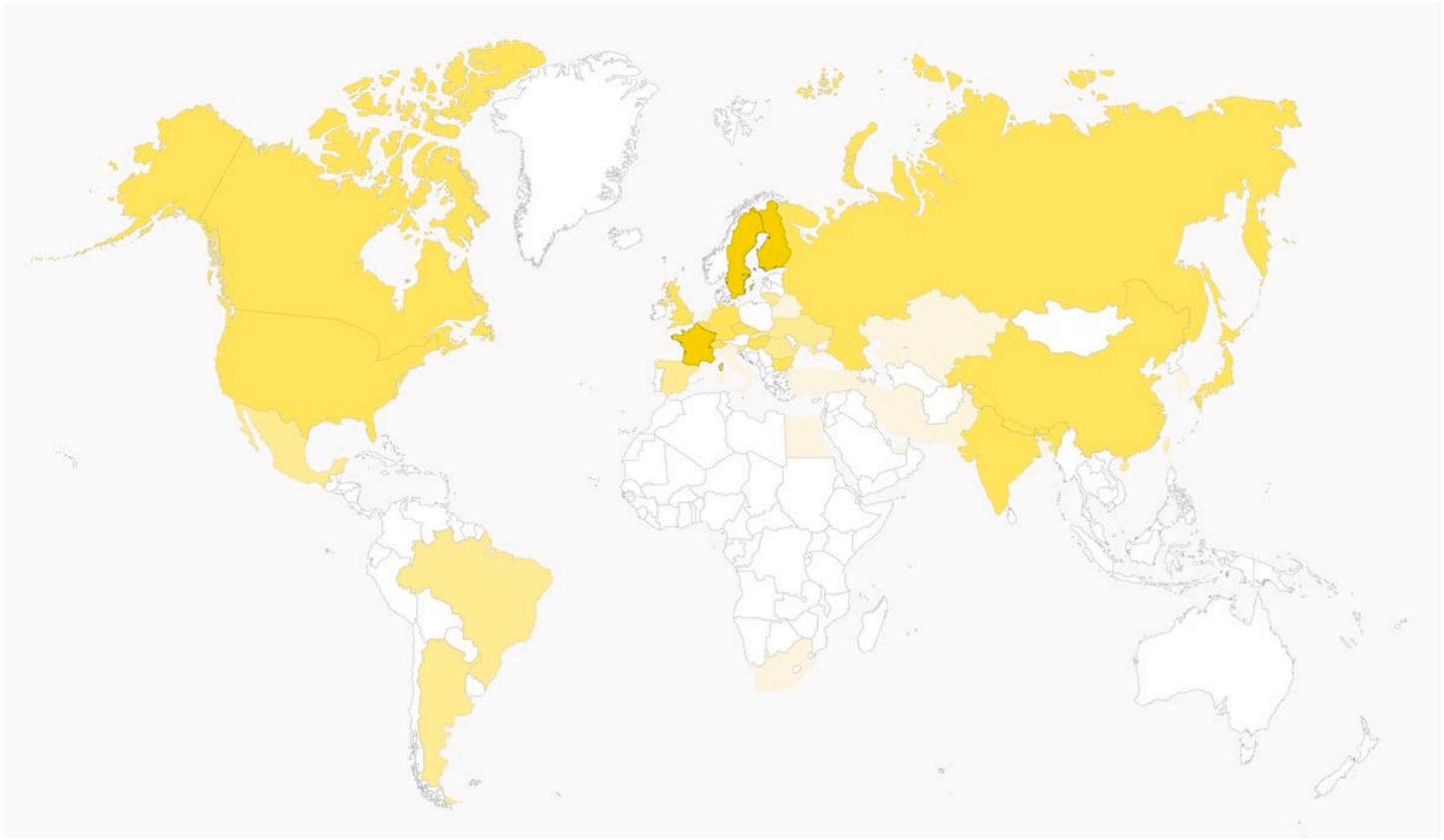


Possible Future Tradition Collage

Worldwide Repository Dynamics: Trends and Perspectives



As said, high level waste repositories are currently a highly researched topic all around the world. As a pioneer in high-level radioactive waste repositories, Switzerland has the opportunity to establish a repository culture.

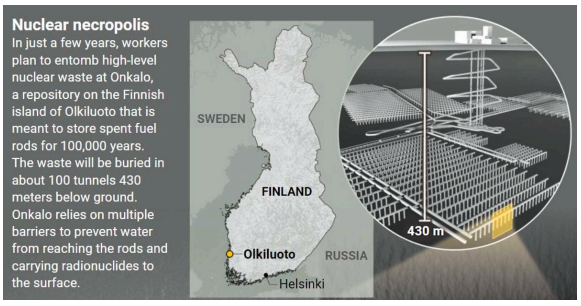


WORLD MAP OF FUTURE REPOSITORY PLANS
(Source: mining-report.de/internationale Endlagerprojekte im Vergleich)

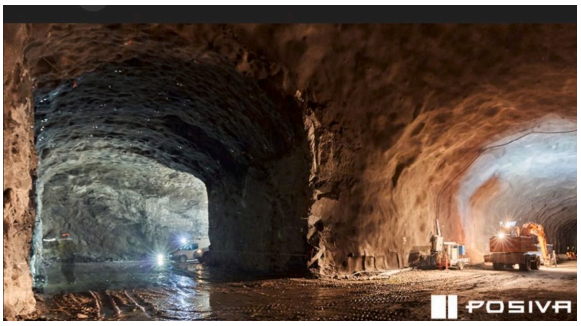
- Countries with designated repository sites
- Countries with long-term concrete repository projects
- Countries with long-term unspecified repository plans
- Countries without discernible repository plans

Case Study Finland: The World's First Deep Repository

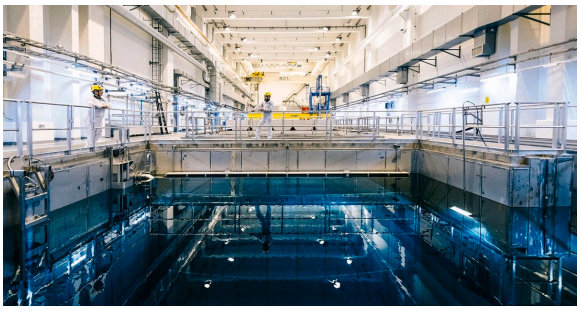
The first case study of siting will be in Finland, in the project of Onkalo. The ground material will not be similar to Switzerland, but the political background of almost 30 years of decisive handling in Eurajoki, near to the cities of Rauma and Pori, can work as a doctrine to Swiss repository culture.



Location of the Deep Repository in Finland



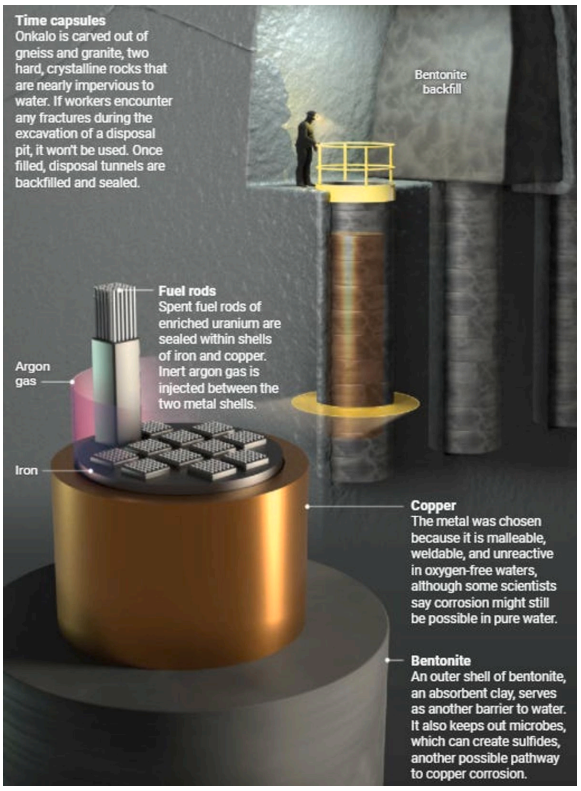
450m Deep Tunnel



Cooling Pool for the Fuel Rods



Uranium Fuel Rods





Construction Site



LOCATION OF THE FINAL REPOSITORY IN FINLAND



CONSTRUCTION SITE
(Source: arutzshevatuzarapost.substack.com/p/finland-is-set-to-open-the-worlds)



URANIUM FUEL RODS
(Source:
arutzshevatuzarapost.substack.com/p/finland-is-set-to-open-the-worlds)

In concluding our research, we emphasize the significance of retrievability and the cultivation of knowledge. However, as discussions persist, we propose adding some considerations to the public discourse. While there is a high likelihood of discovering a safe repositioning solution, there is a risk of prematurely assuming that the nuclear power debate is resolved. Perceiving nuclear energy as a safe and environmentally friendly option may inadvertently discourage the implementation of other necessary measures, such as lifestyle changes, to combat the climate crisis. Despite initial concerns revolving around nuclear fears within communities, our research underscores the imperative for action. Addressing the climate crisis necessitates comprehensive action across all aspects of life.

SOURCES

- Andreas Bucher. “Die Nationale Risikoanalyse”. 2020. https://blog.alertswiss.ch/de/gefahren-kennen/die-nationale-risikoanalyse-2020/
- ARCH+, number 253. “The Great Repair: Politiken der Reparatur Gesellschaft”. p.80-p.83. 2023.
- AXPO. “Media releases”. 2013-2024. https://www.axpo.com/ch/de/ueber-uns/medien-und-politik/medienmitteilungen.html
- AXPO. “Our key financial figures”. 2022-2023. https://www.axpo.com/ch/en/about-us/investor-relations.html
- Bloomberg. “Switzerland to Use Nuclear Energy Longer Than Expected”. 7th of November 2023. Accessed in May 2024. https://www.bloomberg.com/news/articles/2023-11-07/switzerland-to-keep-using-nuclear-energy-longer-than-expected
- Carlo L. Vinoya, Aristotle Ubando, Alvin B. Culaba, Wei-Hsin Chen. “State-of-the-Art Review of Small Modular Reactors”. April 2023. https://www.researchgate.net/publication/369764690_State-of-the-Art_Review_of_Small_Modular_Reactors
- Cembureau: The European Cement Association. “The Secret of the World’s longest tunnel”. 2010. Accessed in May 2024. https://useofcement.cembureau.eu/2018/04/06/the-secrets-of-the-worlds-longest-concrete-tunnel/
- ee-news. “SES: Strommix von Axpo, Alpiq, BKW und Repower ist deutlich klima- und umweltschädlicher als der Schweizer Produktionsmix”. 20th of July 2021. Accessed in March 2024. https://www.ee-news.ch/de/article/46580/ses-strommix-von-axpo-alpiq-bkw-und-repower-ist-deutlich-klima-und-umweltschadlicher-als-der-schweizer-produktionsmix
- Eidgenössisches Nuklearsicherheitsinspektorat ENSI. “Nuclear Power Plants”. 2024. Accessed 2024. https://www.ensi.ch/en/topic/nuclear-power-plants/
- Eidgenössisches Nuklearsicherheitsinspektorat ENSI. “Sachplan geologische Tiefenlager”. Updated in 2024. Accessed in April 2024. https://www.ensi.ch/de/aufsicht/entsorgung/geologische-tiefenlager/das-sachplanverfahren/#:~:text=Der%20%C2%ABSachplan%20geologische%20Tiefenlager%C2%BB%20legt,Zusammenarbeit%20zwischen%20Bund%20und%20Kantonen
- EU Commission. “Small Modular Reactors explained”. 2023. https://energy.ec.europa.eu/topics/nuclear-energy/small-modular-reactors/small-modular-reactors-explained_en
- Forbes, James Conca. “Finland Breaks Ground On World’s First Deep Geologic Nuclear Waste Repository”. 31st of May 2021. Accessed in April 2024. https://www.forbes.com/sites/jamesconca/2021/05/31/finland-breaks-ground-on-its-deep-geologic-nuclear-waste-repository
- Hannah Ritchie. “How does the land use of different electricity sources compare?”. June 2022. https://ourworldindata.org/land-use-per-energy-source
- Hannah Ritchie, Pablo Rosado and Max Roser. “Energy Production and Consumption”. July 2022. https://ourworldindata.org/energy-production-consumption
- Helsingin Sanomat. “Lauttasaaren viereen väläytetään pientä ydinvoimalaa – Näin vastaavat asukkaat”. Marika Holappa. 22nd of June 2022. https://www.hs.fi/kaupunki/art-2000009667794\.html
- International Atomic Energy Agency (IAEA). “Fusion – Frequently asked questions”. 2023. https://www.iaea.org/topics/energy/fusion/faqs
- International Atomic Energy Agency. “What are Small Modular Reactors (SMRs)?”. September 2023. https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs
- Kanton Zürich. “Standortregion Nördlich Lägern”. Updated in 2024. Accessed in April 2024. https://tiefenlager-zuerich.ch/standortportrait/nordlich-lagern/#slider-2
- KIBAG. “Der Kies rollt im Kieswerk Stadel”. 4th of May 2022. Accessed in May 2024. https://www.kibag.ch/de/news/beitraege/der-kies-rollt-im-kieswerk-stadel.html
- Mining Report, Dr. Franck Charlier. “Internationale Endlager Projekte im Vergleich”. 2022. Accessed in May 2024. https://mining-report.de/internationale%20Endlagerprojekte%20im%20Vergleich/
- NAGRA. “Das geologische Tiefenlager: Abfälle im Untergrund sicher entsorgen”. 2015. Accessed in April 2024. https://nagra.ch/wissensforum/das-geologische-tiefenlager/
- Nagra. “Der Standort für das Tiefenlager”. 2015. Accessed in April 2024. https://nagra.ch/bilder-und-karten-zum-download/
- Noun Project. “Noun Project: Free Icons and Stock Photos for Everything”. December 2010. Accessed in May 2024. https://thenounproject.com/
- Office of Nuclear Energy. “The Ultimate Facts Guide to Nuclear Energy”. (n. d.). https://www.energy.gov/sites/default/files/2019/01/f58/Ultimate%20Fast%20Facts%20Guide-PRINT.pdf
- Salvatores. “Spent nuclear fuel decay”. Wikipedia page. 2006. Accessed April 2024. https://fr.m.wikipedia.org/wiki/Fichier:Spent_nuclear_fuel_decay_sievert.jpg
- Schweizerische Energie-Stiftung SES. “Simulation eines schweren Unfall in Kernkraftwerk Beznau”. January 2017. Accessed in March 2024. https://energiestiftung.ch/files/energiestiftung/publikationen/Piguet%20Studie%202019/170828%20Beznau%20DE.mp4
- Schweizerische Energie-Stiftung SES. “Simulation eines schweren Unfall in Kernkraftwerk Gösgen”. January 2017. Accessed in March 2024. https://energiestiftung.ch/files/energiestiftung/publikationen/Piguet%20Studie%202019/170119_Goesgen%20DE.mp4
- Schweizerische Energie-Stiftung SES. “Simulation eines schweren Unfall in Kernkraftwerk Leibstadt”. January 2017. Accessed in March 2024. https://energiestiftung.ch/files/energiestiftung/publikationen/Piguet%20Studie%202019/170129%20Leibstadt%20DE.mp4
- Swiss Info. “Das Leben der Bauarbeiter im Gotthard-Tunnel”. 17th of July 2009. Accessed in April 2024. https://www.swissinfo.ch/ger/wissenschaft/das-leben-der-bauarbeiter-im-gotthard-tunnel/7514268

- Swiss Info. “The nuclear future of Switzerland”. 2011. Accessed in April 2024. https://www.youtube.com/watch?v=iV4GBs4K76E
- Wikipedia authors. “Liste der Kernkraftwerke”. Wikepedia online. 17th of March 2024. Accessed 31 Mars 2024. https://de.wikipedia.org/wiki/Liste_der_Kernkraftwerke
- World Nuclear Association. “Small Nuclear Power Reactors”. February 2024. https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx
- World Nuclear Association. “Storage and Disposal of Radioactive Waste”. 2016-2023. https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx
- World Nuclear Association. “What is nuclear waste, and what do we do with it?”. 2016-2023. https://world-nuclear.org/nuclear-essentials/what-is-nuclear-waste-and-what-do-we-do-with-it.aspx#:~:text=Used%20nuclear%20fuel%20is%20kept,allow%20the%20fuel%20to%20cool

This work by Eeva Rosenqvist, Tabea Brochier, and Andrei Zündel was created as part of the design studio Kraftwerk Schweiz at ETH Zurich in Spring 2024. The PDF is intended for educational purposes only. Its commercial distribution is strictly forbidden.

© 2025, Architecture of Territory

Architecture of Territory
Professor Milica Topalović

TEACHING TEAM
Dorothee Hahn
Milica Topalović
Jakob Walter
Jan Westerheide

Prof. Milica Topalović
ETH Zurich
ONA G41
Neunbrunnenstrasse 50
8093 Zurich
Switzerland
+41 (0)44 633 86 88
www.topalovic.arch.ethz.ch