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

Kraftwerk Schweiz
Spring 2024

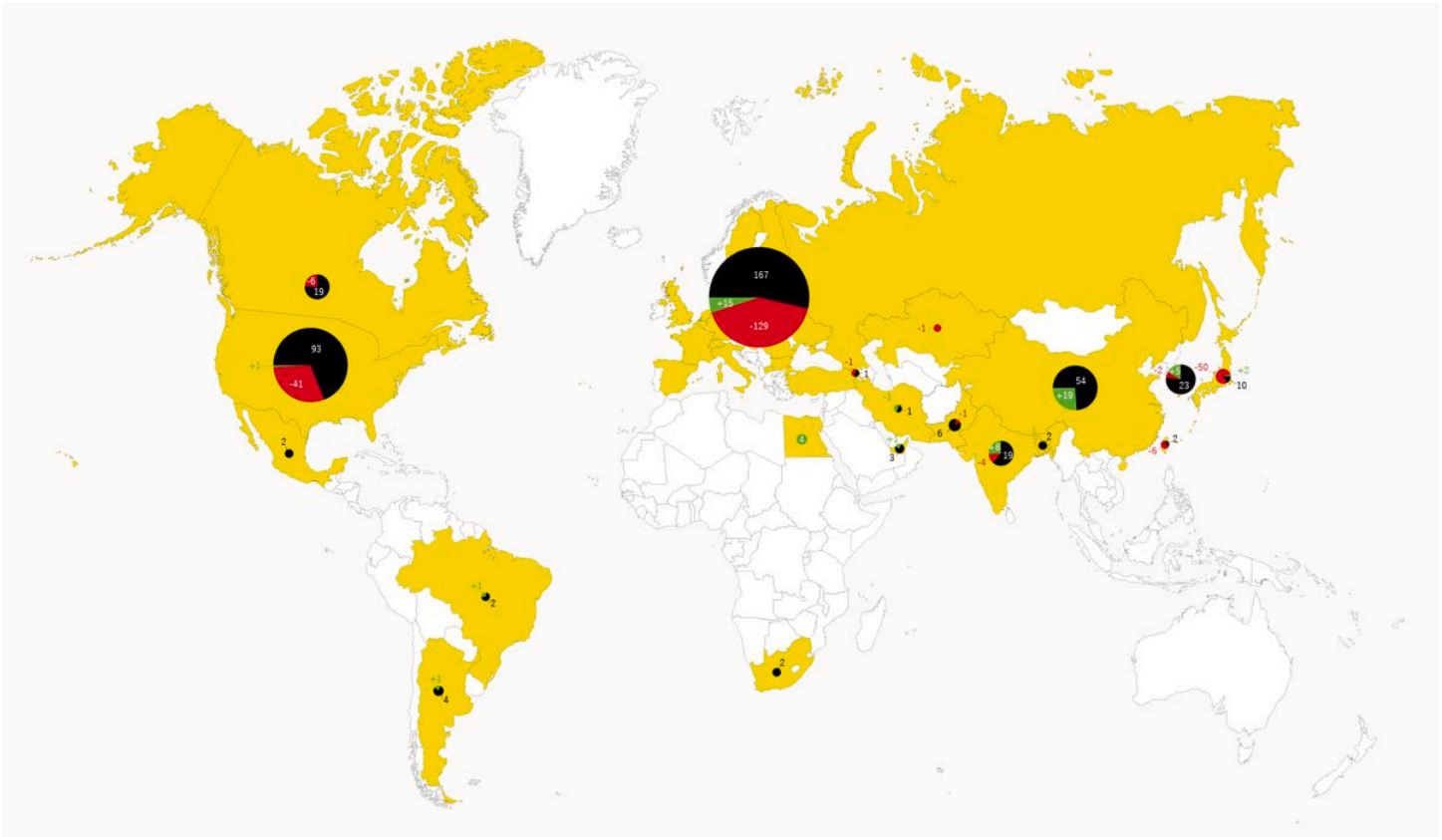
Atlas

Nuclear and Axpo

Eeva Rosenqvist, Tabea Brochier, and Andrei Zündel

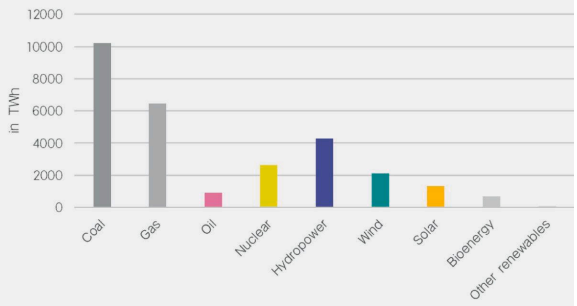
Today, the concrete cooling towers of nuclear power plants seamlessly blend into our landscape, yet seventy years ago, such facilities did not exist. It is therefore essential to understand the rapid development of this industry. Originally conceived for military applications through the Manhattan Project, nuclear energy has since evolved to encompass electricity generation for civilian purposes. The inception of commercial nuclear power began with the inauguration of “Calder Hall” in England in 1957, marking the beginning of a global trend that extended across Europe and America. Today, nuclear energy is harnessed by 32 countries, constituting approximately 10 % of the world’s electricity production.

The Atom: A Global Energy Source

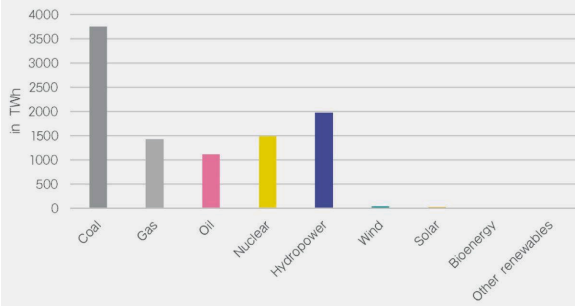


Status of nuclear power plants worldwide.

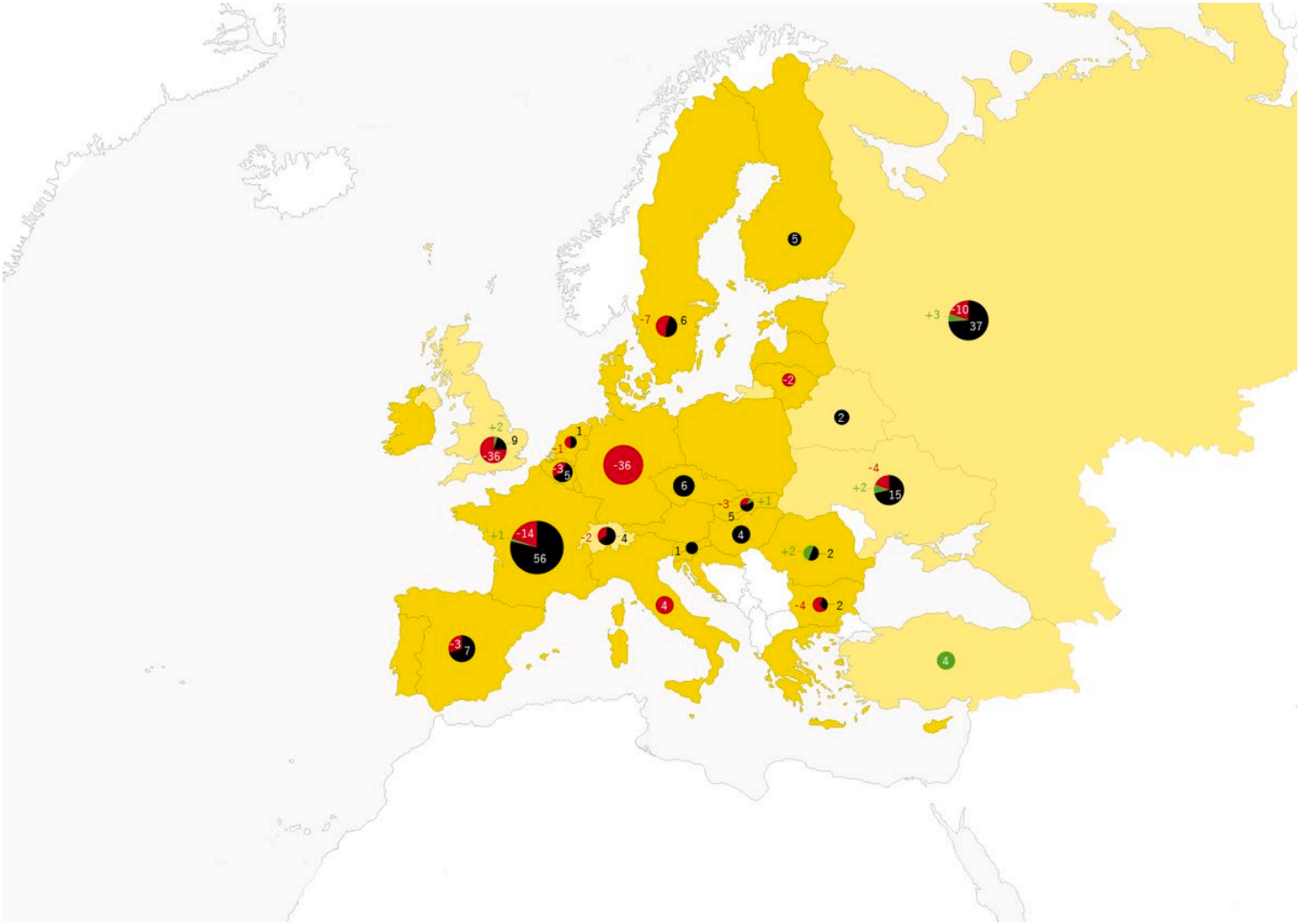
Countries with nuclear power plants
Number of active nuclear power plants.
Number of power plants under construction
Number of decommissioned power plants



Global electricity production per source in 1985.

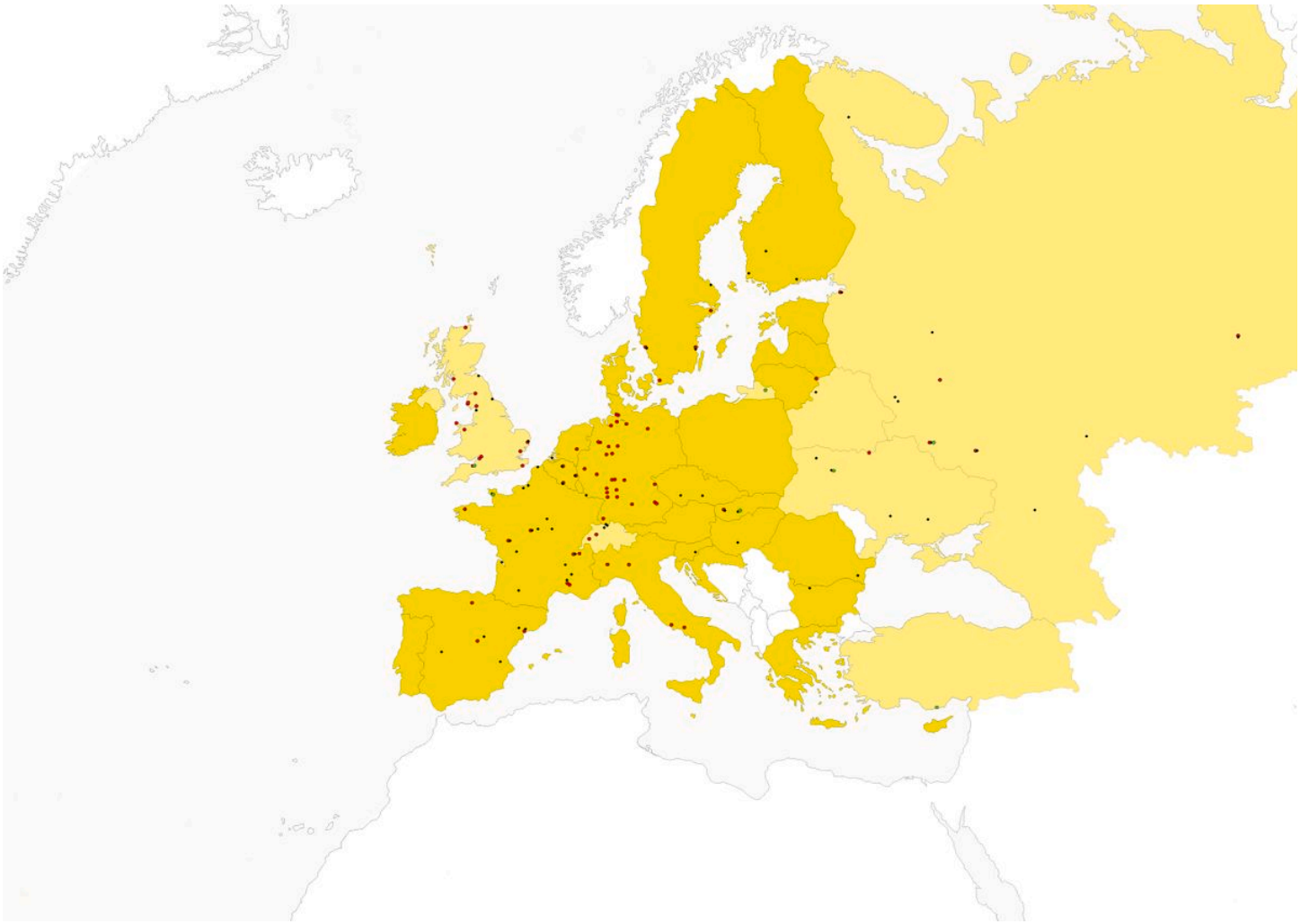


Global electricity production per source in 2022.



Status of nuclear power plants in Europe.

- Number of active nuclear power plants
- Number of nuclear power plants under construction
- Number of decommissioned nuclear power plants
- EU countries
- Countries that have nuclear power plants



Locations of nuclear power plants in Europe.

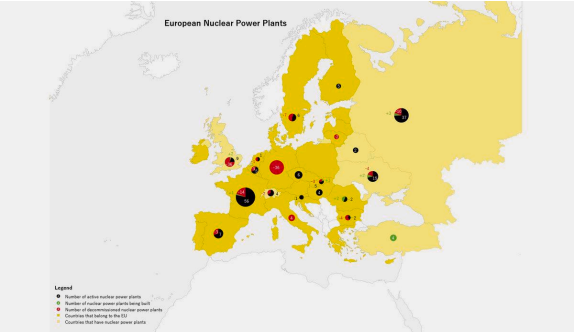
- Active nuclear power plants
- Nuclear power plants under construction
- Decommissioned nuclear power plants
- EU countries
- Countries that have nuclear power plants

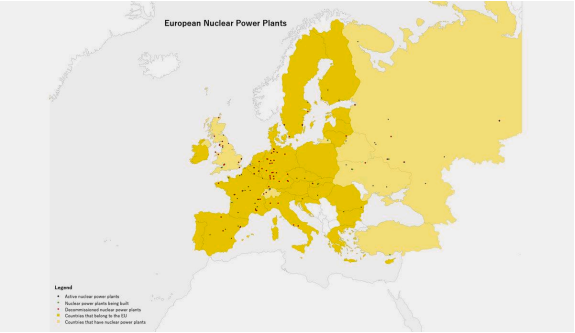


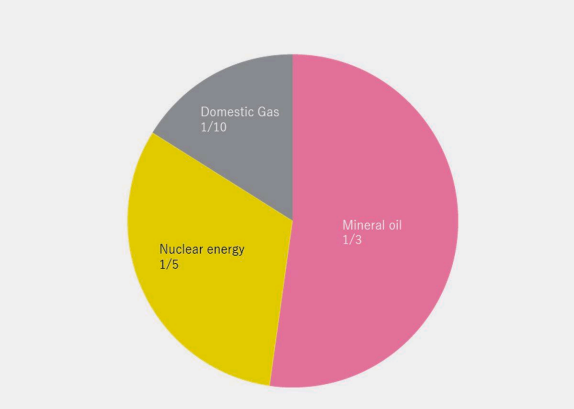
AKW LEIBSTADT, JWS

NUCLEAR ENERGY IN SWITZERLAND

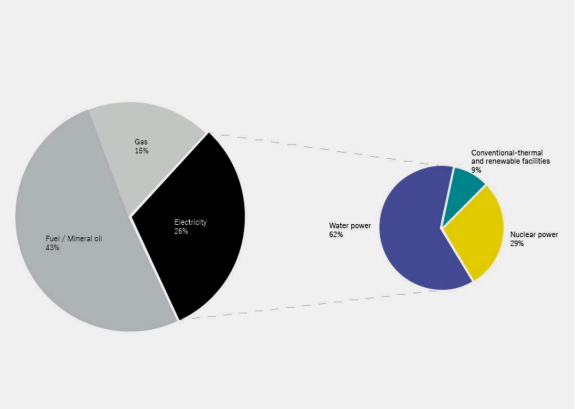
In Switzerland, the nuclear industry comprises four operational power plants, namely Beznau I & II, Gösgen, and Leibstadt, contributing significantly to the country's energy mix.







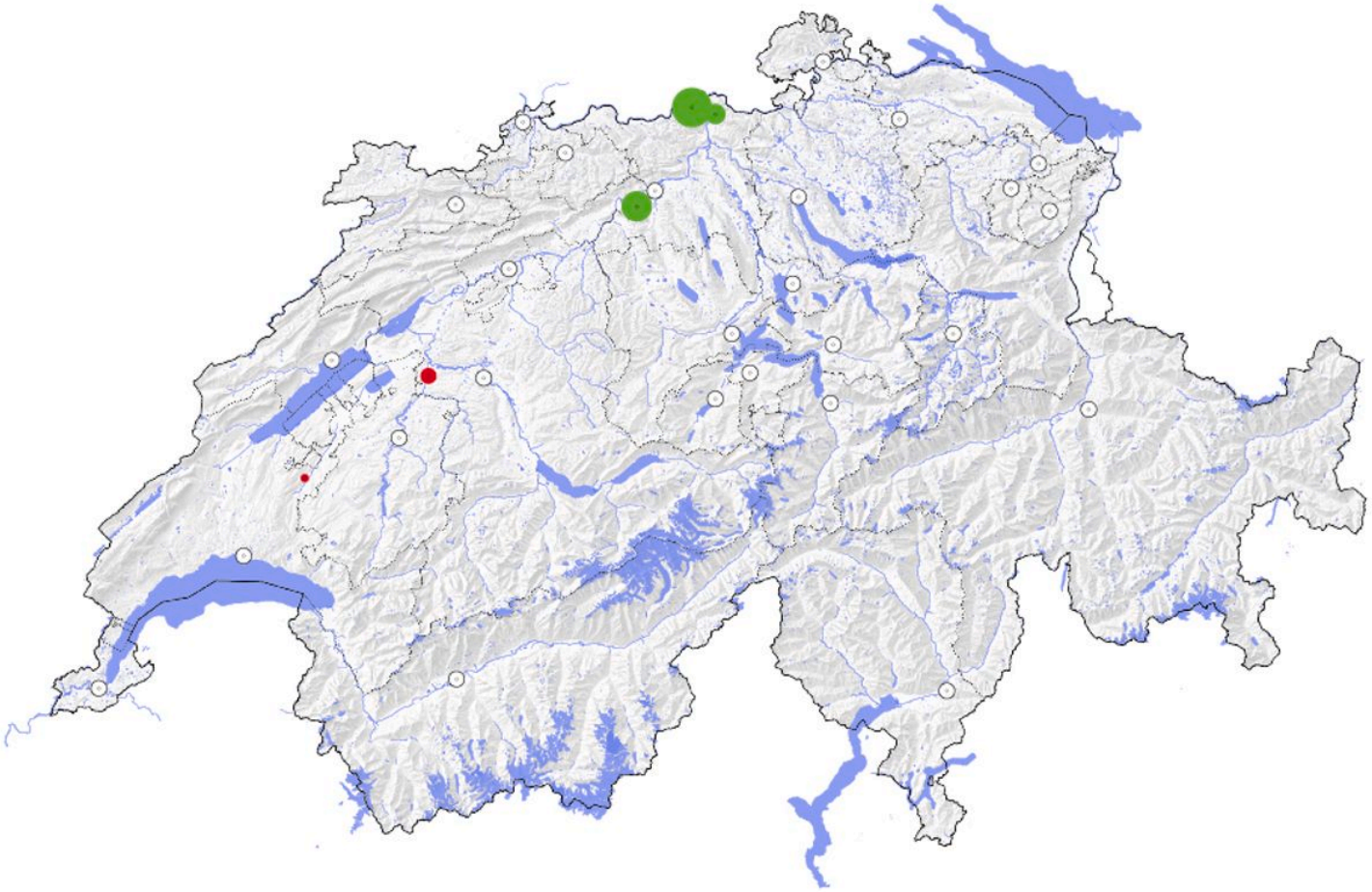
NON-RENEWABLE ENERGY MIX OF SWITZERLAND



ENERGY USE IN SWITZERLAND

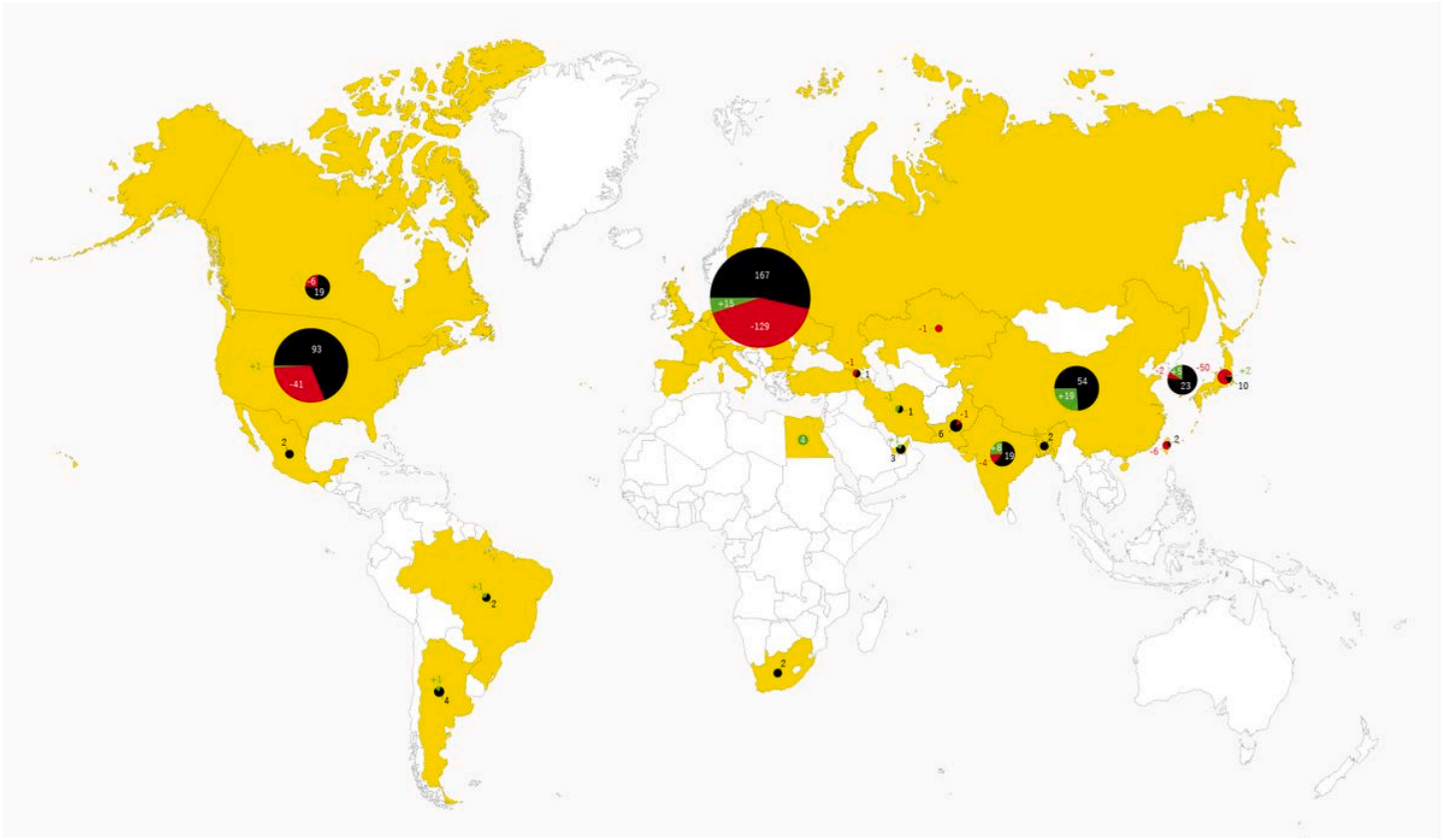


TIMELINE OF NUCLEAR POWER PLANTS IN SWITZERLAND



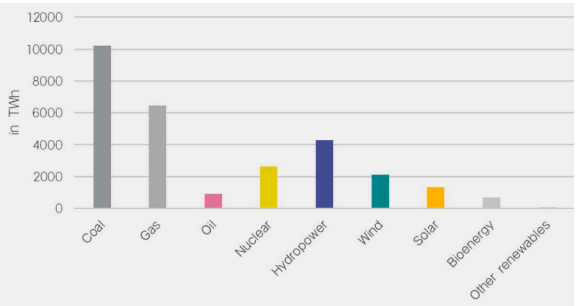
NUCLEAR POWER PLANTS IN SWITZERLAND
Active: Beznau I and II: 1130 MW; Gösgen: 3002 MW; Leibstadt: 3600 MW
Decommisioned: Mühleberg: 1097 MW; Lucens: 30 MW

Active nuclear power plants
Decommissioned nuclear power plants
Capital cities of Cantons
Water

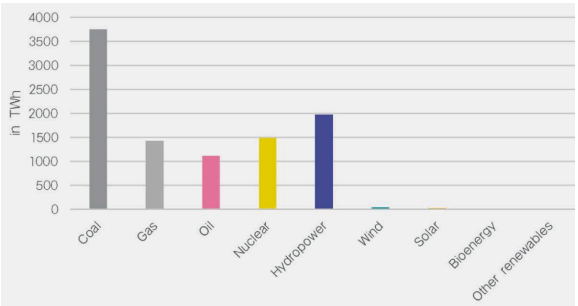


Status of nuclear power plants worldwide.

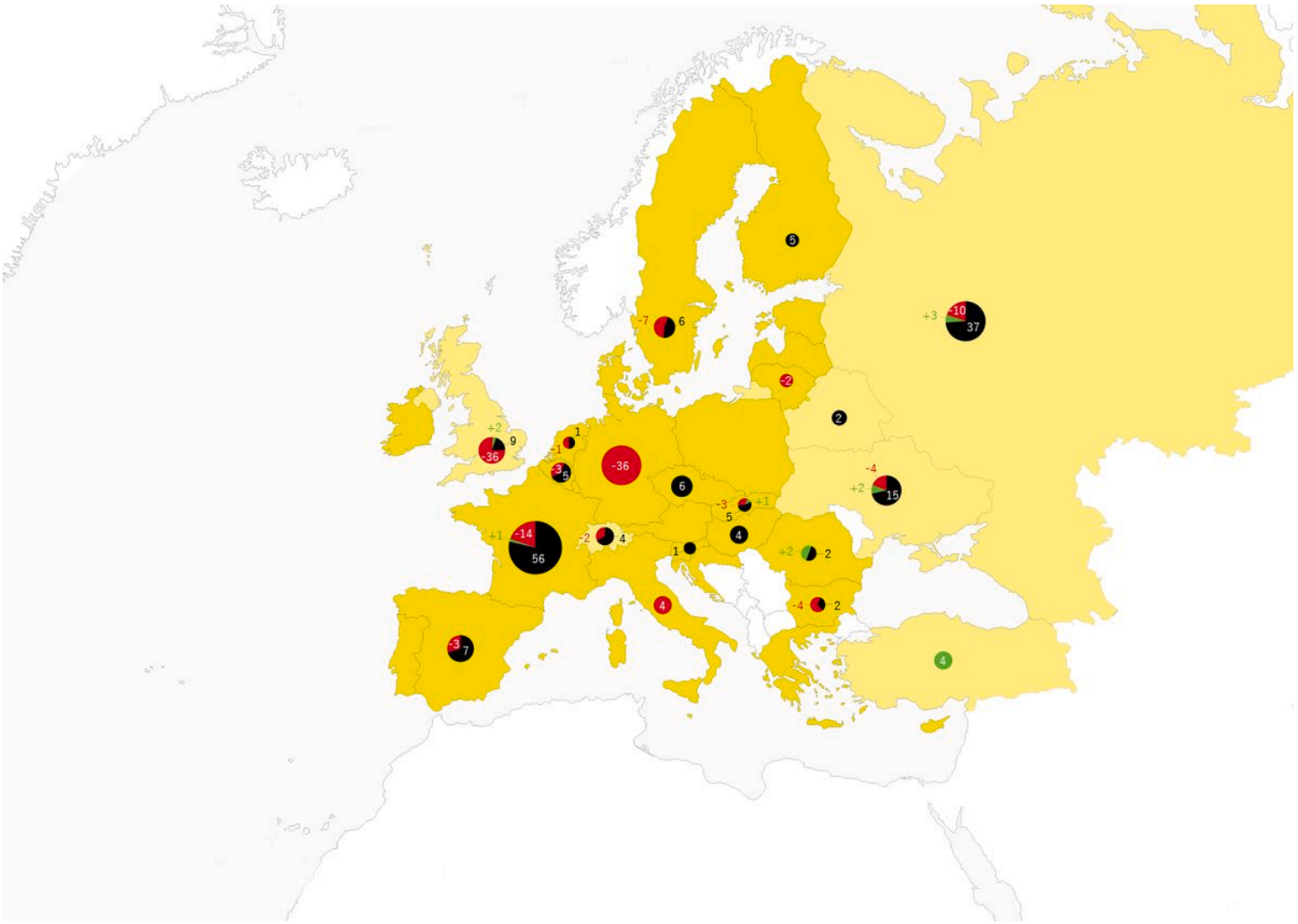
- Countries with nuclear power plants
- Number of active nuclear power plants.
- Number of power plants under construction
- Number of decommissioned power plants



Global electricity production per source in 1985.

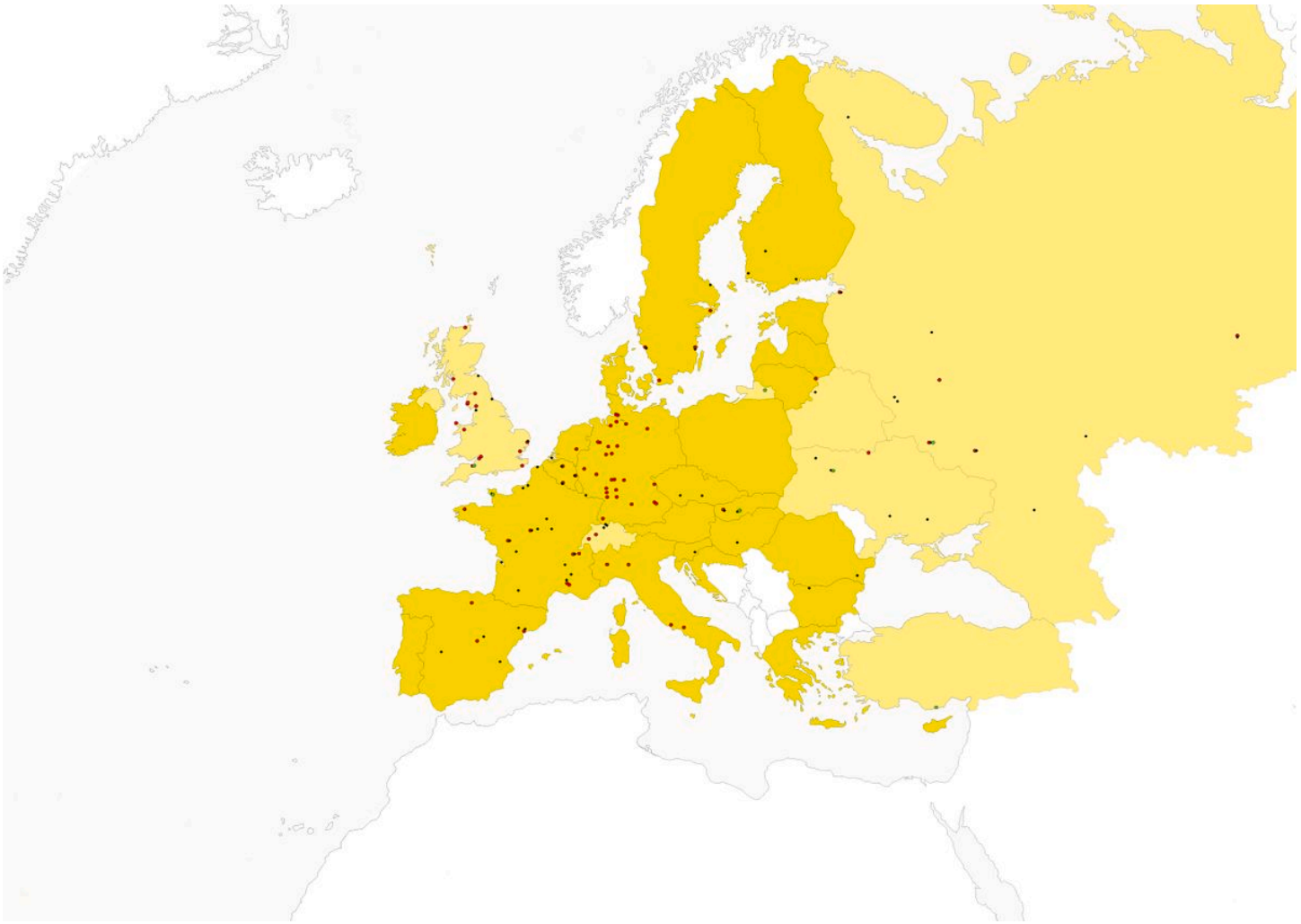


Global electricity production per source in 2022.



Status of nuclear power plants in Europe.

- Number of active nuclear power plants
- Number of nuclear power plants under construction
- Number of decommissioned nuclear power plants
- EU countries
- Countries that have nuclear power plants



Locations of nuclear power plants in Europe.

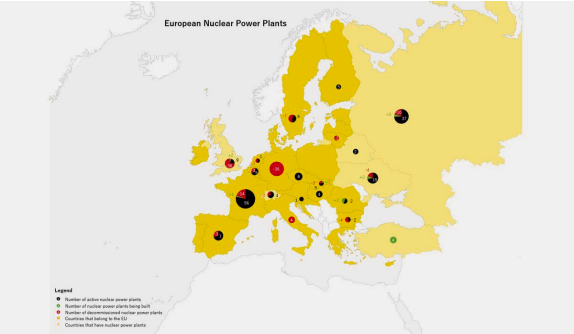
- Active nuclear power plants
- Nuclear power plants under construction
- Decommissioned nuclear power plants
- EU countries
- Countries that have nuclear power plants

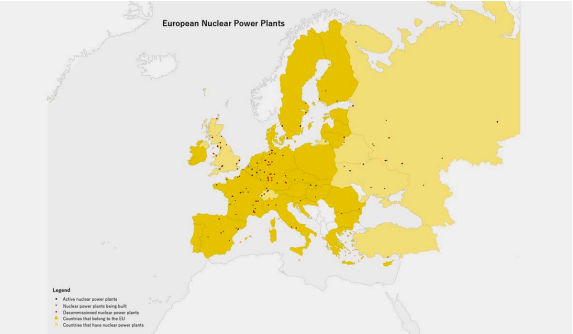


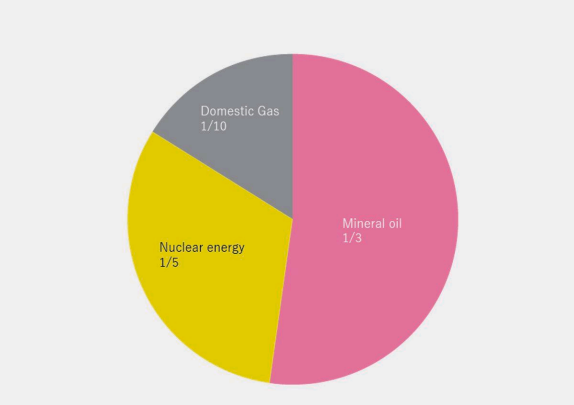
AKW LEIBSTADT, JWS

NUCLEAR ENERGY IN SWITZERLAND

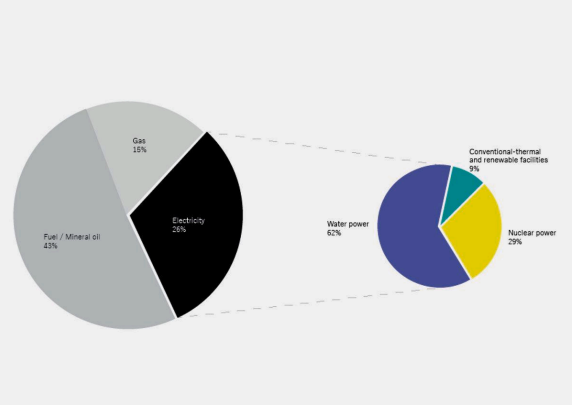
In Switzerland, the nuclear industry comprises four operational power plants, namely Beznau I & II, Gösgen, and Leibstadt, contributing significantly to the country's energy mix.







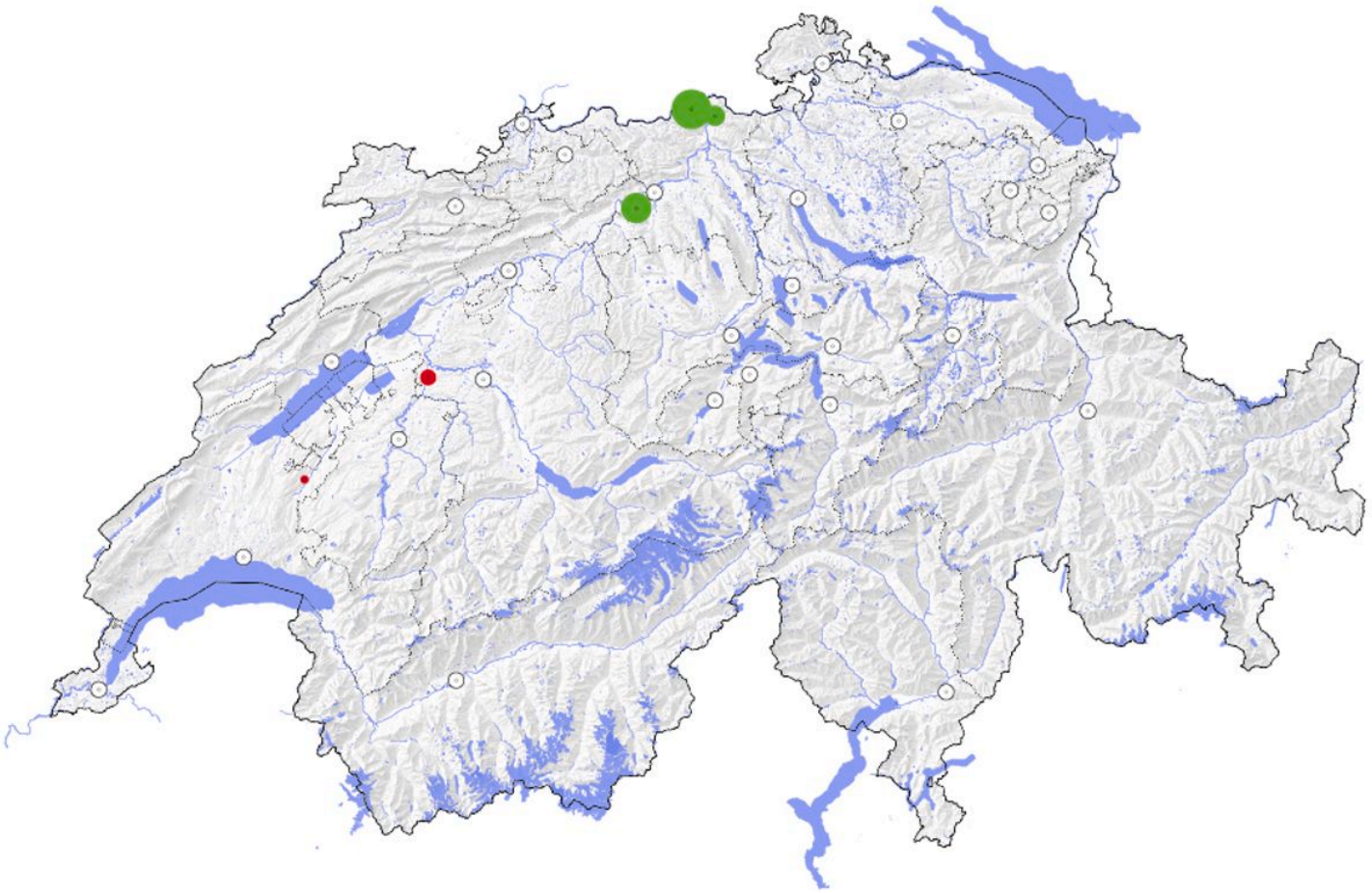
NON-RENEWABLE ENERGY MIX OF SWITZERLAND



ENERGY USE IN SWITZERLAND



TIMELINE OF NUCLEAR POWER PLANTS IN SWITZERLAND



NUCLEAR POWER PLANTS IN SWITZERLAND
Active: Beznau I and II: 1130 MW; Gösgen: 3002 MW; Leibstadt: 3600 MW
Decommisioned: Mühleberg: 1097 MW; Lucens: 30 MW

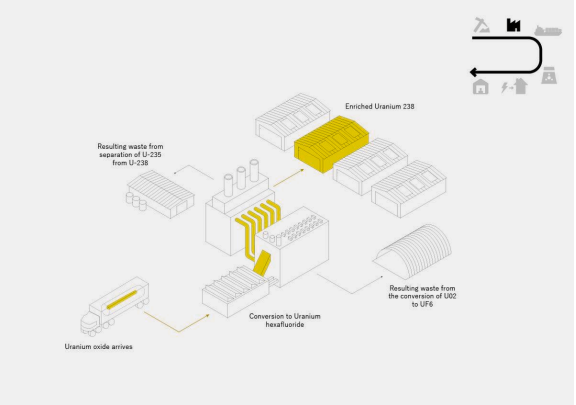
Active nuclear power plants
Decommissioned nuclear power plants
Capital cities of Cantons
Water

A Complex Logistic: Uranium from the Mine to the Repository

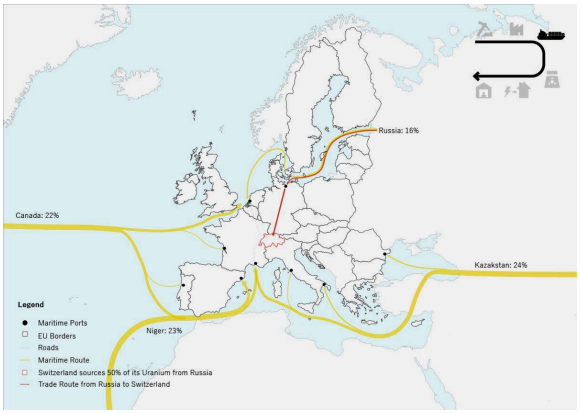
Although nuclear energy demands relatively small quantities of raw materials, the process of extracting and supplying uranium involves a complex infrastructure. Initially, uranium is sourced from large open mines predominantly situated in regions like Kazakhstan, Australia, and Canada. For every ton of uranium ore extracted, only 1 kilogram of pure uranium can be obtained. Subsequently, this uranium undergoes transportation to enrichment facilities, where the concentration of U-235 is artificially increased from 1% to 90%.



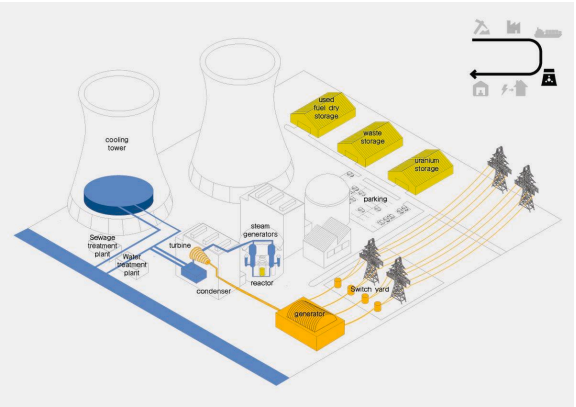
URANIUM EXTRACTMENT FROM THE MINE



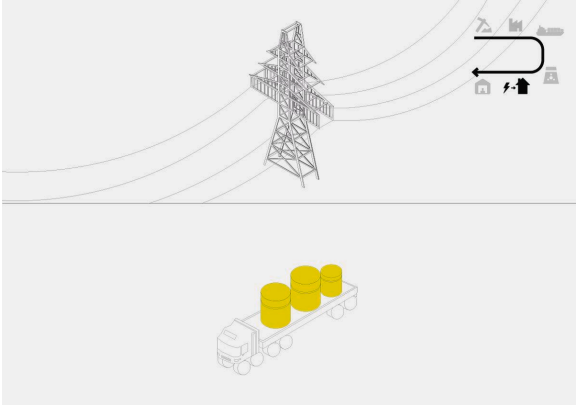
ENRICHMENT IN THE FACTORY



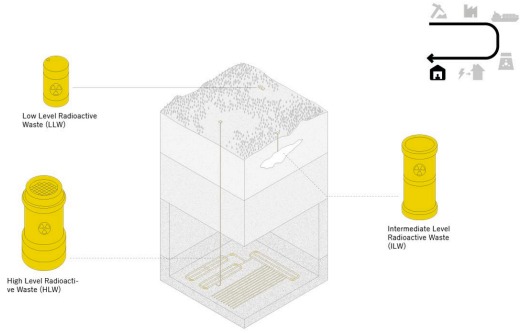
TRANSPORTATION TO EUROPE



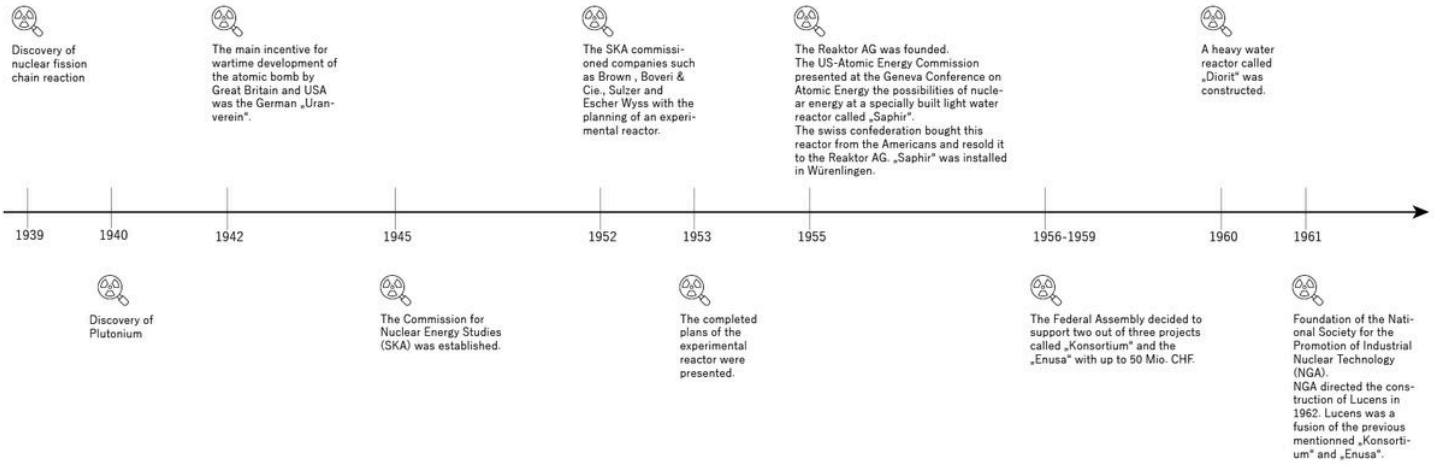
FISSION IN THE POWER PLANT



DISTRIBUTION TO SWISS ELECTRICITY NETWORK AND WASTE TRANSPORTATION

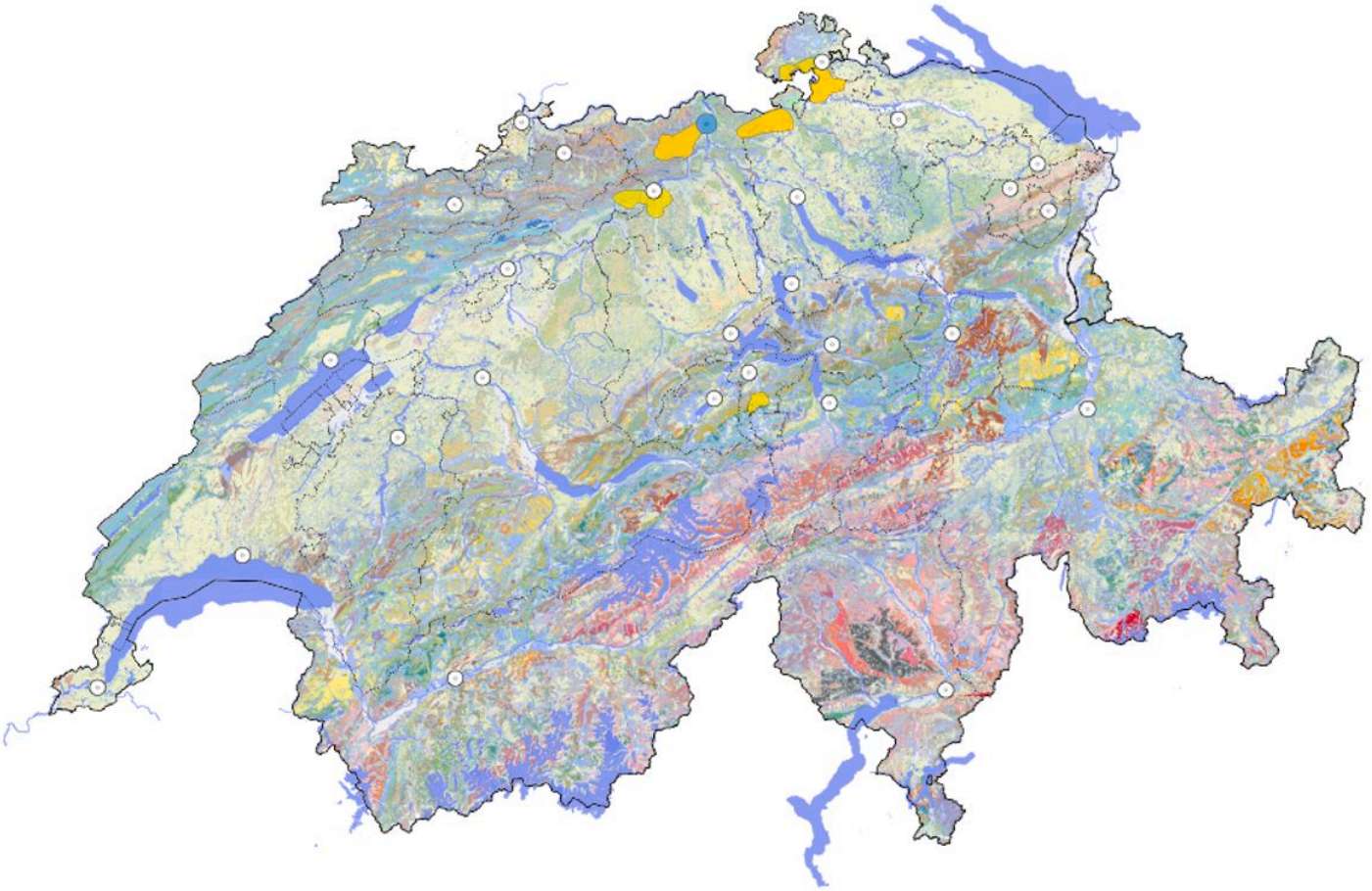


NUCLEAR WASTE STORAGE



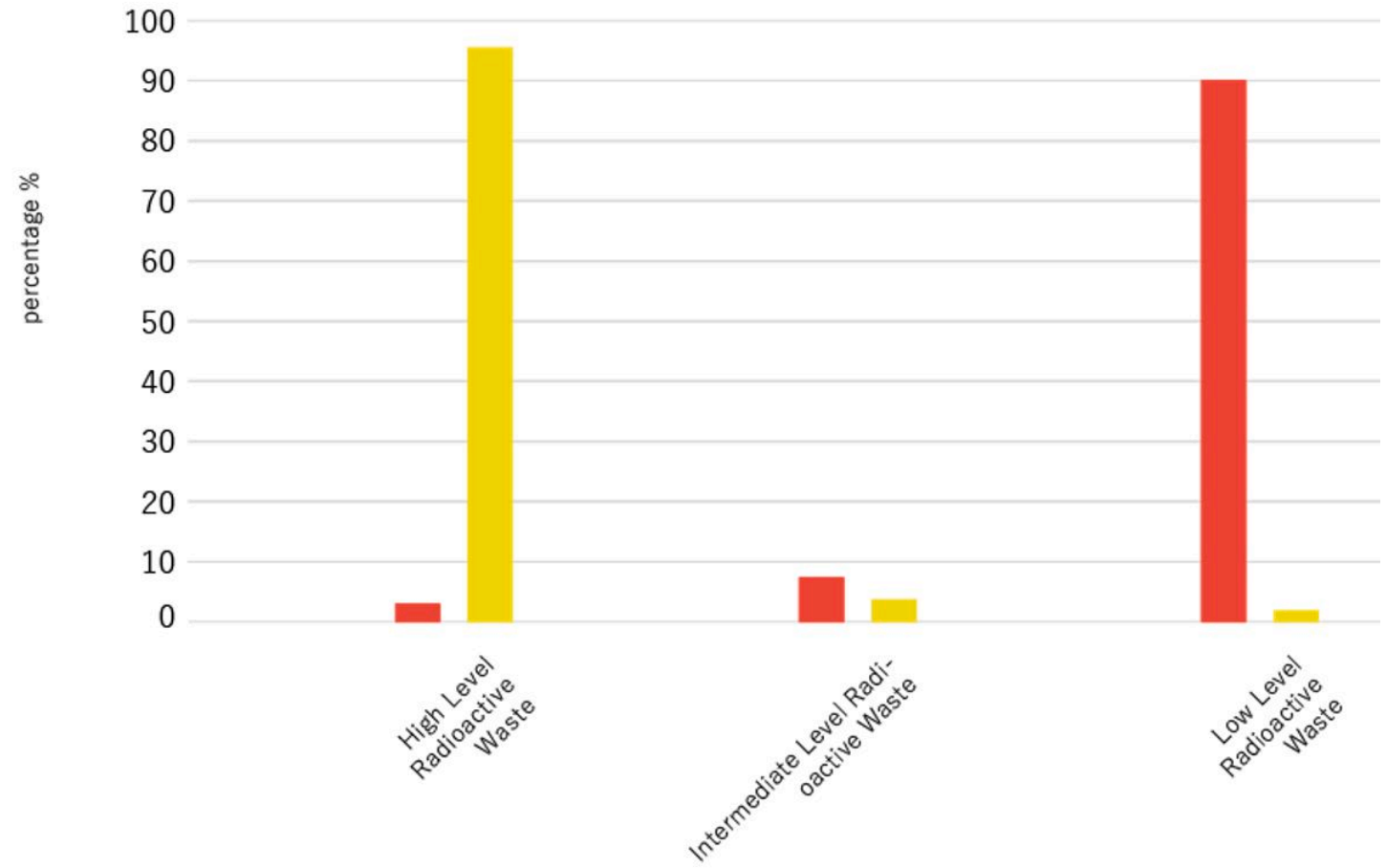
TIMELINE OF NUCLEAR RESEARCH

Once enriched, the nuclear fuel is distributed for utilization, and in some cases, subjected to recycling processes. However, the resultant nuclear wastes have various levels of radioactivity, necessitating diverse storage solutions. Presently, no country possesses an infrastructure for the permanent storage of High-Level Radioactive Waste. In response to this challenge, Switzerland has outlined plans to construct a deep geological repository by the year 2032.



MAP OF DIFFERENT TYPES OF REPOSITORIES IN SWITZERLAND.

- Deep repository for low and intermediate (preliminary evaluation, remains as a reserve option)
- Deep repository for high-level radioactive waste (interim result, further clarification required)
- Zwilag repository for low-level radioactive waste (existing)
- Capital cities of Cantons
- Water



Nuclear waste statistics.

Total volume of nuclear waste in percentage

Contributing radioactivity in percentage

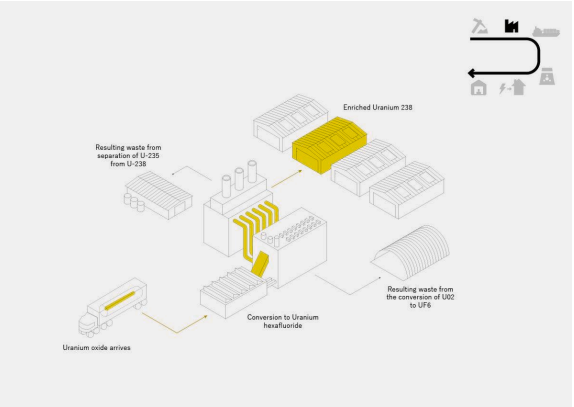


TEMPORARY REPOSITORY
Source: Zwilag AG.

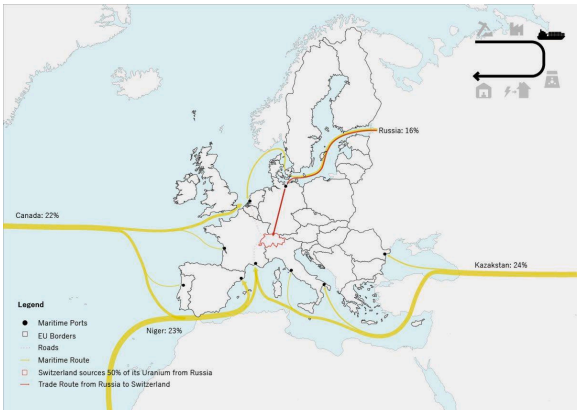
Although nuclear energy demands relatively small quantities of raw materials, the process of extracting and supplying uranium involves a complex infrastructure. Initially, uranium is sourced from large open mines predominantly situated in regions like Kazakhstan, Australia, and Canada. For every ton of uranium ore extracted, only 1 kilogram of pure uranium can be obtained. Subsequently, this uranium undergoes transportation to enrichment facilities, where the concentration of U-235 is artificially increased from 1% to 90%.



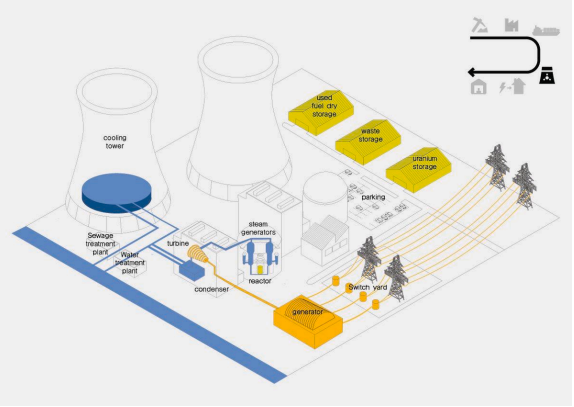
URANIUM EXTRACTMENT FROM THE MINE



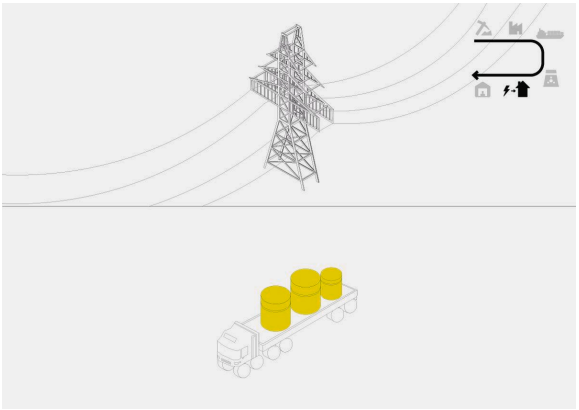
ENRICHMENT IN THE FACTORY



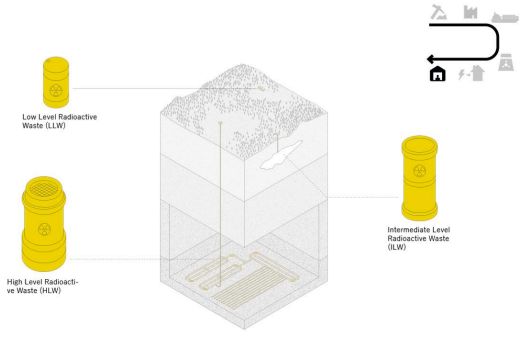
TRANSPORTATION TO EUROPE



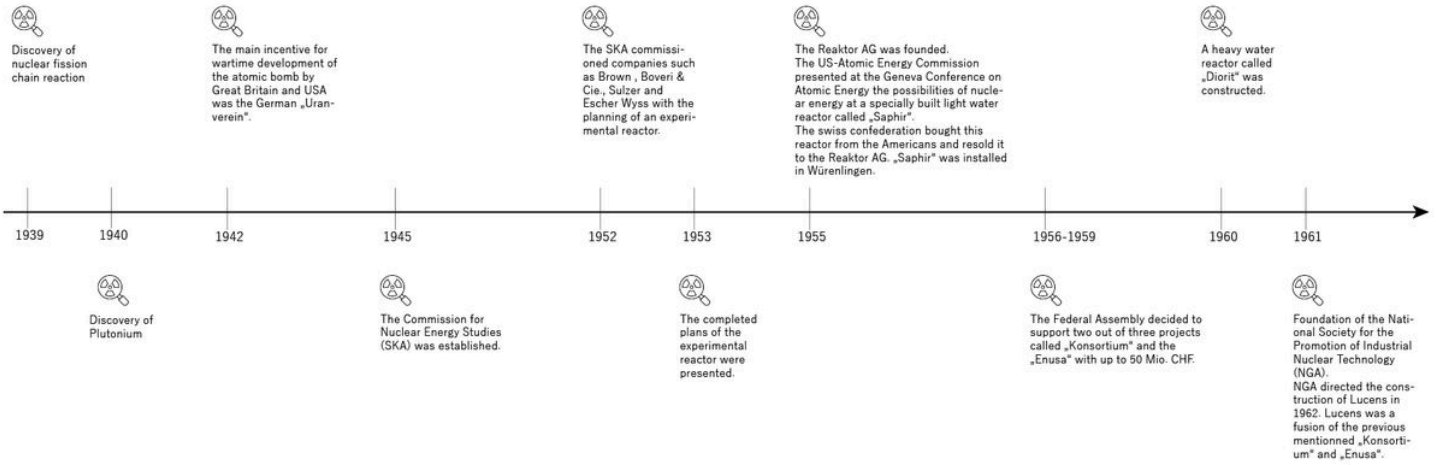
FISSION IN THE POWER PLANT



DISTRIBUTION TO SWISS ELECTRICITY NETWORK AND WASTE TRANSPORTATION

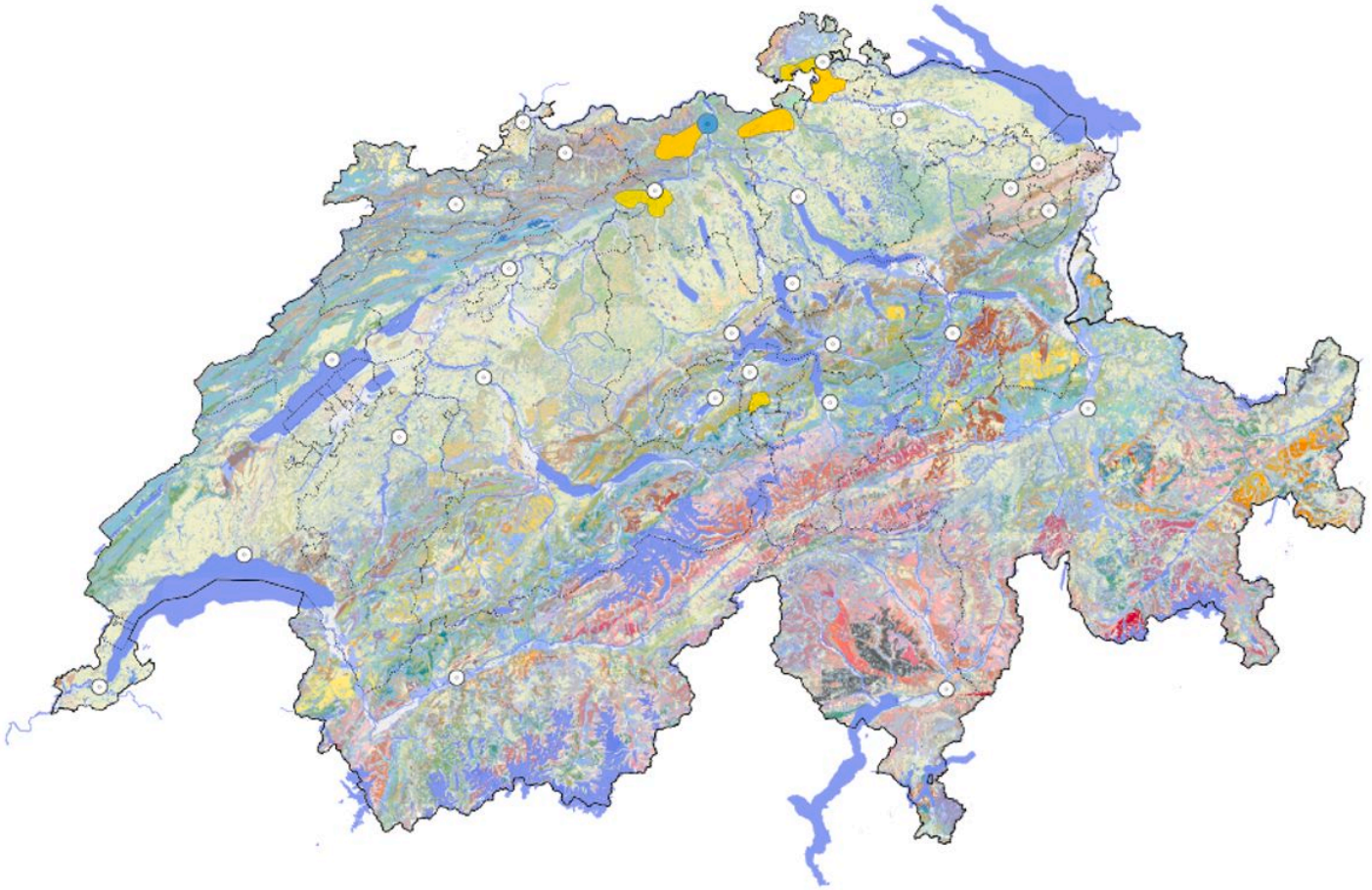


NUCLEAR WASTE STORAGE



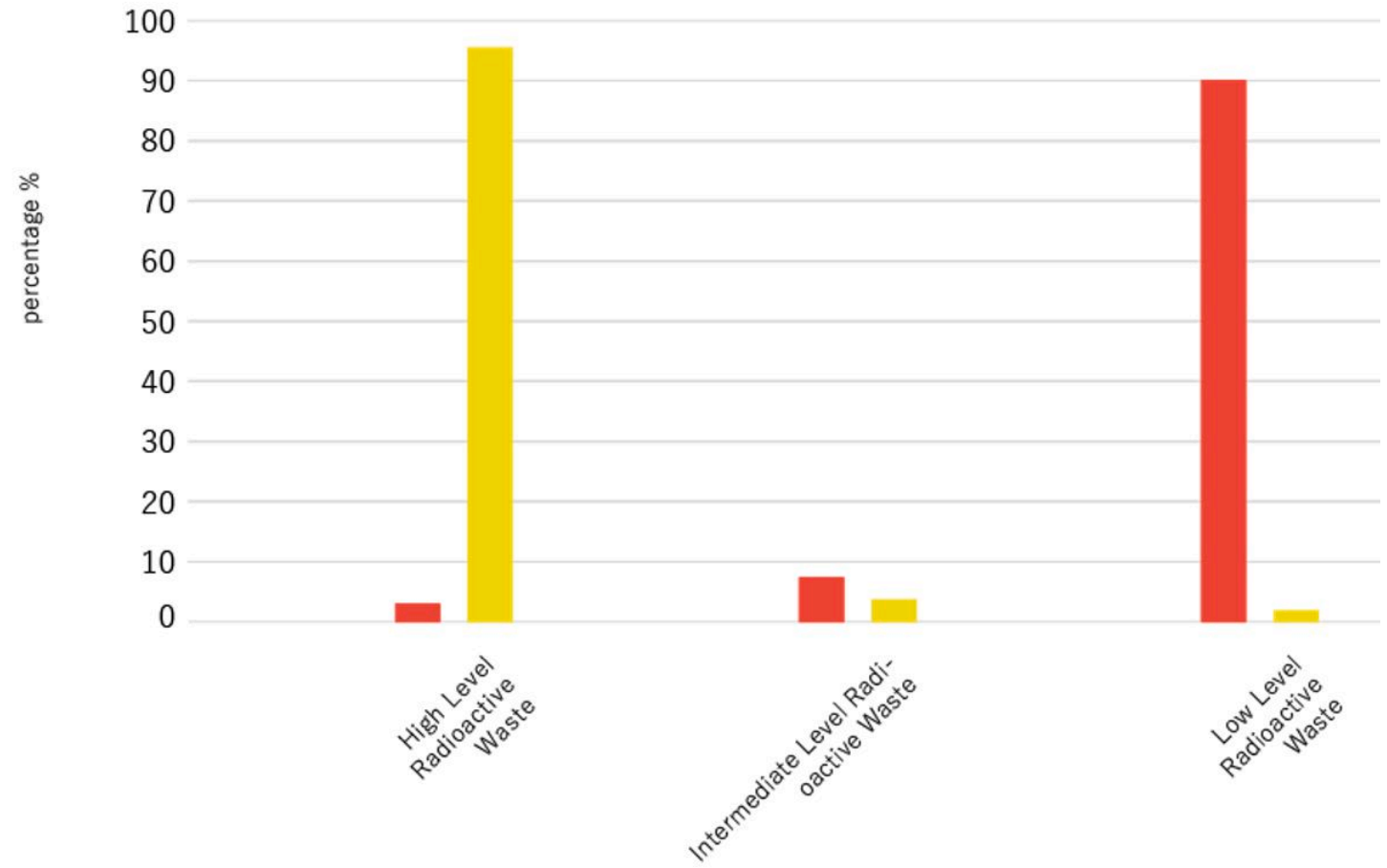
TIMELINE OF NUCLEAR RESEARCH

Once enriched, the nuclear fuel is distributed for utilization, and in some cases, subjected to recycling processes. However, the resultant nuclear wastes have various levels of radioactivity, necessitating diverse storage solutions. Presently, no country possesses an infrastructure for the permanent storage of High-Level Radioactive Waste. In response to this challenge, Switzerland has outlined plans to construct a deep geological repository by the year 2032.



MAP OF DIFFERENT TYPES OF REPOSITORIES IN SWITZERLAND.

- Deep repository for low and intermediate (preliminary evaluation, remains as a reserve option)
- Deep repository for high-level radioactive waste (interim result, further clarification required)
- Zwilag repository for low-level radioactive waste (existing)
- Capital cities of Cantons
- Water



Nuclear waste statistics.

Total volume of nuclear waste in percentage

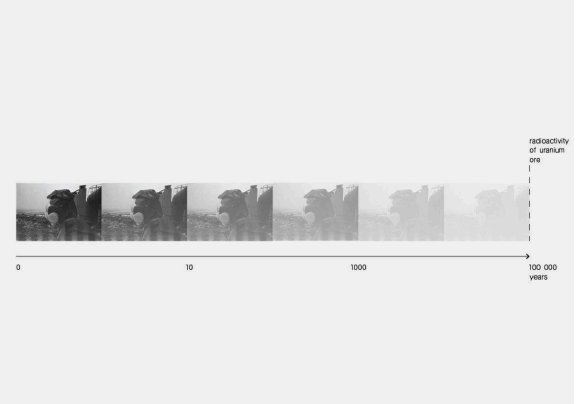
Contributing radioactivity in percentage



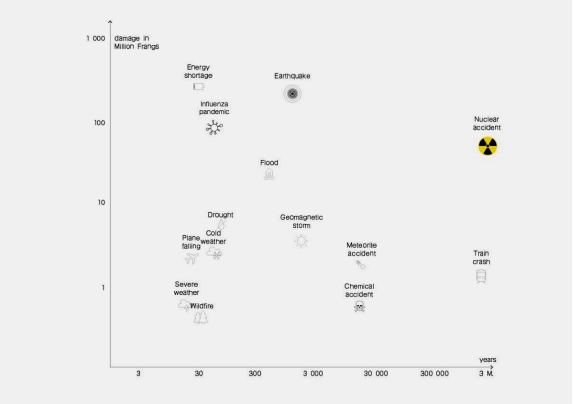
TEMPORARY REPOSITORY
Source: Zwilag AG.

What Are the Risks?

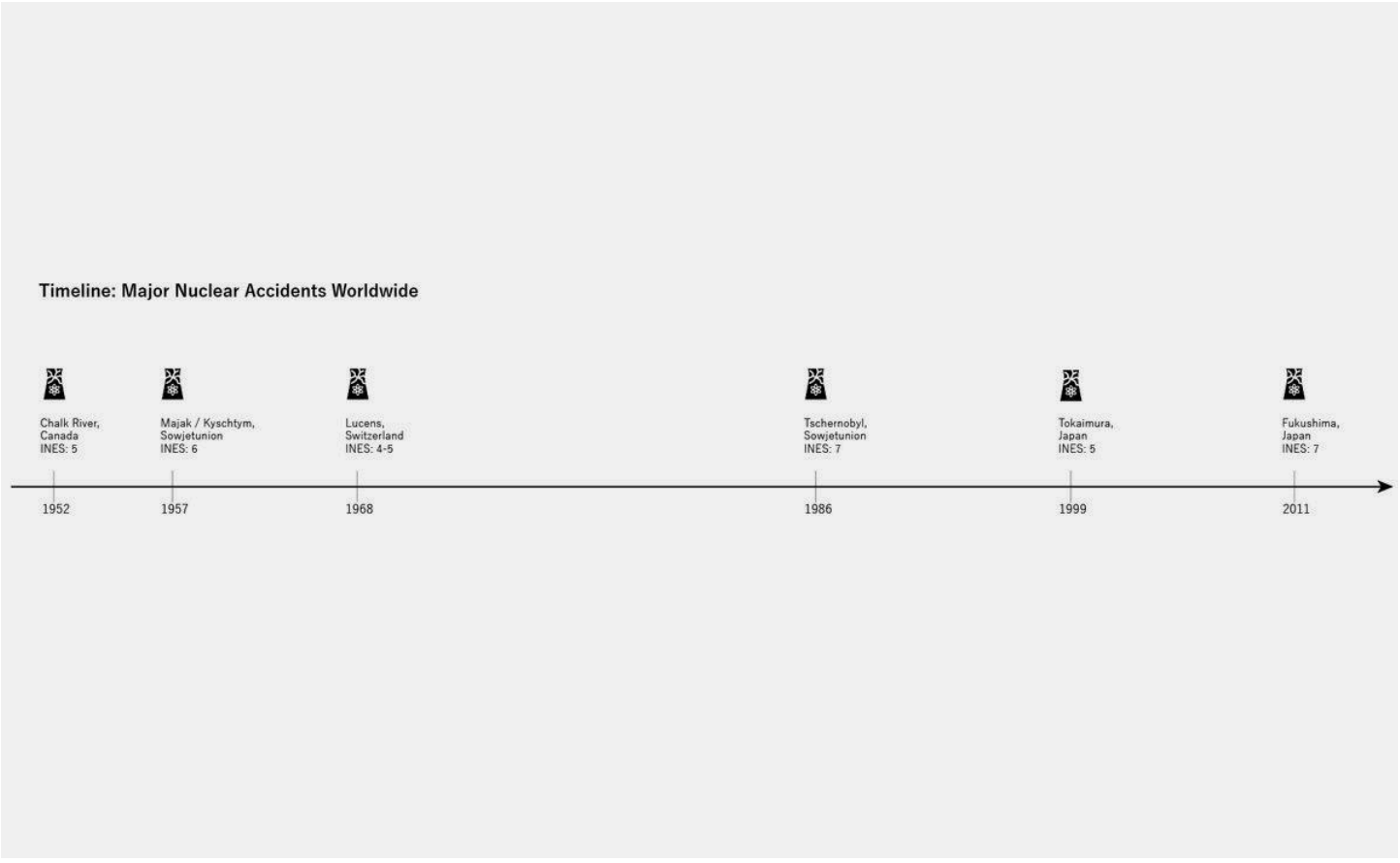
High-profile incidents such as the Chernobyl disaster in 1986 and the Fukushima Daiichi disaster in 2011 have highlighted the catastrophic consequences of nuclear accidents, leading to heightened concerns about safety. If a swiss nuclear reactor were to have a serious accident, the potential radioactive cloud could result in the death of 25,000 people caused mainly by cancer and heart problems. Around 20 million people could be at risk of radiation exposure, requiring them to temporarily leave their homes. Additionally, the long-term impact involves the release of radioactive caesium, a harmful metal, into forest ecosystems, causing contamination for centuries.



RADIOACTIVITY LEVEL DECAY IN YEARS
Source: Igor Kostin / Novosti Press Agency



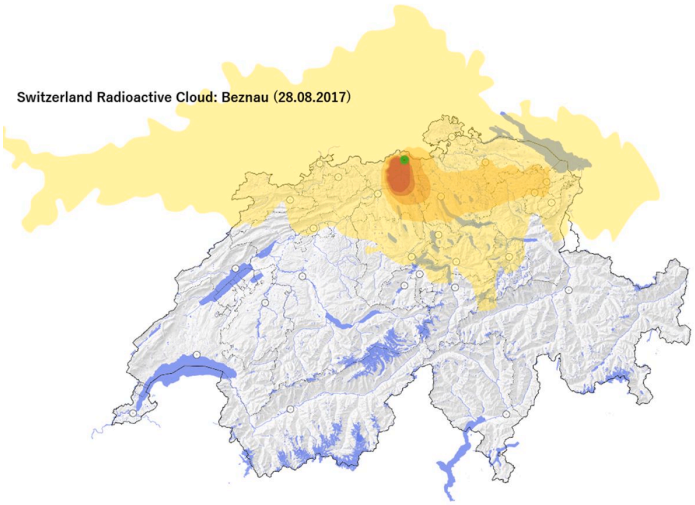
RISK DIAGRAM



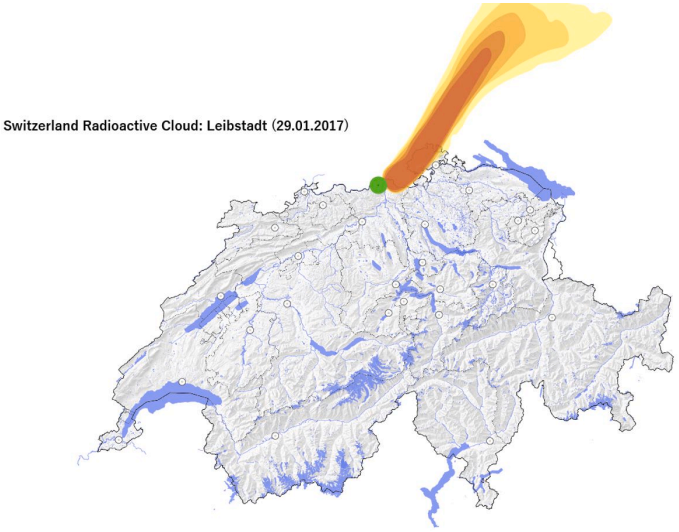
TIMELINE OF MAJOR NUCLEAR ACCIDENTS

This raises important questions about the future we want to leave for the next generations. Do we want to risk creating a radioactive wasteland as their legacy? Is the ten percent of our energy mix provided by nuclear energy worth taking such risks? And who gets to make decisions about these risks?

POSSIBLE RADIOACTIVE CLOUDS

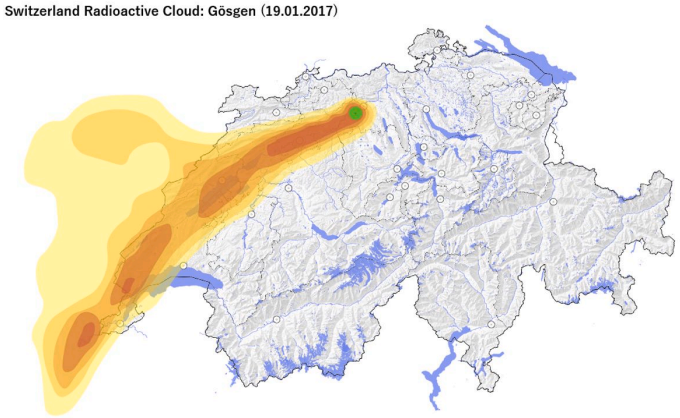


BEZNAU



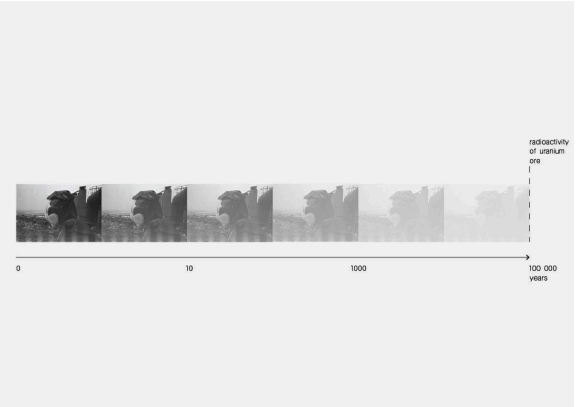
LEIBSTADT

- 100 mSv/year: area is unhabitable for several centuries
- 50 mSv/year: area should be evacuated
- 20 mSv/year: area is habitable under certain conditions
- 6 mSv/year: area releases radioactivity slightly above the recommendation of 4 mSv/year
- 1 mSv: area is safe to habit
- Capital cities of Cantons
- Water bodies

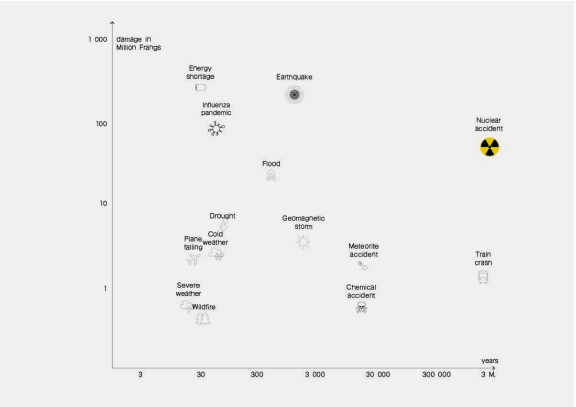


GÖSGEN

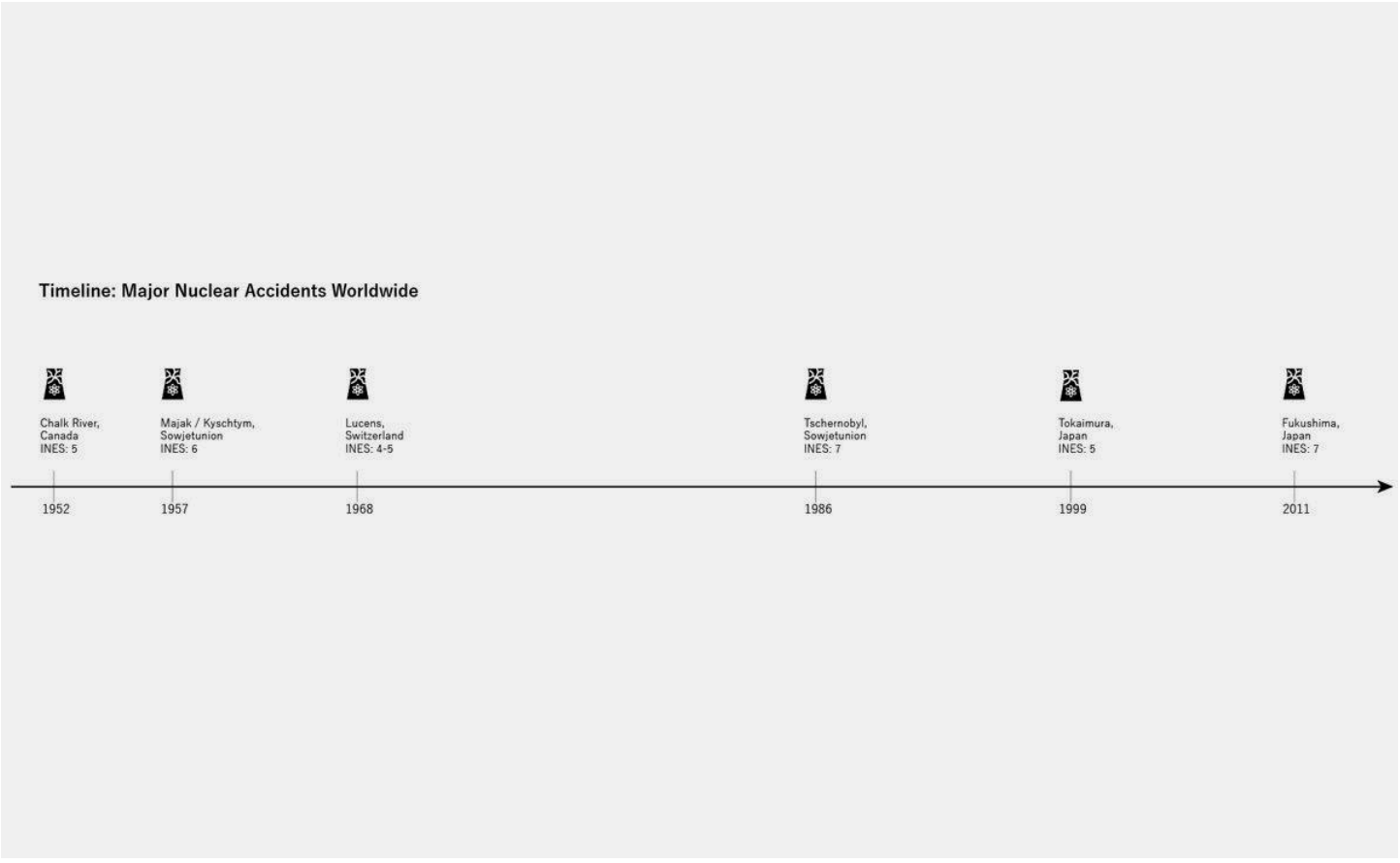
High-profile incidents such as the Chernobyl disaster in 1986 and the Fukushima Daiichi disaster in 2011 have highlighted the catastrophic consequences of nuclear accidents, leading to heightened concerns about safety. If a swiss nuclear reactor were to have a serious accident, the potential radioactive cloud could result in the death of 25,000 people caused mainly by cancer and heart problems. Around 20 million people could be at risk of radiation exposure, requiring them to temporarily leave their homes. Additionally, the long-term impact involves the release of radioactive caesium, a harmful metal, into forest ecosystems, causing contamination for centuries.



RADIOACTIVITY LEVEL DECAY IN YEARS
Source: Igor Kostin / Novosti Press Agency



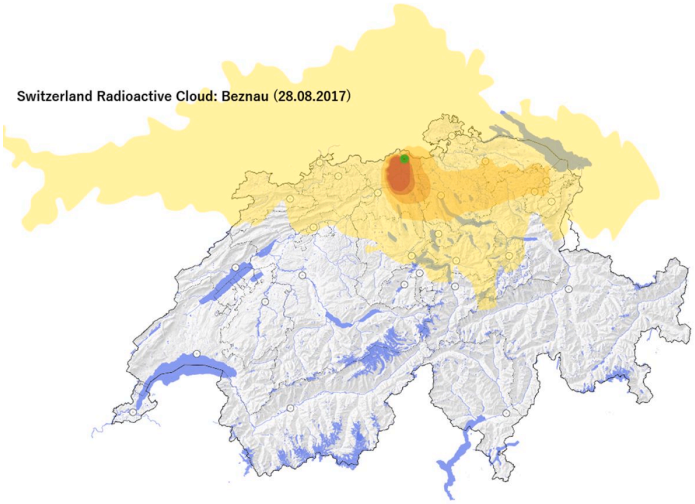
RISK DIAGRAM



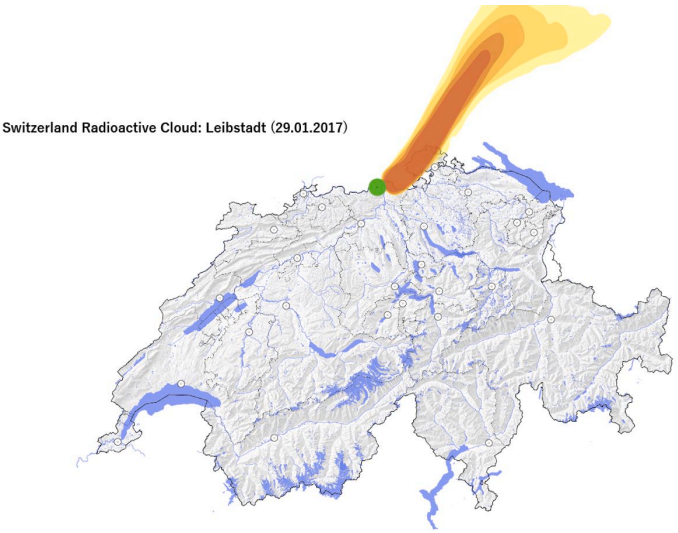
TIMELINE OF MAJOR NUCLEAR ACCIDENTS

This raises important questions about the future we want to leave for the next generations. Do we want to risk creating a radioactive wasteland as their legacy? Is the ten percent of our energy mix provided by nuclear energy worth taking such risks? And who gets to make decisions about these risks?

POSSIBLE RADIOACTIVE CLOUDS

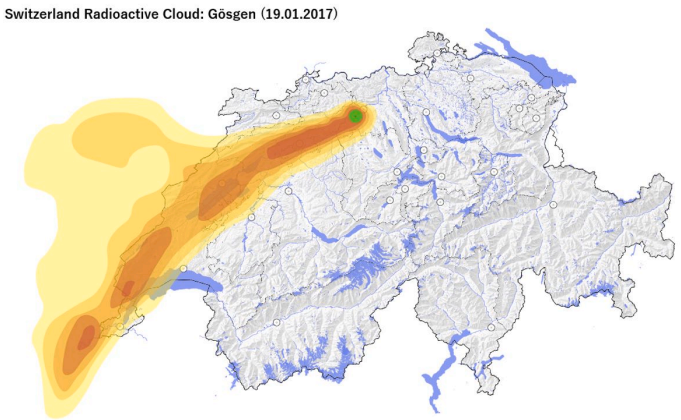


BEZNAU



LEIBSTADT

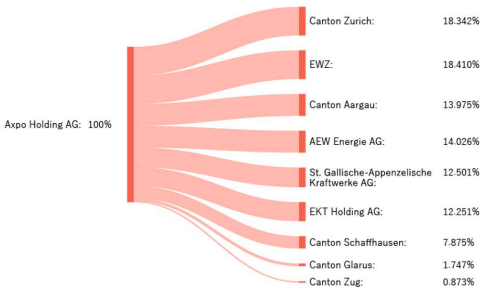
- 100 mSv/year: area is unhabitable for several centuries
- 50 mSv/year: area should be evacuated
- 20 mSv/year: area is habitable under certain conditions
- 6 mSv/year: area releases radioactivity slightly above the recommendation of 4 mSv/year
- 1 mSv: area is safe to habit
- Capital cities of Cantons
- Water bodies



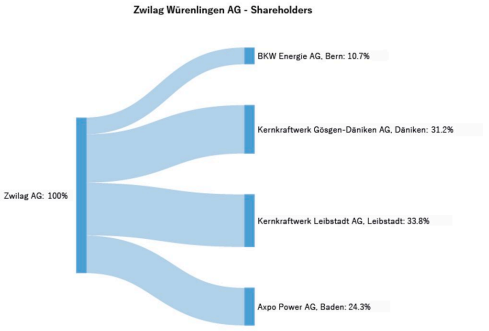
GÖSGEN

Who Owns Nuclear Energy?

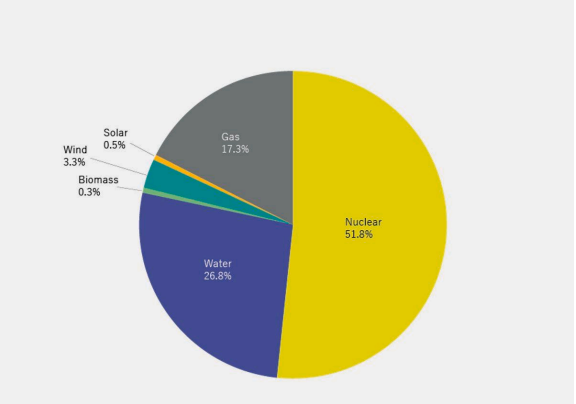
Nuclear energy is integrated within a large corporate and governmental framework that holds significant sway over the industry's future trajectory. AXPO, one of the leading firms of electricity production in Switzerland, also has a grasp on a large European market, with economic activities in 32 countries. The company claims to be part of the energy transition by financing green energy projects like offshore wind farms and solar farms. Yet the shareholders of this company are Swiss cantons (Zurich, Aargau…) who subsequently finance nuclear energy (Beznau I&II). As a return on investment these cantons can build and improve public infrastructure within their administrative borders.



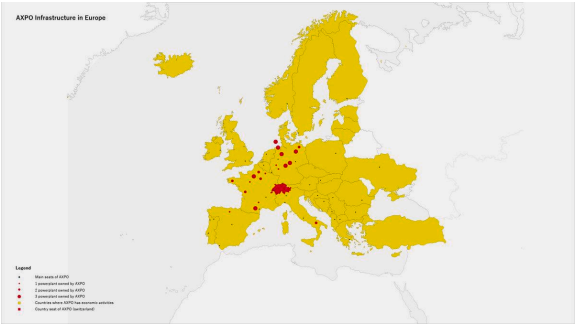
AXPO SHAREHOLDERS



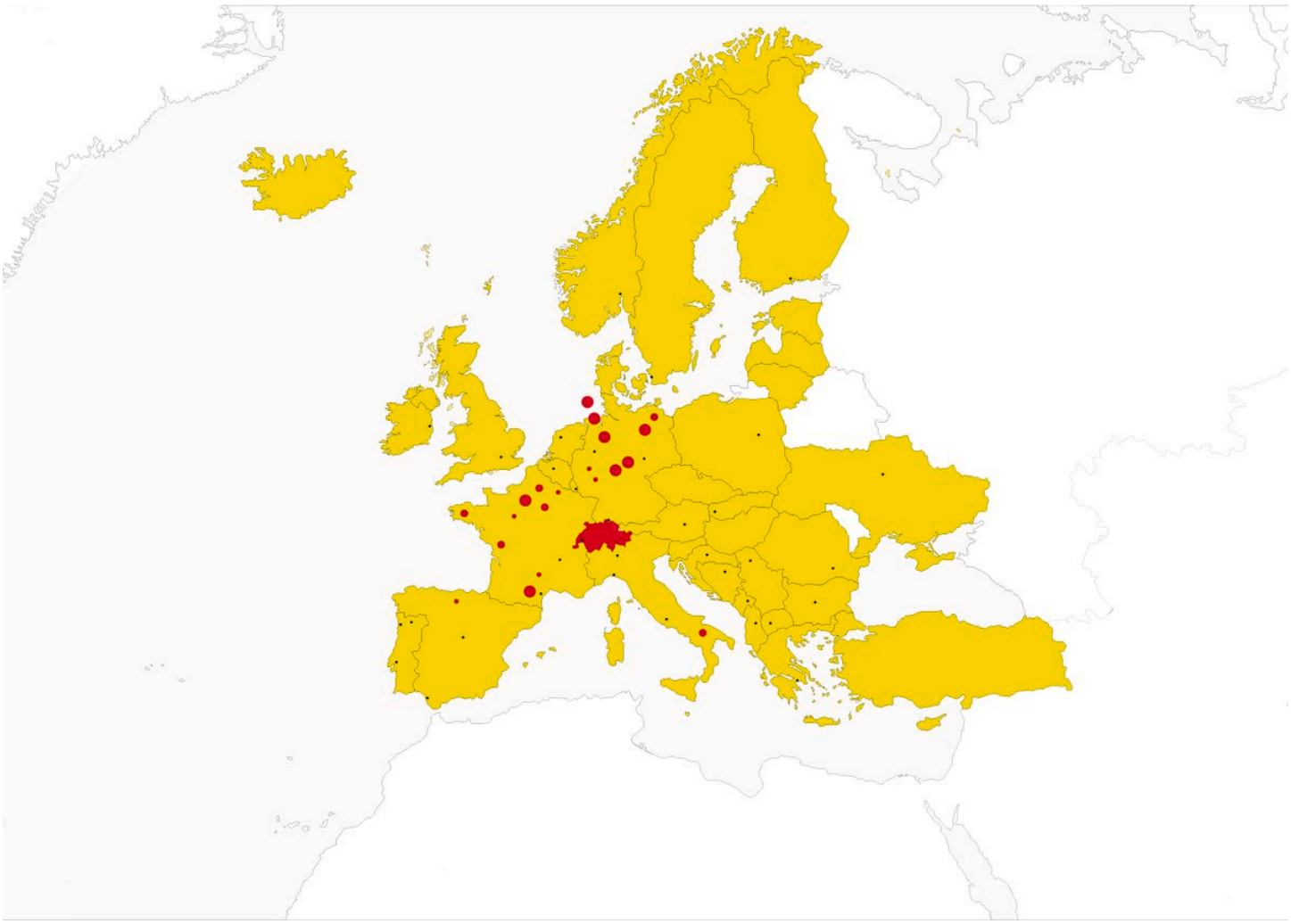
ZWILAG SHAREHOLDERS



ENERGY MIX OF AXPO



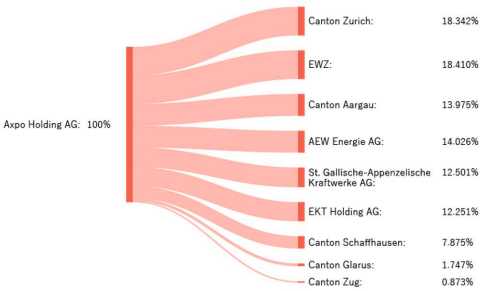
AXPO INFRASTRUCTURE IN EUROPE



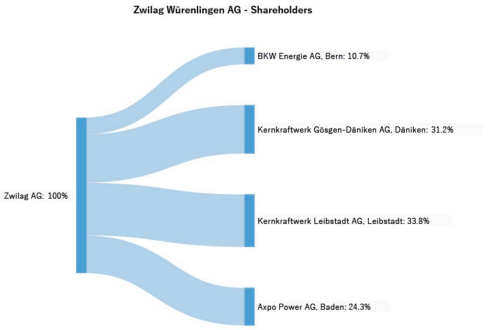
AXPO infrastructure in Europe

- Power plant(s) owned by AXPO
- Main seats of AXPO
- Countries where AXPO undertakes economic activities
- AXPO headquarter (Switzerland)

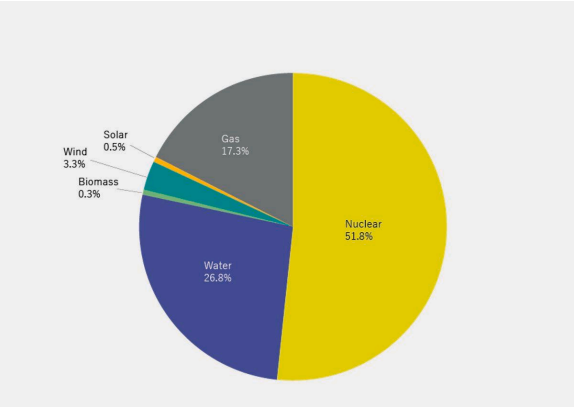
Nuclear energy is integrated within a large corporate and governmental framework that holds significant sway over the industry's future trajectory. AXPO, one of the leading firms of electricity production in Switzerland, also has a grasp on a large European market, with economic activities in 32 countries. The company claims to be part of the energy transition by financing green energy projects like offshore wind farms and solar farms. Yet the shareholders of this company are Swiss cantons (Zurich, Aargau…) who subsequently finance nuclear energy (Beznau I&II). As a return on investment these cantons can build and improve public infrastructure within their administrative borders.



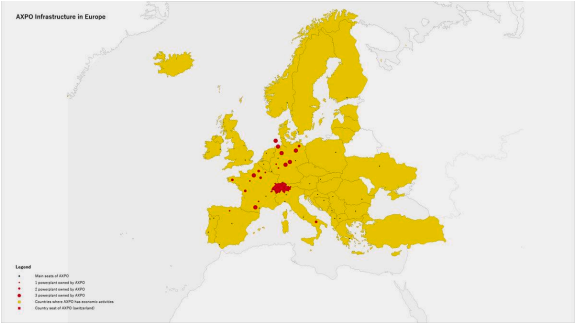
AXPO SHAREHOLDERS



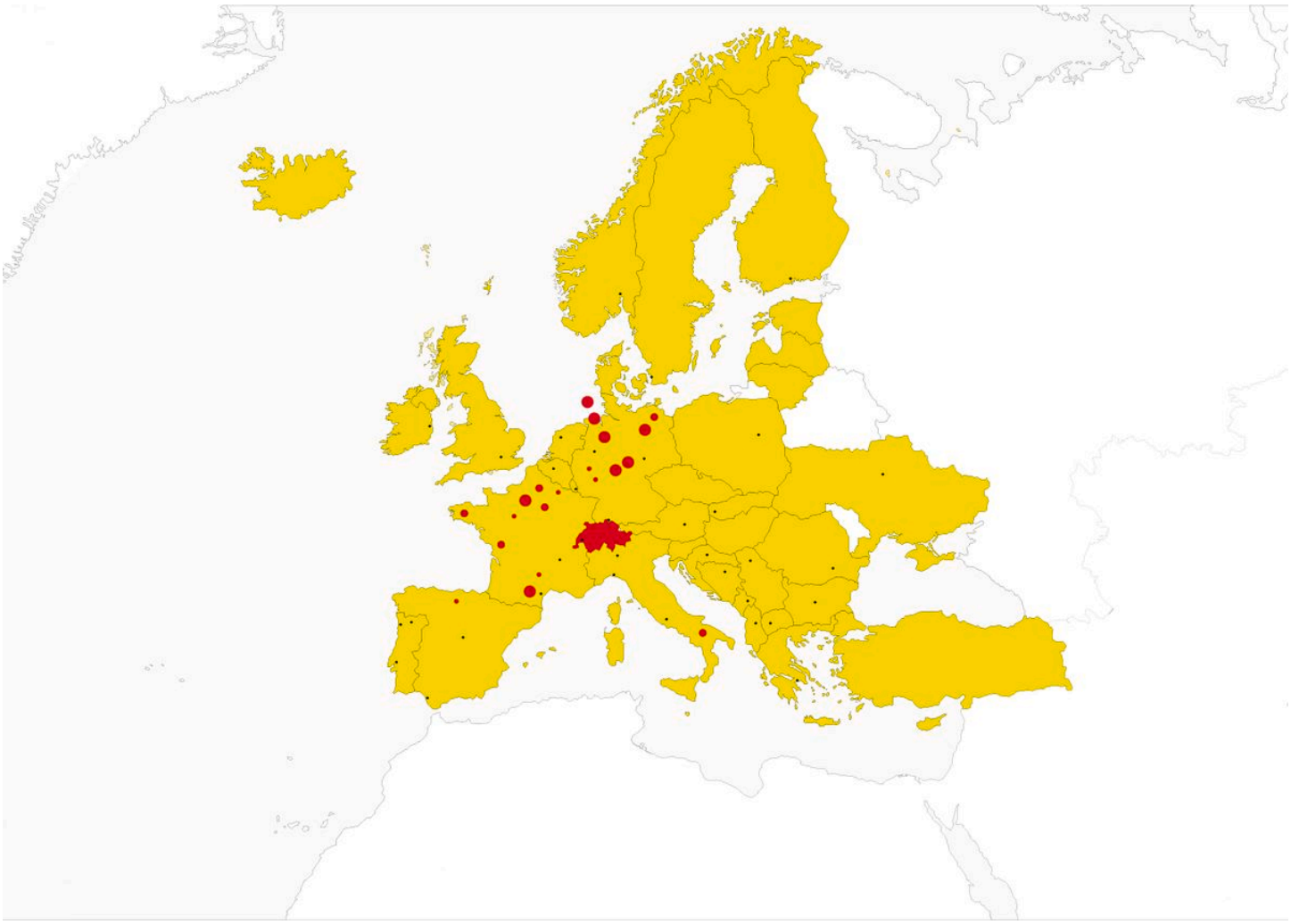
ZWILAG SHAREHOLDERS



ENERGY MIX OF AXPO



AXPO INFRASTRUCTURE IN EUROPE



AXPO infrastructure in Europe

- Power plant(s) owned by AXPO
- Main seats of AXPO
- Countries where AXPO undertakes economic activities
- AXPO headquarter (Switzerland)

Resistance & NIMBYism: Nuclear Energy as a Political Matter

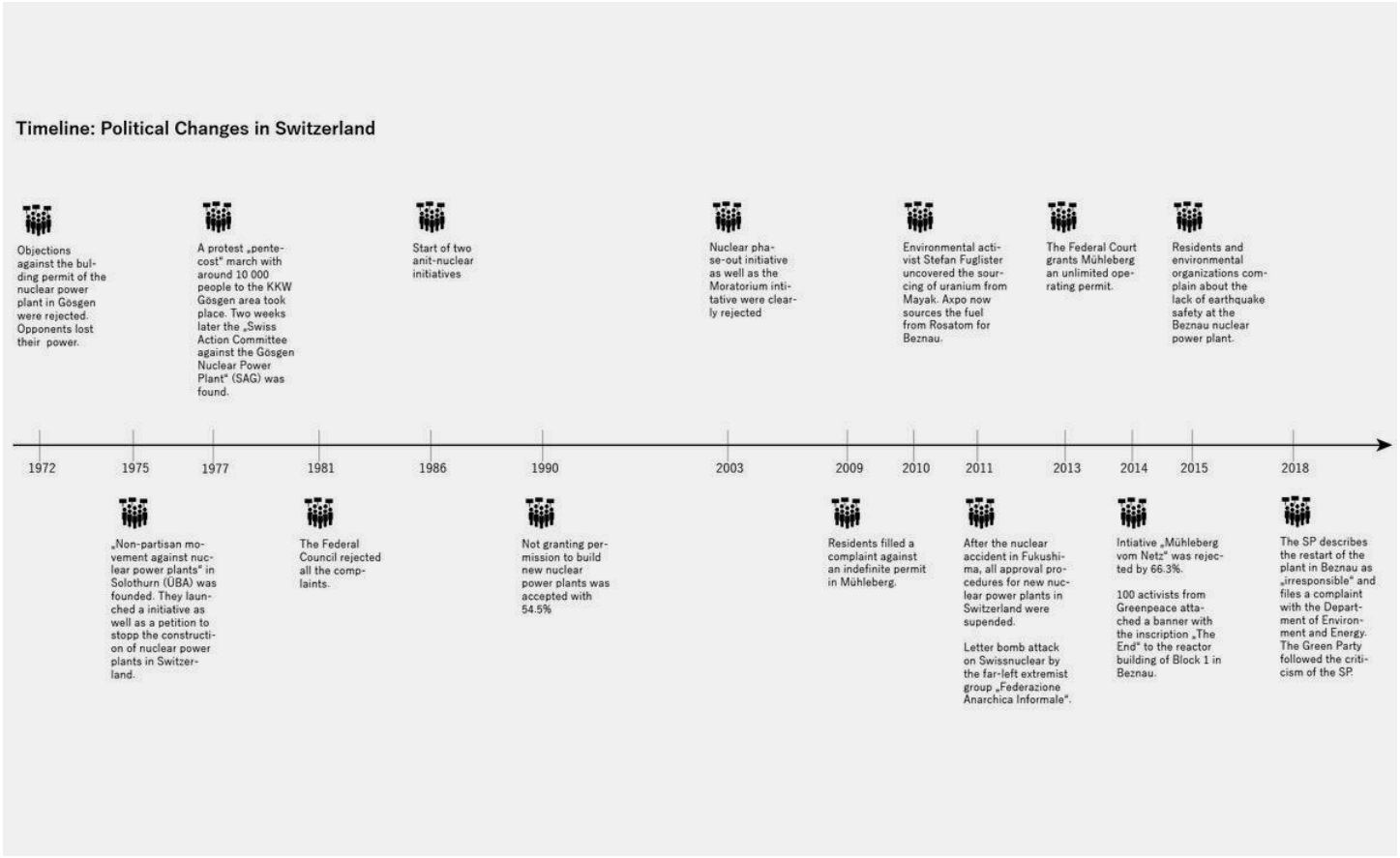
While there is a universal desire for a solution to safely store nuclear waste, there is a reluctance to have such facilities located near residential areas. Over time, environmental activists have advocated for the complete cessation of all nuclear activities as seen in the Kaiseraugst protest, leading to the abandonment of a nuclear project near Basel. The ongoing investigation by NAGRA for a deep geological repository for High Radioactive Waste has faced global opposition from affected areas. The documentary “Der Grüne Berg” specifically depicts this opposition in Wellenberg, a rural town of the Nidwalden canton, where the inhabitants feared the leakage in nature of stored nuclear waste .

However, it is acknowledged that nuclear energy serves as a compensatory source when wind or solar production is insufficient. Also the Beznau nuclear power plant not only provides 450 jobs but also contributes 4 million euros in taxes. It is therefore supported by the workers and inhabitants who depend on this economy. Some political parties, such as the SVP or FDP, also support nuclear energy and still believe in its reliability.

In 2011, a referendum led to a gradual phase-out of nuclear energy, meaning that aging nuclear power plants won't be replaced. However, the agreed-upon timeline for achieving the goals of the energy transition remains a topic of political debate.



PROTEST IN KAISERAUGST IN 1975



TIMELINE OF POLITICS IN SWITZERLAND



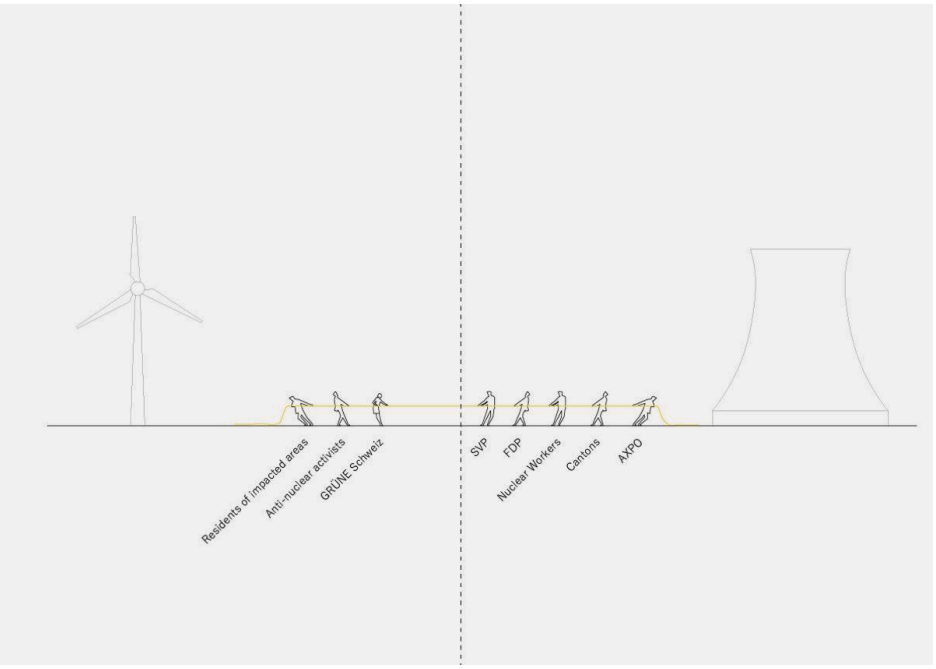
WELLENBERG FROM DER *GRÜNE BERG*, FREDI MURER



INTERVIEWED COUPLE FROM DER *GRÜNE BERG*, FREDI MURER



SITE OF INVESTIGATION BY NAGRA FROM DER *GRÜNE BERG*, FREDI MURER



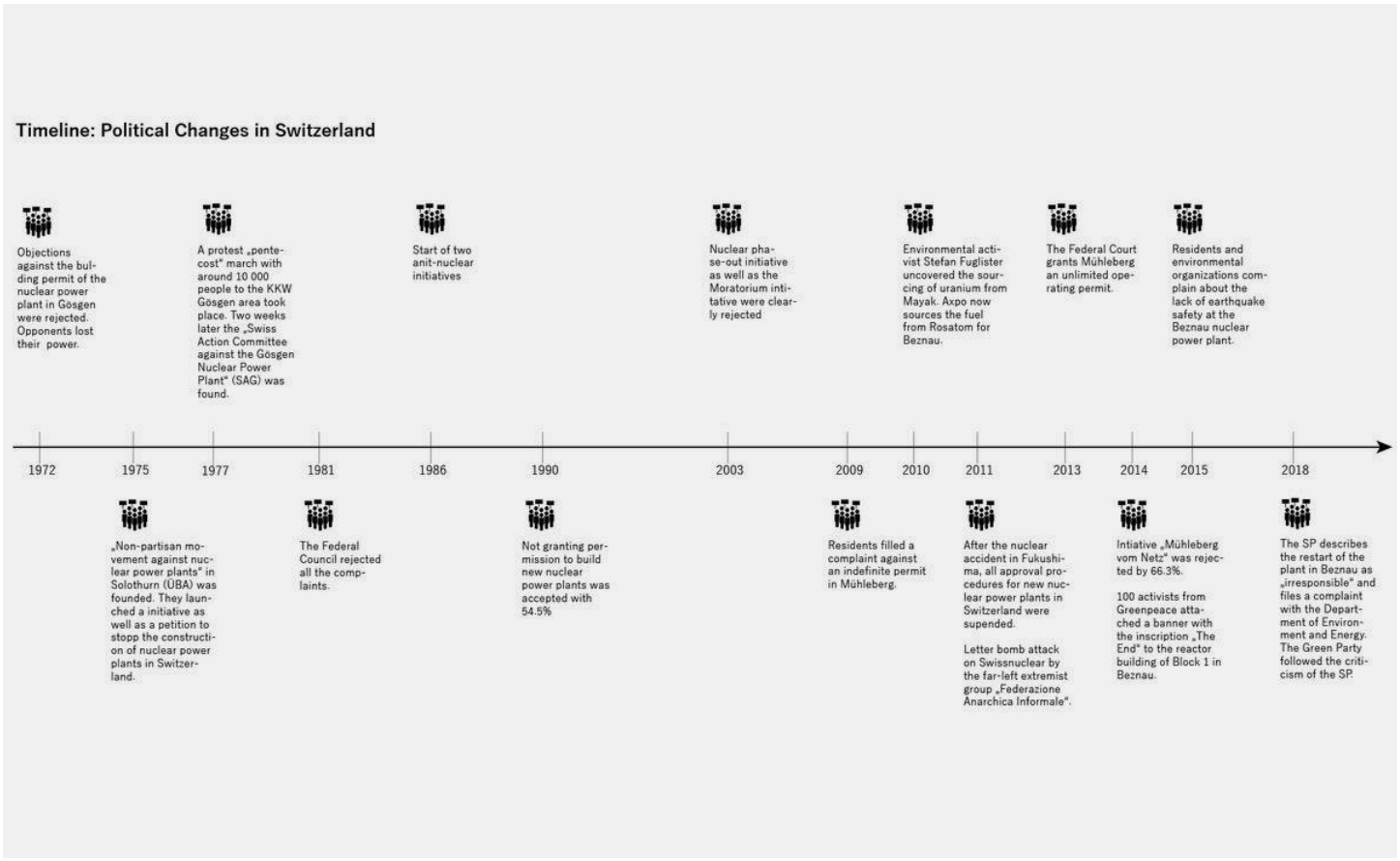
While there is a universal desire for a solution to safely store nuclear waste, there is a reluctance to have such facilities located near residential areas. Over time, environmental activists have advocated for the complete cessation of all nuclear activities as seen in the Kaiseraugst protest, leading to the abandonment of a nuclear project near Basel. The ongoing investigation by NAGRA for a deep geological repository for High Radioactive Waste has faced global opposition from affected areas. The documentary “Der Grüne Berg” specifically depicts this opposition in Wellenberg, a rural town of the Nidwalden canton, where the inhabitants feared the leakage in nature of stored nuclear waste .

However, it is acknowledged that nuclear energy serves as a compensatory source when wind or solar production is insufficient. Also the Beznau nuclear power plant not only provides 450 jobs but also contributes 4 million euros in taxes. It is therefore supported by the workers and inhabitants who depend on this economy. Some political parties, such as the SVP or FDP, also support nuclear energy and still believe in its reliability.

In 2011, a referendum led to a gradual phase-out of nuclear energy, meaning that aging nuclear power plants won’t be replaced. However, the agreed-upon timeline for achieving the goals of the energy transition remains a topic of political debate.



PROTEST IN KAISERAUGST IN 1975



TIMELINE OF POLITICS IN SWITZERLAND



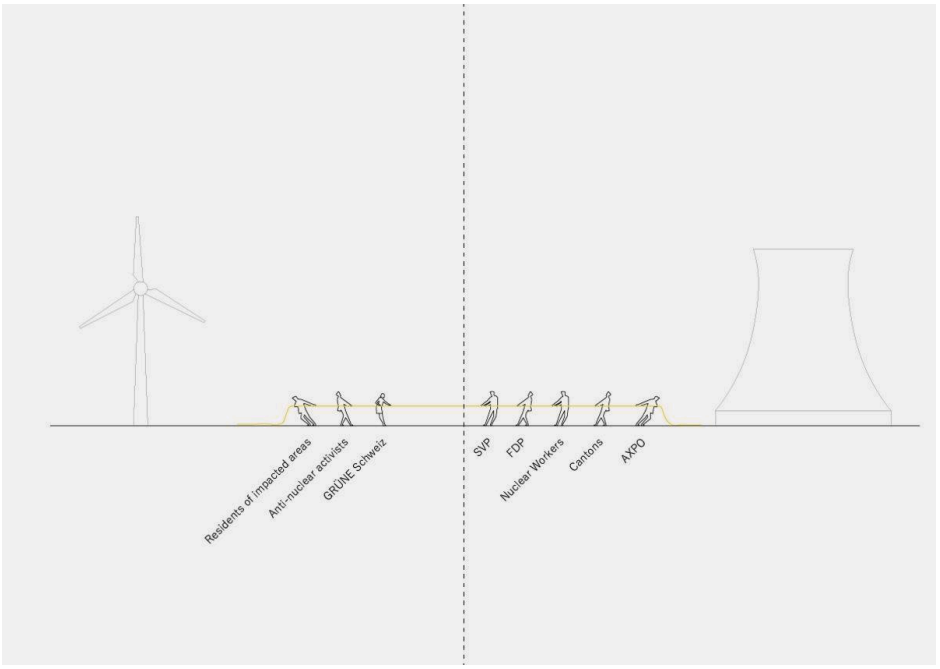
WELLENBERG FROM DER
GRÜNE BERG, FREDI MURER



INTERVIEWED COUPLE FROM
DER *GRÜNE BERG*, FREDI MURER



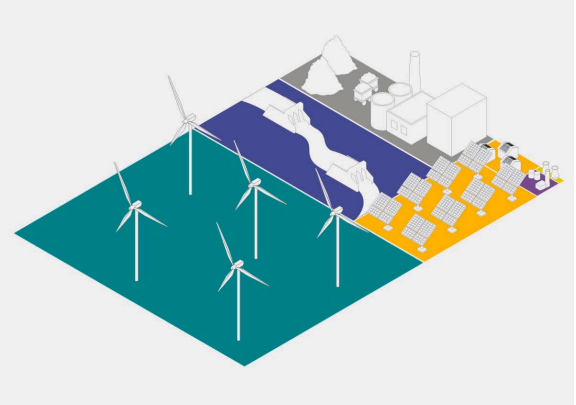
SITE OF INVESTIGATION BY NAGRA
FROM DER *GRÜNE BERG*, FREDI MURER



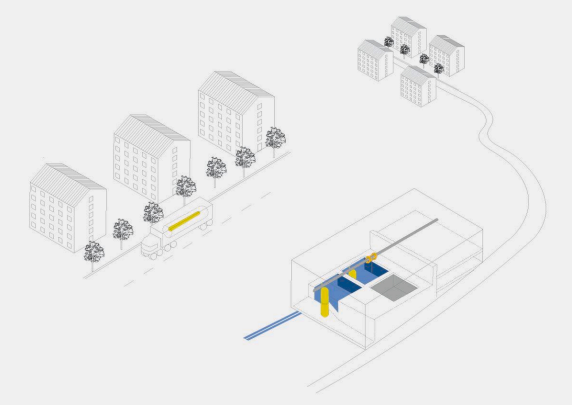
The Promise of Fusion Energy

Fusion is seen by many scientists as a possible solution to the issue of nuclear waste. A fusion reactor would create a relatively small amount of nuclear waste and produce a far greater quantity of energy than a fission reactor. In addition to that, the fusion reactor takes up far less space than wind or solar farms, making it more flexible on the territory. The first fusion reactor for commercial use is expected to be built by 2040. One can wonder about the impact of a nearly infinite source of energy on our society and our way of consuming.

Fusion is widely regarded by scientists as a promising solution to the challenges posed by nuclear waste. Unlike fission reactors, fusion reactors generate a comparatively small amount of nuclear waste while yielding significantly more energy. In addition, fusion reactors require less space to operate than solar and wind farms. Anticipated to be operational by 2040, the first fusion reactor has the potential to transform our society and consumption habits, given its capacity to provide a nearly infinite source of energy.



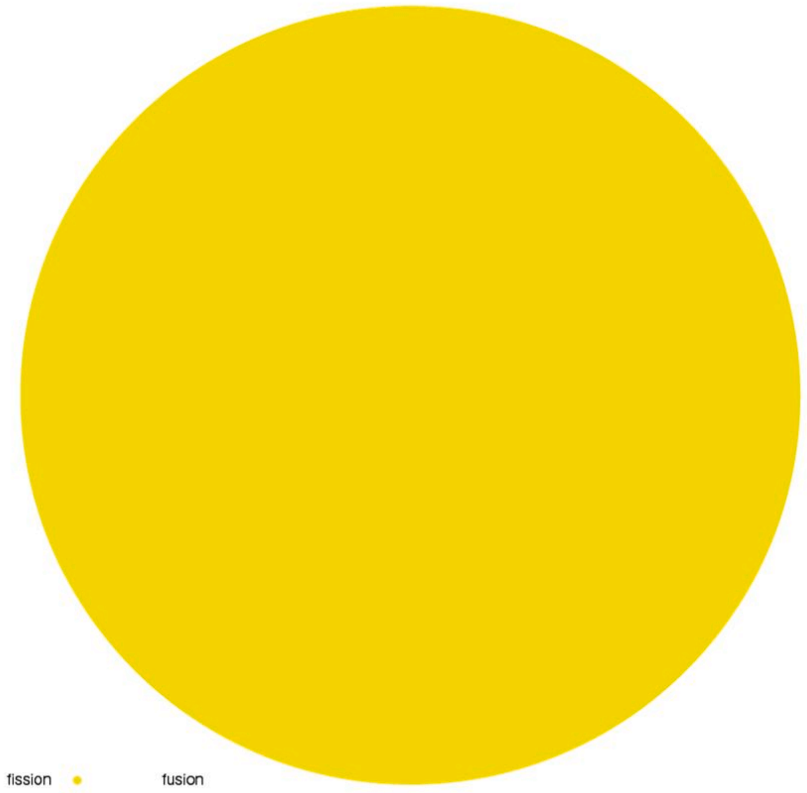
LAND USE BY ENERGY SOURCE



MICROREACTORS AND SMALL NUCLEAR REACTORS (SMR)



SIZE COMPARISON BETWEEN MICROREACTOR, SMR AND NUCLEAR POWER PLANT



FISSION ENERGY PRODUCTION VS. FUSION ENERGY



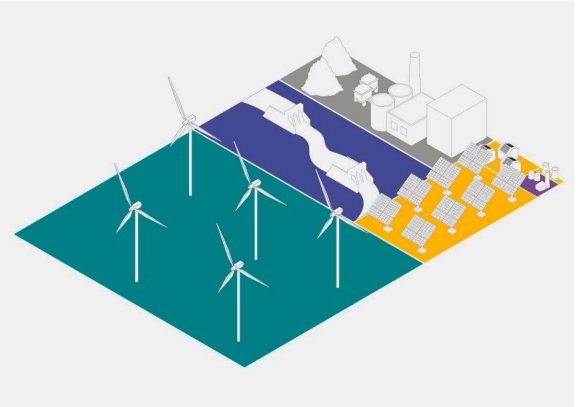
LIFESTYLE BEFORE MODERN
ENERGY PRODUCTION
Source: Photochrom Print Collection



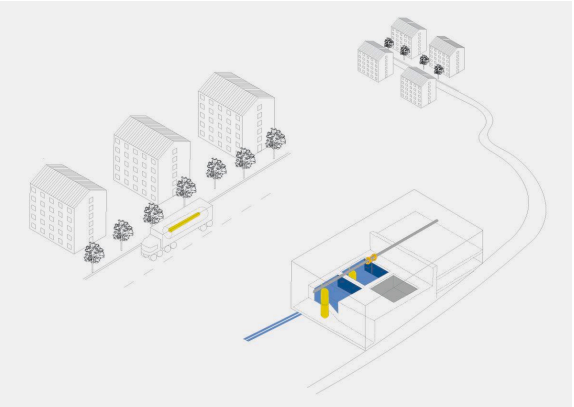
MODERN CONSUMER LIFESTYLE
Source: LittleMissSilly

Fusion is seen by many scientists as a possible solution to the issue of nuclear waste. A fusion reactor would create a relatively small amount of nuclear waste and produce a far greater quantity of energy than a fission reactor. In addition to that, the fusion reactor takes up far less space than wind or solar farms, making it more flexible on the territory. The first fusion reactor for commercial use is expected to be built by 2040. One can wonder about the impact of a nearly infinite source of energy on our society and our way of consuming.

Fusion is widely regarded by scientists as a promising solution to the challenges posed by nuclear waste. Unlike fission reactors, fusion reactors generate a comparatively small amount of nuclear waste while yielding significantly more energy. In addition, fusion reactors require less space to operate than solar and wind farms. Anticipated to be operational by 2040, the first fusion reactor has the potential to transform our society and consumption habits, given its capacity to provide a nearly infinite source of energy.



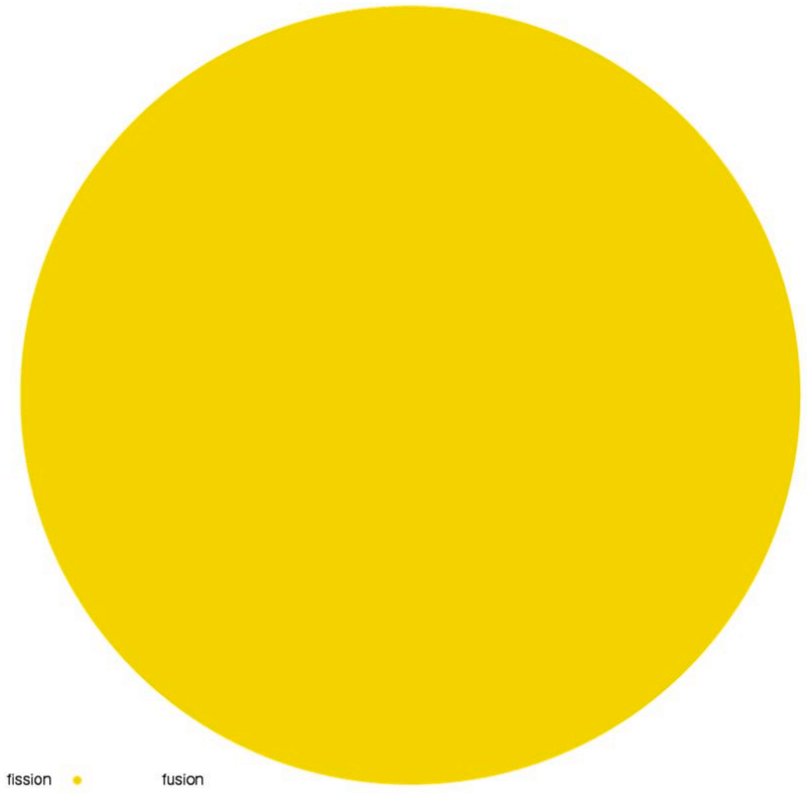
LAND USE BY ENERGY SOURCE



MICROREACTORS AND SMALL NUCLEAR REACTORS (SMR)



SIZE COMPARISON BETWEEN MICROREACTOR, SMR AND NUCLEAR POWER PLANT



FISSION ENERGY PRODUCTION VS. FUSION ENERGY



LIFESTYLE BEFORE MODERN
ENERGY PRODUCTION
Source: Photochrom Print Collection



MODERN CONSUMER LIFESTYLE
Source: LittleMissSilly

SOURCES

- Andreas Bucher, “Die Nationale Risikoanalyse”, 2020. https://blog.alertswiss.ch/de/gefahren-kennen/die-nationale-risikoanalyse-2020/
- 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
- 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
- ee-news,“SES: Strommix von Axpo, Alpiq, BKW und Repower ist deutlich klima- und umweltschädlicher als der Schweizer Produktionsmix”, 20 july 2021. SES: Strommix von Axpo, Alpiq, BKW und Repower ist deutlich klima- und umweltschädlicher als der Schweizer Produktionsmix https://ee-news.ch
- EU Commission, “Small Modular Reactors explained”, 2023. https://energy.ec.europa.eu/topics/nuclear-energy/small-modular-reactors/small-modular-reactors-explained_en
- Fredi M. Murer, Images taken from the film “Der Grüne Berg”, 1990. https://fredi-murer.ch/der-gruene-berg
- 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, Energy Production and Consumption – Our World in Data
- Helsingin Sanomat, “Lauttasaaren viereen väläytetään pientä ydinvoimalaa – Näin vastaavat asukkaat”, Marika Holappa, 22.06.2023. https://www.hs.fi/kaupunki/art-2000009667794\.html
- Image of “Zentrales Zwischenlager für radioaktive Abfälle”,Zwilag AG. Zentrales Zwischenlager für radioaktive Abfälle (Zwilag) - Zwilag https://kernenergie.ch
- 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
- 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
- Schweizerische Energie-Stiftung SES, “Simulation eines schweren Unfall in Kernkraftwerk Beznau”, January 2017. https://energiestiftung.ch/files/energiestiftung/publikationen/Piguet Studie 2019/170828 Beznau
- Schweizerische Energie-Stiftung SES, “Simulation eines schweren Unfall in Kernkraftwerk Gösgen”, January 2017. https://energiestiftung.ch/files/energiestiftung/publikationen/Piguet Studie 2019/170119_Goesgen
- Schweizerische Energie-Stiftung SES, “Simulation eines schweren Unfall in Kernkraftwerk Leibstadt”, January 2017. https://energiestiftung.ch/files/energiestiftung/publikationen/Piguet Studie 2019/170129 Leibstadt
- 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