Changing the Course:
Reimagining Switzerland's Aging Nuclear Infrastructure

by

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BSc in Architecture,
Swiss Federal Institute of Technology
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ABSTRACT

Countries worldwide have been experiencing a rise in the number of decommissioned nuclear power plants due to the infrastructure's finite lifespan, ranging from 20 to 60 years. Consequently, nearly all of today's global operating 410 nuclear power plants will soon reach their operating end of life, with an additional 263 already having ceased operations. Of those, only a few have attempted to repurpose them with programs aimed at reintegrating the isolated site into its existing context. This thesis proposes to change that course by reimagining alternative ways of adaptively reusing the remaining infrastructural buildings to facilitate the process of reconnection.

The thesis centers on Switzerland, home to some of the world's oldest nuclear power plants. One of them, based in Mühleberg, is the only decommissioned nuclear power plant in Switzerland to date and is therefore a pioneer to this process. The lengthy 15-year and costly $3.2Bn USD process dedicated to the safe nuclear fuel removal and building demolition lasts until 2034. Following that, the remaining greenfield, currently surrounded by agricultural land, would be available for new purposes.

The proposal imagines transforming the nuclear power plant in Mühleberg into an accessible pumped hydro storage system for energy storage. In addition, indoor hydroponics and outdoor agricultural land serve as extensions for the longstanding agricultural community. Beyond economical uses, recreational spaces are dispersed throughout the site for larger community engagement and participation.

Zooming back out to the larger picture of aging nuclear energy infrastructure, this thesis uses the Mühleberg narrative on other affected sites globally. It also reflects on potential opportunities that arise when considering scalability.

Thesis Co-Supervisor: **Christoph Reinhart**
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Acknowledgments

Committee

Christoph, Mohamad, and Rosalyne. I am not sure what I would have done without your support. Your weekly guidance and expertise on my research, project design, and final presentation were instrumental in refining the thesis outcome. I cannot thank you enough for your time and dedication to support me during my academic journey.

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Erich (Dad). Thank you for visiting Mühleberg to take photographs of the area and taking part in the official tour inside the nuclear power plant. Your contributions were highly valuable in providing insight into the current phasing out process.

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Team NPP Leibstadt. Thank you for the tour at the Leibstadt nuclear power plant, which greatly contributed to the research process.

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Sesil L. Huge thanks to you for supporting me in building the reactor model during the last busy stretch of the thesis phase. I very much appreciated your time and help.

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Michele (Mum), Patrick, and Ben. A big thanks to all of you to for thoroughly reviewing my thesis paper various times to ensure consistency, reading flow, and spelling that really made the paper come together nicely in the end.

Financial Support

IKEA Stiftung Schweiz. I would have not been able to complete my thesis with ease without your generous support throughout the last three and a half years. Your contributions directly impacted the quality and depth of the thesis by allowing me to go on site visits and conduct interviews with several people engaged in the nuclear realm.

Private Donor. Thank you for your immense support and your dedication to encouraging me to pursue my academic path abroad. I would not have achieved this milestone without you.

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Foreword

This thesis aims to change the course of decommissioned nuclear power plants by reimagining alternative ways of adaptively reusing the infrastructural buildings on-site. Through this approach, these isolated sites can follow a pathway of reintegration that helps them reconnect with their existing surrounding.

Chapter 1 examines the larger picture of aging nuclear energy infrastructure on a global scale with emphasis on the Swiss context at the regional scale. It breaks down the status quo of decommissioning nuclear power plants with the potential issues that come about.

Chapter 2 investigates one case study, the KKM Mühleberg, located in Switzerland. This example tests a novel adaptive reuse strategy as an alternate approach to reintegrating it back into its picturesque rural surrounding.

Chapter 3 reflects on the case study proposal in Mühleberg and how certain parts of its methodology could be applied to other phased out nuclear power plant sites worldwide.

Chapter 4 includes a few images that were taken during the thesis defense day, which took place on Thursday, December 21st, 2023.

A list of figures and frequently used abbreviations are provided in the Appendix.

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Contents

Chapter 1 - On the Global Scale

The Rise of Nuclear Energy

Nuclear energy experienced a worldwide construction boom during the 1970s and 80s[1] (as shown in **Figure 1**) due to its new energy generating method that allowed for more electricity to be produced than any of the other sourcing options. The Soviet Union, the United Kingdom, and the United States were amongst the earliest adopters of nuclear energy at the time[2].

From that point onward, many other countries began to add nuclear energy to their energy production mix to bridge the delta that no longer was being covered by leading fossil fuel energy sources. More frequent oil and gas crises, including the 1973/74 Oil Shock[3] and 1979 Energy Crisis[4] had accelerated various governments to re-centralize their energy production in-house to avoid any further external fuel sourcing reliance.

In the 1990s, the construction of nuclear reactors began to decline due to emerging safety concerns around this sourcing method. Some major nuclear accidents that contributed to this fear were the 1979 Three Mile Island Nuclear Meltdown[5] (INES Level 5 of 7), the 1986 Chernobyl Accident[6] (INES Level 7 of 7), and the 2011 Fukushima Daiichi Accident[7] (INES Level 7 of 7), all of which had a lasting impact on the public's perception of this energy sourcing method. Similar to how earthquake severity is measured, the International Atomic Energy Agency introduced the INES scale from 0 to 7 to better communicate safety measures depending on the level of the accident (see **Figure 2**).

1 Gene Smith, "A Building Boom for Nuclear Power Plants."
2 World Nuclear Association, "History of Nuclear Energy."
3 Adam Hayes, "1973 Energy Crisis: Causes and Effects."
4 Lucas Downey, "1979 Energy Crisis."
5 World Nuclear Association, "Three Mile Island Accident."
6 World Nuclear Association, "Chernobyl Accident 1986."
7 World Nuclear Association, "Fukushima Daiichi Accident."

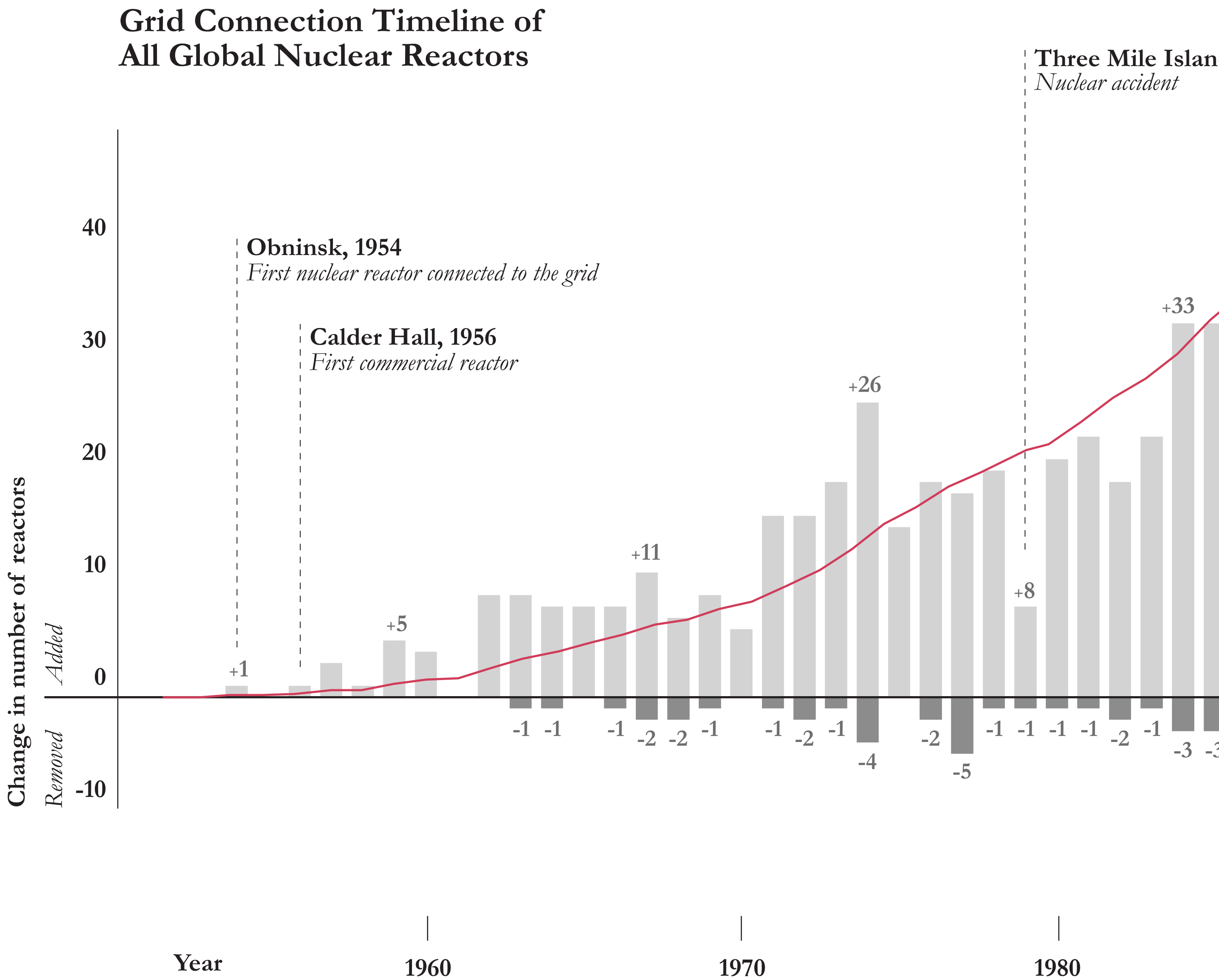
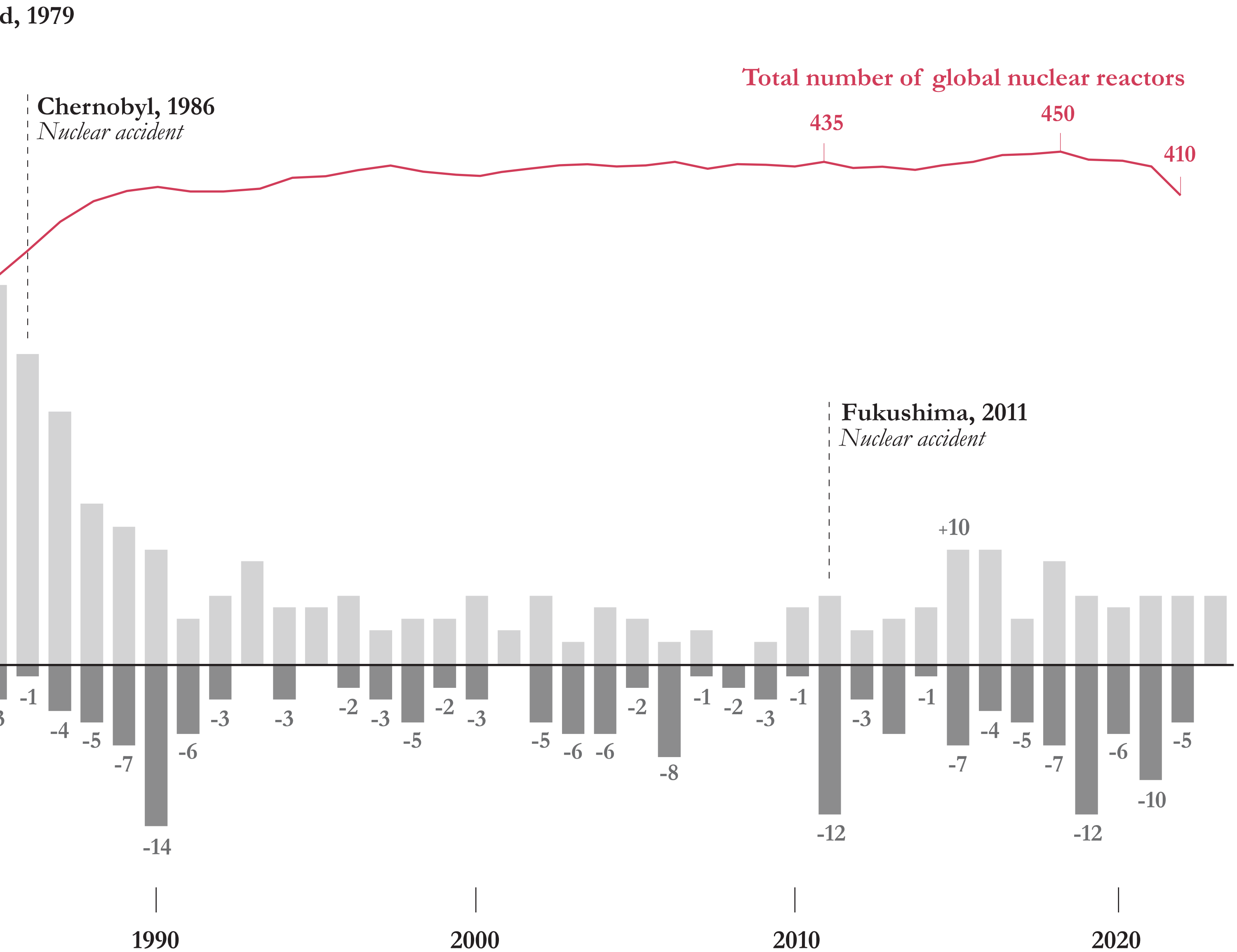


Figure 1. Visualization of all global nuclear reactors that were either connected to the grid or shutdown between 1954 and 2023. Data source: World Nuclear Association. Diagram: by author.


d, 1979
Chernobyl, 1986
Nuclear accident
Total number of global nuclear reactors
435
450
410
Fukushima, 2011
Nuclear accident
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-4
-5
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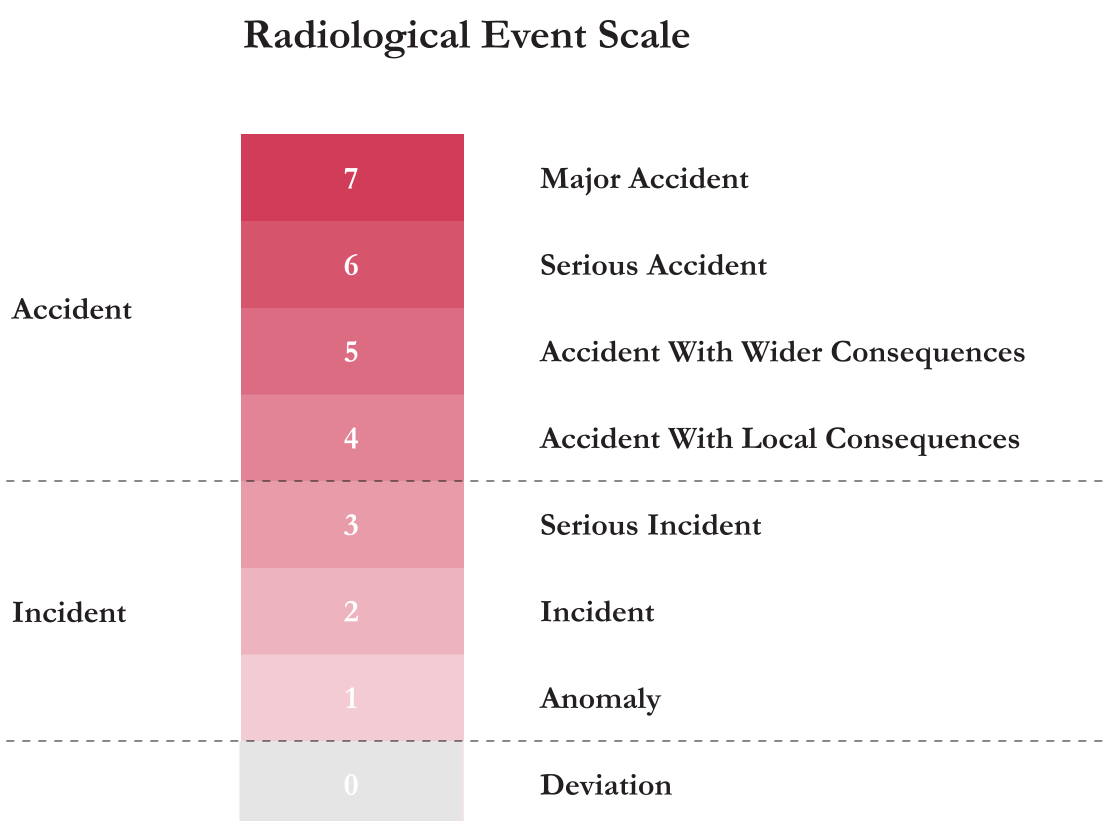


Figure 2. International Nuclear Radiological Event Scale (INES) was introduced in 1990.
Data source: IAEA and NEA. Diagram: by author.

Nuclear Energy Today

To date, 54 countries[1] worldwide have adopted nuclear fission as part of their electricity production mix, as indicated in **Figure 3**. From those countries, 65% of the 410 operating units are located within in the United States (92 units), China (57 units), France (55 units), Russia (36 units), and South Korea (25 units).

Despite the rise in safety concerns around this energy sourcing method, several countries have announced new projects, with some in pre-construction and others already under construction, making a total of 305 additional power plant units globally.

Parallel to the planning and construction of new nuclear power plants, 263 existing projects have already ceased operations for a variety of reasons, highlighted in **Figure 4**. The predominant two reasons are recent governmental policy changes[2,3] and the aging of the country's nuclear energy infrastructure[4].

- - - - - - - - - - - - -

1 Global Energy Monitor, "Global Nuclear Power Tracker."
2 Laura Paddison, Nadine Schmidt, and Inke Kappeler, "'A New Era': Germany Quits Nuclear Power, Closing Its Final Three Plants."
3 The Federal Council, "Grundsätze Der Energiepolitik."
4 U.S. Congress, Office of Technology Assessment, *Aging Nuclear Power Plants: Managing Plant Life and Decommissioning*.

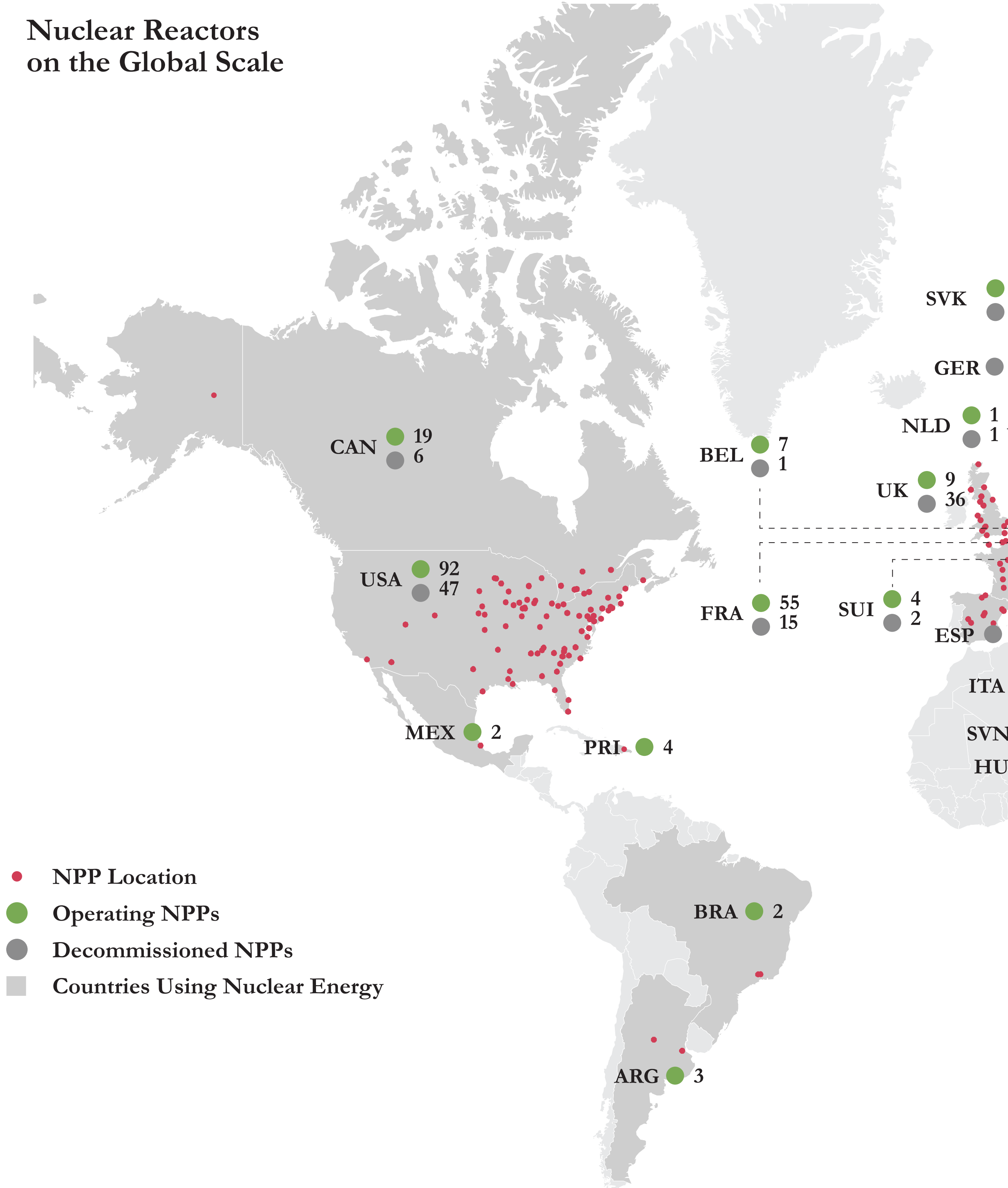
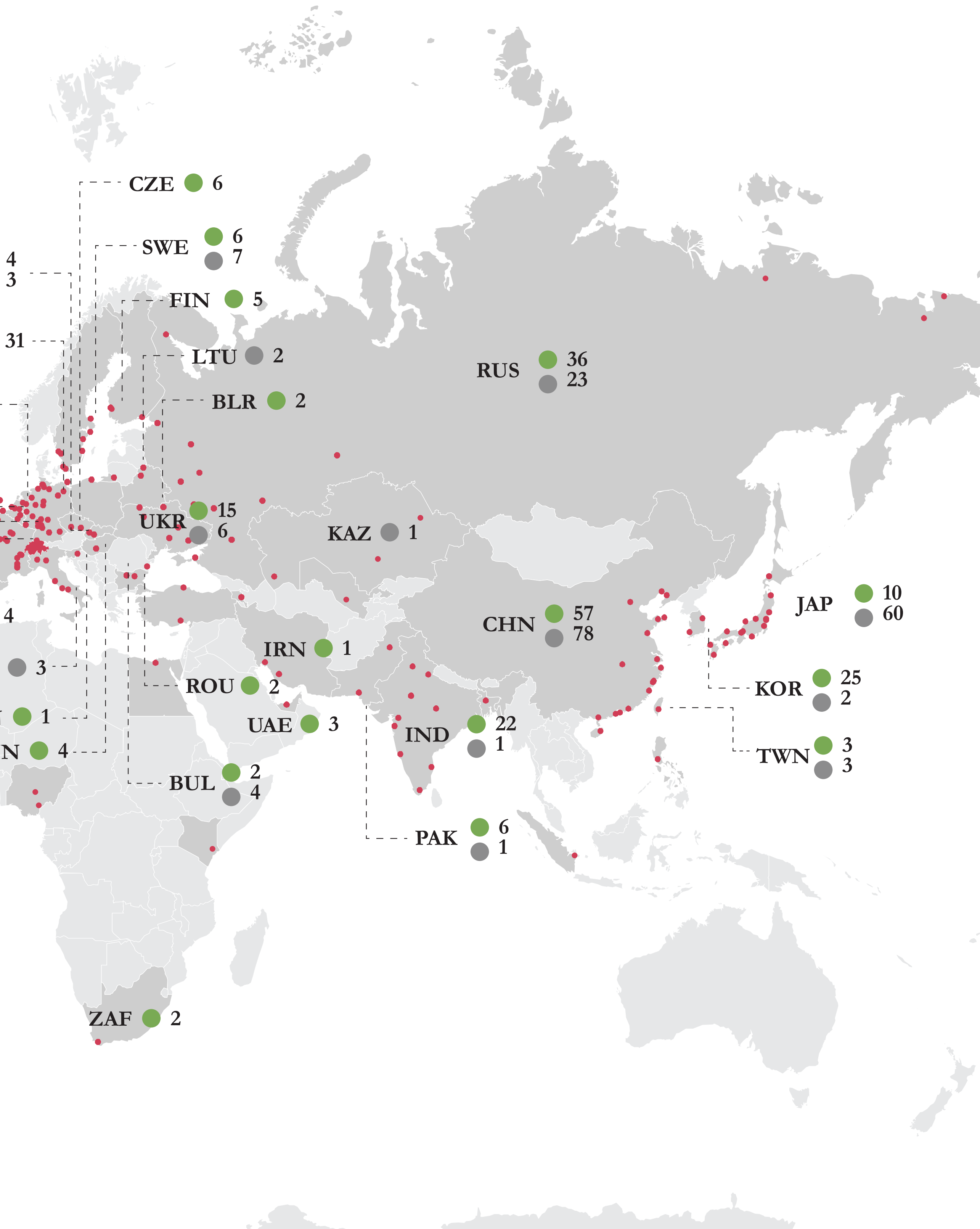


Figure 3. Visualization of the global nuclear reactor distribution as per December 2023.
Data source: Global Energy Monitor. Diagram: by author.



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SWE 6 7
4 3
FIN 5
31
LTU 2
BLR 2
RUS 36 23
UKR 15 6
KAZ 1
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JAP 10 60
CHN 57 78
IRN 1
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UAE 3
IND 22 1
N 4
TWN 3 3
BUL 2 4
PAK 6 1
ZAF 2

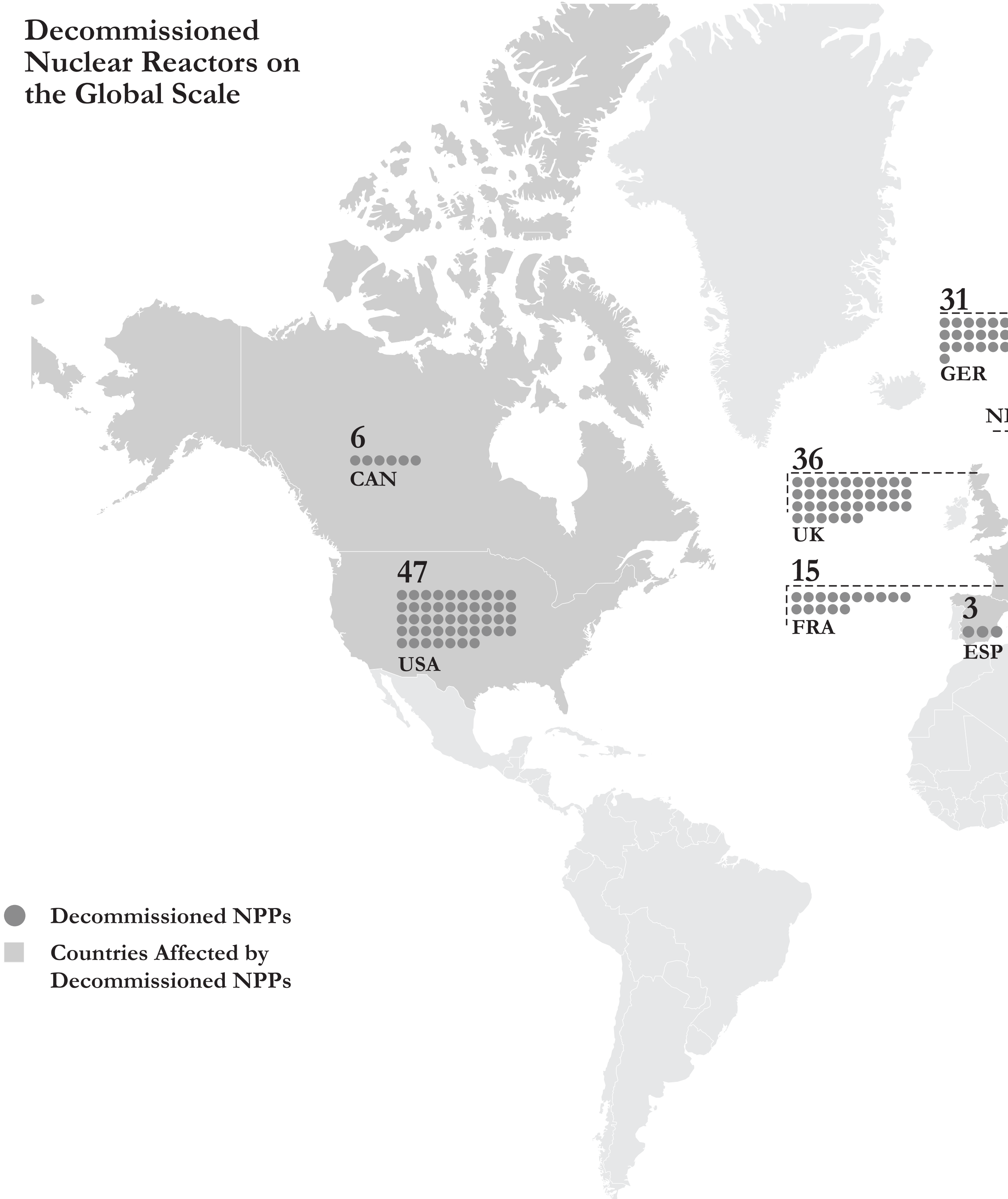
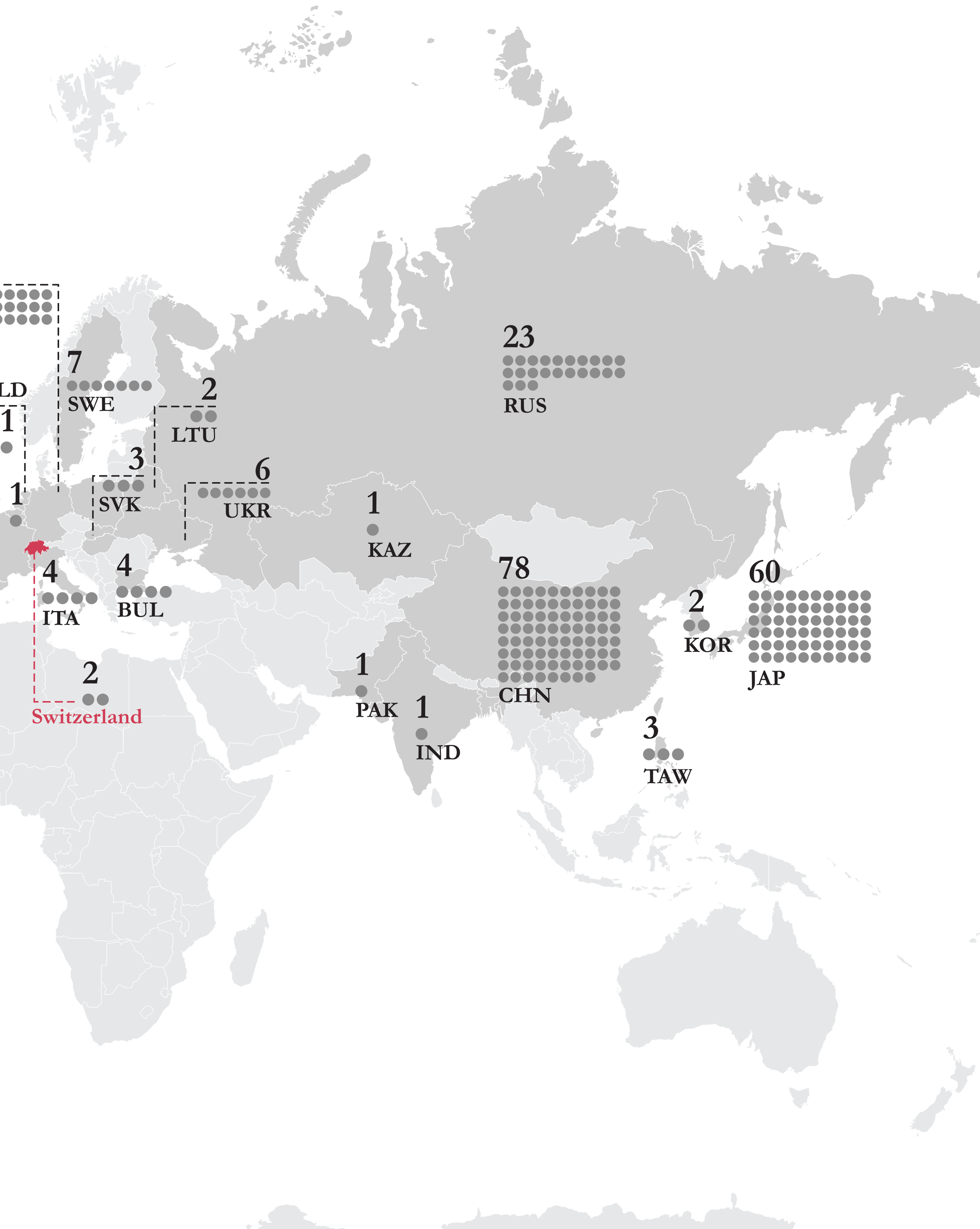


Figure 4. Highlighted in dark gray are all affected countries that have decommissioned nuclear energy projects as per December 2023. Data source: Global Energy Monitor. Diagram: by author.



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Aging Nuclear Energy Infrastructure

Concurrent to policy changes that accelerated the closure of many nuclear power plants, a considerable number of them were subject to decommissioning due to the infrastructure's finite lifespan.

Nuclear power plants built during the early states of the technology's implementation were meant to last for 20 to 40 years[1], with exceptions of a maximum of 60 years[2]. One of the major reasons defining that time period are the maintenance costs that begin to outweigh the benefits.

Some of the attributes that describe aging nuclear facilities are changes in physical properties which include: corrosion of the building materials, wear and tear, and material degradation.

By laying out all operating nuclear reactors to date and aligning them according to their reactor age (see **Figure 5**), one begins to see that many of them are already in their 40s. Consequently, most of today's nuclear power plants will reach their operating end of life in the near future.

For that reason, an additional 316 nuclear power plants will be shut down in the upcoming 15 to 30 years respectively. This in turn means that the total number of decommissioned nuclear power plants will almost double during that time frame (see **Figure 6**).

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1 Stanislav Novak and Milan Podest, "Nuclear Power Plant Ageing and Life Extension: Safety Aspects," 31-33.
2 World Nuclear Association, "Decommission Nuclear Facilities."

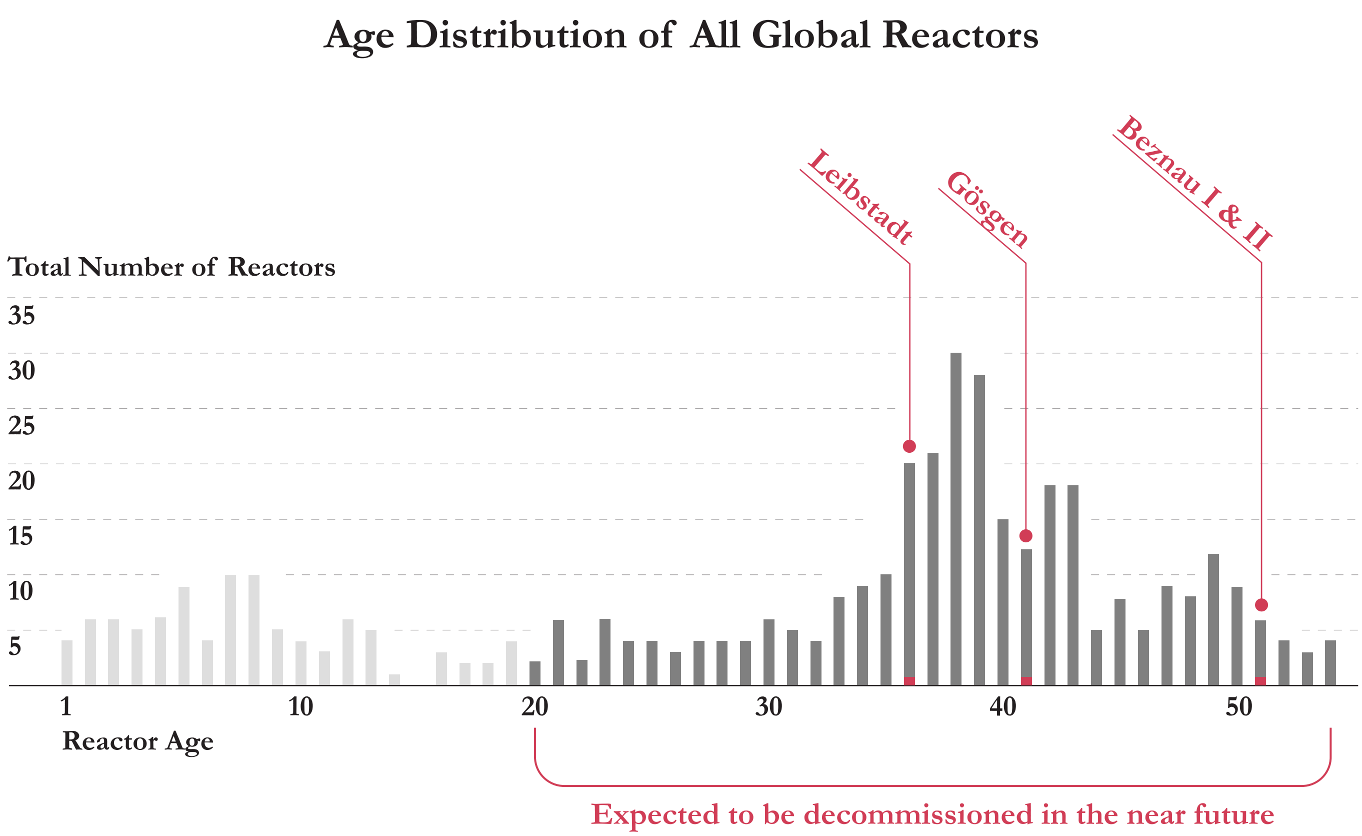

Figure 5. Age distribution of all global nuclear reactors with all Swiss nuclear power plants highlighted.
Data source: IAEA PRIS. Diagram: by author.

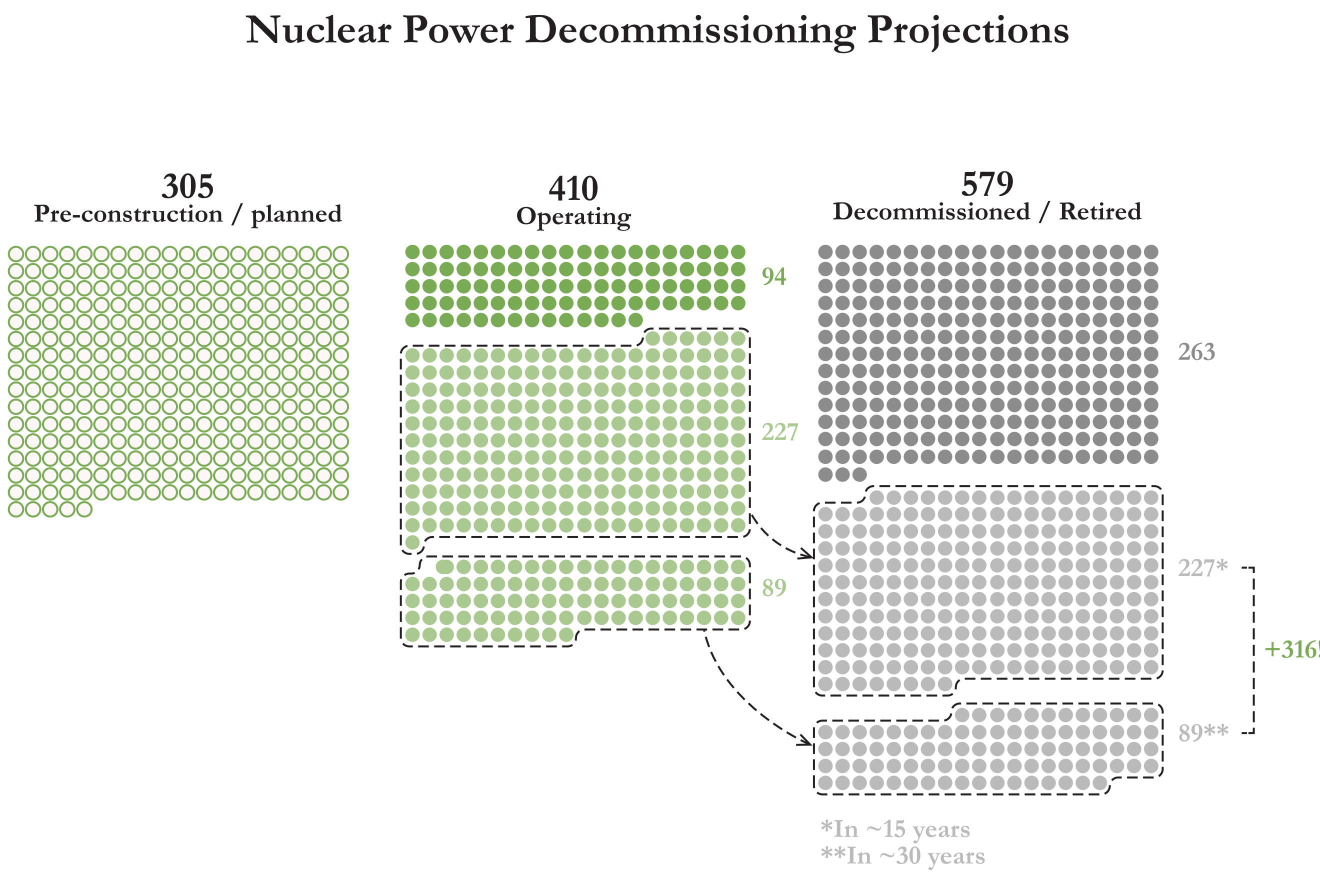

Figure 6. Future estimated projection of the increasing number of decommissioned nuclear power plants in the next few years. Source: by author.

Nuclear Decommissioning Today

After being decommissioned, nuclear power plants begin the site's reversal process which primarily aims at safely removing any radioactive material from the site (see **Figure 7**).

Nuclear power plant operators generally select one of the following three decommissioning procedures: DECON (Deconstruction), SAFSTOR (Safe Storage), or ENTOMB (Entombment)[1]. What distinguishes these from each other is the duration and the cost required to finance the process. Most nuclear power plants follow the DECON route because it is the most cost effective one of all three options.

For the DECON decommissioning route, nuclear power plant operators follow a pre-determined protocol that mainly includes the following steps:
1. Nuclear power plant shutdown
2. Core reactor dismantling
3. Nuclear fuel removal (e.g. uranium, plutonium) and all hazardous materials
4. Conventional dismantling of remaining buildings on-site
5. Nuclear power plant license termination and site release

The end of the process is achieved by demolishing all remaining buildings on-site using explosives[2,3] to accelerate the process (see **Figure 8**) with subsequent license termination. Following that, the site is either converted into a brown- or greenfield site (**Figure 9** provides three completed case examples). A few power plant operators have applied the partial reuse[4] route of repurposing the existing infrastructure with new functions. These, however, predominantly remain within the industrial or nuclear-specific realm, which continues the site's state of isolation.

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1 Nuclear Energy Institute, "Decommissioning Nuclear Power Plants."
2 Clarissa Rapps, Rainer Melzer, and Max Gündel, "How to Blast Cooling Towers."
3 NBC News and DSM Demolition LTD, "Controlled Demolition of U.K. Power Station Towers."
4 International Atomic Energy Agency, *Redevelopment and Reuse of Nuclear Facilities and Sites: Case History and Lessons Learned: Technical Reports.*

Nuclear Decommissioning Process

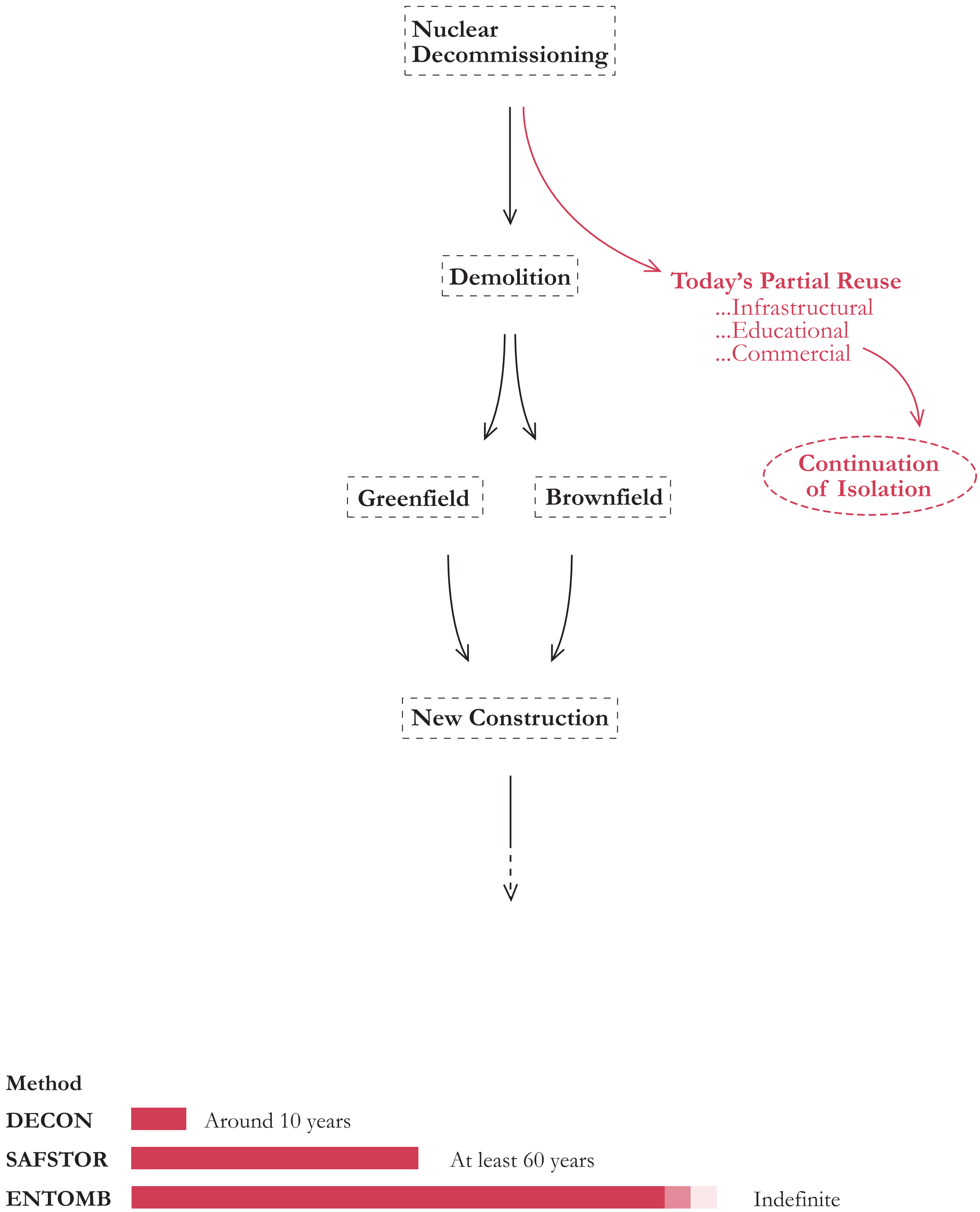

Figure 7. Visualization of the decommissioning process of nuclear power plants.
Data source: NEI. Diagram: by author.

Rapid Demolition

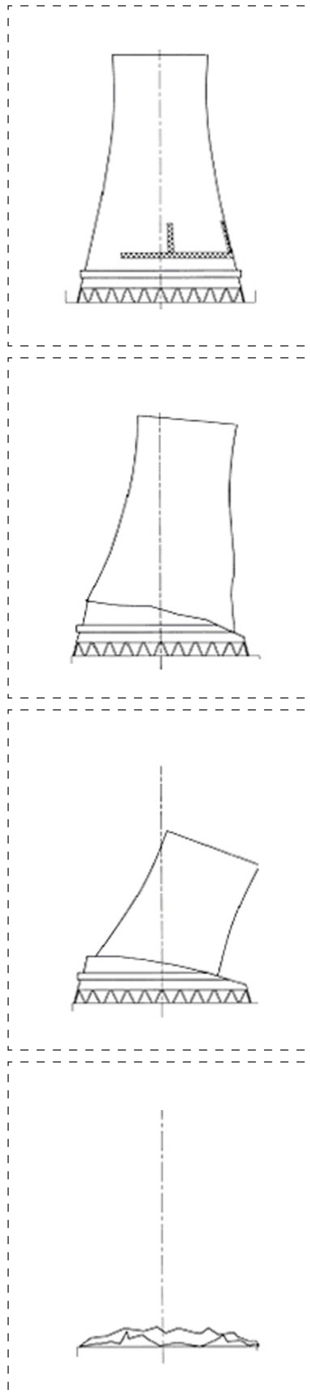

Figure 8. Frequent use of explosives to speed up the demolition process of nuclear power plants. Collage is based on diagram source: D. L. Foss, "Demolition of Cooling Towers from the World's First Commercial Reactors - the Nuclear Factor."

Site Comparison

Saxton

Pennsylvania, USA

Reactor type	**PWR**
Thermal Capacity	**24 MW_t**
Net Capacity	**3 MW_e**
First grid connection	**1967**
Decommissioned	**1972**
Years of operation	**5 years**

Trojan

Oregon, USA

Reactor type	**PWR**
Thermal Capacity	**1095 MW_t**
Net Capacity	**3411 MW_e**
First grid connection	**1975**
Decommissioned	**1992**
Years of operation	**17 years**

Zion 1 and 2

Illinois, USA

Reactor type	**PWR**
Thermal Capacity	**3250 MW_t**
Net Capacity	**1040 MW_e**
First grid connection	**1973**
Decommissioned	**1998**
Years of operation	**25 years**

Figure 9. Green- and brownfield outcomes of selected decommissioned nuclear power plants (MIT building for scale reference). Source: Google Data source: IAEA. Diagram: by author.

Completed Case Examples

25[1] out of all 263 nuclear power plants that have been shut down have successfully completed the decommissioning process. Two reasons for this small number are firstly the lengthy decommissioning phase that takes several years and secondly the many unexpected delays occurring along the way that prolong this phase.

To date, the afterlife of nuclear power plants tends to go in two directions: they either remain within a state of isolation throughout the continuation of privatized use, or they are made physically accessible through conversion to non-economic uses.

Figure 10 lists 17 out of 25 completed cases and their dedicated new use after decommissioning. When laying them out according to their reintegration efforts (on the left side leaning towards isolation and the right side maximizing accessibility) we can see a polarization occurring. Two examples on the left are gas power stations and nuclear fuel storage buildings. On the right are mostly green- and brownfield sites that can be used for new construction at a later stage.

Thesis Approach

This thesis proposes an alternate route that reimagines the decommissioning process of phased out nuclear power plants (see **Figure 11**). The remaining non-radioactive structures are kept and are adaptively reused for new purposes. These programs create an environment for various users to partake in the site's new multipurpose identity that invites public engagement. Through this, these formerly detached sites can be reconnected with their existing context.

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1 Nuclear Energy Institute, "Decommissioning Nuclear Power Plants."

Completed Worldwide Case Examples

Figure 10. 17 out of 25 completed nuclear decommissioning cases to date with focus on their reintegration efforts. Data source: IAEA, *Redevelopment and Reuse of Nuclear Facilities and Sites*. Diagram: by author.

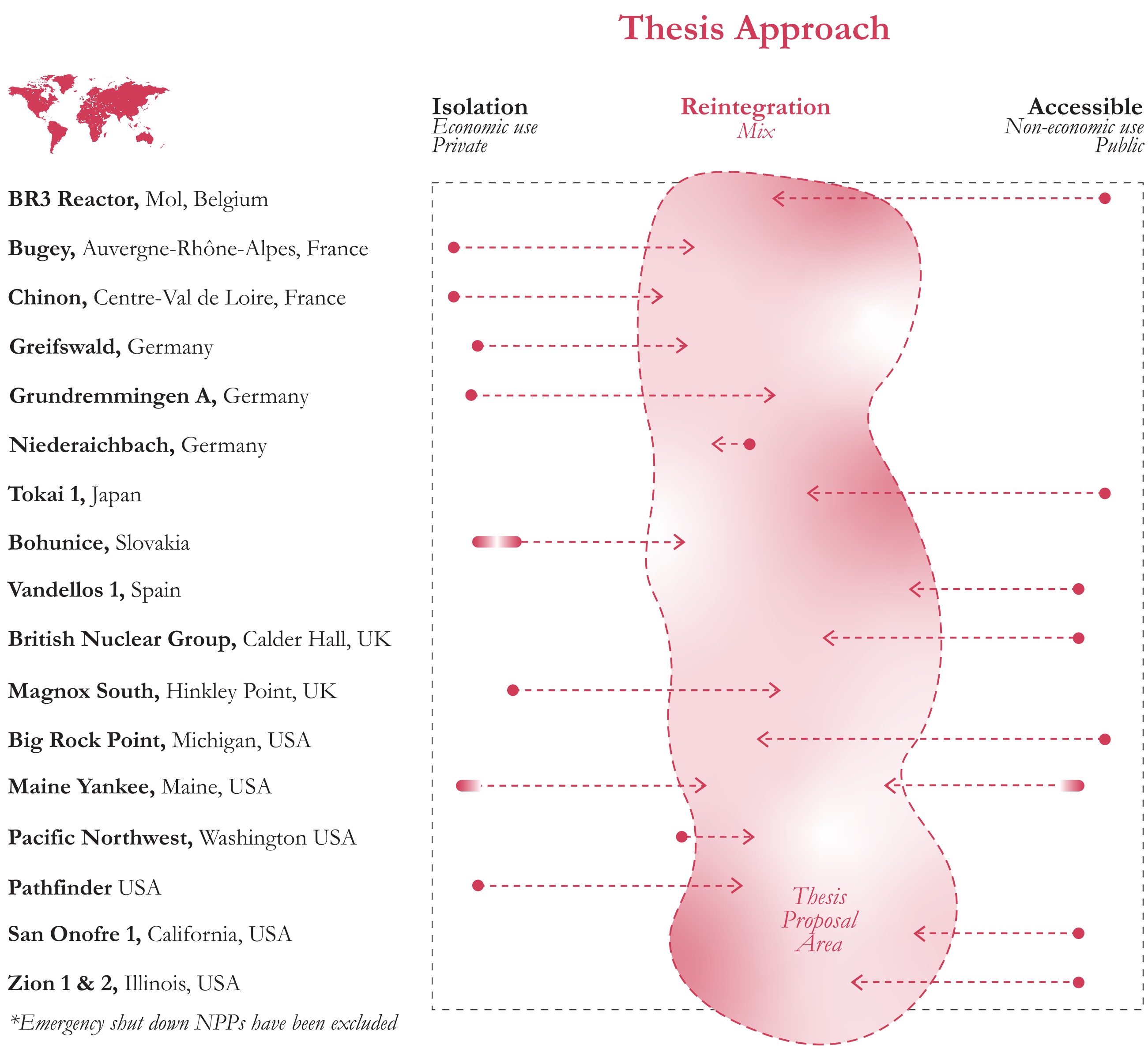

Figure 11. Applying the thesis proposal that suggests adaptive reuse with a mix of new programs to facilitate the reintegration process. Diagram: by author.

On the Regional Scale
Switzerland's Nuclear Energy

Switzerland's nuclear energy infrastructure has undergone several political, economical, and social changes since the first nuclear power plant was built back in 1965 (see **Figure 13**). Nuclear power, once optimistically considered the newest technology of the century, or as this quote states: *"Rein in die Atomenergie – und zwar so schnell wie möglich!"* (Translation: *"Into Nuclear Energy - as quickly as possible!"*)[1], was later gradually rejected by the public due to nuclear power problems that were emerging around the world.

As a consequence, many planned projects that were aimed at covering the rising energy demands were put on halt or canceled[2] after the government legislated the prohibition of any new construction of nuclear power plants as well as the slow phasing out of its existing NPPs at the end of their operating lifetimes[3].

To date, Switzerland has five nuclear power reactors out of the initially planned thirteen projects. Three are still operating today (Leibstadt, Beznau, and Gösgen), one was forced to shut down after a few months of operation due to a reactor meltdown[4] in 1969 (Lucens), and the last one was recently decommissioned in 2019[5] (Mühleberg).

Although this thesis focuses on the Swiss nuclear power plant in Mühleberg, there is an emphasis on the larger picture of phasing out nuclear infrastructures and how some aspects of the case study in hand could be extrapolated to other sites that are undergoing or will undergo a similar discontinuation.

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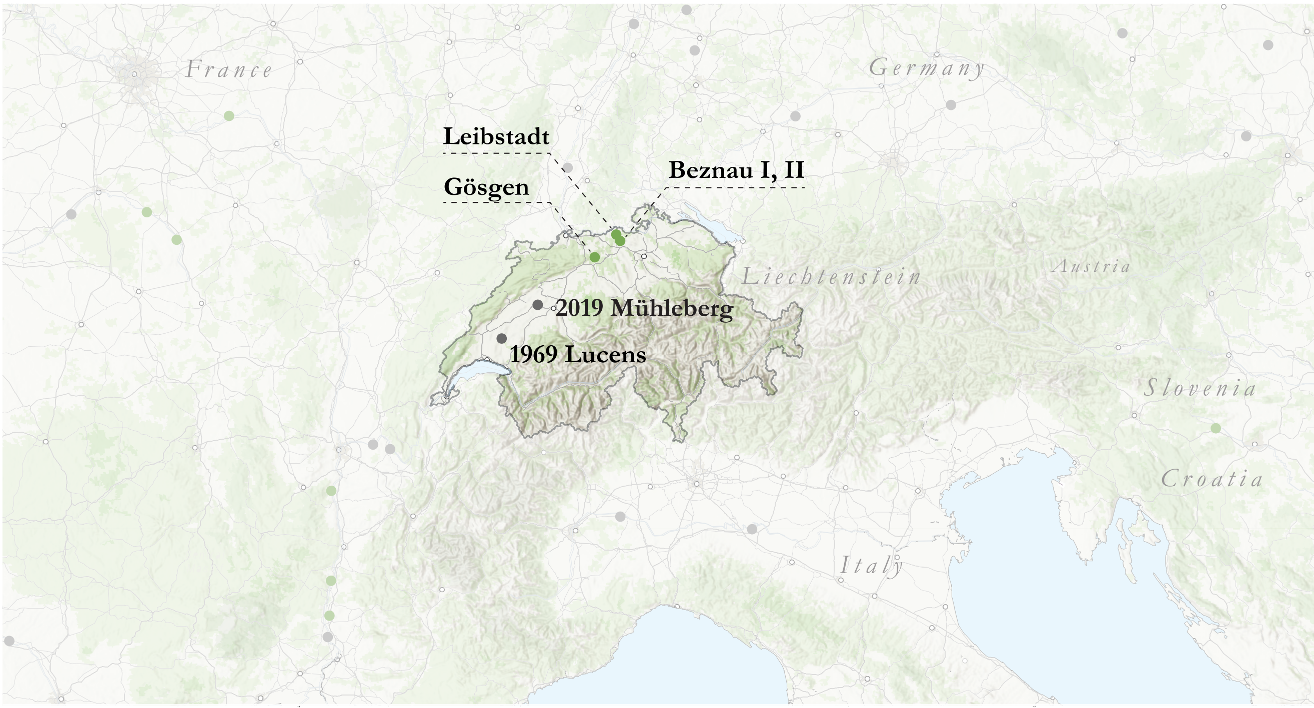
1 Lukas Leuzinger, "KERNENERGIE: Kuhweide Statt Atomkraftwerk."
2 Mirjam Kohler, "Protestbewegung Erinnert Sich – Wie Vor 51 Jahren Der Bau Des AKW Kaiseraugst Verhindert Wurde."
3 Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation (UVEK), "Ausstieg Aus Der Kernenergie."
4 Swissinfo, "Historic Nuclear Accident Dashed Swiss Atomic Dreams."
5 BKW AG Media Relations, "Mühleberg Nuclear Power Plant Ceases Operations."

Switzerland



Around Switzerland

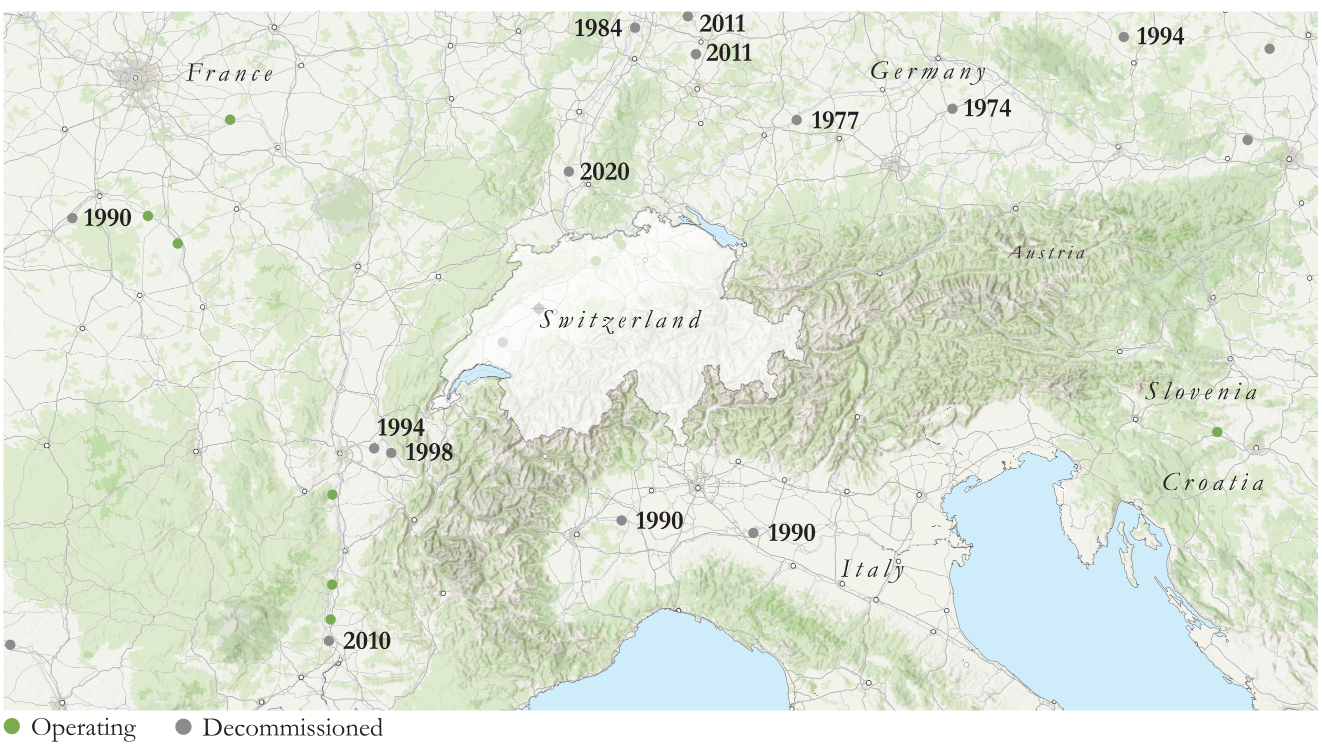


Figure 12. Above: Switzerland's nuclear energy landscape with two shutdown project cases to date. Below: the larger region shows several nuclear power plants are already shut down. Diagram: by author.

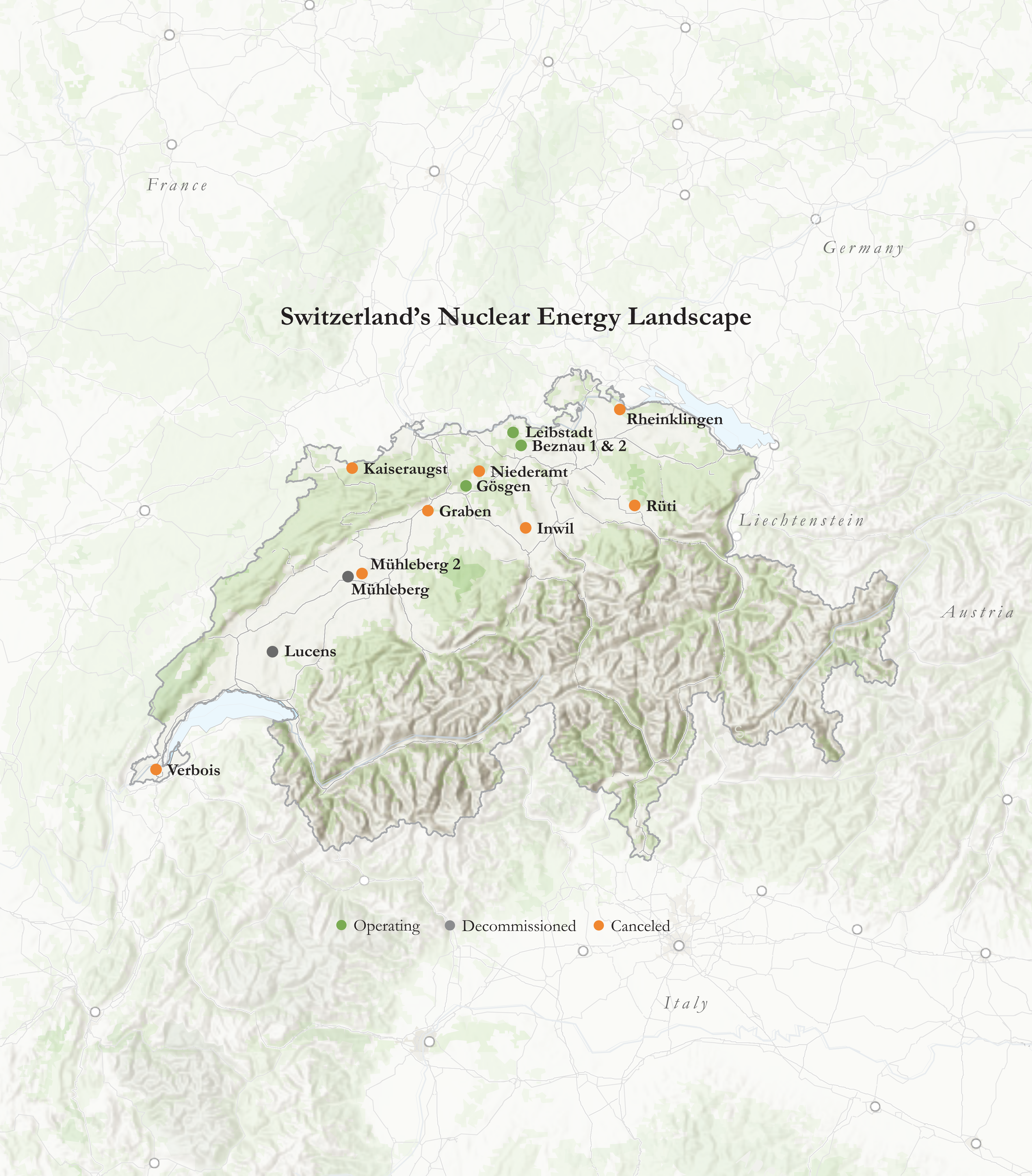


Figure 13. Visualization of all Swiss nuclear power plants that are either operating, decommissioned, or canceled. Diagram: by author.

The next chapter focuses on the Mühleberg site visit that took place earlier this year.

Chapter 2 - KKM Mühleberg

June 24th, 2023 - Mühleberg, Switzerland

I am on my way to meet with Oliver Kühne, who works as an engineer and revision manager at the nuclear power plant.

On my walk down there, I notice a small sign that helps me navigate through the quiet, rural neighborhood.

The last time I visited the site was fifteen years ago, as a high school student. Back then, I wasn't fully aware of the political, cultural, and economical implications that this place embodied.

Kernkraftwerk »» «« **Nuclear Power Plant**

Figure 14. Walkway view down towards the nuclear power plant. Photo credit: Erich Reinhard.

As I am walking, I glance at the power plant's surrounding and am perplexed by the disconnect between the heavily secured site and the surrounding picturesque rural landscape.

After all, the village name gives hints at its historical roots.

The nuclear power plant, built during 1960s, has radiated this impression of detachment and isolation ever since. To be built here, local farmers had to give up their land and farmhouses, for the greater collective good.

Since then, Mühleberg's predominantly large farming community has adapted to living and working side by side with this plant.

Mühleberg »» «« **Milling Hill**

Figure 15. The KKM embedded within the picturesque landscape.
Image source: Swissair Photo AG and ETH Bibliothek, Bildarchiv.

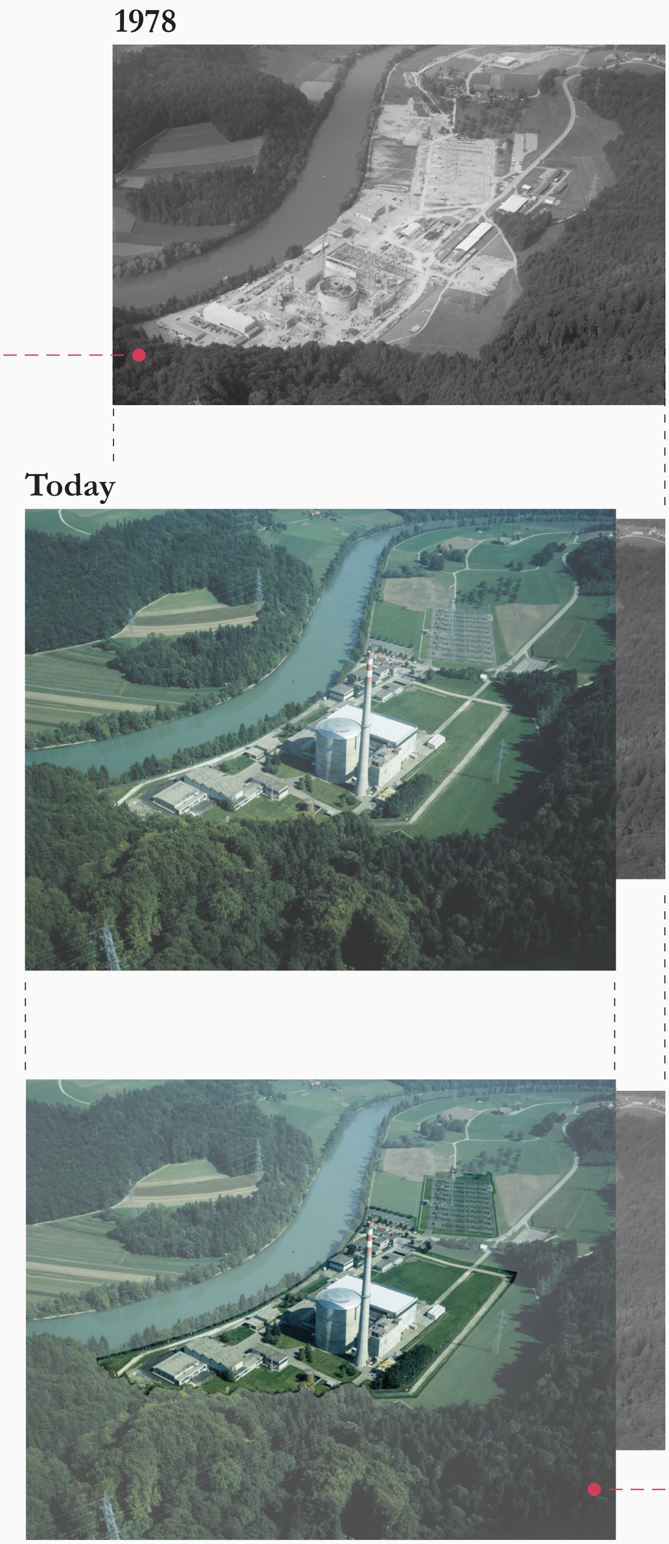


Figure 16. The site's state of isolation over time. Image sources: Comet Photo AG, Swissair Photo AG, and ETH Bibliothek, Bildarchiv. Diagram: by author.

Mühleberg Municipality

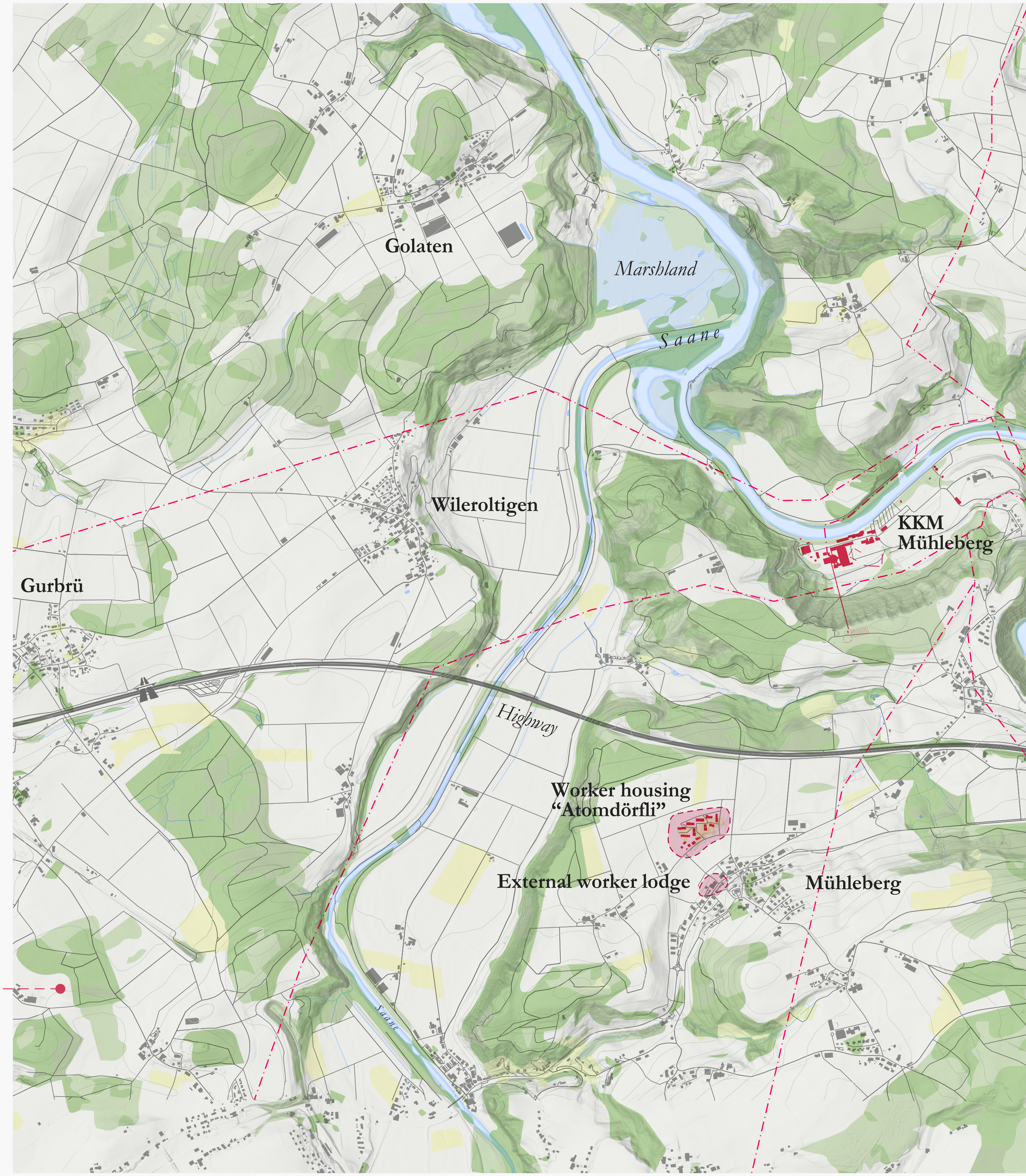
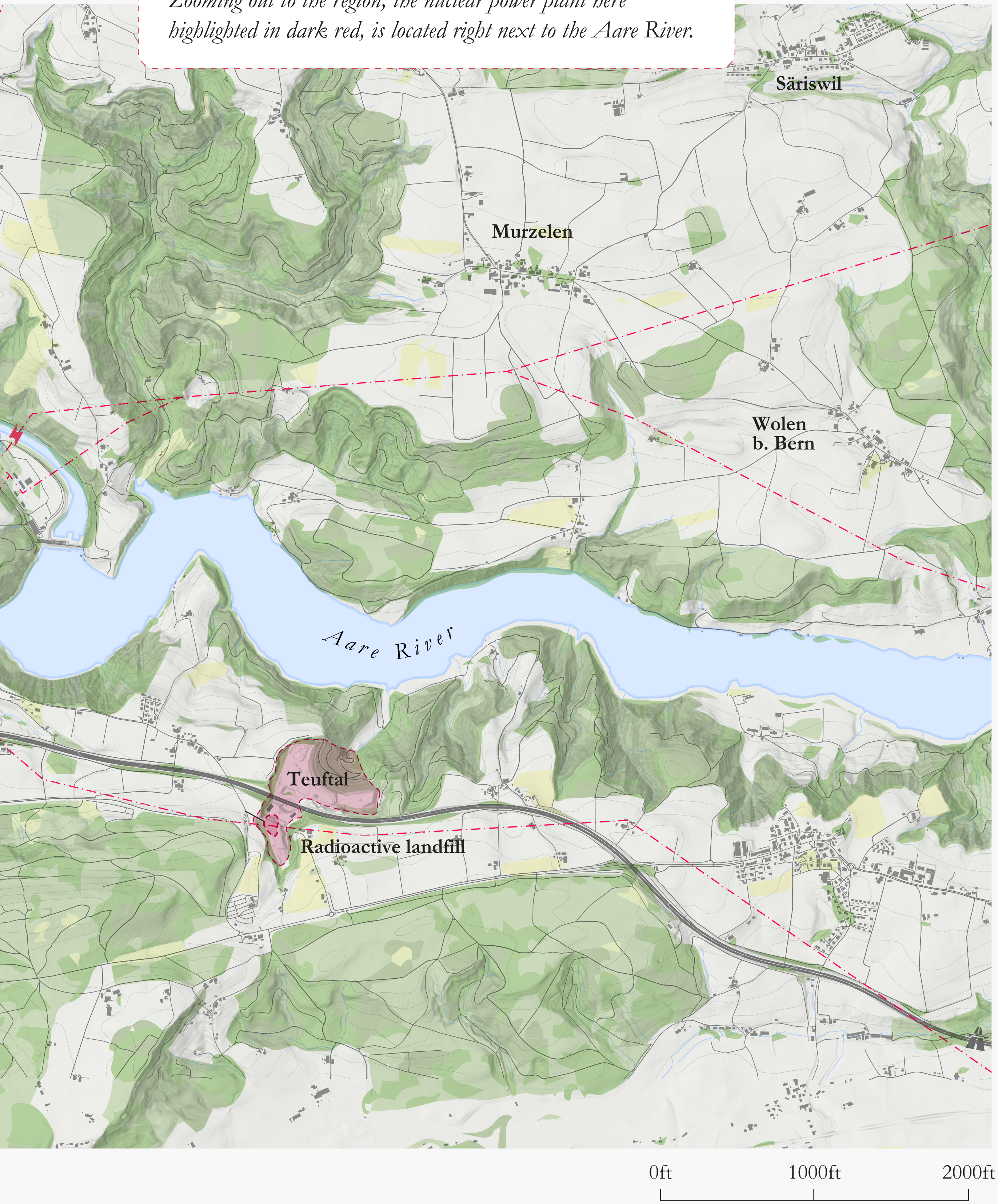


Figure 17. Map of the larger region marked by smaller villages.
Diagram: by author.

Zooming out to the region, the nuclear power plant here highlighted in dark red, is located right next to the Aare River.



Agricultural Production in Mühleberg

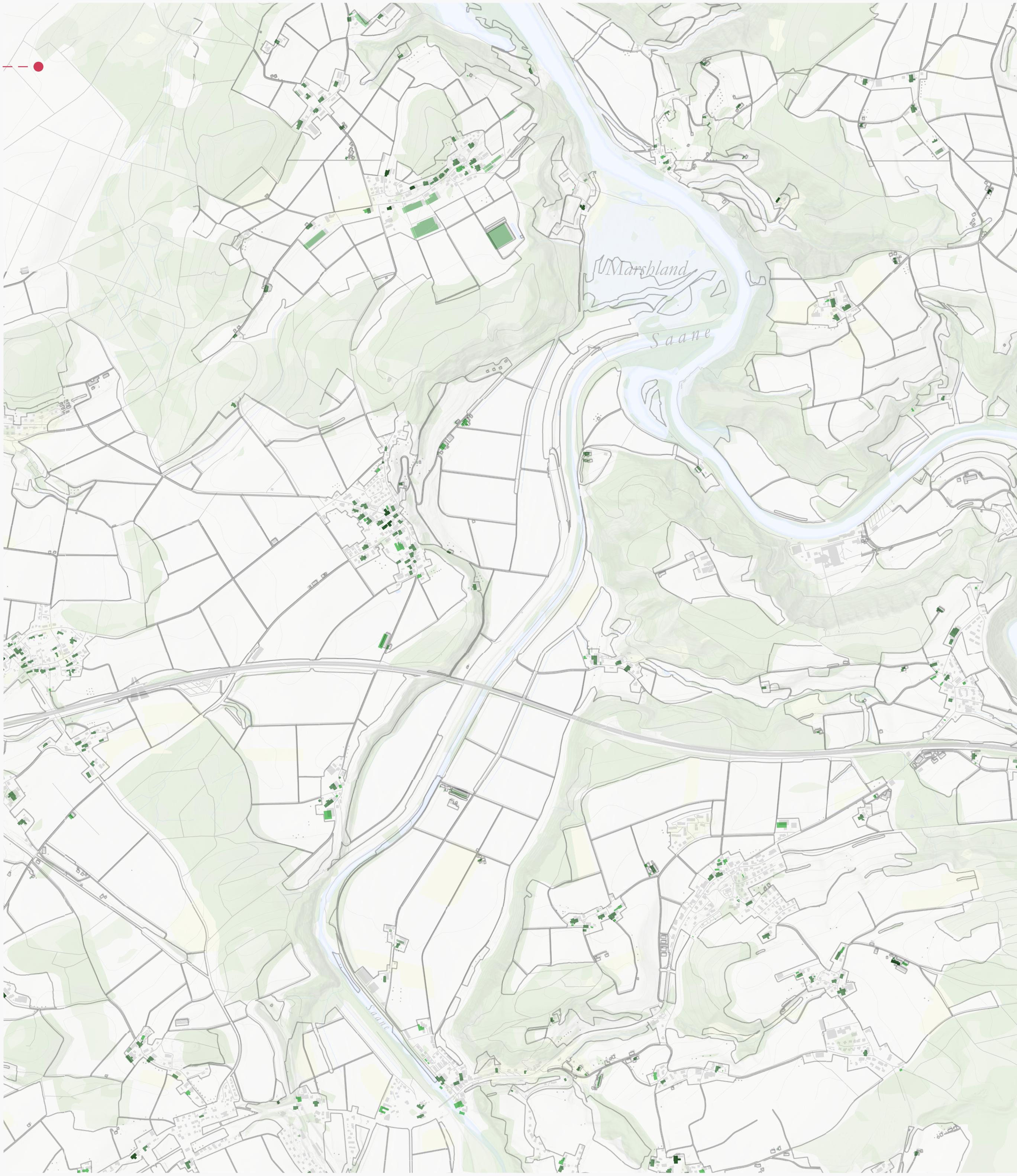
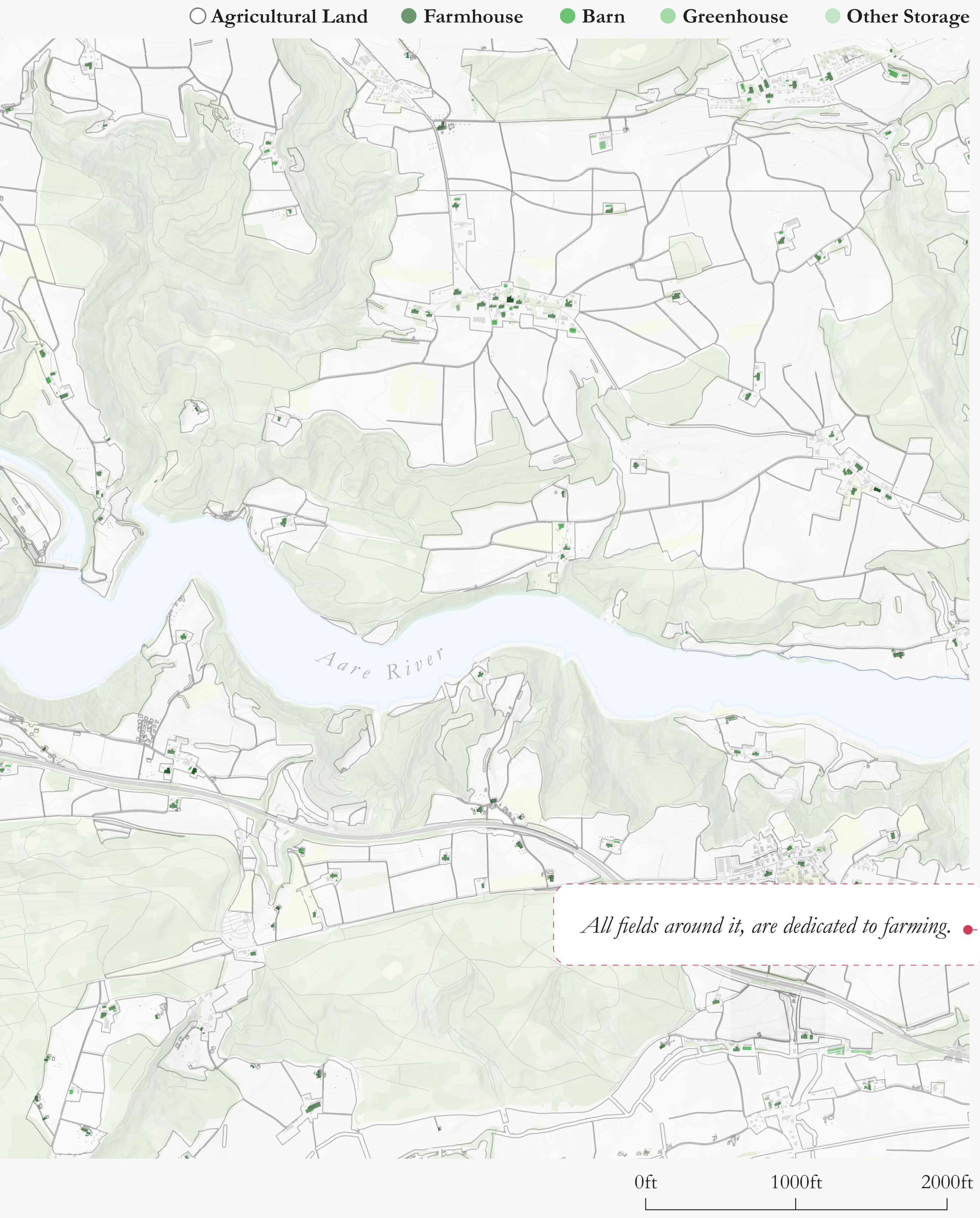


Figure 18. Agricultural cultivation around the Mühleberg region.
Diagram: by author.



All fields around it, are dedicated to farming.

Soil Conditions

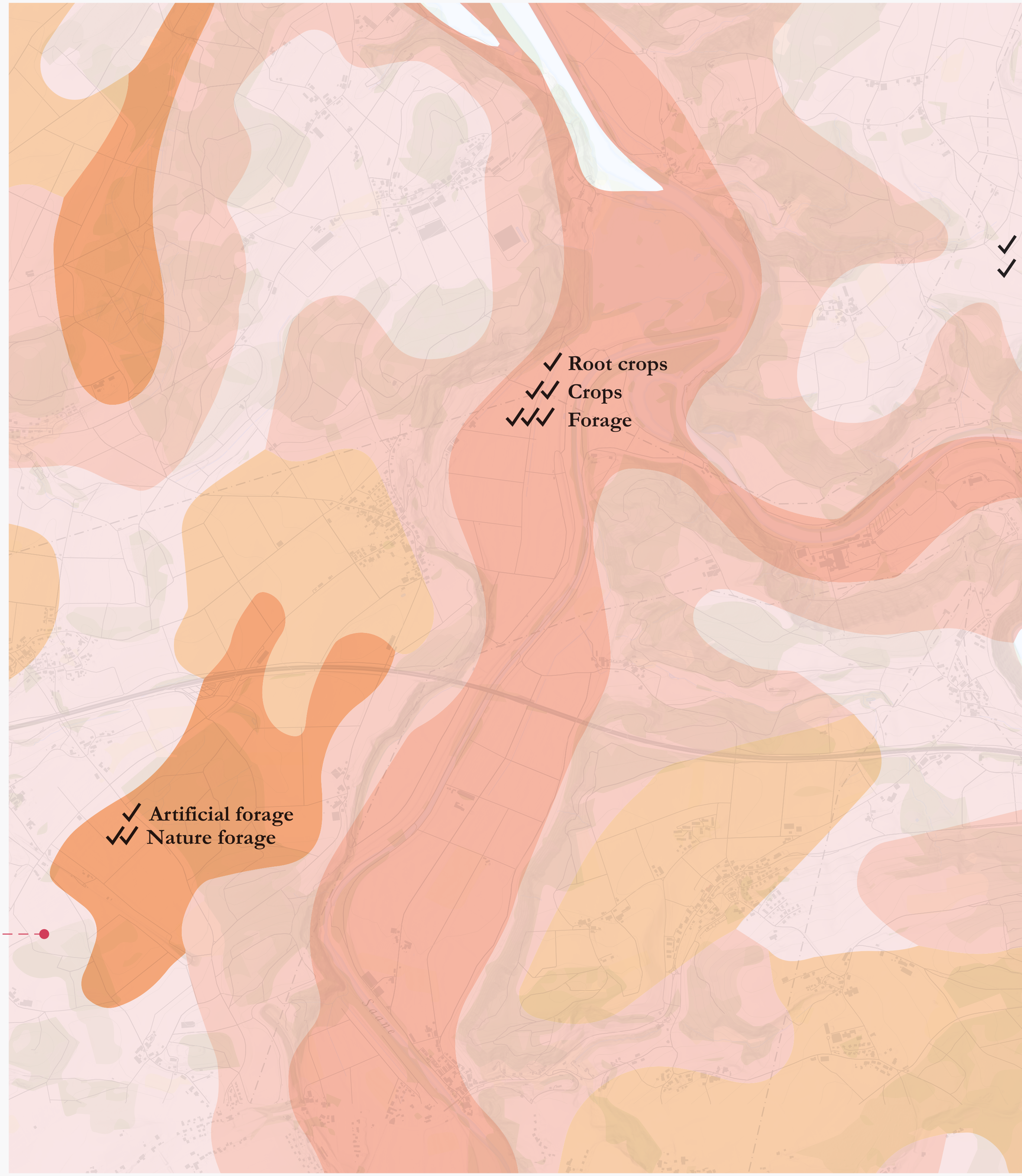
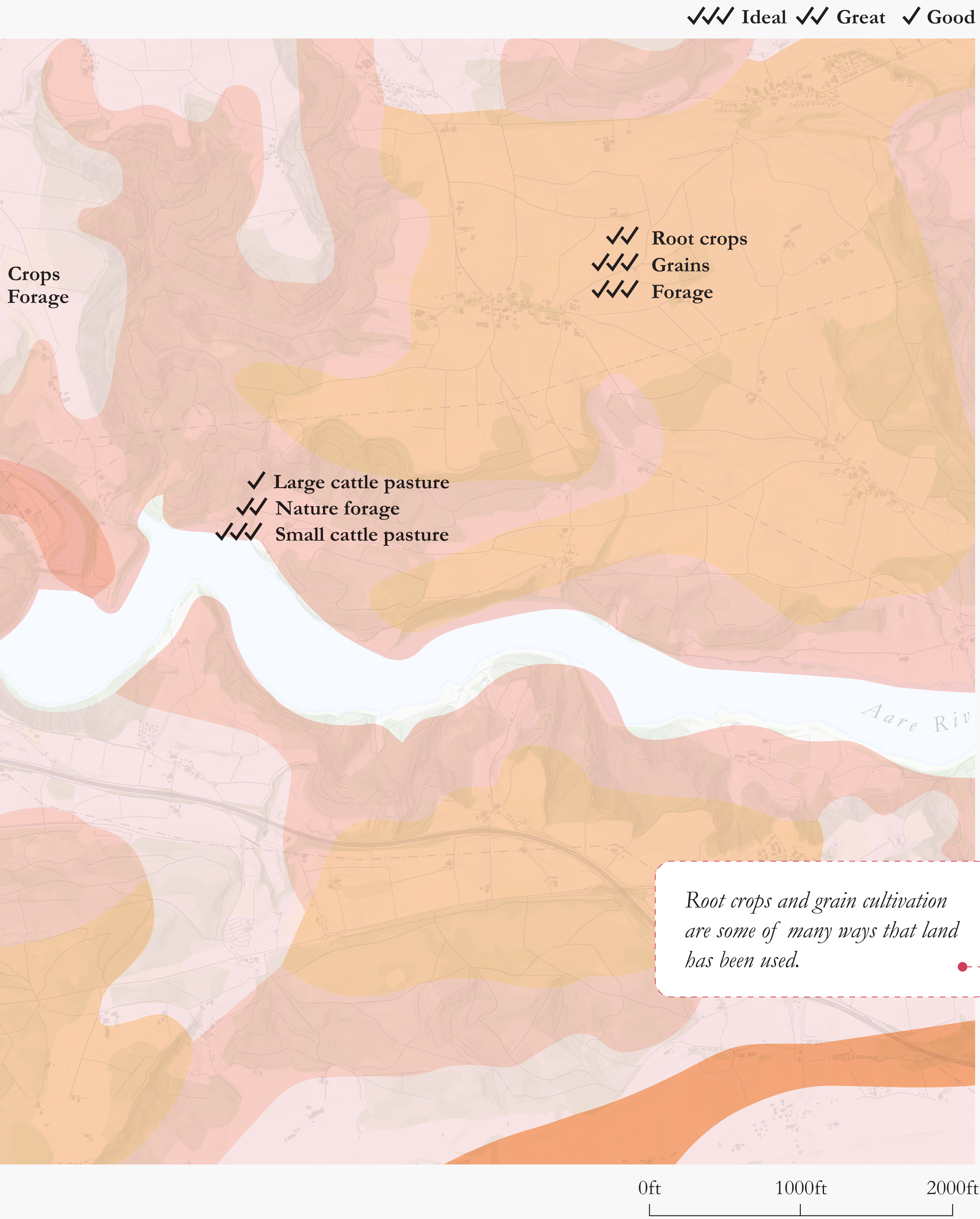


Figure 19. Site soil compositions guide farmers for optimal farming conditions.
Diagram: by author.

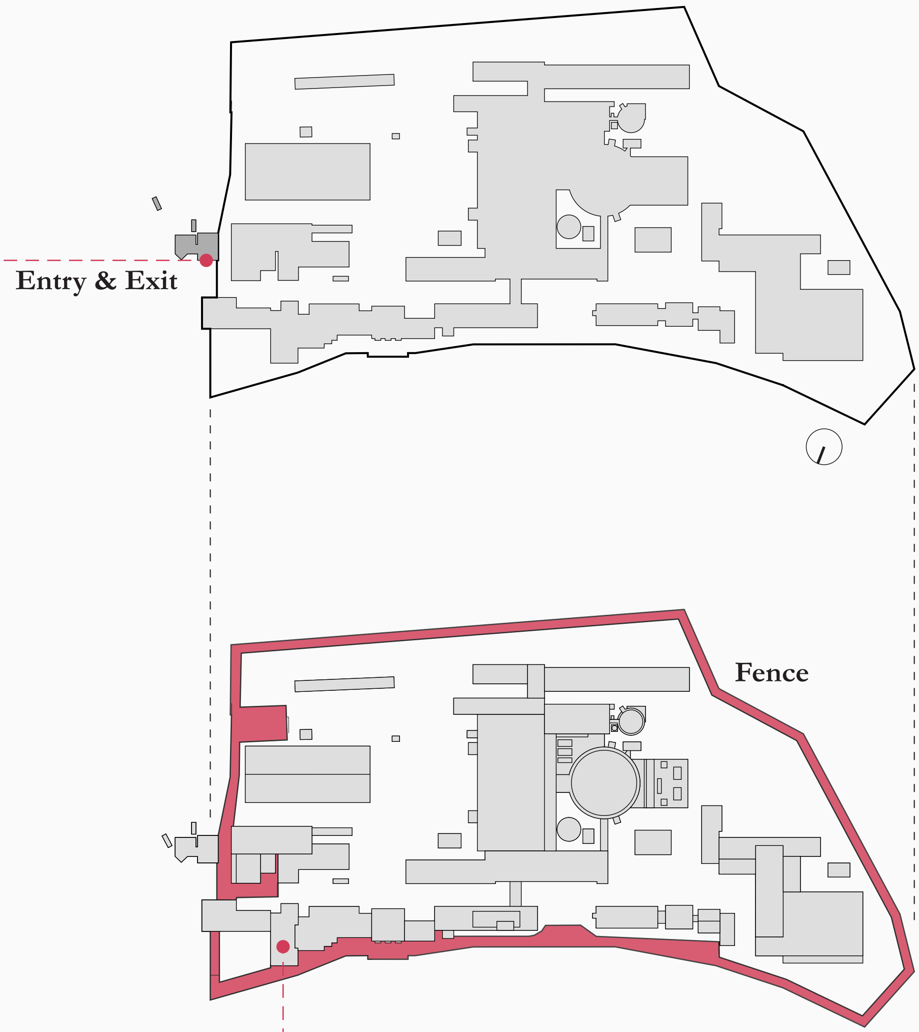


Root crops and grain cultivation are some of many ways that land has been used.

I wonder how they have been able to go about their day since the power plant began to operate. Knowing that, in case of an emergency, their crop cultivated land would become unusable, aside from the more serious caused health-related harms.

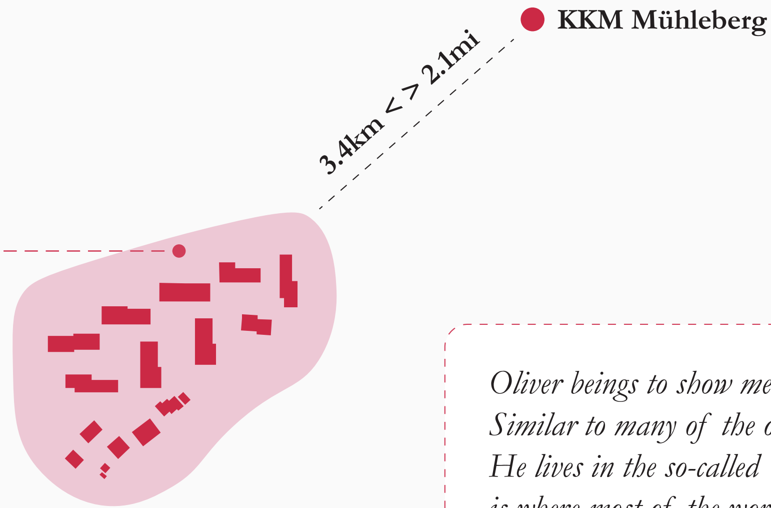
As I finally arrive at the gate, the guard waves me over to go through the security checkpoint. No bags are allowed inside, no photos and note taking are permitted. Passing by the double-fenced off area, I enter the nuclear power plant.

Figure 20. Affected crop region by adioactivity in case of an emergency meltdown at the nuclear power plant Mühleberg (in percentage). Data Source: Spiegel Wirtschaft Online. Diagram: by author.



For security reasons, he takes me through several pathways to avoid going directly from A to B. The only points of reference I have are the floor height levels in relation to the ground, and the color coding of the pipes.

Figure 21. Nuclear Power Plant Site Map Diagram. Diagram: by author.

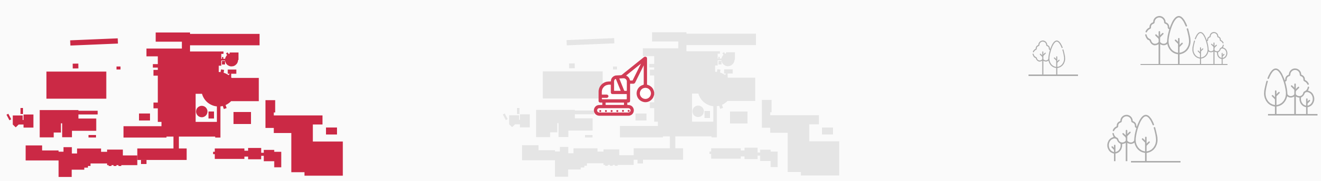


Oliver beings to show me around the site. Similar to many of the other 500 employees, He lives in the so-called "Atomdörfli" – that is where most of the workers live since it belongs to the power plant.

Atomdörfli ››› ‹‹‹ **Nuclear Village**

On our way through one of the tunnels, he tells me that the site is currently undergoing a larger decommissioning process. This will last until 2034, after it had been operating for 48 years. Following that, it will be turned into a greenfield.

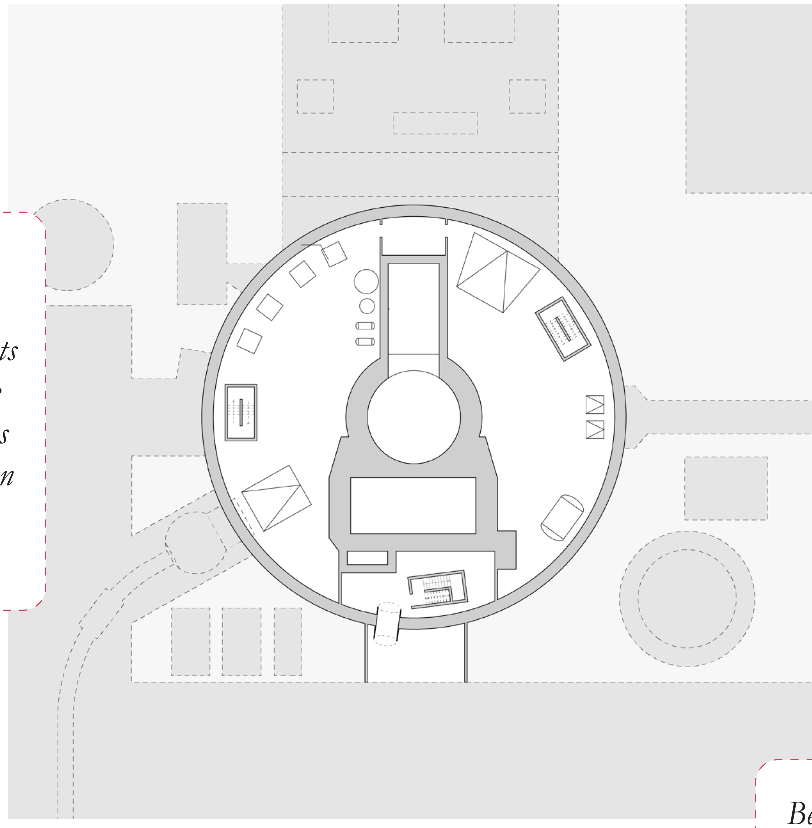
Decommissioned | **Dismantling & Removal** ~14 years | **Greenfield**



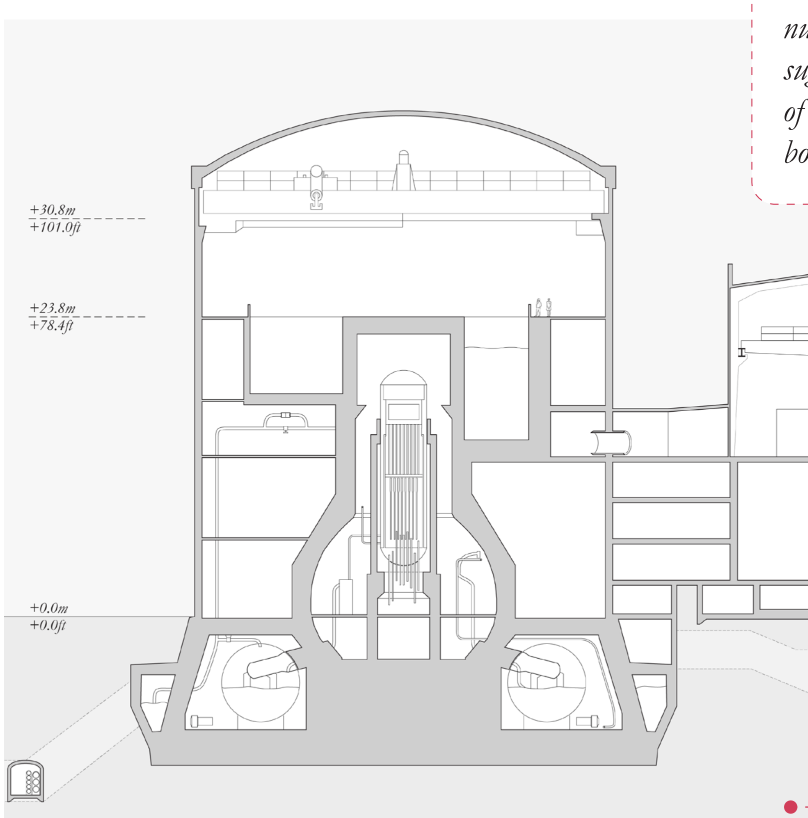
2019 Shutdown	**2020 - 2024** Core Dismantling	**2025 - 2030** Hazardous Material Removal	**2031 - 2033** Conventional Dismantling	**2034 onwards** New Use

Figure 22. Diagram of the distance between the Atomdörfli and the NPP Mühleberg. Diagram: by author.
Figure 23. Decommissioning process of the NPP Mühleberg. Data source: BKW. Diagram: by author.

The owners decided to shut down the plant in 2019, because the maintenance costs outweighed the benefits. The decommissioning cost for this plant is estimated at $3.2Bn USD, fully funded by the power plant operator itself.



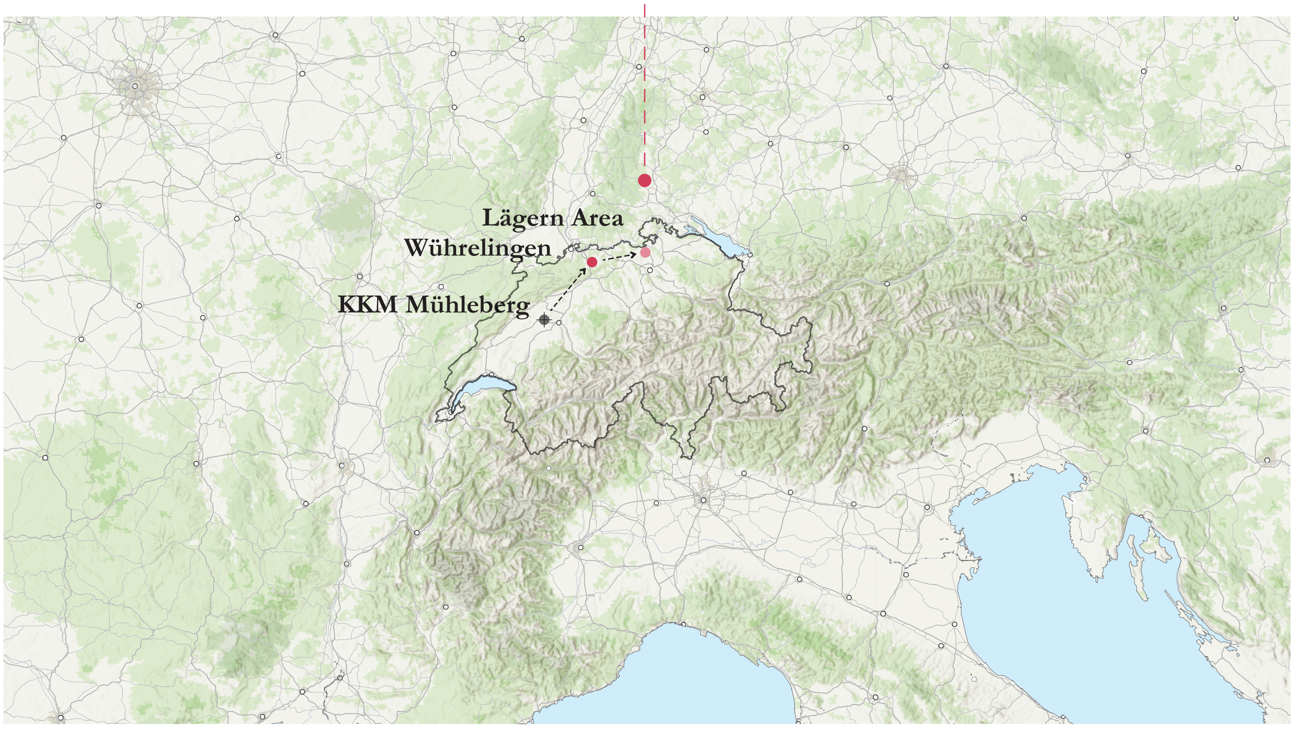
Because I am new to the dismantling process of nuclear power plants, he suggests we go to the heart of the building – the boiling water reactor.



Existing structure
Layout

Figure 24. Section (above) and floor plan drawing (below) of the nuclear power plant before the dismantling process. Diagram: by author.

Arriving at 78ft above ground, I see the gigantic reactor space in front of me. Since shutting down the plant, Oliver tells me, every part of the building has been measured meticulously for radioactivity-levels over the course of several months.

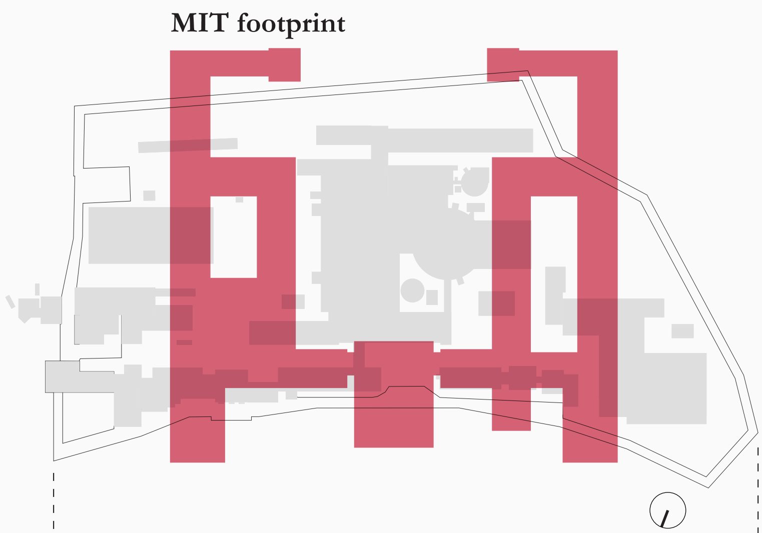


After marking them in pink, every inch of the building is cut into small parts with machinery, cleaned diligently, measured again, and stored temporarily to then be transferred to either a recycling facility, or for still-radioactive materials, to a temporary storage spot 2.5 hours away. The final underground storage was only defined last year is expected to be built by 2060.

Figure 25. Storage Pathway for high radioactive material in Switzerland. Wührelingen is the temporary storage and Lägern Area is the permanent storage location. Diagram: by author.

What remains on-site are the outer shells of the former reactor and turbine hall. I asked him what will happen with the 26 buildings after not being exposed to any radioactivity. He continues, "after removing all radioactive materials and components over the next 8 years, the site will be demolished and turned into a greenfield."

I was startled to hear him tell me about the power plant's afterlife, after seeing all other buildings still being well maintained, some even recently built.



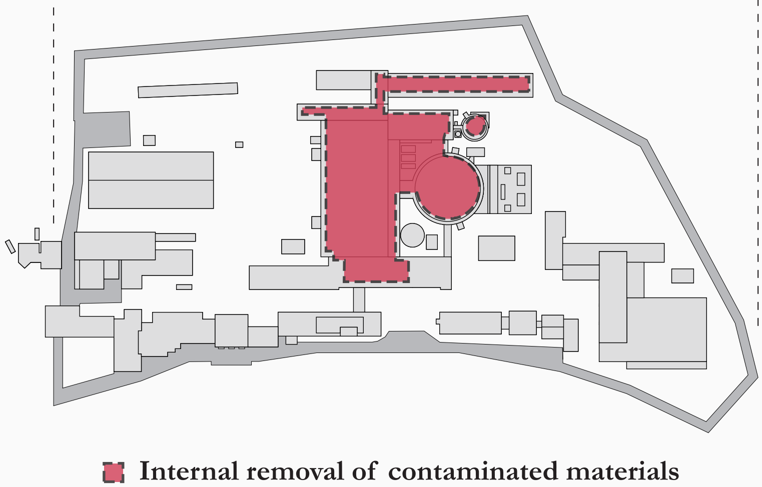


Figure 26. Above: Mühleberg site comparison with the main MIT building as a scale reference. Below: Buildings marked in red are in the contaminated zone and will have all radioactive materials removed by 2030. Diagram: by author.

I began to wonder...

Could adaptive reuse of the remaining buildings help reintegrate the site back into its context?

If so, what mix of activities and other aspects would support this process?

Transforming the site into a hydro energy storage system could allow the workers (having been cross-trained for the decommissioning process) to continue working here with the community they've built over decades.

1. Water for Electricity Generation

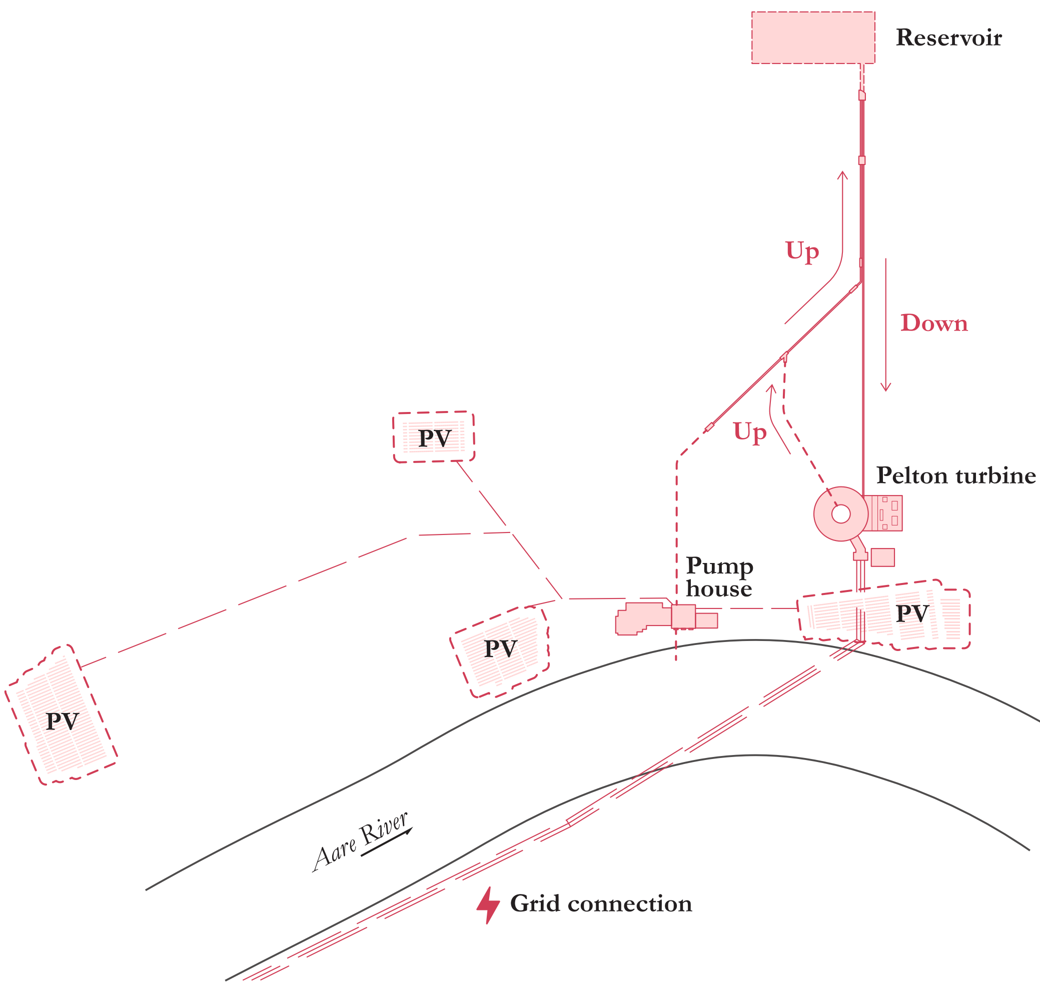


Figure 27. The first layer of the adaptive reuse proposal includes a pumped hydro energy storage system to generate electricity. Diagram: by author.

A secondary layer, dedicated to an agricultural Co-op could serve as an extension for Mühlebergs large farming community. The water, after being treated and used for electricity production, would now partially be used for various agricultural uses, including indoor hydroponics, water storage, and field irrigation.

2. Water for Agricultural Uses

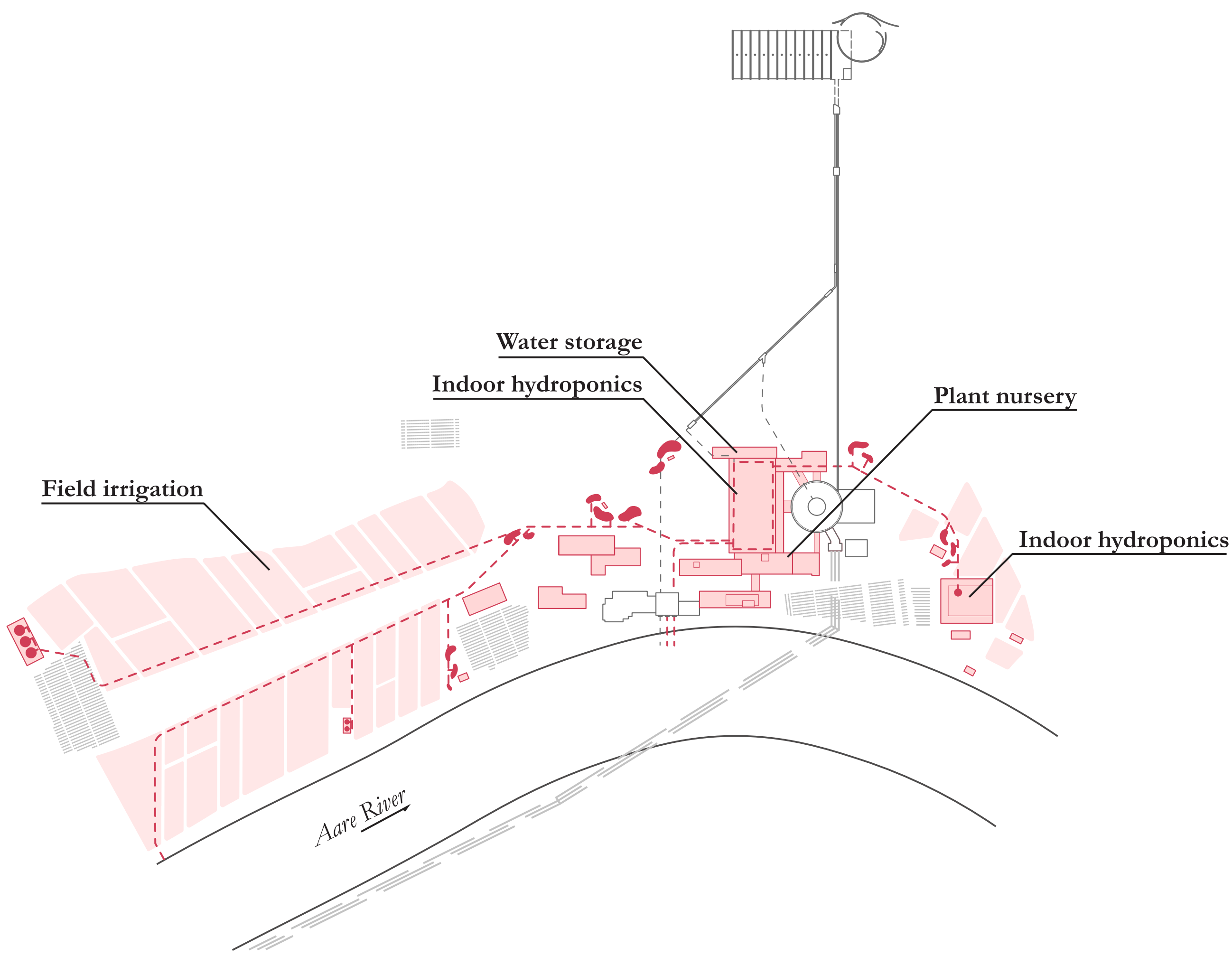


Figure 28. The second layer of the adaptive reuse proposal introduces agricultural programs on-site. Diagram: by author.

And lastly, adding a third layer of collective and recreational activities would now invite visitors to partake in the site's new multipurpose identity.

3. Water for Recreational Uses

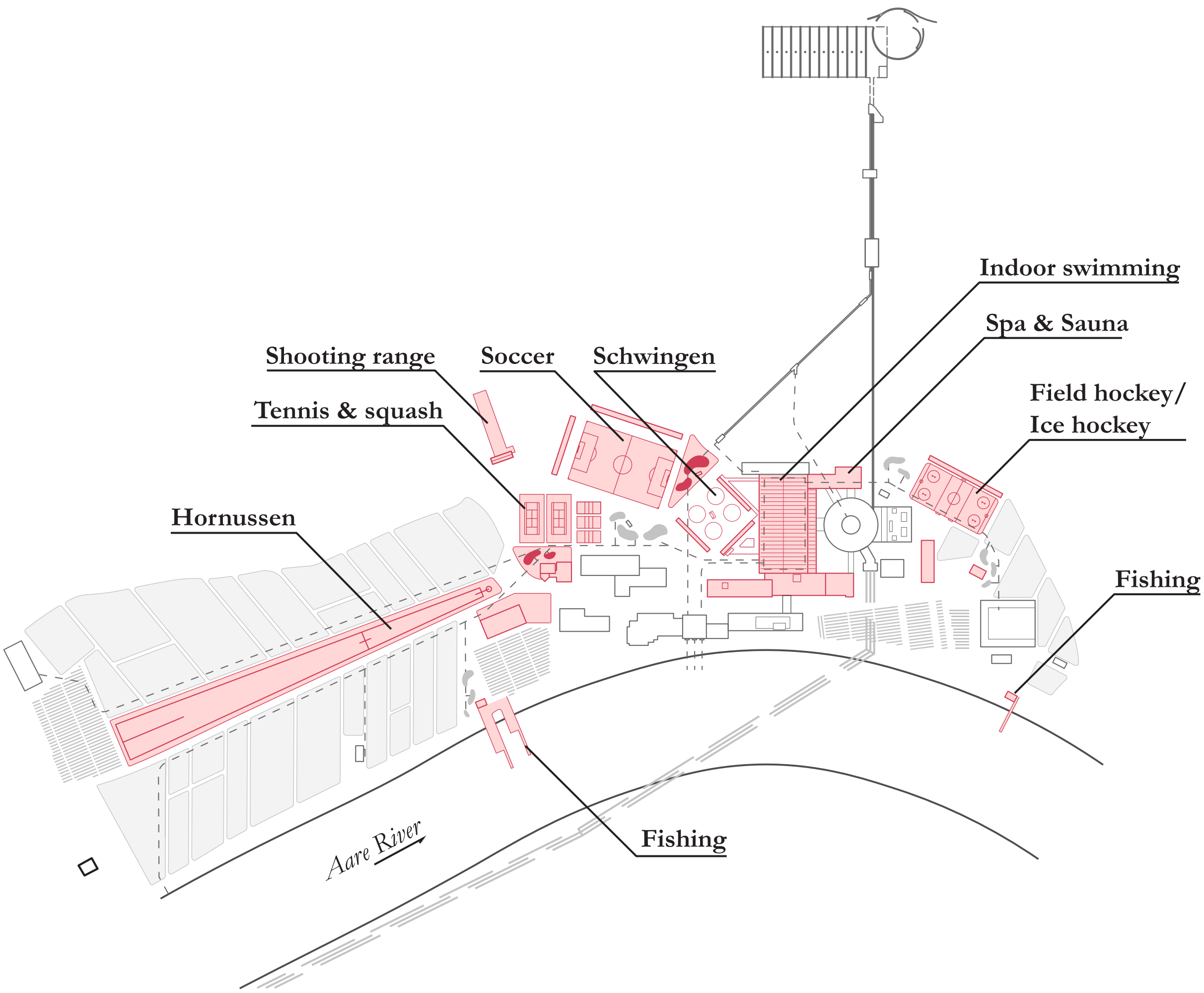


Figure 29. The third layer of the adaptive reuse proposal provides new recreational activities on-site for the public. Diagram: by author.

Unlike nuclear energy that prohibits the connection between site, people and context, here the energy source inverts that relationship and allows a co-existence of all three layers.

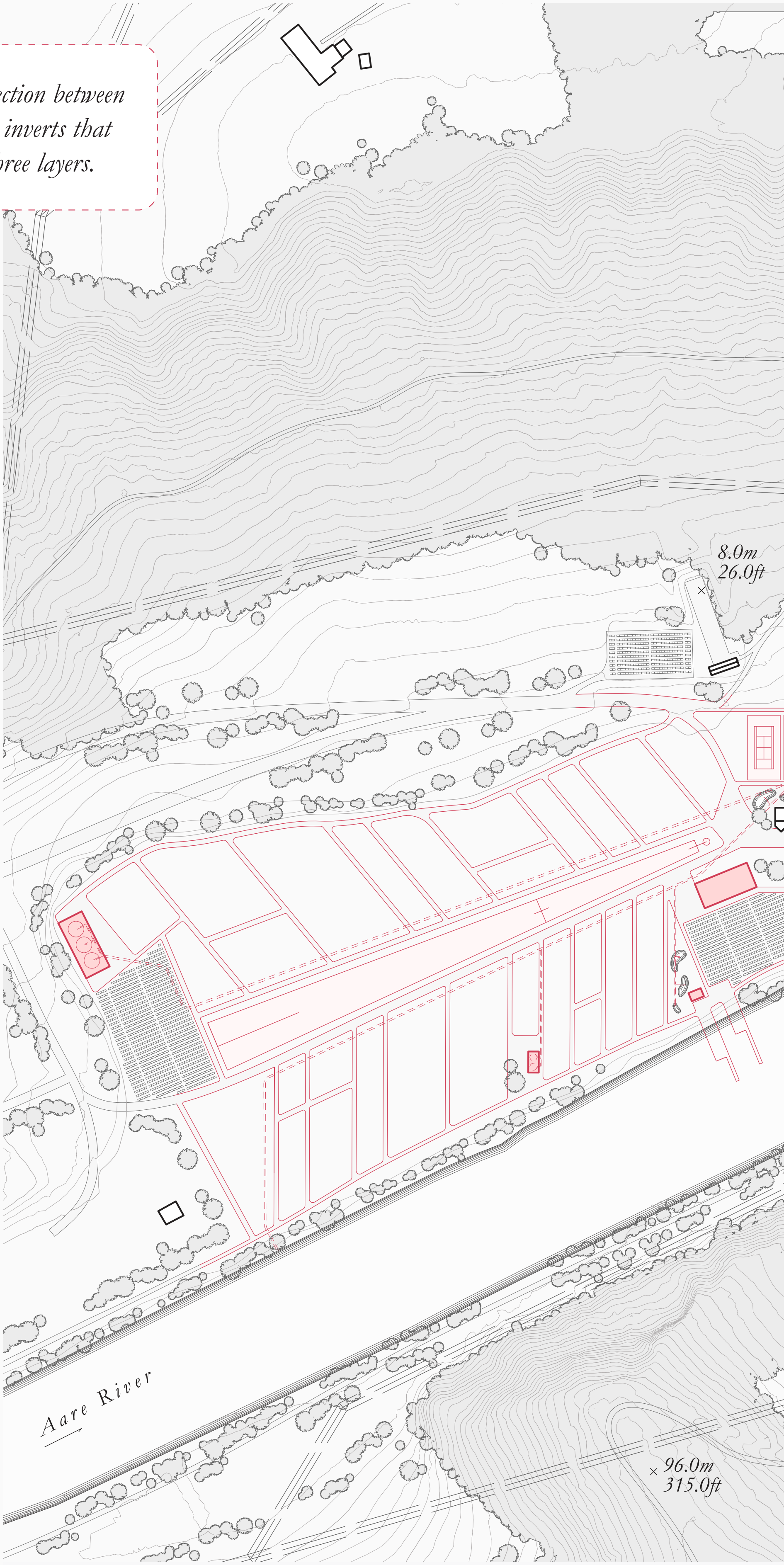
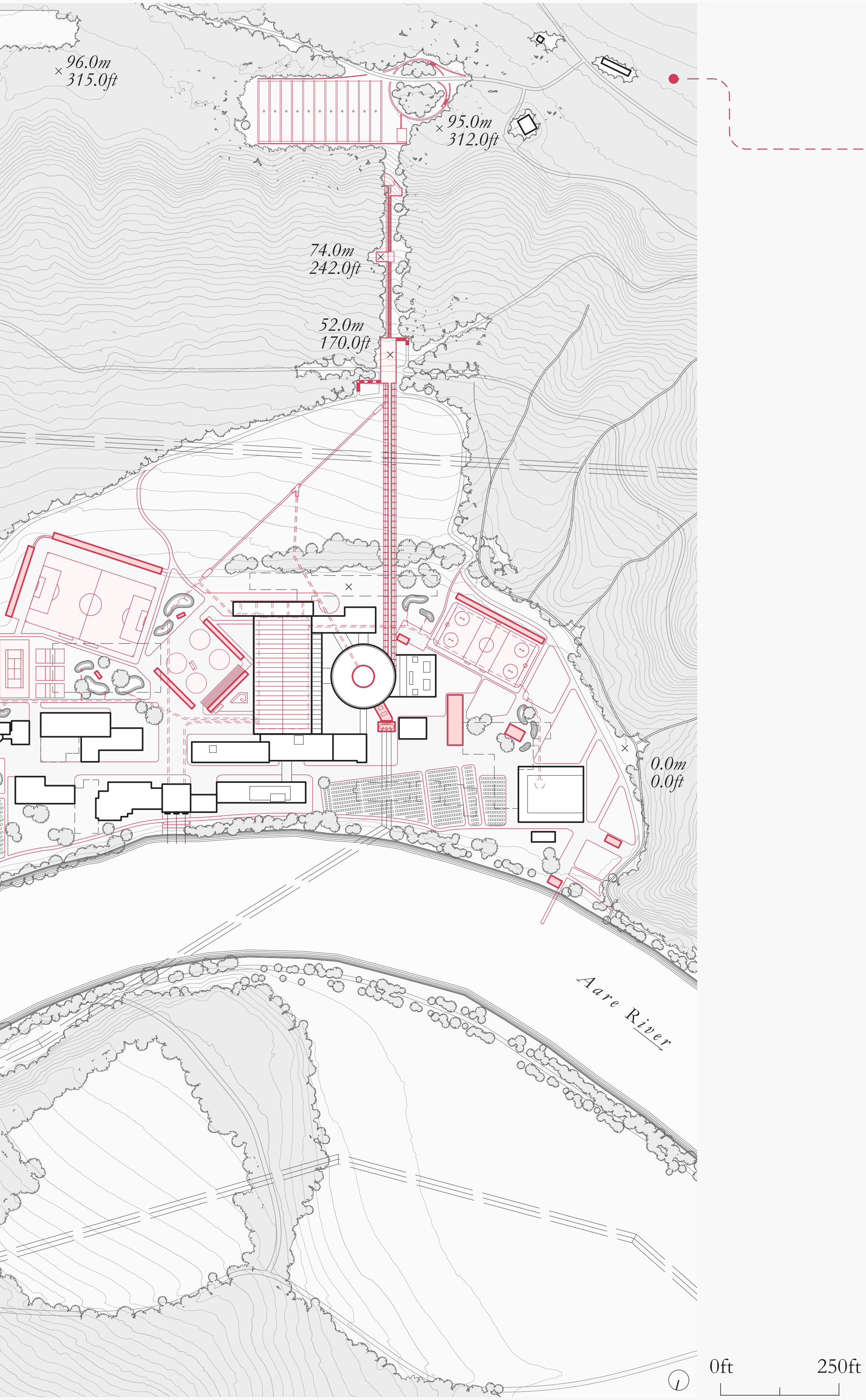
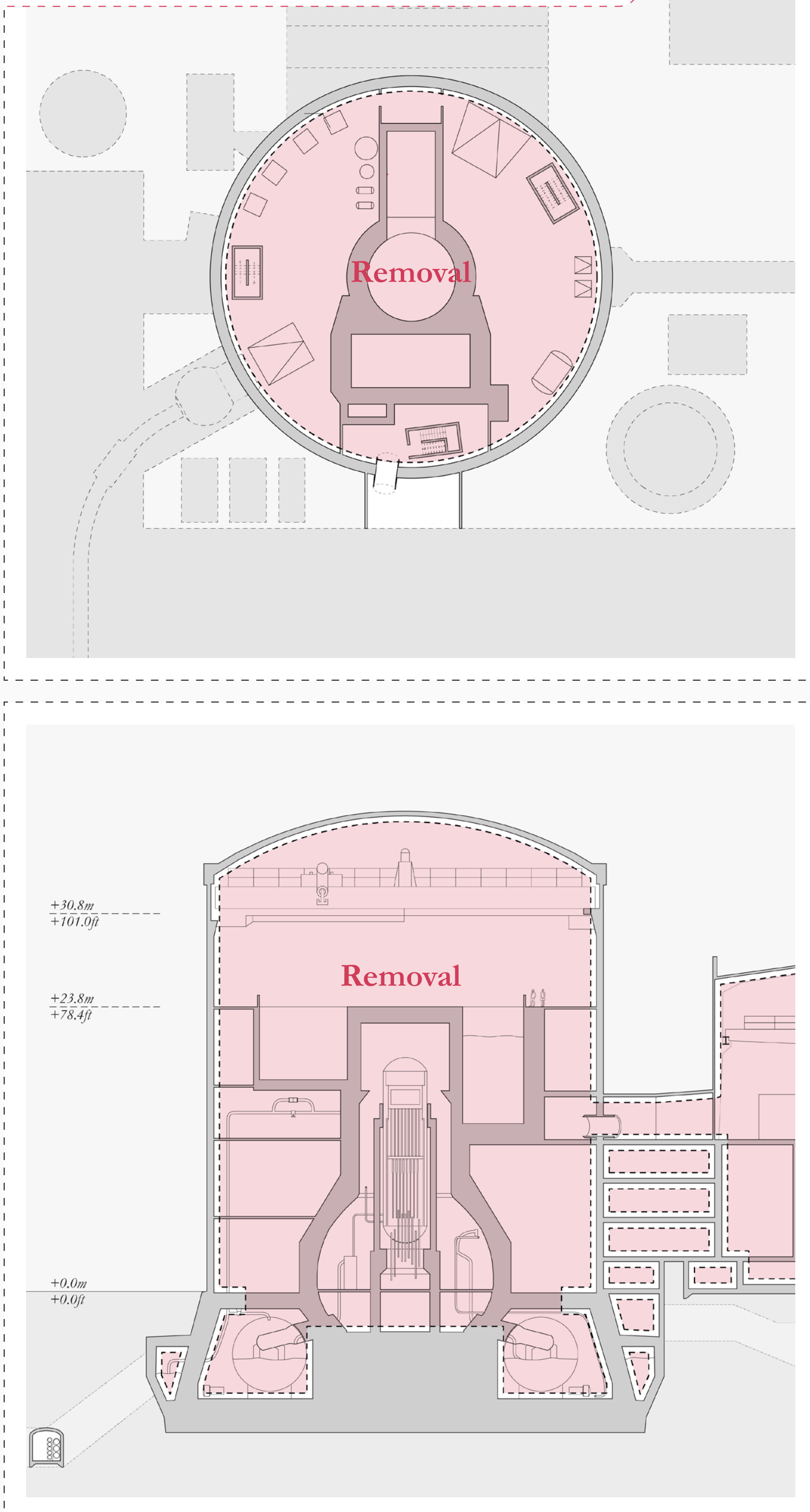


Figure 30. Site with new masterplan proposal.
Drawing: by author.



96.0m
315.0ft
95.0m
312.0ft
74.0m
242.0ft
52.0m
170.0ft
0.0m
0.0ft
Aare River
0ft
250ft

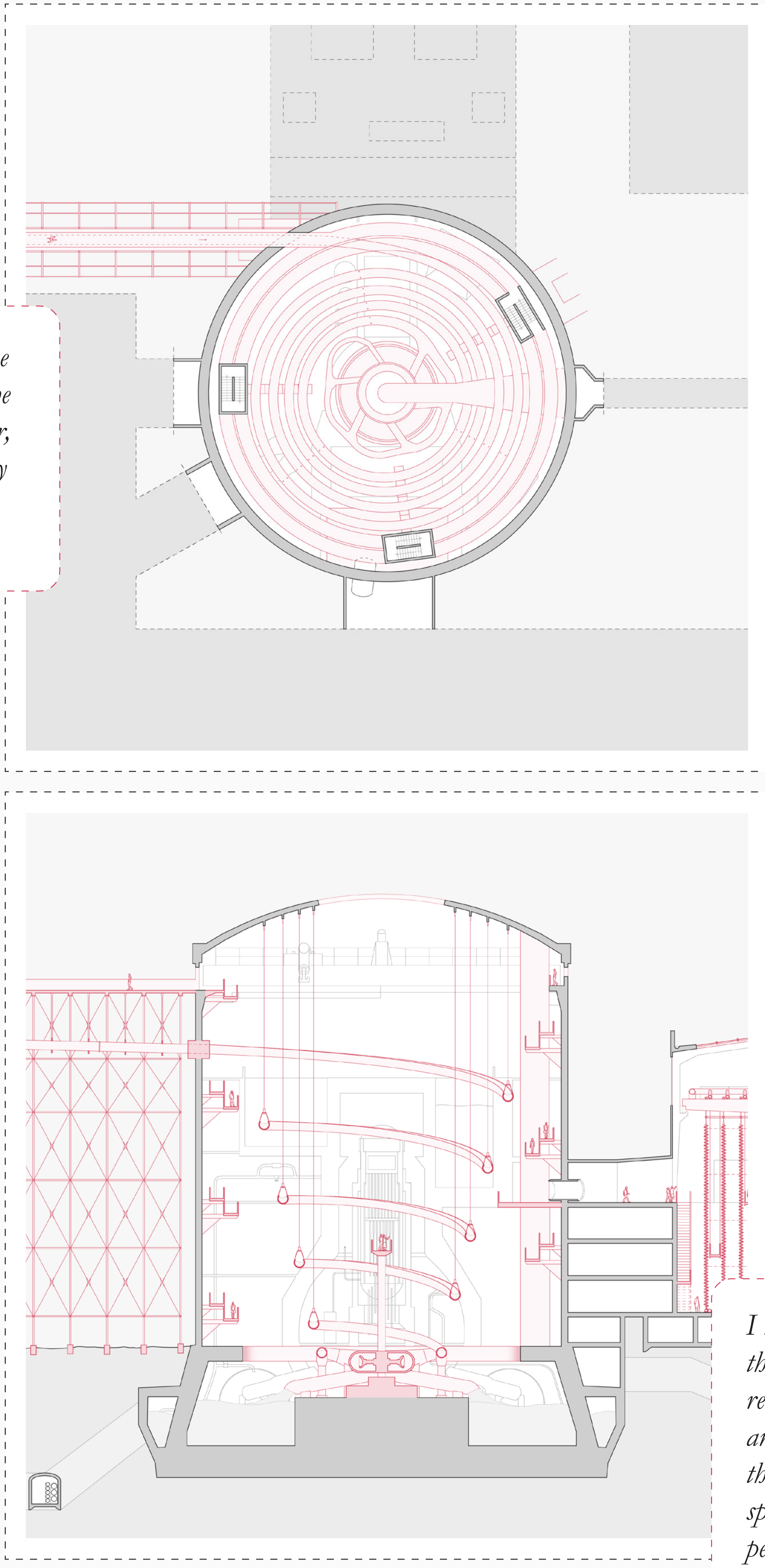
Before we leave the reactor building to move on to the command room, I glance around the space. Reflecting on its current state, I envision the reactor space transforming a hydro energy storage system. This means, …



Existing structure
Layout

Figure 31. Reactor building after removing all radioactive material components on the inside (Above: plan view, below: section view). Drawing: by author.

... a Pelton Turbine would now be at the heart of the reactor, generating electricity through the use of water.



I look down into the blue colored reactor water basin and wonder, how through this, the space would be perceived differently.

Figure 32. Site Map with new masterplan proposal. (Above: plan view, below: section view). Drawing: by author.

Walkways would wrap around the wall for visitors to experience the spaces in a new light. Seeing, hearing, and smelling the water rushing down would greatly change one's direct experience.

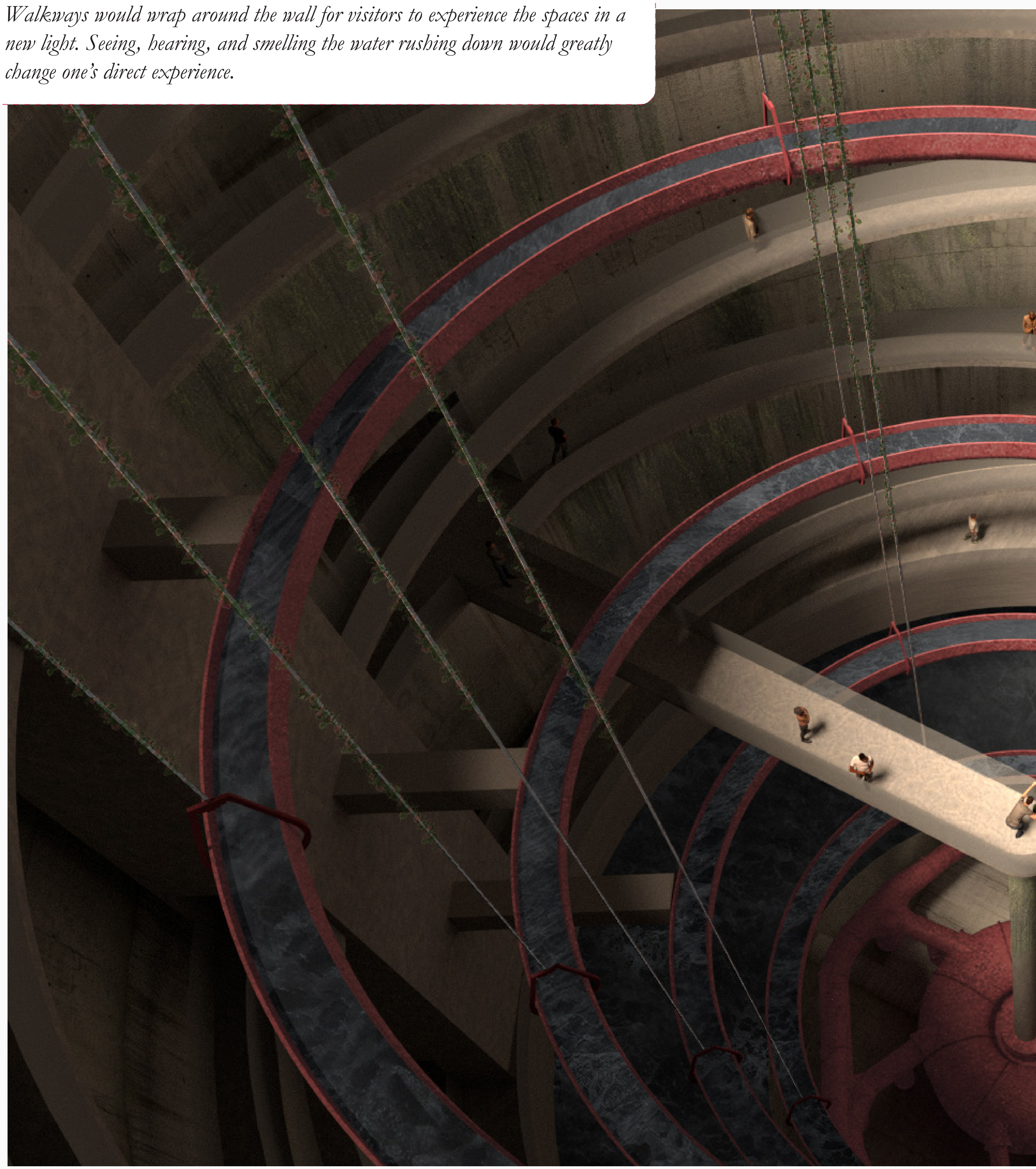
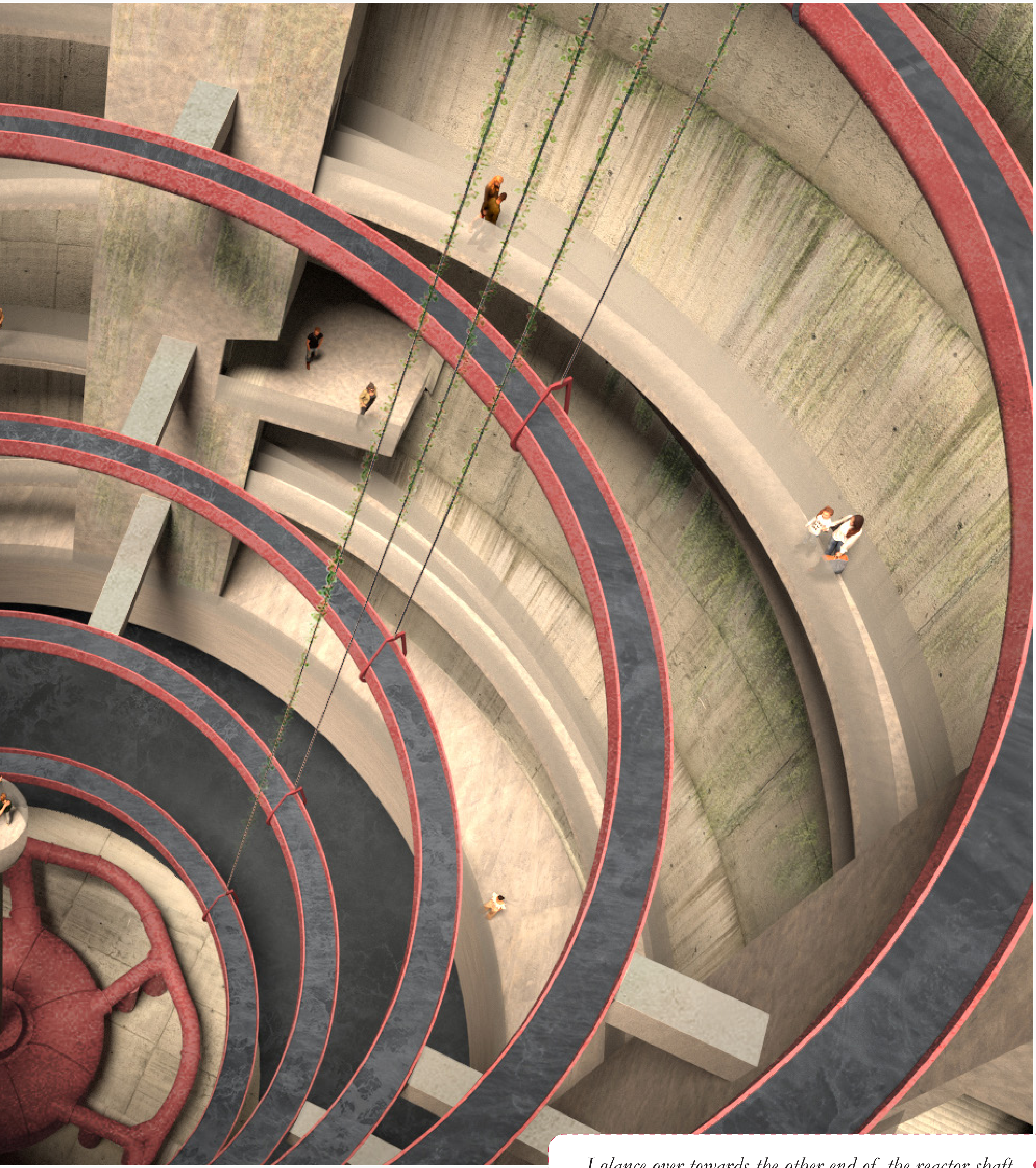
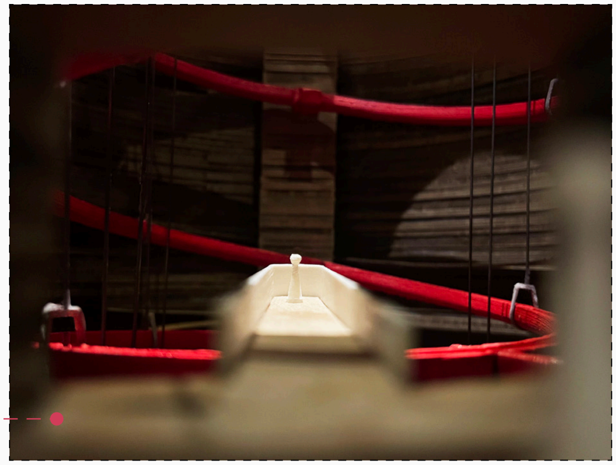
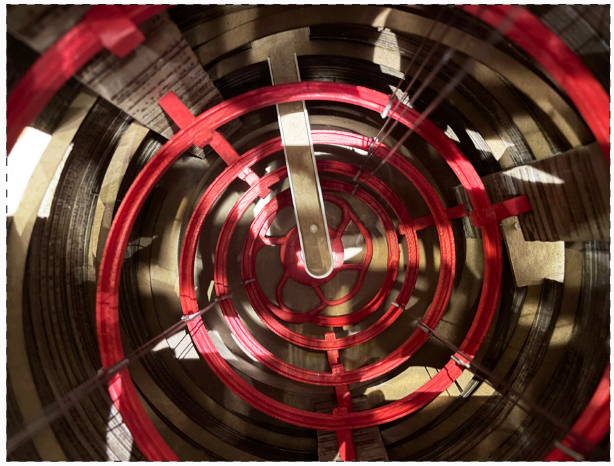


Figure 33. View down towards the Pelton Turbine after implementing the design proposal. Visualization: by author.



I glance over towards the other end of the reactor shaft.





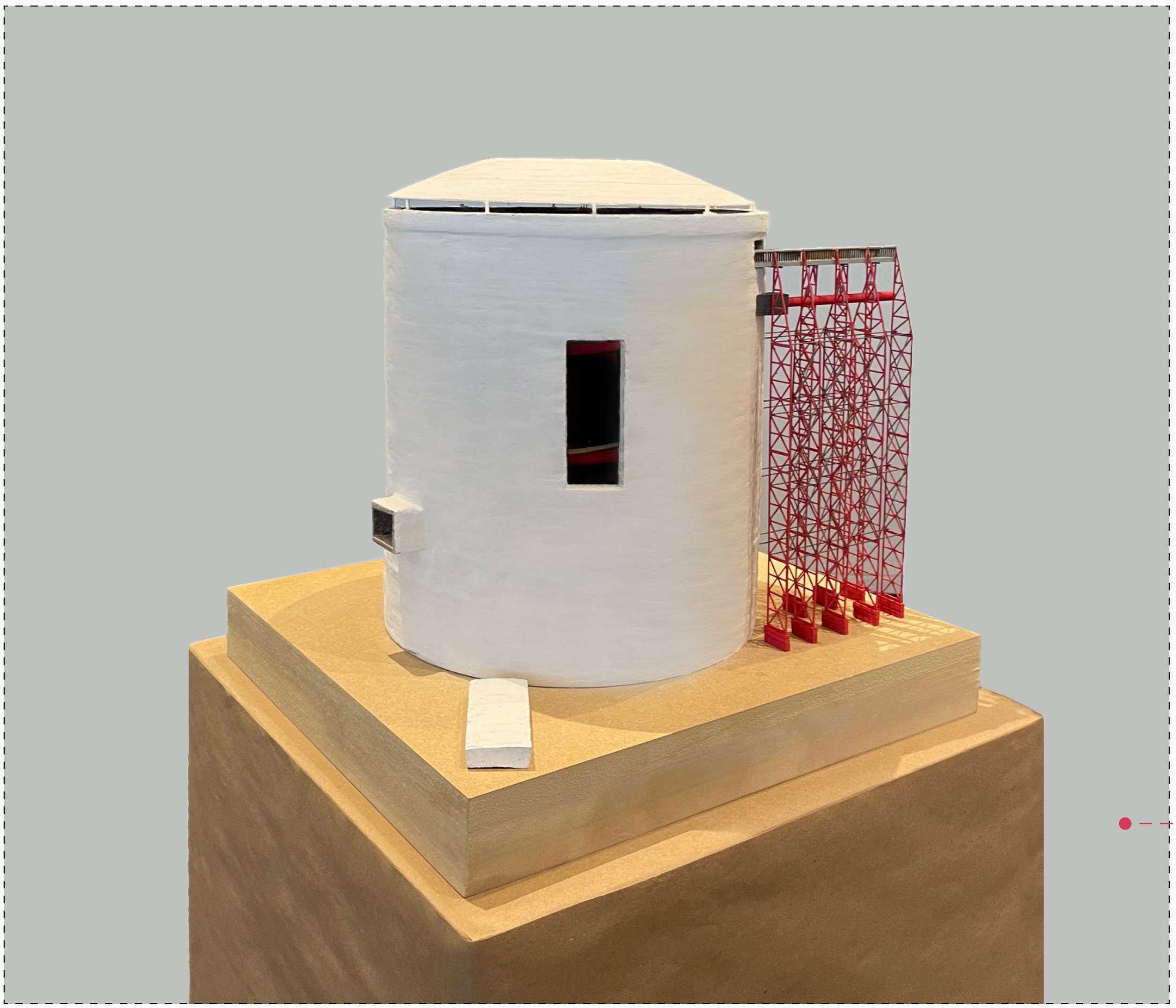


Figure 34. Interior View of the former nuclear reactor that now generates electricity through a hydro energy storage system.
Figure 35. Walkway view inside the former nuclear reactor.
Figure 36. Exterior model view of the former nuclear reactor building.

Figure 37. Site Model with intervention. Red: new structures, pink: adaptively reused structures, gray: existing structures. Photos of Figures 34 to 37: by author.

By opening up the domed roof, this space would let in natural light for the first time in decades. How would the experience be different during spring, summer, autumn, …

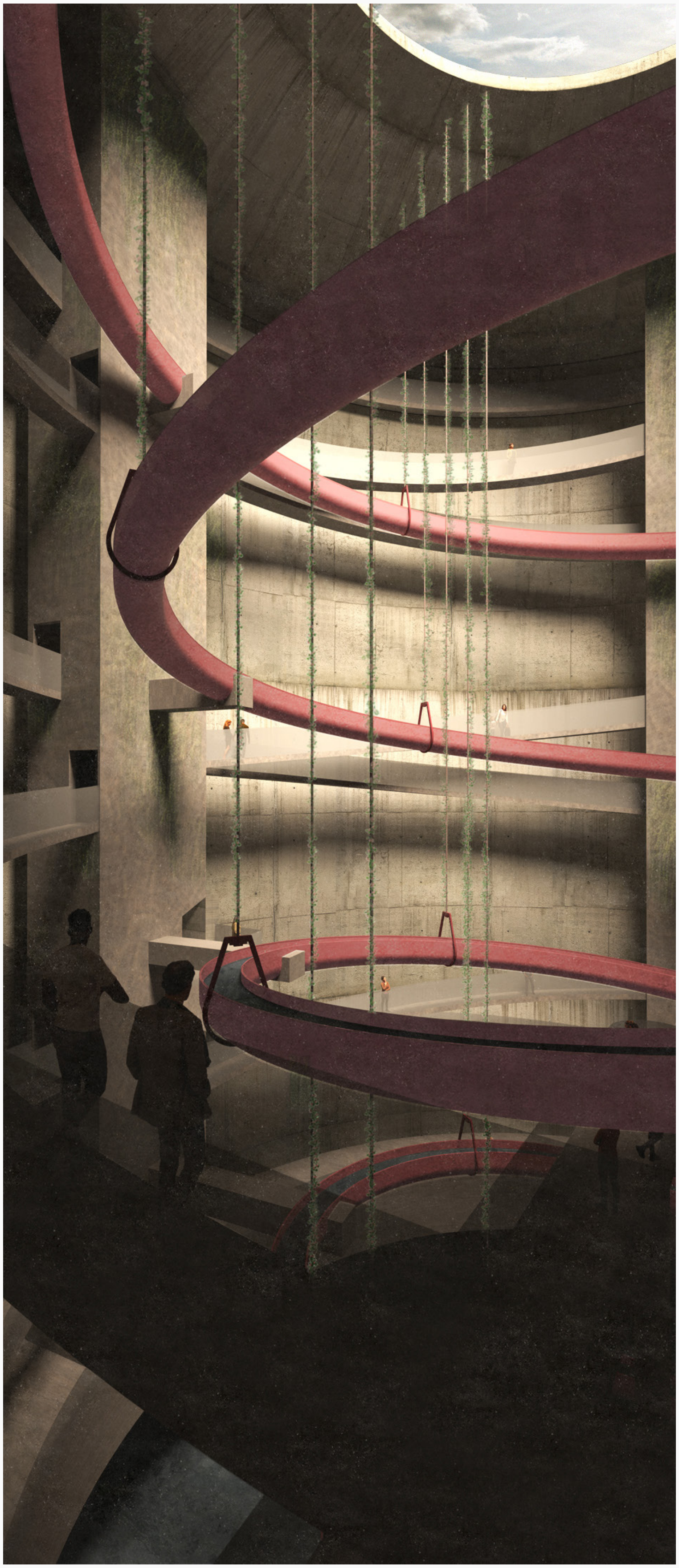


Figure 38. View inside former nuclear reactor. Visualization: by author.

… what about winter?

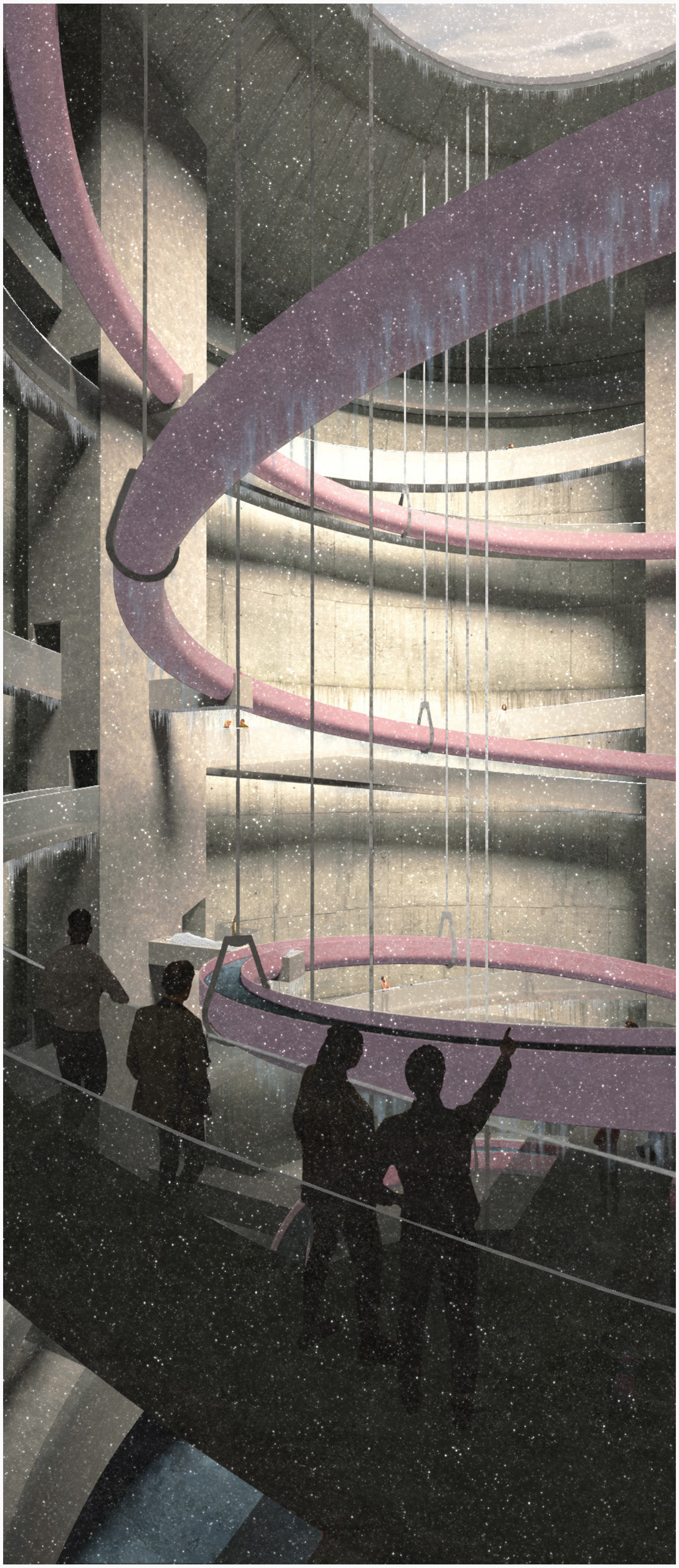


Figure 39. Winter scenario of previous reactor.
Visualization: by author.

To accelerate the turbine, the water would need to come from a new water reservoir at a higher altitude. The water would then flow down to the site through a water pipe.

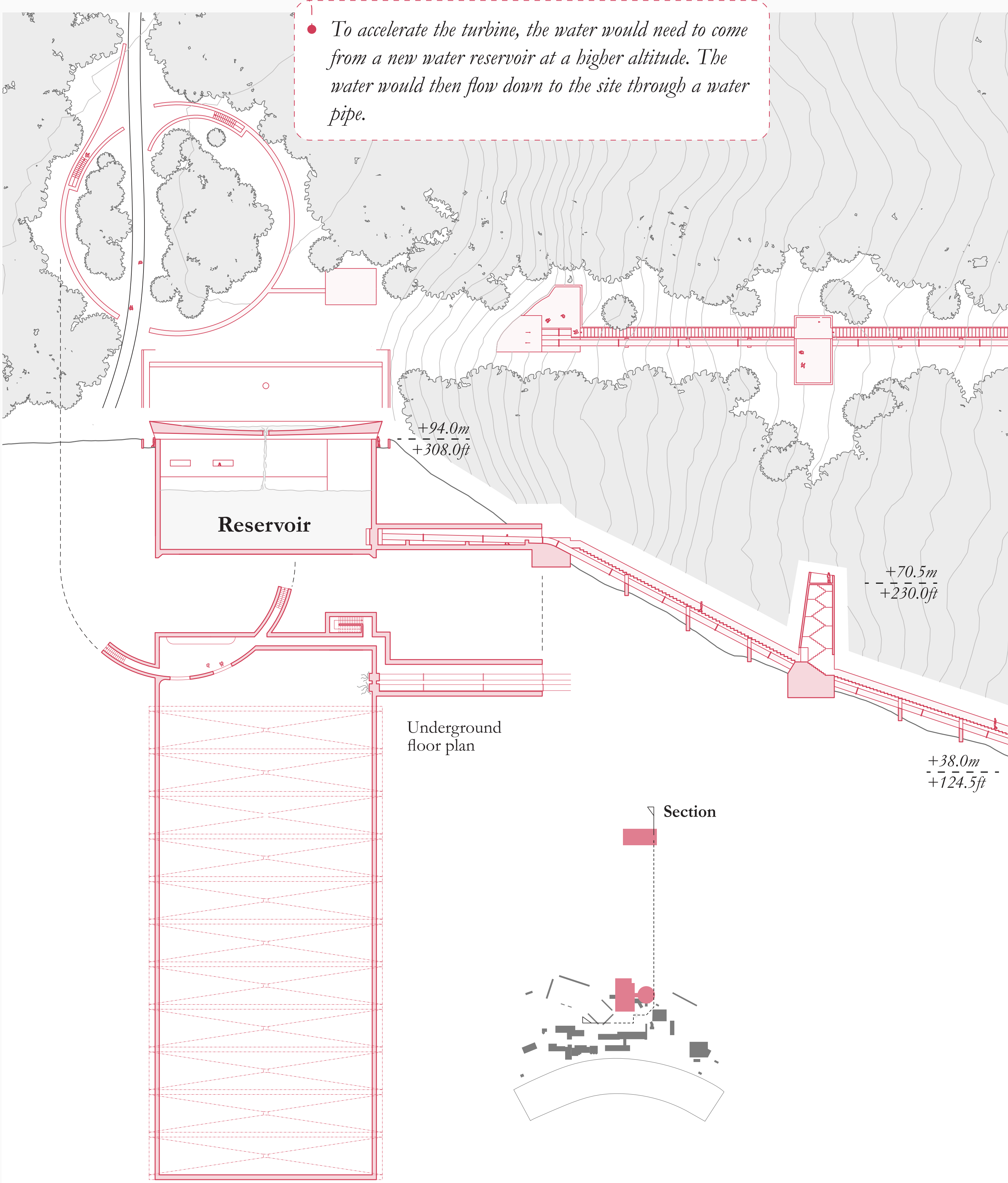
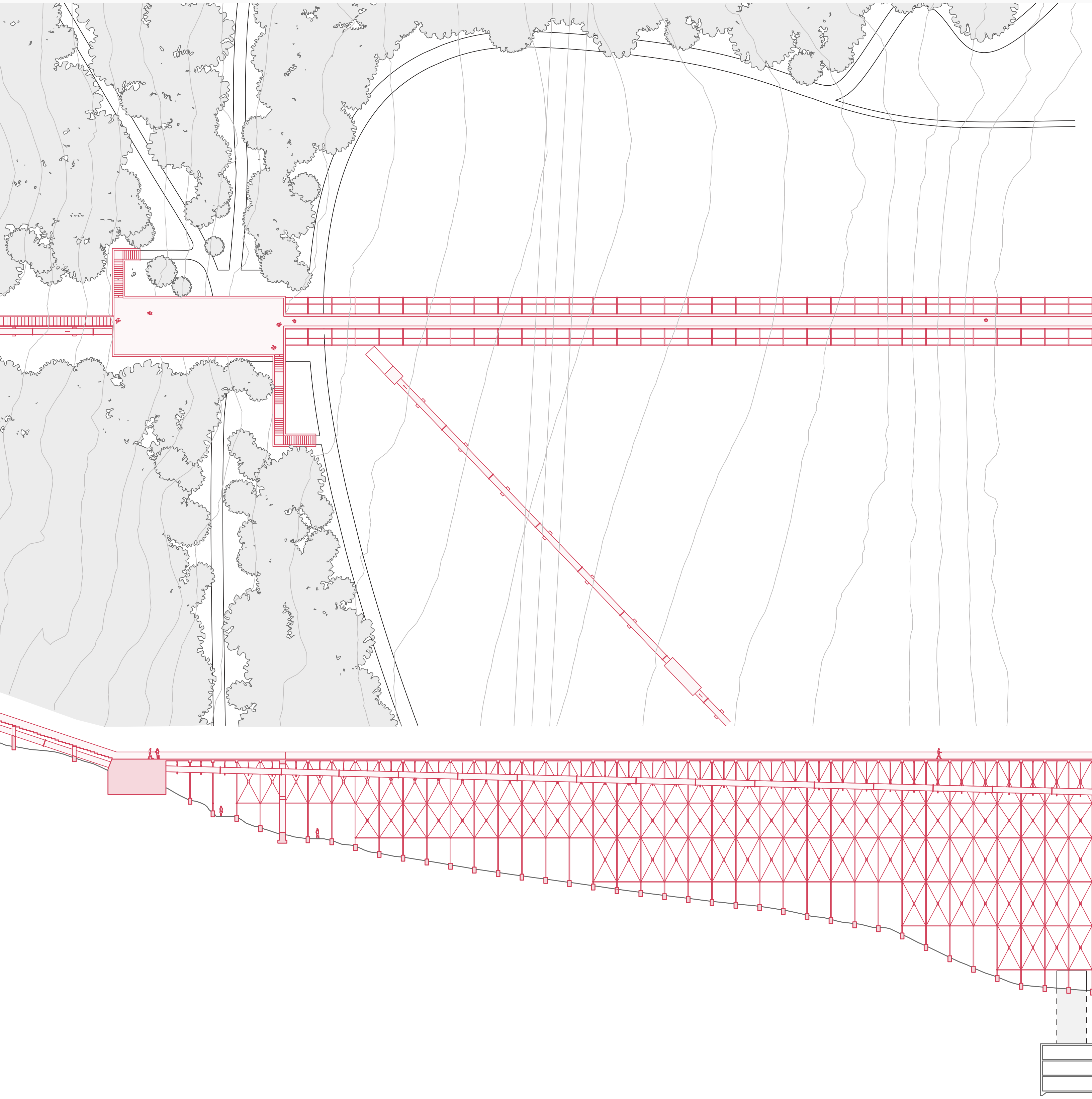
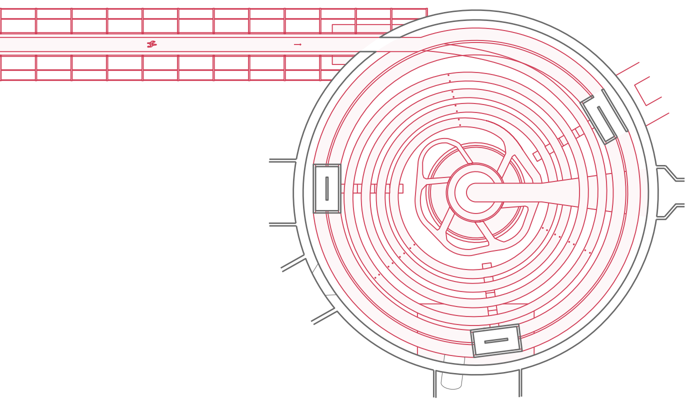
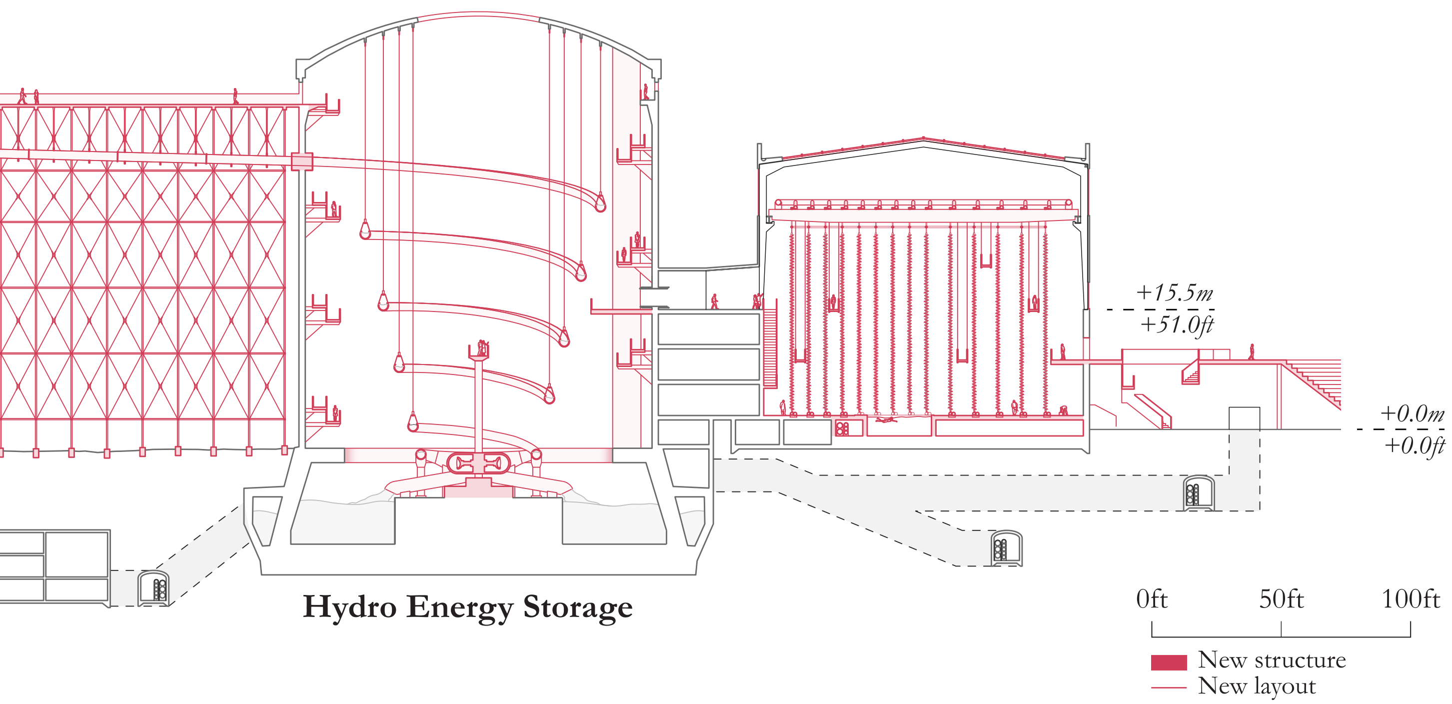


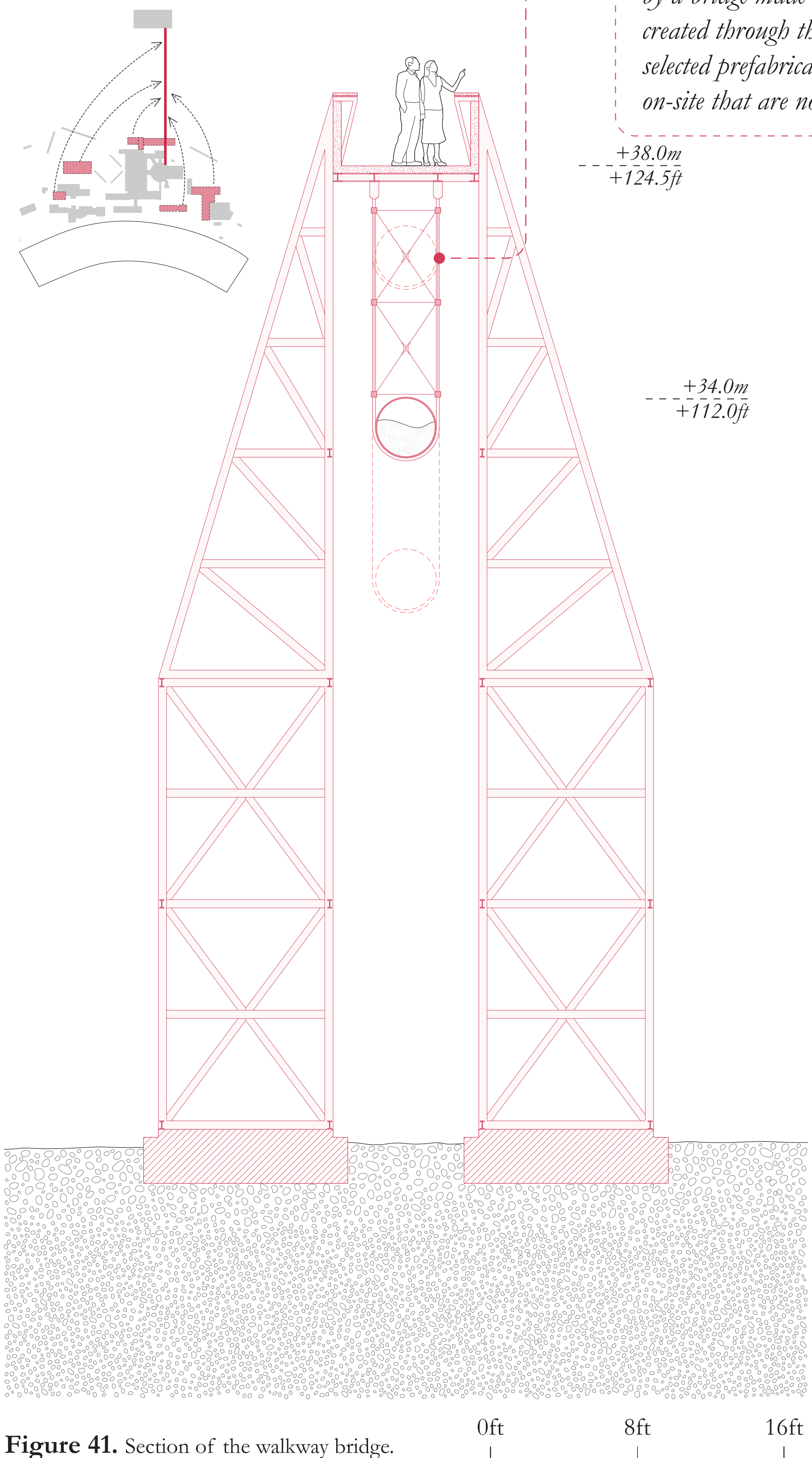
Figure 40. Long section view of the water reservoir (top left) and the hydro energy storage system (bottom right on next page). Drawing: by author.







Hydro Energy Storage



The water pipes would be supported by a bridge made of steel and wood, created through the dismantling of selected prefabricated storage buildings on-site that are no longer in use.

Figure 41. Section of the walkway bridge.
Drawing: by author.

Walking up the hill, subsequently following the water pipes, one would enter the reservoir through an underground passage.

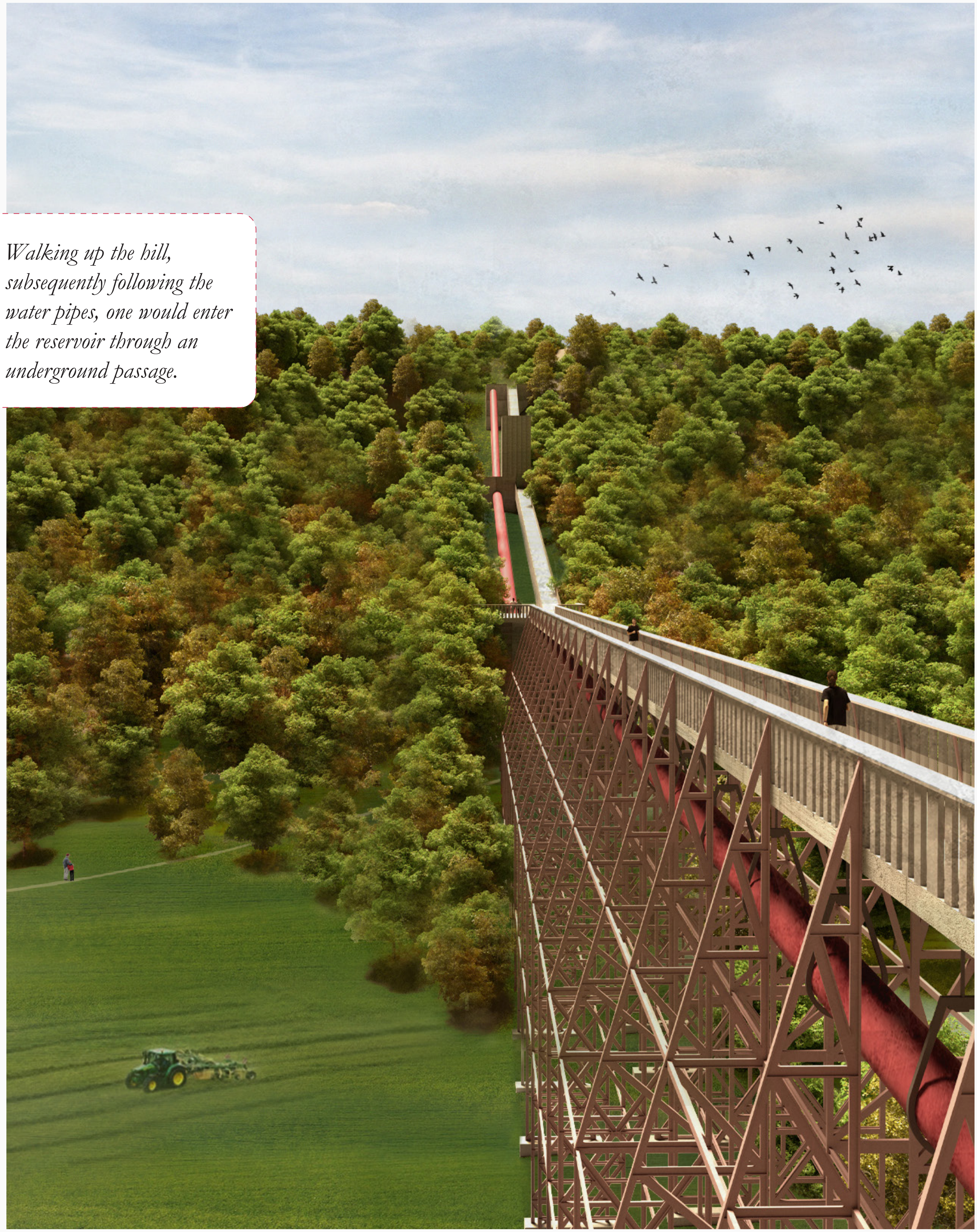


Figure 42. Walkway view up towards the reservoir, nested within the Mühleberg forest. Visualization: by author.

Unlike in the reactor space before, one now encounters a very dark and unusually quiet space. Gazing into the sublime and infinitely spanning reservoir, one tries to find its ending.

Figure 43. View into the new reservoir.
Visualization: by author.

Immersed in imagination, I faintly notice Oliver waving me over to continue our journey to the command room. Still in my thoughts, I reflect on where the water would go after it's been used to produce electricity.

1978

We arrive in the command room, and I am quite shocked by its retro look. The reason why elements haven't been replaced, he tells me, is because many of them are no longer reproduced. Looking at a historic photo after its launch, one sees, not much has changed ever since.

Figure 44. Historic photograph of the command room that monitored the all reactor operations.
Source: Hans Krebs and ETH-Bibliothek Zürich, Bildarchiv

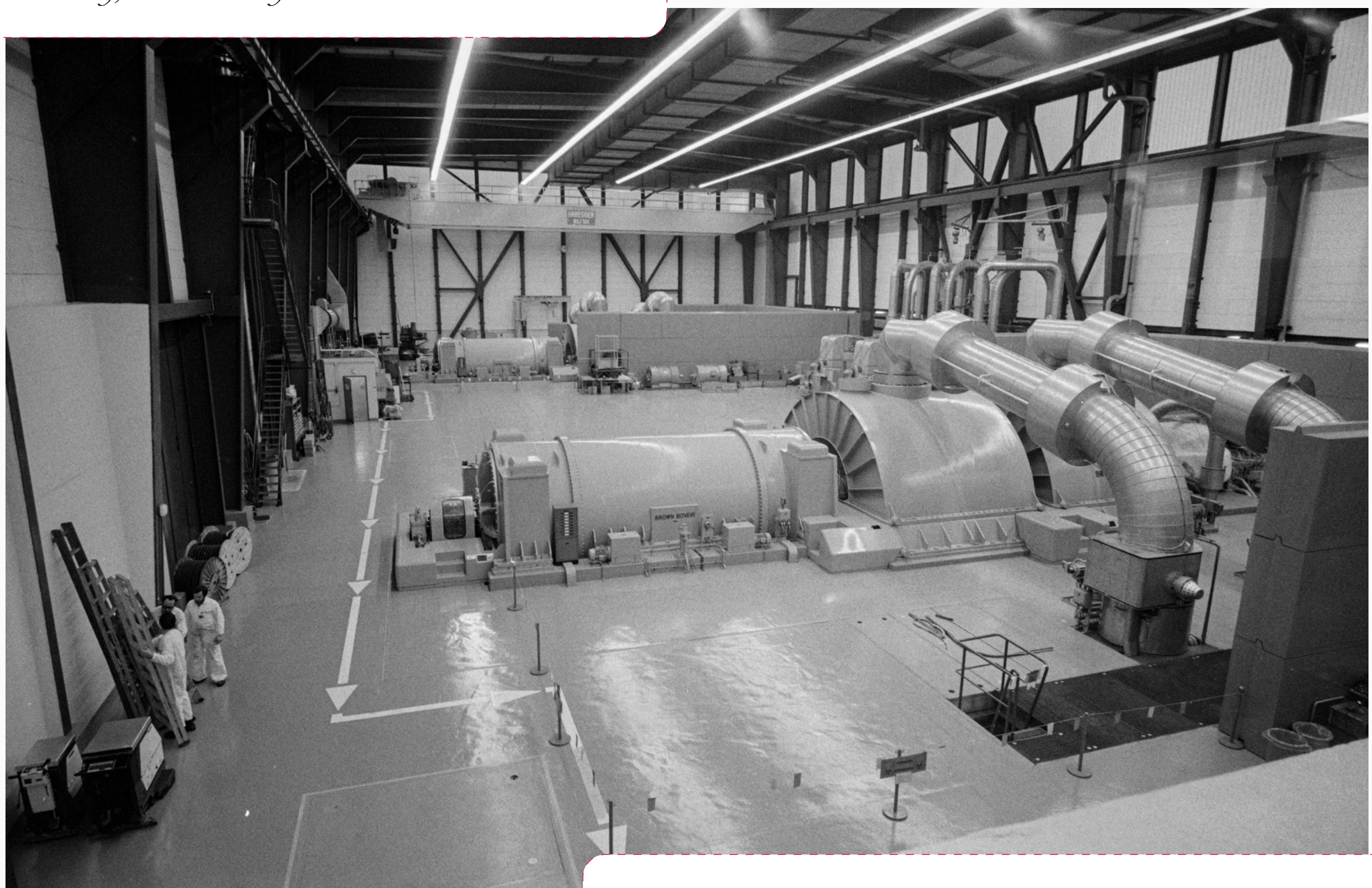
Could there be a way of transforming this into a plant nursery that later can be used for indoor hydroponics farming? Opening one of the walls, would allow a direct visual connection to the water reactor itself.

We move on from the command room and enter the last main space of the tour, …

Figure 45. Repurposing the former command room into a plant nursery for the indoor hydroponics farm. Visualization: by author.

… the turbine hall. Once dedicated to generating electricity, the hall today …

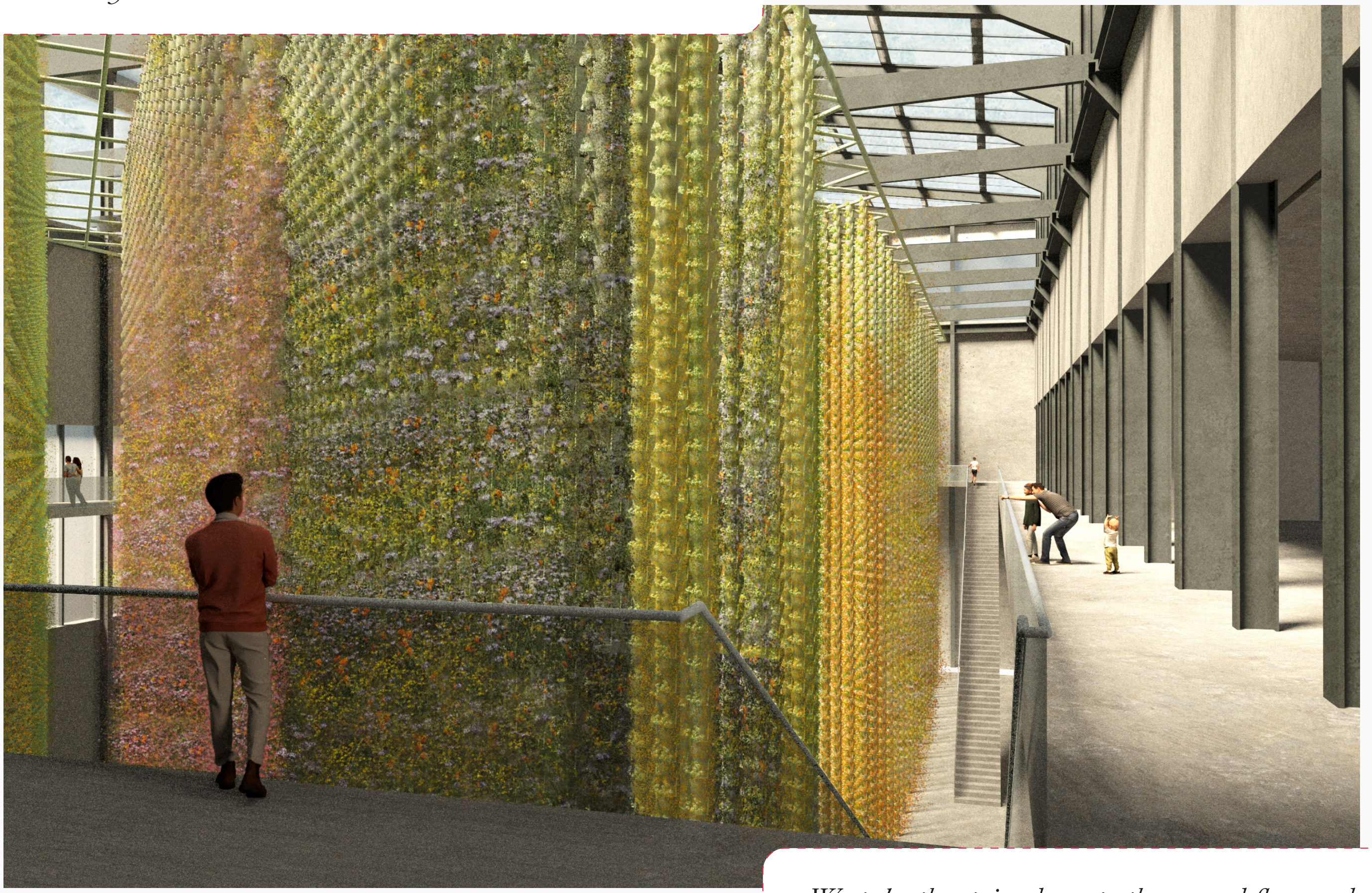
1978



…has been changed into a material cleaning stop for the dismantling process. By the year 2031 it will be emptied out, with only the shell remaining.

Figure 46. Historic photograph of the Turbine Hall that has temporarily been transformed into a material cleaning hub.
Source: Hans Krebs and ETH-Bibliothek Zürich, Bildarchiv

In a way, the spatial conditions would be great for an indoor hydroponics hub that would allow for the farmers to grow large quantities of food throughout the year. The space, now filled with different plant types and vegetables would be using water from the new water cycle.



We take the stairs down to the ground floor and continue our walk through the space.

Figure 47. View inside the newly transformed indoor hydroponics hub that was formerly the turbine hall. Visualization: by author.

We take the stairs down to the ground floor and continue our walk through the space.

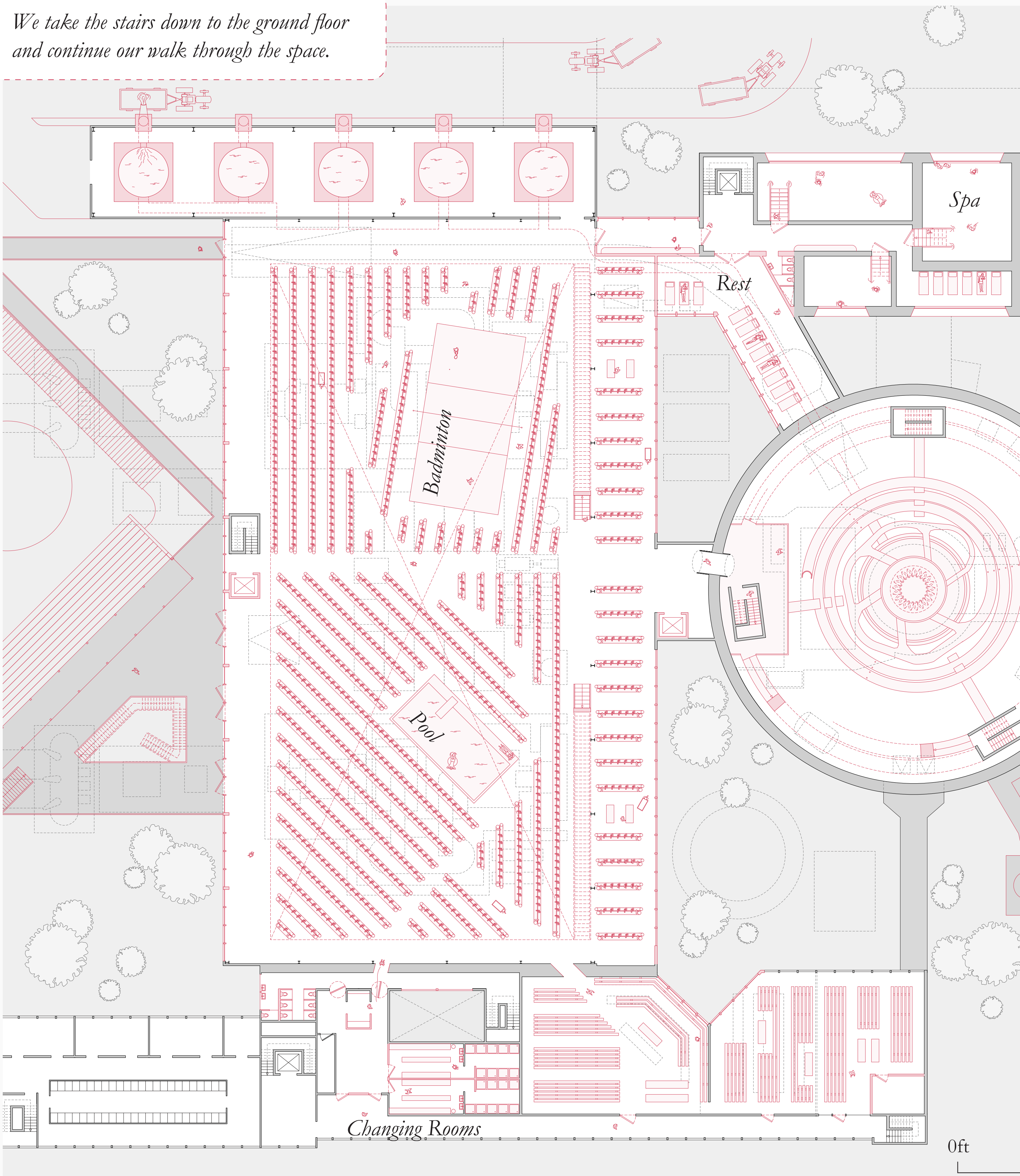
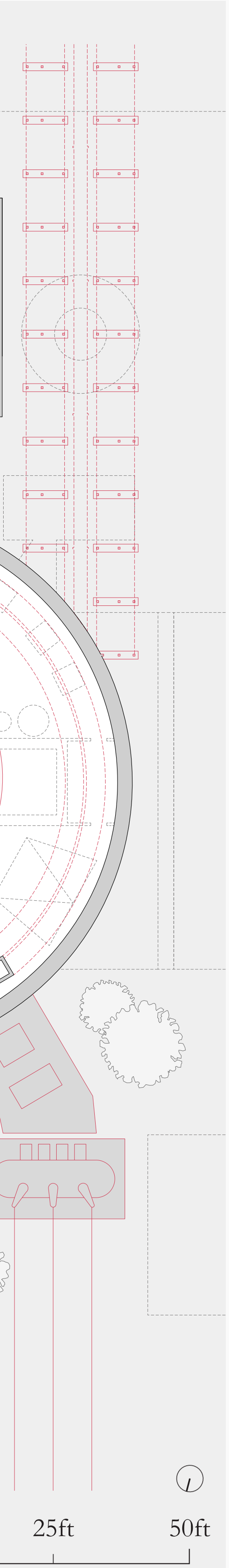


Figure 48. Plan view of the transformed reactor building and the turbine hall. Drawing: by author.



What would it be like if there were nested pockets of recreational activities, such as indoor swimming for the public?

Figure 49. Ground floor view of the indoor hydroponics hub with an indoor swimming pool. Visualization: by author.

Reaching the end of the tour, we leave the turbine hall and head back to the main entrance. Passing by the reactor, the fire station, and arriving at the gate, I thank him for taking the time to showing me around the site and begin my journey back to the bus stop.

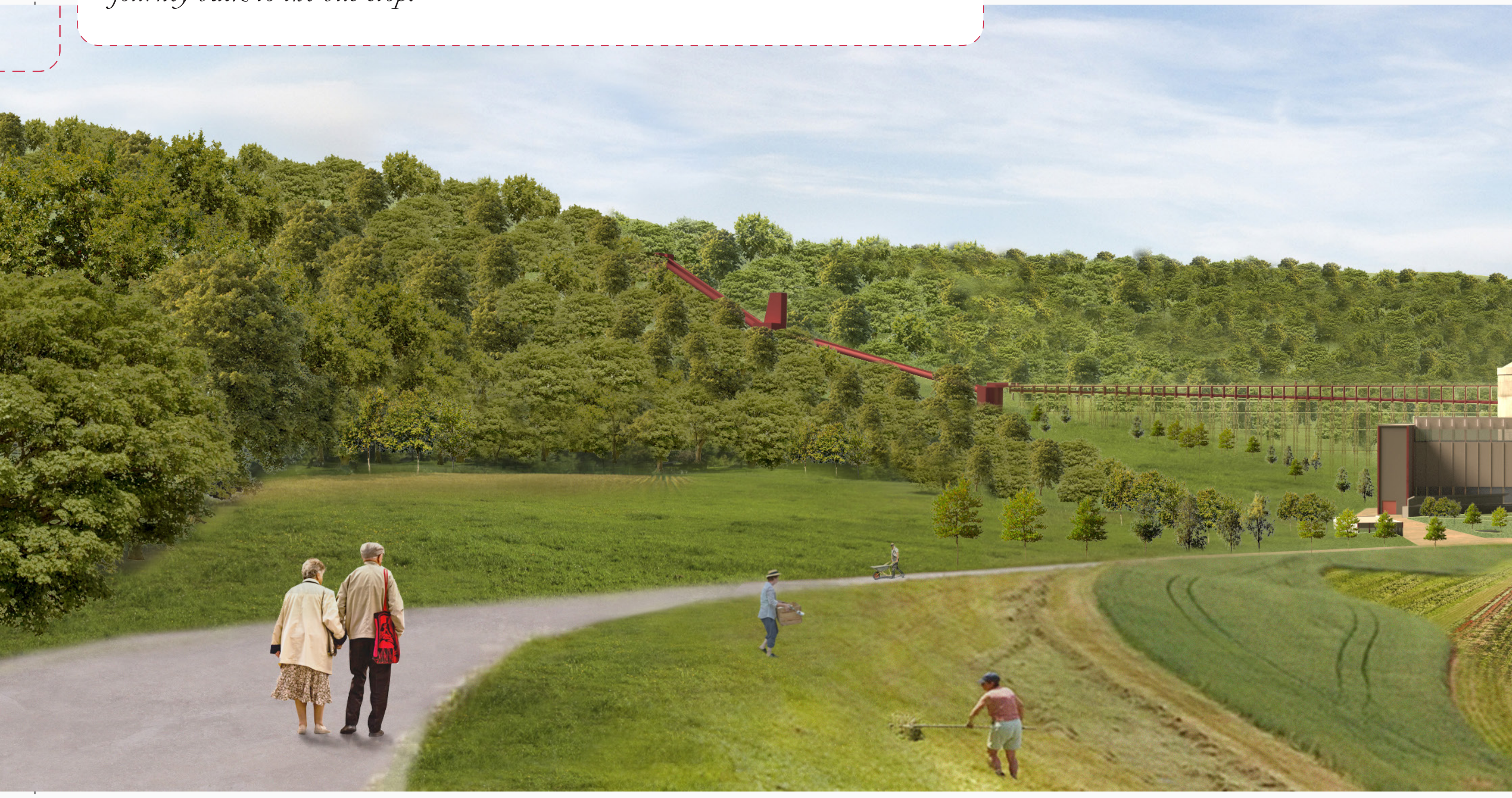


Figure 50. View back towards the nuclear power plant after it has been transformed. Visualization: by author.

On my way back up the hill, I turn around to look at the power plant one last time and envision what its's future could potentially entail.

Chapter 3 - Reflections

Scalability Potential

Throughout this thesis, there were important points to note concerning the design proposals scalability on the macro-scale of phased out nuclear infrastructure. As described in **Chapter 1**, there are a small number of cases that pursued the partial reutilization route. However, those sites remained somewhat isolated and public engagement was hindered.

Overlaying the Mühleberg case analogy that proposes adaptive reuse through a combination of programs, would shift the needle more towards somewhere in the middle of the spectrum (see **Figure 11**). That area, however, could deviate to the right or left, depending on the case site's context and specific needs.

Some architectural techniques which allowed the proposal to break apart the state of detachment could be transferable to other decommissioned sites (see examples shown in **Figure 51**). This should not be seen as an extensive list, rather as a list of options to determine how architects can help transform such large nuclear energy industry sites.

Looking at the remaining Swiss nuclear power plants and envisioning what their afterlife could be using this novel approach could open up further possibilities that invite public engagement (see **Figure 52**). This could be a first step into encouraging society to integrate energy infrastructure as part of the public domain again.

The fact that there are currently only a few case examples of adaptive reuse of decommissioned nuclear power plants does not undermine the large potential for a wider scalability.

Therefore, changing the course and implementing adaptive reuse for decommissioned nuclear power plants could pave a way towards a more sustainable future.

Architectural Techniques

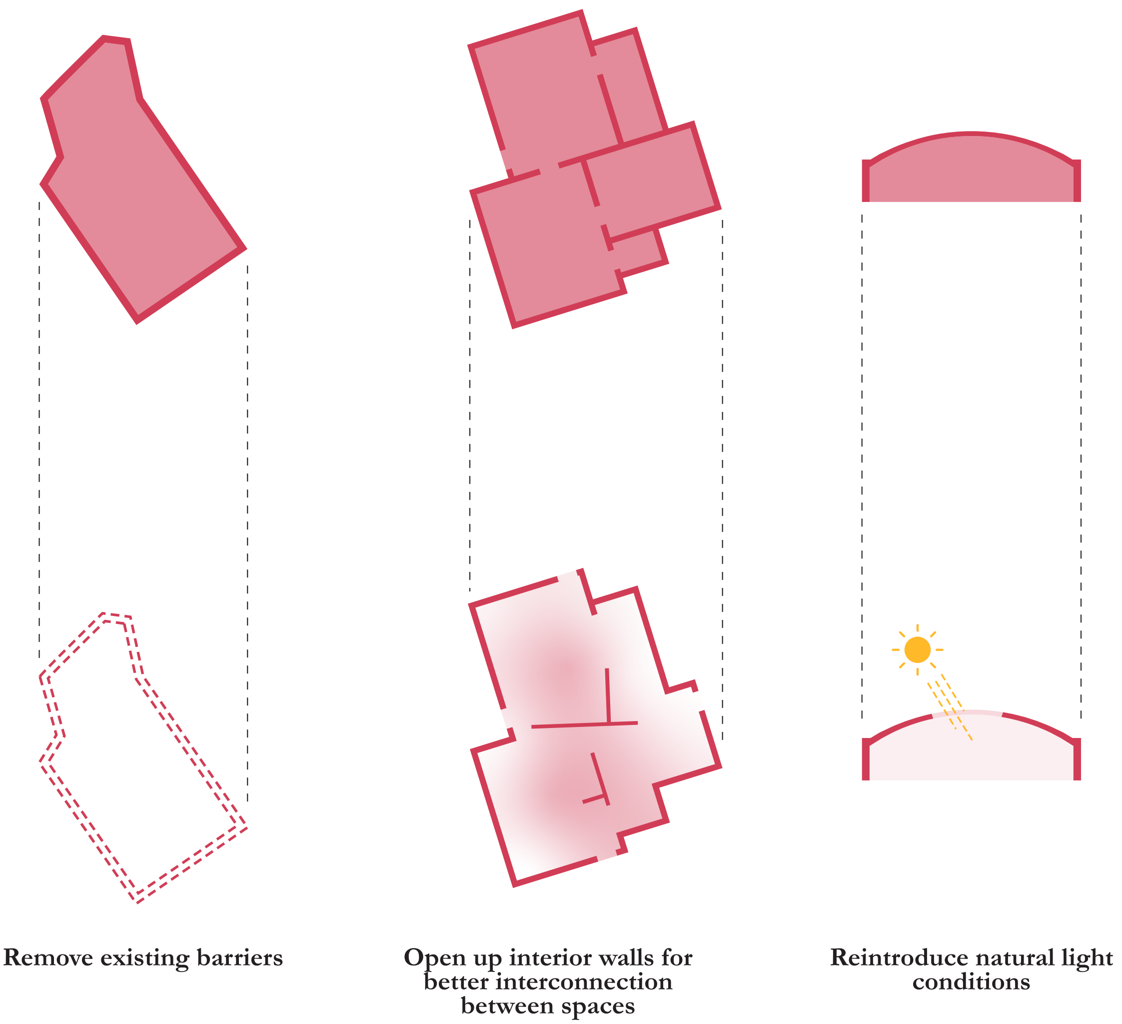


Figure 51. A few examples of how to architecturally reintegrate nuclear facilities after their operation termination. Diagram: by author.

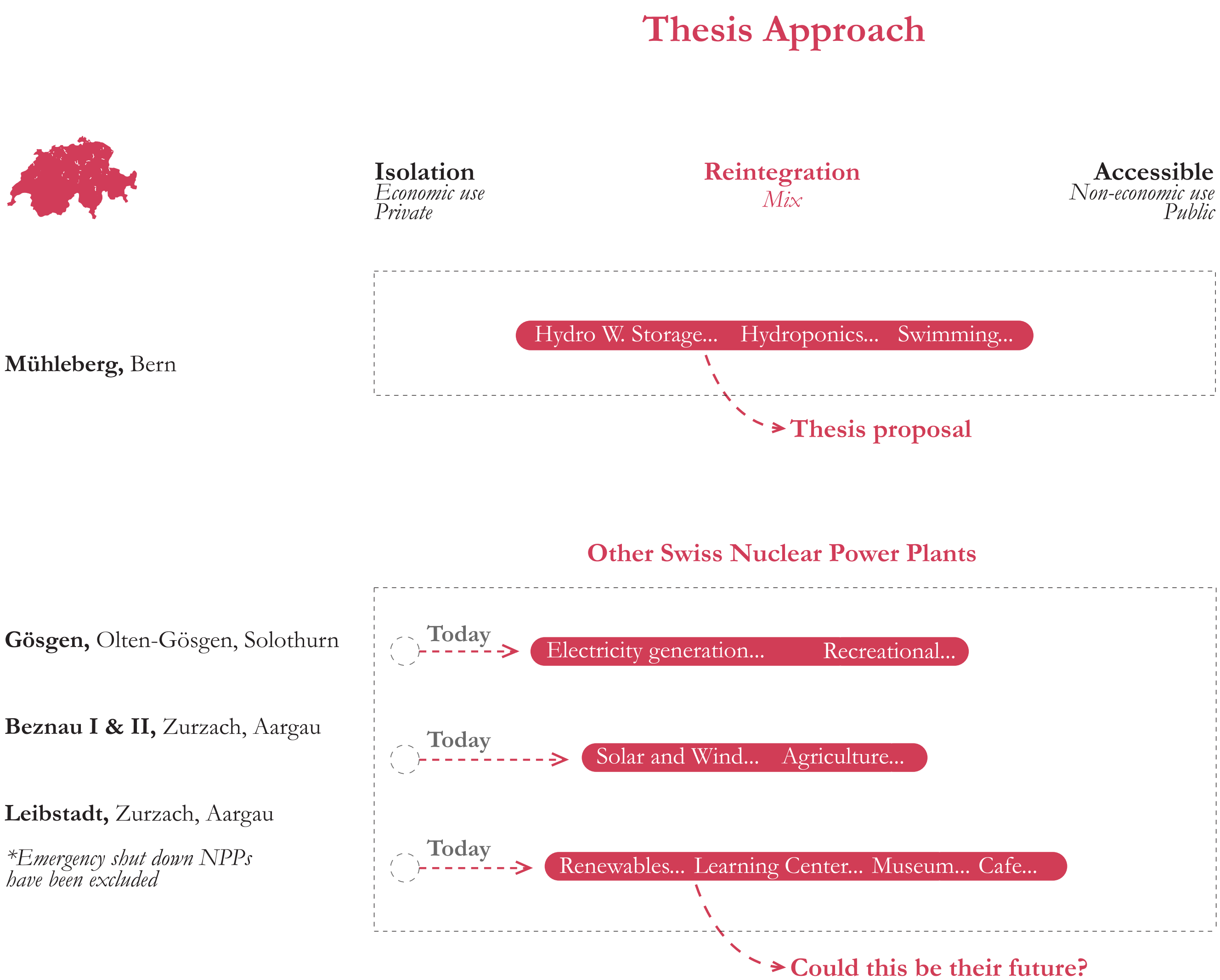


Figure 52. Swiss nuclear power plants and their potential future afterlife by applying the thesis proposal approach. Diagram: by author.

Chapter 4 - Thesis Defense Day

Figure 53. Establishing context of aging nuclear infrastructure on the global scale. Photo credit: Mackinley-Wang Xu

Figure 54. Final board presentation layout. Photo: by author.

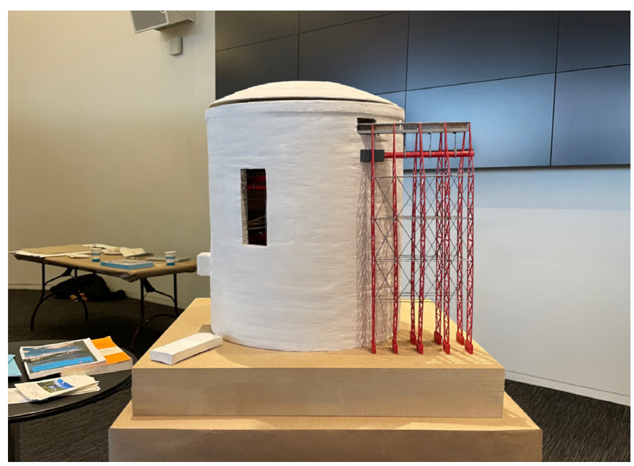


Figure 55. Left: reactor model analysis by guest critics.
Figure 56. Top right: my thesis committee members.
Photo credit: Erich Reinhard

Figure 57. Middle right: reactor model in 1:150 scale.
Figure 58. Bottom right: site model in 1:2000 scale.
Photos of Figures 55, 57, and 58: by author.

Appendix

List of Figures

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Abbreviations

Abbreviation	English Description	German Description
BWR	Boiling Water Reactor	Siedewasserreaktor
DECON	Nuclear Decontamination	Schrittweises Dekontaminieren
ENTOMB	Nuclear Entombment	Einschliessung der radioaktiven Bereiche
IAEA or INES	International Nuclear Radiological Event Scale	Internationale Bewertungsskala für nukleare und radiologische Ereignisse (INES)
KKM	Nuclear Power Plant Mühleberg	Kernkraftwerk Mühleberg
KKW	Nuclear Power Plant	Kernkraftwerk
NPP	Nuclear Power Plant	Kernkraftwerk
PWR	Pressurized Water Boiler	Druckwasserreaktor
PV	Photovoltaics	Photovoltaik
SAFSTOR	Nuclear Safe Storage	Sicheres Lagern mit verzögertem Abbauen

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