Talking to the Future - about Radioactivity
Understanding radioactivity through everyday product interactions
“The cities have forgotten the earth and will rot at heart till they remember again.”

Wendell Berry, 1969, in a letter to Ed McClanahan and Gurney Norman in California
Abstract

Talking to the Future - about Radioactivity

Understanding radioactivity through everyday product interactions.

Nuclear waste remains radioactive for thousands of years. Burying it underground in an enormous repository, called Onkalo, surrounded and secured by solid rock is the long-term solution Finnish authorities implement right now. Once the repository is filled up, it will be locked up forever and never opened again. At the same time three new nuclear power plants are built.

Out of Sight, out of Mind?

Ultimately, this raises questions: Can this be the solution for final disposal of nuclear waste? How do we understand a problem clearly exceeding our capabilities as human beings? How do we deal with the dilemmas of uncertainty, invisibility, time, demand, possible contamination, and our individual responsibility as human beings?

Understanding Through Interaction

I designed three everyday products, a lamp, a piggy bank for children, and a pregnancy test, that afford a familiar everyday action on one hand, while exposing a dilemma related to Onkalo on the other. In doing so, the artifacts make those dilemma tangible and facilitate understanding and critical thinking. Sharing a personal experience, the users can engage in a personal discourse around nuclear waste actively, opposing the distant and highly politicalised discourse spread by the media.
Preface

I would like to especially thank Laurens Boer, Birgitta Sundberg, and Niklas Andersson for their encouragement and support in becoming a part of UID;

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And my parents and sister, whose endless trust and support made my adventure lead me exactly where I want to be.
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1. Introduction

UNKALO, a nuclear waste repository, is being constructed on Olkiluoto Island, Finland. It is designed to Quarantine Finland's nuclear waste.

The physical barriers created by its underground location, structure, and engineering aim to protect people and the environment from radiation—the contagion that nuclear waste will emit for millions of years.

Onkalo is Finnish for "cavity."

0: number of deep geological repositories containing high-level nuclear waste today (about 10,000 tons of waste are generated worldwide yearly)

100,000 years: length of time Onkalo is designed to contain nuclear waste (homo sapiens has existed for about 200,000 years)

4.46 billion years: half-life of uranium 238, which makes up most of the spent nuclear fuel (the Earth is now 4.54 billion years old)

2020: year the repository will begin accepting waste

2120: year the final canister will be buried

6,000-20,000 years: estimated time before the next ice age begins

(20,000 years ago, NYC and Onkalo were buried under ice age glaciers)

1.2-1.8 miles: depth of ice expected to bury Finland during the next ice age (the Manhattan Bridge is 1.2 miles long)

212 degrees F: surface temperature of packed nuclear waste in the Onkalo repository (water boils at 212 degrees F)

27,000 fuel bundles: planned capacity of Onkalo

40 years: length of time it takes for radiation levels in spent fuel to drop 1/4 when immersed in a cooling pool

1640-2300 ft: depth of burial in Onkalo (5 NYC blocks or the distance from Storefront for Art & Architecture to Dean & Deluca on Broadway)

3.4 mi: length of access tunnel at Onkalo (Manhattan is 2.3 miles wide at its widest)

5: threats to the certainty of Onkalo's design: sinking permafrost, earthquakes, copper-eating microbes, rising water, land developers

5.2 gallons: volume of water leaking into Onkalo tunnels per minute

3000: number of canisters that need to be created and packaged at Onkalo

55,000 lbs: the weight of a canister loaded with spent fuel (about the same as three 18-wheeler trucks)

9840 ft: the thickness of ice cap the canisters are designed to withstand in the next ice age (the same height as eight Empire State Buildings placed on top of one another)

"When you make a decision concerning this kind of thing, there will always be uncertainty. So you have to have trust."

—Timo Aikas, Onkalo's vice president in charge of engineering
1.1 background

Back in 1896, no one could predict what the discovery of plutonium, uranium and radioactivity could possibly lead to. Today, 119 years later, a large part of the world builds its energy production and consumption around nuclear energy, advertised as 'clean' energy, leaving behind around 250,000 tons of spent nuclear fuel, which is useless but remains radioactive for thousands of years, depending on the individual half-life of each element. Securing, maintaining and managing spent nuclear fuel are complex and dangerous, even more so since life above ground is unpredictable. Weather conditions and environmental changes, political crisis, wars and not the least human nature are unstable and threaten the safe storage of spent nuclear fuel.

Nuclear waste remains a threat to life for thousands of years. Burying it underground in an enormous repository surrounded and secured by solid rock is the long-term solution Finnish authorities implement right now. Once the repository is filled up, it will be locked up forever and never opened again.

Ultimately, this raises questions: How long is forever? Can we be sure it will remain locked up? How do we communicate to future civilizations what the repository holds and is? Rather rely on forgetting? Is it really safe? What will be in 100,000 years and what will happen along the way? Will environmental changes affect the repository? Can and should we send messages into deep time for people of the future to find? Also, is burying the waste the longed for solution? Is the nuclear waste problem solved eventually? Will more countries follow the example of Finland?

Imagining and relating to life on earth in deep time years seems impossible. It involves us, the survival of the human species and still confronts of with a time span we cannot handle. In our young history, looking back thousands of years leaves us clueless. Thinking long-term has always been challenging for humans, thinking long-term thousands of years ahead clearly exceeds human capability.
1.2 relevance

Introducing Onkalo

In 1994 Finnish authorities passed the Finnish Nuclear Act that states that all nuclear waste produced in Finland must be disposed in Finland. In 2000, Olkiluoto was selected as the site for a final underground storage facility for Finland’s spent nuclear fuel. It was named Onkalo, translating into cave or cavity. The company Posiva executes the planning, construction and operation of Onkalo. Posiva is owned by Fortum and TVO, the two existing producers of nuclear power in Finland (Posiva, 2015).

The construction of Onkalo is arranged in four phases. Phase 1 (2004 – 2009) involved the excavation of the access tunnel, spiraling downwards 420 meters. The second phase (2009 – 2011) focused on further excavation up to 520 metres as well as on studying the bedrock. Phase 3 will begin this year, 2015 and will focus on the construction of the actual repository. The last phase is expected to begin around 2020 and involves the disposal process, the encapsulation and burial of spent nuclear fuel. This phase is estimated to stretch over 100 years. Twelve fuel assemblies will be placed into a boron steel canister and then enclosed into a copper capsule. Each capsule will then be stored in its own space in the repository and further secured with bentonite clay (Posiva, 2015). Read more about Posiva in Appendix A.

The Finnish population generally accepts nuclear power as there are no significant anti-nuclear movements (Fjaestad and Hakkarainen, 2013). Whereas Germany’s immediate reaction to the incident in Fukushima in 2011 was the nuclear phase-out, the news stirred only little political attention in Finland, arriving even in the middle of elections. Read more about Sweden, Finland and the German Energiewende in Appendix B.
1.3 motivation

The podcast on 99% invisible, Episode 114: Ten Thousand Years addresses the assignment given out by WIPP, the only permanent underground repository in the United States, ‘to develop a marker system that will remain operational during the performance period of the site – 10.000 years’ (99% Invisible, 2014). How can we communicate to people in the future? Following the podcast, users left comments and suggestions on the website, ranging from a ‘10.000 year earworm’, a song to discourage settlement near the repository, to a genetically engineered species of cat that changes colours in the presence of radiation. Every argument was quickly discouraged by a counter argument and the dilemma presented itself quite clearly throughout the comments and discussions.

The United States is not the only country dealing with the problem. Sweden and Finland, also planning underground disposal facilities, discuss the same questions. During my research on Onkalo (Finland), WIPP (USA) and SKB (Sweden), the mixed feelings between uncertainty about and execution of what has been decided on, left a feeling of unease in me - humans try to control the uncontrollable.

The documentary INTO ETERNITY by Michael Madsen, draws a very dramatic picture of the scenery in Finland; however, also portrays the Finnish authorities of Onkalo as realistic and pragmatic. Taking action is our responsibility and this is the best solution they could come up with. At the same time, they admit that they could possibly not know or understand what will happen and if their reasoning makes sense to people in 100.000 years. A vital part of the documentary is the discussion around whether they should rely on an active marker system on site displaying detailed information about the site, or whether it would be best if people would forget about the site as time passes (Into Eternity, 2010).

Both, the podcast as well as the documentary presented a very different discourse around nuclear waste from what we are used to from the media. A very personal discourse, opening up and also allowing many questions, rather than presenting solutions and ‘facts’ of political parties and authorities. Outside of the political context, it struck me how real the problem really is. The different perspective, a personal context made the dilemma stuck with me for quiet some time.

Having a background in communication studies and linguistics, I am aware of the construction of social reality through discourse (Berger and Luckmann, 1966). The discourse around nuclear power and nuclear
waste is highly politically charged and often distant to the general public. They often do not seem part of the discourse, as their are not actively included and participating. I see an opportunity and a need for an active and inclusive discourse around nuclear waste disposal.

As humans, we have the urge to make sense of the world. We do so in acting upon our environment. Understanding the world through interaction is essential to human behaviour and a crucial human characteristic.

I believe that creating a personal discourse around nuclear waste, that is triggered and enriched with a personal experience of an interaction, helps revealing the dilemma as well as reflecting on it. Here, I see a great potential and opportunity for Interaction Design.

I chose this topic not least because of a deep interest in outer space, the human being on earth and the future, which I share with my 92-year-old granddad and often discuss with him when we meet. When I told him about my thoughts, he wrote me an inspiring letter sharing his opinion on the topic. Growing up in between two World Wars, the world he grew into was very different from mine, he makes sense of the world differently than I do. Still, we care and wonder about the same things.

I feel, my generation cares too little about the future. Focusing on individual development rather than individual responsibility, our society lacks engagement, debate and critical thinking.

Artifacts can create engagement, cause for thought and ignite a debate - something we see too little these days. A thought and an opinion is the first move towards change. The future is full of possibilities for change, waiting for someone to make them.

I believe, design can be a tool to create artifacts that speak for themselves when language is not enough. In the same way as we need an artifact to hold the coffee that we drink every morning, we need artifacts to express our utter inner thoughts, opinions, questions and dilemmas. Design offers more dimensions that language, has a different kind of presence and impression on people, which makes it powerful and long lasting.

Letter from my Granddad, February 11, 2015
1.4 research questions and dilemmas

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**time scale**

Nuclear waste will remain radioactive for up until 4.6 billion years*  
Nuclear waste will be ever present into deep time and constitute a threat to all living systems on earth. It lies beyond human capability to take precautions for that period of time. Nevertheless, authorities worldwide seek to plan ahead for 10,000 years (WIPP, US)**, 100,000 years (Onkalo, Finland), and even 250,000 years (Sweden).

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**uncertainty**

‘Fins are protected’ - On their website www.stuk.fi, STUK, the Finnish Radiation and Nuclear Safety Authority presents Onkalo as safe and ensures the safety of every Finish citizen. Is that justifiable?

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**invisibility**

Radioactive waste implies dealing with a toxic that we cannot sense. Exposure to radiation has short- and long-term effects, depending on the intensity of radiation. Intense exposure to radiation may cause symptoms of radiation sickness and/or death, weaker radiation levels might cause illnesses at a later stage, such as cancer, as radiation disturbs the cell development in the human body and thus allows for cell mutation and malevolent cell growth. See Appendix D.

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*In about 5 to 6 billion years, the sun will have depleted the hydrogen fuel in its core and will begin to expand into a red giant. At its largest, its surface will approximately reach the current orbit of Earth, which will consequently lose its atmosphere completely causing the extinction of all living systems on earth. There is reason to believe that radioactive elements outlive humanity, as they will still be radioactive when all living organism have died. See Appendix C for nuclear decay chains.

** WIPP is going to be radioactive for hundreds of thousands of years, though the WIPP panel was only responsible for keeping this place sufficiently marked for 10,000 years. This was justified with the statement that thinking beyond that time frame was thought to be impossible.

Project for nuclear awareness, 2014. source: www.pnausa.org

Timeline, Into Eternity, 2010
Like the layer of accumulated and left behind trash in outer space orbiting Earth, burying nuclear waste beneath our feet might come with unpredictable risks. The soil is our main source for nutrition and water. An undetected leakage of radiation into the ground water and soil might have devastating consequences. Are we burying a Trojan Horse?

Will other countries follow the Finish example? How much nuclear waste can we possibly bury in a limited and due to global warming decreasing amount of land on earth? Will Onkalo become the precedence? How will international policies on nuclear waste disposal change after Onkalo?

China, Russia and India build and plan to build new reactors, relying heavily on nuclear power. Other countries such as Nigeria (2014) just joined the nuclear industry. Nuclear waste will increase and thus the demand for disposal solutions.
2. Method / Research
2.1 initial research

Deep Time = Deep Space

Initially research focused on deep space and how space travel evoked attempts to communicate to extraterrestrial life. Trying to communicate to extraterrestrial life and trying to communicate to life on earth in 100,000 years have similar implications: are they there and will they share human traits with us?

Astronomer Carl Sagan made the first attempt to communicate to life outside our atmosphere. His Pioneer Plaque received great criticism regarding the unequal depiction of man and woman. Astrophysicist Gregory Benford, artist Jon Lomberg and astronomer Carolyn Porco gave it a second try and designed a message to fly on NASA’s Cassini spacecraft, launched in November 1997, bound for Saturn. Find more in Appendix E (Benford, 1999).

Artist Trevor Paglen created a collection of one hundred photographs depicting humanity in 2012. ‘The Last Pictures’ orbiting earth since November 2012. ‘The satellite will spend fifteen years broadcasting television and high-bandwidth internet signals before maneuvering into a ‘graveyard’ orbit where it will become a ghost-ship, carrying The Last Pictures towards the depths of time’ (The Last Pictures, 2012).

All of the above, as well as the theme of this project, constitutes a clear link to the Anthropocene, the era of human imprint on earth.
Looking ahead vs. Looking back

Looking 100.000 years back in time might give us valuable insights about what to expect in 100.000 years from now. I continued my research with creating time lines focusing on specific themes such as Science and Radioactivity, Message and Medium, Culture Religion, and Civilization and Future Prospects. A full display of all time lines can be found in Appendix F.

How did humans try to convey meaning in the past? Humans used different kind of media and tools humans to covey a message and manifest knowledge and insights in the past, such as monuments and tombs, language, time capsules, marker systems, myth and story telling, art, music, symbols, memorials, even games.

Language and symbols are heavily relied on throughout history; however, they are also altering over time. They are not reliable as they are ambiguous and changing to a great extent over time. Languages evolve constantly. Beowulf is written in an English that differs greatly from contemporary English. In the same way, symbols evolve over time. A great example is the swastika, originally a symbol of luck, it was later adopted and abused by Adolf Hitler and became a symbol of national socialism and fascism.

Looking back 100.000 years in our young history leaves us clueless. However, the timelines also show that history is dynamic and the past, present and future are connected, related and influencing eachother. We have a strong connection to the past, we value artefacts of the past highly. We can also see that humans have the urge to leave a legacy, to manifest great achievements, knowledge and insights so they will be remembered forever, using the tools available. In fact, the manifestation of knowledge and insights has been key to human culture and civilization. Many religions manifest themselves in rituals. The combination of word and action is powerful and proves itself to last.
2.3 design method and literature review

This project follows the Critical Design practice, which is driven by the thought of raising questions and exposing dilemmas, rather than providing solutions and answers, and thus fostering awareness and understanding. It provides a great tool to reflect on both the status quo as well as the future from a new perspective. Meaning is created through the artifacts’ expressiveness, which is then mirrored in the observer’s attitude towards it. The work of Anthony Dunne and Fiona Raby is path breaking in this field. Their Placebo Project (2001) investigates people’s attitudes towards electronic objects in their home, such as the Nipple Chair, whose nipples vibrate when exposed to electromagnetic fields. By making visible the invisible, the Nipple Chair raises awareness of the electronic products’ nature extending visible realms.

Dunne and Raby’s approach to Critical Design has been wildly discussed in the field. It gained criticism for not taking full responsibility for their design by avoiding a critical discourse around it, a neo-liberal world view, repetitive content and being ignorant towards what is already happening right now. Their artifacts have been described as ‘only by and for white, upper middle-class men, privileged, intellectual and European’ as well as asocial and apolitical, with no purpose other than being ‘speculative’ (Design and Violence, MOMA, 2013).

Critical Design is rooted in an ongoing frustration with the present and thus stirs discussion about the status quo. Speculative Design operates on equal terms as Critical Design; however, can be defined as more future driven and has great potential to provoke discussion about both what is possible, but also what is desirable in the future.

Both terms, Critical and Speculative Design, are fairly young design practices and their definition and implications are still discussed within the field. Concerning Speculative Design the work of Lucy McRae has been influencing this project.

Next Nature is a Dutch multi-disciplinary open network that speculates around the evolution and adaption of nature to the supposedly needs and desires of today’s society, a nature caused by people. They claim that the nature of today will be superseded by a Next Nature that obeys to our technological environment that became ‘so omnipresent, complex, intimate and autonomous that it becomes a nature of its own’ (Next Nature Network, 2015).
Since nuclear waste is a highly politicalized topic, this project has also been influenced by Carl DiSalvo’s Adversarial Design approach, which evokes and engages political issues. Fundamental to DiSalvo’s approach is the facilitation of agonism as a condition of productive contestation and dissensus. Designed artifacts serve as manifestations of bias and active positioning in relation to a political issue and invite for others to participate in the critique, commentary and contestation (DiSalvo, 2012).

Smudge Studio and their project Containing Uncertainty have been especially influential since it also addresses the issues and dilemmas around Onkalo. Smudge was established in 2005 in New York as a collaboration between the artists Jamie Kruse and Elizabeth Ellsworth. They pursue what they ‘take to be our most urgent and meaningful task as artists and humans: to invent and enact practices capable of acknowledging and living in responsive relationship to forces of change that make the world.’ (Smudge Studio, 2007). The pieces of Containing Uncertainty ‘draw a poetic connection between the contemporary act of designing a deep geologic repository and historic human efforts to design architectures and/or infrastructures that connect humans to what exceeds them, such a the cosmos and geologic time’ (Smudge Studio, 2010).
2.4 problem analysis

‘A typical 1000 MWe light water reactor will generate (directly and indirectly) 200-350 m³ low- and intermediate-level waste per year. It will also discharge about 20 m³ (27 tonnes) of used fuel per year, which corresponds to a 75 m³ disposal volume following encapsulation if it is treated as waste. (...) This compares with an average 400,000 tonnes of ash produced from a coal-fired plant of the same power capacity.’ World Nuclear Association, March 2015

How much waste is produced?

Around 8910 tonnes of heavy metal nuclear waste are generated each year. This waste mainly comes from nuclear power stations. Three territories produce over 1000 tonnes a year: the United States, Canada and France. Canada also produces the most waste per person living there, although Sweden is not far behind (World Nuclear Association, 2015).

Regardless of whether the volumes of nuclear waste produced is relatively small compared to other methods of energy production, their contaminating nature makes it more than just ‘waste’. It ought to be handled carefully so it does not constitute danger to the environment and humans. Can this be ever achieved and even guaranteed?

Radiation is natural, radiation levels can be found almost everywhere on earth; however, they are low and thus harmless. Radiation levels in Outer Space are higher and harmful for the human body.

Radiation is invisible. Humans cannot perceive, experience, or sense it. We are dependent on machines that detect radiation particles and rays and translate them into numbers and curves we can interpret. We have difficulties with relating to radiation, its consequences and implications since it is an abstract, alienated matter and highly politically charged.
What to do with nuclear waste?

Nuclear waste disposal has been disposed in the past as follows:

- Temporary Spent Fuel Pools
- Temporary Dry Cask Storage
- Long-Term Burial
- Reprocessing for Plutonium
- Powering Spacecraft
- Dumping into the sea

‘To decay half of the amount of plutonium 239, which is the primary fissile isotope used for the production of nuclear weapons, it takes around 24000 years or 1000 human generations, much longer than the known history of homo sapiens. After decades of nuclear energy production, the pile of nuclear waste is still growing, even though worldwide not a single site for final disposal of spent fuels is operating and temporary storage is continuously being extended.’

John Loretz, International Physicians for the Prevention of Nuclear War, March 2010

On Terminology: Waste

Nuclear waste is not waste, as it should not be thrown, openly collected, left behind, it cannot be recycled (yet), neither burnt or dissolved in any way. However, it is waste, as it presents itself as useless. Rather it is the afterlife of the energy that we consume, and consider ‘clean’, it is a byproduct, the collateral damage, the toxic remains that need to be watched, maintained, kept out of human reach, a threat.

Out of sight, out of mind?

At Onkalo, tons of radioactive remains will be buried. Considering the limited ground on earth on one hand, and the exponentially increasing amounts of radioactive waste material and demand for disposal on the other hand, burying nuclear waste worldwide cannot be the solution, in my opinion.

My design shall display why by articulating the dilemmas and risks attached to Onkalo.
2.6 objectives

The overall objective is to create artifacts that eventually foster a discussion around the case of Onkalo specifically, which might lead to more general universal questions such as:

What is my Individual responsibility as a human being in the future?

How do I relate to the future? Can I make a change? Which direction should it lead?

What does it mean to be human?

What is possible, probable, most likely, but also desirable?

I want to challenge the human inability to think long-term and embrace long-term consequences. The artifacts I am creating should reveal and challenge attitudes and mindsets thinking about future scenarios as well as the present and how they might, can, should, will relate and influence each other.

My design will expose what is happening at Onkalo. The artifacts will help understanding the dilemmas, challenges and risks of underground repositories by making them tangible, experiencable, easy to relate to, engaging, concrete, and revealing themselves through familiar products and interactions.
2.7 final design brief

Who am I designing for?
Onkalo is happening right now, it is concrete. It has a physical shape and a specific location. This is the reason why I will focus on people right now rather than any speculated future scenario. The timeline research has shown that it is the people, culture, and society that carry the message into the future. Today’s population are the protagonists that will carry the message all the way, or at least some way.

It requires different and new strategies, channels, opportunities and relationships to carry the message of Onkalo forward.

I want to create believable scenarios that people can relate to. My designs are based on human nature and predispositions.

What am I designing?
In my design I will focus on nuclear waste only.

My artifacts will address and visualize the following dilemmas:

- the clash between an exponentially increasing and a limited and decreasing entity.
- making visible the invisible and thus create awareness, understanding, sensitivity, and an emotional response.
- bridge between political debate around nuclear waste and me as a human and how it affects me personally.

I want to create interactions that make radiation understandable, tangible, experiencable, engaging, concrete, and thus revealing the challenges and risks related to underground repositories.

base and present artifacts in context and scenarios.

The leading question is:
How can design help us to understand radiation and nuclear waste by giving it a physical shape but also by challenging us to ask ourselves new and better questions?
3. Creative Process
3.1 inspiration

Onkalo is the starting point, centre of this project and main source of inspiration.

My design process was influenced by the Next Nature Network, Lucy McRae, and Dunne and Raby, as well as Gregory Benford’s Deep Time - How humanity tries to communicate through millenia, Timothy Morton’s notion of Hyperobjects, and Smudge Studios Containing Uncertainty.

I was inspired by human nature and human predispositions, which is driven by hope, curiosity, irrationality. MIT’s WAMSR technology and research that allows unboiling eggs by untangling proteins advancing cancer research are great examples for how humans are driven and empowered by hope.

A great source of inspiration was also unfolding processes within radiation therapy and how radiation acts upon the body as well as nature itself.
3.2 ideation

**strategy: The Living Marker / Manifestation in identity**
Taking individual responsibility by becoming the marker itself

**strategy: Living with Onkalo / Consumerism**
Incorporating message into Everyday Life through products

**strategy: Hacking Nature**
Using Biotechnology and Bio-Hacking to breed species who become markers and/or Onkalo ambassadors

**strategy: Hope**
Hope drives people to update their knowledge

**strategy: Contextualisation**
Bringing two pieces of information in one context forces the user to relate them in the particular context.

**strategy: Embodiment**
Magnetism drags us away from Onkalo - the end of bodily autonomy and self-determination?

**strategy: Anthropomorphisation**
Appeal to human rationality, translating 100,000 years into a time scale humans can relate to - human age

See Appendix G for ideation overview.
3.3 focused ideation

strategy: Living with Onkalo / Consumerism

incorporating Onkalo’s existence and characteristics into everyday life through products and their affordances:

desk lamp
wardrobe
wall paper
wrapping paper

strategy: Manifestation in identity and society

nuclear waste as a tool for introducing children to nuclear waste.

taking individual responsibility by preparing the future generation as they are the ones who will have to bear the load without having the short-term benefit of the current generation.

Onkalo becomes part of my identity and moves into the close family realm. The user commits to convey the message to the future generation.

strategy: Contextualisation

Bringing two pieces of information in one context forces the user to relate to them in the particular context.

Choosing the peculiar moment of determining pregnancy, the emotional dilemmas connected to radiation and the unborn are revealed.
3.4 mock-ups
In need of a framework

As is started thinking about promoting and distributing my products, I had to think of a suitable and convincing framework. In which context will my products be understood in the right way? Which framework can support and contribute to the artifacts in the right way?

An Authority?

Using an authority as a sender brings a certain level of seriousness and credibility with it. On the other hand, it also emphasizes the political nature of the topic, which could potentially lead the discussion towards a political discussion around nuclear waste, energy, politics and laws. I created the Next Frontier Institute that was to be established to prepare humanity for a life on a contaminated planet.

A Consumer Brand?

Creating a brand around the artifacts that is user friendly and promotes and praises the product. I used MUJI as a template to see if my artifacts could fit into a brand like MUJI smoothly. See Appendix H.

A Campaign?

Promoting the artifacts through a campaign is valuable since it takes elements of both, an authority and a brand. Thus, I designed ‘The New Neighbour Campaign’. The brochure can be found in Appendix I.
3.6 concept evaluation

Concept Evaluation Workshop

As I was struggling to find the right framework to put my artifacts in, I decided to test the campaign in a workshop. This workshop was a great opportunity to discuss my artifacts the different contexts I designed, such as the brand vs. the authority vs. the campaign as a mix of the two (semi-consumer and semi-authority). To get the discussion started, I decided to present the New Neighbour campaign brochure to the workshop participants.

On April 28th 2015 I invited five colleagues to a workshop to test, evaluate and discuss the framework of the new neighbour campaign. They were exposed to the brochure and the scenario first at the workshop. It became clear that the brochure itself required a lot of effort to make sense of it, as it was ambiguous. The participants were not sure how to read and interpret it. Is it serious, is it a joke, who is this from, should I read it?

All of the participants agreed that they would not take further notice of the campaign unless they start to see that friends and other people around them would follow. Another insight was that the campaign overruled the products, they became secondary. None of them would purchase the products on the basis of the brochure. However, they agreed that they would maybe purchase them, if they would see them displayed in a shop, and could see the product in real life. The brochure alone was not enough to encourage further action or thought.

I concluded, that the artifact need a clearer framework that supported the products in a way that they become the message itself. The artifacts are stronger on their own, as they speak for themselves. They need full attention.

I refrained from the campaign and decided to focus on the artifacts as consumer products on their own through a clean and subtle Design Brand. The design brand’s philosophy and history provides the consumer with the background information needed.

Onkalo is the starting point of my project and the brand thus constitutes itself around Onkalo. In fact, Onkalo becomes the brand itself. The artifact are then further promoted through ads/videos, posters and a catalogue.

The participants showed great interest in the products once they got to the page in the brochure. They appreciated their underlying meaning and could fit them into the context smoothly and instantly. The workshop showed that the New Neighbour campaign keeps attention away from artifacts. It thus proved itself not suitable as a promotion and context of the products itself.
3.7 final concept

A Finnish middle-class Design brand promoting everyday products to costumers around the world.

Their products are special in the way that their form language, semantics and/or function evolve around Onkalo. Each product draws upon a fact that constitutes a dilemma. The costumer learns about that dilemma in everyday interaction with the product.

Aim of the project is the display and launch of the first three products, a lamp, a piggy bank / marble toy for kids, and a pregnancy test.

They are promoted through display, a video, and a poster.
Understanding radioactivity through an experience

The Artifacts operate on two axis. Firstly, the axis of function that they display as a product, in this case a lamp, a piggy bank / marble toy, and a pregnancy test. This function is deliberately chosen to get people hooked, to invite people for interaction. Familiar products display characteristics and affordances that we can recognize and define. The user is confident to interact with the product, as it is familiar.

This is the point where my design interferes and the second axis is revealed. The axis of expressive meaning related to Onkalo and underground nuclear waste disposal.

Because the interaction is familiar, different responses and changes in the design become more recognizable and apparent for the user. This is strange, why is this working differently from the other lamp, piggy bank, pregnancy test that I know? The user has to figure out why this interaction is different from the usual routine and what that means and implies.

Both levels can be detached from eachother, the lamp can only be a lamp, the piggy bank only be a marble toy, the pregnancy test only be used for determining pregnancy. The consumer can choose to ignore the underlying expressive meaning and use the product as any other product of the same kind.

Products of everyday use are easy to approach and invite for interaction. Through familiar interaction and confidence in interaction the user is more receptive for subtle changes in the design that result in different outcomes than the expected. The user comes with expectations, which are met, since the product performs its function; however, the user also is presented something unexpected. The user can either accept it, or, because he/she wants to make sense of it, question the intention behind the design.

The big numbers translating to the ON / OFF function on the lamp switch, the quickly accumulating waste marbles, the RAM values on the pregnancy test, are translated into meaning through the interaction.
3.9 refining the design

Onkalo Lamp

Which behaviours should the light display? Since I am using a LED Neo-Pixel Strip I can control every neo pixel on that strip in light behaviour and colour. I experimented with giving the light a light neon green touch as well as with different behaviours. The lamp lights up randomly even when not switched on, as if it was saying ‘Hey, I am still here’. I also experimented with the literal translation of half-life into the behaviour. Whenever the light is switched off, the lamp continues to light up for half the time it has been switched on before, referring to the half-life of the radioactive elements. It is not ‘off’ when you want them to, it has an afterlife, that you are reminded of everytime you want to switch it off.

Onkalo Piggy Bank and Marble Toy

The base of the lamp is made out of granite, just as the spent fuels are buried in granite. Posiva specifically emphasizes how granite is the most durable and thus the most reliable material for a safe burial. Thus, granite plays a special role here.

Onkalo Pregnancy Test

The pregnancy test will be a digital pregnancy test, so the test result ‘pregnant’ and the mSv / ram values will be presented in the same display window.

As with every usual pregnancy test, the Onkalo Pregnancy Test will come with a heavy information loaded user manual displaying and explaining mSv and RAM values and what they mean for body and health.
3.10 building the models

The Lamp

The Body
The body serves as a skeleton where the Neo Pixel string and the shade will be attached to. It has to be stable and firm, but also bendable. I experimented with different steel tubes. The hollow 480 cm / 16 cm diameter tube was hard to bend and did not bend nicely, as it was hollow. For the second iteration I used a 300 cm / 12 cm diameter solid steel tube, which bended nicely.

The Base
The base fixes the skeleton, arrests the while lamp and is housing to the electronics. Since Onkalo is built in solid granite, I also used granite for my base.
The Switch
The switch is the central element of the interaction, thus the experience is of switching the lamp on and off requires fine tuning, tweaking and iterating. I experimented with a slider, a knob for turning and a SoftPot membrane potentiometer. All three elements allow dimming the light, which is essential to the design.

The membrane potentiometer and the slider switch involve a linear movement, right/left or top/down. A linear movement constitutes a challenges since it implies different affordances worldwide. In the Western world movement to the right implies ‘more’, as in on, whereas movement to the left implies less, off. However, a vertical movement is universal, as up is understood as more, up is on, whereas down is less, off. The knob rotates while working on the same parameters. Turning clockwise implies a greater value, on, whereas counter clockwise translates to less, as in off.

Affordance is important to consider and crucial in my design in order to convey the right meaning through the right interaction.
The Shade
For the outer layer of the lamp, the shade, I experimented with different materials ranging from transparent tubes, a metal spiral ‘slinky’, covered with light fabric, folded paper, to braided cable sleeves. Weight, transparency and light effect were the crucial criteria.

The pointy light characteristic of the LED strip forced me to expand the volume of the shade to enable diffusion of the light. I added volume in favour for light quality and oved away from the intended slim fit shading.
The Piggy Bank and Marble Toy

The Body
The body shape is, as well as the lamp, inspired by the Onkalo access tunnel. In the piggy bank model the shape also works as a tunnel, where the waste marbles run through. Thus, the shape needs to be hollow. It was hard to find a stable, hollow tube that I could bend without causing kinks in the corners that would hinder the marble to run through smoothly.

The Waste Marbles
For the waste marbles I used water jelly crystals consisting of water-absorbing polymer. These crystals are long chains of molecules, called polymers, that absorb incredible amounts of water and release them at a later time.
The Pregnancy Test

The Test
The pregnancy test model is consisting of a commercially available digital pregnancy test, which is covered in a housing made from red foam.

The Packaging
The packaging carries the logo and has been designed with regards to commercially available pregnancy tests.
4. Final Design
4.1 the brand

Onkalo is a Design brand promoting everyday consumer products. Their design language and corporate identity establishes itself around Onkalo, the Finnish underground repository for nuclear waste. All products’ form language and expressive meaning play around the theme of nuclear waste.

The brand’s aim is to implement issues and risk, as well as plain facts related to Onkalo to raise awareness to this relevant topic and generate an understanding in everyday life.

Onkalo addresses and attracts primarily customers in close proximity of Onkalo.

Products that are here to stay.  
- Please store safely forever.’
4.2 the artifacts and scenarios

Onkalo Lamp

The first artifact is a lamp that represent Onkalo in shape and interaction. Instead of ON and OFF, the switch says 2015 and 102015 translating into the time scale of 100,000 years. As the lamp is switched on/off the switch moves in time, the light, representing Onkalo’s activity as in emitting radiation, fades in/out, and the dilemma unfolds itself.

The interaction represents what is happening in Onkalo in an everyday action. A lamp is used on an everyday basis, it has a clear assigned function. The lamp is a filmic, friendly, neutral and concrete object. It sits in a social setting being in constant use.

The three-dimensional shape allows it to turn to different angles, so the icon will not always be visible: turning the lamp = turning away from the problem. Firstly, it is a lamp and can be used as such only. Secondly, it carries a strong emotional meaning. Its semantics unfold in interaction.

One of the final realisations is that the lamp is possibly using energy produced by nuclear power plants. A dilemma in itself.
Onkalo Piggy Bank and Marble Toy

The second artifact is a piggy bank for children. The scenario starts in the kitchen, where parents, as many already do now, filter the tap water. They do that but adding filter units/waste balls to the water that absorb radiation particles from the water and enclose them. Those units swell into little balls and are basically home grown nuclear waste. They contain the radiation particles safely and are harmless, nevertheless, it is nuclear waste. Just like pocket money, every child gets one of those units to put in their piggy bank. It becomes a currency, something to trade; however, it has a negative value. Just like nuclear waste, you don’t want to accumulate it, you want to get rid of it. The child can do that by trading the waste balls for favours and other worthwhile actions. This scenario shows a very personal relationship to nuclear waste, as well as the burden we put on future generations. It is not us that will have to deal with it, it is our children. We have to teach them how to deal with it. The piggy bank also has the shape of Onkalo, you fill the tunnel with the balls, they roll all the way down the ‘tunnel’, a little threshold at the bottom hinders them from falling out, but they can easily be taken out at the bottom - also showing how Onkalo could leak, and in close dialogue to the lamp.
Onkalo Pregnancy Test

The third artifact is a Pregnancy Test that not only shows you whether you are pregnant or not, but also how much radiation you have inside your body.

The act of making a pregnancy is a deliberately chosen moment in time, well planned and emotionally charged. This moment is consciously chosen to tap in and address the problem of radiation.

By showing those two presumably unrelated pieces of information into the same context, the woman is forced to relate them to each other. What does that mean for me? and for the unborn child? In which world will I be raising this child? Both pieces of information communicate processes from the inside of your body. Turning the inside outside, again, making the invisible visible and thus tangible.

One aim of the test is to introduce the mSv scale to the general public and establish a general understanding of the values in a context.
4.3 future work

expansion in ratio / distribution

Expanding the reach of the project beyond university and Umea will be the next step. Presenting and displaying the artefacts in different settings, which foster a discourse grounded in the topic or bring in different perspectives is essential.

The project will be displayed and discussed at the JVEA event, a platform for theory, art and design, in Berlin, 27 July - 2 August. The event is organized by The Jan van Eyck Academy in Maastricht, The Netherlands, and will be a great opportunity to exchange thoughts and perspectives on the topic.

involving different media channel

Future work could also include a broader application of media, genres and channels through which the artefacts are distributed. Distributing the project through a website and establishing an online community might be a feasible next step as well as will strengthen the discourse.

expansion in product range

Thinking ahead, expanding on the product range would be desirable. Involving more consumer products opens up new opportunities and touchpoints as well as strengthens credibility.
5. Reflection
5.1 exhibitions

The artifacts were exhibited at the UID 15 Design Talks as well as at the Semcon exhibition in Gothenburg. At the Design Talks a closed exhibition shop was chosen, the three artifacts were presented behind glass to resemble a shopping window scenario. The visitors experienced the artifact as displays of the newly launched Onkalo shop.

At Semcon in Gothenburg the artifacts were displayed freely enabling the visitor to touch and interact with the artifacts, which they did.

Both exhibition spaces were accompanied by the concept video and a poster (see Appendix J). You can find the video by clicking the following link: https://vimeo.com/132344785

The artifacts were evaluated by in-depth interviews with visitors. The artifacts can be evaluated as follows:

Pregnancy Test

The pregnancy test was accepted most by both women and men. It was easily and instantly understood triggering the most responses. Visitor’s immediate reaction was serious, they found the thought of having a considerable amount of radiation inside of them scary and noticed that they have not thought about it before. It became obvious that no one could relate the mSv values to a meaningful consequence; however, most of them wish they would have more knowledge about it. Many people suggested to facilitate understanding and bridge the meaningless mSv indicator by adding a colour indicator. Green would mean the value is within normal parameters, yellow would indicate a risk whereas red would clearly indicate danger.

‘Yeah, because then it is about me as an individual.’ Visitor’s reflection upon the Onkalo Pregnancy Test.

The most powerful value acknowledged by the visitors was the strong personal link. The test triggers me as an individual to reflect about what radiation does to my body and which affect it has to me as an individual without me noticing. Surprisingly, both women and men could relate to the pregnancy test equally. Both genders felt connected to and could identify themselves with the outlined scenario.
The Piggy Bank and Marble Toy

The marble toy clearly required the most explanation, which in return however triggered the most discussion. Visitors at Semcon who could touch the waste marbles described touching the marbles as a ‘scary and fascinating experience’. Nearly every visitor touched the marbles and spend a considerable amount of time trying to figure them out, which confirms the choice of Polymer as an interesting medium. Most of the people thought they were made out of glass and literally sprang back when they found that they are wet and slippery. One visitor pointed out the combination of the colour, the transparency, and the perfect shape as the driving force that made him touch and interact with it.

Another visitor appreciated the marbles as a nice token for children to remember later and throughout their lives, as its unique characteristics will be remembered by children. When the marbles become a token for radioactive nuclear waste in children’s mindsets, a first step towards creating awareness around radiation and nuclear waste within the next generation is achieved.

‘Is there radiation in it?’ Visitor’s reflection upon the Waste Marbles.

Visitors repeatedly experienced mixed feelings when engaging with the waste marble scenario, as they could see how the marble toy and the marbles invite children to play – one visitor complimented me on the easy and ‘toyish’ way of assembling the toy using Velcro – however, on the other hand how the scenario of seeing children play with it is utterly scary leaving a feeling of unease.

Lamp

‘It’s interesting, but I don’t understand.’ Visitor’s reflection upon the lamp.

The lamp was intended and designed as the most straightforward artifact, which however did not succeed. The year engravings required explanation and the concept was not understood instantly. Only a few people saw in it what I saw and intended.

From what I could observe, it was because most visitors did not spend enough time looking at the lamp, were distracted by other artifacts (marbles!!).
5.2 conclusion

All in all, I can say that the project was a success as it engaged people in both intended and predicted as well as in surprising and unpredicted ways. Everyone was especially engaged and fascinated by the topic itself which one described as a 'wonderful, interesting and burning topic', and appreciated my attempt to find ways of creating access to the different conflicts and dilemmas attached to it. However, as expected, not everyone understood every artifact instantly. Most visitors accepted and appreciated the pregnancy test, whereas the marble toy fascinated and engaged the most visitors. The lamp was either the favourite artifact or completely neglected, and in any case the artifact that triggered the least discussion.

A lot of visitors were interested in other products I have thought about, which were then also discussed. That shows me that this project could be continued endlessly. Thinking about other products, the visitors encouraged me to think about products that are changing and evolving over a longer period of time, something that keeps the user coming back over a longer time span rather than focusing on short interaction patterns. The video was much appreciated.
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FOREWORD

Final disposal of spent nuclear fuel generated in Olkiluoto and Loviisa nuclear power plants, has been prepared in Finland for 30 years. Company tasked for the preparation and the actual implementation of final disposal, Posiva Oy, has compiled the key figures related to the project to be easily available in this pocket guide.

Some disposal-related key figures will change as the project progresses and as the data are specified further according to the amount of fuel disposed of, for example.
The data in the brochure has been updated according to the situation in autumn 2012 so that the figures for the disposal facility volume are based on the current estimate of the amount of spent nuclear fuel (5,440 tonnes of uranium) during the entire lifecycle of existing nuclear plant units and OL3.
POSIVA

- Established in 1995
- Owners:
  - Teollisuuden Voima Oyj 60 %
  - Fortum Power and Heat Oy 40 %
- The mission of Posiva is to take care of the disposal of its owners’ spent nuclear fuel
- Number of staff: 101 (2012)
- Turnover € 67.3 million (2012)
ONKALO IN FIGURES

- ONKALO is a research tunnel which will be connected to the disposal facilities later.
- ONKALO excavation was launched in 2004 and disposal depth (420 m) was reached in summer 2010.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of access tunnel</td>
<td>about 5 km</td>
</tr>
<tr>
<td>Incline</td>
<td>1:10</td>
</tr>
<tr>
<td>Tunnel dimensions (width x height)</td>
<td>5.5 x 6.3 m</td>
</tr>
<tr>
<td>Combined length of shafts</td>
<td>about 1 km</td>
</tr>
<tr>
<td>Passenger shaft diameter</td>
<td>4.5 m</td>
</tr>
<tr>
<td>Inlet and exhaust air shaft diameters</td>
<td>3.5 m</td>
</tr>
<tr>
<td>Total volume of water leaking into ONKALO</td>
<td>37 l/min</td>
</tr>
</tbody>
</table>

![Diagram of ONKALO tunnel network]
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of fuel</td>
<td>5,440 tU</td>
</tr>
<tr>
<td>Number of fuel bundles</td>
<td>about 26,000</td>
</tr>
<tr>
<td>Number of disposal canisters</td>
<td>about 2,800</td>
</tr>
<tr>
<td>Final disposal shaft diameter × height (OL 1-3 tunnels)</td>
<td>3.5 x 4.4 m</td>
</tr>
<tr>
<td>Repository volume</td>
<td>about 1.3 million m$^3$</td>
</tr>
<tr>
<td>Total length of disposal tunnels</td>
<td>about 35,000 m</td>
</tr>
<tr>
<td>Total length of central tunnels</td>
<td>about 7,000 m</td>
</tr>
<tr>
<td>Amount of bentonite in disposal hole (OL1-2)</td>
<td>about 25 tonnes</td>
</tr>
<tr>
<td>Repository footprint (bedrock facilities)</td>
<td>1.5 km$^2$</td>
</tr>
<tr>
<td>Disposal canister distance in tunnels (OL1-2 fuel)</td>
<td>about 9 m</td>
</tr>
<tr>
<td>Disposal hole diameter × height (OL1-2 fuel)</td>
<td>1.75 x 7.80 m</td>
</tr>
<tr>
<td>Electricity consumption of encapsulation and disposal facility</td>
<td>7,600 MWh per year</td>
</tr>
<tr>
<td>Canisters for disposal annual average</td>
<td>36</td>
</tr>
</tbody>
</table>

- The disposal budget (2012) is about € 3.5 billion.
- The number of personnel in the encapsulation plant and disposal facility is about 100.
- Fuel bundles are replaced annually in nuclear plants (OL1-2 about 240, LO 1-2 about 200).
Spent fuel is packed into copper and cast iron canisters, which come in different sizes depending on the fuel bundle size.

The disposal project uses the following volumes of material for the disposal canisters:

- About 20,000 tonnes of copper.
- About 40,000 tonnes of iron and steel parts.

### FINAL DISPOSAL CANISTER

<table>
<thead>
<tr>
<th></th>
<th>LO1-2</th>
<th>OL1-2</th>
<th>OL3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside diameter (m)</td>
<td>1.05</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>Total length (m)</td>
<td>3.55</td>
<td>4.75</td>
<td>5.22</td>
</tr>
<tr>
<td>Number of fuel bundles (pcs)</td>
<td>12</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Amount of fuel (tU)</td>
<td>1.4</td>
<td>2.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Maximum heat output upon disposal</td>
<td>1,370</td>
<td>1,700</td>
<td>1,830</td>
</tr>
<tr>
<td>Total weight</td>
<td>18.8</td>
<td>24.5</td>
<td>29.0</td>
</tr>
</tbody>
</table>
SPENT FUEL

<table>
<thead>
<tr>
<th>LO1-2</th>
<th>OL1-2</th>
<th>OL3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fuel bundles, forecast (pcs)</td>
<td>7,752</td>
<td>14,034</td>
</tr>
<tr>
<td>Cooling period (years)</td>
<td>27-38</td>
<td>28-40</td>
</tr>
<tr>
<td>Volume of uranium (tU)</td>
<td>950</td>
<td>2,460</td>
</tr>
</tbody>
</table>

- Accrual is based on plant lifecycle: LO1-2: 50 years, OL1-2: 60 years, OL3: 60 years.

MULTIBARRIER PRINCIPLE

- Different barriers back up each other up and ensure safety.

1. Tunnel filling
2. Bentonite
3. Disposal canister
4. Bedrock
RADIATION OF SPENT FUEL

500 years / 4mSv/h:
The hourly radiation dose from the fuel bundle corresponds with the average radiation dose received by one Finn during 12 months.

- Hourly radiation dose (mSv/h) from the spent fuel, measured at one metre from fuel bundle.

RADIATION OF DISPOSAL CANISTER

<table>
<thead>
<tr>
<th>Fuel cooling time, years</th>
<th>Radiation dose on canister surface mSv/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>59</td>
</tr>
<tr>
<td>500</td>
<td>0.4</td>
</tr>
<tr>
<td>10,000</td>
<td>0.1</td>
</tr>
</tbody>
</table>
The 1970s

- Olkiluoto 1-2 and Loviisa 1-2 nuclear plants are built, nuclear waste management preparations commence.

1983

- Posiva is established.

The Government’s decision in principle on the overall schedule and goal for nuclear waste management, start of geological screening for potential sites for final disposal.

1994

- Olkiluoto is selected as the disposal site by a decision in principle by the Government.

1995

- Posiva submits a construction licence application for the repository.

2000

- The Government's decision in principle on the overall schedule and goal for nuclear waste management, start of geological screening for potential sites for final disposal.

2004
The 2120s

- **ONKALO excavation commences.**
- **ONKALO excavation reaches disposal depth, i.e. 420 metres.**
- **Start of disposal.**
- **Closure of the repository.**

The Parliament forbids the import and export of nuclear waste into and out of Finland.
Drilling machine
**BEDROCK RESEARCH**

| Number of deep drilling holes in Olkiluoto | 57 |
| Total length of drill core samples | about 32 km |
| Number of ONKALO pilot holes | 22 |
| Total length of ONKALO pilot holes | about 2.76 km |
| Diameter of drill core sample | about 50 mm |
| Diameter of drill hole | about 76 mm |

- The first deep research hole was drilled in Olkiluoto as early as 1989.
FAQ

Why is the spent fuel not taken abroad?

Finnish law forbids the import and export of nuclear waste into and out of Finland. The producers of nuclear waste, that is, the parties under the nuclear waste management obligation, are responsible for nuclear waste. The power companies TVO and Fortum who are under the nuclear waste management obligation established the company Posiva to take care of the final disposal of its owner companies’ spent fuel in the bedrock in Olkiluoto.

What is the intended method for transporting the spent fuel from the Loviisa plants to Olkiluoto? What kinds of arrangements will this require?

There is specific legislation covering nuclear waste transportation. There are strict transport rules: approved containers, a separate licence for every transport, and a requirement according to which each container shall retain its radiation protection characteristics even in the worst-case scenario for an accident. Every transport will be accompanied by the police and a supervisor from the Radiation and Nuclear Safety Authority. Whenever possible, the transportation routes will avoid densely populated areas. The options available include transportation by road, rail and sea, and designated standards have been stipulated for all of these.
What will happen if the final disposal canisters unexpectedly corrode and start to leak in the repository?

If a final disposal canister corrodes so that there is a hole in it, groundwater may come into contact with the fuel bundles inside the canister. However, the release of radioactive elements is slow since the fuel is in solid form and does not dissolve easily. Release of radionuclides into the bedrock is also prevented by a bentonite buffer surrounding the canister.
Why is copper a suitable material for final disposal canisters?

Copper will endure the anoxic conditions deep inside the bedrock and will not corrode. There have been findings in the natural environment of metallic copper which is many millions of years old and it has retained good protective characteristics.

Have the effects of permafrost and a possible ice age been sufficiently observed in planning the final disposal?

Permafrost and the effects of an ice age on the final disposal solution have been investigated in Finland and other countries. The research results suggest that in Olkiluoto the creation of permafrost and ice and the back and forth movement of the ice sheet will have only a minor effect on the safety of the final disposal.

What would happen if a major earthquake occurred at the final repository?

The likelihood of a major earthquake is very small, but the possibility cannot be completely excluded in the case of long periods of review. That is why the disposal tunnels will be positioned in intact bedrock blocks of Olkiluoto, which means that the impact of earthquakes will be small.
Is it possible that the waste will contaminate groundwater?

No. The spent fuel is located in the bedrock inside multiple protective barriers. The fuel is encapsulated in a tight copper canister and it is surrounded by a bentonite clay buffer.

Is it possible that something might happen to prevent the final disposal being executed in Olkiluoto?

The suitability of the Olkiluoto bedrock for the final disposal of the spent nuclear fuel has been under investigation since the 1980s. The construction of ONKALO in 2004 has confirmed the understanding of Olkiluoto’s suitability for the final disposal of spent nuclear fuel. It is highly unlikely that the decisions concerning the bedrock or technical reasons will be changed.

Is there any intention to mark the final disposal site so that future generations will know of the location?

The law says that the state will be responsible for the final disposal location once the final disposal has been acceptably carried out. At the same time, the information about the final disposal will be entered into the applicable registries. However, safe final disposal must be based on the principle that the final disposal location need not be monitored, and the information on it need not be maintained. According to existing plans, the final disposal will take about 100 years, so if the aim is to consider marking the site for other reasons, there is a lot of time to develop the method.
Bentonite, bentonite buffer
Bentonite is a naturally occurring type of clay, created as a result of the alteration of volcanic ash. A special feature of bentonite clay is its swelling as a consequence of moisture (wetting). Bentonite is designed to be used as a buffer material.

Burn-up (specific burnup)
The total amount of energy generated in the fuel per unit of mass. When the burnup increases, the residual heat production increases, and fuel must be cooled for a longer time prior to final disposal.

Canister, copper canister
A technical release barrier intended for the disposal of spent fuel bundles and built of a copper overpack, and a cast iron insert.

Cooling time
The time during which the thermal output of spent fuel has decreased to the level required by the disposal requirements.

Demo facilities, demonstration facilities (in ONKALO)
Test tunnels excavated according to the disposal requirements.
Drill core sample
A rock sample obtained from the rock by drilling. The sample can be used for determining the rock type consistency and fracturing, for example.

EBS (Engineered Barrier System)
Technical release barriers in the disposal facility, such as the canister, bentonite buffer and tunnel backfill.

EDZ (Excavation Damaged Zone)
A broken zone caused by tunnel excavation.

EIA
Environmental Impact Assessment, which investigates the impact of major projects on the environment.

Final disposal
The long-term isolation of spent fuel from living nature and the human habitat.

Fuel assembly, fuel bundle
The fuel bundle of a nuclear power plant comprises fuel rods which contain nuclear fuel.

KBS-3V and KBS-3H
The technical solution of final disposal. According to the 3V principle, canisters are placed vertically in the bedrock, and horizontally in the 3H solution.
Multibarrier principle
The isolation of spent fuel from living organisms with several independent release barriers so that no radioactive substances enter the organic nature in any circumstances.

NDT (Non-Destructive Testing)
An inspection method which does not break the substance, such as X-ray.

Nuclear waste
A nuclear power results in low-level and intermediate-level waste as well as highly radioactive spent nuclear fuel. Low- and intermediate-level waste is disposed of in final repository located in power plant areas. At the moment, spent fuel is stored in spent fuel pools located in power plant areas, and will be later disposed of in the Olkiluoto bedrock.

OL1-3, LO1-2
Olkiluoto and Loviisa nuclear power plants (OL1, Olkiluoto 1).

ONKALO
An underground rock characterisation facility for the final disposal of spent nuclear fuel.
**Pilot hole**
A hole drilled in the rock surrounding ONKALO. The hole is for obtaining information for excavation planning and implementation, for example.

**PL (pole number)**
The figure indicates the distance (in metres) from the tunnel mouth.

**Release barriers**
The purpose of release barriers is to keep radionuclides within the final disposal system. Technical release barriers: canisters, bentonite buffer and tunnel backfill. The bedrock is a natural release barrier.

**RSC (Rock Suitability Classification)**
A procedure for developing and defining the suitability of the bedrock for final disposal panels, tunnels and holes.

**RTD (Research, technical design and development of disposal operations)**
Final disposal has been researched and developed in Finnish conditions since the 1970s and the research and development is still continuing.

**Spent nuclear fuel**
Radiated fuel, removed from the reactor, the burnup of which is too high to be re-used in the reactor.
Subcritical
A system which does not sustain a chain reaction. In all circumstances, the disposal canister must remain subcritical, i.e. no chain reactions may occur in it.

Technical rooms (ONKALO)
The technical facilities comprise parking and service garages, rescue facilities, the elevator centre and canister reception facility.

Total volume of water leakage
Volume of water leaking to ONKALO from the bedrock, litres per minute.

VLJ
Low- and intermediate-level radioactive waste, created in nuclear plant operations, such as activated ion-exchange resins used for purification of process water and contaminated plastics, clothes, tools etc. during maintenance work.
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www.posiva.fi
ONKALO

Underground Rock Characterisation Facility at Olkiluoto, Eurajoki, Finland
Finland has been preparing for the final disposal of spent nuclear fuel for some 25 years. Based on the screening of investigation areas, detailed site investigations and environmental impact assessment, in 1999, Posiva submitted an application to the Government for a decision in principle to choose Olkiluoto in the municipality of Eurajoki as the site of the final disposal facility for spent nuclear fuel. Since the municipality of Eurajoki had given its consent to locate the disposal facility in the area and the Radiation and Nuclear Safety Authority’s (STUK) safety assessment had noted that there were no objections to the decision in principle, in December 2000 the Finnish Government duly issued a decision in principle in favour of the project. The Finnish Parliament approved the decision in principle by 159 votes in favour and 3 against. Since then, planning disposal has progressed to the next stage – constructing an underground characterisation facility, known as ONKALO, at Olkiluoto. Work on the entire final disposal project is progressing so that disposal can commence in 2020.

ONKALO – the underground rock characterisation facility

The map shows the location of ONKALO at Olkiluoto. Numerous deep boreholes have been drilled in the investigation area to obtain further information for planning ONKALO.
ONKALO will be used to obtain further information to plan the repository in detail and to assess safety and construction engineering solutions. ONKALO will also enable final disposal technology to be tested under actual conditions.

ONKALO is not intended solely for research premises, but has also been designed to serve as an access route to the repository when constructed.

ONKALO will take 6–7 years to complete. Construction is scheduled for 2004–2010 and investigations will be made from the start of construction in conjunction with excavation. An application for a building permit for ONKALO was submitted to the municipality of Eurajoki in May 2003 and construction work began in June 2004.

Once ONKALO has been completed, work will start on building the encapsulation plant and final disposal repository in the 2010s. These stages of construction and commissioning of the facility itself are subject to separate permit procedures.

Preparation and implementation of the final disposal of spent nuclear fuel

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Excavation in June 2004

Blast signifying the start of work on the tunnel in September 2004
ONKALO progresses deep into the bedrock

ONKALO construction and investigations

An access tunnel and ventilation shaft will be excavated to the main characterisation level at a depth of 420 m. Other engineering work including tunnel opening structures, cable ducts, floor structures and pipelines, etc will be carried out at the same time. Excavation will be carried out using drill and blast technology. The access tunnel is being excavated in stretches of about five metres at a time. Charges of explosive are placed in holes drilled into the rock. The charge is then detonated and the blasted rock removed. The rock walls are washed and any loose stones removed.

Pre- and post-grouting and lining structures will be used to seal the rock in places as required. Cemented rock bolts and shotcrete will be used to strengthen the rock. Cast concrete, which serves as both a water insulator and a rock reinforcement, can also be used in the ventilation shaft. Final choice of materials will depend on the findings of preliminary investigations and investigations carried out while work is in progress.

A shaft building, maintenance and control buildings and a civil defence shelter will be built at ground level. Road building, earthworks and electrical work will also be carried out.

Planning and construction investigations will be carried out from the access tunnel in conjunction with excavation. The findings will be drawn on immediately in excavation and construction work. Investigations focusing on rock groundwater conditions and the location of the repository will commence at a depth of 200–300 metres.

Later, excavation of the access tunnel and ventilation shaft will continue to the lower characterisation level at a depth of 520 m. The access tunnel will total 5.5 km in length at an inclination of 1:10. The premises involve the excavation of a total of 330,000 cubic metres.

The lower characterisation level will be used to investigate rock mechanics conditions and factors impacting on the positioning of the repository. This stage also includes disposal demonstrations, which, like other investigations and tests, will also continue during 2010–2020, after ONKALO has been completed.

Drilling of grout holes

Mapping of the tunnel rock surface
Diagrammatic plan of ONKALO and the repository

Main characterisation level –420 m

Access tunnel

Repository

Ventilation shaft

Lower characterisation level –520 m

Drilling

Blasting

Removal of blasted rock

Grouting and reinforcement

Repository tunnel

Ventilation shaft

Access tunnel

5.5 m

5.7 m

5.5 m
Legislation passed in Finland requires nuclear waste generated in Finland to be processed, stored and finally disposed of in Finland. The power companies concerned, Teollisuuden Voima Oy and Fortum Power and Heat Oy, are responsible for nuclear waste management. The power companies’ responsibility covers all actions until such time as the nuclear waste is finally and permanently disposed of. Posiva Oy, which is owned by the power companies concerned, is responsible for the practical implementation of final disposal.

Finland has two nuclear power plants, each with two reactor units. The power plants are at Olkiluoto in Eurajoki, on the Finnish west coast, and at Hästholmen in Loviisa, on the Finnish south coast. The combined output of the two reactors at Teollisuuden Voima Oy’s power plant at Olkiluoto is 1,680 MW and that of the two reactors at Fortum Power and Heat Oy’s power plant in Lovisa is 976 MW. Finland made a decision in principle in 2002 to build a fifth reactor unit. The new reactor unit (OL3) being built at Olkiluoto will have an output of 1600 MW.

The Finnish authorities are responsible for the principles governing nuclear waste management, safety criteria and for ensuring that legislation is complied with. The Ministry of Trade and Industry (KTM) is responsible for licenses and legislation and the Radiation and Nuclear Safety Authority (STUK) for supervising safety.
Under nuclear waste management regulations, radioactive waste is divided into low level, intermediate level and highly radioactive waste. The disposal of low and medium level radioactive waste or so called operating waste is already underway and is being carried out by each power plant on its own site. At Olkiluoto, the final disposal of operating waste began in 1992 and in Loviisa in 1997. Finland has also made a decision in principle as regards the final disposal site and solution of highly radioactive spent nuclear fuel. It is planned to begin the disposal of spent nuclear fuel at Eurajoki in 2020. Until then, the spent fuel is being temporarily stored in pools built on the power plant sites. Posiva Oy, established in 1995 and jointly owned by TVO and Fortum Power and Heat, is responsible for practical preparations and research into and the actual final disposal of nuclear waste. Posiva coordinates research and preparation in the final disposal project and works together with expert organisations in many different specialist fields and with similar nuclear waste management companies and other organisations in different countries.

Under the Nuclear Energy Act, funds for nuclear waste management are collected in advance in the price of nuclear electricity and paid into the State Nuclear Waste Management Fund. In 2005, the Fund stood at some EUR 1400 million, which will also be used to cover the cost of decommissioning of the plants. Under the Government’s decision in principle, the spent nuclear fuel generated by Finland’s existing nuclear power plant units and the new unit (OL3) can be finally disposed of at Olkiluoto. A maximum of some 6,500 tonnes of uranium will have accumulated for disposal at Olkiluoto.
Posiva works together with numerous organisations

Implementation of ONKALO represents a decentralised model, where Posiva has outsourced the work to outside researchers, consultants, suppliers and contractors. Posiva is responsible for implementation management and overall administration of the project, which highlights collaboration and compatibility with investigations, design of the disposal facility and the construction of ONKALO.

Posiva’s international partners include:

- SKB (Svensk Kärnbränslehantering AB), Sweden
- ANDRA (Agence nationale pour la gestion des déchets radioactifs), France
- NAGRA (Nationale Genossenschaft für die Lagerung radioaktiver Abfälle), Switzerland
- OPG (Ontario Power Generation), Canada
- RAWRA (Radioactive Waste Repository Authority), Czech Republic
- NUMO (Nuclear Waste Management Organisation), Japan
- RWMC (Radioactive Waste Management Funding and Research Center), Japan

Posiva also has a contract to exchange information with the above organisations and regularly cooperates with SKB and ANDRA on research into disposal facility systems and bedrock investigations.
Appendix B
Finland and Sweden have taken very different paths from Germany after Fukushima; both countries plan to build new nuclear power stations. This article charts the historical development of nuclear power in Sweden and Finland in order to explain why they have not followed Germany in its post-Fukushima decision and whether changes in their respective positions are to be expected.

Sweden, despite a similar heritage to Germany in the form of its strong environmental movement, has deviated from that path. Swedish reactions to the German phase-out decision exhibit significant political polarisation. The Left points to Germany as a forerunner in renewable energy, whereas the Right warns of increased greenhouse gas emissions and calls the Energiewende »a decision made in panic«.

Finland is peculiar in that it lacks a significant anti-nuclear movement. Furthermore, it is the only European country to build new nuclear power facilities in recent years. The news about Fukushima came in the middle of the Finnish election campaign, but did not receive much political attention. Representatives of the energy industry and ministries warned of rising electricity prices after the German decision.

Neither Finland nor Sweden, despite their cultural and geographical proximity to Germany, show any sign of changing their nuclear policies after Fukushima and the German phase-out decision.
When the CDU/CSU and the FDP formed the federal government in Germany in 2009 they promised an »Ausstieg aus dem Ausstieg« (an exit from the exit), representing a slowdown in the pace of nuclear decommissioning compared to the previous agreements. But the accident in Fukushima, a fully modern nuclear power plant in a developed country, made it politically impossible to stay the course, at least in Germany. By contrast, Sweden and Finland continue on the road to increased use of nuclear power. Why? What historical rationale forms the basis for this? And what were the reactions to the German decision?

Although it is a simplification, in Sweden and Finland the Energiewende or new energy transition being pursued in Germany is often reduced to the nuclear phase-out decision. Prior to Fukushima, nuclear power still played a significant role in all three countries dealt with in this article. A snapshot of the situation in 2010 shows that the share of nuclear power in net electricity production was 22.5 per cent in Germany, 38.3 per cent in Sweden, and 28.4 per cent in Finland (cf. Eurostat 2011). However, the reactions to the Fukushima accident were fundamentally different in Sweden and Finland compared to that in Germany.

Swedish Nuclear Power

It has often been pointed out that the development of their respective environmental movements during the 1970s was similar in Sweden and Germany, featuring major protests, social movements and, above all, massive opposition to nuclear power. Also, the Swedish environmental movement has been described as unusually strong by international standards (Jamison et al. 1990: 13). Reasons for this can be found in the tradition of the Social Democratic labour movement or in the fact that another party, the Centre Party, made nuclear power a profile issue for itself early on.

The role of the environmental movement is one key characteristic of the development of the Swedish approach to nuclear energy; another is the fact that a referendum on nuclear energy was held in 1980. The referendum itself did not spell out a specific date for the phase-out, but, after the vote, the Swedish Parliament decided that nuclear power would be phased out by 2010, based on the life expectancy of the reactors.

The Centre Party was long the major anti-nuclear party in the Swedish parliament. However, pressure to facilitate cooperation with the other parties on the political right pushed the party in the other direction. In 2006, when the Centre Party entered a centre-right coalition government with the Moderates, the coalition launched a compromise solution: no decommissioning and no new nuclear power plants for a period of four years. Finally, a subsequent centre-right agreement in 2009 opened the way for new nuclear reactors, replacing existing nuclear power plants. Even though the result of the 1980 referendum had been questioned before, this was the final break with the original policy. By the time of the Fukushima accident in 2011 and the subsequent Energiewende in Germany, Swedish nuclear policy had thus already moved from qualified abolition to fairly robust support for continued use of nuclear power by the Swedish political majority.

The Fukushima accident, of course, did raise great concerns in the Swedish media, but it led to no immediate political consequences. A parliamentary bill from the Green Party to immediately start nuclear decommissioning in Sweden after the Japanese incident was turned down in May 2011, with the following comment by the Parliament: »Furthermore, the parliament notes that the accident in Japan should not be an excuse for an almost panicky decision on a radical shift in the direction of energy policy« (Swedish Parliament 2011a).

This was the political climate when news about the German decision to phase out nuclear power spread at the end of May 2011. The Swedish Minister for the Environment, Andreas Carlgren (Centre Party), was harsh in his comment to the Swedish news agency TT:

»To focus so strongly on which year nuclear power should be phased out risks missing the essential point: that is, how are we to meet the dual challenge of reducing both reliance on nuclear power and climate emissions. (…) The key question now for Germany is that they most likely will increase imports of nuclear electricity from France and risk a slower departure from dependency on fossil fuels, above all on coal. (…) Other countries seem to have chosen a different path. Germany is now in danger of falling into a situation with a very disjointed energy policy.« (Dagens Nyheter 2011)
The attitude to the German decision quickly became strongly politically divided. In parliamentary debates, Germany was praised by the Social Democrats, the Greens and the Left. The polarisation itself was commented on by Member of Parliament Åsa Romson, the newly elected party leader of the Greens, on 10 June 2011:

»In our debate the conservative government in Sweden has by all possible means tried to demonstrate that the decision in Germany would lead to increased greenhouse gas emissions, despite the fact that the agreement the decision is based on is very clear with regard to what the German way is. Germany’s way is to reduce greenhouse gas emissions, improve energy efficiency and become the front runner in renewable energy.« (Swedish Parliament 2011b)

Her party colleague Lise Nordin developed the case a few days later:

»Has anyone in the government read the German energy agreement? The goal of reducing greenhouse gases by 40 per cent is clear. Germany, despite the decision to decommission, has a much more ambitious climate goal than the Swedish government can boast. Germany, one of the world’s largest industrial nations, shows that it is possible to combine renewable energy with affordable electricity prices and a strong industry.« (Swedish Parliament 2011a)

The Social Democrats and the Left agreed with this view, describing Germany as a role model and the driving force of an energy transition in Europe, while criticising the Swedish government for its passivity (cf. Swedish Parliament 2011a). A recurring point made from the centre-right, in response, was that the result of the German decision would be an increased use of fossil fuels, as well as the import of French nuclear power. The Minister for Energy, Maud Olofsson, even remarked that Germany had not been leading in climate negotiations, as Sweden had (cf. Swedish Parliament 2011b). The Christian Democrats claimed that Germany would double its carbon dioxide emissions (cf. Swedish Parliament 2011a).

This harsh divide continued even after the immediate reaction to the German news. In December 2011, the conservative MoP Cecilie Tenfjord-Toftby strongly advised against viewing Germany as a good example:

»(Germany) faces incredible challenges in energy supply, while they struggle with huge pollution problems from their coal power plants« (Swedish Parliament 2011c). At the same time, the liberals claimed that no decision could be as dangerous for European supply as the German one (cf. Swedish Parliament 2011c). And in June 2012, the liberals argued even more antagonistically in parliament:

»In Germany, praised by the anti-nuclear protagonists for its decision to shut down nuclear power, the use of coal has increase by 13.5 per cent already this year with increased emissions, sickness and ultimately death as a result. […] a decision made in panic by a government under pressure.« (Swedish Parliament 2011c)

It may be noted that, beyond the strong right-left divide on nuclear power, reactions differ in terms of what energy is expected to replace German nuclear power: the left-wing parties point to Germany as a model for renewables, whereas the Right warns of increased greenhouse gas emissions from coal.

Thus despite a history of strong environmentalism, like Germany, Sweden has had a radically different response to the Fukushima accident. Why?

First, there is a Swedish »diffidence« towards nuclear safety. The Swedish left-wing paper Ordfront claimed in 2002 that the oldest Swedish reactors were of poor international standard, comparing the number of incidents on the INES scale with other countries (cf. Lundberg 2002). During 2000–2011, 47 incidents classified as 1 on the INES scale were reported in Swedish nuclear facilities, as well as one 2 and one 3 (Fukushima being a 7). In spite of this, the risk of accidents in Swedish nuclear power plants is generally considered low by the public (cf. Hedberg et al. 2010). Swedish political scientist Sören Holmberg also points out that the effect of the Chernobyl accident on public opinion in Sweden was gone after only a year (cf. Holmberg et al. 2011: 14).

Second, climate change has become a major national policy issue. Sweden has had a strong international profile in climate policy, partly by stressing that the country’s electricity generation is virtually fossil-free (cf. Zannakis 2009). The Swedes, in general, are strongly engaged in
climate issues and concerned about global warming (cf. Jagers et al. 2007). To risk increasing imports of fossil fuels by decommissioning nuclear power is not politically possible. Even the centre-right in Swedish politics adopted the climate issue in 2006 after the Stern Review and the Al Gore movie. This also became apparent in the parliamentary discussions referred to above – it is worth noting that Swedish opponents of the German decision usually invoked the climate argument.

The future is still unclear, despite a clear stand in favour of new nuclear power on the part of the centre-right government. Whether the industry really dares to invest on this scale, when the prerequisites may change completely after a change of government, remains uncertain. The heritage from the strong anti-nuclear movement and the phase-out referendum, combined with the present-day public acceptance of nuclear power, does not seem to indicate a clear way forward. The debate after Fukushima has underlined the presently strong polarisation on nuclear issues in Swedish politics: the Left and the Right are deeply entrenched and not ready to review their positions despite events outside Sweden.

Finnish Nuclear Power

In Finland, the origins of nuclear power are closely intertwined with the Cold War. The balance between East and West was sensitive in Finland during the time the first reactors were built. Another decisive factor has been the role of energy-intensive private industry. Teollisuuden Voima (TVO), a consortium of forest and paper industries and power utilities controlled by them, was active in ordering nuclear reactors from the West.

Another persistent characteristic of Finnish nuclear policy has been the complete absence of a debate about phasing out nuclear energy (cf. Sunell 2004: 179ff, 205). This tendency, as opposed to developments in Sweden and Germany, has survived the accidents in Three Mile Island, Chernobyl and, most recently, Fukushima. Safeguarding the competitiveness of the Finnish industry by providing it with cheap, reliable and domestically produced energy is an argument that has enjoyed remarkably widespread support in Finnish society. Most strikingly, not even the environmental and anti-nuclear movements in Finland have ever genuinely demanded a nuclear exit. Many reasons for this absence have been discussed, but two more recent elements seem to stand out to provide the most plausible explanation: the government’s climate and energy strategies portraying nuclear power as a means to reduce greenhouse gas emissions and the decisions on the final deposition of nuclear waste. In 2001, the decision-in-principle for a final repository in Olkiluoto was approved by Parliament. Although the decision technically concerned only the site selection, soon afterwards it was framed as a solution to the nuclear waste issue.

Finland is notably one of very few countries in the Western world that is actively building new nuclear power. TVO is now preparing a fourth unit in Olkiluoto and Fennovoima plans to build a nuclear power plant in Pyhäjoki in Northern Finland. Not even the massive problems and expanding costs of the Olkiluoto 3 power plant have been able to change the generally positive attitudes towards nuclear power.

In Finland the Fukushima accident occurred at a time of intense preparations for parliamentary elections. The news from Japan naturally made the main headlines for several days, but the political fallout in Finland was very limited. One might have imagined that the future of nuclear energy would have become a major election theme, but that was not the case. Not even the Greens made a major theme out of nuclear energy. Their party leader simply wanted to rule out additional decisions-in-principle for new nuclear power plants during the next legislative period – hardly a radical phase-out agenda (cf. Sinnemäki 2011).

The election result proved to be problematic for coalition building and the negotiations lasted longer than usual. Finally, an exceptionally broad six-party coalition led by the conservative Coalition Party agreed on its government programme in late June 2011. Direct references to nuclear power in the programme are limited to two short paragraphs: the option of giving new decisions-in-principle for new nuclear power plants during the legislative term 2011–15 is explicitly ruled out, but immediate processing of construction permits for the ones that have already received the decision-in-principle is promised (Cabinet of Finland 2011). No political party genuinely questioned the permits granted only a year before, let alone talked about a nuclear phase-out.

Representatives of the energy industry and officials in the Ministry for the Economy responsible for energy policy,
on their behalf, were quick to highlight possible problems due to the German decision. Their main worries concerned the potential impact of rising electricity prices in the internal European market and their implications for Finland. Another concern was the impact of the German phase-out on European climate protection efforts, since the general assumption was that the gap left by nuclear would be filled with fossil fuels. Voices arguing for the frontrunner role of Germany in the field of renewable energy technology were in the minority (cf. Pietiläinen et al. 2011).

What possible explanations are there for the Finnish response? Finland certainly shares the fairly relaxed public attitude to safety concerns in its own nuclear power plants with Sweden – from the Finnish perspective, nuclear accidents tend to happen in totally different political or geographical circumstances. The Finnish radiation and nuclear safety authority, STUK, enjoys widespread public trust as a reliable and independent regulator.

The climate argument also plays a role in Finland, but, in contrast to Sweden, it is accompanied by a very strong industrial element. The relatively recent rebranding of nuclear energy as emissions-free has been combined with the traditional role of energy-intensive industry in Finland and the country’s overall willingness to maintain its competitiveness by means of affordable energy. This combination has strengthened even further a Finnish peculiarity, namely, the complete absence of a discussion of a nuclear phase-out.

In Finland, Chernobyl’s impact has never materialised in discussions about a nuclear phase-out. The decisive fork in the road was at the turn of the century – the decision taken for Olkiluoto 3 in 2002 brought Finland more permanently onto a different path. The historical lack of phase-out debates is now fortified by a relatively broad consensus in favour of additional nuclear power plants, too. Hence, a more long-term future for nuclear power seems to be set in stone in Finland. At least the Fukushima accident and the subsequent German Energiewende were not sufficient to alter this conviction.
Bibliography


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Appendix C
All radioactive atoms undergo radioactive decay. However, they do so spontaneously. Thus, half-life is an estimate of how long it will take a sample of a radioactive element to undergo radioactive decay. Half-life is used as a measurement to estimate the probability that atoms of a radioactive element will go through decay within that amount of time and can therefore determine how stable a radioisotope is. As radioactive isotopes go through decay they will continue to transmute into new elements until the atom reaches a non-radioactive and stable element. This process is called a half-life or decay cycle.

Each radioactive element’s half-life is a different period of time. Below is a chart of uranium-238’s nuclear half-life cycle. About half of a sample of Uranium-238 atoms will spontaneously undergo alpha decay within 4.5 billion years. An estimated half of the sample will still be U-238, but the other half will now be Thorium-234. About half of the sample of this element undergoes beta decay every 24.1 days transmuting the atoms into Practinium-234. As you can see by this chart, the process continues until a stable isotope is reached. In Uranium-238’s decay chain that stable isotope is Lead-206. Since Lead is stable and non-radioactive it does not go through the process of radioactive decay such as radioactive isotopes do.

Knowledge of radioactive half-life can be used for many things. One example is radioactive Carbon-14 dating of organic archaeological artifacts in which the level of Carbon-14 still present in the artifact is tested. Carbon-14 has a half-life of about 5,700 years and decays into Nitrogen-14. By using half-life estimates, an artifact’s age can be approximated. Another example of the use of radioactive half-life is during cancer treatment when radioactive isotopes are used. Radiation therapy involves exposure or injection of radioactive isotopes into a patient’s body. For the purposes of treatment, low-doses of gamma radiation released from the injected radioactive isotopes can be allowed to spread throughout the patient’s body and organs. This radiation is needed to last for a sufficient amount of time but not long enough to drastically harm the patient from too much radiation exposure. Radioactive elements with a half-life of several hours are generally used. Read more about radiation therapy here.

A sample of Uranium atoms has about a 50% chance of undergoing radioactive decay at any time. Within the Uranium-238 decay cycle, half-life can range from billions of years to mere seconds. Radioactive waste disposal is another example of the use of radioactive half-life knowledge in creating estimates that ensure proper handling and disposal of this waste. As illustrated in the chart above, Uranium-238 can eventually decay into Lead-206 which is non-radioactive. It takes an estimated several hundred thousand years for U-238 to decay into a stable non-radioactive isotope. However, keep in mind we used U-238 as an example of a decay chain in this segment. Other radioactive isotopes of Uranium and Plutonium are used in nuclear energy and weapons production that have different half-life cycles and decay chains. What does not change is that this process of decaying into a stable element can take a long time and pose many challenges for radioactive waste disposal.
Appendix D
IONIZING RADIATION
(radiation delivered to human cells from beta rays, x-rays, gamma rays or alpha particles)

THYROID
Iodine-131 beta (gamma), 8 days

SKIN
Sulfur-35 beta, 87 days

LIVER
Cobalt-60 beta (gamma), 5 yrs.

OVARIES
Iodine-131 gamma, 8 days
Cobalt-60 gamma, 5 yrs.
Krypton-85 gamma, 10 yrs.
Potassium-42 gamma, 12 hours
Cesium-137 gamma, 30 yrs.
Plutonium-239 alpha, 24,000 yrs.

ON THE REPRODUCTIVE ORGANS ARE ATTACKED BY ALL RADIOACTIVE ISOTOPES EMISSING GAMMA RADIATION. IN ADDITION, THE DEADLY PLUTONIUM-239 IS KNOWN TO CONCENTRATE IN THE GONADS. THE RADIATION IT EMITS CAN CAUSE BIRTH DEFECTS, MUTATIONS AND MISCARRIAGES IN THE FIRST GENERATION AFTER EXPOSURE AND/OR SUCCESSIVE GENERATIONS.

MUSCLE
Potassium-42 beta (gamma), 12 hours
Cesium-137 (and gonads) beta (gamma), 30 yrs.

The times listed next to the type of ray emitted are the half-lives: how long it takes for half of the radioactive material to break down.

If you ingest alpha and beta emitters, they set up permanently next to the marrow of your bones, in your reproductive organs or elsewhere.

The effects of ionizing radiation are not immediate. Exposure to radiation can cause cancers many years later. Exposure to very low levels of radiation can be equally dangerous over time.
DECONTAMINATION FOR YOURSELF AND OTHERS

1. TAKE OFF OUTER LAYER OF CLOTHING
   - Taking off your outer layer of clothing can remove up to 90% of radioactive material.
   - Put the clothing in a plastic bag or other sealable container.
   - Be very careful in removing your clothing to prevent radioactive dust from shaking loose.
   - Put the bag in an out-of-the-way place, away from other people and pets.

2. WASH YOURSELF OFF
   If you can take a shower:
   - Use soap and shampoo. Do not use conditioner because it will cause radioactive material to stick to your hair.
   - Do not scald, scrub, or scratch your skin.
   - Keep cuts and scrapes covered when washing to keep from getting radioactive material in open wounds.

   If you cannot take a shower:
   - Wash your hands, face, and parts of your body that were uncovered at a sink or faucet.
   - Use soap and plenty of water.
   - If you cannot use a sink or faucet:
     - Use a moist wipe, clean wet cloth, or damp paper towel to wipe the parts of your body that were uncovered.
     - Pay special attention to your hands and face.
     - Blow your nose and wipe your eyelids, eyelashes, and ears with a moist wipe, clean wet cloth, or damp paper towel.

3. PUT ON CLEAN CLOTHES
   If you have clean clothes:
   - Clothes stored in a closet or drawer away from radioactive material are safe to wear.
   - Take off your outer layer of clothing, shake or brush off your clothes, and put your clothes back on.

   If you do not have clean clothes:
   - Rewash your hands, face, and exposed skin at a sink or faucet.

4. HELP OTHERS AND PETS
   - Wear waterproof gloves and a dust mask if you can.
   - Keep cuts and scrapes covered when washing to keep radioactive material out of the wound.

   Rewash your hands, face, and parts of your body that were uncovered at a sink or faucet.

STAY TUNED FOR UPDATED INFORMATION FROM PUBLIC HEALTH OFFICIALS.

http://emergency.cdc.gov/radiation
RADIATION CONTAMINATION VERSUS EXPOSURE

EXTERNAL CONTAMINATION

External contamination occurs when radioactive material comes into contact with a person’s skin, hair, or clothing.

RADIOACTIVE MATERIAL

IN THE AIR SOLID LIQUID

INTERNAL CONTAMINATION

Internal contamination can occur when radioactive material is swallowed or breathed in.

Internal contamination can also occur when radioactive material enters the body through an open wound.

Different radioactive materials can accumulate in different body organs.

RADIATION EXPOSURE

Another word for radiation exposure is irradiation.

Radioactive materials give off a form of energy that travels in waves or particles.

A person exposed to radiation is not necessarily contaminated with radioactive material.

For a person to be contaminated, radioactive material must be on or inside of his or her body.

When a person has an x-ray, he or she is exposed to radiation but is not contaminated.

When a person is exposed to certain types of radiation, the energy may penetrate the body.

http://emergency.cdc.gov/radiation
Appendix E
1971 - 1997
Cassini Diamond Medallion, USA

DEEP TIME EQUALS DEEP SPACE

DEEP TIME

First Ten Digits in Binary Code

1u = 1 unit,
We are thinking in lengths and units.

Would they see the same mathematical underpinning to our universe?

Golden Section, Radial Symmetry in nature

Math as non-verbal communication, it allows us to describe 'things' accurately without even knowing what they are.

Would they understand 2D / 3D?

6 Axis View of Earth, cloud-free, consistent lighting maps - continental drift dating

6 Axis View of Cassini Spaceship

Hi-Res Image of Saturn

Gallery of Previous Spacecrafts, Earth has no spaceship suggesting that it is our home

Solar System showing Planets, Symbols and Cassini/Huygens Trajector

Photos of Big Dipper, M51 and Hercules Cluster as Astronomical Time Markers

small

large

This is who we are.

Figure 2.6: Astronomical mile of the Cassini Huygens Design. January 1997-February 1999 of the Earth

Figure 2.7: Symbolic mile of the Cassini Huygens Design. December 1997-February 1999
The Cassini Portrait of Humanity, 1997, Courtesy by Simon Bell and Jon Lomberg
Appendix F
Talking to the Future - about radioactivity

First traces of radioactivity, 1896, Henri Becquerel

Research
filter: SCIENCE / RADIOACTIVITY

1895
Wilhelm Roentgen: Discovery of X-Rays, GER

1896
Antoine H. Bequerel: First Trace of Radioactivity, FRA

1898
Pierre and Marie Curie: Discovery of Radium, ‘Radioactivity’, FRA

1917
Ernest Rutherford, Father of Nuclear Physics: First Splitted Atom in a Nuclear Reaction, UK

16.07.1945
First Detonation of a Nuclear Weapon, USA

1945
First Detonation of a Nuclear Weapon, USA

06./09.1945
Hiroshima Bombings, JPN

10.12.1961
Project Gnome, Project Plowshare

1951
C. F. V. D. Natuurkundig Genootschap: The Smiling Sun, DK

1960's
The Golden Years of Nuclear Development, USA

20.12.1951
First Electricity Production by Nuclear Energy Experimental Breeder Reactor EBR-I, Arco, Idaho, USA

1963
Project Orion, Nuclear Propulsion

11.03.2011
Fukushima Disaster, JPN

2011
Waste-Annihilating Molten Salt Reactor, MIT, USA

2014
NGR plans Country's First Nuclear Power Plant

2015
Scientists can Unboil Eggs, Untangling Proteins, Cancer Antibodies

1970's / 1999
FIN and USA plan Underground Spent Fuel Repositories

1975
The Smiling Sun, DK

1960 - 1963
Project Orion, Nuclear Propulsion

06.07.1962
Sedan Crator Project Plowshare

10.12.1961
Project Gnome, Project Plowshare

2014
RIO: 439 (USA, FRA, JPN) RUC: 69 (CHN, RUS, IND)

2015
Onkalo, FIN
40,800 years ago
Australian Dreamtime

40,000 years ago
Australian Petroglyphs, South Australia

45,000 years ago
Agriculture

3500 BC
Watson Brake Mounds, Louisiana, USA

3000 BC
Stonehenge, ENG

2686 - 2181 BC
Old Kingdom
Giza Necropolis: Pyramid of Cheops, the Sphinx, King Tut-Ankh-Amun, priesthood

2000 BC
Islamic Tradition: Abraham builds Kaaba Mecca

800 BC
Homer: Odyssey, Iliad, first known literature of Europe

753 BC
Rome was founded, Romulus and Remus

737 BC
Abraham builds Kaaba Mecca

206 BC
The Great Wall, China (Qin Dynasty)

221 BC
Terracotta Warriors, Qin Shi Huang (Qin Dynasty)

520 BC
Buddhism, Northeastern India

600-500 BC
Confucianism, China

535 BC
Acropolis, Athens, GRE

555 BC
Buddhism, Northeastern India

668 - 627 BC
Library of Ashurbanipal, King of Babylonia, cuneiformed scripts

776 BC
Olympia, Olympian Games

200 BC
Imperial China

3000 BC
Stonehenge, ENG

785 BC
Imperial China

2900 BC
Ancient India

399 BC
Ancient Greece

411 BC
Ancient China

2000 BC
Islamic Tradition:

466 BC
Ancient Greece

489 BC
Ancient Rome

700 BC
Ancient Mesopotamia

535 BC
Buddhism, Northeastern India

3700 BC
Ancient Mesopotamia

2686 - 2181 BC
Old Kingdom
Giza Necropolis: Pyramid of Cheops, the Sphinx, King Tut-Ankh-Amun, priesthood

600-500 BC
Confucianism, China

520 BC
Buddhism, Northeastern India

535 BC
Buddhism, Northeastern India

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Stonehenge, ENG

3000 BC
Stonehenge, ENG

800 BC
Homer: Odyssey, Iliad, first known literature of Europe

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Rome was founded, Romulus and Remus

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filter: CULTURE. RELIGION. CIVILIZATION. AD.

RITUALS: WORD AND ACTION

15th Century Printing Revolution

1406 - 1420 Forbidden City, Beijing, World's Largest Palace Complex, Ming Dynasty

1438 - 1471 Machu Picchu, The Lost City of the Inca, Peru

1517 Protestant Reformation

1517 95 Theses, Martin Luther

1871 Heinrich Schliemann begins excavation of Troy

1912 Discovery of Nefertiti Bust (1370–ca.1330 BC) by Ludwig Borchardt

1940 The Crypt of Civilization, not to be opened until 8113, Oglethorpe University, Brookhaven, GA, USA

1929 Vatican was founded

1960's Abu Simbel is dismantled and moved due to Aswan High Dam

1970 EXPO, Osaka, Japan, Time Capsule 5,000 years

1986 Burning Man, Black Rock Desert, Nevada, USA, Celtic Ritual

1992 World's Fair Sevilla, Time Capsule, everyone can contribute

2009 Keo Time Capsule, www.keo.org, will return to Earth 50,000 years later

2012 Olympic Games, Rio de Janerio, Brasilia

2016 Mars One Project

0 - CHRISTIANITY

570. ISLAM - Muhammad was born in Mecca

400 MEDIEVAL EUROPE

500 AFRICAN KINGDOMS

1377 Printing Press, Johannes Gutenberg

1438 - 1471 Printing Revolution

1517 PROTESTANT REFORMATION

1517 95 Theses, Martin Luther

1871 Heinrich Schliemann begins excavation of Troy

1912 Discovery of Nefertiti Bust (1370–ca.1330 BC) by Ludwig Borchardt

2012 Industrial Revolution - Anthropocene

2016 Digital Revolution
Remains of the past attract us.
We want to connect to the past, make sense of it.
We don't leave it alone, we move it and interact in it.
Human Needs and Desires, Emotional Response, Human Memory, Sense Making, Action and Reaction, Semiotics, Evolutionary Legacy and Predispositions, Ambiguity and Lack of Rationality, Appreciation for Beauty and Simplicity (Symmetry, Golden Section, Maths, Cognitive Universals, 2D/3D)
Appendix G
Ideation Overview

**emotional**
- Anthropomorphisation
- Contextualisation
- Pregnancy Test
  - Affordance
  - Senses
  - Human Nature
  - Bodily Reactions

**pragmatic**
- Consumerism
- Living with Onkalo
  - Wardrobe
  - Lamp
  - Wallpaper
  - Wrapping Paper
  - Temporary Teeth Repository

**public**
- Manifestation (dynamic, static)
- Monuments, Memorials, Markers
- Rituals
- Maps
- Useless Tools

**private**
- Distraction
- Anticipation
- Outsourcing
- Hyperobjects

**law**
- Learning from Nature / Bio-Hacking
  - Making the Invisible Visible
  - Digital Presence
- Education
Appendix H
**Products of the week**

**Onkalo Lamp**
SEK 499
Table lamp features a dimmable slider switch that sets the mood to anything from bright light to soft glow. It got its slim and stylish shape from the Onkalo tunnel in Finland which leads to the first permanent underground repository for spent nuclear fuel which remains radioactive for at least 100,000 years.
Cord Length: 80cm
Design life: about 40,000 hours
Dimensions:

**Onkalo Wrapping Paper**
SEK 29
Made from recycled paper.
Dimensions: 1x20m

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**Our Top Products**

**0.5 Gel Ink Pens**
SEK 10

**Radiation Water Filter**
SEK 399

**Lined A4 Kraft Notebook**
SEK 20

**Acrylic Box - 5 Drawers**
SEK 249

**Food Supplement**
Potassium Iodide (KI)
SEK 35

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**Our Newest Products**

**Lined A4 Kraft Notebook**
SEK 20

**Acrylic Box - 5 Drawers**
SEK 249
Appendix I
A WHOLE EARTH CATALOGUE initiative

the new neighbour

welcoming nuclear waste in your area.

Vol.1 #1

Eurajoki, Finland

Dear Reader,

the problem of final disposal of nuclear waste is finally solved. Nuclear waste will be stored in deep geological repositories, such as Onkalo, the first underground repository for spent nuclear fuel in Finland. Living close to such a repository calls for a rethinking in daily life, as there are risks and challenges. Our aim is to provide communities like Eurajoki, who are in close proximity to a repository with the fundamental things they need to live a modern lifestyle while being aware of radiation and contamination risks.

This initiative aims at establishing an understanding of nuclear waste as the byproduct of clean energy, facilitating the integration of nuclear waste in our ecosystem and lifestyle, and preparing for risks and challenges. The new neighbour addresses and supports communities nearby nuclear waste repositories through products and events, welcoming the new neighbour in their area.

Stay tuned - We might be coming to your community soon!

The new neighbour Team
Welcome to 27100 Eurajoki, Fin-

Hello nuclear waste. Hello Onkalo.

The Onkalo spent nuclear fuel repository is a deep geological repository for the final disposal of spent nuclear fuel, the first such repository in the world. It is currently under construction at the Olkiluoto Nuclear Power Plant in the municipality of Eurajoki, on the west coast of Finland, by the company Posiva.

The encapsulation and burial of areas filled with spent fuel is projected to begin around 2020. The Onkalo repository is expected to be large enough to accept canisters of spent fuel for around one hundred years, i.e. until around 2120. At this point, the final encapsulation and burial will take place, and the access tunnel will be backfilled and sealed. The buried waste is said to remain radioactive for another 100,000 years.

The process of selecting appropriate deep final repositories is now under way in several countries. The Onkalo site in Finland is the furthest along the road to becoming operational. Sweden is also well advanced with plans for direct disposal of spent fuel, as its Parliament has decided that this is acceptably safe, using the KBS-3 technology.
Invest in a good neighbourship. Get your Onkalo Welcome Package now.

99,99 EUR excl. shipping

order NOW:
www.thenewneighbour.org/Onkalo

The Onkalo Welcome Package includes:

**Onkalo Lamp.**
Table Lamp that helps you getting familiar with the new neighbour. The switch represents your new relationship.

**Pregnancy Test.**
Know what is going on in your body. This test measures the human chorionic gonadotropin levels as well as your millisievert and ram values.

**Food Supplement.**
Better safe than sorry - Potassium Iodide (KI), limits your daily take in of radioiodine. Now with new formula and less side effects.

**Radiation Water Filter Units.**
Are you sick of the ongoing discussions about potential ground water contamination? No need to bother anymore. Filter tap water comfortably and use the filter units to teach your children how to deal with nuclear waste on a daily basis.
Coming Soon:

- Temporarily buried nuclear waste
- Final Repositories planned/under construction

Get in touch

Different countries handle nuclear waste differently, different communities need different things.

You have heard about repository plans in your area?
Contact us now and help us meet your needs by customizing the Welcome Package for your community!

Contact us:
www.thenewneighbour.com/contact
Appendix J
The Onkalo Pregnancy Test does not only tell you whether you are pregnant or not, but also how much radiation you carry inside you.

What if small filter units would absorb potential traces of radiation from our tap water and grow into waste marbles? This homegrown nuclear waste could be used as a tool to introduce children to nuclear waste. The marbles would be stored in the Onkalo-shaped piggy bank and could be traded for favours and worthwhile actions as the piggy bank fills up quickly.

The lamp is a literal representation of the repository. It operates on the time scale of 100,000 years. It is switched on in 2015, and gradually fades out as the switch is moved to the year 202015.

How long are 100,000 years?

What if it was our children’s responsibility to handle nuclear waste?

How can design help us to understand Onkalo, the first final disposal repository for nuclear waste?

Henrike Feckenstedt
Germany
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henrikefeckenstedt.com

Master Degree Project
Interaction Design