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Monitored this issue:

Ten years ago the east coast of Japan was hit by a sever earthquake, followed by a tsunami. It led to thousands of casualties and destroyed cities and villages. Both earthquake and tsunami hit the Fukushima Daiichi nuclear power plant. In this issue of the Nuclear Monitor we not only look back at the events but, together with staff members of CNIC, the Japanese Citizen's Nuclear Information Centre look at the present status. The accident is certainly not 'over' yet and has continuing impact.

Fukushima Now Part 1: Human Time, Time of Radioactivity

Yamaguchi Yukio, CNIC Co-Director

Very soon now, ten years will have passed since the Great Eastern Japan Earthquake and the Fukushima nuclear catastrophe.

Some aspects of the "recovery" from the hard infrastructure damage, such as that to houses, roads and seawalls, brought about by the massive earthquake and tsunami has indeed moved forward somewhat with time. According to a questionnaire survey conducted by Kyodo News in November 2020, the percentage of responses saying that the recovery was "advancing satisfactorily" were 80% in Miyagi Prefecture, 66% in Iwate Prefecture and 30% in Fukushima Prefecture. In Fukushima Prefecture, the percentage of "not satisfactorily" was 41% and that of "on balance, not satisfactorily" was 29%. This is probably because from the viewpoint of the impacts due to radioactivity, ten years is nothing but an instant in time.

The "State of Emergency Declaration" issued on March 11, 2011 has continued to this day, and it looks as if it will continue for a long time to come. Now a second "State of Emergency Declaration" has been issued for the COVID-19 coronavirus, and the people of the region are living under two states of emergency at the same time.

How did the Fukushima accident occur and how did it develop into meltdowns? Unit 1 was discussed by the Niigata Prefecture Technical Committee, but there are many points that are as yet unclear. A suspicion that the sealing around the upper lid of the nuclear reactor distorted due to the high temperature of the heat of radiation, leading to large amounts of radioactive materials leaking into the environment, was pointed out. Also possibly related to this was that during the later investigation by the Nuclear Regulation Authority, extremely high concentrations of contamination were found on the shield plugs of Units 2 and 3.

What about the distribution of radioactive nuclides that fell on the Japanese archipelago? How much of the insoluble cesium particles, which has a huge effect on internal exposure, have been incorporated into human bodies? What process preceded the explosion of Unit 3? Even though ten years have passed there is just so much that we do not yet understand. This is because the level of radioactivity is too high to allow onsite examinations to verify inferences and hypotheses. Some insist that if only protection from the tsunami had been possible, but the

This shrine in Futaba Town, Fukushima, collapsed in the earthquake ten years ago but no one has been able to repair it as it is in the 'hard-to-return zone' where radiation levels are still high and restrictions apply. Recovery seems impossible even for gods.

A reading of 8.790 µSV/h (Tokyo is typically around 0.05µSV/h) in front of a sign declaring the road is closed due to 'Hard-to-Return Zone' restrictions (Futaba Town, 16 January 2021)

impact assessment of the earthquake itself does nothing to efface the doubt that it was as severe as or more severe than the tsunami. But it is still not possible to provide actual proof of this.

Not only the coverup of problems in 2002, TEPCO has a scandalous history of forged or falsified inspection data. There is undisclosed data concerning the nuclear catastrophe, and this is proving to be a hindrance to uncovering the facts. Which materials are of importance? It seems that TEPCO itself is unable to make a judgement on some of the material. They claim company confidentiality, but the psychology of tending to hide inconvenient data is also probably at work. According to Tanaka Mitsuhiko, who was a member of the National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission and who later served as a core member for one of the six issue themes for the Fukushima accident examination as a member of the Niigata Prefecture Technical Committee, even if public discussions are held, since TEPCO does not show calculation sheets or blueprints, there is very little option but to hold closed-door discussions (see article by Tanaka Mitsuhiko in **NIT 197**).

When nuclear power was just getting started in Japan young researchers were strongly opposed to the idea due to the experiences of Hiroshima and Nagasaki. The Science Council of Japan issued a declaration stating "disclosure, autonomy and democracy" as the three principles of nuclear power, and these principles were incorporated in the Atomic Energy Basic Act. However, the three principles were disdained and ignored from a very early stage. Thinking about it now, the three principles were basically unrealistic. All kinds of excuses were given for hiding information, such as company confidentiality or claiming that the information belonged to the more enigmatic points of nuclear technology, and they were all too easily accepted. The community of interest known as the "nuclear power village," which would not pay the least attention to dissenting opinions or counterarguments, was formed, and the fact that it was able to totally control nuclear power stations is in outright opposition to the three principles.

The land, 1.4 times the area of Osaka City, that is designated as Fukushima Prefecture's hard-to-return zone is termed "blank land." It is land to which the residents cannot return far into the future. The half-lives of different nuclides are of various lengths, but that of the largest amount of radioactivity that was released to the environment during the Fukushima nuclear catastrophe, cesium-137, is around 30 years, meaning that in 300 years it will have finally fallen to one-thousandth of its original value. For the ashes of death that are spewed from nuclear power stations to lose their potency we must wait for ages measured in tens of thousands of years.

Fukushima Now Part 2: Current State of Post-Accident Operations at Fukushima Daiichi Nuclear Power Station

By Matsukubo Hajime

State of the Plant

The water temperature in the containment vessels and the spent fuel pools (SFPs) varies mostly around less than 35°C and no great changes have been seen. The state of releases of Xenon-135 (half-life roughly nine hours), released when uranium fuel undergoes fission is also unchanged and it can therefore be estimated that the state of the reactors is stable. Further, according to an assessment by TEPCO in November 2020, around 24,000 becquerels per hour (Bq/h) of radioactive materials were being released to the air from the buildings (Fig.1).

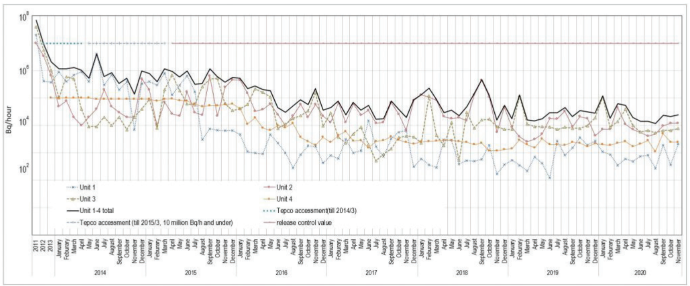


Fig. 1. Radioactivity from Units 1 to 4 of Fukushima Daiichi Nuclear Power Station (Bq/h) released to the air

At the same time, decay heat has fallen greatly with the passage of time, and thus the volume of cooling water injected into the reactors has been reduced (falling from 7-10m³ per hour in May 2011 to 1.3-1.5m³ per hour in December 2020).

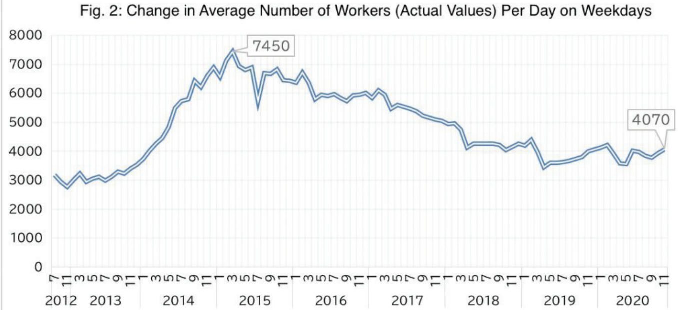
The state of removal of spent nuclear fuel from the SFPs is summarized in Table 1. Spent nuclear fuel removal from Unit 4 has been completed. While multiple problems have been experienced with the equipment (fuel handling equipment crane and fuel-handling machine) for removal of spent fuel from Unit 3, removal began on April 15, 2019. (It was originally set to begin around mid-FY2018.) Delays have occurred in the work, which is now ongoing on a 24-hour basis with a view to completion of the spent fuel removal by the end of fiscal year 2020 (i.e. March 2021).

Table 1 State of Spent Fuel Pool Cleanup

Unit	Overview
Unit 1	The plan is to install a large cover and then carry out the removal of debris and fuel extraction inside the cover. Removal of the remains of the originally installed building cover began in December and is due to be completed in June 2021. It is expected that spent fuel removal will begin in fiscal years 2027-28.
Unit 2	Work on the removal of objects remaining on the operating floor has been carried out. The containers into which the remaining objects were loaded were transferred out of the site from August to December. The original plan was to totally dismantle the upper part of the operating floor to extract the nuclear fuel, but as the radiation dose on the floor is showing a decline, the method has been altered to the installation of an access gantry on the south side of the floor.
Unit 3	Frequent problems with the fuel-handling machine. Fuel removal began on April 15, but with frequent interruptions. As of December 24, 2020, of 566 fuel assemblies [of which 514 are spent fuel and 52 are fresh fuel] 441 had been removed. The schedule called for removal of the fuel to be completed during FY2020, but there are 18 assemblies for which problems such as deformed handles have to be dealt with, and of these there are three assemblies for which separate handling methods will be necessary in order to lift them out of the pool.
Unit 4	Completed (December 22, 2014)

In a Nuclear Regulation Authority (NRA) review meeting related to analysis of the accident at TEPCO's Fukushima Daiichi Nuclear Power Station (FDNPS) in June 2020, extremely high dose rates were reported in the vicinity of the shield plugs, the upper lids of the nuclear reactor containment vessels, of Units 2 and 3. Regarding this issue, the draft interim summary, reported at the December review meeting, estimated that of the total of cesium-137 in Units 1-3, 71 × 10^{16} Bq, 1.5 × 10^{16} Bq had been released to the atmosphere, 43 × 10^{16} Bq had transferred to contaminated water, and of the remaining 26.5 × 10^{16} Bq, that affixed to the lower surface of the shield plug was 100-200 × 10^{12} (trillion) Bq in Unit 1, 4-7 × 10^{16} Bq in Unit 2 and 3 × 10^{16} Bq in Unit 3. The reason for the amount of affixed cesium-137 being small in Unit 1 was thought to be that the substance had leaked out onto the operating floor, the fifth floor of the building, due to deformation of the shield plug. The dose rate is extremely high and will have a great impact on the forthcoming decommissioning work.

Fig. 2: Change in Average Number of Workers (Actual Values) Per Day on Weekdays



Changes in the number of workers per day are shown in Fig. 2. As of November 2020, the number was 4,070. The changes in the number of cases of work non-conformance are shown in Fig.3, as reported on the TEPCO website. As ever, problems appear to occur frequently, and this attests to the severe conditions under which work is being carried out at the site.

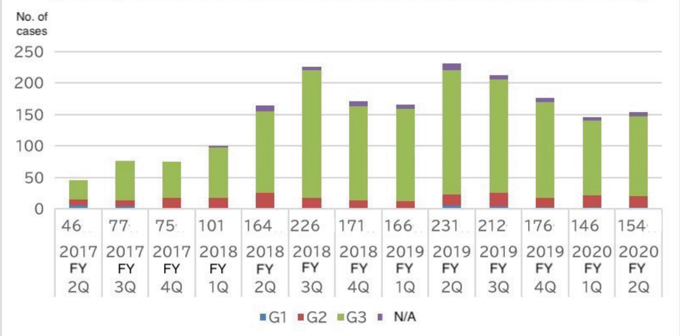


Fig. 3: Change in No. of Cases of Non-conformance Discussed at Performance Improvement Meetings

State of Contaminated Water

Contaminated water countermeasures at FDNPS can be broadly divided into three areas: 1) Reduction of groundwater flowing into buildings, 2) Reduction of contaminated water flowing into the sea, and 3) Reduction of the toxicity of contaminated water. Regarding the reduction of water volumes flowing into buildings, the main countermeasures are, from higher elevations downward, A) Pumping up groundwater at the groundwater bypass and releasing it into the sea (607,063m^3 up to December 23, 2020), B) Installation of a frozen earth barrier (on-land water barrier, total length roughly 1,500m) surrounding FDNPS Units 1-4. C) Pumping up water at the subdrains and releasing it into the sea (1,029,129m^3 up to December 22, 2020), and D) Paving of the site with asphalt to suppress permeation of rainwater into the soil. Regarding reduction of contaminated water flowing into the sea, the countermeasures being taken include A) Groundwater leakage prevention by a steel water barrier on the sea side, B) Pumping up of groundwater dammed up behind the sea-side water barrier from the well points and groundwater drains (roughly 256,868m^3 up to December 23; as this groundwater is highly contaminated, it is being transferred to the turbine building), and other measures.

Regarding the reduction of the toxicity of contaminated water, after removal of cesium and strontium and removal of impurities using reverse osmosis (RO), radionuclides other than tritium are removed by the multi-radionuclide removal equipment (ALPS – Advanced Liquid Processing System) and then stored in tanks (containing 1,216,512m^3 as of December 17. However, due to past equipment malfunctions and operational policies, in many cases radionuclides other than tritium are present, resulting in only around 27% of the stored water being below the notification concentration). Besides this, water remaining in buildings is roughly 12,190m^3, strontium-treated water, etc. is 23,725m^3, water treated by RO is 8,310m^3, concentrated brine is 300m^3, concentrated wastewater is 9,311m^3, etc.

The target for the mid-term roadmap was that water remaining in buildings, except for a) reactor buildings of Units 1-3, into which cooling water is being injected and circulated, b) the main processing building, in which there are high dose rate zeolite sandbags, and c) the high-temperature incinerator building, would be processed by the end of 2020. This target was attained on December 24. At the same time, exposure of the floor surfaces was achieved, but it proved impossible to confirm the locations from which groundwater was flowing into the buildings. In other words, it is strongly suggested that groundwater is flowing into the buildings where contaminated water exists.

Concerning contaminated water following ALPS treatment, the government is continuing to take the stance of ocean release. On November 27, the Minister of Economy, Trade and Industry, Hiroshi Kajiyama, stated, “We cannot postpone a decision on the policy forever,” while also mentioning that “It is imperative to consider the necessity of constructing tanks in light of the disposal method.” Further, on December 11, TEPCO completed the installation of the final group of tanks. TEPCO has no further land on which to increase the number of tanks and says that the tanks will be full by summer 2022. However, on December 18, the Kahoku Newspaper reported that, as a result of a careful investigation of TEPCO materials, there was sufficient land to increase the installation of tanks to store 56,700 tons of treated water, roughly the amount treated in one year.

Fukushima Daiichi Nuclear Power Station Accident List (August to December 2020)

(Excerpts from reports of problems in the NUClear Information Archives (NUCIA))

Date	Location	Summary of Accident	R/C
Aug. 14	Units 5 & 6 Retained Water Storage Facility Purification Unit	Water was found to be leaking from the flange of C pipe on the Units 5 & 6 Retained Water Storage Facility Purification Unit. No external impact.	
Sep. 1	Unit 3 Waste Materials Underground Storage Building	In the Unit 3 Waste Materials Underground Storage Building, waste liquid was found to be leaking into the building from a pipe connected to the tank. There was no external impact, but the accumulated water was transferred to the Unit 3 Waste Materials Treatment Building.	

Fukushima Daiichi: Contaminated water should not be dumped in the ocean and radioactive debris should not be removed without debate on the end state

By Ban Hideyuki, CNIC Co-Director

Decommissioning work is underway at the Fukushima Daiichi Nuclear Power Station (below, FDNPS), with Fukushima Prefecture requesting that the site be rendered radiation-free vacant land 30 to 40 years after the nuclear accident. On the other hand, while the Mid-and-Long-Term Roadmap is supposedly in accordance with this, how the decommissioning is to be handled after the buildings are demolished remains unclear.

As if casting a stone at these circumstances, the Atomic Energy Society of Japan (AESJ) published a report last year titled "Waste Management from the Point of View of International Standards" (published in July 2020 by their review committee for the nuclear decommissioning of the FDNPS). The report held that in proceeding with decommissioning, establishing the final conditions for the nuclear plant's former site beforehand (expressed as the "end state") was important and was intimately related to the resolution of various issues connected with the decommissioning and the future image of Fukushima's recovery. It was intended to serve as an impetus for deepening discussion among the stakeholders.

In addition, the report estimated the amounts of radioactive wastes to be generated by the FDNPS decommissioning. In this issue, we would like to introduce the contents of the report, including those estimates.

Estimated Amounts of Radioactive Waste Generated by the FDNPS Decommissioning

The report gave its estimates in the form of a table (see Table 1 below), at this point in terms of tonnage. No explanation has been provided on the categories, but what I would like readers to note are the clearance levels estimated for normal nuclear reactors, and the lack of a category for non-radioactive wastes. Filters and adsorption towers from the Advanced Liquid Processing System (ALPS), along with base-isolated buildings, office buildings and other structures, and also trees and other wastes generated, have been exposed to radioactivity and are contaminated by it, so this is to be expected. The severity of contamination is expressed well. What's at issue in this report is how the ideas behind the categorization of the wastes that are not radioactive wastes specific to the FDNPS have been organized. It is an issue, but relaxation of standards in order to reduce the amount of wastes generated would be inappropriate.

Note that in Japan, spent fuel is considered to have value and is not defined as a "waste," so fuel debris would *pro forma* not be included, but it is nonetheless included from the standpoint of realistic thinking.

Four Scenarios of the End State Debate

The basic policy for decommissioning measures will be one of the following three: 1) immediate dismantling, 2) deferred dismantling and 3) long-term preservation.

Immediate dismantling is the policy Japan's nuclear power plant operators have adopted. They have established a safe storage period of about ten years before dismantling heavily contaminated nuclear reactors, but proceed in the meantime with dismantling of peripheral facilities and equipment. Deferred dismantling is said to be the policy adopted by the UK. Their policy is to preserve the plant for 80 to 100 years and then dismantle it. The sarcophagus method employed at Chernobyl can be considered an example. Long-term preservation is a policy of not dismantling the plant, but waiting for the radioactivity to subside. Long-term preservation has been excluded from consideration in establishing the scenarios. Note that deferred dismantling is expressed as "safe storage" in the scenarios.

Meanwhile, two patterns have been established as assumptions for the "end state": 1) a state in which the contaminants affecting the equipment and structures and the polluted soil and groundwater have all been eliminated (below, "complete removal"), and 2) a state in which part of the contaminants affecting the equipment and structures and/or some of the polluted soil and groundwater are stored and monitored (below, "partial removal"). The combinations of these produce the four scenarios, as follows.

1. Immediate dismantling with complete removal: All of the equipment, buildings, etc. are dismantled and the entire area within the site is restored. All radioactive wastes generated are transported away from the site. The site is freed up for unlimited use.
2. Immediate dismantling with partial removal: The above-ground portions of equipment and buildings are dismantled and removed. The site is partially restored. Underground structures are left as they are and continue to be supervised. Part of the contaminated soil, groundwater, etc. is treated and removed. The radioactive wastes generated are kept in an on-site storage area until they can be transported to processing facilities. Note that the radioactive materials remaining continue to be supervised and monitored. The site is freed for use with limitations.

3. Safe storage with complete removal: After a defined safe storage period, all of the equipment, buildings, etc. are dismantled and the entire area within the site is restored. All radioactive wastes generated are kept in an on-site storage area as long as needed, then transported away once processing facilities have been secured. The site is freed up for unlimited use.
4. Safe storage with partial removal: Dismantling is performed after a defined safe storage period. Details on the dismantling and wastes targeted are as in 2) above. The site is freed for use with limitations.

Scenario Time Bases

In each of the above scenarios, once decontamination and dismantling of the facilities and buildings has been accomplished, the site is to be restored, i.e., the soil, groundwater, etc. are to be treated, and freed up for use. Thus the time base in the case of immediate dismantling is 30 years for decontamination and dismantling (following the Roadmap), with completion of site restoration set at 100 years. In the case of safe storage, the period until completion of decommissioning is 100 years. The period of continued supervision and monitoring of the radioactive wastes is 300 years. The longer the safe storage period, the more the radioactive substances decay, reducing the amount of radioactive wastes needing treatment and disposal.

If Debris Removal Proves Difficult

Retrieval of the fuel debris is postponed for one year from early 2021. TEPCO announced that equipment being made in the UK is not completed yet because of COVID-19. First, a small amount will be retrieved and its properties will be ascertained. During the meltdown, the molten fuel reacted with the concrete below it, and corium as hard as rock is also present. The equipment to retrieve this has yet to be designed and produced, so an investigation to determine what kinds of debris and corium are present is necessary. Such an investigation, however, is impossible. The intense radiation creates various obstacles, such as preventing wireless transmission, damaging integrated circuitry and degrading lenses, making it impossible to view what's inside. Thus this equipment is still under development. That it would be possible to retrieve the fuel debris within the time frame of the current Roadmap is utterly inconceivable.

Seen this way, the only likely scenarios are necessarily 3) and 4), in which "safe storage" is adopted.

Table 1. Example of estimated amounts of radioactive wastes that will be generated by the decommissioning of the FDNPS and the site's restoration[20] (tons).

Category	Reactors 1-6	Other facilities	Water treatment facilities	Waste treatment and storage facilities	Site restoration	Total
Fuel debris	644	0	0	0	0	644
HLW	2,042	0	0	0	83	2,125
TRU	0	0	16	0	830	846
L1	100,135	104,543	310	1,050	76,030	282,068
L2	429,462	329,364	38,174	200	1,424,600	2,221,800
L3	951,309	2,825,634	151,320	26,325	1,375,000	5,329,588
Totals	1,483,592	3,259,541	189,820	27,575	2,876,543	7,837,071

HLW: Items included under high-level radioactive waste, TRU: Items included under transuranic waste, L1: Waste items with relatively high levels of radioactivity, L2: Waste items with relatively low levels of radioactivity, L3: Waste items with extremely low levels of radioactivity

At What Point is Decommissioning Complete?

"Hairo" (reactor dismantling) is the general term used by the public in Japan, but legally, a different expression that translates as "discontinuance measures" is used. These measures differ from the normal in the case of the FDNPS, so the report uses the term *"hairo."* In any case, there are four conditions with a total of 121 articles defining completion of "discontinuance measures" under "Regulations on the installation, operation, etc. of nuclear reactors for practical power generation": 1) completion of the transference of nuclear fuel substances, 2) elimination of radioactivity from the site's soil and remaining facilities (to or below standard levels), 3) completion of the disposal of radioactive wastes and 4) completion of the handing over of radiation management records.

It will probably be impossible to meet all of these conditions at FDNPS. Particularly condition 3) will be impossible. This is because there will probably be no municipalities willing to receive the radioactive waste. FDNPS is essentially a radioactive waste management facility, and it may wind up continuing to monitor the waste for several hundred years.

What Lessons Can We Learn for the Future?

The report makes the assumption that the contaminated water will be disposed of, but in the case of continued "safe storage," we are forced to assume that it will be released into the ocean. As fisheries organizations and many municipalities nationwide are opposed to such releases, however, the government is unable to make the decision for oceanic release. Progress in discussions about the "end state" is required prior to oceanic release.

Sustainable investment in Doel 5

Marc Alexander, 11 march movement

The last nuclear reactors in Belgium will be closed in 2025. That is how it is planned in the law on nuclear exit. Doel 4 will then stop producing. But what about the employees of Doel? Is there no perspective for the Doel site itself? Will the site become an industrial graveyard, resulting in severe job losses and social drama? Or are other developments possible?

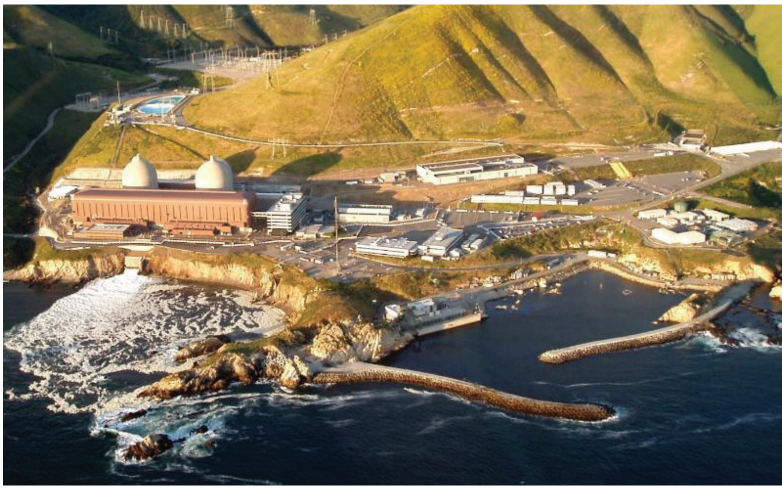


Foto: https://commons.wikimedia.org/wiki/File:Diablo_canyon_nuclear_power_plant.jpg#metadata
The Diablo Canyon nuclear power plant in California, where management, unions, governments and civil society organizations reached an agreement. As a result, this nuclear power plant will close in 2025 without an extension. It is being transformed into a company with renewable activities and energy services. Nuclear power plant personnel are trained for remaining and new tasks.

Employees of Doel deserve a safe and sustainable future

About 1,000 employees currently work at the Doel nuclear power plant. This is the number without the employees of subcontractors. It often concerns highly trained and experienced employees who know how to maintain and operate a high-risk installation. Like their colleagues from other nuclear power plants, they are the first to potentially become victims of a nuclear accident, as was the case in Chernobyl or Fukushima. Despite the specific safety culture, a serious accident cannot be ruled out here either. Doel 1 had a leak in the primary circuit in the spring of 2018, close to the reactor itself. Fortunately it was a leak, and not a break in the pipe. However, a serious accident with rapid loss of the coolant cannot be ruled out.

In addition, Fukushima and Chernobyl are relatively remote from densely populated areas and large concentrations of industries. The opposite can be said of Doel. It is situated at the gateway to the world's largest concentration of petroleum and petrochemical facilities in a limited space. Just within 10 km you are in the center of Antwerp. A nuclear accident in that area will cause enormous human suffering and industrial damage. The employees and residents will have to pay very heavily for this. In addition to the human suffering, Electrabel is also hugely underinsured regarding the possible compensation to survivors of a serious nuclear disaster.

Setting up a new type of energy site for 50 years, instead of extending one old reactor by 10 years

The safety and reliability problems increase with age. The experience with the oldest Doel 1 and 2 reactors is significant. Even Electrabel has to admit that the second extension of the oldest reactors is not meeting expectations, and that they are not profitable. Doel 4 (and Tihange 3) would become the same age as Doel 1 and Doel 2 in case of an extension. Doel will not be the first nuclear power plant that, if extended after 2025, and despite an allowed extension, will have to stop earlier than planned. This threatens the future of the employees of Doel. Why risk extending installations after more than 40 years, while the future and job security of the employees can be better guaranteed with new installations?

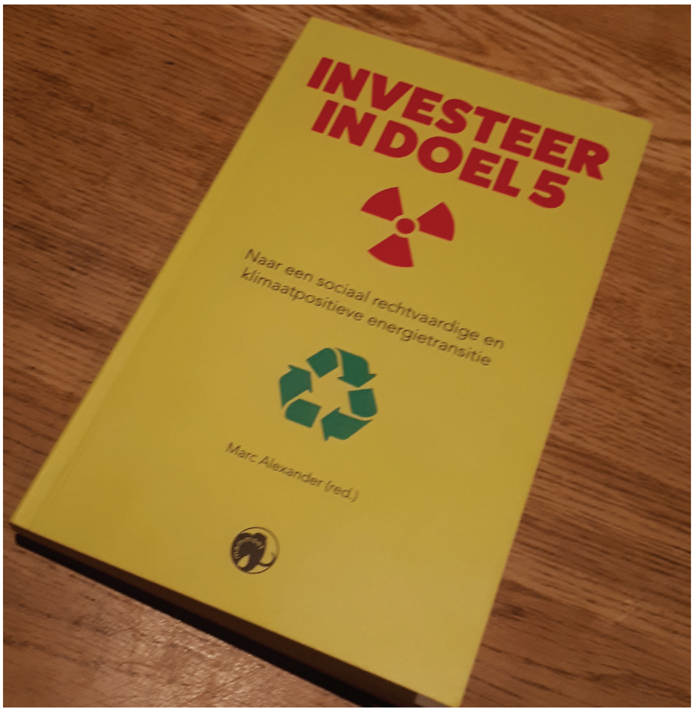
Apparently Electrabel does not currently intend to develop a real industrial plan for the Doel site. To her it seems to be black or white: a nuclear power plant in Doel or nothing else. And if there is a gas-fired power station, then not in Doel. The workers are forced in this dilemma: either you defend the nuclear power plant or there is nothing. With such a message, the employees have every reason to be concerned and angry about their future. Electrabel also allows society to choose between either nuclear energy or gas-fired power stations. Instead of making truly forward-looking investments - neither fossil nor nuclear, at the Doel site itself. This offers a future guarantee for many decades, instead of the poor extension by 10 years in one high-risk and aging reactor.

Climate science confirms the need to capture greenhouse gases for years

Which installations are really future-oriented? These are installations that take into account the great challenges of the time and help avert the greatest dangers to mankind. This concerns both the civil and military dangers of nuclear installations, as well as the threat of an out of control climate degradation. Common sense says we don't want the plague or the cholera. We do not want the climate problem to be traded for the nuclear danger. Nor do we want the avoidance of nuclear danger through a structural increase in fossil power plants that emit more greenhouse gases into the atmosphere.

How to solve this apparent dilemma? Let us look to the future for that. What does it take to avoid a climate apocalypse, without relying on the danger of nuclear armageddon? For many years now, the call from scientific reports has been growing that we should not only become climate neutral. No, the ultimate goal is to secure very large amounts of greenhouse gases. This is needed for many decades, right into the next century. And it concerns enormous amounts of greenhouse gases that need to be captured. The latest IPCC report speaks of several hundreds of billions of tons worldwide. One of the ways is industrial capture and circular reuse of CO2. Certain types of renewable energy can do that, while nuclear energy cannot.

Future-oriented investments in Doel should take this into account. They must enable the switch to energy sources for the generation of steam and reusable heat, whereby these installations can store net CO2 and reuse it or have it reused as a circular raw material. Then they will not only become climate neutral (no greenhouse gas emissions). They then become climate positive (net fixation and thus reduction of greenhouse gases). For example, the combustion of sustainable biogas in new thermal units in Doel can generate the necessary steam for flexible production of electricity, in addition to wind and sun. The CO2 that is released can then serve as a raw material in the current Antwerp chemical companies, instead of fossil raw materials. In this way we can accomplish two goals: we are making Doel more sustainable, and we are making Antwerp's chemical industry more sustainable. If the petroleum refineries also focus on the production of circular green gases, a coherent industrial ecology will arise between (ex-petroleum) refineries, (ex-petro) chemical companies and the (ex-nuclear) power station. . When these types of installations are maximally supplemented with solar and wind energy in and around Doel, and the production of green hydrogen, Doel can evolve from a controversial nuclear site now, to a renewable and circular site of the future.



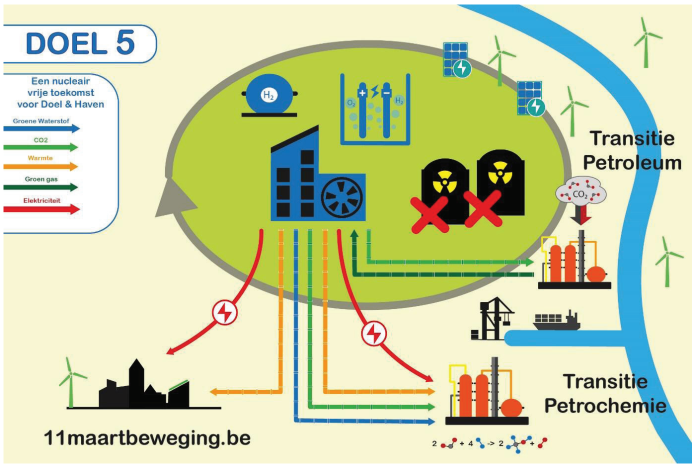


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Diagram of energy and material flows in and around an alternative power plant Doel

Nuclear energy: a bad social and climate choice

We have just had a severe winter period. It is almost unimaginable what would have happened if this occurred in the early winter of 2018, or the winter of 2014-2015. In that period several nuclear reactors were out of service, some of them planned, but also some unexpectedly. If Belgium has ever been close to a blackout, then it was during those two periods. Instead of nuclear power proving to be reliable, it then proved otherwise. Given this experience, there is a serious risk to assume that nuclear energy is reliable. This can be very costly for any citizen. Moreover, its existence and further investment in it prevents renewable and climate-positive energy from having the resources it needs to fulfill its mission quickly and thoroughly: to provide reliable climate-neutral and climate-positive energy.

In addition, nuclear energy is becoming increasingly expensive, while renewable energy is becoming rapidly and drastically cheaper. If nuclear energy does not emit greenhouse gases during the nuclear reaction, renewable energy does so in a more reliable, cheap and climate-friendly way. It is not without reason that the authors of the WNISR, the World Nuclear Industry Status Report, claim that renewable energy per dollar spent and per year avoids or absorbs more greenhouse gases than the nuclear option. And last but not least, windmill blades or discarded solar panels cannot be turned into weapons of mass destruction, while the nuclear sector poses serious security risks in all its steps, not least in terms of the risk of spreading materials for military or terrorist use.

The 11th March movement is a movement that strives for a socially just transition from nuclear energy to renewable energy.

The March 11 Movement has released a book that elaborates on previous points in the article in much more detail. This book can be ordered via **http://investeerindoel5.be/**