Annual Radioactive Effluent Release Report
No. 46

2020

Limerick Generating Station

ANNUAL RADIOACTIVE EFFLUENT RELEASE REPORT

NO. 46

January 1, 2020 through December 31, 2020

EXELON GENERATION COMPANY, LLC

LIMERICK GENERATING STATION
UNITS NO. 1 AND 2

DOCKET NO. 50-352 (Unit 1)

DOCKET NO. 50-353 (Unit 2)

DOCKET NO. 72-065 (ISFSI)

Submitted to
The United States Nuclear Regulatory Commission
Pursuant to
Renewed Facility Operating License:

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SITE: LIMERICK GENERATING STATION – UNITS 1 & 2
LICENSEE: EXELON GENERATION COMPANY, LLC

1. Preface

The following sections of the preface are meant to help define key concepts, provide clarity, and give context to the readers of this report.

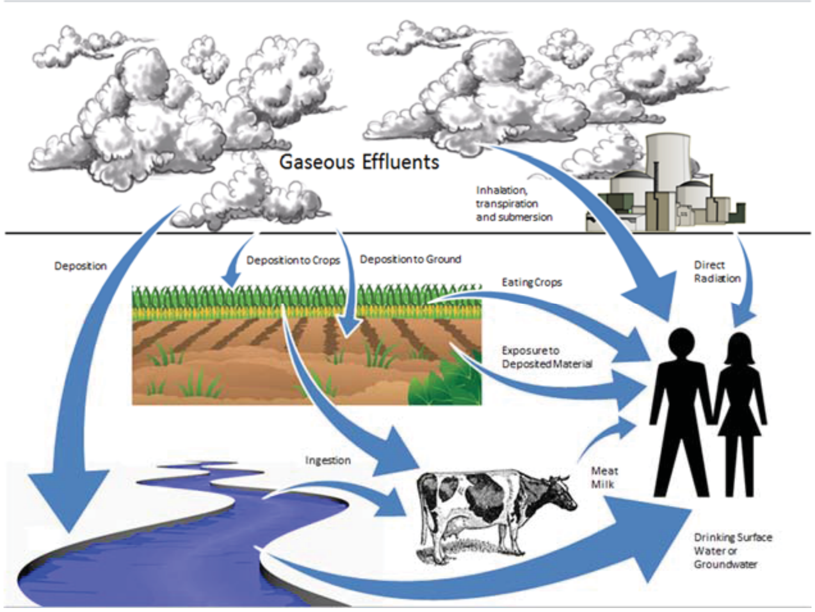
Annual Reports

The Nuclear Regulatory Commission (NRC) is the federal agency who has the role to protect public health and safety related to nuclear energy. Nuclear Power Plants have made many commitments to the NRC to ensure the safety of the public. As part of these commitments, they provide two reports annually to specifically address how the station's operation impacts the environment of the local community. Then the NRC reviews these reports and makes them available to the public. The names of the reports are the Annual Radioactive Effluent Release Report (ARERR) and the Annual Radiological Environmental Operating Report (AREOR).

The ARERR reports the results of the sampling from the effluent release paths at the station and analyzed for radioactivity. An effluent is a liquid or gaseous waste, containing plant-related radioactive material emitted at the boundary of the facility.

The AREOR reports the results of the samples obtained in the environment surrounding the station and analyzed for radioactivity. Environmental samples include air, water, vegetation, and other sample types that are identified as potential pathways radioactivity can reach humans.

Graphic 1. Examples of Gaseous and Liquid Effluent Pathways

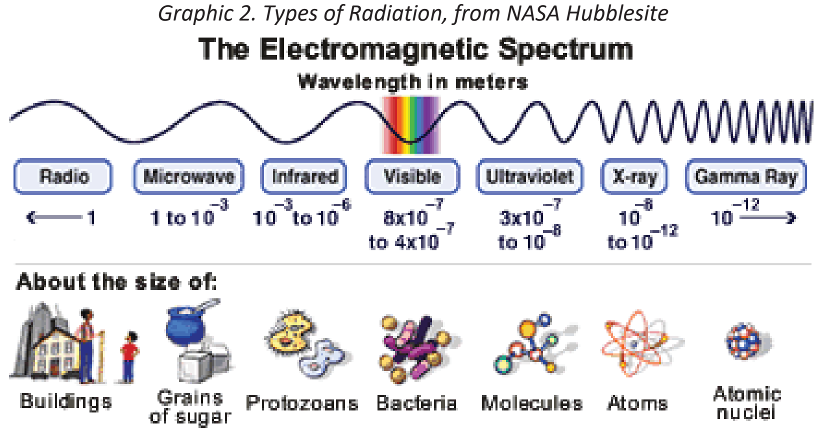


Graphic 1 demonstrates some potential exposure pathways from Limerick Generating Station. The ARERR and AREOR together ensure Nuclear Power Plants are operating in a manner that is within established regulatory commitments meant to adequately protect the public.

Understanding Radiation

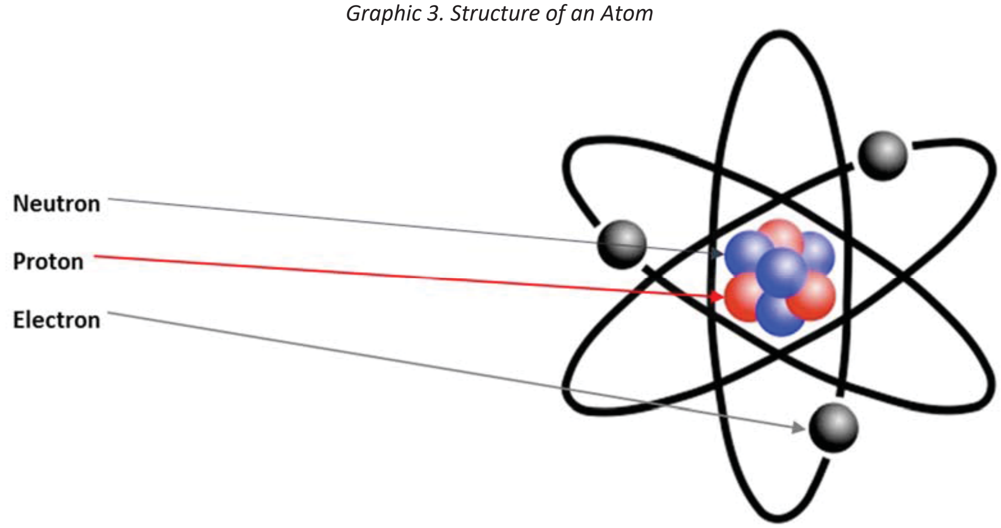
Generally, radiation is defined as emitted energy in the form of waves or particles. If radiation has enough energy to displace electrons from an atom it is termed "ionizing", otherwise it is "non-ionizing". Non-Ionizing radiation includes light, heat given off from a stove, radiowaves and microwaves. Ionizing radiation occurs in atoms, particles too small for the eye to see. So, what are atoms and how does radiation come from them?

Graphic 2. Types of Radiation, from NASA Hubblesite



An atom is the smallest part of an element that maintains the characteristics of that element. Atoms are made up of three parts: protons, neutrons, and electrons.

Graphic 3. Structure of an Atom



The number of protons in an atom determines the element. For example, a hydrogen atom will always have one proton while an oxygen atom will always have eight protons. The protons are clustered with the neutrons forming the nucleus at the center of the atom. Orbiting around the nucleus are the relatively small electrons.

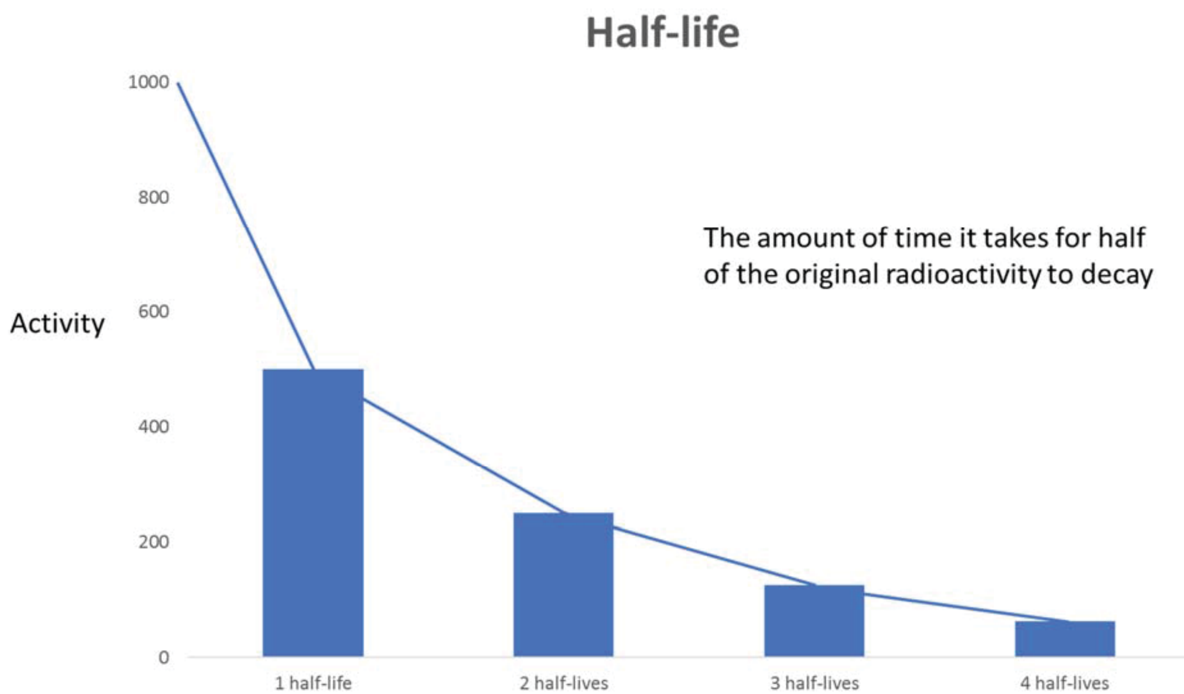
Isotopes are atoms that have the same number of protons but different numbers of neutrons. Different isotopes of an element will all have the same chemical properties and many isotopes are radioactive while other isotopes are not radioactive. A radioactive isotope can emit radiation because it contains excess energy in its nucleus. Radiactive atoms and isotopes are also referred to as radionuclides and radioisotopes.

There are two basic ways that radionuclides are produced at a nuclear power plant. The first is fission, which creates radionucides that are called *fission products*. Fission occurs when a very large atom, such as Uranium-235 (U-235) or Plutonium-239 (Pu-239), absorbs a neutron into its nucleus making the atom unstable. The unstable atom can then split into smaller atoms. When fission occurs there is a large amount of energy released in the form of heat. A nuclear power plant uses the heat generated to boil water that spins turbines to produce electricity.

The second way a radionuclide is produced at a nuclear power plant is through a process called activation. The radionuclides produced in this method are termed *activation products*. Pure water that passes over the fissioning atoms is used to cool the reactor and also produce steam to turn the turbines. Although this water is considered to be very pure, there are always some contaminants within the water from material used in the plant's construction and operation. These contaminants are exposed to the fission process and may become activation products. The atoms in the water itself can also become activated and create radionuclides.

Over time, radioactive atoms will reach a stable state and no longer be radioactive. To do this they must release their excess energy. This release of excess energy is called radioactive decay. The time it takes for a radionuclide to become stable is measured in units called half-lives. A half-life is the amount of time it takes for half of the original radioactivity to decay. Each radionuclide has a specific half-life. Some half-lives can be very long and measured in years while others may be very short and measured in seconds.

Graphic 4. Radioactive Decay Half-Life



In the annual reports you will see both man made and naturally ocurring radionuclides listed, for example Potassium-40 (K-40, natural) and Cobalt-60 (Co-60, man-made). We are mostly concerned about man-made radionuclides because they can be produced as by-products when generating electricity at a nuclear power plant. It is important to note that there are also other ways man-made radionuclides are produced, such as detonating nuclear weapons. Weapons testing has deposited some of the same man-made radionuclides into the environment as those generated by nuclear power, and some are still present today because of long half-lives.

Measuring Radiation

There are four different but interrelated units for measuring radioactivity, exposure, absorbed dose, and dose equivalent. Together, they are used to scientifically report the amount of radiation and its effects on humans.

- Radioactivity refers to the amount of ionizing radiation released by a material. The units of measure for radioactivity used within the AREOR and ARERR are the Curie (Ci). Small fractions of the Ci often have a prefix, such as the microCurie (μCi), which means 1/1,000,000 of a Curie.

- Exposure describes the amount of radiation traveling through the air. The units of measure for exposure used within the AREOR and ARERR are the Roentgen (R). Traditionally direct radiation monitors placed around the site are measured in milliRoentgen (mR), 1/1,000 of one R.

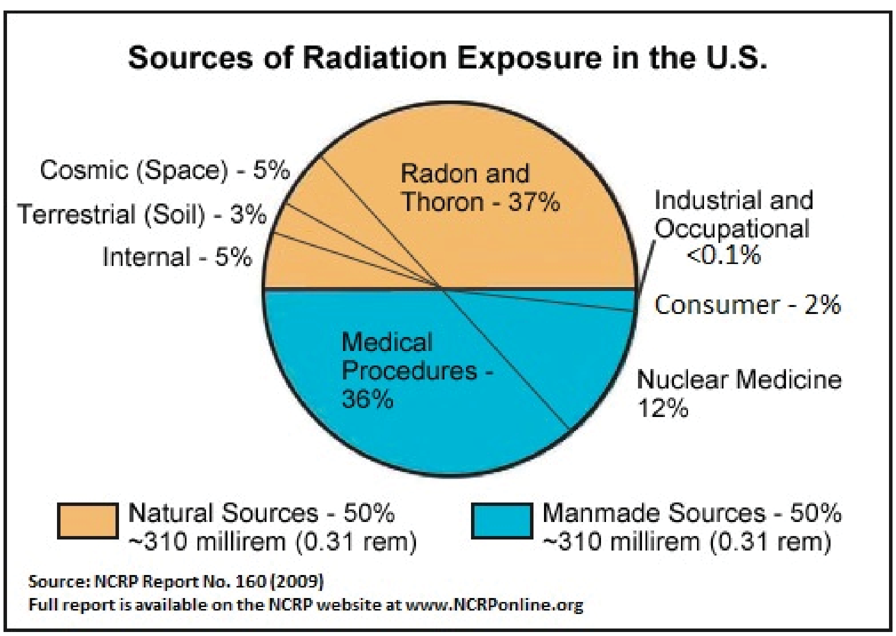
- Absorbed dose describes the amount of radiation absorbed by an object or person. The units of measure for absorbed dose used within the AREOR and ARERR are the rad. Noble gas air doses are reported by the site are measured in millirad (mrad), 1/1,000 of one rad.

- Dose equivalent (or effective dose) combines the amount of radiation absorbed and the health effects of that type of radiation. The units used within the AREOR and ARERR are the Roentgen equivalent man (rem). Regulations require doses to the whole body, specific organ, and direct radiation to be reported in millirem (mrem), 1/1,000 of one rem.

Sources of Radiation

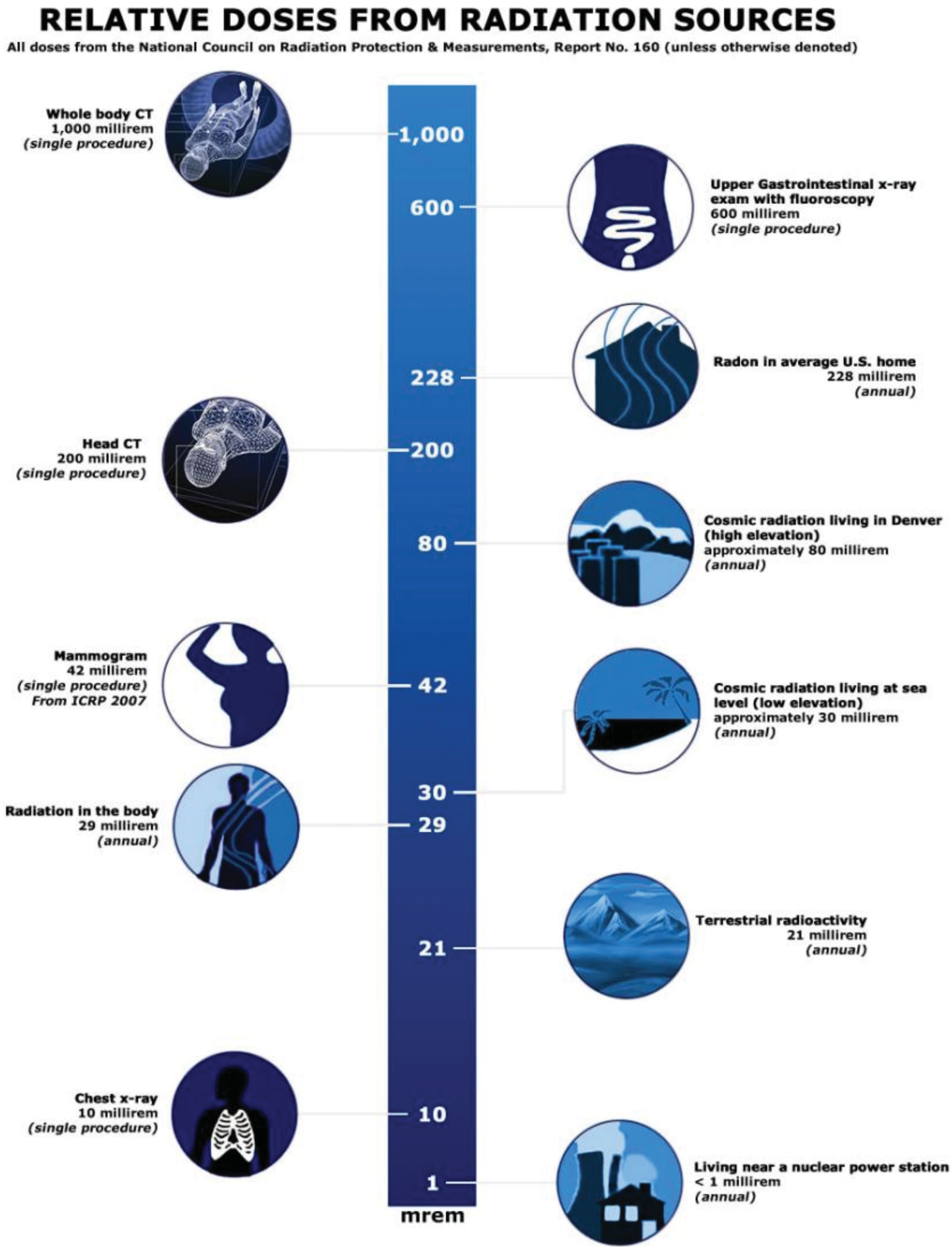
People are exposed to radiation every day of their lives and have been since the dawn of mankind. Some of this radiation is naturally occurring while some is man-made. There are many factors that will determine the amount of radiation individuals will be exposed to such as where they live, medical treatments, etc. The average person in the United States is exposed to approximately 620 mrem each year. 310 mrem comes from natural sources and 310 from man-made sources. Graphic 5 shows what the typical sources of radiation are for an individual over a calendar year:

Graphic 5. Sources of Radiation Exposure in the U.S., from NCRP Report No. 160



The radiation from a nuclear power plant is included in the chart as part of the "Industrial and Occupational" fraction, <0.1%. The largest natural source of radiation is from radon, because radon gas travels in the air we breathe. Perhaps you know someone who had a CT scan at a hospital to check his or her bones, brain, or heart. CT scans are included in the chart as "Medical Procedures", which make up the next largest fraction. Graphic 6 on the following page shows some of the common amounts of dose humans receive from radiation every year.

Graphic 6 .Relative Doses from Radiation Sources, from EPA Radiation Doses and Sources

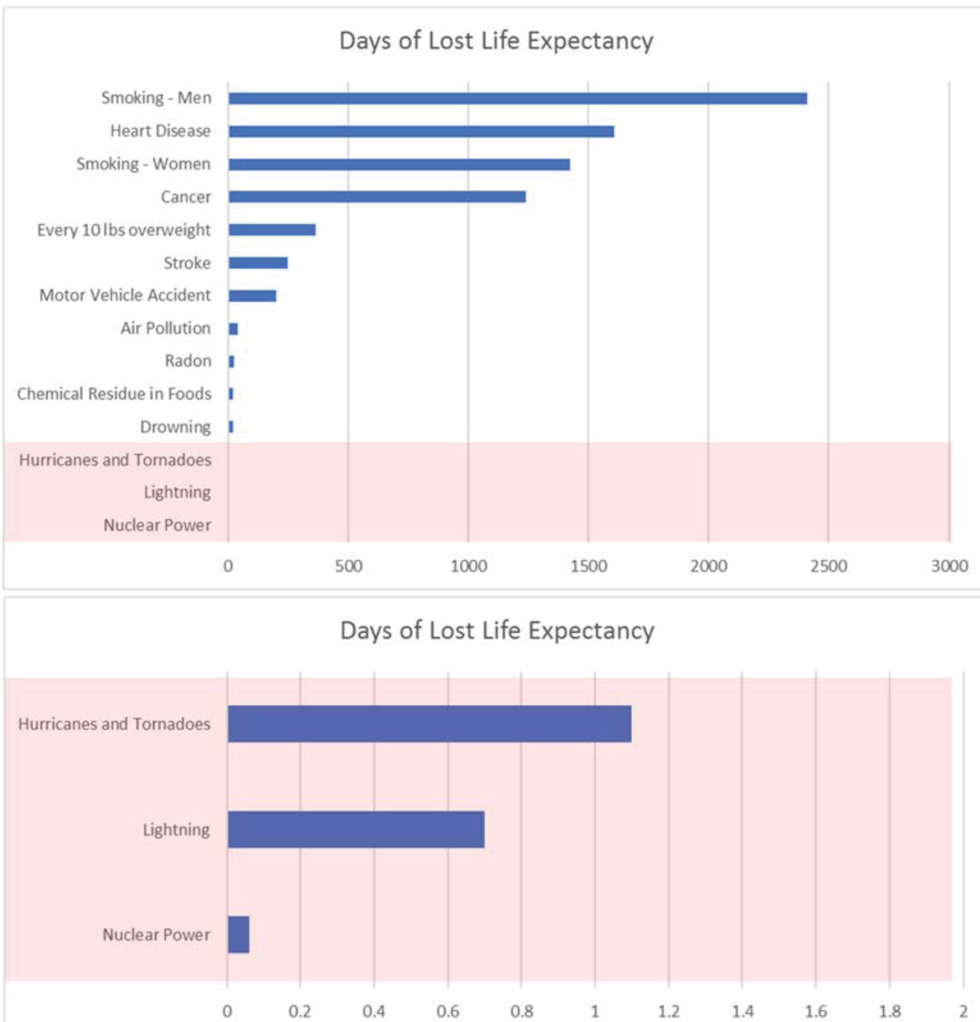


Radiation Risk

Current science suggests there is some risk from any exposure to radiation. However, it is very hard to tell whether cancers or deaths can be attributed to very low doses of radiation or by something else. U.S. radiation protection standards are based on the premise that any radiation exposure carries some risk.

The following graphs are an example of one study that tries to relate risk from many different factors. This graph represents risk as “Days of Lost Life Expectancy”. All the categories are averaged over the entire population except Male Smokers, Female Smokers, and individuals that are overweight. Those risks are only for people that fall into those categories. The category for Nuclear Power is a government estimate based on all radioactivity releases from nuclear power, including accidents and wastes.

Graphic 7. Days of Lost Life Expectancy, Adapted from the Journal of American Physicians and Surgeons Volume 8 Number 2 Summer 2003



2. Introduction

In accordance with the reporting requirements of Technical Specification 6.9.1.8 applicable during the reporting period, this report summarizes the effluent release data for Limerick Generating Station Units 1 and 2 for the period January 1, 2020 through December 31, 2020. This submittal complies with the format described in Regulatory Guide 1.21, "Measuring, Evaluating and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water Cooled Nuclear Power Plants", Revision1 1 and 2.

Meteorological is maintained in available in records in the format specified in Regulatory Guide 1.23, Revision 1, "Meteorological Monitoring Programs for Nuclear Power Plants".

All vendor results were received and included in the report calculations. Therefore, the 2020 report is complete.

3. Supplemental Information

A. Regulatory Limits

	Limit	Units	Receptor	ODCM and 10 CFR 50, Appendix I Design Objective Limits
1. Noble Gases:				
a.	≤ 500	mrem/Yr	Total Body	ODCM Control 3.2.2.1.a
	≤ 3000	mrem/Yr	Skin	
b.	≤ 10	mRad	Air Gamma	Quarterly air dose limits
	≤ 20	mRad	Air Beta	ODCM Control 3.2.2.2.a
c.	≤ 20	mRad	Air Gamma	Yearly air dose limits
	≤ 40	mRad	Air Beta	ODCM Control 3.2.2.2.b
d.	≤ 10	mrem	Total Body (Gamma)	10 CFR 50, Appendix I, Section II.B.2(b) (limits listed here are
	≤ 30	mrem	Skin (Beta)	based on two-unit operation)
2. Iodines, Tritium, Particulates with Half Life > 8 days:				
a.	≤ 1500	mrem/Yr	Any Organ	ODCM Control 3.2.2.1.b
b.	≤ 15	mrem	Any Organ	Quarterly dose limits ODCM Control 3.2.2.3.a
c.	≤ 30	mrem	Any Organ	Yearly dose limits ODCM Control 3.2.2.3.b
3. Liquid Effluents				
a.	10 times the concentration limits in 10 CFR 20, Appendix B, Table 2 Col. 2			ODCM Control 3.2.1.1
b.	≤ 3	mrem	Total Body	Quarterly dose limits
	≤ 10	mrem	Any Organ	ODCM Control 3.2.1.2.a
c.	≤ 6	mrem	Total Body	Yearly dose limits
	≤ 20	mrem	Any Organ	ODCM Control 3.2.1.2.b
4. 40 CFR 190, 10 CFR 72.104				
	≤ 25	mrem	Total Body or Organ	Yearly dose limits
	≤ 75	mrem	Thyroid	ODCM Control 3.2.3

B. Effluent Concentration Limits

Gaseous dose rates rather than effluent concentrations are used to calculate permissible release rates for gaseous releases. The maximum permissible dose rates for gaseous releases are defined in Offsite Dose Calculation Manual (ODCM) Controls 3.2.2.1.a and 3.2.2.1.b as 500 mrem/yr (Total Body), 3000 mrem/yr (Skin), and 1500 mrem/yr (Organ).

The Effluent Concentration Limit (ECL) specified in 10 CFR 20, Appendix B, Table 2, Column 2 for identified nuclides, were used to calculate permissible release rates and concentrations for liquid release per the Limerick ODCM Control 3.2.1.1. The total activity concentration for all dissolved or entrained gases was limited to < 2E-04 μCi/ml.

C. Average Energy ($\bar{E}$)

The Limerick ODCM limits the instantaneous dose equivalent rates due to the release of noble gases to less than or equal to 500 mrem/year to the total body and less than or equal to 3000 mrem/year to the skin. The average beta and gamma energies ($\bar{E}$) of the radionuclide mixture in releases of fission and activation gases as described in Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants," may be used to calculate doses in lieu of more sophisticated software. The Limerick radioactive effluent program employs the methodologies presented in U.S. NRC Regulatory Guide 1.109 "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Revision 1, October 1977 and NUREG-0133, "Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants, October 1978. Therefore, average energies are not applicable to Limerick.

D. Measurements and Approximations of Total Radioactivity

1. Fission and Activation Gases

The method used for Gamma Isotopic Analysis is the Canberra Gamma Spectroscopy System with a gas Marinelli beaker. Airborne effluent gaseous activity was continuously monitored and recorded in accordance with ODCM Table 4.2-2. Additional vent grab samples were taken from the North Stack, Unit 1 South Stack, and Unit 2 South Stack and analyzed at least monthly to determine the isotopic mixture of noble gas activity released for the month. The data from the noble gas radiation monitors were analyzed to report net noble gas effluent activity. When no activity was found in the grab isotopic analysis, the isotopic mixture was assumed to be that evaluated in the UFSAR (Section 11.5, Table 11.5-4). If activity was found in the grab isotopic analysis, the isotopic mixture for the Noble Gas Monitor was determined from that isotopic mixture.

A monitor background has been determined for each radiation monitor. When no isotopic activity was identified in the grab noble gas sample, then when radiation monitor reading is above the background, the isotopic mixture from the UFSAR (Section 11.5, Table 11.5-4) is used to determine and report the noble gas effluent activity.

2. Particulates and Iodines

The method used for Gamma Isotopic Analysis is the Canberra Gamma Spectroscopy System with a particulate filter (47 mm) or charcoal cartridge, respectively. Particulate and iodine activity was continuously sampled and analyzed in accordance with ODCM Table 4.2-2. Particulate and charcoal samples are taken from the North Stack, Unit 1 South Stack, Unit 2 South Stack and Hot Maintenance Shop exhausts and analyzed at least weekly to determine the total activity released from the plant.

3. Carbon-14 in gaseous effluents

Gaseous releases of Carbon-14 were estimated based upon a study by EPRI (EPRI 1021106, Estimation of Carbon-14 in Nuclear Power Plant Gaseous Effluents). The principal production reaction leading to the release of C-14 during plant operation is the O-17(n,α) C-14 nuclear reaction in reactor coolant. Carbon-14 is also produced by neutron activation of N-14 in the BWR drywell and dissolved nitrogen in the reactor coolant, however these sources are a small fraction of that produced by the O-17(n,α) C-14 reaction and can be neglected since reactor coolant normally contains less than 0.1 ppm by weight nitrogen and the neutron flux in the drywell is low. Most of the C-14 produced in a BWR is released in a gaseous form by the off-gas system, primarily in the form of $^{14}CO_2$.

An Exelon fleet-wide spreadsheet was developed using the production factors from the EPRI report. The spreadsheet requires site specific inputs of total reactor power ratings (7030) MWth and Equivalent Full Power Operation days. Using this method, total C-14 released was estimated at 35.84 Curies (Ci). Ninety-five percent or 33.71 Ci was in the form of $^{14}CO_2$, which was the chemical form necessary to be incorporated in the dose pathways of vegetation, meat and milk. Only inhalation pathway uses the full C-14 release value in estimating dose.

To simplify the dose calculations for C-14, the total release value was used in calculating dose via the offsite effluent pathways. Using the total C-14 release value results in a conservative five percent overestimation of dose via the vegetation, meat and milk pathways. In addition, releases of C-14 were assumed to occur only through the North Vent, which is common to both units. The North Vent has the most conservative X/Q factors for calculating dose.

4. Liquid Effluents

Each batch of liquid effluent was sampled and analyzed for gamma isotopic activity in accordance with ODCM Table 4.2-1 prior to release. The total activity of each released batch was determined by multiplying each nuclide's concentration by the total volume discharged and then summing. The total activity released during a quarter was then determined by summing the activity content of all batch releases discharged during the quarter.

5. Tritium in Liquid and Gaseous Effluents

Liquid effluents are analyzed for tritium using a Liquid Scintillation Counter.

Gaseous effluents are analyzed for tritium by passing air from stack effluents through two bubblers in series. An aliquot of the water from each bubbler was analyzed using a Liquid Scintillation Counter.

The monthly liquid radwaste composite was analyzed for tritium using a Liquid Scintillation Counter.

6. Composite Samples

Particulate air samples were composited monthly and analyzed for gross alpha, Sr-89, Sr-90, and Ni-63. Liquid radwaste samples were composited monthly and quarterly and analyzed for gross alpha (monthly) and Fe-55, Sr-89 and Sr-90 (quarterly). These composites were submitted to an offsite vendor laboratory for analysis.

7. Lower Limit of Detection (LLD)

The ODCM required lower limit of detection for airborne and liquid releases as follows:

Airborne:	LLD
Gross Alpha, Sr-89, Sr-90	1E-11 uCi/cc
H-3	1E-06 uCi/cc
I-131	1E-12 uCi/cc
Principal Gamma Emitters (Mn-54, Fe-59, Co-58, Co-60, Zn-65, Mo-99, I-131, Cs-134, Cs-137,Ce-141, Ce-144)	1E-11 uCi/cc
Noble Gas (Kr-87, Kr-88, Xe-133, Xe-133m, Xe-135, Xe-135m, Xe-138)	1E-04 uCi/cc

Liquid:	LLD
Principal Gamma Emitters (Mn-54, Fe-59, Co-58, Co-60, Zn-65, Mo-99, Cs-134, Cs-137, Ce-141, Ce-144)	5E-07 uCi/ml
I-131	1E-06 uCi/ml
Entrained Gases (Kr-87, Kr-88, Xe-133, Xe-133m, Xe-135, Xe-135m, Xe-138)	1E-05 uCi/ml
H-3	1E-05 uCi/ml
Gross Alpha	1E-07 uCi/ml
Sr-89, Sr-90	5E-08 uCi/ml
Fe-55	1E-06 uCi/ml

8. Estimated Total Error Present

Procedure CY-AA-170-2100, Estimated Errors of Effluent Measurements, provides the methodology to obtain an overall estimate of the error associated with radioactive effluents. The sum of errors used in this report was documented in IR 138895-02.

E. Batch Releases

Liquid	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Number of Batch Releases	2	12	11	1	26
Total time period for batch releases (min)	4.00E+02	1.29E+03	2.20E+03	2.00E+02	4.09E+03
Maximum time period for batch release (min)	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
Average time period for batch release (min)	2.00E+02	1.07E+02	2.00E+02	2.00E+02	1.57E+02
Minimum time period for batch release (min)	2.00E+02	2.00E+01	2.00E+02	2.00E+02	2.00E+01
Average stream flow (Schuylkill River) during periods of release of effluents into a flowing stream (LPM)	1.56E+07	2.28E+07	1.43E+07	7.52E+06	1.67E+07
Average Blowdown Flowrate (LPM)	3.79E+03	2.02E+04	3.79E+03	3.79E+03	8.95E+03

Gaseous	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Number of Batch Releases	0	0	0	0	0
Total time period for batch releases (min)	0	0	0	0	0
Maximum time period for batch release (min)	0	0	0	0	0
Average time period for batch release (min)	0	0	0	0	0
Minimum time period for batch release (min)	0	0	0	0	0

F. Abnormal Releases

1. Liquid	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Total
Number of Releases	0	1	0	0	1
Total Activity Released (Ci)	0	5.62-06	0	0	5.62-06

2. Gaseous	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Total
Number of Releases	0	0	0	0	0
Total Activity Released (Ci)	0	0	0	0	0

All the liquid abnormal releases being reported were released through the plant drain system or the storm drain system to the on-site holding pond. The on-site holding pond is a body of water that is ultimately released through the permitted discharge point. The on-site holding pond is sampled daily for gamma emitters and an aliquot is saved to create a monthly composite which is ran for tritium. Though the on-site holding pond provides a large volume of water for dilution, for the purposes of reporting these abnormal releases we do not use the on-site holding pond dilution to calculate the activity released and only use the normal dilution from the blowdown line and the river. The concentrations released from all abnormal releases represent a small fraction of the Total Body and Organ Dose limits and have been included as part of Appendix A in Table 2A.

Per Regulatory Guide 1.21 Rev. 2, "Normal system leakage captured by effluent ventilation control systems or sumps is not an abnormal release (provided that, before discharge of the radioactive material, the discharge is planned and controlled).". Each Unit has an Underground Normal Waste Holding Tank (UGNWHT). These tanks collect water from various sumps and drains in the plant. When the tank high level alarm is received, the tank is isolated and sampled for analysis. Once the analysis is complete, the tank is drained to the holding pond and released as describe above. The concentrations released from UGNWHT's represent a small fraction of the Total Body and Organ Dose limits and have been included as part of Appendix A in Table 2A. During 2020, there were fifteen instances where tritium was identified in the UGNWHT's and drained to the holding pond.

- Tritium was identified in the Unit 2 Condensate Storage Tank (CST) dike from a sample taken on April 28, 2020 at a concentration of 2.97E-06 uCi/ml. The water is released through the normal waste system to the on-site holding pond. This dike collects rainwater and is periodically drained. The potential sources of tritium in the dike are recapture of previously released tritium in rainwater, CST tank and piping leaks and auxiliary heating system leaks if contaminated. The CST tank and piping were inspected, no leaks were identified (IR 4347141).

G. Insignificant Releases

In January of 2016 new pathways were identified and classified as a less significant Effluent Pathway. Gaseous effluents from the Main Turbine and Reactor Feed Pump Turbine lubrication oil vapor extractor exhaust vents to the Turbine Building roof. These pathways are not continuously monitored. Tritium analysis was performed in January and December 2016 of the water vapor exiting the vent and of nearby standing water. The tritium in the water is the result of condensation and direct deposition from the discharge of the entrained water vapor from the exhaust vents. This condensation does occur year-round but increases during seasonally cold weather.

The lube oil exhaust vents and associated systems were operating as designed to remove accumulated water from the lubricating and seal oil for the various turbine systems. The water was discharged as entrained vapor out the Turbine Building roof vent and a portion of it condensed on lower temperature surfaces. This water includes tritium, as the source is from the primary system. (IR 2606991)

Based on Regulatory Guide 1.21, Rev 2, Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste these release pathways are considered less significant. A significant release point is any location, from which radioactive material is released, that contributes greater than 1 percent of the activity discharged from all the release points for a particular type of effluent considered. Regulatory Guide 1.109 lists the three types of effluent as (1) liquid effluents, (2) noble gases discharged to the atmosphere, and (3) all other radionuclides discharged to the atmosphere. As such, the percentage of U1 and U2 MTLO exhaust vent activity in 2020 is relatively small compared to the total activity released of all other radionuclides from the site in 2020. This percentage is calculated below.

Vent	Tritium Concentration, uCi/cc	Site Gaseous Annual Release of Tritium, Ci	Percentage of Activity Relative to Total Release from the Site
		2020	2020
U1 MTLO extractor exhaust vent	1.30E-08		8.38E-01%
U2 MTLO extractor exhaust vent	1.02E-08	3.23E+01	6.58E-01%
U1 and U2 RFPT extractor exhaust vent	<LLD		N/A

H. Spills

There were no spills to ground containing radioactive material in 2020.

I. Revisions to the ODCM

There were no revisions to the ODCM in 2020.

J. Radioactive Effluent Monitoring Instrumentation Out of Service for More Than 30 Days

The Unit 2 Service Water radiation monitor was inoperable from 12/23/2019 – 1/29/2020. The extended inoperable time of the instrument was due to the instrument not bringing in the low flow alarm due to the flow meter sticking at low flow rates. The flow switch needed to be replaced with a new model switch. During this period compensatory samples were collected and analyzed to meet the requirements of the ODCM. (IR 4305883 and 4312857)

K. Independent Spent Fuel Storage Installation (ISFSI)

An Independent Spent Fuel Storage Installation (ISFSI) was placed in service starting July 21, 2008. Direct radiation exposure was determined using dosimetry measurements (minus background levels) obtained from the Radiological Environmental Monitoring Program for the nearest residence to the Independent Spent Fuel Storage Installation (ISFSI). In 2020 there was no facility related dose detected to the nearest resident including from the ISFSI.

L. Annual Land Use Census Changes

The 2020 Land Use Survey identified sixteen new gardens. The station uses gardens closer to the site then those identified. There were no changes in the nearest residences and dairy farms from 2019. Based on the results of the 2020 Land Use Survey, there are no changes required to the REMP sampling locations.

4. Radiological Impact to Man and Compliance to 40 CFR 190 Limits

A. Dose to Members of the Public at or Beyond Site Boundary

Per ODCM Control 6.2, the Annual Radioactive Effluent Release Report shall include an assessment of the radiation doses to the hypothetically highest exposed MEMBER OF THE PUBLIC from reactor releases and other nearby uranium fuel cycle sources. The ODCM does not require population doses to be calculated. For purposes of this calculation the following assumptions were made:

- Long term annual average meteorology X/Q and D/Q and actual gaseous effluent releases were used.
- Gamma air dose, Beta air dose, Total Body and Skin doses were attributed to noble gas releases.
- Critical organ and age group dose attributed to iodine, particulate, carbon-14 and tritium releases.
- 100 percent occupancy factor was assumed.
- Dosimetry measurements (minus background levels) obtained from the Radiological Environmental Monitoring Program for the nearest residence to the Independent Spent Fuel Storage Installation (ISFSI) was used to determine direct radiation exposure.
- The highest doses from the critical organ and critical age group for each release pathway was summed and added to the net dosimetry measurement from nearest residence to the ISFSI for 40CFR190 compliance.

Gaseous Releases (Table 1):

The critical age-organ group was the child-bone. Calculated dose was 1.33 mrem, which represents 4.42% of the allowable limits. Carbon-14 represented 100% or 1.33 mrem of the total dose.

Liquid Releases (Table 1):

The critical age-organ was the teen-bone. Calculated total body dose was 2.83E-04 mrem and organ dose was 2.34E-03 mrem.

40 CFR 190 Compliance (Table 2):

The maximum calculated dose to a real individual would not exceed 0.27 mrem (total body), 1.33 mrem (organ), or 0.28 mrem (thyroid).

All doses calculated were well below all ODCM and 40 CFR Part 190 limits to a real individual.

SITE: LIMERICK GENERATING STATION – UNITS 1 & 2
LICENSEE: EXELON GENERATION COMPANY, LLC

Table 1 Summary of Gaseous and Liquid Effluent Doses to Members of the Public at the Highest Dose Receptors

Maximum Individual Noble Gas	Applicable Dose	Estimated Dose	Age Group	% of Applicable Limit	Limit	Unit
Nearest Residence	Gamma Air Dose	2.66E-03	All	1.33E-02	20	mRad
Nearest Residence	Beta Air Dose	2.13E-03	All	5.33E-03	40	mRad
Nearest Residence	Total Body	2.52E-03	All	2.52E-02	10	mrem
Nearest Residence	Skin	4.39E-03	All	1.46E-02	30	mrem
Iodine, Particulate, C-14 & Tritium						
Vegetation Pathway	Bone	1.33E+00	Child	4.42E+00	30	mrem
Liquid						
LGS Outfall	Total Body	2.83E-04	Adult	4.71E-03	6	mrem
LGS Outfall	Bone	2.34E-03	Adult	1.17E-02	20	mrem

Table 2 Summary of Gaseous and Liquid Effluent Doses to Members of the Public for 40CFR190 Compliance

40 CFR 190 Compliance								
	Gaseous Effluents		Liquid Effluents	Net Direct Radiation	Total	% of Applicable Limit	Limit	Unit
	Noble Gas	Particulate, Iodine, C-14 & Tritium						
Total Body Dose	2.52E-03	2.66E-01	2.83E-04	0.00E+00	2.69E-01	1.08E+00	25	mrem
Organ Dose	4.39E-03	1.33E+00	2.34E-03	0.00E+00	1.33E+00	5.33E+00	25	mrem
Thyroid Dose	2.13E-03	2.76E-01	2.28E-04	0.00E+00	2.78E-01	3.71E-01	75	mrem

B. Dose to Members of the Public Inside the Site Boundary

ODCM Control 6.2 also requires that the Annual Radioactive Effluent Release Report shall include an assessment of the radiation doses from radioactive liquid and gaseous effluents to members of the public due to activities inside the Site Boundary during the report period. MEMBER OF THE PUBLIC shall include all persons not occupationally associated with the plant. This category does not include employees of the utility or contractors. Also excluded from this category are persons who enter the site to service equipment or to make deliveries. This category does include persons who use portions of the site for recreational, occupational education, or other purposes not associated with the plant. A MEMBER OF THE PUBLIC may receive up to 100 mrem in a year (10CFR20.1301). Areas within the site boundary, where radiation dose of this type could occur include the Limerick Information Center on Longview Road, Frick's Lock on the south shore of the Schuylkill River, and the railroad track that runs along the north shore of the Schuylkill River. The radiation doses to Members of the Public have been estimated using methodology stated in the ODCM. The maximum gaseous dose to members of the public at these locations is based on the following assumptions:

- Long term annual average meteorology and actual effluent releases for the sectors encompassing the Railroad Tracks (W), Information Center, and Frick's Lock.
- Dose is from ground plane and inhalation only. No ingestion dose is included.
- The maximum expected occupancy factor is 25% of a working year at all locations.

The maximum calculated dose for activities on site was 3.54E-02 mrem at the Rail Road Tracks in the West sector (Table 3). All Doses calculated were a small fraction of the 10 CFR 20.1301 limits.

Table 3 Summary of Gaseous Radiation Doses to Members of the Public for Activities on Site

Location	Sector	Approx. Distance (meters)	X/Q s/m^3	D/Q 1/m^2	Total Body Dose, mrem(1)		Organ Dose, mrem(1)	Total
					Noble Gas	Iodine, Particulate, C-14 & H-3	Iodine, Particulate, C-14 & H-3	
R.R. Tracks	W	225	2.66E-06	2.36E-08	2.97E-03	5.53E-03	2.69E-02	3.54E-02
Info. Center	ESE	884	7.32E-07	9.27E-09	8.18E-04	1.53E-03	7.43E-03	9.77E-03
Frick's Lock	WSW	450	5.58E-07	4.78E-09	6.24E-04	1.16E-03	5.65E-03	7.44E-03

(1) The limit for sum of the Total Body Dose and Organ Dose = 100 mrem (ref. 10 CFR 20.1301)

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Appendix A
Effluent and Waste Disposal Summary

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LIST OF TABLES

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SITE: LIMERICK GENERATING STATION – UNITS 1 & 2
LICENSEE: EXELON GENERATION COMPANY, LLC

TABLE 1A GASEOUS EFFLUENTS - SUMMATION OF ALL RELEASES PERIOD 2020

A. Fission And Activation Gasses	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total Release	Ci	4.32E+01	4.83E-01	2.65E-01	1.60E+01	6.00E+01	36.6
Average Release Rate for Period	uCi/sec	5.49E+00	6.15E-02	3.34E-02	2.02E+00	1.90E+00	
Dose - Gamma Air Dose	mrad	1.04E-03	4.15E-05	1.34E-05	1.57E-03	2.66E-03	
- Beta Air Dose	mrad	1.20E-03	2.43E-05	8.35E-06	9.07E-04	2.13E-03	
Percent of ODCM Limit - Gamma Air Dose	%	1.04E-02	4.15E-04	1.34E-04	1.57E-02	1.33E-02	
- Beta Air Dose	%	5.97E-03	1.21E-04	4.17E-05	4.53E-03	5.33E-03	
B. Radioiodines	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total I-131	Ci	2.02E-03	3.96E-04	3.20E-05	1.42E-04	2.59E-03	20.4
Average Release Rate for Period	uCi/sec	2.57E-04	5.03E-05	4.03E-06	1.79E-05	8.19E-05	
Percent of ODCM Limit	%	*	*	*	*	*	
C. Particulates	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total Release	Ci	8.40E-06	< LLD	< LLD	< LLD	8.40E-06	22.6
Average Release Rate for Period	uCi/sec	1.07E-06	< LLD	< LLD	< LLD	2.66E-07	
Percent of ODCM Limit	%	*	*	*	*	*	
D. Gross Alpha	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total Release	Ci	< LLD	< LLD	< LLD	< LLD	< LLD	22.6
Average Release Rate for Period	uCi/sec	< LLD	< LLD	< LLD	< LLD	< LLD	
Percent of ODCM Limit	%	*	*	*	*	*	
E. Tritium (H-3)	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total Release	Ci	1.19E+01	3.65E+00	6.40E+00	1.06E+01	3.25E+01	15.7
Average Release Rate for Period	uCi/sec	1.51E+00	4.64E-01	8.06E-01	1.34E+00	1.03E+00	
Percent of ODCM Limit	%	*	*	*	*	*	
F. Carbon-14	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	
Total Release	Ci	7.51E+00	9.08E+00	1.11E+01	7.81E+00	3.55E+01	
Average Release Rate for Period	uCi/sec	9.55E-01	1.15E+00	1.40E+00	9.82E-01	1.12E+00	
Percent of ODCM Limit	%	*	*	*	*	*	
G. Iodine 131 & 133, Particulate, C-14 & H-3	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	
Organ Dose	mrem	2.80E-01	3.39E-01	4.14E-01	2.92E-01	1.33E+00	
Percent of ODCM Limit	%	1.87E-00	2.26E-00	2.76E-00	1.94E-00	4.42E+00	

* ODCM Limit for combined Iodine, Carbon-14, Tritium and particulate only, which is shown in Item G.

SITE: LIMERICK GENERATING STATION – UNITS 1 & 2
LICENSEE: EXELON GENERATION COMPANY, LLC

TABLE 1B–1 GASEOUS EFFLUENTS—MIXED-LEVEL RELEASE—BATCH MODE PERIOD 2020

Fission And Activation Gasses	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	N/A	N/A	N/A	N/A	N/A
Radioiodines	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	N/A	N/A	N/A	N/A	N/A
Particulates	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	N/A	N/A	N/A	N/A	N/A
H-3	**Units**	**Qtr 1**	**Qtr**	**Qtr**	**Qtr 4**	**Total**
Total	Ci	N/A	N/A	N/A	N/A	N/A
Gross Alpha	**Units**	**Qtr 1**	**Qtr**	**Qtr**	**Qtr 4**	**Total**
Total	Ci	N/A	N/A	N/A	N/A	N/A
C-14	**Units**	**Qtr 1**	**Qtr**	**Qtr**	**Qtr 4**	**Total**
Total	Ci	N/A	N/A	N/A	N/A	N/A

SITE: LIMERICK GENERATING STATION – UNITS 1 & 2
LICENSEE: EXELON GENERATION COMPANY, LLC

TABLE 1B–2 GASEOUS EFFLUENTS – MIXED-LEVEL RELEASE - CONTINUOUS MODE PERIOD 2020

Fission And Activation Gasses	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Kr-85m	Ci	8.22E-01	9.08E-03	4.58E-03	3.09E-01	1.15E+00
Kr-85	Ci	1.27E-02	2.52E-02	< LLD	1.12E+00	1.16E+00
Kr-87	Ci	1.92E-01	1.41E-02	4.58E-03	5.32E-01	7.43E-01
Kr-88	Ci	1.19E+00	2.31E-02	4.58E-03	9.31E-01	2.15E+00
Ar-41	Ci	6.94E-02	1.00E-02	1.91E-02	5.61E-02	1.55E-01
Xe-131m	Ci	3.17E-04	6.32E-04	< LLD	2.80E-02	2.90E-02
Xe-133m	Ci	9.59E-01	< LLD	< LLD	< LLD	9.59E-01
Xe-133	Ci	2.71E+01	5.45E-02	9.94E-02	3.96E-01	2.76E+01
Xe-135m	Ci	1.28E+00	9.56E-02	7.04E-02	2.81E+00	4.25E+00
Xe-135	Ci	1.15E+01	1.19E-01	5.20E-02	4.24E+00	1.59E+01
Xe-138	Ci	1.02E-01	1.32E-01	1.07E-02	5.61E+00	5.86E+00
Total	Ci	4.32E+01	4.83E-01	2.65E-01	1.60E+01	6.00E+01
Radioiodines	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
I-131	Ci	2.02E-03	3.96E-04	3.20E-05	1.42E-04	2.59E-03
I-133	Ci	9.21E-04	1.99E-04	5.07E-04	4.02E-03	5.64E-03
Total	Ci	2.94E-03	5.95E-04	5.39E-04	4.16E-03	8.23E-03
Particulates	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Co-60	Ci	8.40E-06	< LLD	< LLD	< LLD	8.40E-06
Total	Ci	8.40E-06	< LLD	< LLD	< LLD	8.40E-06
H-3	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	1.19E+01	3.65E+00	6.40E+00	1.06E+01	3.25E+01
Gross Alpha	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	< LLD	< LLD	< LLD	< LLD	< LLD
C-14	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	7.51E+00	9.08E+00	1.11E+01	7.81E+00	3.55E+01

SITE: LIMERICK GENERATING STATION – UNITS 1 & 2
LICENSEE: EXELON GENERATION COMPANY, LLC

TABLE 2A LIQUID EFFLUENTS – SUMMATION OF ALL RELEASES PERIOD 2020

Fission and Activation Products Excluding Tritium, Gasses & Alpha	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total Release	Ci	< LLD	1.63E-03	< LLD	< LLD	1.63E-03	21.1
Average Concentration	uCi/ml	< LLD	6.11E-08	< LLD	< LLD	4.35E-08	
Dose - Whole Body	mrem	< LLD	2.83E-04	< LLD	< LLD	2.83E-04	
- Organ	mrem	< LLD	2.34E-03	< LLD	< LLD	2.34E-03	
% of ODCM Limit - Whole Body Dose*	%	N/A	9.42E-03	N/A	N/A	4.71E-03	
- Organ Dose*	%	N/A	2.34E-02	N/A	N/A	1.17E-02	
Tritium	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total Release	Ci	2.20E-04	3.54E+00	6.33E-03	1.05E-03	3.55E+00	6.4
Average Concentration	uCi/ml	1.42E-07	1.32E-04	7.41E-07	1.36E-06	9.43E-05	
% of ODCM Limit - ECL	%	1.42E-03	1.32E+00	7.41E-03	1.36E-02	9.43E-01	
Dissolved and Entrained Gases	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total Release	Ci	< LLD	< LLD	< LLD	< LLD	< LLD	21.1
Average Concentration	uCi/ml	< LLD	< LLD	< LLD	< LLD	< LLD	
% of ODCM Limit - ECL	%	N/A	N/A	N/A	N/A	N/A	
Gross Alpha	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total Release	Ci	< LLD	< LLD	< LLD	<LLD	< LLD	23.0
Average Concentration	uCi/ml	< LLD	< LLD	< LLD	<LLD	<LLD	
Volume of Waste Released	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total	Liters	3.79E+04	7.55E+05	2.08E+05	1.89E+04	1.02E+06	5.0
Volume of Dilution Water used during period	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**	**Uncertainty (%)**
Total	Liters	1.51E+06	2.60E+07	8.33E+06	7.57E+05	3.66E+07	5.0

* Percent of limit includes gases and tritium.

SITE: LIMERICK GENERATING STATION – UNITS 1 & 2
LICENSEE: EXELON GENERATION COMPANY, LLC

TABLE 2A–1 LIQUID EFFLUENTS - BATCH MODE PERIOD 2020

Fission and Activation Products	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Cr-51	Ci	< LLD	1.66E-05	< LLD	< LLD	1.66E-05
Mn-54	Ci	< LLD	5.57E-05	< LLD	< LLD	5.57E-05
Co-58	Ci	< LLD	3.27E-05	< LLD	< LLD	3.27E-05
Co-60	Ci	< LLD	3.41E-04	< LLD	< LLD	3.41E-04
Zn-65	Ci	< LLD	1.01E-05	< LLD	< LLD	1.01E-05
Sr-89	Ci	< LLD	9.76E-04	< LLD	< LLD	9.76E-04
Sr-90	Ci	< LLD	2.00E-04	< LLD	< LLD	2.00E-04
Total	Ci	< LLD	1.63E-03	< LLD	< LLD	1.63E-03
Dissolved and Entrained Gases	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Xe-133	Ci	< LLD	6.07E-03	< LLD	< LLD	6.07E-03
Xe-135	Ci	< LLD	7.01E-06	< LLD	< LLD	7.01E-06
Total	Ci	< LLD	6.07E-03	< LLD	< LLD	6.07E-03
H-3	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	2.20E-04	3.54E+00	6.33E-03	1.05E-03	3.55E+00
Gross Alpha	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	< LLD	< LLD	< LLD	< LLD	< LLD

SITE: LIMERICK GENERATING STATION – UNITS 1 & 2
LICENSEE: EXELON GENERATION COMPANY, LLC

TABLE 2A-2 LIQUID EFFLUENTS - CONTINUOUS MODE PERIOD 2020

Fission and Activation Products	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	N/A	N/A	N/A	N/A	N/A
Dissolved and Entrained Gases	**Units**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Total**
Total	Ci	N/A	N/A	N/A	N/A	N/A
H-3	**Units**	**Qtr**	**Qtr**	**Qtr**	**Qtr**	**Tot**
Total	Ci	N/A	N/A	N/A	N/A	N/A
Gross Alpha	**Units**	**Qtr**	**Qtr**	**Qtr**	**Qtr**	**Tot**
Total	Ci	N/A	N/A	N/A	N/A	N/A

Appendix B
Solid Waste and Irradiated Fuel Shipments

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SITE: LIMERICK GENERATING STATION – UNITS 1 & 2
LICENSEE: EXELON GENERATION COMPANY, LLC

A. Solid waste shipped offsite for burial or disposal (not irradiated fuel) 1/1/20 – 12/31/20

1. Type of waste

Type of waste	Unit	12 Month Period	Estimated Error %
a. Spent resin, filters sludges, evaporator bottoms, etc	m^3	86.7	25%
	Ci	520	

b. Dry compressible waste, contaminated equipment, etc.	m^3	605	25%
	Ci	1.24	

c. Irradiated components, control rods, etc.	m^3	None	N/A
	Ci	None	

d. Other (Describe)	m^3	48.1	25%
	Ci	0.134	

2. Estimate of Major Nuclide Composition (By Waste Type)

Category A – Spent Resin, Filters, Sludges, Evaporator Bottoms, etc.

Isotope	Waste Class A Curies *	Percent Abundance
Mn-54	3.13E+01	6.01%
Fe-55	7.93E+01	15.25%
Co-60	3.39E+02	65.26%
Zn-65	4.44E+01	8.54%
TOTALS	4.94E+02	95.06%

* Activity is estimated

Category B – Dry Compressible Waste, Contaminated Equipment, etc.

Isotope	Waste Class A Curies *	Percent Abundance
Mn-54	6.61E-02	5.34%
Fe-55	5.20E-01	42.05%
Co-60	5.22E-01	42.23%
TOTALS	1.11E+00	89.62%

* Activity is estimated

Category D – Other Waste (Mop Water)

Isotope	Waste Class A Curies *	Percent Abundance
Mn-54	7.31E-03	5.45%
Fe-55	4.05E-02	30.16%
Co-60	8.15E-02	60.76%
TOTALS	1.29E-01	96.37%

3. Solid Waste (Disposition)

Number of Shipments	Mode of Transportation	Destination
9	Hittman Transportation Services	Energy Solutions-1560 Bear Creek Road, TN
7	Hittman Transportation Services	Energy Solutions-Gallaher Road Facility, TN
19	Hittman Transportation Services	Energy Solutions-Clive Disposal Site, UT

Comments: None

B. Irradiated Fuel Shipments (disposition)

Number of Shipments	Mode of Transportation	Destination
0	N/A	N/A

C. Changes to the Process Control Program

There were no revisions to RW-AA-100, “Process Control Program for Radioactive Wastes” in 2020.

Appendix C
Meteorological Data

In accordance with Regulatory Guide 1.21, the meteorological data do not need to be reported in the ARERR, but the data is summarized and maintained as documentation (records). An annual meteorological summary report that provides the joint frequency distributions of wind direction and wind speed by atmospheric stability class (see Regulatory Guide 1.23) are prepared and maintained in records for the life of the plant.

Appendix D
Errata

There is no errata data reported.