Nuclear Fuel Waste Projections in Canada – 2011 Update

NWMO TR-2011-25 December 2011

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ABSTRACT

Title: **Nuclear Fuel Waste Projections in Canada – 2011 Update**
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Abstract
Since the Nuclear Waste Management Organization submitted its Final Study in 2005, there have been a number of planned and proposed nuclear refurbishment and new-build initiatives which could extend the projected end of nuclear reactor operation in Canada from about 2034 to about 2085 or beyond.

The important technical features of these recent nuclear initiatives include:

- The amount of used nuclear fuel produced in Canada; and
- The type of used nuclear fuel produced in Canada;

This report updates the 2010 report [Garamszeghy, 2010] and summarizes the existing inventory of used nuclear fuel wastes in Canada as of June 30, 2011 and forecasts the potential future arisings from the existing reactor fleet as well as from proposed new-build reactors. The report focuses on power reactors, but also includes prototype, demonstration and research reactor fuel wastes held by AECL.

As of June 30, 2011, a total of approximately 2.3 million used CANDU fuel bundles (approx 46,000 tonnes of heavy metal (t-HM)) were in storage at the reactor sites, an increase of approximately 77,000 bundles (approx 1,500 t-HM) from the 2010 report. For the existing reactor fleet, the total projected number used fuel bundles produced to end of life of the reactors ranges from about 3.0 to 5.3 million used CANDU fuel bundles (61,000 t-HM to 107,000 t-HM), depending upon decisions to refurbish current reactors. The lower end is based on an average of 25 effective full power years (EFPY) of operation for each reactor (i.e. no refurbishment), while the upper end assumes that reactors are refurbished and life extended for an additional 25 EFPY of operation. This is increased slightly from the 2010 report due to change in life assumptions.

Based on currently announced refurbishment and life extension plans for the existing nuclear reactor fleet in Canada, the NWMO has assumed a reference projected used fuel inventory of 4.6 million CANDU fuel bundles.

Used fuel produced by potential new-build reactors will depend on the size and type of reactor and number of units deployed. New-build plans are at various stages of development and the decisions about whether to proceed with individual projects, reactor technology and number of units have not yet been made. If all of the units where a formal licence application has already been submitted are constructed, the total additional quantity of used fuel from these reactors could be up to approximately 1.6 million CANDU fuel bundles (30,000 t-HM), or 10,800 PWR fuel assemblies (5,820 t-HM). This total is has been reduced from the 2010 report due to the formal withdrawal of some new-build licence applications by the proponents.

When decisions on new nuclear build and reactor refurbishment are made by the nuclear utilities in Canada, any resulting changes in forecasted inventory of nuclear fuel waste will be incorporated into future updates of this report.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 BACKGROUND

The Nuclear Waste Management Organization (NWMO) has a legal obligation to manage all of Canada's used nuclear fuel – that which exists now and that which will be produced in the future. The NWMO continually monitors new developments to be prepared to assume its legal responsibility to manage used nuclear fuel in light of these evolving energy developments.

In recent years, interest in new nuclear generation has increased. New Brunswick, Ontario, Saskatchewan, and even Alberta (heretofore a "non-nuclear" province) have considered adding new nuclear capacity to their energy mix. Ontario submitted an application to the Canadian Nuclear Safety Commission (CNSC) for the construction of new nuclear at Darlington. In its application, in addition to two CANDU reactor designs, consideration is also being given to introducing light water reactors, a technology used elsewhere in the world that produces used nuclear fuel with characteristics different from those which Canadian nuclear operators now manage.

Decisions on new nuclear reactors, advanced fuel cycles or other changes in energy choices will not be made by the NWMO. They will be taken by nuclear operators in conjunction with government and the regulators. It is important that the NWMO recognize these uncertainties and put in place an active process for ongoing monitoring and review of new developments so that it can plan for the long-term management of used fuel arising from such decisions.

As energy policy decisions are taken that substantially affect the volumes and/or types of used fuel that the NWMO must manage, the ongoing engagement of Canadians on the social, ethical and technical appropriateness of the long-term management plans for these materials must be provided for. As part of continuing engagement of Canadians, the NWMO will be discussing with interested individuals and organizations how changing conditions, such as new-build, different fuel types or advanced fuel cycles should be addressed. The NWMO will continually review, adjust and validate implementation plans as appropriate against the changing external environment.

1.2 PURPOSE

The NWMO has made a commitment to publish information on current and future potential inventories of used fuel volumes and types on an annual basis [NWMO, 2010]. This document is the fourth such annual report and provides an update to the 2010 version [Garamszeghy, 2010].

1.3 SCOPE

This report summarizes the existing inventory of used nuclear fuel wastes in Canada as of June 30, 2011 and forecasts the potential future arisings from the existing reactor fleet as well as from proposed new-build reactors. The report focuses on power reactors, but also includes information on prototype, demonstration and research reactor fuel wastes held by AECL.

1.4 CHANGES SINCE THE 2010 REPORT

The primary changes to the Canadian nuclear landscape since the 2010 report are:

a) Schedule changes in reactor refurbishment projects at Pt Lepreau and Bruce A and changes to the end-of-life assumptions for Pickering and Bruce reactors (due to planned maintenance activities);

b) The inclusion of the AECL EC-6 reactor type in the list of potential reactor types for the Darlington new-build project;

c) The completion of the public hearings around the Darlington new-build environmental assessment and the issuing of the Joint Review Panel (JRP) report; and

d) An increase in the amount of used fuel currently in wet and dry storage, due to another year of reactor operation.

The overall effects of these changes on the projected used fuel inventory are:

a) An increase in the total amount of used fuel currently in storage from June 30, 2010 to June 30, 2011.

	June 30, 2010	**June 30, 2011**	**Net change**	
Wet storage	1,541,473	1,545,642	4,169	bundles
Dry storage	655,138	728,231	73,093	bundles
TOTAL	**2,196,611**	**2,273,873**	**77,262**	**bundles**

b) An increase to the projected future total number of used fuel bundles produced by the existing reactor fleet for the low forecast (to 3.0 million bundles from 2.8 million bundles) and the high forecast (to 5.3 million bundles from 5.1 million bundles) due to changes in the assumptions around end-of-life dates for the reactors. A “reference scenario” has been added based on announced refurbishment plans of reactor operators resulting in a forecast of 4.6 million bundles; and

c) A reduction in the total projected quantity of used fuel assumed from new-build reactors to approximately 1.6 million CANDU fuel bundles (30,000 t-HM), or 10,800 PWR fuel assemblies (5,820 t-HM). This total has been reduced from the 2010 report due to the formal withdrawal of some new-build licence applications by the proponents. (Note that the new-build projections depend on the selection of reactor type which has not yet been determined).

Additional changes and considerations include the sale of AECL reactor division to a private company, which may affect the future development and commercialization of reactors in Canada.

2. INVENTORY FROM EXISTING REACTORS

2.1 CURRENT INVENTORIES

Table 1 summarizes the current inventory of nuclear fuel waste in Canada as of June 30, 2011. The inventory is expressed in terms of number of CANDU used fuel bundles and does not include fuel which is currently in the reactors, which is not considered to be "nuclear fuel waste" until it has been discharged from the reactors.

TABLE 1: Summary of Nuclear Fuel Waste in Canada as of June 30, 2011

Location	Waste Owner	Wet Storage (# bundles)	Dry Storage (# bundles)	TOTAL (# bundles)	Current Status
Bruce A	OPG(2)	361,206	60,288	421,494	- 2 units operational, 2 units under refurbishment (expected 2012 return to service)
Bruce B	OPG(2)	368,773	175,478	544,251	- 4 units operational
Darlington	OPG	334,092	65,631	399,723	- 4 units operational
Douglas Point	AECL	0	22,256	22,256	- permanently shut down
Gentilly 1	AECL	0	3,213	3,213	- permanently shut down
Gentilly 2	HQ	33,533	87,000	120,533	- operational (expected to be shut down for refurbishment in 2012)
Pickering A	OPG	407,280	226,211	633,491	- 2 units operational, 2 units permanently shut down
Pickering B	OPG				- 4 units operational
Point Lepreau	NBPN	40,758	81,000	121,758	- currently undergoing refurbishment (expected 2012 return to service)
AECL Whiteshell	AECL	0	2,268	2,268	- permanently shut down. See Note (1)
AECL Chalk River	AECL	0	4,886	4,886	- mostly fuel from NPD (permanently shut down) and with small amounts from other CANDU reactors. See note (3)
	TOTAL	***1,545,642***	***728,231***	***2,273,873***	Total of: - 17 units in operation - 3 units under refurbishment - 6 units permanently shut down

Notes:

AECL = Atomic Energy of Canada Limited
HQ = Hydro-Québec
NBPN = New Brunswick Power Nuclear
OPG = Ontario Power Generation Inc

(1) 360 bundles of Whiteshell fuel are standard CANDU bundles. The remaining bundles are various research, prototype and test fuel bundles, similar in size and shape to standard CANDU bundles.
(2) Bruce reactors are leased to Bruce Power for operation.
(3) In addition to the totals shown in Table 1, AECL also has some ~22,000 components of research and development fuels such as fuel elements, fuel pellets and fuel debris in storage at Chalk River. While the total mass of these components is small compared to the overall quantity of CANDU fuel, their varied storage form, dimensions, etc. requires special consideration for future handling.

Assuming a rounded average of 20 kg heavy metals in a fuel bundle, 2.3 million bundles is equivalent to approximately 46,000 tonnes of heavy metal (t-HM). Further details on the existing reactors can be found in Appendix A.

2.2 FUTURE FORECASTS

Forecasts of future nuclear fuel waste arisings are given in Table 2. Three scenarios are provided in the forecasts:

a) **Low:** the reactors are shut down at the end of the projected life of the fuel channels (i.e. nominal 25 effective full power years of operation, with some planned life extension maintenance activities;

b) **Reference:** Based on announced life plans for the reactor fleet (i.e. refurbishment or not).

c) **High:** most of the reactors are refurbished with a new set of pressure tubes and other major components, then operated for a further nominal 25 effective full power years. Pickering reactors will be run until 2019 [OPG, 2010].

Note that these scenarios are constructed for NWMO planning purposes only to provide a range of possible fuel arisings and may differ from the official business plans and operational assumptions of the reactor operators. Operation of the reactors, including whether or not to refurbish or life extend, are subject to future business planning decisions of the individual reactor operators. Forecasts are expressed in terms of number of used CANDU fuel bundles and are rounded to nearest thousand bundles. Details are provided in Appendix B.

TABLE 2: Summary of Projected Nuclear Fuel Waste from Existing Reactors

Location	Waste Owner	Total June 2011 (# bundles)	Typical Annual Production (# bundles)	Low Scenario (# bundles)	Reference Scenario (# bundles)	High Scenario (# bundles)
Bruce A	OPG	421,494	20,500 (1)	530,000	1,170,000 (4)	1,170,000 (4)
Bruce B	OPG	544,251	23,500 (1)	768,000	768,000	1,497,000
Darlington	OPG	399,723	22,000 (1)	631,000	1,291,000	1,291,000
Douglas Point	AECL	22,256	0 (2)	22,256	22,256	22,256
Gentilly 1	AECL	3,213	0 (2)	3,213	3,213	3,213
Gentilly 2	HQ	120,533	4,500	131,000	268,000	268,000
Pickering A	OPG	633,491	7,200 (3)	797,000	797,000 (5)	797,000 (5)
Pickering B	OPG		14,500 (1)			
Point Lepreau	NBPN	121,758	4,500	121,758	260,000 (7)	260,000 (7)
AECL Whiteshell	AECL	2,268	0 (2)	2,268	2,268	2,268
AECL Chalk River	AECL	4,886	0 (6)	4,886	4,886	4,886
TOTAL (bundles)(8)		**2,273,873**	**96,700**	**3,012,000**	**4,587,000**	**5,306,000**
(t-HM)		***45,000***	***1,940***	***61,000***	***92,000***	***107,000***

Notes:

1) Based on 4 reactors operating.
2) Reactor is permanently shut down and not producing any more fuel.
3) Based on 2 reactors operating.
4) All units at Bruce A are assumed to be refurbished (refurbishment currently under way for 2 units).
5) Pickering reactors assumed to be operated until 2019 only.
6) Future forecasts do not include research fuels. AECL Chalk River does not produce any power reactor CANDU used fuel bundles.
7) Point Lepreau is currently shut down for refurbishment and is expected to re-start in 2012.
8) Totals may not add exactly due to rounding to nearest 1,000 bundles for future forecasts.

3. INVENTORY FROM POTENTIAL NEW-BUILD REACTORS

There are two categories of proposed new reactor projects:

a) projects which are currently undergoing an environmental assessment; and

b) projects which are in the preliminary discussion or consideration phase

This report does not assess the probability of any of these projects proceeding. Execution of the projects rests entirely with the proponent. In addition, the technologies for each project have not yet been selected. Until such decisions have been made by the proponents, the forecast regarding types and amounts of fuel resulting from new-build projects is highly speculative. The NWMO will continue to monitor the situation and will evaluate the implications and options for the different fuel types as part of the review of the Adaptive Phased Management approach.

TABLE 3: Summary of Proposed New Reactors

Proponent	Location	In-service timing	Reactor Type(s)	Status
Projects currently undergoing an Environmental Assessment				
OPG	Darlington, Ontario	First unit 2018 (see note 1)	4 x ACR 1000 or 4 x EC-6 or 4 x AP1000 or 3 x EPR (see note 1)	Selected as site for first 2 reactors by Ontario Government EIS report & updated application for a site preparation licence was submitted Sept 30, 2009. [OPG, 2009] Joint Panel Review public hearing conducted in 2011 and report issued on EIS, Aug 2011 [JRP, 2011].
Additional projects in preliminary discussion or previous consideration				
Bruce Power / Energy Alberta	Northern Alberta	First unit assumed 2017	4 x ACR 1000 or 3 x AP1000 or 2 x EPR or 2 x ESBWR	Site preparation licence application submitted to CNSC March 2008, withdrawn 2009. [Bruce Power, 2009b]
Province of New Brunswick	Point Lepreau, New Brunswick	First unit assumed 2020	ACR 1000 ATMEA1 PWR KERENA BWR	Feasibility study being conducted [MZConsulting, 2008] [AREVA, 2010]
Bruce Power Saskatchewan	Saskatchewan (no specific site selected yet)	First unit assumed 2020	ACR 1000 or AP1000 or EPR	Feasibility study conducted by Bruce Power [Bruce Power, 2008b]

Notes:

1) Selection of reactor type for new-build in Ontario was to be made by Ontario Government (Infrastructure Ontario) in 2009. However, although the procurement process was suspended in June 2009 until further notice [Infrastructure Ontario, 2009], in November 2010 the Ontario Government stated that they were still committed to constructing new nuclear units at Darlington. [MEI, 2010]. The EA process continued with public hearings in the spring of 2011 and the Joint Review Panel issued its report on the EIS in August. [JRP, 2011]

3.1 PROJECTS CURRENTLY UNDERGOING ENVIRONMENTAL ASSESSMENT

3.1.1 ONTARIO POWER GENERATION

OPG is currently undertaking an environmental assessment (EA) for building up to 4 new reactors at its Darlington site, in Clarington just east of Toronto [OPG, 2007]. The Darlington site has been selected by the Government of Ontario to host the first two new-build reactors in the province, with an expected in service date of 2018. The Environmental Impact Statement (EIS), which was submitted in 2009, was based on the maximum physical capacity of the site to allow for possible future expansion. A Joint Panel Review was conducted in 2011. In August 2011, the Joint Review Panel issued its report on the EA with a conclusion that “the project is not likely to cause significant adverse environmental effects, provided the mitigation measures proposed and commitments made by OPG during the review, and the Panel’s recommendations are implemented” [JRP, 2011].

Currently four reactor types are being considered:

a) ***AECL ACR 1000 (Advanced CANDU reactor)***, which is a 1085 MW(e) net heavy water moderated, light water cooled pressure tube reactor. Up to 4 ACR 1000 reactors would be built on the site in two twin unit pairs. This would result in a total lifetime production of approximately 770,400 used fuel bundles (12,480 t-HM).

b) ***AECL EC-6 (Enhanced CANDU 600 reactor)***, which is a 686 MW(e) net heavy water reactor, similar to the existing CANDU 600 reactors at Gentilly-2, Point Lepreau and elsewhere in the world. Up to 4 EC-6 reactors would be built on the site in two twin unit pairs. This would result in a total lifetime production of approximately 1,572,000 used fuel bundles (30,000 t-HM).

c) ***Westinghouse AP1000***, which is a 1037 MW(e) net pressurized light water reactor. Up to 4 AP1000 reactors would be built on the site, which would result in a total lifetime production of approximately 10,800 PWR fuel assemblies (5,820 t-HM).

d) ***AREVA EPR (Evolutionary Power Reactor)***, which is a 1580 MW(e) net pressurized light water reactor. Up to 3 EPR reactors would be built on the site, which would result in a total lifetime production of approximately 9,900 PWR fuel assemblies (5,220 t-HM).

All four reactor designs are considered to be “Generation III+”, and are designed to operate for 60 years. The Province, through its Infrastructure Ontario program, will be selecting the preferred vendor. However, the selection process was suspended in June 2009 [Infrastructure Ontario, 2009].

The EC-6 uses standard CANDU fuel, with options for advanced fuel types (SEU, MOX, etc). As described below in Section 3.3 (with further details in Appendix C), the other three reactor types operate with enriched uranium fuel. The ACR 1000 fuel is similar in size and shape to existing CANDU fuel bundles. The AP1000 and EPR fuel assemblies are considerably different from the CANDU fuels in terms of size and mass, but are very similar to conventional pressurized light water reactor fuels used in many other countries around the world.

3.2 ADDITIONAL PROJECTS IN PRELIMINARY DISCUSSION OR RECENT CONSIDERATION

These projects have been discussed in various public fora and feasibility studies in recent years. However, there are currently no active environmental assessments underway for these projects and any potential implementation would be in the much longer term. (Note that the projected in-service dates are those which were referenced in the original plans.)

3.2.1 ALBERTA

Bruce Power Alberta submitted a site preparation licence application to the CNSC in March 2008 to construct up to 4 power reactors in the municipal district of Northern Lights, Alberta, with the first unit being in-service as early as 2017 [Bruce Power Alberta, 2008]. The application for the preferred site was withdrawn in 2009, with a statement indicating that Bruce Power was studying other sites and would re-submit an application once a site had been chosen. [Bruce Power, 2009b].

A preferred reactor type was not specified in the licence application. However, four reactor types were included:

a) ***AECL ACR 1000*** – up to 4 ACR 1000 reactors would be built on the site in two twin unit pairs. This would result in a total lifetime production of approximately 770,400 used fuel bundles (12,480 t-HM).

b) ***Westinghouse AP1000*** – up to 3 AP1000 reactors would be built on the site, which would result in a total lifetime production of approximately 8,100 PWR fuel assemblies (4,365 t-HM).

c) ***AREVA EPR*** – up to 2 EPR reactors would be built on the site, which would result in a total lifetime production of approximately 6,600 PWR fuel assemblies (3,480 t-HM).

d) ***GE ESBWR (Economic Simplified Boiling Water Reactor)***, which is a 1535 MW(e) net boiling light water reactor. Up to 2 ESBWR reactors would be built on the site, which would result in a total lifetime production of approximately 27,000 BWR fuel assemblies (3,384 t-HM).

3.2.2 NEW BRUNSWICK

The Province of New Brunswick has conducted a feasibility study to construct a second reactor at the Point Lepreau site, based on an ACR 1000 reactor type [MZConsulting, 2008]. No in-service date has been publicly announced yet. The ACR 1000 would result in a total lifetime production of approximately 192,600 used fuel bundles (3,120 t-HM).

More recently, a “letter of intent” has been signed between the Province of New Brunswick and AREVA to develop a “clean energy park” near the existing Point Lepreau site [AREVA, 2010], which would consist of one or more mid-sized Generation III+ light water reactors, such as the 1250 MW(e) KERENA boiling water reactor (formerly known as the SWR-1000 reactor) or the 1100 MW(e) ATMEA 1 pressurized water reactor. The original planning assumed that the first unit would be in operation about 2020.

The three reactor types included above are:

a) ***AECL ACR 1000*** – This would result in a total lifetime production of approximately 192,600 used fuel bundles (3,120 t-HM).

b) ***AREVA KERENA*** – No estimates are currently available for the lifetime fuel production of the KERENA reactor. However, based on the relative power ratings, the total number and mass of fuel assemblies is expected to be less than that for the ESBWR.

c) ***AREVA ATMEA 1*** – No estimates are currently available for the lifetime fuel production of the ATMEA 1 reactor. However, based on the relative power ratings, the total number and mass of fuel assemblies is expected to be similar to the AP1000.

3.2.3 SASKATCHEWAN

Bruce Power Saskatchewan has conducted feasibility studies for constructing one or more power reactors in the Province of Saskatchewan. No specific site has been selected. The originally assumed earliest in-service date was in the 2020 timeframe.

The facility would likely be a single unit and three reactor technologies were being considered [Bruce Power, 2008b]:

a) ***AECL ACR 1000*** – This would result in a total lifetime production of approximately 192,600 used fuel bundles (3,120 t-HM).

b) ***Westinghouse AP1000*** – This would result in a total lifetime production of approximately 2,700 PWR fuel assemblies (1,455 t-HM).

c) ***AREVA EPR*** – This would result in a total lifetime production of approximately 3,300 PWR fuel assemblies (1,740 tonnes of uranium).

In August 2011, the Government of Saskatchewan announced a nuclear research and development agreement with Hitachi-GE. One of the objectives was for research on the design and feasibility of small reactor technologies for potential use in future Saskatchewan energy supply [Saskatchewan, 2011].

3.2.4 ONTARIO

Bruce Power had submitted its Environmental Impact Statement (EIS) for new-build at the Bruce Power site in 2008 [Bruce Power, 2008a]. Bruce Power also announced on October 31, 2008 that they would be starting an environmental assessment to construct 2 reactors near the Nanticoke site in Ontario. In July 2009, Bruce Power subsequently announced that they had withdrawn their applications for these two projects [Bruce Power, 2009a].

3.3 SUMMARY OF NUCLEAR FUEL CHARACTERISTICS FROM NEW-BUILD REACTORS

Table 4 presents a summary of the major characteristics and quantities of nuclear fuels that are used in the proposed new-build reactor types. Further details can be found in Appendix C. The data have been extracted from references [Bruce Power, 2008a], [Bruce Power, 2008c], [IAEA, 2004] and [JRP, 2011]. Note that various other sources of data may quote different numbers for fuel properties and used fuel production rates. This is generally due to the preliminary nature of some of the designs combined with the various ways some of the reactors can be operated (e.g. enrichment level and burnup, assumed capacity factors, length of operating period between re-fuelling outages for light water reactors, conservative assumptions used for environmental assessment purposes, etc). The quantities and characteristics used for forecasting in this report will be updated as reactor types are selected and their designs are further defined.

Details of the fuel used in the ATMEA 1 and KERENA reactors recently proposed for New Brunswick are not currently available. However, the characteristics and quantities are expected to be similar to other PWR (e.g. AP1000) and BWR (e.g. ESBWR) fuels of equivalent power ratings. Further details will be included in future updates of this report. (Currently available basic information about these fuel types is included in Table 4 from published sources).

Table 5 summarizes the total quantity of used fuel that might be produced for the various proposed new-build reactors. Note that the totals correspond to the case where all of the new-build reactors are of the same type. In reality, different reactor types might be built in the different locations. As mentioned above, until decisions on reactor types, number of units and operating conditions are taken by the proponents, these forecasts remain highly speculative.

The total additional quantity of used fuel from these reactors could be up to 1.9 million CANDU fuel bundles (31,200 t-HM), or 21,600 PWR fuel assemblies (11,640 t-HM), or 27,000 BWR fuel assemblies (3,384 t-HM), or some combination thereof.

These total projections have not changed from the 2010 forecasts. However, the sale of AECL to a private company in 2011 may affect the future development of reactor types in Canada (e.g. choice of EC-6 versus ACR).

For NWMO planning purposes, a conservative, but reasonable, projection for new-build is based on four AECL EC-6 reactors at Darlington. This is the only project currently undergoing regulatory approvals and, of the technologies under consideration, the EC-6 reactor will produce the most used nuclear fuel over its lifetime for this project (1.6 million bundles for 4 reactors, compared to 0.8 million bundles for 4 AECL ACR reactors).

TABLE 4: Summary of Fuel Types for Proposed New Reactors

Parameter	ACR 1000	EC-6	AP1000	EPR	ESBWR	KERENA	ATMEA 1
Reactor Type	Horizontal pressure tube, heavy water moderated, light water cooled	Horizontal pressure tube, heavy water moderated and cooled	Pressurized light water reactor	Pressurized light water reactor	Boiling light water reactor	Boiling light water reactor	Pressurized light water reactor
Net Power [MW(e)]	1085	686	1037	1580	1535	1250	1100
Fuel type	CANFLEX ACR fuel bundle	37 element CANDU bundle	Conventional 17x17 PWR fuel design	Conventional 17x17 PWR fuel design	Conventional 10x10 BWR fuel design	12x12 BWR fuel design	Conventional 17x17 PWR fuel design
Fueling method	On power	On power	Refueling shutdown every 12 to 24 months and replace portion of the core	Refueling shutdown every 12 to 24 months and replace portion of the core	Refueling shutdown every 12 to 24 months and replace portion of the core	Refueling shutdown every 12 to 24 months and replace portion of the core	Refueling shutdown every 12 to 24 months and replace portion of the core
Fuel enrichment	Up to 2.5% for equilibrium core	Natural U, with options for SEU (1.2%) and MOX	2.4-4.5% avg initial core 4.8% avg for reloads	Up to 5% for equilibrium core	1.7-3.2% avg initial core 4.5% avg for reloads	2.47% avg initial core 3.54% avg fo reloads at equilibrium 4.7% max	Up to 5% for equilibrium core
Fuel dimensions	102.49 mm OD x 495.3 mm OL	102.49 mm OD x 495.3 mm OL	214 mm square x 4795 mm OL	214 mm square x 4805 mm OL	140 mm square x 4470 mm OL	3765 mm OL	214 mm square x 4200 mm OL
Fuel assembly U mass [kg initial U]	16.2	19.2	538.3	527.5	126.9	~205	n/d
Fuel assembly total mass [kg]	21.5	24.0	789	780	~238	~325	n/d
# of fuel assemblies per core	6,240	4,560	157	241	1,132	664	157
Fuel load per core [kg initial U]	101,088	87,552	84,513	127,128	143,651	137,000	n/d
Annual used fuel production [t-HM/yr per reactor]	52	126	24	29	28	n/d	n/d
Annual used fuel production [number of fuel assemblies/yr per reactor]	3,210	6,550	45	55	225	n/d	n/d
Lifetime used fuel production [t-HM per reactor]	3,120	7,500	1,455	1,740	1,692	n/d	n/d
Lifetime used fuel production [number of fuel assemblies per reactor]	192,600	393,000	2,700	3,300	13,500	n/d	n/d

Note: Data extracted from references [Bruce Power, 2008a, 2008c], [IAEA, 2004] and [JRP, 2011]. Annual and lifetime data have been rounded.
n/d = data not available

TABLE 5: Summary of Fuel Forecasts for Potential New Reactors

Reactor	Ontario	Alberta	New Brunswick	Saskatchewan	Potential Total
Expected operation*	2018 to 2085	2017 to 2085	~2020 to 2080	~2020 to 2080	**2017 to 2085**
ACR 1000					
# of reactor units	4	4	1	1	**10**
Quantity of fuel (# bundles)	770,400	770,400	192,600	192,600	**1,926,000**
Tonnes of heavy metals (t-HM)**	12,480	12,480	3,120	3,120	**31,200**
EC-6					
# of reactor units	4	N/A	N/A	N/A	**4**
Quantity of fuel (# bundles)	1,572,000				**1,572,000**
(t-HM)**	30,000				**30,000**
AP 1000					
# of reactor units	4	3	N/A	1	**8**
Quantity of fuel (# assemblies)	10,800	8,100		2,700	**21,600**
(t-HM)**	5,820	4,365		1,455	**11,640**
EPR					
# of reactor units	3	2	N/A	1	**6**
Quantity of fuel (# assemblies)	9,900	6,600		3,300	**19,800**
(t-HM)**	5,220	3,480		1,740	**10,440**
ESBWR					
# of reactor units	N/A	2	N/A	N/A	**2**
Quantity of fuel (# assemblies)		27,000			**27,000**
(t-HM)**		3,384			**3,384**
KERENA					
# of reactor units	N/A	N/A	??	N/A	**??**
Quantity of fuel (# assemblies)			??		**??**
(t-HM)**			??		**??**
ATMEA 1					
# of reactor units	N/A	N/A	??	N/A	**??**
Quantity of fuel (# assemblies)			??		**??**
(t-HM)**			??		**??**

Note:
* Original planning dates. Actual dates will depend on decisions by reactor proponents
** “tonnes of heavy metals” (t-HM) includes uranium and all of the transuranics isotopes produced in the reactor as part of the nuclear reactions via various neutron activation and decay processes.

N/A = Not Applicable ?? = unknown at this time

4. SUMMARY OF PROJECTED USED FUEL INVENTORY

The projected inventory from current reactor operations, reactor refurbishment, and potential new reactors, developed in Sections 2 and 3, is summarized in Figure 1.

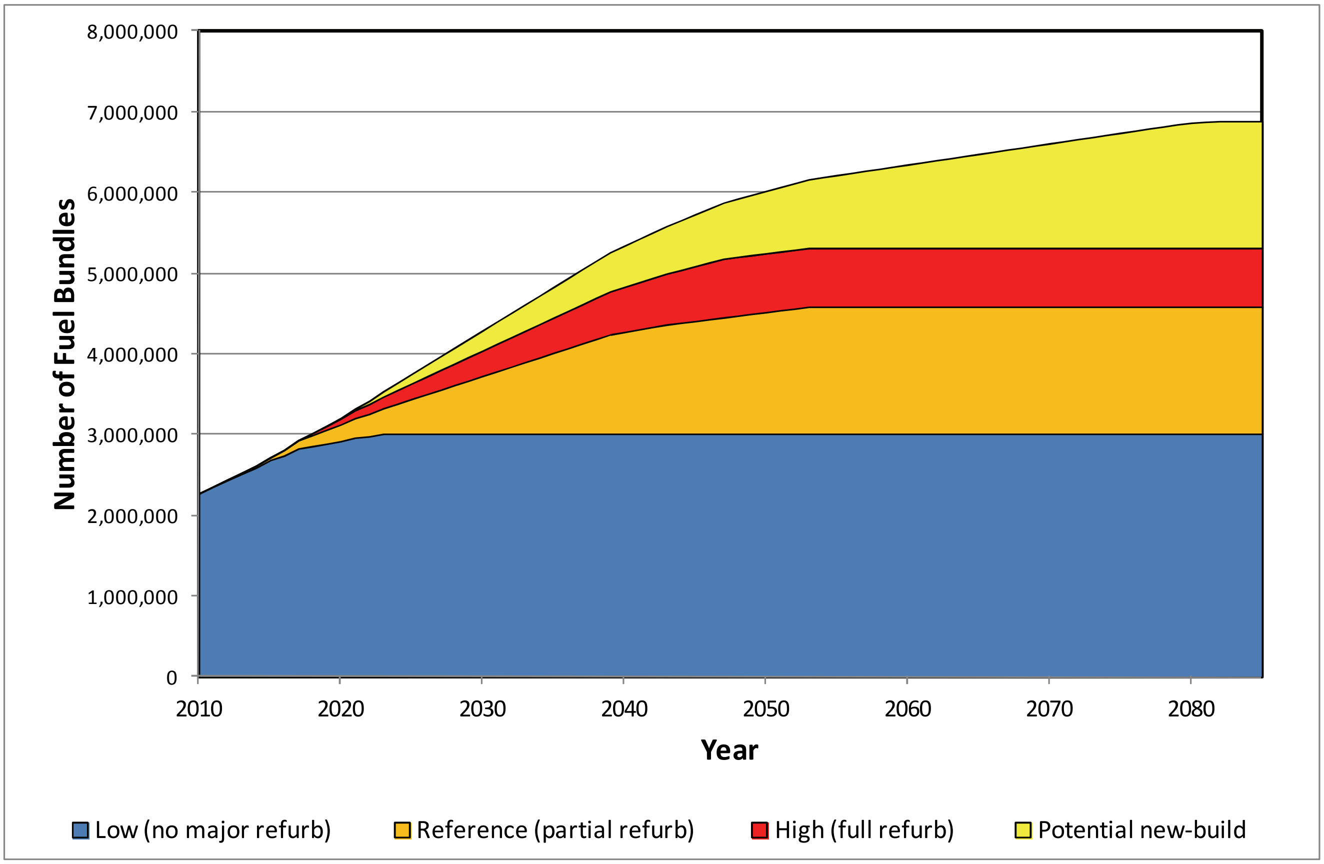

FIGURE 1: Summary of Projected Used Fuel Inventory

The "low forecast" (blue shaded area) represents the inventory from the existing Canadian fleet of reactors, up to the end of their initial operating period (nominal 25 effective full power years), including currently planned life-extension activities, but prior to major refurbishment (e.g. large scale fuel channel replacement or steam generator replacement). This amounts to a total of approximately 3.0 million CANDU fuel bundles, of which 2.3 million bundles are already existing in storage as of June 2011.

The "reference forecast" (orange shaded area) represents the additional fuel bundles that would be generated if all of the currently announced refurbishment and life extension projects for the existing Canadian reactor fleet are implemented. This amounts to an additional approximately 1.6 million CANDU fuel bundles, for a total of 4.6 million CANDU fuel bundles.

The "high forecast" (red shaded area) represents the additional used fuel bundles that would be generated if all of the existing Canadian reactor fleet is refurbished and life extended for another nominal 25 effective full power years of operation (except Pickering, which is planned to be shut down in 2019). This amounts to an additional approximately 0.7 million CANDU fuel bundles, for a total of 5.3 million CANDU fuel bundles.

Note that not all of the existing reactors may be refurbished and the decisions over whether or not to refurbish reactors will be taken by their owner/operators on a case-by-case basis over the next few years.

Based on currently announced refurbishment and life extension plans for the existing nuclear reactor fleet in Canada, the NWMO has assumed a reference projected used fuel inventory of 4.6 million CANDU fuel bundles (see Appendix B for details).

The “potential new-build” (yellow shaded area) represents the additional used fuel bundles that could be generated if four new AECL EC-6 reactors are constructed (i.e. the four currently undergoing environmental assessment at Darlington), amounting to approximately 1.6 million bundles over their projected 60 year operating life. This quantity and timing is highly speculative at this time, since decisions regarding potential new reactor numbers, types and in-service dates have not yet been taken. It will also depend on the operating history of the new reactors, such as capacity factors and achieved fuel burnup.

When definitive decisions on new nuclear build and reactor refurbishment are made by the nuclear utilities in Canada, any resulting changes in forecasted inventory of nuclear fuel waste will be incorporated into future updates of this report.

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APPENDIX A: SUMMARY OF EXISTING CANADIAN REACTORS

TABLE A1: Nuclear Power Reactors

Location	Rating (MW(e) net)	Year In-service	Fuel Type*	Current Status
Bruce Nuclear Power Development, Ontario				
Bruce A – 1	750	1977	37 element CANDU bundle	Undergoing refurbishment
Bruce A – 2	750	1977		Undergoing refurbishment
Bruce A – 3	750	1978		Operating
Bruce A – 4	750	1979		Operating
Bruce B – 5	795	1985	37 element CANDU bundle; 37 element "long" bundle; (option for 43 element CANFLEX LVRF bundle)	Operating
Bruce B – 6	822	1984		Operating
Bruce B – 7	822	1986		Operating
Bruce B – 8	795	1987		Operating
Darlington, Ontario				
Darlington 1	881	1992	37 element CANDU bundle; 37 element "long" bundle	Operating
Darlington 2	881	1990		Operating
Darlington 3	881	1993		Operating
Darlington 4	881	1993		Operating
Gentilly, Quebec				
Gentilly 2	635	1983	37 element CANDU bundle	Operating
Pickering, Ontario				
Pickering A – 1	515	1971	28 element CANDU bundle	Operating
Pickering A – 2	515	1971		Permanently shutdown in 2005
Pickering A – 3	515	1972		Permanently shutdown in 2005
Pickering A – 4	515	1973		Operating
Pickering B – 5	516	1983		Operating
Pickering B – 6	516	1984		Operating
Pickering B – 7	516	1985		Operating
Pickering B – 8	516	1986		Operating
Point Lepreau, New Brunswick				
Point Lepreau	635	1983	37 element CANDU bundle	Undergoing refurbishment

*Note: refer to Appendix C for description of fuel types

TABLE A2: Prototype and Demonstration Power Reactors

Location	Rating (MW(e) net)	Year In-service	Fuel Type	Current Status
Bruce Nuclear Power Development, Ontario				
Douglas Point (CANDU PHWR prototype)	206	1968	19 element CANDU bundle	Permanently shut down in 1984; All fuel currently in dry storage on site
Gentilly, Quebec				
Gentilly 1 (CANDU-BLW boiling water reactor prototype)	250	1972	18 element CANDU-BLW bundle	Permanently shut down in 1978; All fuel currently in dry storage on site
Rolphton, Ontario				
NPD (CANDU PHWR prototype)	22	1962	19 element CANDU bundle; various prototype fuel designs (e.g. 7 element bundle)	Permanently shut down in 1987; All fuel currently in dry storage at AECL Chalk River

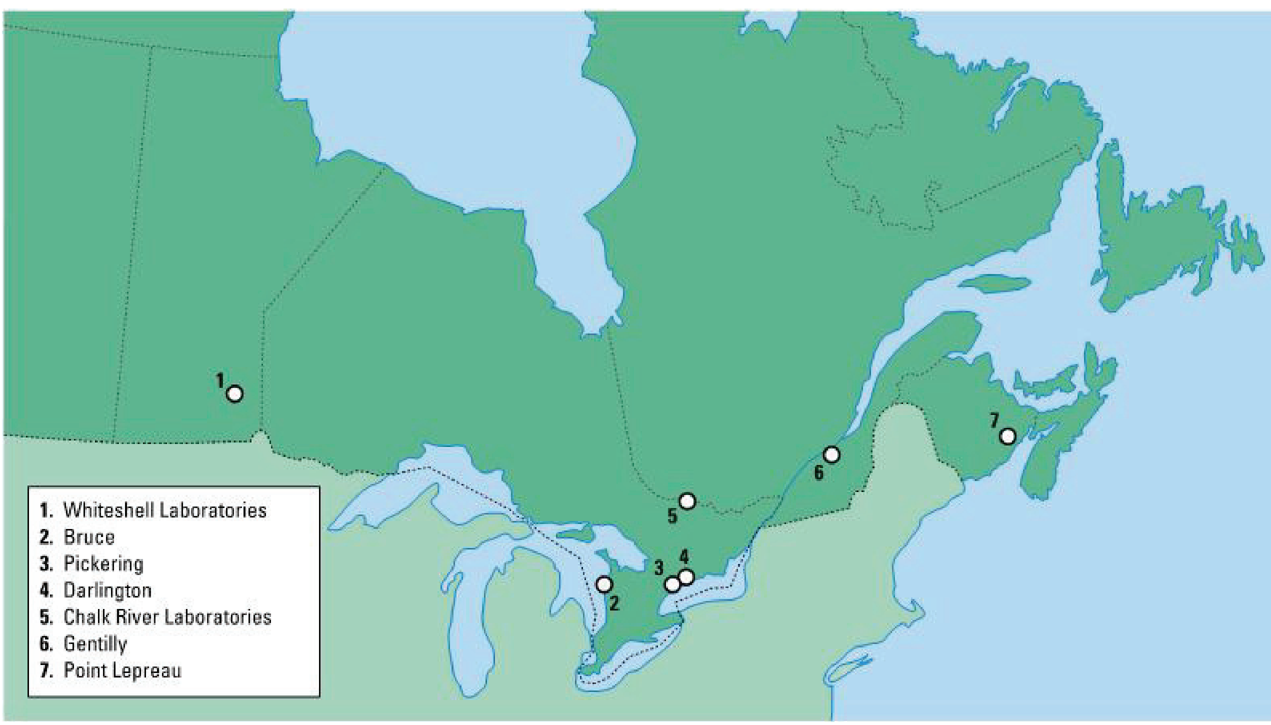


FIGURE A-1: Current Nuclear Fuel Waste Storage Locations in Canada

TABLE A3: Research Reactors

Location	Rating (MW(th))	Year In-service	Fuel Type	Comments
Hamilton, Ontario				
McMaster University	5	1959	(research)	MTR Pool type reactor
Kingston, Ontario				
Royal Military College	0.02	1985	(research)	(20 kW(th) SLOWPOKE 2)
Chalk River, Ontario				
NRU	135	1957	(research)	Operating
NRX	42	1947	(research)	Permanently shut down in 1992
MAPLE 1	10		-	Never fully commissioned
MAPLE 2	10		-	
ZED-2	250 W(th)	1960	(research)	Operating
Whiteshell, Manitoba				
WR-1 (organic cooled reactor prototype)	60 MW(th)	1965	various research and prototype fuel bundle designs (similar size and shape to standard CANDU bundles)	Permanently shut down in 1985; All fuel currently in dry storage on site
Montreal, Quebec				
Ecole polytechnique	0.02	1976	(research)	(20 kW(th) SLOWPOKE 2)
Halifax, Nova Scotia				
Dalhousie University	0.02	1976	(research)	(20 kW(th) SLOWPOKE 2, decommissioned 2011)
Edmonton, Alberta				
University of Alberta	0.02	1977	(research)	(20 kW(th) SLOWPOKE 2)
Saskatoon, Saskatchewan				
Saskatchewan Research Council	0.02	1981	(research)	(20 kW(th) SLOWPOKE 2)

Note: the SLOWPOKE reactors use U-235 enriched fuel and can operate on one fuel charge for 20 to 40 years. The total mass of U-235 fuel in a SLOWPOKE reactor core is about one kilogram. Other former research reactors include the 2 MW(th) Slowpoke Demonstration Reactor at Whiteshell, the low power PTR and ZEEP reactors at AECL Chalk River, and several shut down SLOWPOKE reactors at university sites. Used fuel from these shut down research reactors is stored at AECL Chalk River site, AECL Whiteshell site or has been returned to the country of origin (e.g. US).

APPENDIX B: USED FUEL WASTE FORECAST DETAILS FOR EXISTING REACTORS

Forecasts are based on:

Existing stations only (new build not considered).

[(June 2011 actuals) + (number of years from June 2011 to end-of-life) * (typical annual production of fuel bundles)] rounded to nearest 1000 bundles.

For multi-unit stations, the station total forecast is the sum of the above calculated on a unit-by-unit basis.

Total mass of fuel is based on an assumed rounded bundle mass of 20 kg of heavy metals (e.g. uranium).

End-of-life (EOL) dates are determined from the following scenario details:

a) **"Low" scenario:**
   - the reactors are shut down at the end of the projected life of the fuel channels (i.e. nominal 25 effective full power years (equivalent to 30 calendar years) of operation);
   - reactors that have been permanently shut down do not restart;
   - reactors that have been previously refurbished and are still operating, will operate to the end of their current expected service life; and
   - reactors which are currently undergoing refurbishment do not restart.

b) **"Reference" scenario:**
   - Based on announced life plans for the reactor fleet (i.e. refurbishment and life extension of all reactors except Pickering and Bruce B).

c) **"High" scenario:**
   - all reactors (except those mentioned below) are refurbished with a new set of pressure tubes and other major components, then operated for a further nominal 25 effective full power years (30 calendar years) to a total of 60 calendar years;
   - reactors that have been permanently shut down do not restart;
   - reactors that have been previously refurbished and are still operating, will operate to the end of their current expected service life only; and
   - reactors where a definite decision has been made not to refurbish (e.g. Pickering B), will operate to the end of their current expected service life only.

Note that forecasts are based on the above assumptions for NWMO planning purposes only and may differ from the business planning assumptions used by the reactor operators. In addition, as definitive decisions on refurbishment are taken by the reactor operators, the "high" and "low" scenarios will merge into the "reference" scenario in the future.

TABLE B1: Detailed Used Fuel Forecasts for Existing Reactors

Location	Unit	Startup	Total to June 2011 (# bundles)	Annual Production (# bundles)	Low Scenario (~25 EFPY) End-of-life	Low Scenario (~25 EFPY) (# bundles)	Reference Scenario End-of-life	Reference Scenario (# bundles)	High Scenario (~50 EFPY) End-of-life	High Scenario (~50 EFPY) (# bundles)
Bruce A	1	1977	421,494	20,500	1998	**530,000**	2042	**1,170,000**	2042	**1,170,000**
	2	1977			1998		2043		2043	
	3	1978			2022		2053		2053	
	4	1979			2022		2054		2054	
Bruce B	5	1985	544,251	23,500	2021	**768,000**	2021	**768,000**	2052	**1,497,000**
	6	1984			2021		2021		2052	
	7	1986			2021		2021		2052	
	8	1987			2021		2021		2052	
Darlington	1	1992	399,723	22,000	2022	**631,000**	2052	**1,291,000**	2052	**1,291,000**
	2	1990			2020		2050		2050	
	3	1993			2023		2053		2053	
	4	1993			2023		2053		2053	
Douglas Point		1968	22,256	0	1984	**22,256**	1984	**22,256**	1984	**22,256**
Gentilly 1		1972	3,213	0	1978	**3,213**	1978	**3,213**	1978	**3,213**
Gentilly 2		1983	120,533	4,500	2012	**131,000**	2043	**268,000**	2043	**268,000**
Pickering A	1	1971	633,491	7,200	2019	**797,000**	2019	**797,000**	2019	**797,000**
	2	1971			2005		2005		2005	
	3	1972			2005		2005		2005	
	4	1973			2019		2019		2019	
Pickering B	5	1983		14,500	2019		2019		2019	
	6	1984			2019		2019		2019	
	7	1985			2019		2019		2019	
	8	1986			2019		2019		2019	
Point Lepreau		1983	121,758	4,500	2008	**121,758**	2041	**260,000**	2041	**260,000**
AECL Whiteshell		1965	2,268	0	1985	**2,268**	1985	**2,268**	1985	**2,268**
AECL (NPD/other)			4,886	0		**4,886**		**4,886**		**4,886**
TOTALS (bundles)			**2,273,873**	**96,700**		**3,012,000**		**4,587,000**		**5,316,000**
(t-HM)			***45,000***	***1,940***		***61,000***		***92,000***		***107,000***

Reactor currently under refurbishment (yellow)

Reactor permanently shut down (red)

Reactor previously refurbished (blue)

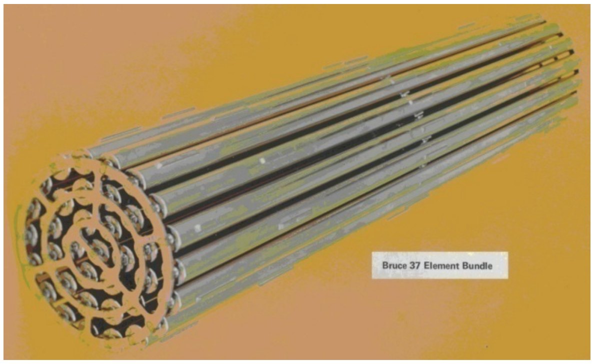
Note: forecasts are rounded to nearest 1,000 bundles or 1,000 t-HM

APPENDIX C: DESCRIPTION OF FUEL TYPES

C.1 FUELS FROM EXISTING REACTORS

<table>
<tr><th colspan="2">28 element CANDU bundle</th></tr>
<tr><td rowspan="5">
</td><td>Physical dimensions:
102.5 mm OD x 497.1 mm OL</td></tr>
<tr><td>Mass:
20.1 kg U (22.8 kg as UO_2)
2.0 kg Zircaloy in cladding, spacers, etc
24.8 kg total bundle weight</td></tr>
<tr><td>Fissionable material:
Sintered pellets of natural UO_2</td></tr>
<tr><td>Average burnup:
8,300 MW day / tonne U
(200 MWh/kg U)</td></tr>
<tr><td>Cladding material:
Zircaloy-4</td></tr>
<tr><td colspan="2">Construction:
- bundle is composed of 28 elements (fuel pins), arranged in 3 concentric rings with 4 elements in the inner most ring, 8 elements in the second ring and 16 elements in the outer ring
- construction includes end plates, spacers and bearing pads to improve flow characteristics and maintain structural integrity</td></tr>
<tr><td colspan="2">Comments:
- used in Pickering A and B reactors</td></tr>
</table>

37 element CANDU "standard" bundle



Physical dimensions:
102.5 mm OD x 495 mm OL

Mass:
19.2 kg U (21.7 kg as UO_2)
2.2 kg Zircaloy in cladding, spacers, etc
24.0 kg total bundle weight

Fissionable material:
Sintered pellets of natural UO_2

Average burnup:
8,300 MW day / tonne U
(200 MWh/kg U)

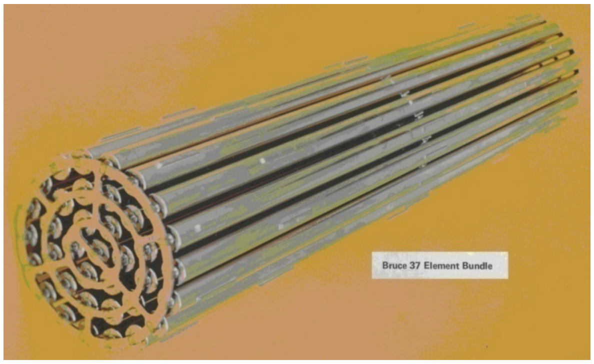
Cladding material:
Zircaloy-4

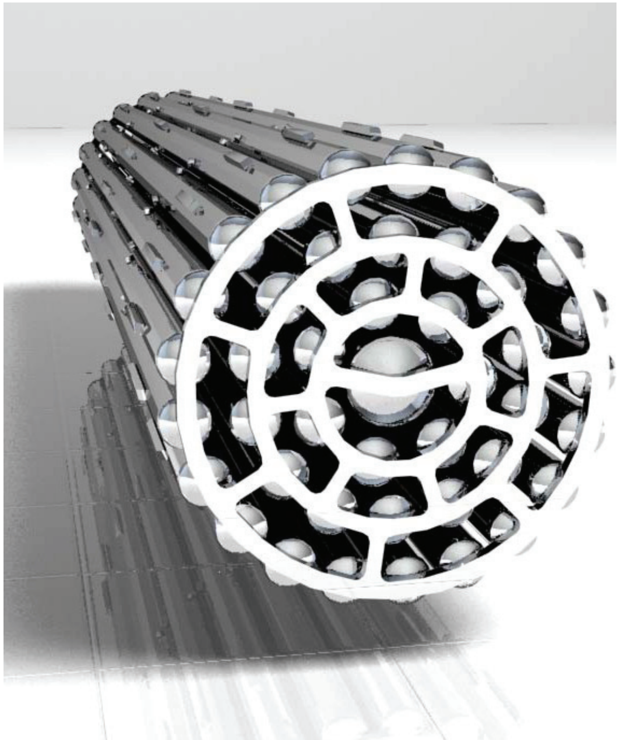
Construction:

- bundle is composed of 37 elements (fuel pins), arranged in 4 concentric rings with 1 element in the inner most central ring, 6 elements in the second ring, 12 elements in the third ring and 18 elements in the outer ring
- construction includes end plates, spacers and bearing pads to improve flow characteristics and maintain structural integrity

Comments:

- used in Bruce A and B, Darlington, Gentilly-2, Point Lepreau and EC-6 reactors (Gentilly-2 and Point Lepreau have minor construction differences on the end plates and spacers compared to the Bruce and Darlington designs)

37 element CANDU “long” bundle	
	**Physical dimensions:** 102.5 mm OD x 508 mm OL **Mass:** 19.7 kg U (22.3 kg as UO_2) 2.24 kg Zircaloy in cladding, spacers, etc 24.6 kg total bundle weight **Fissionable material:** Sintered pellets of natural UO_2 **Average burnup:** 8,300 MW day / tonne U (200 MWh/kg U) **Cladding material:** Zircaloy-4
Construction: - bundle is composed of 37 elements (fuel pins), arranged in 4 concentric rings with 1 element in the inner most central ring, 6 elements in the second ring, 12 elements in the third ring and 18 elements in the outer ring - construction includes end plates, spacers and bearing pads to improve flow characteristics and maintain structural integrity	
Comments: - similar to 37 element “standard” bundle, but is 13 mm longer - used in Bruce B, and Darlington reactors	

43 element CANFLEX LVRF bundle	
	**Physical dimensions:** 102.5 mm OD x 495.3 mm OL
	Mass: 18.5 kg U (21.0 kg as UO_2) 2.1 kg Zircaloy in cladding, spacers, etc 23.1 kg total bundle weight
	Fissionable material: Sintered pellets of UO_2 slightly enriched to 1.0% U-235
	Average burnup: 8,300 MW day / tonne U (200 MWh/kg U)
	Cladding material: Zircaloy-4

Construction:

- bundle is composed of 43 elements (fuel pins), arranged in 4 concentric rings with 1 element in the inner most central ring, 7 elements in the second ring, 14 elements in the third ring and 21 elements in the outer ring
- the inner central element uses Dysprosium (a rare earth element that readily absorbs neutrons and reduces the bundle power maintaining a flat neutronic field profile across the bundle during operation)
- diameter and composition of fuel pins varies by ring
- construction includes end plates, spacers and bearing pads to improve flow characteristics and maintain structural integrity

Comments:

- used in Bruce B reactors, option for use in EC-6 reactors

C.2 FUELS FROM POTENTIAL NEW-BUILD REACTORS

43 element CANFLEX ACR bundle

Physical dimensions:
102.5 mm OD x 495.3 mm OL

Mass:
16.2 kg U (18.4 kg as UO_2)
3.1 kg Zircaloy and other materials in cladding, spacers, etc
21.5 kg total bundle weight

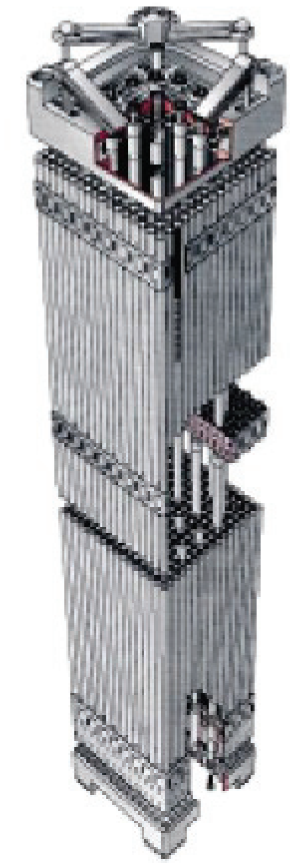
Fissionable material:
Sintered pellets of UO_2
enriched to 2.5% U-235

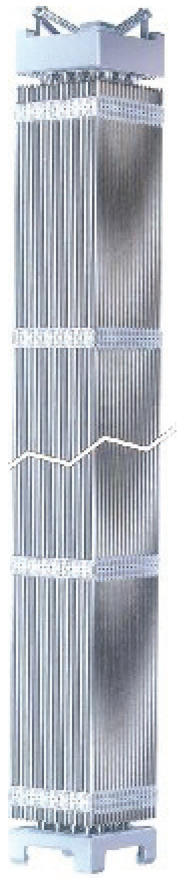
Average burnup:
20,000 MW day/ tonne U

Cladding material:
Zircaloy-4

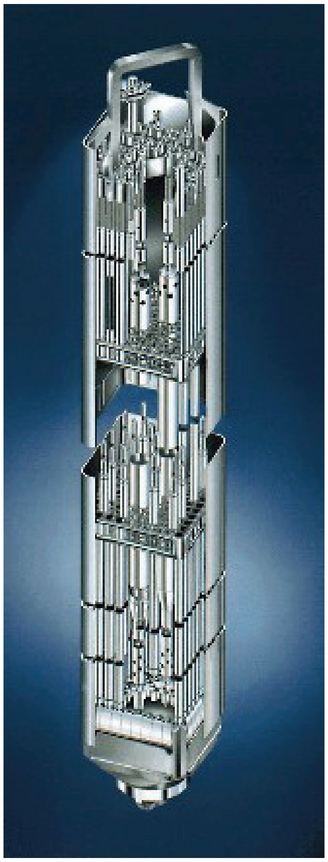
Construction:
- bundle is composed of 43 elements (fuel pins), arranged in 4 concentric rings with 1 element in the inner most central ring, 7 elements in the second ring, 14 elements in the third ring and 21 elements in the outer ring
- diameter and composition of fuel pins varies by ring
- construction includes end plates, spacers and bearing pads to improve flow characteristics and maintain structural integrity

Comments:
- used in AECL ACR-1000 reactors

<table>
<tr><th colspan="2">AP1000 PWR fuel assembly</th></tr>
<tr><td rowspan="5"></td><td>Physical dimensions:
214 mm square x 4795 mm OL</td></tr>
<tr><td>Mass:
538.3 kg U (613 kg as UO_2)
~176 kg ZIRLO and other materials in cladding, spacers, etc
789 kg total weight</td></tr>
<tr><td>Fissionable material:
Sintered pellets of UO_2
enriched up to 5% U-235</td></tr>
<tr><td>Average burnup:
60,000 MWday/tonne U</td></tr>
<tr><td>Cladding material:
ZIRLO</td></tr>
<tr><td colspan="2">Construction:
- Each fuel assembly consists of 264 fuel rods, 24 guide thimbles, and 1 instrumentation tube arranged within a 17 x 17 matrix supporting structure. The instrumentation thimble is located in the center position and provides a channel for insertion of an in-core neutron detector, if the fuel assembly is located in an instrumented core position. The guide thimbles provide channels for insertion of either a rod cluster control assembly, a gray rod cluster assembly, a neutron source assembly, a burnable absorber assembly, or a thimble plug, depending on the position of the particular fuel assembly in the core.</td></tr>
<tr><td colspan="2">Comments:
- used in Westinghouse AP1000 reactors</td></tr>
</table>

EPR PWR fuel assembly	
	**Physical dimensions:** 214 mm square x 4805 mm OL **Mass:** 527.5 kg U (598.0 kg as UO_2) ~182 kg other materials in cladding, spacers, etc 780 kg total weight **Fissionable material:** Sintered pellets of UO_2 enriched up to 5% U-235 **Average burnup:** 62,000 MWday/tonne U **Cladding material:** M5
Construction: - Each fuel assembly consists of 265 fuel rods and 24 guide thimbles which can either be used for control rods or for core instrumentation arranged within a 17 x 17 matrix supporting structure. The guide thimbles provide channels for insertion of either a rod cluster control assembly, a gray rod cluster assembly, a neutron source assembly, a burnable absorber assembly, a thimble plug or core instrumentation, depending on the position of the particular fuel assembly in the core.	
Comments: - used in Areva EPR reactors	

ESBWR fuel assembly



Physical dimensions:

140 mm square x 4470 mm OL

Mass:

126.9 kg U (143.9 kg as UO_2)

94.1 kg Zircaloy and other materials in cladding, spacers, etc

238 kg total weight

Fissionable material:

Sintered pellets of UO_2

enriched up to 5% U-235

Average burnup:

50,000 MWday/tonne U

Cladding material:

Zircaloy-4

Construction:

- The BWR fuel assembly consists of a fuel bundle and a channel. The fuel bundle contains the fuel rods and the hardware necessary to support and maintain the proper spacing between the fuel rods. The channel is a Zircaloy box which surrounds the fuel bundle to direct the core coolant flow through the bundle and also serves to guide the movable control rods.
- Each fuel bundle consists of a 10x10 array of 78 full length fuel rods, 14 part length rods (which span roughly two-thirds of the active core), two large central water rods and 8 tie rods.

Comments:

- used in GE ESBWR reactors

KERENA BWR fuel assembly	
(picture not available)	**Physical dimensions:** (details not available) Overall length ~3765 mm
	Mass: ~205 kg U (233 kg as UO_2) ~325 kg total weight
	Fissionable material: Sintered pellets of UO_2 enriched up to 4.7% U-235
	Average burnup: Up to 65,000 MWday/tonne U
	Cladding material: Zircaloy-2
Construction: - Details not available, but expected to be similar to AREVA ATRIUM series BWR fuels, with the exception that it uses a larger 12x12 array rather than conventional BWR 10x10 array. - 128 fuel rods per assembly	
Comments: - used in AREVA KERENA (SWR-1000) reactors	

ATMEA-1 PWR fuel assembly	
(picture not available)	**Physical dimensions:** 214 mm square x 4200 mm OL **Mass:** (details not available) **Fissionable material:** Sintered pellets of UO_2 enriched up to 5% U-235 MOX version also available **Average burnup:** Up to 62,000 MWday/tonne U **Cladding material:** (not available)
Construction: - Conventional PWR 17 x 17 array design. - Details not available, but expected to be similar to conventional AREVA/Mitsubishi PWR fuels	
Comments: - used in AREVA ATMEA-1 reactors	