CANDU 6

Proven Technology for the 21st Century

Canada

AECL


公司承运秦山核电三期设备
TRANSPORT FOR TQNPC

CANDU 6: Proven Technology for the 21st Century

The CANDU® power reactor design is visionary in its approach, remarkable for its on-power refuelling capability, and proven over years of safe, economical and reliable power production.

Designed by Atomic Energy of Canada Limited (AECL), CANDU 6 offers a combination of provenness and superior, state-of-the-art technology. It was designed specifically for electricity production, unlike other major reactor types that evolved from other uses. This focused development is one of the reasons that CANDU 6 has such high fuel efficiency.

CANDU 6 is AECL's 700 MWe class nuclear power reactor. The continuous evolution of its technology assures maximum performance—a result of AECL's continued and long-term commitment to its advancement through research and product development.

The first CANDU 6 plants went into service in the early 1980s as leading-edge technology, and the CANDU 6 design has continuously advanced to maintain superior technology and performance.

The evolutionary CANDU 6 design includes all the enhancements and improvements from recent CANDU projects.

The Wolsong site in Korea: Unit 1 began operating in 1983 and is still a top-performing reactor. Unit 2 began operating in 1997, Unit 3 in 1998, and Unit 4 in 1999.

The first CANDU 6 plants—Gentilly 2 and Point Lepreau in Canada, Embalse in Argentina, and Wolsong Unit 1 in Korea—have been in-service for more than 20 years. They are still producing electricity at peak performance, and to the end of 2004, their average lifetime capacity factor was 83.2%.

In the year ending 2004, the newer units—Wolsong Units 2, 3 and 4 achieved lifetime capacity factors of 92.6%, 93.8% and 96.3% respectively. The Qinshan Phase III, Units 1 and 2 achieved lifetime capacity factors of 84.2% and 87.8% respectively.

Cernavoda Unit 2 construction is underway and the plant is scheduled to go into service in the year 2007.

Cernavoda Unit 1, in service since 1996, is the first CANDU nuclear power reactor in Europe.

CANDU 6 reactors operating or under construction around the world

Embalse, Argentina: This unit went into service in 1984.

CANDU 6 Units in Operation

Unit	Location	In-Service Date	Gross Output	Lifetime Capacity Factor (to the end of Dec.2004*)
Point Lepreau	Canada	Feb. 01, 1983	680 MWe	82.7%
Wolsong 1	Korea	Apr. 22, 1983	679 MWe	86.0%
Gentilly 2	Canada	Oct. 01, 1983	675 MWe	79.3%**
Embalse	Argentina	Jan. 20, 1984	648 MWe	84.9%
Cernavoda 1	Romania	Dec. 02, 1996	706 MWe	86.8%
Wolsong 2	Korea	July 1, 1997	715 MWe	92.6%
Wolsong 3	Korea	July 1, 1998	715 MWe	93.8%
Wolsong 4	Korea	Oct. 1, 1999	715 MWe	96.3%
Qinshan 1	China	Dec. 31, 2002	728 MWe	84.2%
Qinshan 2	China	July 24, 2003	728 MWe	87.8%

** Source: CANDU Owners Group (COG) website*
*** Gentilly Unit 2 operated at 50% capacity during much of its first four years of operation, in order to limit the surplus of energy in the grid.*

CANDU 6 Units under construction

Unit	Location	Projected In-Service	Gross Output
Cernavoda 2	Romania	2007	706 MWe

CANDU 6: Provenness and State-of-the-Art Technology

A totally integrated project system provides improved configuration management.

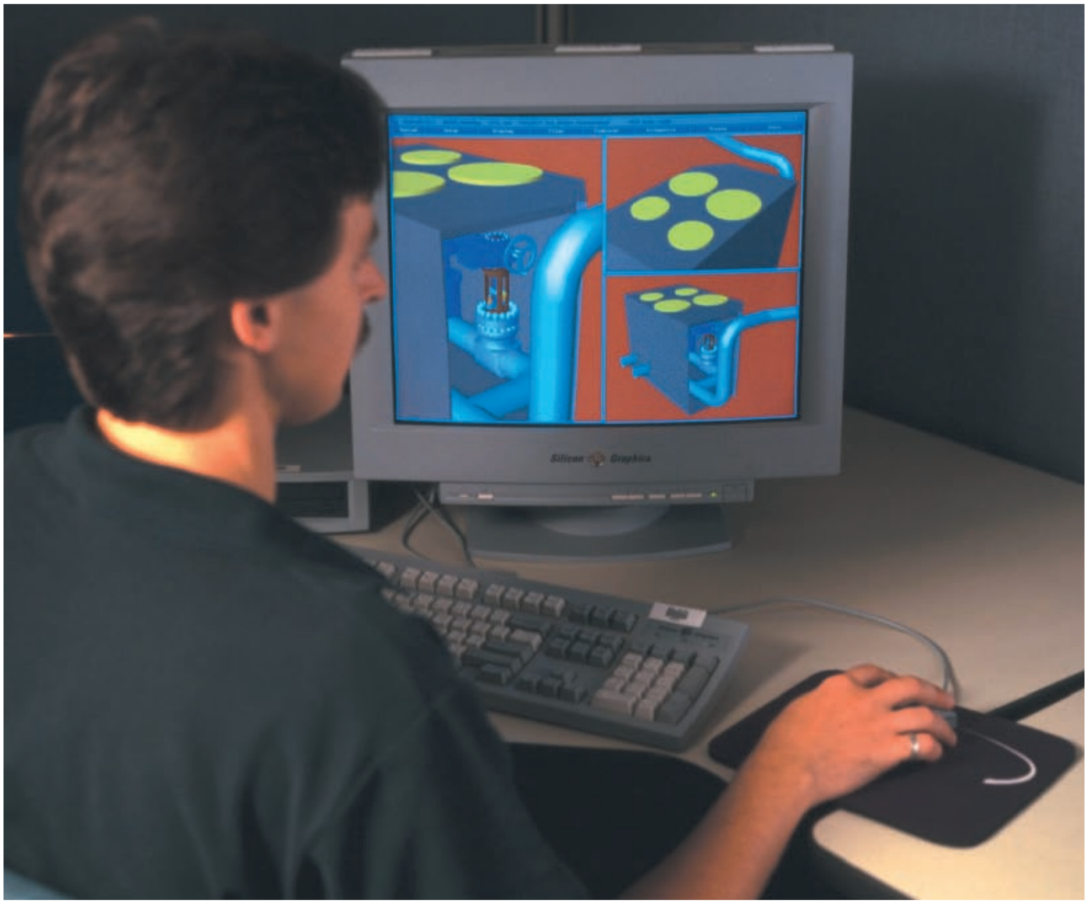
CANDU 6 offers a combination of provenness and state-of-the-art technology. This is because AECL is committed to research and product development programs that continuously evolve the CANDU technology to advanced standards. These programs focus on customers' needs for reduced costs and improved performance, enhanced safety, and sustainable development through CANDU's inherent fuel cycle flexibility.

AECL's vision is to maintain all major and proven CANDU features, while aggressively incorporating new knowledge and advanced technology in the CANDU 6 design which is truly proven technology for the 21st century.

Advanced Construction and Engineering Tools

Wolsong Units 2, 3 and 4 were designed and constructed using the most up-to-date, state-of-the-art integrated electronic engineering tools, including comprehensive Computer Aided Design and Drafting (CADD) systems and IntEC automated wiring. IntEC is a data management software tool, developed by AECL, for the design and installation of cabling and wiring.

AECL constantly strives for reduced costs, improved performance and enhanced safety.



Preparing for open-top construction, a temporary roof is installed on Unit 2 of the Qinshan Phase III CANDU project in China.

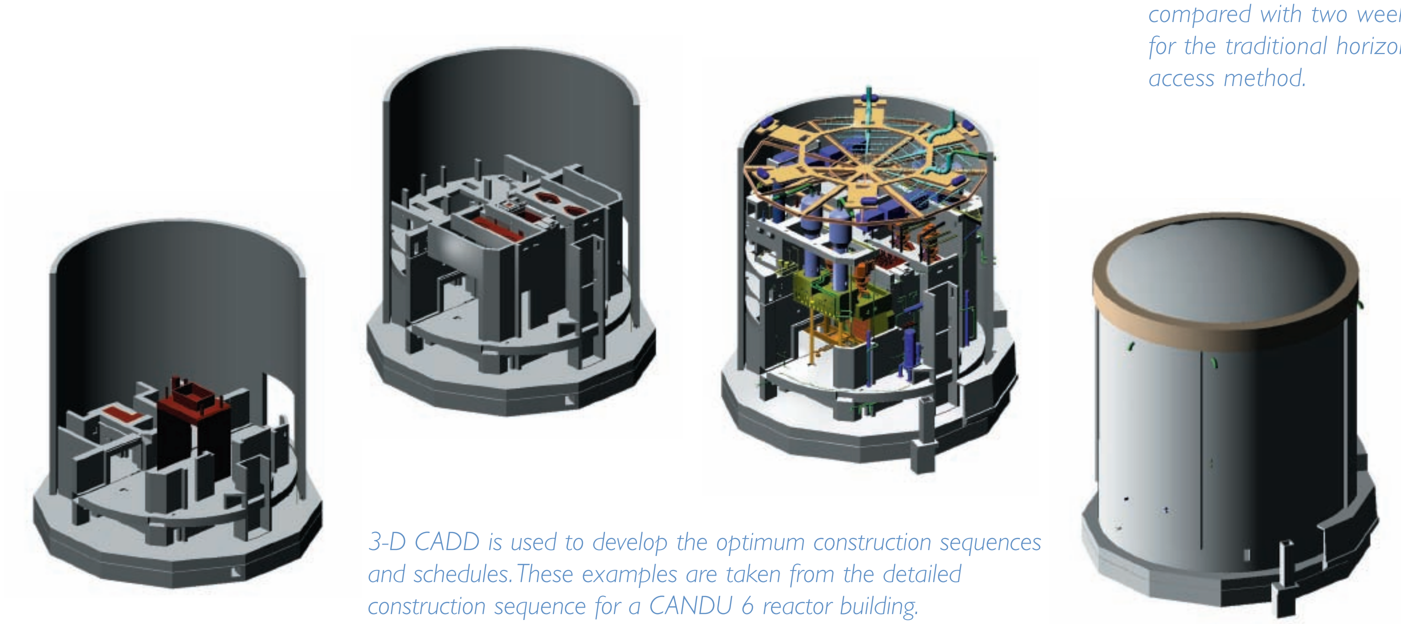
In addition to these tools, at the Qinshan Phase III CANDU 6 project in China, open-top construction and 3-D CADD systems were used to further streamline construction.

With open-top construction, the dome of the reactor building is installed near the end of construction. This allows easy access to the interior of the reactor building, and by using a very-heavy-lift (VHL) crane, major equipment can be lifted through the openings of a temporary roof, rather than through the traditional horizontal method. Installation sequences are more efficient and flexible, and critical path activities can be carried out in parallel.

3-D CADD systems allow the constructor to visualize and animate construction sequences, in order to develop the optimum schedule well before construction begins.

With a CANDU 6 project, all design databases will be completely linked, including CADD systems, equipment and materials management, and project management. This totally integrated project system provides improved configuration management.

A steam generator can be installed in one or two days, using a VHL crane to lift equipment through the top of the reactor building, as compared with two weeks for the traditional horizontal-access method.



3-D CADD is used to develop the optimum construction sequences and schedules. These examples are taken from the detailed construction sequence for a CANDU 6 reactor building.

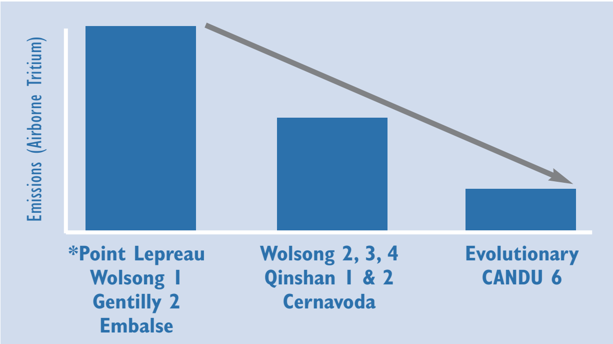
Increased Plant Output

Earlier CANDU 6 plants were designed for about 680 MWe gross electricity output. With improved efficiencies in the turbine-feedwater systems, the Wolsong Units 2, 3 and 4 CANDU 6 plants were designed to generate approximately 715 MWe gross electricity. The units at Qinshan in China are designed for approximately 728 MWe gross output.

AECL has a continuous commitment to evolving the CANDU technology.

Point Lepreau Nuclear Generating Station, New Brunswick, Canada - in service since 1983

Ventilation and Heavy Water Recovery Systems



Evolution of Design means Emissions Decline

** public doses already less than 1% of Canadian limit.*

For Wolsong Units 2, 3 and 4, and the two units at the Qinshan CANDU 6 site, emissions of tritium have been reduced to less than half that of previous units. With the installation of a Reactor Building Inlet Dryer and an improved heavy water (D_2O) Vapour Recovery System, already-low emissions of heavy water vapour from the reactor building will be essentially eliminated, and operating staff dose will be further reduced. The D_2O Vapour Recovery System for the CANDU 6 design has been further extended to cover all areas of the reactor building, automatically collecting even tiny quantities of heavy water leakage.

Advanced Control Centre Design

CANDU 6's advanced control centre was designed by AECL, well-known as a world leader in computer control and monitoring systems for nuclear power plants. As with other superior CANDU 6 features, proven technologies form the basis for evolutionary enhancements. The CANDU 6 control centre design has always used leading-edge technology, based on dual, redundant computer control of all operations, including computer-operated refuelling. Extensive and regular consultation and feedback from CANDU owners and operators guides control centre design priorities. The evolutionary CANDU 6 design includes a central control console, improved video display terminals (VDTs), an enhanced safety parameter display system, and an advanced plant display system that incorporates alarm recognition and messaging. There is a central overview plant diagram, digital information display, and keyboard and touch-screen control actions. This advanced control centre design allows the operator to easily control the entire plant from a central console system and VDTs, using standup panels as backup only.

Customer feedback is crucial in the evolution of the CANDU control centre.

Qinshan Phase III Unit 1 control room

Safety System Design

CANDU 6 has proven to be one of the safest reactor designs in the world. It has a reputation for very low radiation doses to operating staff, well below internationally -recognized limits.

In addition to the numerous safety systems that also have a role in plant operation, the CANDU 6 reactor has special safety systems that perform no active function in the operation of the plant—they are there only for safety. These include two totally independent, redundant safety systems that can automatically shut down the reactor. They also include a feature unique to all CANDU reactors—an inherent emergency fuel coolant capability, in which the moderator system acts as a "heat sink" to absorb excess heat from the reactor. The moderator system backs up both the regular and emergency core cooling systems for added safety. And finally, the CANDU 6 reactor is designed with multiple barriers that prevent the release of radioactive emissions into the atmosphere.

In Wolsong Units 2, 3 and 4, and the Qinshan CANDU 6 reactors, all phases of the Emergency Core Cooling (ECC) system have been automated. This allows the operator to concentrate on monitoring plant status and extends the grace period for "design basis accidents".

The containment leakage monitoring system is on-line, which provides operators with a regular status report of the measurement of atmospheric conditions within the station.

Better-designed elastomeric material increases airlock seal life and reduces the need for maintenance. This elastomeric technology was developed by AECL's R&D specialists, who are well-known for their contribution to solving sealing problems for the U.S. Space Shuttle program.

The design of CANDU 6 plants offers exceptionally high levels of safety.

Superior elastomeric material, used in the latest CANDU 6 containment airlocks, is based on technologies that have been used to improve U.S. Space Shuttle performance.

Dousing System: AECL focuses on enhancing CANDU safety.

Licensing

The CANDU 6 design fully meets the requirements of Canada's nuclear regulator. It was licensed in the early 1980s in Canada, Argentina and the Republic of Korea. In 1996, Cernavoda Unit 1 was licensed in Romania, and Wolsong Unit 2 was licensed in Korea. Wolsong Units 3 and 4 were licensed in Korea in 1997 and 1999 respectively. The two CANDU 6 units at Qinshan Phase III were licensed in China in 2002 and 2003. The design meets the International Atomic Energy Agency (IAEA) safety and licensing guidelines, which also form the basis for the Chinese regulatory framework.

Long Plant Life

The more recent CANDU 6 nuclear power plant designs, including Qinshan Phase III in China are designed for a 40-year life. This is ten years longer than earlier CANDU 6 reactors, which were designed for 30 years. Additionally, with proper plant management and maintenance, a 60-year operating life is feasible for a CANDU 6 nuclear power plant with some equipment replacement at mid life.

Material and Component Design

Improved pressure tube material was used in Wolsong Units 2, 3 and 4 and for the Qinshan units to reduce impurities, minimize hydrogen content and further improve fracture toughness. Optimized installation and advanced design of the pressure tubes reduce dimensional changes and increase the operating life.

With evolutionary enhancements to the CANDU 6 design, the calandria tubes, which contain the pressure tubes, have an improved surface texture treatment. This provides for more effective heat transfer to the moderator under upset and accident conditions. Materials have been chosen for in-core reactivity mechanism support, to reduce neutron absorption and increase fuel burnup. The chromium content of feeder piping has been increased to improve corrosion resistance. Auxiliary pumps, heat exchangers and other components are more space-efficient to increase maintenance accessibility.

From its original design-life of 30 years, CANDU 6 is now designed for a 40-year life.

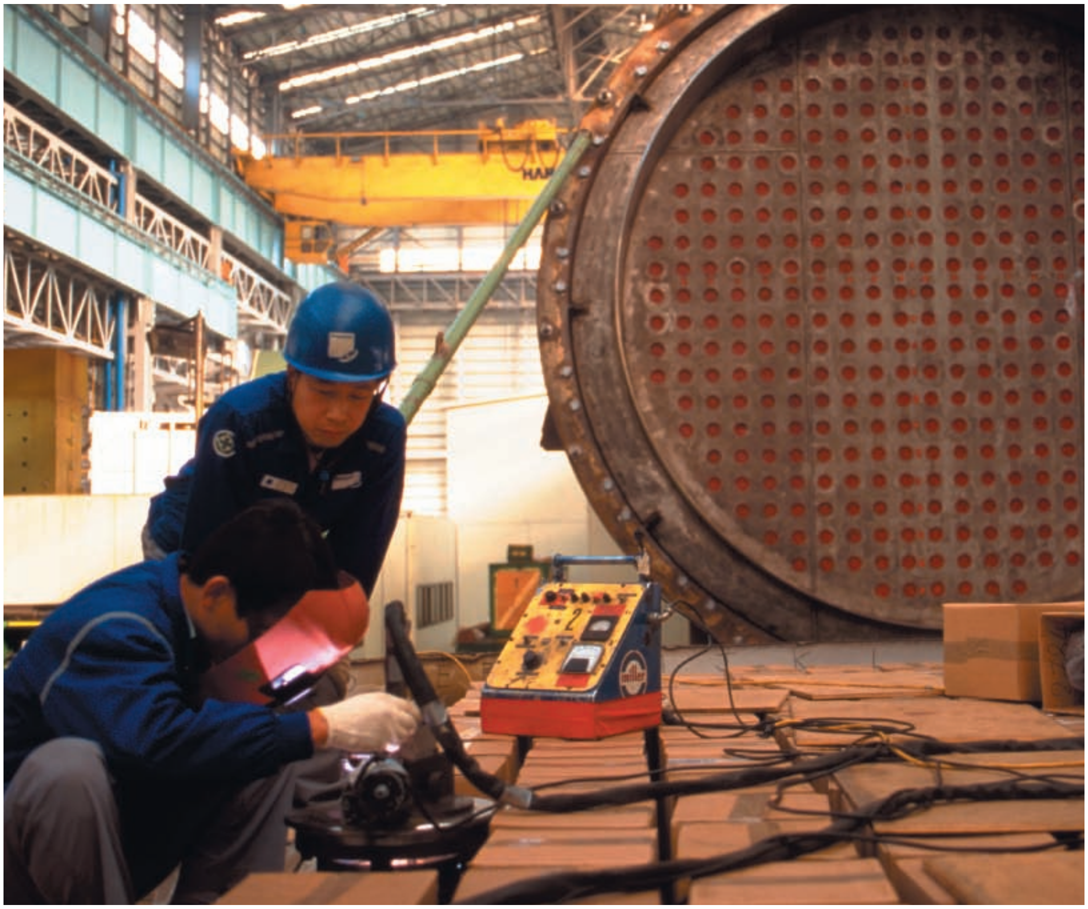
Improved pressure tube material metallurgy reduces impurities, minimizes hydrogen content and further improves fracture toughness.

CANDU 6: Its Advantages

AECL's well-focused research and product engineering programs continue to advance the evolution of CANDU 6, ensuring its technology is always state-of-the-art. As well, CANDU 6 has many inherent and unique design advantages that contribute to its high performance and safety.

- The CANDU 6 design is simple and modular, to accommodate evolutionary improvements.
- Most major CANDU 6 components, including the reactor core, or calandria, can be manufactured in user-countries.
- CANDU 6's simple fuel bundles can be easily manufactured by user-countries. The Republic of Korea, Argentina, Romania and the People's Republic of China have their own fuel fabrication facilities.
- Heavy water is used as the moderator. Combined with other features of the CANDU 6 design, heavy water allows natural uranium and other nuclear fuels to be used more efficiently than in light water reactors (LWRs). CANDU 6 gets 30% more electricity from a kilogram of uranium than LWRs.
- CANDU 6 uses readily-available natural uranium with no requirement for enrichment. This contributes to energy self-reliance and low nuclear fuel costs.

User-countries can easily establish their own fuel manufacturing capability, as has already been achieved in the Republic of Korea, Argentina, Romania and the People's Republic of China.



Through technology transfer programs, the Republic of Korea has the capability to manufacture the CANDU reactor calandria, or core.

- CANDU 6 also has unsurpassed fuel cycle flexibility, thanks to its neutron-efficient design and the advanced CANFLEX™ fuel bundle. CANFLEX that can further enhance fuel performance and reduce operating costs when used with natural uranium, as well as other fuel options. AECL is advancing slightly enriched uranium (including used fuel recovered from light water reactors), mixed oxide, and thorium as fuel options.
- CANDU 6 has the unique ability to refuel during full-power operation. This contributes to its high performance, lower operating costs and greater flexibility in scheduling maintenance shutdowns.
- CANDU 6 has more backup safety systems than any other reactor type. These include additional heat sinks and two independent shutdown systems.
- The major components in CANDU 6 plants, such as steam generators, coolant pumps and pressure tubes, are standardized and can be replaced, potentially extending the operating life of CANDU 6 to 60 years.
- CANDU 6 leads the way globally in automated reactor control, thus enhancing safety and performance.

CANDU leads the way globally in automated reactor control.

The advanced CANFLEX fuel bundle can further enhance fuel performance and reduce operating costs.

AECL

AECL Head Office
Marketing Services
2251 Speakman Drive
Mississauga, Ontario Canada
L5K 1B2
Tel: (905) 823-2325
Toll free: 1 866 344-2325
Fax: (905) 403-7420
Web-site: www.aecl.ca

Publié aussi en français.

Printed in Canada. May 2005. PP&I 1074

AECL

AECL Head Office
Marketing Services
2251 Speakman Drive
Mississauga, Ontario Canada
L5K 1B2
Tel: (905) 823-2325
Toll free: 1 866 344-2325
Fax: (905) 403-7420
Web-site: www.aecl.ca

Publié aussi en français.

Printed in Canada. May 2005. PP&I 1074