When Do Commercial Reactors Permanently Shut Down? The Recent Record

I. Introduction

1. Purpose and Scope

This article provides an overview of global commercial nuclear reactor closures that have occurred since 1 January 1999. The last three commercial reactors closed in the United States were Zion 1 and 2 and Millstone 1. Because their closure took place prior to 1999, they are not included in this survey. Worldwide, twenty-three reactors closed since the beginning of 1999, compared to thirty-five reactors commissioned during that period and to the 442 reactors now operating in the world. The reasons why each reactor has closed and the types of reactors closed are listed in a table. Because this article is an overview, some of the reasons listed for closures are necessarily summaries of more complex situations. In addition, it is sometimes difficult to identify when a reactor was actually closed. A reactor listed as "shutdown" by the International Atomic Energy Agency (IAEA) is considered to be closed.

The reasons a reactor is closed can be multi-faceted. While explanations regarding why particular reactors have closed can be both economic-related and public policy-related, economic decisions in the end are initiated by the commercial interests of the owners or operators while long-term public safety/social cost-related closure is usually initiated by public policy. On Tables 2 and 4 below these closure reasons are classified as Policy and Economics. Subsequent to 1999 key decisions to close water-cooled and moderated reactors worldwide were not initiated by the reactor owners nor do they appear to have been based on internal economic or immediate safety concerns. In several cases policy decisions related to reactor closure were related to long term safety views as well as other social costs. This article does not critically judge potential reactor closures that have not yet been publicly announced and discussed.

2. Definitions

In this article, we divide varieties of commercial power reactors among those that are cooled and moderated by either light or heavy water and those that are not. Of 442 reactors operating worldwide on in May 2006, 401 were water cooled and moderated. Water-cooled and moderated reactors include such families of reactors as pressurized water reactors (PWR), boiling water reactors (BWR) and pressurized heavy water reactors (PHWR). All commercial reactors in the United States are PWRs and BWRs. Those two designs are sometimes collectively called light water reactors (LWRs). Russian vendors make a type of PWR called the "VVER" based on the Russian language name for the reactor. Design features of the VVER are not significantly different from western PWRs, but the history of nuclear power discussion has often resulted in VVERs being discussed separately from other PWRs.

The PHWR design has been particularly promoted by Canadian vendors under the name Candu reactor. PHWRs are also operated in India, Pakistan, South Korea, China, Romania and Argentina. Not all of these PHWRs are strictly defined as Candu reactors though many either are Candu reactors or are based on Candu-originated designs. Prototype reactor designs are excluded from reactors defined as water-cooled and water-moderated in this article.

Other types of commercial reactors exist and operate worldwide, but they are not both water-cooled and -moderated. The convention followed in this article is to call these “other” reactor designs. Many of these reactors, notably gas cooled reactors (GCRs), are at least as old (commercially) as the water-cooled and -moderated reactors. There are several sub-groups of GCRs. One closed reactor, Fugen, is defined as other because it was a prototype for a discontinued design series, even though it was light water cooled and heavy water moderated. Also included as other reactor designs are fast breeder reactors (FBRs) and water-cooled but graphite moderated reactors, notably the Russia-designed RBMK. (RBMK is an abbreviation of the reactor’s Russian name.)

This article is intended to be neutral on the assessment of reactor safety. At no time are the merits evaluated regarding an assertion that a specific reactor was permanently closed for “safety” reasons. Some closures since 1999 were the result of national policies in Germany and Sweden that were at least partly based on assessments of long-term safety risks. International agencies and governments, notably the European Union, have sometimes used assessments of long term safety risks as an explanation for policies advocating the closing reactors in Eastern Europe. During the period covered, each of these assessments has been subjected to considerable debate, domestically and internationally.

As will be seen the definition of when a reactor is shut down is not always easy to obtain. This article uses inclusion on Table 12 of the International Atomic Energy Agency’s “Nuclear Power Reactors in the World” (April 2005) as the primary definition of a power reactor being shut down. In the cases of reactors shut down subsequent to this publication, inclusion was the author’s decision based on available public information. The following sections of the article will indicate that even this definition of “shutdown” is not clear cut.

Reasons for reactor closure are complex. They might be divided into such categories as policy, economics, safety or design obsolescence, but such terms overlap. For example, if it is decided that the expense of investment and maintenance needed to safely run a reactor are too high to permit continued operation, it is difficult to classify the reason for the closure as reactor economics, safety, safety-based policy, or obsolescence. Elements of each are involved. In the following discussion one or another summary cause is asserted to be a primary reason for a reactor closure. This is not intended to exclude contributions of other components in the decision.

There is also the issue of whether plant aging will cause closure at any nuclear generating facility. While all components do age, the issue is whether such aging will cause the entire facility to close. As used here, aging occurs when the expense of replacing or maintaining deteriorating equipment exceeds the benefits of replacement. At the very least this should result in increased operating costs, if the plant continues to operate with aging components. Most power plants, not just nuclear ones, are modular in the sense that many components can be replaced as they wear out. This makes aging an issue of both the economics and feasibility of replacing component parts. If key parts are not replaced or the economics of replacement is unfavorable to continued operation, closure could occur. If it is economically feasible to replace all components, aging might not be a significant issue. Continued operation would depend on the costs of refurbishment and continued operation compared to the costs of alternative generation technologies available. This includes the costs of shutting down the nuclear unit, if an alternative unit is chosen. A good portion of the components of a water-cooled and -moderated nuclear power reactor can be economically replaced and, indeed, many have been. The situation of water-cooled and –moderated reactors has not been true of other designs, notably Magnox GCRs that now operate only in the United Kingdom. All of these reactors are scheduled to be retired before the end of the present decade, in part because replacement of major components is not economically justified.

There are some components of a water-cooled and -moderated reactor that have not yet faced a wide need for replacement among still operating units. These components include the reactor vessel itself and perhaps the containment structures. The re-tubing now proposed for Point Lepreau in Canada is the equivalent of replacing a Candu pressure vessel but the process of reactor vessel replacement would be quite different for an LWR design. If it is uneconomic to replace key components, existing water-cooled and -moderated reactors might become uneconomical to operate safely. If all key components can be economically replaced, the "age" of a nuclear reactor has little or no economic meaning in regard to reactor safety or long term operating costs.

3. Experience prior to 1999

This article does not follow in detail reactor changes prior to 1999. The reason for this is that there has been an apparent change in the motivations behind reactor closures starting in the late 1990s. In the first place, most prototype reactors that have been closed were closed prior to 1999. (This article discusses two exceptions, Fugen and Phenix.) Also economic and safety motivations for closing water-cooled and -moderated reactors appear to have declined since the mid-1990s. For example the last three reactors closed in the United States, Zion 1 and 2 and Millstone 1, were closed in 1998. In each case substantial and potentially expensive investments might have been required to bring the reactors up to necessary performance standards. This would place the motivation for their closure ambiguously in either the economic or safety criterion though more appropriately a bit in both.

A brief review of reactor closures listed by the IAEA for France and the United States illustrates the different character of pre-1999 closures. In France eleven reactors were listed as closed before 1999. Eight of these were Magnox GCRs, designs whose operation has been discontinued in France. The remaining three were "prototype" designs. One of these three "prototypes" was a 310 MW reactor that was completed in 1967 as the first PWR in France and which was considerably smaller than any reactor still operating in France.

The IAEA's list of United States' reactors closed before 1999 includes 23 units. Four of these were prototypes for designs that are no longer in commercial use in the US. The remaining 19 reactors were light water reactors. Ten of these LWRs are smaller than the smallest reactor still in operation in the US. These smaller LWR closures would thus have characteristics of prototypes as well as some indication that the reactors had insufficient economies of scale to be commercially viable. Seven of the remaining nine larger reactors were PWRs. Many of these were among the reactors that experienced difficulties with their steam generators, a key component of PWRs. Replacing steam generators is now a commercially viable action in most cases but this was not the case in the early and mid 1990s. Additionally, these reactors included Rancho Seco which was closed in part due to policies of local authorities and Three Mile Island 2 which was shut due to an accident in 1979. The Three Mile Island 2 case is the last accident-related permanent closure of a water-cooled, water-moderated commercial reactor in the world. The two large BWRs that were closed were Millstone 1 and Shoreham. Millstone 1 was closed in response to questions related to the operation of the reactor and the cost of bringing the reactor to owner and regulator standards. Shoreham was never licensed to go to full commercial scale operation.

II. Reactor Closures Since 1 January 1999

Table 1 lists commercial power reactors that have been closed worldwide since the beginning of 1999 together with the country in which each was located, the reactor design, the year the reactor was closed, and the primary reason for closure. These causes for closure will be generalized in terms of Economics, Policy, and Prototype reasons on Table 2.

The use of IAEA definition of "shutdown" leads to some notable exclusions from Table 1. The German reactor Muelheim-Kaerlich was closed in 1988 though its owners did not agree to decommission the reactor until 2004 as part of the German national policy on nuclear reactor closures. Similarly, eight Canadian reactors were defined as shut down before 1998. The owner in each Canadian case intended to later restart these reactors following extended maintenance, rebuilding or refurbishment. This has occurred at four of the Canadian reactors and is in process at Bruce 1 and 2. The owner of the other two still-closed Canadian reactors, Pickering 2 and 3, has recently decided to further delay any decision on their future status. These reactors were closed in 1997, by the IAEA definition, but their final disposition is still in a form of abeyance. Announced decisions to de-fuel and de-water the two Pickering reactors make their eventual restart more expensive and less likely, though eventual restart cannot yet be ruled out. In each of the Canadian and German cases the reactors were defined as shutdown before 1999 though a clear decision whether the reactors might be permanently closed had not been made in 1999 by the owners or operators.

The case of Brown's Ferry 1 in the United States shows a contrasting situation due to the IAEA definitions of shutdown. No formal permanent closure decision was ever made and the Brown's Ferry 1 operating license was not fully surrendered. Although the reactor has not operated since 1985 and Brown's Ferry 1 is not considered as shutdown on the IAEA list. The plant's owner, the Tennessee Valley Authority (TVA), now plans to restart Brown's Ferry 1 during 2007.

Table 1. Reactors closed worldwide since 1 January 1999

Reactor	Nation	Design	Capacity (MW)	Year Closed	Primary Reason Closed
Kozloduy 1	Bulgaria	VVER	408	2002	EU-Bulgaria agreement
Kozloduy 2	Bulgaria	VVER	408	2002	EU-Bulgaria agreement
Stade	Germany	PWR	640	2003	Nuclear closure policy/law
Obrigheim	German	PWR	340	2005	Nuclear closure policy/law
Fugen ATR	Japan	ATR	148	2003	Prototype discontinued
BN-350	Kazakhstan	FBR	52	1999	Prototype discontinued
Ignalina 1	Lithuania	RBMK	1185	2004	EU-Lithuania agreement
Jose Cabrera (Zorita)	Spain	PWR	142	2006	Policy
Barsebeck 1	Sweden	BWR	600	1999	Nuclear closure policy
Barsebeck 2	Sweden	BWR	600	2005	Nuclear closure policy
Chernobyl 3	Ukraine	RBMK	925	2000	EU-Ukraine agreement
Bradwell 1	United Kingdom	GCR	123	2002	Aging
Bradwell 2	United Kingdom	GCR	123	2003	Aging
Calder Hall 1	United Kingdom	GCR	50	2003	Aging
Calder Hall 2	United Kingdom	GCR	50	2003	Aging
Calder Hall 3	United Kingdom	GCR	50	2003	Aging
Calder Hall 4	United Kingdom	GCR	50	2003	Aging
Chapelcross 1	United Kingdom	GCR	50	2004	Aging
Chapelcross 2	United Kingdom	GCR	50	2004	Aging
Chapelcross 3	United Kingdom	GCR	50	2004	Aging
Chapelcross 4	United Kingdom	GCR	50	2004	Aging
Hinkley Point A1	United Kingdom	GCR	235	2000	Aging
Hinkley Point A2	United Kingdom	GCR	235	2000	Aging

Source: IAEA, press notices and reports
Abbreviations (reactor types):
PWR- Pressurized Water Reactor
VVER- Russian-designed PWR
BWR- Boiling Water Reactor
PHWR- Pressurized Heavy Water Reactor (including Candu)
GCR- Gas-cooled Reactor
RMBK- Russian designed water-cooled, graphite moderated reactors
ATR-Advanced Thermal Reactor

The common themes in reactor closures since 1999 can be illustrated by examining Table 2, which groups reactor closures by design category. Primary reasons for closure are aggregated into broader categories than are used in Table 1. “Policy” as used in the table means that the closure decision was initiated either by a government decision or by an agreement among government and international institutions or agencies. “Economics” means that the decision was based on an evaluation of the continued profitability (or net favorable cash flow) of operating the reactors. Economic closure decisions are typically initiated by the reactor owner or operator, though policy decisions might also be involved. “Prototype”, when listed as a reason for closing, means the unit closed for a complex set of reasons including economics, policy, or an end of research usefulness. None of the reactors on the list is specifically designated as closed for immediate safety reasons, although policy and economic decisions include some components related to assessments of long-term safety prospects.

Table 2. Summary of reactor designs and closure reasons since 1 January 1999.

Design Category	Number of Reactors Closed	Primary Reason for Closure
Water-cooled and water-moderated reactors		
PWR	3	Policy
VVER	2	Policy
BWR	2	Policy
PHWR	0	Not applicable
Other reactor designs		
FBR	1	Prototype
GCR	12	Economics
RMBK	2	Policy
ATR	1	Prototype
Source: Table 1		

The reasons for closure vary by reactor category. The only water-cooled and -moderated reactors that were closed since 1999 were closed for policy reasons. The closure decision at each of the six water -cooled and -moderated reactors was at least partly based on judgments by governing or international bodies that continued operation of the reactor involved concerns regarding the long term "safety" of continued operation.   The owners at each of the seven closed water-cooled and -moderated reactors eventually accepted the closure policy, but had indicated that they thought continued profitable and safe operation was possible.

The two closed Bulgarian reactors at Kozloduy (VVER in Table 2) were early models (VVER440-230) of the Russian-designed VVER440 pressurized water reactor series. The policy involved was an agreement between the European Union (EU) and the government of Bulgaria linking eventual Bulgarian accession to EU membership to the closure of the reactors. The five western-designed reactors, three PWRs and two BWR (Table 2) were located in Germany, Sweden, and Spain. Both Germany and Sweden have policies or laws that require the eventual closure of all nuclear power reactors within their jurisdictions based on the long term safety views of the government in power at the time the policy or law was initiated. The governments were also concerned about the costs of the eventual disposition of spent fuels from their reactors. The German law presently requires the closure of reactors after approximately 32 years of operation, based on assumptions of capacity factors at each plant. The 2003 closure of Stade is a bit ambiguous because the reactor was closed a few months earlier than required by German law. This early closure was partly due to the costs of maintenance required on the reactor and partly due to the ability to transfer permitted generation at Stade to a newer unit. Swedish closure decisions, though part of a broader closure policy, has been applied only to a specific reactor site, Barsebeck. The policies that were implemented in Sweden and Germany are longer term policies and those policies remain subject to debate within each nation.

Spain's Jose Cabrera (Zorita) was one of the world's oldest (1968) and smallest (142 MWe) water-cooled and -moderated commercial reactors. The Zorita closure was originally resisted by the reactor's owners. The closure decision was based on a long term, governmental assessment of the reactor's technology and safety. Zorita's recent closure is the product of an agreement between the Spanish government and the reactor's owners.

Thus, no water-cooled and -moderated reactor has been permanently shut down worldwide due to economic or short term safety status since the beginning of 1999. Possible exceptions to this conclusion were noted above. Excluded from the above lists are reactors, such as Davis-Besse or Indian Point 2 that experienced extended but temporary closures, subsequent to 1998, due to short term safety or operational concerns. These reactors were repaired and regulators and operators agreed to the units resuming full commercial operation. If one seeks a case in which immediate plant safety was clearly the reason for the closure of a water-cooled and -moderated reactors, the most recent might be Three Mile Island 2 in 1979.

Twelve of the sixteen "other" reactors in Table 2 that closed since 1999 were Magnox-type GCRs located in the United Kingdom. These reactors are gas-cooled and graphite-moderated. Several were small (as low as 50 MWe) and were among the oldest and smallest operating commercial reactors in the world. The oldest Calder Hall reactors connected to the grid in 1956. While other nations have operated similar reactors, the United Kingdom is the only country that still has commercial Magnox GCRs in operation. During the earlier portion of the period under consideration, the U.K.'s Magnox GCRs saw their commercial viability deteriorate as required repairs multiplied and as competing fossil fuels had an apparent commercial edge in the nation's liberalized electricity markets. This was especially true of the smallest Magnox reactors at Chapelcross and Calder Hall which saw their already scheduled closures pushed forward at that time. The remaining Magnox GCRs in the United Kingdom have anticipated schedules for their closure, though the schedules have some flexibility depending on plant conditions. The twelve GCRs that closed after 1999 are examples that nuclear reactors can "age" producing unfavorable plant economics. In the case of the GCR reactors, the graphite in the reactor core has been particularly prone to "aging" though additional components have also deteriorated at individual plants. It has not been demonstrated that the graphite in the Magnox cores can be economically replaced. Magnox reactors are also prone to high reprocessing costs. The oldest retired plants, Calder Hall 1 & 2, closed after forty-seven years of operation. This compares to an initially intended design life of twenty-five years.

The two Calder Hall units held the world record for continuous commercial reactor operation, but their commercial life was much less than the permitted sixty year life under U.S. licensing regulations as now being implemented. It is impossible to translate Magnox experience to the water-cooled and -moderated reactors that are used in the United States where the oldest operating reactors began commercial electricity generation in 1969. Magnox reactors differ from light water reactors in coolant, moderator, fuel, and operational standards and designs. Therefore, no comparison should be made in anticipating plant longevity.

The two prototype reactors that closed since 1999 were the BN-350 (FBR) in Kazakhstan and Fugen ATR in Japan. In both cases the reactor development activities related to these prototypes were discontinued. This could be classified as either an economic or a policy based closure. Russia, which built the BN-350 reactor, continues to show interest in developing FBRs. Technology has progressed beyond the now closed design which will not be repeated at the original prototype scale. The ATR design shows no notable prospect of revival.

Finally, two water-cooled, graphite-moderated reactors have closed since 1999. These are Russian-designed RMBK reactors also sometimes called "Chernobyl-type" reactors because they are of the design family of the Chernobyl 4 reactor which exploded in April 1986. The two closed reactors were Chernobyl 3 in Ukraine and Ignalina 1 in Lithuania. The reasons for their closings were agreements between Ukraine and Lithuania, respectively, and the international community, including the European Union (EU) and other parties. In both Lithuania and Ukraine, there were unsuccessful domestic efforts to gain international acceptance to keep the reactors operating beyond the agreed closure dates. Lithuania and Russia continue to operate the RBMK design. Russia has been upgrading its RBMK plants with the goal of supporting extended operation and improving safety. Elsewhere, not solely in EU circles, it is held that the RBMK design is not safe to operate in the long term. The EU has led efforts to obtain a schedule for the closure of the remaining RBMK units though no closure agreement exists or is pending with Russia.

III. Anticipated Closures

Table 3 shows nuclear reactors which are planned to close before the end of 2010. The dates are only approximations as reactor closures are frequently delayed or accelerated as policies or reactor conditions change. Some additional closures might occur that are not presently planned. Only reactors whose planned closure is judged to be firm are included. Because there is ongoing discussion regarding life extension for the United Kingdom's AGR family of reactors, these are excluded.

Reactors with identifiable closure schedules are all located in Europe, with by far the largest number in Germany and the United Kingdom. German closures are subject to the plant’s history of operation and to rules that permit some swapping of operating time from older to newer reactors. No allowance was made for a permitted transfer of thirty years of operating time from Mulheim-Kaerlich to other German reactors. German reactor closure dates in Table 3 are thus approximations based on a permitted equivalent of 32 years of operation. The reactor closure law remains in place though it is possible that recent and future elections might change the status of the law. Belgium also has mandatory closure legislation, but these closures would occur after 2010. Sweden's reactor closure plans do not presently involve clear fixed dates. Closure rules have recently been proposed by elements of the governments of Spain and Taiwan, but have not been implemented.

Table 3. Anticipated worldwide reactor closures before 2010.

Reactor	Nation	Design	Capacity (MW)	Projected Closure	Reason
Kozloduy 3	Bulgaria	VVER	408	2006	EU-Bulgaria agreement
Kozloduy 4	Bulgaria	VVER	408	2006	EU-Bulgaria agreement
Phenix	France	FBR	233	2009	Prototype retirement
Biblis A	Germany	PWR	1167	2008	Nuclear closure policy/law
Biblis B	Germany	PWR	1240	2009	Nuclear closure policy/law
Brunsbuettel	Germany	BWR	771	2009	Nuclear closure policy/law
Neckarwestheim 1	Germany	PWR	785	2008	Nuclear closure policy/law
Ignalina 2	Lithuania	RBMK	1185	2009	EU-Lithuania agreement
Bohunice 1	Slovakia	VVER	408	2006	EU-Slovakia agreement
Bohunice 2	Slovakia	VVER	408	2008	EU-Slovakia agreement
Dungeness A1	United Kingdom	GCR	225	2006	Aging
Dungeness A2	United Kingdom	GCR	225	2006	Aging
Oldbury A1	United Kingdom	GCR	230	2008	Aging
Oldbury A2	United Kingdom	GCR	230	2008	Aging
Sizewell A1	United Kingdom	GCR	210	2006	Aging
Sizewell A2	United Kingdom	GCR	210	2006	Aging
Wylfa 1	United Kingdom	GCR	490	2009	Aging
Wylfa 2	United Kingdom	GCR	490	2009	Aging
Source: IAEA, press notices and reports					

The United Kingdom closures are a continuation of the anticipated closures of Magnox GCR series of reactors. All UK Magnox units are expected to be closed by 2010. Table 3 continues to list the reason for closure as "aging." The lack of availability of fuel assemblies will most likely prevent the extension of Magnox GCR operating lives beyond 2010 even though there is some interest in extending the operating life of Wylfa. The dates for the closures of these reactors are approximates based on public statements of their operator.

The only additional western European reactor on the list is Phenix, a prototype FBR in France. The Phenix reactor has an intermittent history of operation and is as much a research facility as a commercial power reactor.

Five reactors slated for closure by 2010 are in Eastern Europe. Four are VVER440 reactors of earlier Russian design, while one is the sole RBMK reactor that is still operated outside of Russia, Lithuania's Ignalina 2. None of the reactors faces closure due to any anticipation of poor economics of continued operation, but rather to EU-led perceptions regarding the long-term safety of the two reactor designs involved. This policy view applies only to the early VVER440-230 design and to all RBMK designs. In each case the operator or operating country initially challenged the safety concerns, but has, at least tentatively, accepted the closure agreement.

Table 4 groups the anticipated closure by reactor type and a summary interpretation of the reason for their closure. The "Primary Reasons for Closure" are an aggregation of the principal reasons for closure listed in Table 3. If Tables 2 and 4 were combined it would be found that of fifteen water cooled and moderated reactors to be closed between 1999 and 2010, twelve are pressurized water reactors (PWRs and VVERs). This is not taken as a trend because, including the western and Russian pressurized water designs together, there are nearly three times as many PWR/VVER reactors in the world as there are BWRs. Also, the policy pressure to close VVER440-230 reactor designs has led to a disproportionate number (6) of recent and planned VVER closures. There is presently no other disproportionate policy effort to close PWRs versus BWRs.

Table 4. Summary of anticipated reactor closures before 31 December 2010.

Design Category	Number of Reactors Closed	Primary Reasons for Closure
Water-cooled and water-moderated reactors		
PWR	3	Policy
VVER	4	Policy
BWR	1	Policy
PHWR	0	Not applicable
Other reactor designs		
FBR	1	Prototype
GCR	8	Economics
RBMK	1	Policy
ATR	0	Not applicable
Source: Table 1		

IV. Conclusions

No water-cooled and -moderated nuclear reactor has been closed for unambiguous commercial economic reasons since 1999. Indeed, since 1999 only GCR units and perhaps prototypes have been closed for economic reasons. Fast breeder reactors are included among these prototypes. There are a few examples where economics might have been considered a contributing cause of reactor closure, though those reactors are here considered as closed before 1999, based on IAEA definitions. There is no reason to anticipate water-cooled and -moderated reactors to remain immune to eventual closure due to economic conditions. This will be the result of continuing operating histories and policies. There is however little recent (since 1999) evidence that there is any extraordinary economic risk to the continued operation of most water-cooled and moderated reactors worldwide.

Safety is a more complex issue. Several reactors have been temporarily closed for transient safety reasons since 1999. The reasons for closure have proven to be due to conditions that could be economically repaired. Such reactors subsequently resumed power generation and their owners intend to operate them for the foreseeable future. Reactor closures in Sweden and Germany are the product of longer-term reactor closure policies. These policies are due to governmental decisions at least partly based on doubts regarding the long-term safety of nuclear power in general. The closures were not based on perceptions of an immediate safety risk from particular reactors.

Concern regarding the long term safety of the Russian-designed RBMK and earlier VVER440-230 reactor designs is a basis for efforts of the European Union and sometimes others to see these reactors eventually closed. A closure schedule for these plants is (or was) a precondition for EU membership for Lithuania, Slovakia, and Bulgaria. The EU position has been challenged, especially in regard to the VVER440-230 designs. Some studies have found the VVER440-230 series of reactors as safe as water-cooled and -moderated European reactors of similar vintage. These findings have not altered the EU policy and the closure agreements remain in place in eastern Europe.