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The failings of the Advanced Boiling Water Reactor (ABWR) proposed for Wylfa Nuclear Power Station

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Construction of the Lungmen Nuclear Power Plant in Taiwan, which was never completed © Mastehr

SUMMARY

- The proposed reactor design for Wylfa Nuclear Power Station is the Advanced Boiling Water Reactor (ABWR), taken through UK regulatory approval by Hitachi–GE
- Hitachi-GE has no markets other than the UK so if Wylfa fails, Hitachi-GE's future as a reactor vendor must be in doubt
- The portrayal of the ABWR as a proven reactor design with a good record of construction and operation is not supported by the record
- There is no reliable information on the costs of the ABWR

INTRODUCTION

The Advanced Boiling Water Reactor (ABWR) is the one of the latest designs of Boiling Water Reactor (BWR). It generates electrical power by using steam to power a turbine connected to a generator; the steam is produced using heat generated by fissions within the nuclear fuel. BWR technology was licensed to several companies by General Electric (GE), but only Hitachi-GE and Toshiba are still marketing their versions of it. About 17 per cent of the world's operating nuclear power reactors are BWRs, most in the US and Japan.

JAPAN'S BWR & ABWR PROGRAMME AND STATUS

The largest operator of BWRs in Japan is Tokyo Electric, which has built 17 units including the six at Fukushima Daiichi. Chubu Electric, which has been mentioned as a potential investor in Wylfa,[1] has built five: two were retired before the Fukushima disaster and three are still in service, including one ABWR. Japan's nuclear plants have operated very little since the 2011 tsunami and meltdown at Fukushima and only six reactors had returned to service by the end of February 2018, none of which were BWRs. Japan's Nuclear Regulation Authority requires major and costly upgrades to reactors before they can be returned to service and the utilities are struggling to raise the funds needed. There have also been strong, sometimes successful, legal attempts to prevent the re-opening of the reactors.[2]

All the reactors at the Fukushima Daiichi plant were BWRs (see Appendix A).

DEVELOPMENT AND CONSTRUCTION OF THE ABWR

Development of the ABWR began in 1978. In 1981, GE, Toshiba and Hitachi announced they were collaborating on it with six Japanese utilities.[3]

The design was completed in about 1986[4] (before Chernobyl). Construction on the first ABWR unit in Japan started in 1992. Four ABWRs were completed in Japan but have not operated much since Fukushima and it is not clear if they will start up again. It is also not clear whether the plants under construction will be completed. Two reactors in Taiwan, where construction has been suspended, are highly unlikely to be completed. All ABWRs ordered are of the first, 1986, design.

The partnership between GE, Toshiba and Hitachi ended when Toshiba took over GE's main rival, Westinghouse, in 2007. With Toshiba now a competitor, Hitachi and GE formed two joint ventures, one mainly for US business (GE-Hitachi) and one for other markets (Hitachi-GE). Hitachi-GE (80 per cent Hitachi) is the developer of Wylfa and Oldbury. It has no markets other than the UK so if Wylfa fails, it is hard to see much future for Hitachi-GE as a reactor vendor.

REGULATORY REVIEW OF THE ABWR

The regulatory process for the ABWR began in the US in 1986. In 1997 an updated ABWR was finally given generic approval for 15 years by the US Nuclear Regulatory Commission (NRC). This allowed it to be built at any site in the US with only site-specific issues to be resolved, although no orders for this design have been placed. The regulatory process is similar in the UK.

In 2010, both GE-Hitachi and Toshiba applied for an extension to their regulatory approval

Pictured: an artist's impression of Horizon's new nuclear power station at Wyfla Newydd © Department of Energy and Climate Change / Flickr

with further updated designs – after 9/11, all new reactors for Europe and the US must be designed to withstand an aircraft flying into them. Toshiba abandoned its renewal request in 2016.[5] There appears to be little progress on GE-Hitachi's US licence renewal and given that there are no prospective customers in the US, GE-Hitachi may also abandon the process.

The US authorities have a somewhat different safety philosophy to the European authorities, so the design submitted to UK regulators differed from the one submitted to the NRC.

The Hitachi-GE ABWR, as planned for Wylfa, was submitted to the UK Office of Nuclear Regulation (ONR) in January 2014 and was given design acceptance in December 2017.[6] The process was completed in four years, significantly less time than taken for other designs. It also appears that the ONR flagged up fewer 'regulatory issues'.

EXPERIENCE WITH THE ABWR

Appendix B shows experience with the ABWRs to date. All ABWRs in Japan were built very quickly, in 4-5 years, which is unusually fast by international standards but typical of reactors built in Japan.

The reactors in Taiwan have been delayed almost since the start of construction.[7] Following the election of a government that pledged to phase out nuclear power by 2025, there appears little chance of the reactors being completed[8] (see Appendix C).

The reliability of the operating reactors in Japan has been poor. Hitachi-GE claim the ABWR will achieve an average load factor of 90 per cent (kWh produced over maximum possible kWh). The average for the operating ABWRs is about 60 per cent.[9] All the plants have undergone very lengthy shutdowns,[10] including dealing with issues raised by earthquakes and turbine failures.

However, even in the years where the reactors were not affected by the need for seismic upgrades or turbine problems, performance was often mediocre. Load factors were seldom much higher than 80 per cent and only reached the 90+ per cent claimed by Hitachi-GE in four out of the 38 reactor years of experience. Even if the lengthy shutdowns were discounted, the average load factor would still be only about 70 per cent.

CONCLUSION

The portrayal of the ABWR as a proven reactor design with a good record of construction and operation is not supported by its record.[11]

Three companies have been involved with the ABWR – Hitachi, Toshiba and GE – and it is difficult to attribute problems at one plant to a particular vendor. Toshiba and GE-Hitachi, with its US market focus, have no realistic prospects for orders, while Hitachi-GE is relying on the UK market. The lack of bids for ABWRs in recent years means cost estimates for the current version of the ABWR are not available.

The construction time record in Japan is good but not significantly different to virtually all reactors built in Japan. Reliable information on the costs of the Japanese ABWRs is not available and given that it would be for a much earlier design, it would be of little predictive value. The construction record in Taiwan is poor, but it is difficult to determine how far the delays and high costs are due to political decisions and funding shortages, and how far to construction difficulties.

APPENDIX A – THE BWR AT FUKUSHIMA DAIICHI[12]

It appears that GE, Toshiba and Hitachi have all had some role with all of Japan's BWRs, so it is difficult to attribute problems at a particular plant to one of the three companies.

A major difference between the early BWRs and later ones, including the ABWR, was improved containment.[13] Units 1-3 at Fukushima Daiichi suffered major explosions at the time of the 2011 tsunami, while Unit 4, which was closed for re-fuelling, suffered a major fire. Units 5 and 6 were less damaged. How far the type of containment contributed to the damage is beyond the scope of this article. All six units have been formally retired.

Fukushima Daiichi

Unit number	*Output (MW)/model*	*Reactor supplier*	*Commercial operation*
1	439 (BWR3)	GE	10/70
2	760 (BWR4)	GE	5/73
3	760 (BWR4)	Toshiba	3/76
4	760 (BWR4)	Hitachi	10/78
5	760 (BWR4)	Toshiba	4/78
6	1067 (BWR5)	GE	10/79

APPENDIX B – CONSTRUCTION AND OPERATION OF ABWR

Experience has been poor. A 6.6 magnitude earthquake at Chuetsu-Oki in 2007 led to a two-year closure of all seven reactors at Kashiwazaki Kariwa, including the ABWRs for investigations. Significant upgrades were required before the reactors could be restarted. Shika 2 was closed from late 2006 until May 2008 due to a steam turbine failure. Hamaoka 5 was shut down for much of 2006 due to a turbine blade failure. Hitachi accepted responsibility for these failures and paid for the repairs. As a result of the 2007 earthquake, all five Hamaoka units were re-assessed and Units 1 and 2 permanently closed. The other units, including the ABWR, were upgraded leading to the closure of the ABWR for more than a year.

Experience with the ABWR

Reactor	*Construction start*	*Commercial operation*	*Owner*	*Supplier*	*Lifetime load factor to end 201 0 (%)*
Kashiwazaki Kariwa 6	11/92	11/96	Tokyo	Toshiba/GE	71.2
Kashiwazaki Kariwa 7	7/93	7/97	Tokyo	Hitachi/GE	68.6
Hamaoka 5	7/00	1/05	Chubu	Toshiba	47.4
Shika 2	8/01	3/06	Hokuriku	Hitachi	49.7
Ohma	5/10	-	J-Power	Toshiba/Hitachi	-
Shimane 3	10/07	-	Chugoku	?	-
Lungmen 1 (Taiwan)	3/99	-	TaiPower	GE	-
Lungmen 2 (Taiwan)	8/99	-	TaiPower	GE	-

APPENDIX C – FAILURE TO BUILD ABWR IN TAIWAN

The reactors in Taiwan have been delayed almost since the start of construction.[14] The reasons cited were escalating prices and government procurement rules. Delays to government funding continued in 2006. But problems were not confined to funding and in 2011, the Taiwan nuclear safety authority considered suspending the project due to construction difficulties and quality concerns.[15] In 2014, the government decided to suspend work at the site.[16] Unit 1 was then said to be largely complete and Unit 2, 90 per cent complete. It was reported that Taiwan had spent US$9.9bn on these plants.[17] In December 2015, GE began arbitration proceedings with Airpower to recover its costs.[18] Following the election of a government that pledged to phase out nuclear power by 2025, there appears little chance of the reactors being completed.

Operating performance with ABWRs (load factor %)

Year	*Kashiwazaki 6*	*Kashiwazaki 7*	*Hamaoka 5*	*Shika 2*
1997	88.2			
1998	92.9	84.3		
1999	84.3	73.3		
2000	81.5	97.3		
2001	80.5	87.5		
2002	99.9	69.4		
2003	72.9	50.2		
2004	74.8	93.5		
2005	96.6	69.2		
2006	73.3	70.9	29.3	
2007	32.6	55.2	71.0	0.0
2008	0.0	0.0	70.6	61.1
2009	31.7	46.6	12.6	58.2
2010	82.7	78.4	0.0	95.6
Lifetime	71.2	68.6	47.4	49.7

Source for tables 1-3: www.iaea.org/PRIS/home.aspx (accessed February 2, 2018)

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