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A Forecasted Analysis of the Nuclear Reactor Market to Meet the Global Low-Carbon Industrial Heat Demands

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Abstract

There is a global need to reduce greenhouse gases, and industrial applications are one of the hardest-to-abate sectors. These energy-intensive industries require high-temperature heat which predominantly comes from fossil fuels. The United Kingdom National Nuclear Laboratory has developed a model to forecast the demand of both electricity and heat up to the year 2050, therefore providing an estimated demand that nuclear energy could help fulfil. This article uses the model to investigate the market potential for light water reactors and high-temperature gas-cooled reactors to determine the applicable heat markets globally. The analysis shows that the demand will be up to 1257 TWh for light water reactors and up to 2123 TWh for high-temperature gas-cooled reactors by 2050.

Keywords: industrial head demand; global energy; light water reactor; high-temperature reactor

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1. Introduction

To support decarbonisation, low-carbon alternatives must be economically viable, low-risk and meet the end user's requirements in the required timeframes. Decarbonisation of the electricity network can be achieved using renewable energy sources where sufficient natural resources allow [1]. However, heat demand is more challenging to decarbonise. Technologies such as heat pumps or electrical heating can be used to reduce the carbon footprint of buildings, but manufacturing and industrial processes require higher temperatures that are difficult to achieve and maintain using renewable energy sources [2]. As such, these industries retain a high dependence on fossil fuel technology. There are significant ongoing efforts to decarbonise the manufacturing and industrial sectors to meet low-carbon emission targets to mitigate the impact of carbon emission pricing and improve environmental credentials [3].

Currently, the main use of energy from nuclear systems is almost exclusively electricity generation, but its primary energy output is heat, which could also be used to support other processes [4]. The low carbon emissions, high availability factor, and security of supply make nuclear energy appealing to industry. However, the high capital costs, long lead times, and perceived risk have meant that a nuclear renaissance is slowly emerging. Over-running and increasing costs of megaprojects such as Hinkley Point C do little to quell concerns [5]. Small Modular Reactors (SMRs) or Advanced Nuclear Technology (ANT) promise factory buildings that reduce capital cost and reduce risk (financial and technological) once established. However, these technologies are yet to be built in the multiples required to demonstrate cost and risk reduction [6]. Challenges to realising the vision for SMRs and ANTs include the following:

- Different regulatory standards: there are no universal regulatory standards, so vendors must develop tailored cases for each new market. The costs and time for regulatory approval may be prohibitive. Regulators are working together, but accepted 'norms' appear to be some time off or not workable.
- The market is very competitive, with new and experienced vendors competing against one another. Over time, specific vendors will take the market share by demonstrating that their business model reduces the risk of the technology—it is likely that these will not be the 'best' technology but will be the most commercially acceptable.
- Investor confidence is undermined by a lack of detail on market demand. In particular, quantifying the role nuclear plays in decarbonising heat-intensive industries could extend the nuclear market beyond electricity. This paper attempts to quantify the market and help by reducing the uncertainty in business models by providing a source of data for industrial heat demand.

There are several reputable institutions that work within the field of demand forecasting, including the World Nuclear Association (WNA) [7] and International Energy Agency (IEA) [8]. WNA analysed each country using three nuclear deployment scenarios based on the uptake of nuclear energy (reference, low, and upper). This analysis provided a range of nuclear energy to be deployed in that country up to the year 2040 [7]. The future nuclear capacity required in each country was assessed for each scenario based on publicly available information. IEA methodology focused on determining the future electricity demand for each country; from this, the proportion that might be provided by nuclear was assessed. IEA has published these scenarios in its annual World Energy Outlook (WEO) report [8]. The degree of nuclear deployment varies between WEO reports (e.g., 2020 [9] versus 2024 [8]), reflecting how the use of nuclear technology is being considered. Neither WNA nor IEA reports quantitively assess the use of nuclear to meet heat demand (yet both note there is potential to contribute towards this sector).

The Internation Atomic Energy Agency (IAEA), which provides advice and guidance on the use of nuclear energy, has identified the use nuclear heat for hydrogen production, desalination, cooling and refrigeration, district heating, and process heat [10]. However, this does quantify the demand for these markets. The "Advances in Nuclear Power Process Heat Applications" IAEA TECHDOC focused on the use of high-temperature gas-cooled reactors (HTGRs) for the production of hydrogen and desalination. The report mainly provided a technical feasibility perspective and did not quantify the potential market for these applications [11]. Similarly, the OECD-NEA published a small amount of information on heat demands and emphasised the industrial heat demands globally, but did not aim to quantify the future market demands [12].

The Generation IV International Forum (GIF) has recently established a Task Force on non-electric applications of nuclear heat. This Task Force will investigate how Generation IV systems can be used to decarbonise future energy mixes for heat applications [13]. The group produced their first position paper in 2022 and have not published much research on global energy demands yet.

A large portion of heat demand comes from industrial applications, which is hard to abate due to temperature requirements and the need for constant process heat. The requirement to decarbonise and the volume of heat required make this sector a likely contender for the first adopters of nuclear technology. A study was performed by Peakman et al. focusing on the UK industrial heat demand, but this only focused on current heat demand and misses the global picture [14].

This article aims to provide a market analysis for nuclear technology based on heat demand globally, with a focus on industrial applications (as electrical demand was covered in an earlier publication [15]). Its objective is to give market confidence in the business case

for new nuclear technology by providing a realistic, yet conservative, quantitative analysis of how nuclear technologies can support the decarbonisation of the heat market.

2. Methodology

The research aimed to determine the total future industrial heat demand globally and then to break this down into the number of reactors that might be able to meet this demand based on conservative assumptions. This can be broken down into the following three stages:

- Demand forecasting to determine the energy demand in the future.
- Determining the required temperature ranges of each of the demands.
- Determining the number of reactors required to meet each given demand.

As identified by Peakman et al., light water reactors could play a role in supplying industrial heat, but this article also investigated the role of HTGRs [14].

2.1. Demand Forecasting

Demand forecasting methodologies are based on predicting future demand based on historical demand and other impacting factors. The functional specification for the model required the prediction of the global energy demand for heat and electricity up until 2050 and the potential markets for nuclear energy.

The accuracy of the future forecast is dependent on the quality of the starting data, but there is limited public information available due to its commercial value. The most suitable data for energy demand comes from the IEA, which works with governments and local organisations to determine the energy spent in each sector. This data was available from 1960 for the 150 countries which the IEA work with. After reviewing the IEA data, it was determined that most countries that could deploy nuclear energy were within the IEA data, meaning this a suitable dataset to be used in the model. The IEA reports provide data on the primary energy sources delivered to each sector, such as raw materials (oil, coal, and natural gas) alongside secondary energy sources, e.g., heat. The granularity provided by the IEA for each heat demand is important to determine the temperature demands.

To forecast the demand, the model used an industry-standard approach where the natural log of the intensity of the energy is proportional to the gross domestic product per capita (GDPPC), as shown in Equation (1) [16]. This method of demand forecasting is similar to that used in the IEA, who do not publish their forecasting methodology, but Hua Liao et al. propose a similar approach as shown in Equation (1) when ignoring market share against other technologies [17]. This relationship can be expanded to include the change in GDPPC and, therefore, the intensity of the demand at future years.

$$\text{Demand relationship}: \; LN(Intensity_i) = \propto + \beta \times \left(\frac{GDP_i}{Population_i}\right) \quad (1)$$

The chosen method for the results presented in this article for demand forecasting were based upon fixed effects panel regression to determine the beta coefficients for each country.

The analysis was performed on data from 2009–2019 as these capture the transition to a low-carbon society and negate the energy impact of the COVID-19 pandemic. Therefore, any energy predictions used in this model assume that energy use will reach that of pre-COVID-19 levels, which aligns with the literature [18].

GDPPC is required to perform the analysis, but this is not easily accessible globally. Therefore, the population database from the World Bank was used [19] to provide forecasted populations for all the required countries. To predict the GDPPC, this used a combination of data from the International Monetary Fund (IMF) on the historical and predicted GDP per country until 2027 [20]. Beyond 2027, the OECD's GDP forecasts were used for 47 countries,

grouping the countries per income group to predict GDP [21]. Similar income groups for GDP growth (fractional) over time were applied to any countries missing in the IMF's database. The use of additional datasets for the world population and GDPPC could provide more rigor and a method of integrating uncertainty into the model based on the data use. However, very few databases with these details for every country required are available and this limits the model to the data chosen.

To determine the beta coefficients (Equation (1)), a script was created in R version 4.1.2 [22] using the PLM module version 2.6.0 [23], which performed the panel regression based on the input data. The beta factors were then added to the model for the demand forecasting.

The model breaks down the heat demand into the thirteen industrial sectors based on the IEA datasets listed below (sometimes referred to as manufacturing in IEA documentation). It is noted that there are several industries which are missing from the IEA data—these industries are captured within the Unspecified category.

- Chemical and Petrochemical
- Construction
- Food and Tobacco
- Unspecified
- Machinery
- Mining
- Non-ferrous Metals
- Non-metallic Minerals
- Paper and Pulp
- Iron and Steel
- Textiles
- Transport Equipment
- Wood and Wood Products

IEA provides primary energy data for heat, coal, oil, and natural gas for each of the thirteen sectors, where all these energy demands were forecasted within the model to determine the required demands.

The option to include buildings in the analysis was omitted (despite data being available) due to the market for space heating being so vast. Due to the low temperatures of space heating, these could be supplied via waste heat of nuclear energy, but this would require a whole-system approach, which is beyond the scope of this study and could make the results seem overly optimistic.

This article focuses on replacing demands met by fossil fuels and has not considered a lifecycle assessment of the energy produced, which would provide a more comprehensive analysis of carbon savings.

2.2. Temperature Requirements

Each of the IEA datasets has different temperature requirements dependent on the process performed. During a literature review for each of the industries, it became apparent that there is limited information on the required temperatures for some industries. There are some modern examples where demands have been calculated, but there is limited information on how the temperatures for these processes were determined [24]. One study by the Ecoheat & Power group in 2006 gathered data from industry users across Europe for their demand and temperature requirements. This study engaged end users, increasing the confidence in the data, such that it is still referenced today and used in European policy and IEA [25,26]. The Ecoheat 2006 study groups the IEA demand sectors into the following temperature ranges: low, medium and high temperatures, as denoted in Table 1.

The broad ranges of temperatures assigned to Table 1 require further refinement for the model to reduce uncertainty in processes greater than 400 °C. The >400 °C section has been split into two, up to 750 °C and over 750 °C, as these are commonly used temperature

brackets. This next section provides some justifications for the temperatures used in the model.

Table 1. Ecoheat temperature demand ranges.

Category	Temperature (°C)
Low	<100
Medium	100 < and < 400
High	>400

Chemical and petrochemical industry—Several high-temperature processes (>750 °C) are required in the chemical industry (e.g., ammonia and ethanol production [24]). Processes such as coke and oil refinement require a temperature up to 730 °C, which account for a significant proportion (17%) of UK industrial heat demand [27]. As this is one of the largest demands globally, there needs to be further clarification on the temperature ranges. Due to the challenge of finding data, the proportion of demand greater than 750 °C is assumed to be 50% of this demand, as this acts as a conservative representation.

Pulp and paper industry—M. Rehfeldt et al. note that chemical pulp requires <200 °C [24]. There is limited information on processes greater than 400 °C, so the model assumes that all this high-temperature demand is below 750 °C.

Iron and Steel industry—The demands in this sector below 400 °C are negligible. Blast furnaces make up most of this demand, where 77% of the demand is greater than 1000 °C. The model, therefore, assumes that none of this demand is below 750 °C. It is recognised that, in some cases, blast furnaces are being phased out in favour of electric alternatives (which should be captured by the forecasting approach based on historical demand).

Non-metallic mineral products industry—The production of products such as glass (800–1500 °C), cement (1300–1500 °C), and ceramics (800–2700 °C) falls within this category [27]. Each of these products require a variety of temperatures, but most of them are above 750 °C.

Non-ferrous metal industry—The demand for these materials is high due to the number of everyday products produced from them. Most manufacturing steps require process operations greater than 750 °C, e.g., Aluminium (1200 °C [28]), Copper (1250 °C [29]), Tin (1150 °C [30]). This puts these demands beyond 750 °C.

Rest of the industries—The Ecoheat 2006 study groups all remaining industries together alongside the unspecified demand. Due to the breadth of these industries, it is assumed that the high-temperature demand is split evenly between <750 °C and >750 °C.

Comparison with the other cited literature indicates that there are large differences in predicted demands per sector [24]. It is challenging to band an industry into temperature brackets, for example, there are 15,000 different chemicals produced, and not every chemical can be assessed in this analysis. This suggests that some sectors may benefit from a degree of flexibility in supplied heat and, in some cases, innovation could reduce the temperature requirements of these processes. These findings highlight the need for a better understanding of the global heat demands of industry, including specific information on the temperatures required and possible future developments.

The revised temperature demand profiles used in the model are shown in Table 2, where the temperatures below 400 °C are from the Ecoheat 2006 study. These demands assume that similar processes will be used across all the industries, as developed from the European data in 2006. For temperatures which sit between brackets, the energy demand is linearly extrapolated across the bracket. For some of the industries with temperature requirements greater than 750 °C, nuclear-enabled hydrogen could be a viable option.

Hydrogen production and demand from nuclear energy are not evaluated here to add conservatism to the outputs of this article. Aviation and shipping (transport) are omitted from the demand requirements in the current version of the model due to the limited market penetration for nuclear in these sectors at the time of writing.

Table 2. The models demand for each of the industries with an extra temperature bracket added.

Temperature Range (°C)	**0 < 100**	**100 < 400**	**400 < 750**	**>750**
Industry	**Percentage of the Demand**			
Chemical and petrochemical industry	23	28	24.5	24.5
Pulp and paper industry	27	55	18	0
Iron and steel industry	0	0	0	100
Non-metallic mineral products industry	0	0	0	100
Non-ferrous metal industry	0	0	0	100
Food, drink, and tobacco industry	55	45	0	0
Rest of the industries	60	30	5	5

As there is not an easy way to determine the future penetration of nuclear energy into the heat market, the model allows the user to input this data as a variable (percentage of total market). A conservative estimation of a 10% replacement of fossil fuel use has been chosen for this analysis. This 10% is likely to comprise the largest facilities in these sectors, which require constant throughput, where it is viable to locate a nuclear reactor on or near the location of the demand.

There is a limitation in the spatial distribution of the heat demand, as heat is not as easily transportable as electricity (but there are ongoing developments in this field [31]). Some examples of how to integrate nuclear heat production in an industrial cluster have been performed, but more work is required to understand the practical application of the technology [32].

Not all countries will be suitable for nuclear energy due to nuclear policies, regulation, and the viability of supply versus demand. The model incorporates several user-defined functions to filter out countries that currently cannot deploy nuclear for one of the following two reasons:

1. Nuclear capability—Nuclear market share is only possible if the country will have nuclear energy by the chosen market year. Countries which have stated they want to deploy nuclear and by when have been included for this filter.
2. Nuclear policy—The model should only consider countries where its legal and/or in line with governmental policies. This current assessment rules out the following countries: Australia, Austria, Belgium, Denmark, Germany, Ireland, Italy, Serbia, Spain, and Switzerland.

The model for this article uses the WNA countries which will have nuclear energy by 2040 to determine the new nations that will adopt the technology [7]. Application of these filters (including WNA's reference data) limits the total accessible market to 41 countries capable of using nuclear energy in 2050. This assumption is relatively conservative, as successful deployments are likely to encourage other countries to adopt the technology. Furthermore, there are a number of countries with anti-nuclear policies that are considering amending these in order to achieve their energy transition targets [33].

2.3. Reactors Used in the Analysis

To determine the demand which can be met by different reactor types, the reactors being used in the analysis should be defined with relevant justifications. The heat market analysis was performed using a standard SMR light water reactor (LWR) with the parameters shown in Table 3. These parameters were chosen to make this study applicable to a broad range of LWR vendors, but the market analysis can be tailored to other designs. Most reactors deployed globally are LWRs, which operate at an outlet temperature from 280 to 330 °C globally [34]. For this analysis, a median value of 305 °C was used as the outlet temperature.

Table 3. LWR SMR parameters used in the model.

Reactor Parameter	LWR
Reactor power (MWe)	300
Reactor power (MWth)	909
Outlet delivery temperature (°C)	305
Heat output efficiency to external demands (%)	80
Capacity factor	0.9

The heat analysis was also performed with a HTGR to determine the difference in market penetration on heat demand between the two designs. The only change in the HTGR parameters was that the outlet temperature was set to 900 °C, allowing access to a larger market.

The study recognises that there is a wide range of other reactor designs that may have advantages over those studied here. Very-High-Temperature Reactors (VHTRs) might obtain temperatures over 1000 °C, and the fluid fuel in molten salt reactors gives them a great deal of flexibility in design with relatively high potential heat output. However, this study has been restricted to the UK Government's preferred technologies, as outlined in their Civil Nuclear: Roadmap to 2050 [35]. HTGRs should be considered as an example technology representing the use case for any ANT; the exact choice of reactor is very likely to be site-, demand-, and application-specific.

3. Results

The demand for a particular reactor type is determined by the heat it is able to supply. Since HTGRs supply higher temperatures, their ability to meet demand is greater for some industries, which is illustrated in Table 4. The impact of post-heating of the outlet via electrical means has not been included in this analysis, as this would require a more granular understanding of the demands for each industrial facility [36].

Table 4. Comparison between the accessible industry market heat demand.

Industry	LWR Demand (%)	HTGR Demand (%)
Chemical and petrochemical industry	42	84
Pulp and paper industry	65	100
Iron and steel industry	0	33
Non-metallic mineral products industry	0	33
Non-ferrous metal industry	0	33
Food, drink, and tobacco industry	86	100
Rest of the industries	81	97

3.1. Light Water Reactor Analysis

The light water reactor specifications used in this analysis are from Table 3. Figure 1 and Table 4 highlight that LWRs can be used in industrial applications such as paper and pulp and the food, drink, and tobacco industries. A lot of the demand from these industries comes from drying processes, which require low temperatures and could be well suited to tertiary circuits from these systems.

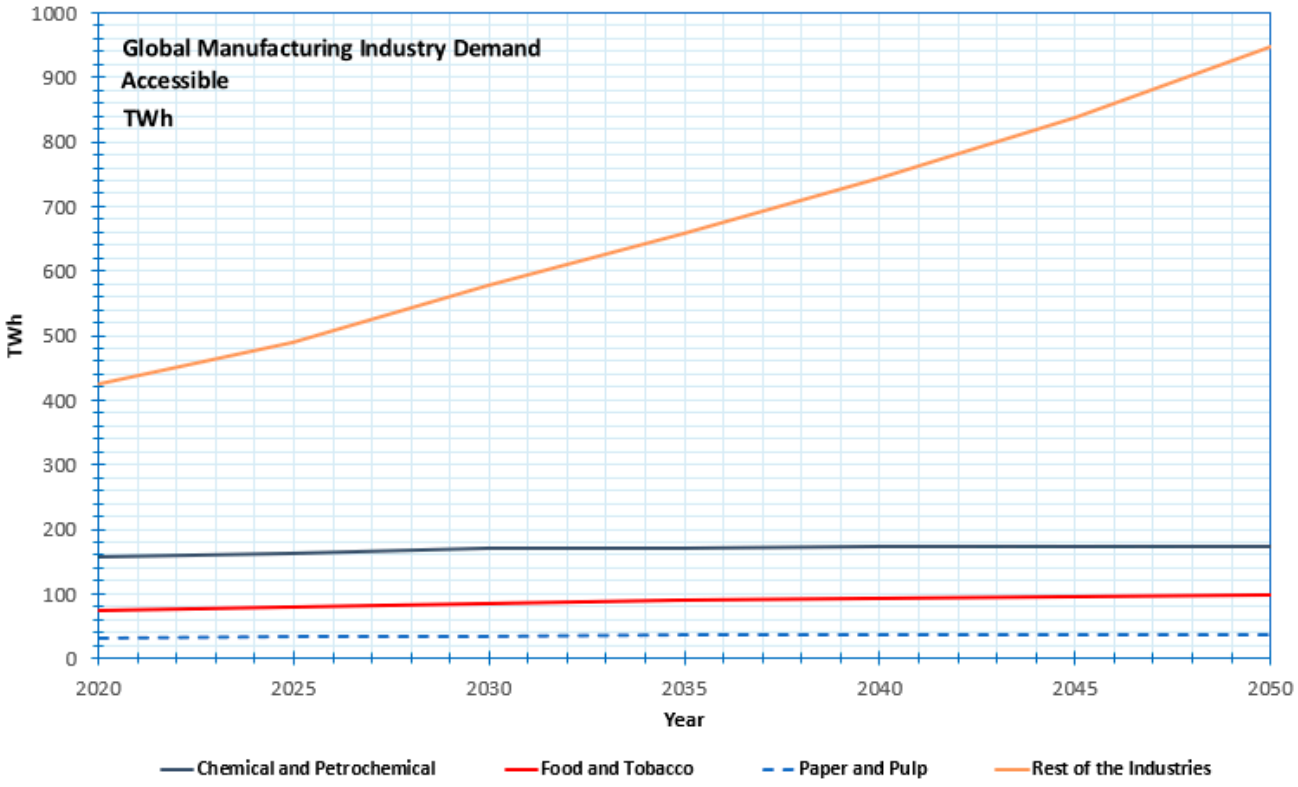

Figure 1. Accessible heat demand for LWRs from nuclear assuming a 10% market penetration.

Most of the demand from industry comes from the "Rest of the Industries", which the model further breaks down in Figure 2. It is likely that these heat demand requirements come from a combination of small industry end users; in this case, there might not be the capital cost and long-term commitment required to justify the deployment of an SMR. The lack of information on these industries highlights the challenges in understanding the international heat demand and provides more evidence that end user engagement is required to support a transition to net zero. The steep rise in this new demand is hard to understand due to the lack of details provided within the dataset, which makes this challenging to decarbonise. Due to the current uncertainty in this data, the demands with and without the "Rest of the Industries" will be presented due to the uncertainty of this demand being penetrable by nuclear technology.

The three remaining industries which are quantifiable have their potential accessible market broken down in the years 2035 and 2050 to determine how many LWR SMRs could be used to support this market, which is shown in Table 5. Within the assumptions of the methodology, it is stated that the 10% market penetration rate will focus on large users, which could mean multiple reactors on a single site. The demand for most of these industries remains quite constant until 2050, which is beneficial, as the existing sites and demand are likely to remain in place for long periods of time.

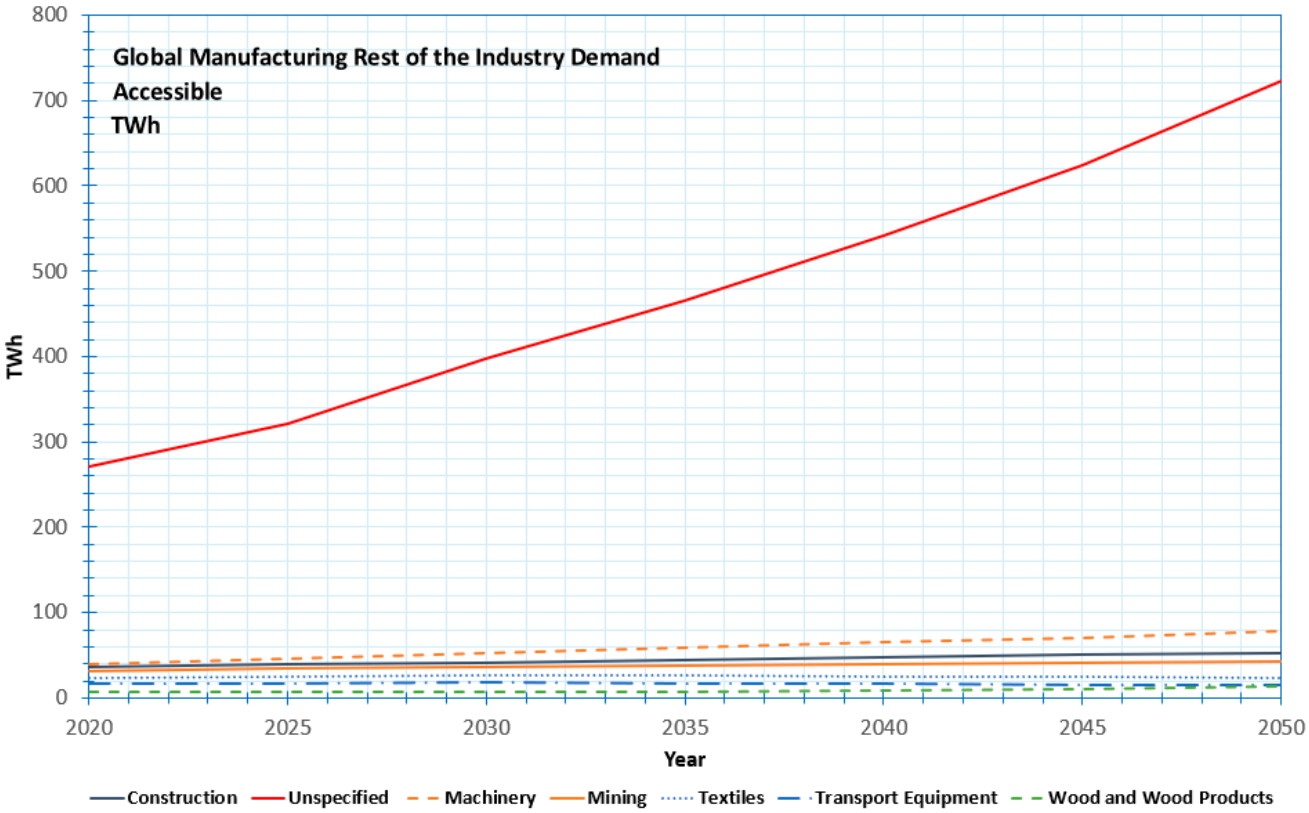

Figure 2. Rest of Industries' demand breakdown for heat requirements, assuming 10% market penetration of the demand.

Table 5. LWR SMR heat market analysis for the years 2035 and 2050 assuming 10% market capitalisation.

Industry	2035		2050	
	Demand (TWh)	Reactors	Demand (TWh)	Reactors
Chemical and Petrochemical	172	28	173	28
Paper and Pulp	36	6	37	6
Food and Tobacco	91	15	98	16
Total	299	49	308	50
Rest of the Industries	658	108	949	150
Total with Rest of Industries	957	157	1257	200

3.2. High-Temperature Gas-Cooled Reactor Analysis

The elevated outlet temperature of HTGRs enables use in three new industries compared to the LWR (Table 4 and Figure 3). The model predicts that the iron and steel industry is growing, and post 2050, this demand could exceed that of the chemical and petrochemical industry. The Rest of Industries energy data is higher for HTGRs than that of LWRs due to the elevated outlet temperature; however, the same arguments hold with respect to the applicability of nuclear to this demand. The demands and total number of reactors for the years 2035 and 2050 are displayed in Table 6.

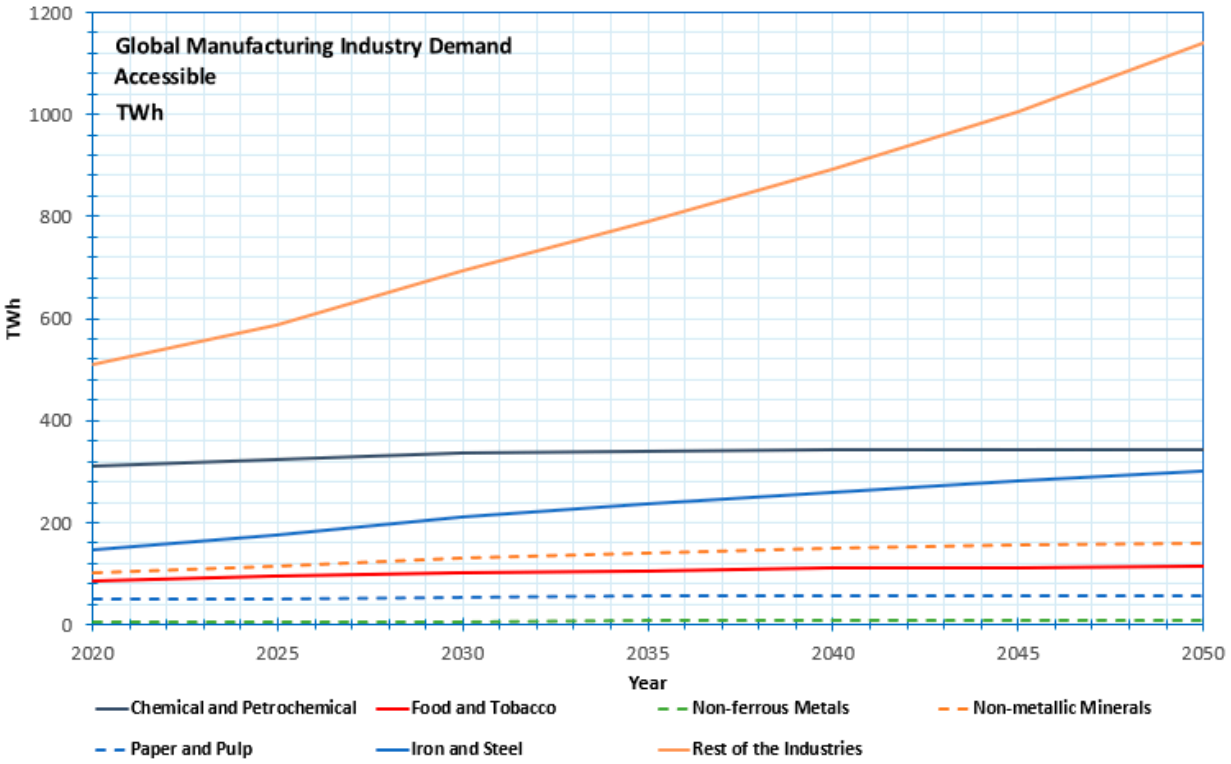

Figure 3. Global manufacturing energy demand in TWh for the HTGR SMR.

Table 6. HTGR demands for each industrial sector for the years 2035 and 2050, assuming 10% market capitalisation.

Industry	2035		2050	
	Demand (TWh)	Reactors	Demand (TWh)	Reactors
Chemical and Petrochemical	341	56	344	56
Paper and Pulp	56	9	57	9
Food and Tobacco	106	17	114	19
Non-Metallic Minerals	141	23	159	26
Non-Ferrous Metals	7	1	9	1
Iron and Steel	236	39	301	49
Total	887	145	984	160
Rest of the Industries	790	130	1139	187
Total with Rest of Industries	1677	275	2123	347

3.3. Demand Summary

This article has aimed to understand the potential number of reactors which could be used to meet the low-carbon transition for industrial heating based on their outlet temperatures. Previous studies by Peakman et al. [14] suggested that most of the demand was below 500 °C for the UK, and this article has highlighted that accessing some of the higher-temperature industries could provide new markets for nuclear in the greater than 750 °C category.

The difference in applications between an LWR (305 °C) and HTGR (900 °C) are highlighted by the demands in Table 7, where even when removing the uncertainty of the "Rest of Industries", the market for process heat is nearly three times higher for a HTGR. The study could benefit from further refinements by providing the costings of

process modelling of both an LWR with post heating compared to those of a HTGR with direct outlet temperature heating, but the data on the costs of these systems comes with a lot of uncertainty. There could also be opportunities for the electrification of industries through the use of an LWR to provide heat, even for industries with greater temperature requirements, and further economic modelling could help to confirm this.

Table 7. Summary of the 2035 and 2050 number of reactors to meet the required demands.

Reactor Type and Scenario	2035		2050	
	Industry Heat Without Rest of Industry	With Rest of Industry	Industry Heat Without Rest of Industry	With Rest of Industry
LWR	49	157	50	200
HTGR	145	275	160	347

3.4. High-Temperature Industry Demand

High-temperature industries are one of the hardest-to-abate sectors due to there being a requirement for constant throughput at elevated temperatures. At temperatures over 750 °C, there is not an easy low-carbon alternative for fossil fuels. The global demand of fossil fuels being used over 750 °C in 2035 is modelled to be 12,934 TWh and rising to 15,665 TWh by 2050, with most of this coming from the iron and steel industries as displayed in Figure 4. The IEA states that the Iron and Steel industry already accounts for 7% of the global CO_2 emissions [9].

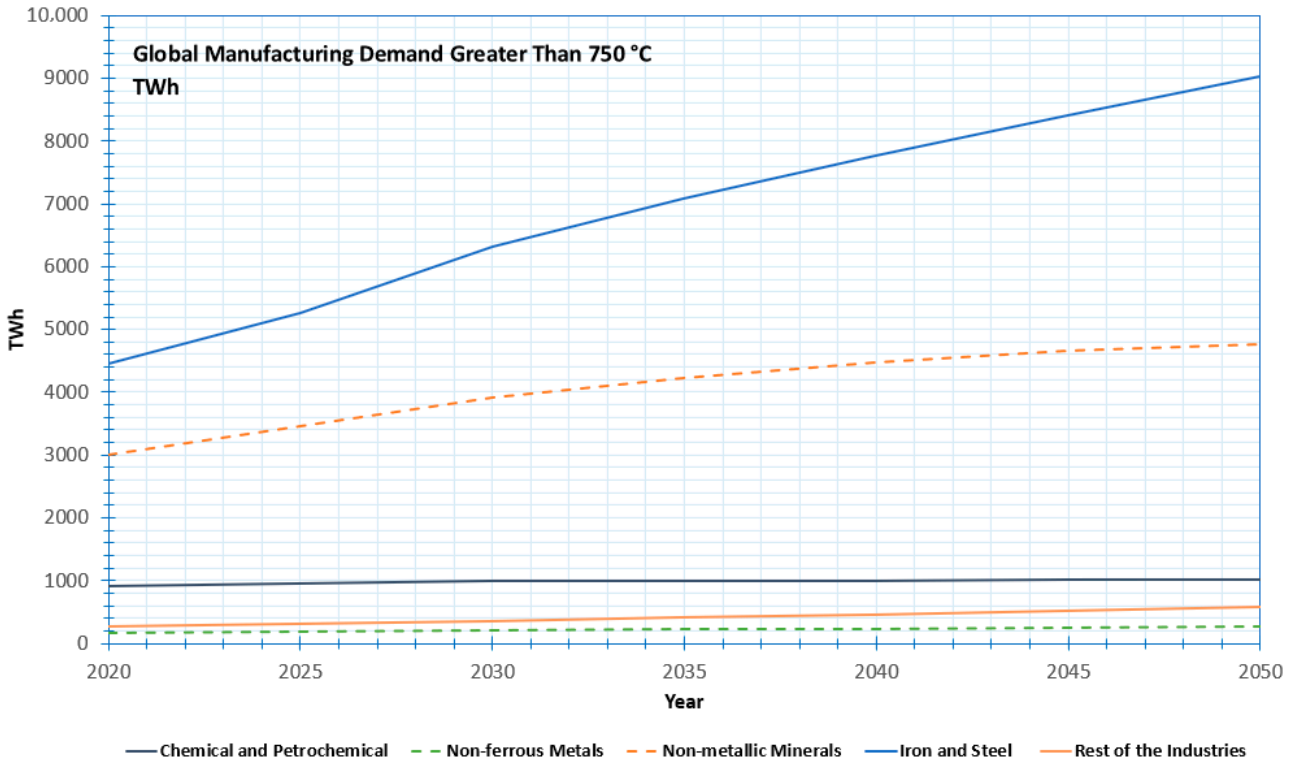

Figure 4. Total heat demand in TWh for industrial processes greater than 750 °C globally.

However, the production of synthetic fuels capable of producing temperatures in excess of 750 °C could be carried out using nuclear energy—hydrogen is an example of one such synthetic fuel. Hydrogen production technology is already at a high technology readiness level when using electricity, and there are several cases which already exist regarding the transition towards hydrogen in the steel industry [37]. The use of nuclear

derived electricity to generate large quantities of hydrogen would add to the demand for electricity.

There are advantages to producing hydrogen using nuclear energy via electricity or thermochemical methods, which could benefit from the temperatures associated with a HTGR, but this technology needs to be proven both technically and economically [38].

4. Conclusions

This study provides a greater understanding of the heat market for SMRs; in doing so, it enhances their business case and brings into focus the challenges associated with decarbonisation of the market. The model has employed a conservative methodology to identify the heat demands that could be provided by nuclear energy from SMRs and estimate a market share.

The heat market is also set to grow globally and will be a relatively new market for nuclear, since it has traditionally been dominated by fossil fuels. This market is particularly difficult to decarbonise due to the high temperatures required for industrial processes. The heat market is more complex than the electricity market, as it is dependent on the temperature demand. The study has highlighted that even IEA data does not provide the granularity of heat demand to perform a global analysis, with the grouping "Rest of Industries" dominating the demand, but this demand requirement is hard to categorise.

This study has shown that the market potential for HTGRs is higher and can reach harder-to-abate sectors than LWRs, but the highest-temperature demands of industry (>750 °C) cannot be achieved with HTGRs. For these applications, nuclear energy could also be used to generate large quantities of low-carbon synthetic fuels, such as hydrogen, that can then be used to achieve the required temperatures.

There are still several barriers all SMRs, including HTGRs, must overcome, such as proving their cost competitiveness and derisking the technology for private investors and companies to construct them. Full lifecycle analysis of the impact of nuclear energy on a site will be required to determine its cost competitiveness to other means of producing heat, but this will need to be performed on a site-to-site basis. Nuclear could end up replacing combined heat and power plants, which adds extra complexity in performing such an analysis.

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Conflicts of Interest: Authors Seddon Atkinson and Olivia Boardman were employed by United Kingdom National Nuclear Laboratory (UKNNL). The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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