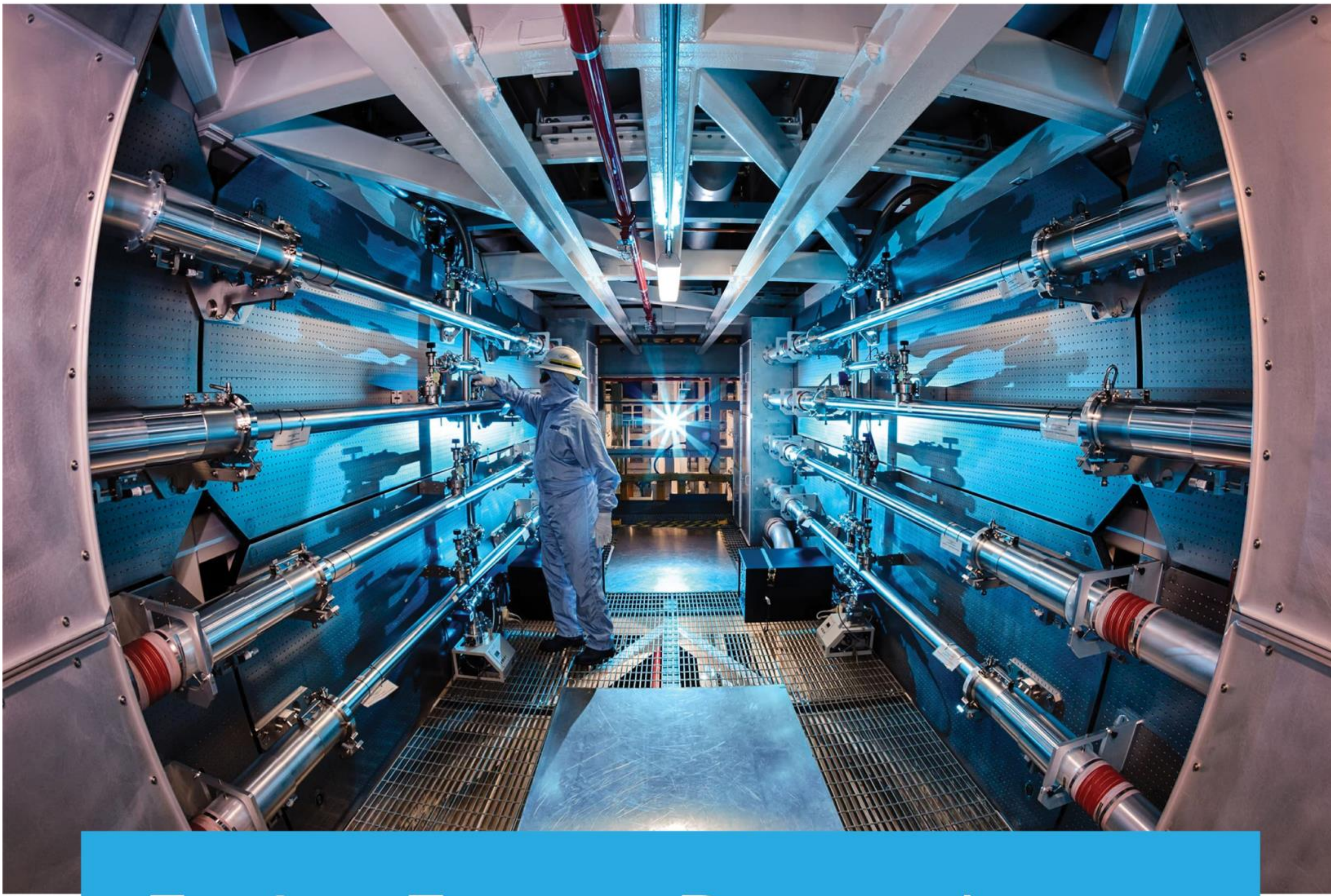


Fusion Energy Demand Market Report

2024

8/1/2024
v7.4

Introduction to the First Ignition Research Fusion Energy Market Report

We wrote this report after one of our clients asked us to help them better understand the fusion market and its potential. Although there is significant data about fusion energy demand and drivers, there was a lack of a true forecast, as the information that was available (before this report) was disparate and required correlation, assessment, and analysis. As a team who has built market projections before for a number of emerging markets, Ignition Research understands the difficulties that startups have raising funding without proper market forecasts. Because of this, we are more than excited to provide this report to the fusion energy market, and to the ecosystem that will make the fusion market happen.

Given that this is the first Fusion Energy Market Report from Ignition Research, it is reasonable to explain what this report is and isn't.

This report forecasts the worldwide market for electricity generated from fusion energy within the overall worldwide electricity market. The forecast extends from 2022 through 2050 in 5-year increments and provides a breakdown by key geographical regions.

The forecast builds on data from the US Energy Information Agency (US-EIA). This particular data source was selected due to its' internal consistency and (relative) completeness. Where needed, Ignition Research will supplement the US-EIA data with other energy market data sources.

The report examines the key drivers of this market from both a demand standpoint and from a generation standpoint, and how these factors affect the overall outlook for fusion energy.

This report does not attempt to forecast the how the market for fusion electricity will be fulfilled (i.e., the likely vendors of fusion electricity powerplants) will be, nor the countries of the lead vendors. The report does provide an overview of the companies that are active in the race to commercialize the generation of electricity from fusion, but only for the purpose of illustrating the current state of the market.

This report does not attempt to forecast what the leading technology/technologies will be fusion energy generation, from the perspective of the consumers of this energy, the differences are unimportant. The report does provide an overview of the leading fusion technologies, but only for the purpose of illustrating the current "state of the art".

With that, I hope that this report meets your needs to understand the fusion energy market and the drivers for that market. Please use your subscription consulting hours (if you have a subscription) to let us help you use this report to make it work for you. Thanks!

--The Ignition Research Staff

Executive Summary Key Points

The Ignition Research Fusion Energy Market Report for 2022 explores the outlook for fusion electricity between now and 2050 through several different scenarios. The highlights from the report include:

1

The market for fusion electricity powerplants (including construction and required equipment, but not including operational, fuel, or maintenance costs) will exceed 1 trillion dollars US ($1T USD) by 2050. Depending on the scenario, this milestone will be achieved between 2046 and 2049.

2

Ignition Research forecasts that the demand for electricity will increase worldwide (WW) by up to 79.4% between 2022 and 2050, with a total worldwide demand of over 50,000 billion kilowatt-hours (BkWh) by 2050. This contrasts with US-EIA's forecast of just under 42,300 BkWh by 2050, an increase of 49.8% between 2022 and 2050.

3

Ignition Research estimates that the WW market for electricity generated from fusion in 2050 will be between 7,393 BkWh (14.6% of WW electricity generation) and 12,100 BkWh (23.9% of WW electricity generation).

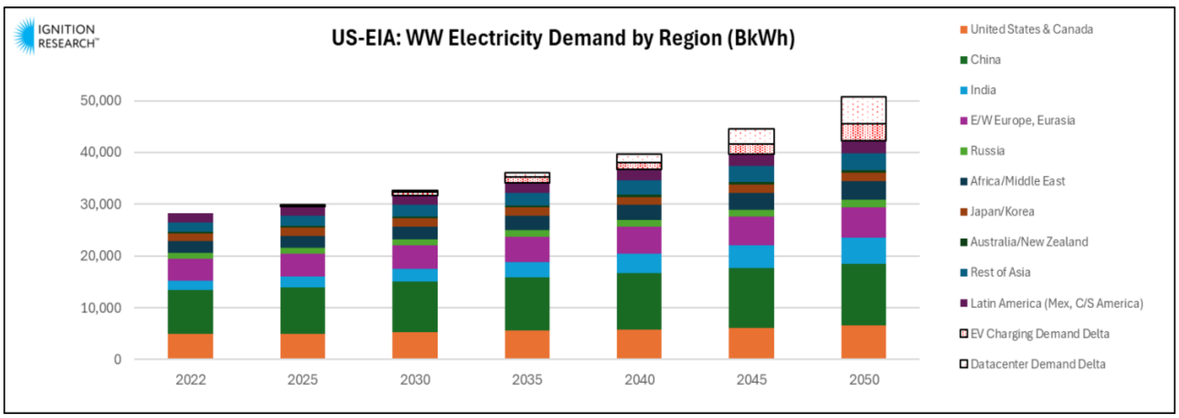
4

Fulfilling this need will require the construction of between 922 and 1,512 1GW fusion power plants worldwide, with each plant producing 8.0 BkWh of net electricity generation to the grid per year.

5

The primary drivers increasing demand for electricity over the US-EIA 2022-2050 forecast include (see graph below):

- Increased electricity demand for charging electric vehicles, adding 3,290 BkWh to worldwide electricity needs by 2050 above the US-EIA projections.
- Increased electricity demand from datacenters (particularly AI ones), which will increase worldwide demand above the US-EIA projections by over 5,000 BkWh by 2050.



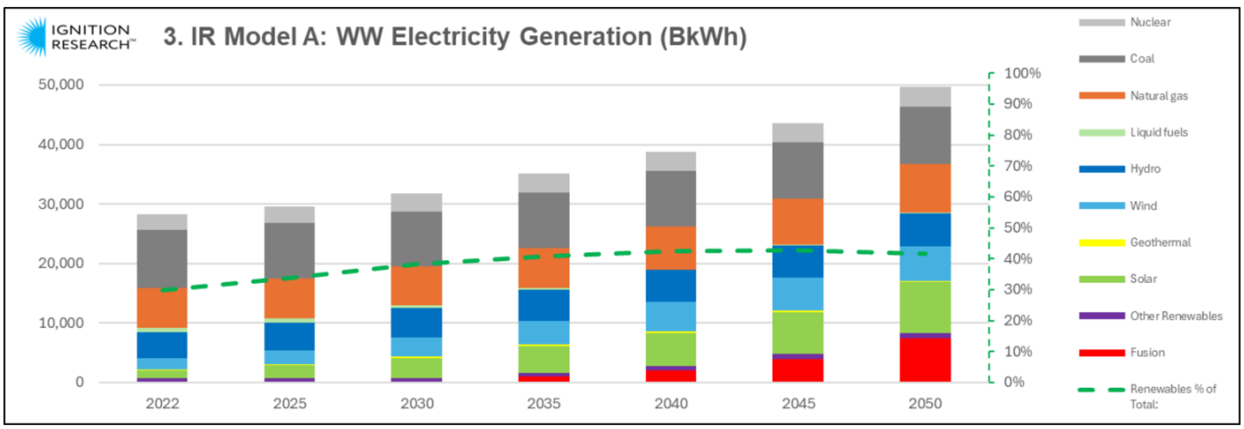
6

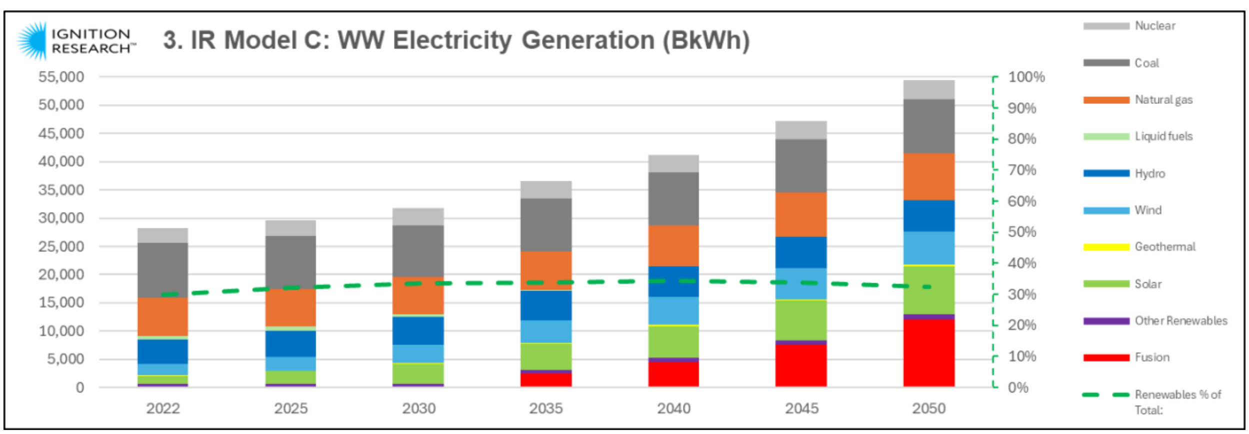
The primary factors that create the "electricity gap" between the above demand and US-EIA's electricity generation between now and 2050 include:

- Environmental pressures to reduce greenhouse gas emissions from fossil fuels, especially coal, will lead to a reduction in the use of those fuels between now and 2050.
- Difficulty scaling renewable sources due to the following factors: the lack of dispatchability of renewable electricity resources; the geographic footprint requirements of renewable electricity resources, which drive increased transmission line requirements; and adversarial supply chain issues which impact scalability for these resources in Western economies.

This leaves fusion energy as the only viable alternative to wind/solar and fossil fuel-based electricity. While there are not any “production” fusion powerplants in existence today, it is not unreasonable to think that commercial fusion electricity can be achieved by 2035. Ignition Research forecasts a scenario where fusion-based electricity produces between 14.6% of the world’s electricity (Model A) and 23.9% of the world’s electricity (Model C) by 2050, as shown in the graphs below.

To achieve fusion electricity independence, a country will need to possess a non-adversarial supply chain for a number of critical fusion technologies such as reactor containment vessels, high-power lasers, magnetics, high-voltage switching systems, fusion fuel manufacturing, and high-power capacitors. Each of these critical fusion technologies has its own associated critical supply chain of materials and enabling technologies.





Contents

1. Background: US-EIA's Worldwide Forecast Between 2022 and 2050

The Ignition Research Fusion Energy Market Report is based on the worldwide dataset contained in United States Energy Information Agency (US-EIA) 2022 forecast. To simplify the analysis of the US-EIA dataset, Ignition Research has grouped countries into the following regions:

- United States and Canada
- China
- India
- East/West Europe and Eurasia
- Russia
- Africa/Middle East
- Japan/Korea
- Australia/New Zealand
- Rest of Asia (Asia minus China, India, Japan, Korea, and Asian Russia)
- Latin America (Mexico, Central America, and South America)

The key findings from the US-EIA forecast include the following:

1.1. Electricity Demand Worldwide Will Increase by Nearly 50% Between 2022 and 2050

Electricity demand will increase WW at an annual rate of 1.45% between 2022 and 2050, led by:

China

(the #1 consumer of electricity in 2022, 28% of WW generation in 2050).

United States/Canada

(15.4% of WW consumption in 2050).

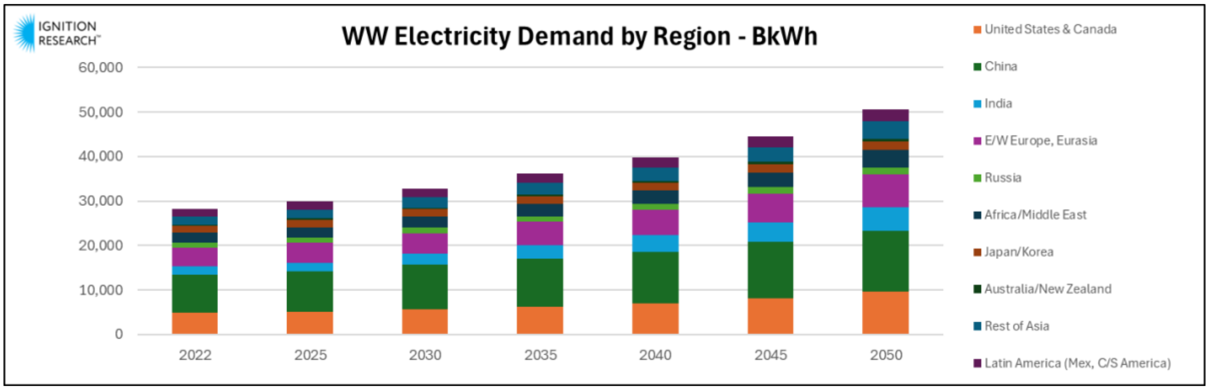
E/W Europe/Eurasia

(13.8% of WW consumption in 2050).

India

(12.2% of WW total electricity consumption in 2050).

Together, these regions will consume more electricity in 2050 than the entire planet does in 2022.



Some additional data points of interest:

a. India is the fastest-growing region for electricity consumption between 2022 and 2050, growing 193% over that period (a CAGR of 3.91%).
b. The Rest of Asia (ROA) is the second-fastest growing region, with an increase of 87.91% between 2022 and 2050 (a CAGR of 2.28%).
c. Japan/Korea electrical consumption is only forecasted to grow by 6.8% (0.23% CAGR), while the electricity consumption in the US & Canada only increases by 31.14% (a 0.97% CAGR).

1.2. Worldwide Electricity Generation Meets Demand, but Appears "Aspirational"

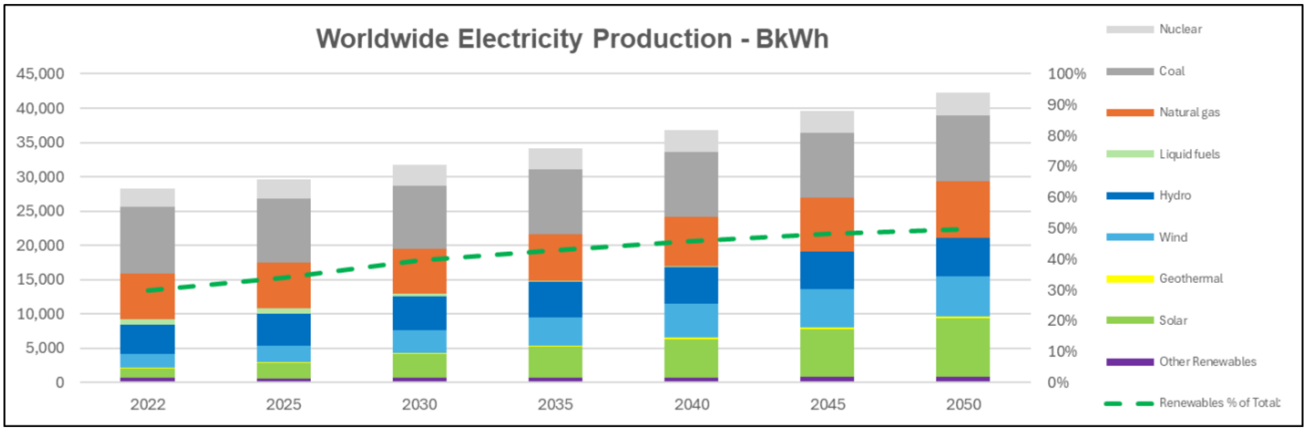
Unsurprisingly, the amount of energy generated worldwide will meet the worldwide demand on both a global and regional basis, but the mix of electricity "fuels" (the resources utilized to generate the electricity) will change significantly:

Renewables (hydro, wind, geothermal, solar, and other renewables) reach 50% of total WW electricity generation, up from 20% in 2020.

Solar electricity is the fastest-growing electricity source, up 6X in 2050 from 2022 (CAGR of 6.61%).

Nuclear power grows by 23.7% from 2022 to 2050.

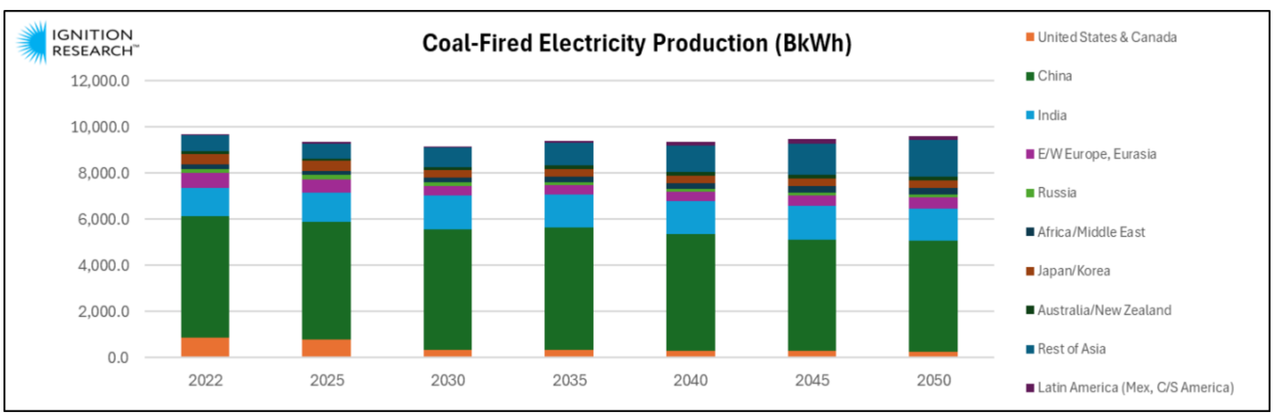
The chart below shows electricity generation between 2022 and 2050 by fuel type:



Some highlights from the US-EIA electricity generation forecast include:

1.2.1. Coal-Fired Electricity Generation Remains Essentially Stable Between 2022 and 2050

While coal-fired electricity generation as a percentage of total electricity generation worldwide will decrease from 2022 to 2050, the absolute amount of coal-fired electricity will remain relatively constant on a worldwide basis. Coal-fired electricity generation in 2050 will be 9,612 billion kilowatt-hours (BkWh), just slightly lower than the 2022 amount of 9,696 BkWh, and higher than the 2030 low point of 9,165 BkWh.



The primary countries producing electricity from coal are:

China will generate

4,797 BkWh

from coal in 2050

this is roughly 50% of the world's total coal-fired electricity in 2050, and 40.4% of China's total electricity. While China's use of coal will decrease from 2022 to 2050 at a rate of 0.32% per year, China will still represent the largest region generating electricity from coal in 2050.

Rest of Asia (ROA; n/I China, Korea, Japan, India, and Australia/New Zealand) will generate

1,583 BkWh in 2050

(16.5% of the world's total)

706 BkWh in 2022

(7.1% of the world's total)

Increasing from 34% of ROA's electricity in 2022 to 46.6% in 2050

India will generate

1,411 BkWh in 2050

(14.7% of the world's total)

1,240 BkWh in 2022

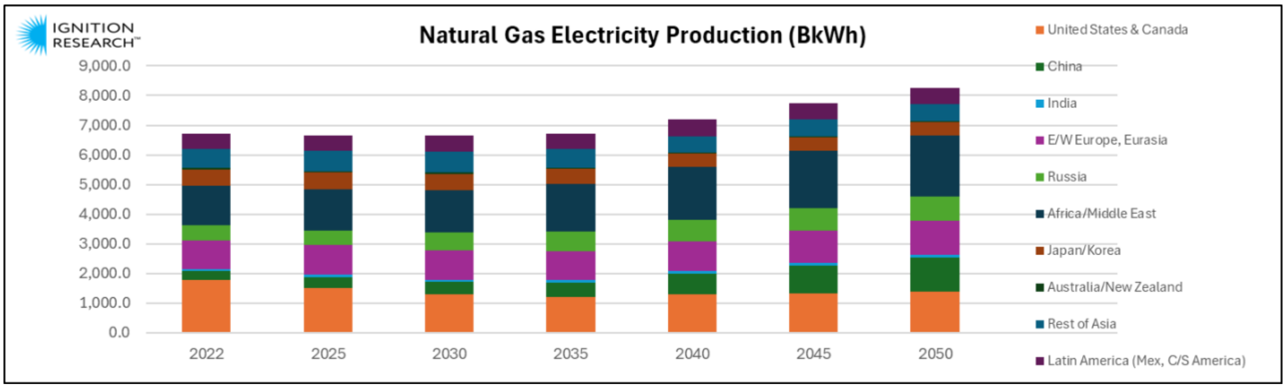
(13.4% of the world's total)

On the positive side, coal's percentage of India's total electricity generation decreases from 12.8% in 2022 to 8.4% in 2050.

Together, these three regions constitute 81% of the world's electricity generation from coal in 2050. While the United States/Canada, Russia, Japan/Korea, and E/W Europe/Eurasia all reduce their generation of electricity from coal, the rest of the world's consumption nearly increases enough to make up for the reductions in these regions. Given coal's contribution to global warming, this is not a good trend for the planet.

1.2.2. Production of Electricity from Natural Gas Increases Substantially From 2022-2050

While electricity production from natural gas as a percentage of total electricity generation will decrease from 22.5% in 2022 to 19.5% in 2050, in absolute terms it will increase from 6,699 BkWh in 2022 to 8,266 BkWh in 2050 (an annual rate of increase of 0.75%). The breakdown by region is shown in the chart below:



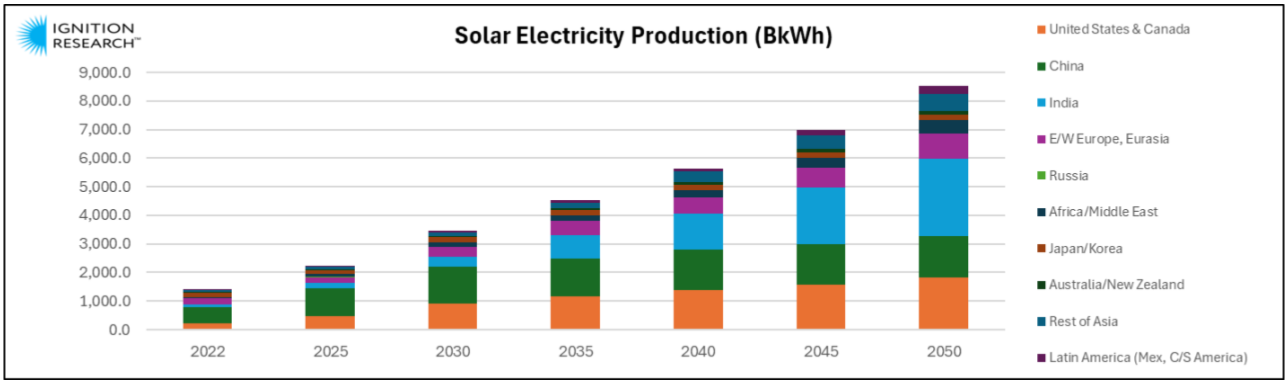
The four regions generating the most electricity from natural gas in 2050 are:

- **Africa/Middle East:** This region will generate 2,076 BkWh of electricity from natural gas in 2050 versus 1,349 BkWh in 2022. Africa/Middle East will represent over 25% of natural gas-based electricity generation in 2050, at an annual rate of increase of 1.55%.
- **United States and Canada:** While the use of natural gas for electricity generation in the United States and Canada will decrease significantly from 2022 (1,777BkWh) to 2050 (1,375 BkWh), the region will still be the second highest consumer of natural gas-based electricity generation in 2050 (it is the highest region in 2022).
- **China:** Natural gas for electricity generation in China will increase at an annual rate of 4.95% between 2022 and 2050, going from 302 BkWh to 1,169 BkWh in 2050.
- **East/West Europe and Eurasia:** This region's use of natural gas for electricity generation will increase by 0.56% per year, from 972 BkWh to 1,139 BkWh in 2050.

While utilizing natural gas for the generation of electricity is cleaner than the use of coal, electricity generation by natural gas also has a negative impact on the environment though the release of greenhouse gases.

1.2.3. 1.2.3 Solar is Forecasted to Become the #1 Renewable Electricity Source in 2050

Electrical generation from photovoltaic solar power is forecasted to increase at an annual rate of 6.61% between 2022 and 2050, from 1,421 BkWh to 8,521 BkWh. By 2050, solar electricity generation is forecasted to be 20.1% of total worldwide electricity generation.



India, the United States/Canada, and China will represent over 70% of worldwide solar electricity generation in 2050. India's solar generation will grow by 12.58% per year; the United States and Canada's will increase by 8.03% per year; and China's will grow by 3.3% per year. Demand for solar electricity in other parts of the world (particularly Africa/Middle East, ROA, and Latin America) are forecasted to grow at rates well over 8% per year.

> Overall, the US-EIA forecast is both "aggressive" in its expectations for renewable electricity resources (particularly solar electricity), while still forecasting levels of fossil fuel use that are troublesome from a greenhouse gas perspective.

2. Issues with the US-EIA Forecast

There are several issues with the US-EIA forecast which Ignition Research adjusts for in our forecast:

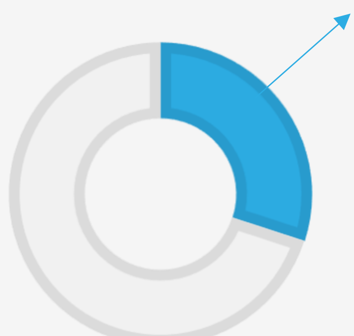
2.1. The Electricity Demand Increase in Most Parts of the World is Likely Understated

There are several reasons to believe that the increase in demand for electricity in the developed world (US/Canada, E/W Europe, Japan/Korea, China, and India) is significantly understated:

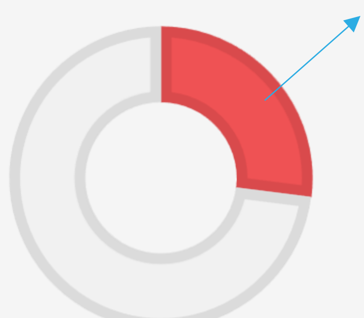
2.1.1. 2.1.1 Electricity Consumption Required to Charge Electric Vehicles (EVs)

Transportation is one of the largest consumers of energy worldwide.

Some facts include:

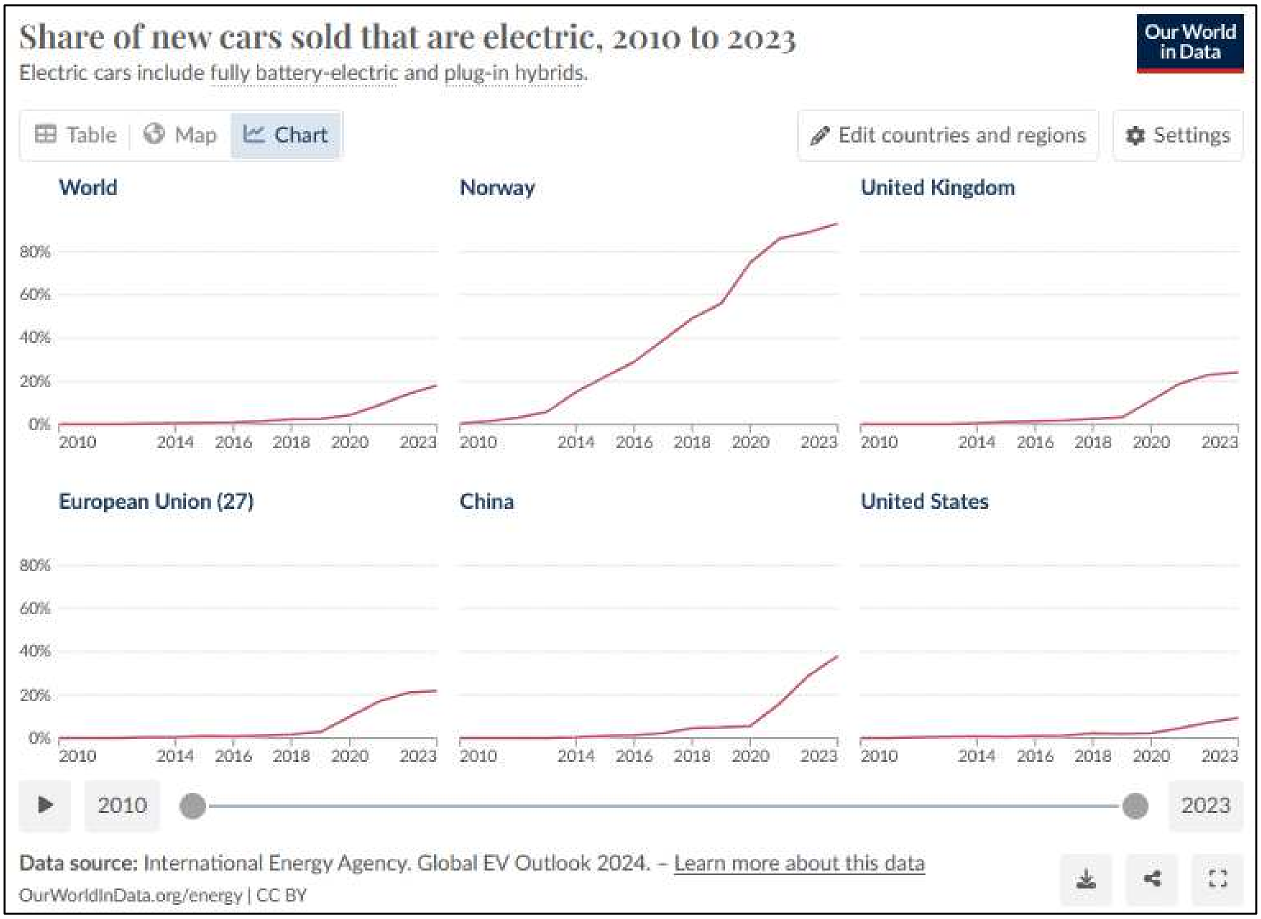


30% of all energy consumed globally is for transportation according to the Energy Institute.



Roughly 27% of total US energy consumption in 2022 was for transport, according to the US-EIA.

In 2023, 18% of all new cars sold worldwide are electric; in China electric vehicles made up 38% of new cars in 2023. As governments “encourage” electrification through legal and regulatory changes, one can expect that these percentages will increase significantly, adding to the demand for electricity.



Looking at other (more realistic) models of EV electricity usage indicate that the US-EIA's forecast for electricity consumption by EVs could be low by 3,290 BkWh in 2050

2.1.2 Growth in Datacenters Will Increase the Demand for Electricity

Datacenters are key to the cloud computing market, especially hyperscale datacenters for artificial intelligence (AI) computing. The worldwide datacenter market is expected to grow by 11.3% annually through 2026 according to PGIM.

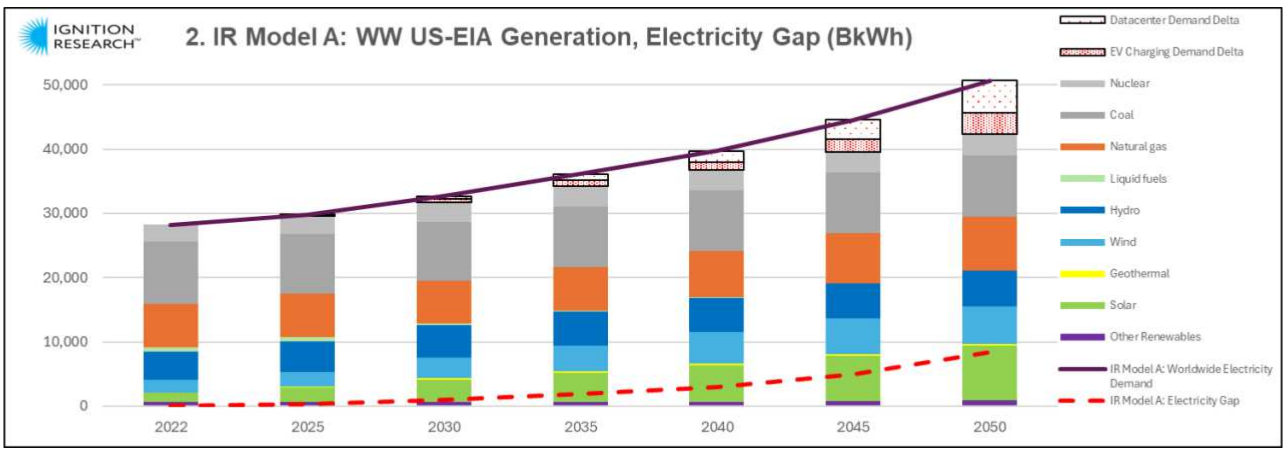
More importantly, the electricity consumed by datacenters will grow from 2.5% of US electricity consumption in 2022 to 7.5% in 2030 (390 BkWh) according to CPower.

Internationally, similar growth rates are forecasted, including:

- India (double in the next 3 years)
- Indonesia (16.2% CAGR)
- Japan (7.16% CAGR)
- Brazil (8.45% CAGR)
- Australia (5.85% CAGR)
- Malaysia (13.92% CAGR)
- Hong Kong (13.36% CAGR)
- Vietnam (7.38% CAGR)
- South Africa (8.44% CAGR)
- Singapore (8.35% CAGR)

This growth will have a significant impact on electricity demand and is one of the reasons that Ignition Research believes that electricity demand is under-forecasted. **Our research indicates that datacenters will consume 5,070 BkWh in 2050 over the US-EIA forecast.**

The result of these increased demands is a worldwide "electricity gap" of 8,361 BkWh, as shown below (the top two bars in each series are the increased demand from EV charging and datacenters causing the gap):



2.2. The Forecasted Growth in Renewables is Problematic

The current US-EIA worldwide forecast has PV solar electricity growing at a CAGR of 6.61%, achieving 20.1% of WW electricity generation by 2050. Similarly, wind electricity is forecasted to achieve a CAGR of 3.94%, making up 13.7% of WW electricity generation by 2050. There are several issues with the primary renewable sources of electricity (PV solar and wind) that make their ability to provides the electricity forecasted by the US-EIA a risky bet:

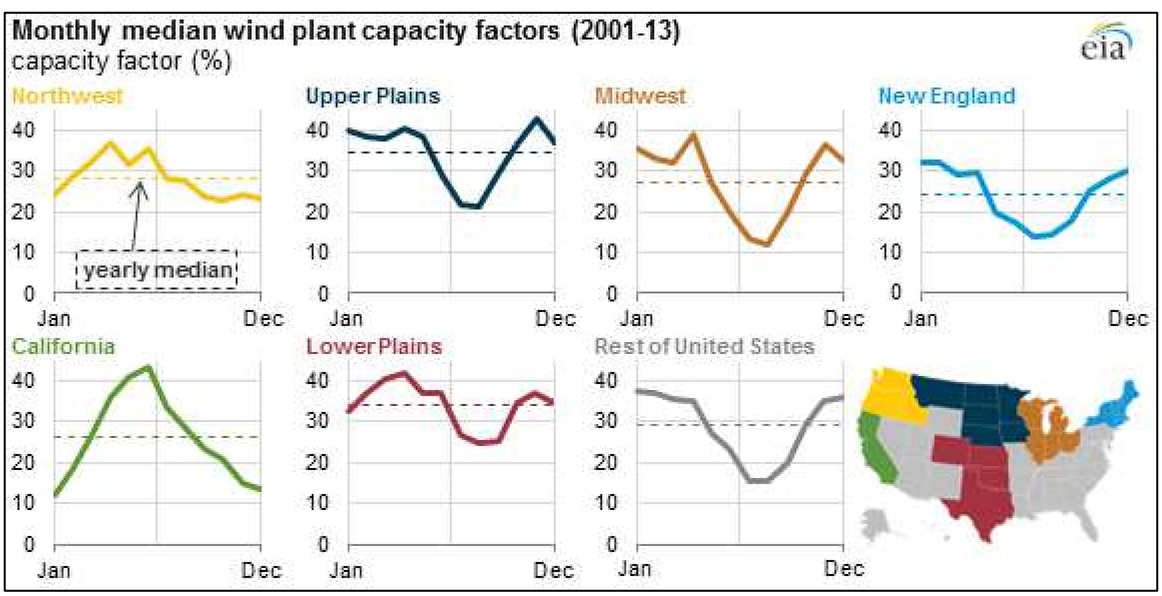
2.2.1. Solar and Wind Energy are Not Dispatchable

Photovoltaic (PV) solar electricity and wind-generated electricity are not dispatchable – the output of solar electricity plants cannot be arbitrarily increased or decreased as needed. Note that this is a fundamental difference from electricity generated by fossil fuels or even nuclear fission, which (to the maximum capacity of the powerplant) can be arbitrarily increased or decreased at will.

The lack of dispatchability of PV solar and wind electricity has two specific characteristics:

a. **Variation due to the time of day:** PV solar energy is only generated during daytime, while the maximum energy demand is generally between 4PM and 9PM. While wind-based electricity is not quite as fickle based on the time of day as PV solar, it also has short-term variability. This means that short-term energy storage resources (today, lithium ion batteries) are necessary to make both PV solar and wind effective sources of electricity.

b. **Seasonable and Annual Variation:** This is one of the primary issues with wind-generated electricity (and to a lesser extent, PV solar electricity). Countries that have had long experiences with wind power have seen significant seasonal variation in electricity generation. The graph below (US-EIA) shows US wind variability through the year, with summer being the "low point" in all but California and the Northwest:



This is particularly a problem as almost all long-term energy storage options are lossy, with loss rates varying from 10%-25%. Moreover, long-term storage solutions (especially pumped hydropower and geothermal storage) tend to have large footprints, and are often very geology or geography specific. The need for both short-term and long-term energy storage significantly increases the cost of electricity generation from both PV solar and wind.

2.2.2. The Supply Chain for Both Wind and PV Solar Are Dominated by Strategic Adversaries

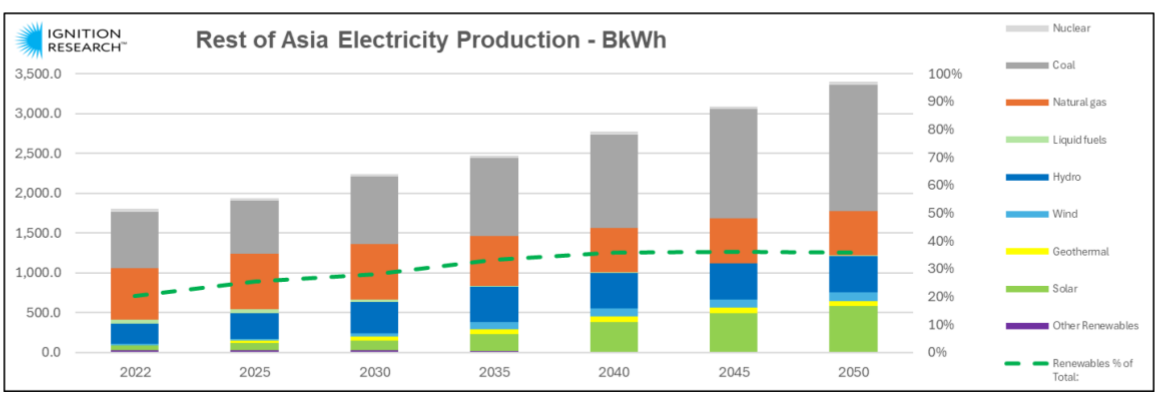
Today China produces [84% of all PV solar panels] worldwide. Additionally, the growth rate for PV solar may not be achievable from a supply chain perspective (or China may not choose to sustain it). This puts China in control of the production of the world's fastest-growing electricity generation source. Note that China also produces 77% of lithium-ion batteries. This is a significant strategic threat to energy independence for the US/Canada, E/W Europe/Eurasia, Japan/Korea, and India.

2.2.3. Renewables Electricity Generation Footprint and Transmission Issues

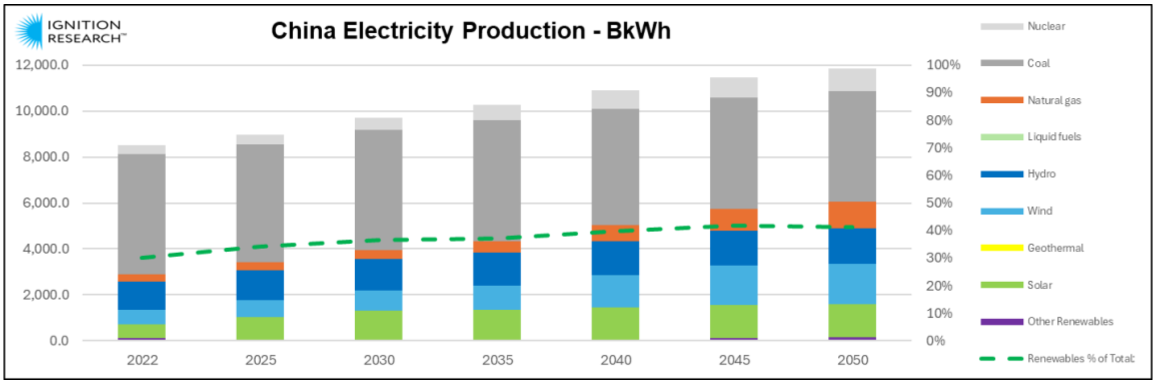
Large-scale PV solar and wind electricity generation facilities share the attribute of having large physical footprints that are incompatible with urban and suburban settings. Furthermore, both require unobstructed areas that are fairly flat. This generally pushes these facilities a significant distance from urban centers where electricity consumption occurs, driving the need for long transmission lines and increased cost of electricity from these sources.

2.3. Increased Pressure to Reduce Fossil Fuel Consumption in China, India, and ROA

As pointed out in Sections 1.2 and 1.3, China, India, Africa/Middle East, and ROA will generate 11,958 BkWh of electricity from coal and natural gas, an increase of 22% from 2022. This is problematic for the reduction of greenhouse gas emissions, particularly the increase in natural



gas use in China and Africa/Middle East. Even more troubling is the increase in coal usage in China and ROA, which will generate 6,380 BkWh of electricity from coal in 2050.



As climate change worsens, expect significant global pressure on these countries to reduce their use of fossil fuels for electricity.

3. How Does Fusion Fit into The Worldwide Electricity Picture?

Based on the above discussion, an ideal electrical generation source to augment renewables would have the following attributes:

It would be dispatchable at scale.

It would be 'green', generating little/no carbon emissions.

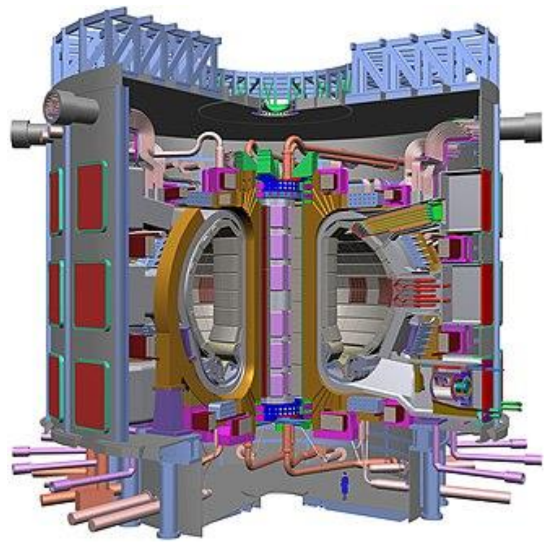
Powerplants would be easily integrated with the existing power grid (particularly from a capacity matching perspective with plants to be replaced).

It would use readily available

Powerplants would also be able to be positioned near solar and/or wind farms to easily augment them without requiring additional grid engineering.

Fusion energy is a near-perfect solution to augmenting renewables electricity generation and filling the electricity gap for the following reasons:

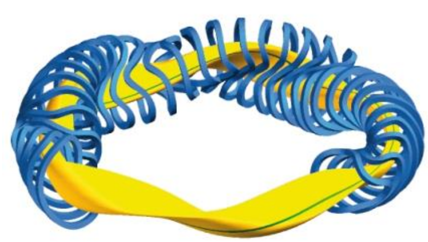
- It is dispatchable at scale – reactors can easily be turned on, off, and have their output modulated.
- Fusion is very green – the only byproduct of a fusion reactor would be helium (which has value).
- Fusion utilizes fuel that is readily available from seawater (deuterium).
- Fusion energy can (reasonably) be scaled up or down by adding more reactors to a given power plant, allowing it to match renewable energy sites from a capacity standpoint.
- The lack of hazardous processes and byproducts allows fusion electricity power plants to be sited at a wide variety of locations, improving integration with the existing power grid.



While fusion energy is not commercially available today, demonstrator reactors have progressed far enough to demonstrate its technical viability to produce commercial electricity in the near future, probably between 2030 and 2035.

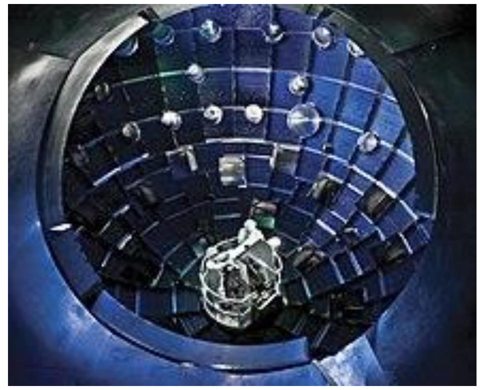
3.1. Types of Fusion Electricity Generation

There are three basic approaches to commercial fusion power generation that are being pursued today:

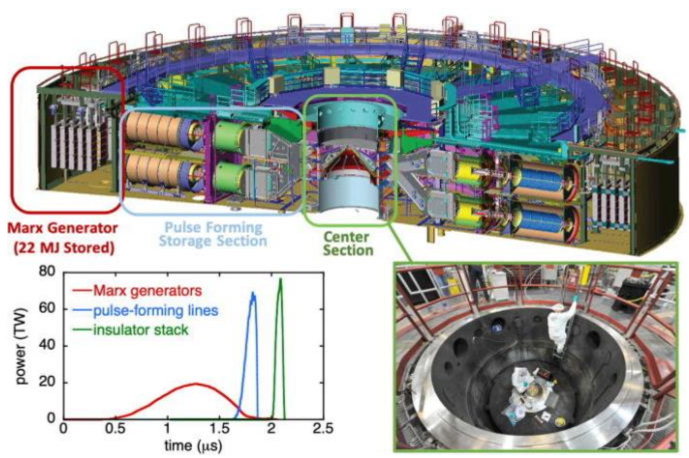


- **Magnetic Confinement:** This approach uses very strong magnetic fields to confine highly heated hydrogen plasma in a donut-shaped magnetic vessel; examples include tokomaks (pictured to the right), and stellarators (pictured on this page). The plasma is accelerated in the vessels to energies high enough to overcome electrostatic repulsion and achieve ignition. ITER (shown to the right) is the most successful tokomak design to date. Construction was started in 2013, and is expected to be testable by 2025 when the ITER plant is commissioned, and sustained fusion would be able to be achieved by 2035.

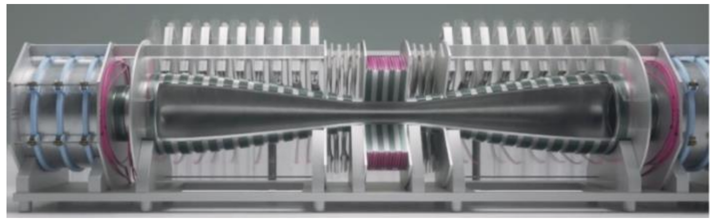
- **Inertial Confinement:** Rather than using magnetic fields to compress hydrogen ions together, inertial confinement utilizes high-energy beams to create the required pressure and heat. The most successful inertial confinement machine today is the US National Ignition Facility (NIF), which uses UV lasers as the energy source. These lasers bombard a pellet of fuel 2mm in diameter, surrounded by a gold-plated covering called a hohlraum. When bombarded by the lasers, the inside of the hohlraum ablates inward, compressing and heating the deuterium-tritium (DT) fuel to the point of fusion. NIF achieved a "fusion gain break-even" ignition (where the target released more energy than was absorbed by the target) in 2013, and "scientific break-even" (where the target released more energy than used by the lasers) in 2022 – this was the first time that scientific break-even was achieved.



- **Pulsed Magnetic Compression:** In a sense, pulsed magnetic compression (also known as magnetized linear inertial fusion or MagLIF) is a combination of magnetic confinement and inertial confinement. The primary differences between MagLIF and laser-based inertial confinement is that the laser in MagLIF is used to heat the fuel in the hohlraum of the fuel pellet rather than compress it; compression is provided by a magnetic field that rapidly increase in intensity.

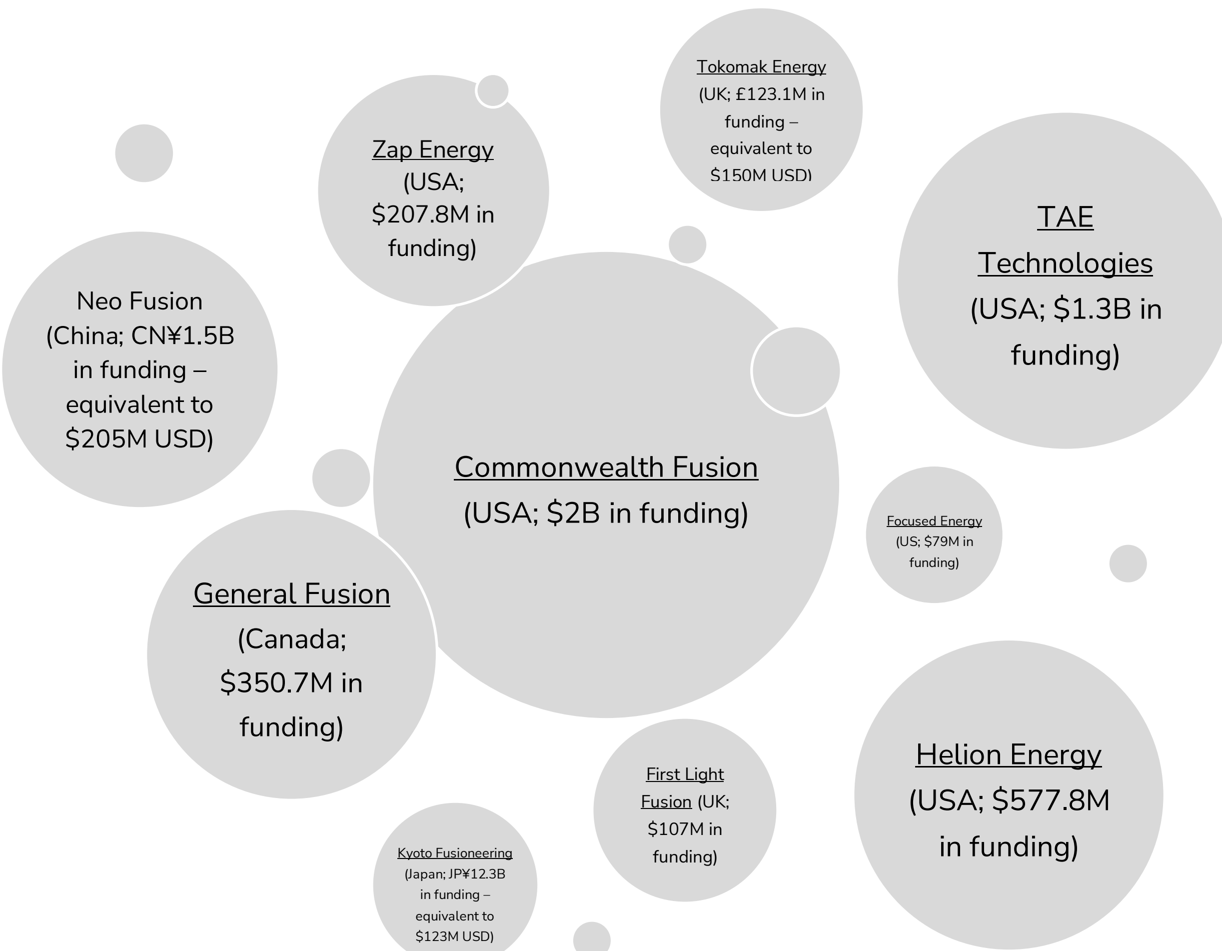


The latest example of this is the (US) Sandia National Laboratory Z-machine, which has been used to experiment with the concept and identify potential issues in the approach. The Z-machine is expected to be replaced at Sandia by the Z-pinch Inertial Fusion Energy (Z-IFE) project, which aims to provide 300MW of fusion energy in a sustainable "production" approach.



Helion (a US fusion startup) is also utilizing this approach in their Trenta and Polaris reactors, which they aim to commercialize (see graphic to the right of a cutaway of the Helion pulsed magnetic compression reactor). The interesting thing about this approach is that it generates electricity from the "recoil" of the fusion reaction, creating a back-current in the containment magnets. Both inertial confinement and pulsed magnetic compression are strong candidates to yield the earliest commercial fusion reactors.

The disclosed worldwide investment in fusion energy research and development is $6.21 billion, with $46 million financed by the US government alone. Chinese government investments are largely "under the radar" but appear to be significantly greater than those of western countries (including the US). These investments support an ecosystem with over 70 companies worldwide; the leading fusion startups include:

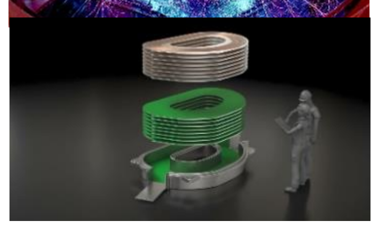


In the US, fusion companies are represented by the Fusion Industry Association (FIA), a non-profit organization founded in 2018 which currently has 25 members. There are also numerous scientific groups working in collaboration on fusion energy power generation. And finally, the Chinese government and private Chinese investment firms have invested immense sums of money into fusion energy and related technologies.

3.2. Critical Technologies for Fusion Commercialization

There are several technologies that are key to commercializing fusion energy to generate energy. These include the following:

- **Fusion Containment Vessel/Thermal Blanket:** Even with magnetic containment technologies, a reactor vessel is still required to shield external systems from the heat and short-term radiation generated by fusion energy reactions. Additionally, one of the key functions of this subsystem is to "siphon" the energy from high-energy neutrons and turn it into thermal energy (usually in a liquid metal or salt), which can then be used to boil water and drive a turbine (hence the name "thermal blanket"). A durable reactor vessel is required to shield external systems from the heat and short-term radiation generated by fusion energy reactions; this typically requires somewhat exotic types of steel, ceramics, and other high-temperature, high-radiation compatible materials.
- **High-Power Lasers:** This need depends on which type of fusion technology is being used, with inertial confinement needing lasers with significantly higher power to achieve ignition than pulsed magnetic compression where the lasers are used to heat the plasma prior to compression.



- **Magnetics:** Magnetic confinement and pulsed magnetic compression approaches both need large, efficient, and powerful magnets to achieve confinement and ignition. This magnetics typically must be able to sustain extremely high magnetic fields in demanding conditions where temperatures are very high, and constant neutron bombardment is likely. These magnets are usually wound from high-temperature superconductor (HTS) tapes or wires.

- **High Voltage Switching:** Extremely high voltages are required to accelerate hydrogen ions towards each other and overcome electrostatic repulsion. This requires high voltage switching technologies that are also extremely fast.
- **Fusion Fuel:** While deuterium is relatively easy to extract from seawater, tritium requires breeder reactors to transmute lithium into tritium under nuclear bombardment. Additionally, inertial confinement also requires the ability to formulate these fuels in a frozen state and then put them in a hohlraum with highly precise dimensions and machining.

- **High-Power Film Capacitors:** Both inertial confinement and pulsed magnetic compression have significant energy storage needs to provide power to their lasers (for inertial confinement) and to the pulsed compression magnets (for pulsed magnetic compression). Film capacitors have typically been used for this purpose.

Getting the above components with the right attributes to build fusion energy reactors, and in the right quantities, is critical to the commercialization of fusion energy for electrical power generation. This not only includes material design and optimization, but also the commercialization of these technologies so that they can be produced in mass quantities in the US.

3.3. The Opportunities Created by Fusion Electricity Generation Technology

Electricity generation from fusion is the clear alternative to relying solely on renewable power to meet the world's growing electricity appetite. Fusion is a clean source of electricity that can be scaled (reasonably) arbitrarily to meet future needs. There are several other drivers for the importance of fusion electricity generation:

- **Jobs:** The research, development, and commercialization of fusion electrical generation will generate $471 billion in manufacturing and 10 million high-paying jobs by 2030 (according to Predence Research). For reference, China currently realized 1.6 million jobs and $52 billion in exports from its dominance of the PV solar panel market
- **Energy Independence:** For western countries, fusion electricity generation is the only clean energy resource whose manufacturing is not dominated by China (at least not yet) which controls 84% of PV solar panel manufacturing, 60% of wind turbine

manufacturing, and 77% of lithium ion battery manufacturing (which is needed to make both solar and wind electricity reasonably dispatchable).

- **Environmental Sustainability:** It is clear that the continued use of fossil fuels (particularly coal, but also natural gas) is detrimental in the long term to the environment. Fusion electricity generation negates these environmental impacts.

The "medium" timelines for commercialization of fusion (such as the above) are targeting 2035 to achieve the steps to productizing fusion, which includes the following steps:

1

Demonstration of Fundamental Technology: This milestone is reached when the energy put into the fusion system is exceeded by that produced by the fusion system, i.e., net positive energy production. This was achieved using inertial confinement in 2022.

2

Engineering Demonstrator: This milestone shows that all of the components required to build a fusion powerplant are viable, including the critical supporting technologies. This phase must be completed in the mid- to late-2020s to support a 2035 production milestone.

3

Production Demonstrator: This milestone requires building a utility-scale powerplant that is deployed commercially. Such a system is not expected to achieve break-even or continuous operation; its purpose is to identify potential issues in production powerplants. This phase must start by late 2020s, and complete by the early 2030s.

Helion believes that they can achieve commercial electricity generation from fusion by 2028. In fact, Microsoft has signed a deal with Helion to buy one of their reactors by 2028. While this may be the "inner bound" on when commercial fusion electricity generation will become available and 2040 may be the "outer bound", neither is particularly far away. It is clear that electricity from fusion generation is coming soon IF governments are motivated to make it happen.

4. Ignition Research's Modified US-EIA Forecasts from 2022-2050

The following section describes the Ignition Research approach to modifying the US-EIA worldwide electricity demand and generation forecasts. Specifically, we will describe the three models that form our forecasts, as well as the key assumptions that go into these models.

4.1. Quick Description of Ignition Research Models

Ignition Research sees three potential modifications to the US-EIA forecasts that better reflect the likely need for and mix of electricity generation between now and 2050:

> **Model A**
> The charging of electric vehicles (EVs) and the increased demand from datacenter electricity needs increases the demand for electricity by 3,290 BkWh and 5,071 BkWh, respectively. Post-2035, this gap is made up by fusion electricity; prior to 2035, it is made up by natural gas. This is described in Section 5 below. In Model A, fusion electricity production provides 7,393 BkWh, or 14.6% of WW power in 2050.

> **Model B**
> The increase in demand is the same as in Scenario A. In addition, the CAGR for solar electricity growth in non-China and non-Russia markets is capped at 6%. The CAGR for wind electricity growth in non-China and non-Russia markets is capped at 3%. This is described in Section 6 below. In Model B, fusion electricity production provides 10,515 BkWh, or 20.8% of WW power in 2050.

> **Model C**
> The increase in demand, and the capping for solar and wind are the same as in Scenario B. In addition, the CAGR for coal consumption is reduced by 1% for high-coal consumption areas (China, India, E/W Europe/Eurasia, Japan/Korea, Australia/New Zealand, and the Rest of Asia). This is described in Section 7 below. In Model C, fusion electricity production provides 12,100 BkWh, or 23.9% of WW power in 2050.

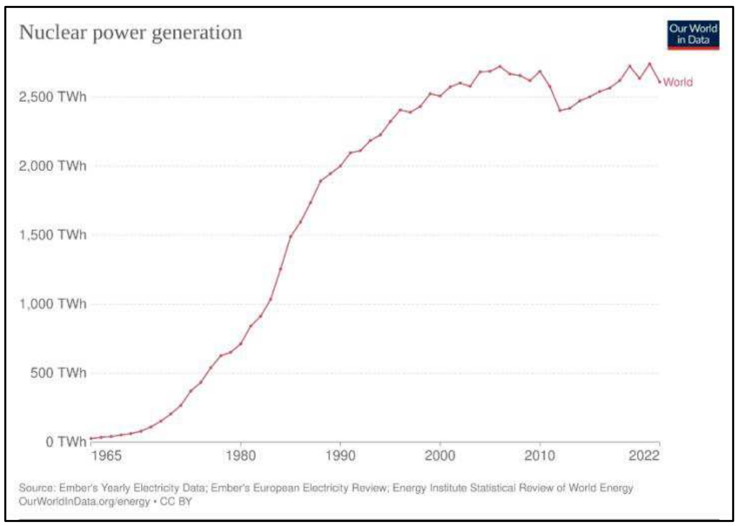
Overall, the goal in these scenarios is to capture the effect of *likely* drivers on both demand and generation capabilities in these models whose impact we can trace back to the original datasets. In this sense, our models are relatively conservative. It is quite possible/likely that electricity demand will increase beyond that forecasted in our models, in which case the potential market for fusion electricity will be even higher than forecast by Model C (the model showing the largest fusion electricity market).

4.2. Key Assumptions in the Ignition Research Models

There are several key assumptions that are embedded in the Ignition Research Models:

4.2.1. Commercial Fusion Power Plants Will Achieve Initial Operating Capacity (IOC) in 2035

In movie parlance, this is the "trillion dollar question" and is generally the hardest question to answer for any emerging market. One approach is to look at adjacent markets that have had similar transitions, and see how long those transitions took; however, that transition may not be applicable if the change occurred a very long time ago in the timeframe of that market. For fusion electricity, the nearest transitions from a time perspective are the emergence of power from nuclear fission power plants.



The first nuclear fission power plants were built in the mid-1950s; these plants, while providing commercial electric power, were also important for breeding plutonium-239. In that sense, the plants in the 1950s were closer to demonstrator plants than true commercial plants that were economically feasible.

Economically feasible nuclear fission power plants began to go online in the 1960s, when the combined power output increased from 1GW (essentially a single plant) to 100GW in the late 1970s (the equivalent of 100 powerplants). This growth, over roughly 15 years, began to slow in the US with the nuclear disasters at Three Mile Island (1979) and Chernobyl (1986), resulting in the cancellation of over 120 light water reactor projects.

However growth in other parts of the world, particularly in France and Japan, continued to accelerate, reaching a maximum over 2,500 BkWh (the equivalent output of 313 1GW power plants) in the mid-2000s. In 2011, the Fukashima Daiichi nuclear plant in Japan suffered a three-core meltdown during the Tohoku earthquake. This disaster, at one of the largest nuclear fission plants in the world, effectively killed the concept of electricity from new nuclear fission power plants (at least for now).

From a timeframe standpoint, the two periods of interest were the timeframe from 1954 (deployment of the demonstration nuclear power plants) to 1965 (the emergence of the first commercially-viable nuclear fission power plants) – a space of 11 years; and the period from 1965 to 1978, when nuclear power grow from under 1% of total world electricity to 12.5% of total world electricity – a space of 13 years. Given that NIF achieved scientific break-even 2022, expecting the first commercially viable fusion electrical power plants in 2035 (13 years later) is not unreasonable, given that nuclear fission achieved that transition in 11 year. Moreover, scaling to between 14.6% and 23.9% of worldwide power (the range of share for fusion in the Ignition Research models) between 2035 to 2050 (15 years) also appears reasonable.

4.2.2. The "Standard Size" of a Fusion Power Plant Will be 1GW

While this assumption does not have a significant effect on the outcome of any of the Ignition Research models, it provides a "shorthand" that simplifies the math. In 2019, the average size of natural gas electrical power plants in the US was 820MW, with more recent plants targeting (or exceeding) 1GW in capacity, largely due to the increased efficiency of large plants vs smaller ones. Similarly, the typical nuclear fission power plant is 1GW in size. This is not to say that a fusion energy power plant is constrained by this number; the target output of each "fusion machine" (equivalent to a single nuclear reactor in a fission power plant) will largely be determined by the optimal cost and operating efficiency of the specific fusion technology being developed. The fusion power plant itself may have multiple "fusion machines" on its campus, depending on the electricity demands of the area it services, and what the fusion power plant is replacing; i.e., if fusion is replacing two 750GW coal-fired plants, it would be sized at a capacity of 1.5GW. Finally, we assume that a 1GW fusion plant is operating roughly 91% of the time, outputting 8 BkWh/year.

4.2.3. The Cost Profile of Fusion Power Plants Will Be Similar to Nuclear Fission Power Plants

Most experts in the field believe that the cost of fusion power plants (including the initial equipment inside of them) will be slightly lower than that of nuclear fission power plants, which have typically had a cost of $6,800 per kW of generating capacity. While the equipment in a fusion power plant will likely be more complex than that of a nuclear fission power plant,

the lack of a need for confining long-term fission isotopes and the use of thermal blankets to contain/extract power from high-energy neutrons eliminates the need for expensive reactor containment building construction, reducing construction costs. The table below shows the construction and operating expense costs for competing fuels sources for electricity generation. Because of this, Ignition Research forecasts that the average cost of a 1GW capacity fusion electricity power plant will be $6.2B in 2022 US dollars.

Fuel Type	2022 Avg. Construction Cost (USD/kW)	2022 Equiv. Constr. Cost, 1GW Plant ($Billion USD)	2022 Avg. Operating Cost (USD/kWh)	2022 Avg. Fuel Cost (USD/kWh)	2022 Avg. Maint. Cost (USD/kWh)	2022 Total Op Expense (USD/kWh)
Liquid fuels	$1,158	$1.158	$0.675	$3.204	$0.509	$4.39
Natural Gas	$920	$0.920	$0.675	$3.204	$0.509	$4.39
Coal	$2,000	$2.000	$0.675	$3.204	$0.509	$4.39
Nuclear	$6,800	$6.800	$1.051	$0.612	$0.610	$2.27
Hydro	$4,000	$4.000	$0.768	$0.000	$0.476	$1.24
Wind	$1,428	$1.428	$0.020	$0.000	$0.030	$0.05
Geothermal	$3,478	$3.478	$0.012	$0.000	$0.018	$0.03
Solar	$1,561	$1.561	$0.010	$0.000	$0.014	$0.02
Other Renewables	$2,592	$2.592	$0.032	$0.000	$0.048	$0.08
Fossil Fuels (Avg)	$1,162	$1.162	$0.681	$3.163	$0.511	$4.35
Renewables (Avg)	$2,160	$2.160	$0.117	$0.000	$0.086	$0.20
Fusion	$6,200	$6.200	$1.051	$0.306	$0.916	$2.27

With an inflation rate of 3.0% per year and a fusion electricity power plant cost-down of 1.5% per year from 2040 to 2050, Ignition Research forecasts that the construction cost (including initial equipment) of a 1GW fusion electricity power plant will reach $12.25B (US) in 2050.

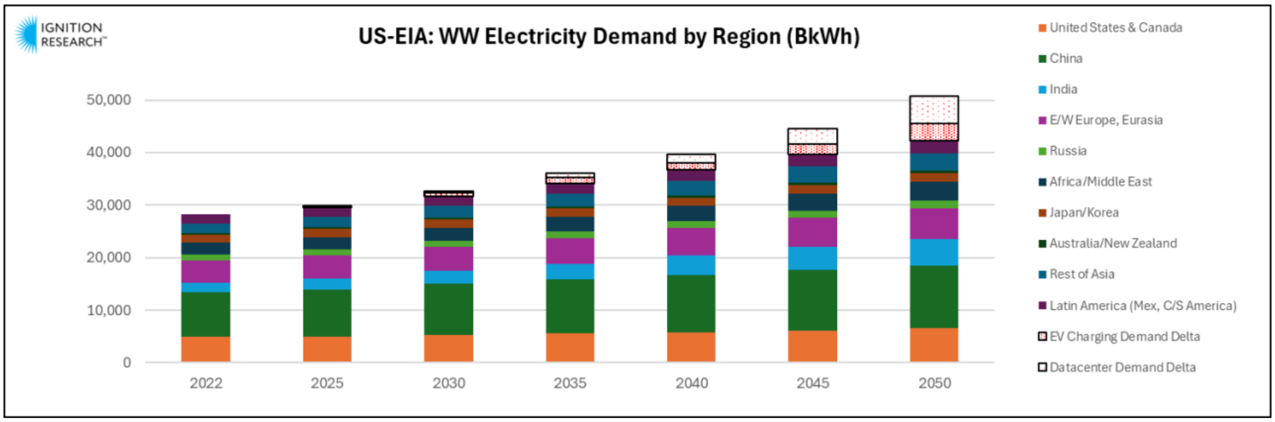
From a total operating expense standpoint, Ignition Research forecasts that the fusion electricity power plant will have an essentially equivalent cost to a nuclear fission power plant, at a total operating expense of $2.27 per kWh (2022 USD). We expect that the fuel cost for a fusion power plant will be roughly half that of a nuclear fission power plant, while the maintenance cost will make up the difference in fuel costs due to the higher cost of components needing to be replaced periodically (thermal blanket, superconducting magnetic coils, lasers, high-power capacitors).

4.2.4. Natural Gas-Fired Power Plants Will Fill the Electricity Gap Until Fusion Comes On-Line

In all of our models, the "electricity gap" begins to appear later this century, reaching between 968 BkWh (Model A) and 3,179 BkWh (Model C) in 2030. Since fusion-generated electricity will not be available by then, Ignition Research's assumption is that the difference will be make up by natural gas-fired electricity. This is based on the fact that natural gas plants are the least expensive electricity plants to construct, and the countries with the largest portion of the electricity gap in all three models (US/Canada and China) all have extensive history with natural gas-fired electrical plants.

5. Model A: Increase in Demand Due to EV Charging and Datacenters

As stated above, the differences between the Model A forecast from the US-EIA forecast are related to demand. Specifically, this model incorporates the additional demand for electricity from the charging of EVs and the increased demand for electricity from data centers. The changes are shown below, and the nature of these changes are described in the following sections.



5.1. Increase in Electricity Demand Due to EV Charging

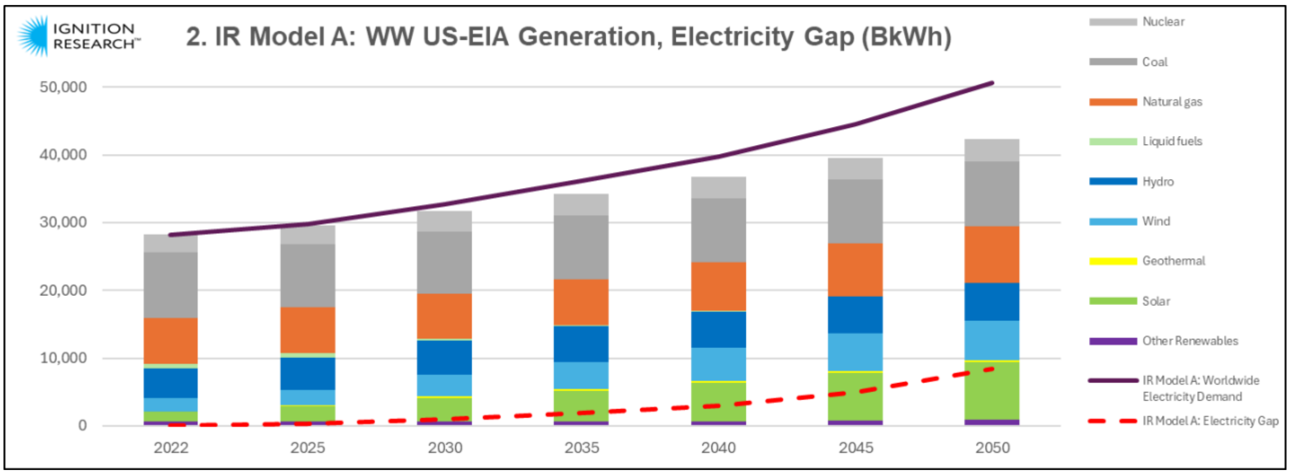
The US-EIA's 2022-2050 forecast incorporates the growth in EVs predicted by their own model, which closely follows the forecasts of the Bloomberg-NEF model. Both of these models predict roughly 650M EVs on the road WW by 2050, utilizing roughly 3,400 BkWh of energy for charging. The US-EIA and Bloomberg NEF model differ with the results of the International Energy Agency (IEA), which predicts nearly 1.3B EVs on the road by 2050, consuming almost 6,400 BkWh of energy for charging. The Ignition Research model takes the difference between these forecasts, and adds it to the worldwide electricity demand. The difference in 2050 is roughly 3,290 BkWh, with China being the roughly 44% of the difference in demand in 2050 (the US is number 2). For more details, please consult the *Ignition Research Electric Vehicle Electricity Usage Report.*

5.2. Increase in Electricity Demand Due to Data Centers

The US-EIA's 2022-2050 forecast incorporates the data center electricity usage which is roughly parallel to the growth in electricity usage worldwide. Ignition Research consulted a number of sources to put together a detailed picture of the growth in data center electricity consumption (it is detailed in our Data Center Energy Consumption Report). This model predicts a WW CAGR of 9.45% for data center electricity consumption between 2022 and 2050. The difference between our model and the US-EIA numbers included in their worldwide forecast by 2050 is 5,071 BkWh.

5.3. Impact of Demand Changes on WW US-EIA Model, Resultant "Electricity Gap"

The result of these additions to the US-EIA baseline is a worldwide electricity demand in 2050

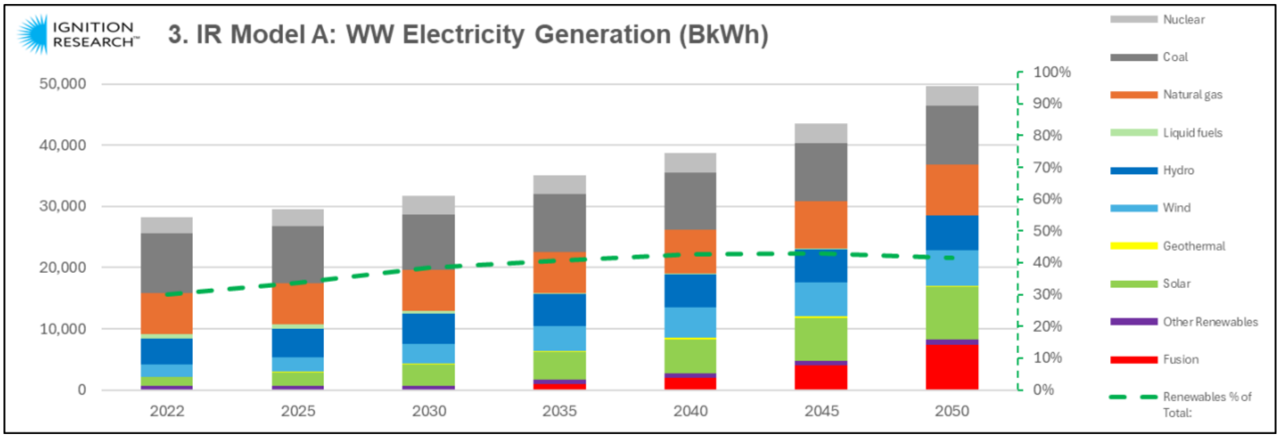


of 50,659 BkWh in 2050, resulting in an "electricity gap" (the difference between the US-EIA forecasted worldwide generation capacity and the Ignition Research Model A forecasted demand) of 8,361 BkWh worldwide in 2050, as shown in the graph below. In the Ignition Research Model A forecast, this "electricity gap" is most pronounced in the US, where it is slightly over 3,200 BkWh in 2050.

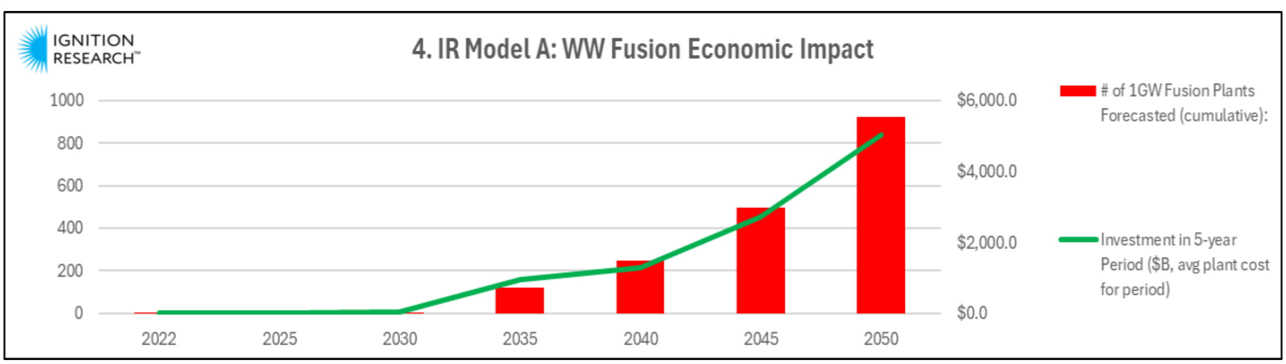
This worldwide electricity gap is where fusion-generated electricity fits in. This results in the electricity generation scenario shown below for Ignition Research Model A. The key electricity generation points from Model A are:

1. Fusion electricity reaches 7,393 BkWh in 2050, fulfilling roughly 14.6% of the world's power.
2. Renewables achieves slightly over 21,000 BkWh in 2050, or 42% of the world's power.
3. Natural gas goes to 9,234 BkWh by 2050, roughly 1,000 BkWh over the US-IEA forecast.

4. The largest market for fusion electricity in 2050 is the US & Canada at 2,874 BkWh, followed by Eastern/Western Europe and Eurasia at 1,376 BkWh. This is unsurprising given that these two regions will also have the largest number of data centers. China follows closely at 1,321 BkWh. Together these three regions constitute 75% of the electricity generated from fusion in 2050.

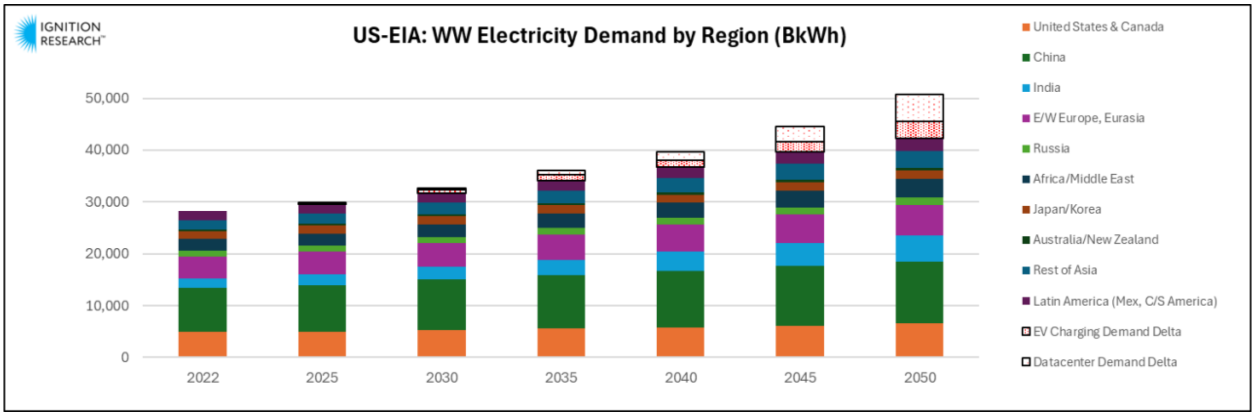


To achieve the power output in Ignition Research Model A will require the construction of 924 1GW fusion power plants by 2050, with each plant producing 8 BkWh of electricity per year with a downtime for maintenance of roughly 8.67%. As discussed in Section 4.2.3, the average cost of each 1GW fusion power plant is expected to reach a price of $12.25B in USD 2050; note that these costs are slightly lower than the cost of constructing a 1GW nuclear fission power plant. The economic impact of fusion electricity in Model A will reach $1.347 trillion (USD) by 2050. This amount is for the construction of the 110 1GW fusion power plants required that year, and is shown in the graph below (graphs for each region are shown in the Appendices).



6. Model B: Model A Demand Increases, Plus Caps on Renewables

The Ignition Research Model B builds on the Model A forecast above by including its increase in electricity demand due to EV charging and datacenters. In addition, Model B adds in caps on the growth of PV solar at 6% and wind at 3% outside of China (who owns the bulk of the world's production of PV solar and wind today) and Russia (which is forecasted to have very minimal amounts of either source). Since it is identical to the demand in Model A, Model B's electricity demand model is unchanged as shown below.



6.1. Cap on PV Solar and Wind Electricity Production

The current US-EIA worldwide forecast has PV solar electricity growing at a CAGR of 6.61%, making up 20.1% of WW electricity in 2050. Similarly, the US-EIA forecasts wind electricity achieving a CAGR of 3.94%, and making up 13.7% of WW electricity in 2050. In specific regions (excluding China), the growth rates for both PV solar and wind electricity have even higher CAGRs that the above:

a) **US & Canada:** The CAGR for PV solar electricity is 8.03%, reaching 28.1% of US/Canada electricity generation in 2050. Similarly, the CAGR for wind electricity is 4.38%, which reaches 24.4% of US/Canada electricity generation in 2050. Together, these sources are forecasted to make up over 50% of electricity in the US and Canada. Move over, this level of dependence on these power sources almost certainly necessitates a significant energy storage infrastructure, which would include a significant investment in lithium-ion batteries or a similar short-term storage medium. Given the adversarial supply chain concerns regarding PV solar, lithium-ion batteries, and wind turbines, these numbers are only achievable if the US can create a domestic supply chain.

b) **India:** If the US/Canada numbers are high, those for India are even more astounding. The CAGR for PV solar electricity is 12.58%, reaching 53.0% of India's electricity generation in 2050. Similarly, the CAGR for wind electricity is 6.26%, which reaches 12.7% of India's electricity generation in 2050. Together, these sources are forecasted to make up nearly 2/3 of electricity generation in India.

c) **Africa/Middle East:** Like US/Canada and India, the CAGRs for Africa/Middle East are also very high. The CAGR for PV solar electricity is 8.78%, reaching 12.5% of Africa/Middle electricity generation in 2050. Similarly, the CAGR for wind electricity is 5.21%, which reaches 3.5% of Africa/Middle East electricity generation in 2050. While the total generation from these two sources is still relatively small (16%), it seems unlikely that Africa/Middle East could achieve this growth.

d) **Japan/Korea:** Wind electricity is the issue in this region, with a CAGR of 10.58%, achieving 12.7% of total power generation in the region in 2050. Given Japan and Korea's concerns regarding China, it seems unlikely that either of these countries would depend on China for a significant amount of their electricity as a first choice.

e) **Rest of Asia (ROA):** Both PV solar and wind electricity are issues in this region. The CAGR for PV solar electricity in ROA is 8.56%, achieving 17.2% of total power generation in the region in 2050. Wind electricity's CAGR in ROA is 7.33%, achieving 3.1% of total power generation in the region in 2050. Like Japan/Korea, the concerns regarding China in ROA make it unlikely that these countries would depend on China for an over 20% of their electricity as a first choice.

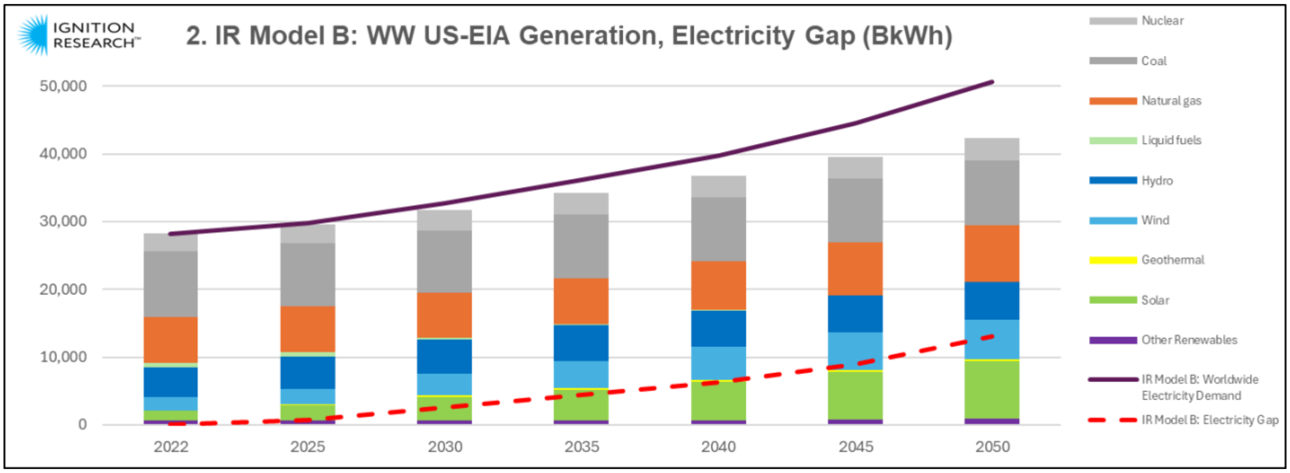
Because of these factors, we have capped the CAGR for PV solar electricity at 6%, and the CAGR for wind electricity at 3% in these regions.

6.2. Impact of Demand/Generation Changes, Resultant "Electricity Gap"

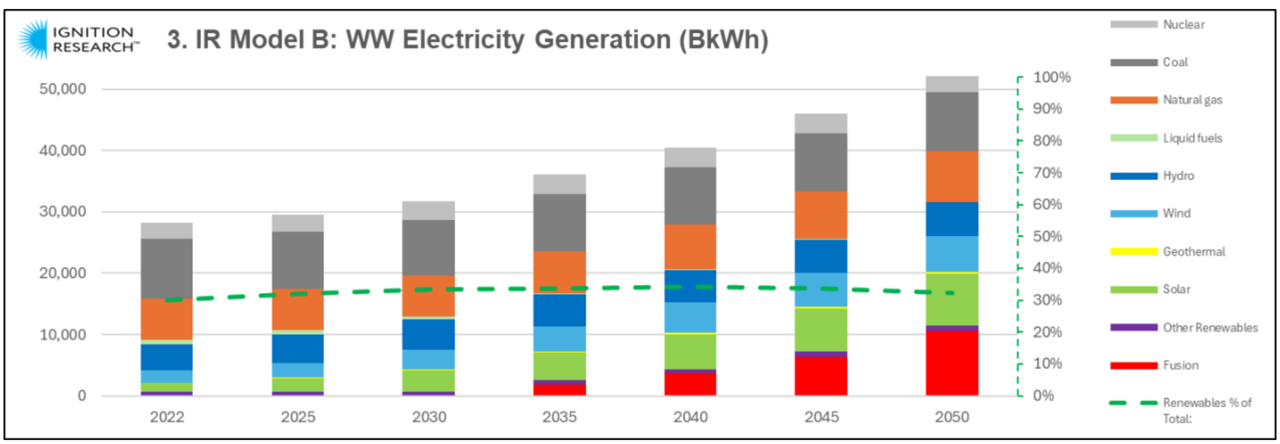
The result of these caps on PV solar and wind electricity is a worldwide "electricity gap" of 13,068 BkWh worldwide in 2050, as shown in the graph below. In the Ignition Research Model B forecast (like Model A), this "electricity gap" is most pronounced in the US, where it is 4,449 BkWh in 2050, nearly 45% of US/Canada demand in 2050.

Again, this worldwide electricity gap is where fusion-generated electricity fits. This results in the electricity generation scenario shown below for Ignition Research Model B. The key electricity generation points from Model B are:

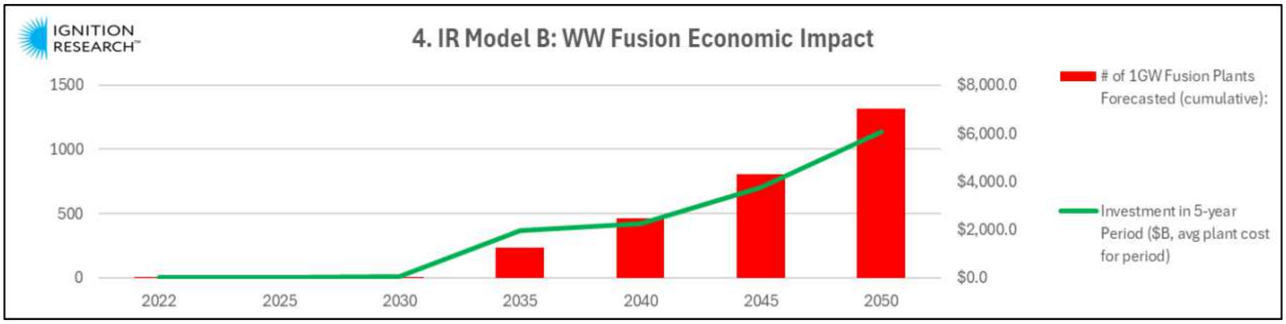
1. Fusion electricity reaches 10,515 BkWh in 2050, fulfilling roughly 20.8% of the world's power.
2. Renewables achieves slightly over 16,361 BkWh in 2050, or 32% of the world's power.
3. Natural gas goes to 10,819 BkWh by 2050, roughly 2,500 BkWh over the US-IEA forecast.



4. The largest market for fusion electricity in 2050 remains the US & Canada at 2,874 BkWh, followed by India at 2,501 BkWh, and Eastern/Western Europe and Eurasia at 1,376 BkWh. China follows closely at 1,321 BkWh. Together these regions constitute nearly 80% of the electricity generated from fusion in 2050.

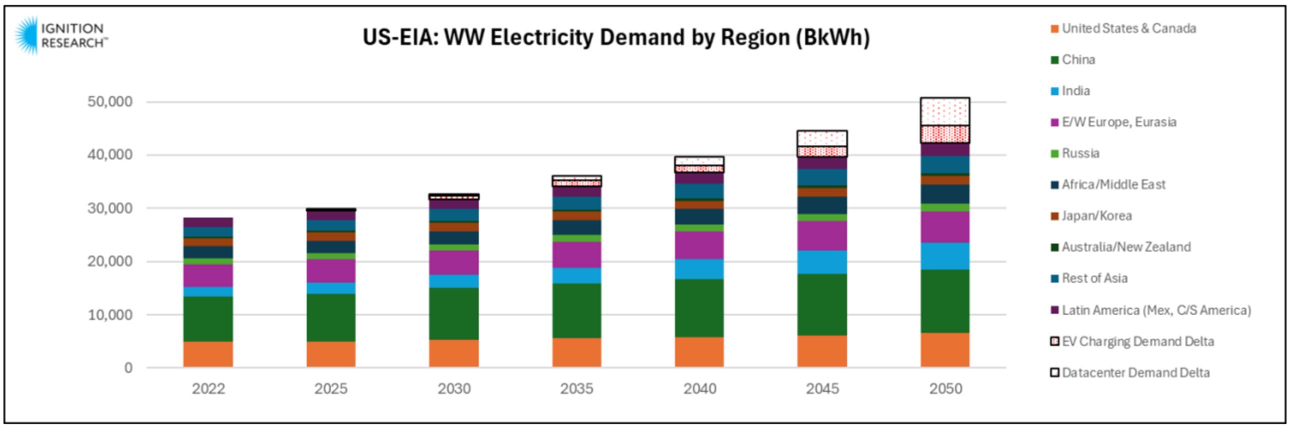


To achieve the power output in Ignition Research Model B will require the construction of 1,314 1GW fusion power plants by 2050. The economic impact of fusion electricity in Model B will reach $1.555 trillion (USD) by 2050. This amount is for the construction of the 127 1GW fusion power plants required that year and is shown in the graph below (graphs for each region are shown in the Appendices).



7. Model C: Model B Demand/Renewable Caps, Plus Coal Reduction

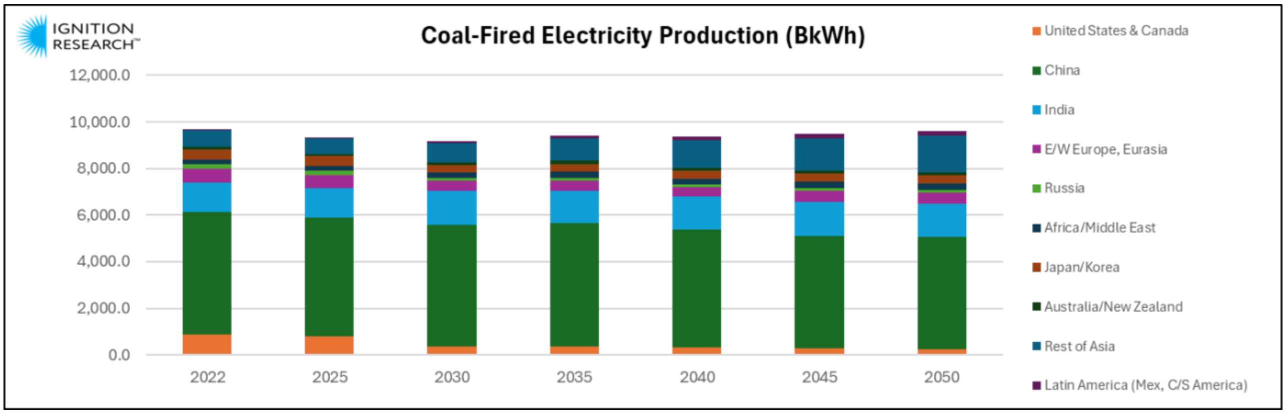
The Ignition Research Model C builds on the Model A and B forecasts above by including their increases in electricity demand due to EV charging and datacenters, as well as the Model B caps on the growth of PV solar at 6% and wind at 3% outside of China. Additionally, Model C adds a reduction in the use of coal for the regions that are the highest users and which are not aggressively cutting back in coal's usage Model C electricity demand is identical that of Models A and B, as shown below.



7.1. Reductions in the Use of Coal for Electricity Generation

The current US-EIA forecast for coal use in electricity generation is 9,612 BkWh in 2050, as shown below. The countries consuming the largest amount of coal for electricity generation are:

1. China: 4,797 BkWh in 2050; CAGR of -0.32%
2. Rest of Asia: 1,583 BkWh in 2050; CAGR of 2.93%
3. India: 1,411 BkWh in 2050; CAGR of 0.46%
4. E/W Europe, Eurasia: 494.9 BkWh in 2050; CAGR of -0.79%
5. Japan/Korea: 341.4 BkWh in 2050; CAGR of -0.91%
6. Africa/Middle East: 275.6 BkWh in 2050; CAGR of 0.90%
7. US&Canada: 256.5 BkWh in 2050; CAGR of -4.34%
8. Latin America: 191.7 BkWh in 2050; CAGR of 5.19%
9. Australia/New Zealand: 139 BkWh in 2050; CAGR of 0.80%



Of these, only the US/Canada have aggressive "de-coalification" efforts, as demonstrate by the -4.34% CAGR; additionally, Latin America consumption is very low relative to the rest of the world. For the rest, we have reduced their CAGRs by roughly 1%, resulting in the following:

1. China: CAGR of -1.32%; 3,617 BhWh from coal in 2050 (a reduction of ~1,100 BkWh)
2. Rest of Asia: CAGR of 1.93%; 1,205 BkWh from coal in 2050 (a reduction of ~380 BkWh)
3. India: CAGR of -0.54%; 1,066 BkWh from coal in 2050 (a reduction of ~350 BkWh)
4. E/W Europe, Eurasia: CAGR of -1.79%; 373 B BkWh in 2050 (a reduction of ~120 BkWh)
5. Japan/Korea: CAGR of -1.91%; 257 BkWh in 2050 (a reduction of ~85 BkWh)
6. Africa/Middle East: CAGR of -0.10%; 208 BkWh in 2050 (a reduction of 68 BkWh)
7. Australia/New Zealand: CAGR of -0.2%; 105 BkWh in 2050 (a reduction of 24 BkWh)

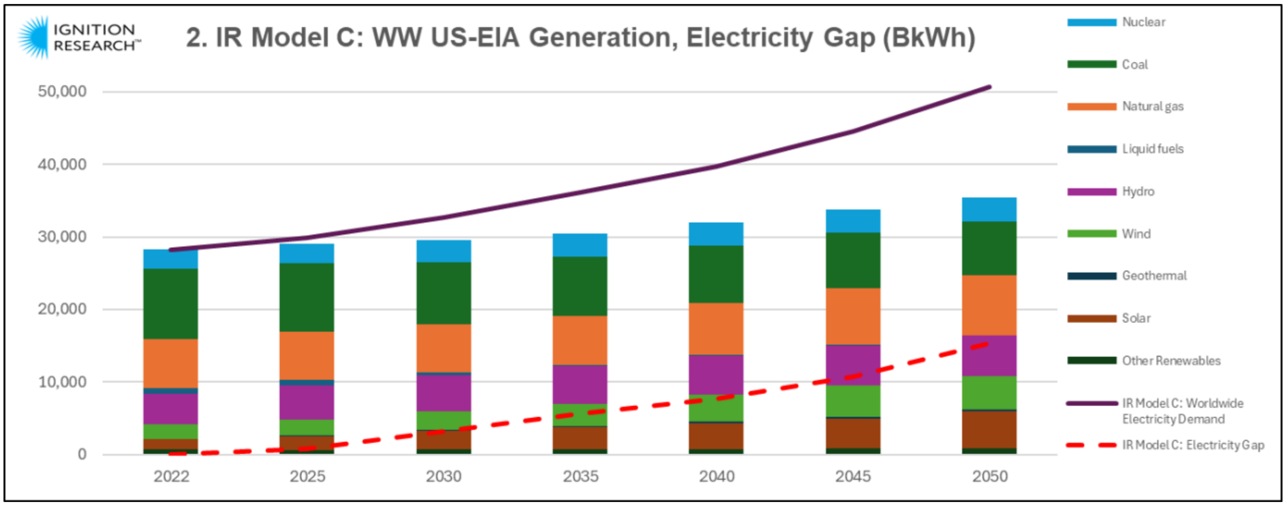
Together, these reductions cut coal-generated electricity WW to 7,401 BkWh (a reduction of 2,211 BkWh from the US-EIA forecast), with a CAGR of -0.91%.

6.1. Impact of Model C Demand/Generation Changes, Resultant "Electricity Gap"

The result of the changes in Model C is a worldwide "electricity gap" of 15,278 BkWh worldwide in 2050, as shown in the graph below. Like the Ignition Research Model B forecast, Model C's "electricity gap" in the US/Canada is the same as Model B (4,449 BkWh in 2050, or 45% of US/Canada demand in 2050). India's gap jumps to 3,198 BkWh in 2050 (almost 60%

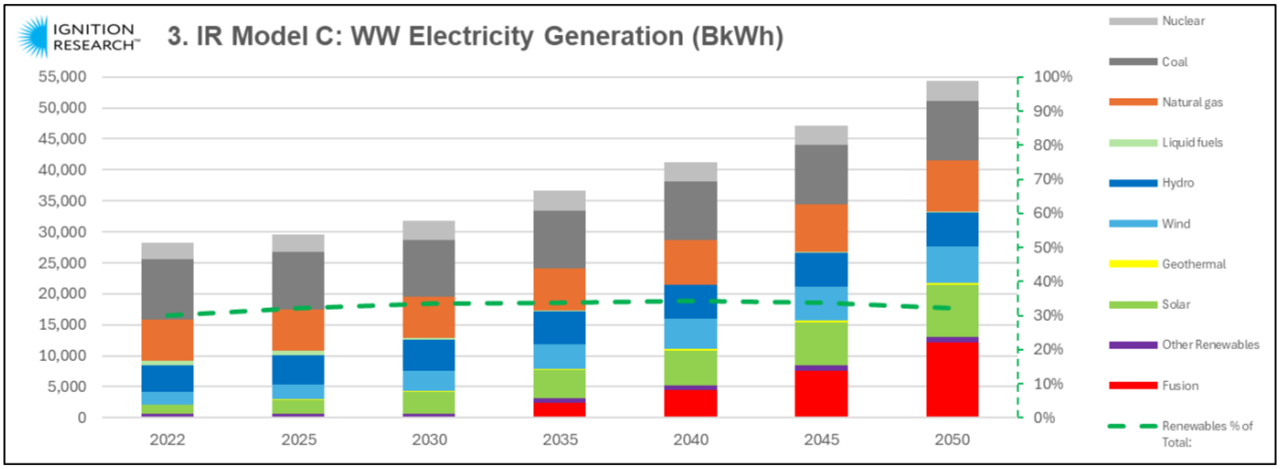
of their demand), while China's electricity gap jumps to 2,824 BkWh (21% of their total demand).

Again, this worldwide electricity gap is where fusion-generated electricity fits. This results in

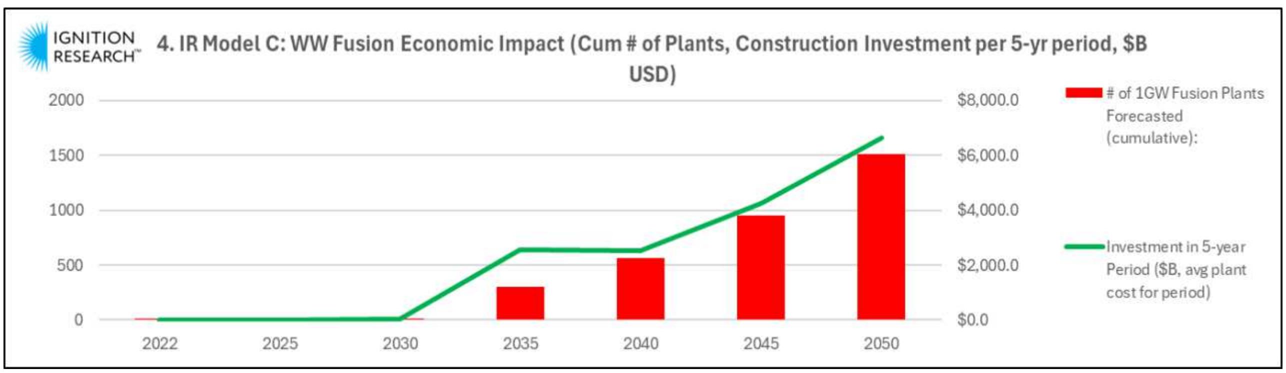


the electricity generation scenario shown below for Ignition Research Model C. The key electricity generation points from Model C are:

1. Fusion electricity reaches 12,100 BkWh in 2050, fulfilling roughly 23.9% of the world's power.
2. Renewables achieves slightly over 16,361 BkWh in 2050, or 32% of the world's power.
3. Natural gas goes to 11,455 BkWh by 2050, nearly 3,200 BkWh over the US-IEA forecast.
4. The largest market for fusion electricity in 2050 remains the US & Canada at 3,120 BkWh, followed by India at 2,560 BkWh, China at 2,008 BkWh, and Eastern/Western Europe and Eurasia at 1,623 BkWh. Together these regions constitute 77% of the electricity generated from fusion in 2050.



To achieve the power output in Ignition Research Model B will require the construction of 1,512 1GW fusion power plants by 2050. The economic impact of fusion electricity in Model C will reach $1.690 trillion (USD) by 2050; this is amount is for the construction of the 138 1GW fusion power plants required in 2050, and is shown in the graph below (graphs for each region are shown in the Appendices). Fusion crosses the $1T "magic line" in 2046.



8. Summary

The use of electricity worldwide will increase significantly between now and 2050. Drivers include:

1. Electrification of the developing world from a residential, business, and industrial perspective.
2. The rapid electrification of transport, specifically ground transportation that today utilizes fossil fuels.
3. The electrification of industrial processes and tools, in particular the switch to rechargeable battery-powered tools from those using fossil fuels.
4. The rapid growth of hyperscale data centers, particularly those for artificial intelligence and machine learning.

There are also several likely drivers that could make the increase in electricity demand outstrip that forecasted by the US-EIA, and possibly result in a growth of nearly 74% versus 2022 levels, as shown in Scenario 3 above. If the pressure to reduce the use of fossil fuels to produce this electricity (particularly coal, but also natural gas) occur simultaneously with the growth of demand, an "electricity gap" will occur between demand and generation, even if renewables can achieve the US-EIA forecasts (which we see as unlikely for a number of previously stated reasons).

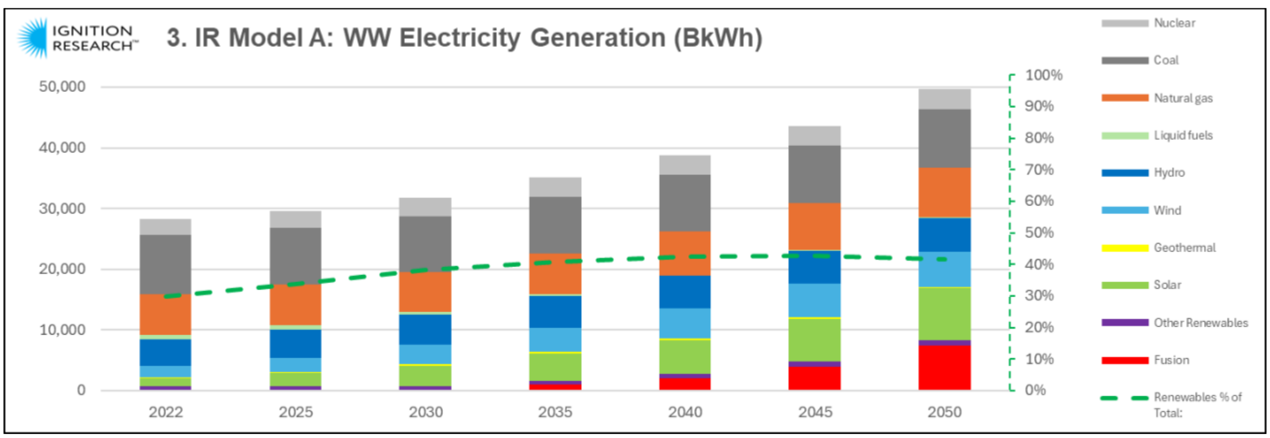
Electricity generated from fusion is the only likely alternative to solve the "electricity gap" (see graphs below). However, it will take the continued concerted efforts that non-adversarial governments, the investment community, and both private and public research into fusion have achieved over the last several years to result in the successful commercialization of fusion by 2035. As we have stated, there are several advantages to being "in the front" of the fusion electricity development train, including:

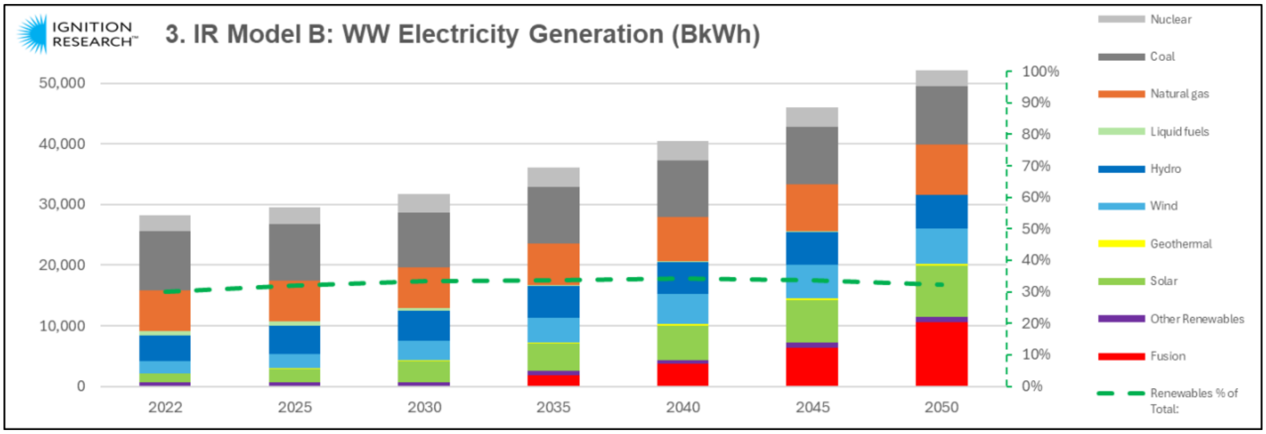
1. The creation of upwards of 10 million new high-paying jobs, and over $470B in manufacturing workload (much of which will be export-focused).
2. A significant improvement in greenhouse gas emissions, particularly in the developing world which is highly dependent on coal and natural gas to achieve its electrification goals.
3. A simplification of electricity transmission and powerplant citing due to the significantly smaller footprint of fusion electricity powerplants versus the footprint of wind and PV solar power farms.
4. Increased energy independence, especially for the technologies, processes, and components required for the building of fusion electricity power plants.

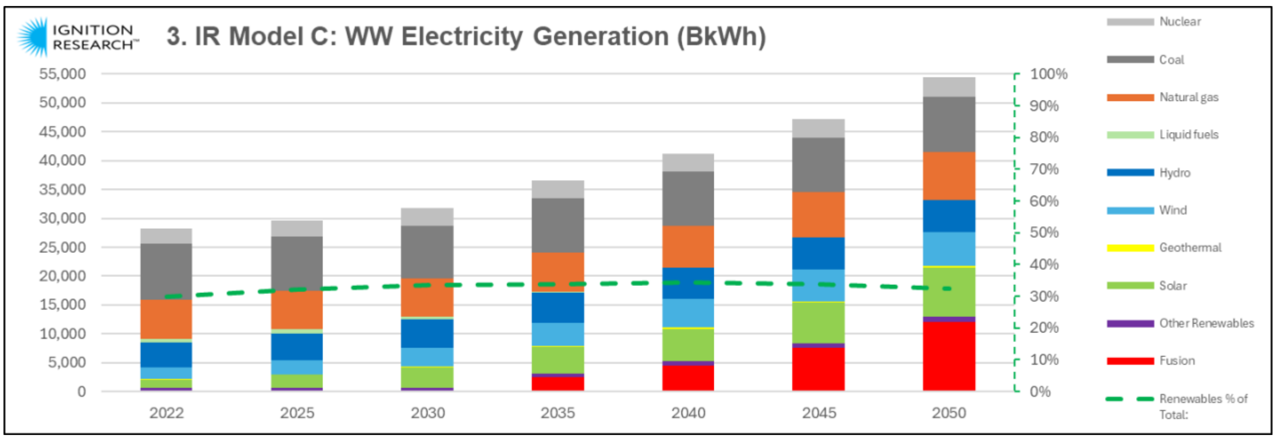
To achieve this result will require government policies that drive the development of a non-adversarial supply chain for critical fusion technologies, including but not limited to reactor containment vessels, high-power laser and magnetics, high voltage switching, fusion fuel manufacturing and injection systems, and high-power capacitors.

> Each of these critical fusion technologies have underlying critical material technologies such as high-performance dielectrics which must also have a non-adversarial supply chain associated with them.

Missing the ability to successfully develop and manufacture these technologies in a non-adversarial supply chain potentially exposes the US and our allies to the potential for energy "blackmail", as has happened for fossil fuels in the past, and is currently a danger for PV solar, wind power, and short-term energy storage solutions such as lithium-ion batteries.




IGNITION RESEARCH
3. IR Model B: WW Electricity Generation (BkWh)
50,000
40,000
30,000
20,000
10,000
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2022
2025
2030
2035
2040
2045
2050
Nuclear
Coal
Natural gas
Liquid fuels
Hydro
Wind
Geothermal
Solar
Other Renewables
Fusion
Renewables % of Total:


IGNITION RESEARCH
3. IR Model C: WW Electricity Generation (BkWh)
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2022
2025
2030
2035
2040
2045
2050
Nuclear
Coal
Natural gas
Liquid fuels
Hydro
Wind
Geothermal
Solar
Other Renewables
Fusion
Renewables % of Total:

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