SANDIA REPORT

SAND2024-03352
Printed March 2024

Sandia National Laboratories

Energy Transitions: Local Water Concerns and Climate Impacts

Thushara Gunda, Michelle Williams, and Tom Lowry

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185
Livermore, California 94550

Issued by Sandia National Laboratories, operated for the United States Department of Energy by National Technology & Engineering Solutions of Sandia, LLC.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represent that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof, or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-Mail: reports@osti.gov
Online ordering: http://www.osti.gov/scitech

Available to the public from

U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312

Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-Mail: orders@ntis.gov
Online order: https://classic.ntis.gov/help/order-methods

ACKNOWLEDGMENTS

The authors would like to thank these individuals for taking the time to provide insights and feedback in support of this work: Sue Caskey, Nicole Jackson, Christian Klassert, Stephanie Kuzio, Andy Nelson, and Raquel Valdez.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

This report summarizes important nuances in local water concerns and potential climate impacts that could influence the roll-out of technologies associated with energy transitions. Current investments in clean energy technologies are very high, which is driving a lot of investments in related manufacturing (i.e., hydrogen, solar, wind, and batteries) and mining (e.g., lithium, copper, and graphite) around the world. To understand how water and climate dynamics could be influencing these activities, we conducted a phased literature review for three countries: China, Germany, and France. China was selected due to its global dominance in manufacturing of solar panels, batteries, and electrolyzers as well as production of rare earth elements while Germany and France were selected due to their emerging leadership in energy transitions-related manufacturing within the European Union. For each of these three nations, we identified areas where manufacturing is occurring within the country and then evaluated relevant water resources and climate impacts. Multiple sources were consulted for this review, including BloombergNEF, international reports, industry sources, peer-reviewed literature, climate data, and media coverage.

Our research identified that energy transitions-related manufacturing is distributed across multiple sub-national areas within the evaluated nations (Table 0-1). Manufacturing within China was mostly concentrated in the eastern and southeastern provinces, such as Anhui, Jiangsu, and Sichuan (Table 0-1). In contrast, manufacturing in Germany was distributed throughout the country. Solar, hydrogen, wind, battery, and mining activities occurred across the western and eastern states (e.g., Rhineland-Palatinate, Saxony, and Brandenburg) as well as northern and southern states (e.g., Hamburg and Bavaria) (Table 0-1). Manufacturing within France was mostly concentrated in the northwest and southeastern regions, with Heights-of-France containing almost all of the battery-related manufacturing. The Auvergne-Rhone-Alps region also has notable mining for lithium as well as solar-related and hydrogen-related manufacturing (Table 0-1).

Concerns regarding availability and usage of water resources are prevalent and has led to the release of national water plans in all three countries. These plans are aiming to develop adaptations and mitigations to both scarcity and flooding issues in anticipation of climate change effects. Prominent concerns are centered around heatwaves, droughts, and flooding (Table 0-2). Some energy-related climate impacts that are unique to China are glacier and permafrost melting, both of which are expected to impact existing energy-related infrastructure, such as railways and pipelines distributing fuels.

Climate data projections indicate that the likelihood for maximum daily temperatures and the range in precipitation values will be higher in all three countries (Figure 0-1). The variability in precipitation is raising concerns over both drought and flooding, both of which can impact manufacturing. For example, droughts in the Sichuan province have led to reduced electricity production whereas droughts in Germany have led to low river levels that has impacted transportation. Heatwaves can also reduce the availability of water (e.g., through higher rates of evapotranspiration) and lead to an increase in energy demands for cooling, which can further stress existing infrastructure. Increased demands from heatwaves in the summer of 2022, for example, led to power restrictions in multiple provinces in China. Compounding effects (of

Table 0-1 Select Areas for Energy-Related Manufacturing within Evaluated Countries*

Country	Area†	Energy Manufacturing	Notes
China	Anhui	Solar, Hydrogen	Yangtze River Delta
China	Fujian	Batteries, Mining	
China	Jiangsu	Solar, Hydrogen, Wind, Batteries	Yangtze River Delta
China	Sichuan	Batteries, Wind, Mining	
China	Zhejiang	Solar, Hydrogen	Yangtze River Delta
Germany	Berlin	Hydrogen, Batteries	
Germany	Brandenburg	Solar, Hydrogen, Batteries	
Germany	Hamburg	Wind, Hydrogen	
Germany	Lower Saxony	Batteries, Wind	
Germany	Rhineland-Palatinate	Solar, Batteries, Mining	Upper Rhine Valley
Germany	Saxony	Solar, Mining	underground project
France	Auvergne-Rhone-Alps	Solar, Hydrogen, Mining	
France	Brittany	Solar, Batteries	
France	Heights-of-France	Batteries	
France	Occitania	Solar, Wind	

*Please see full report for a more complete listing of manufacturing areas and associated references.

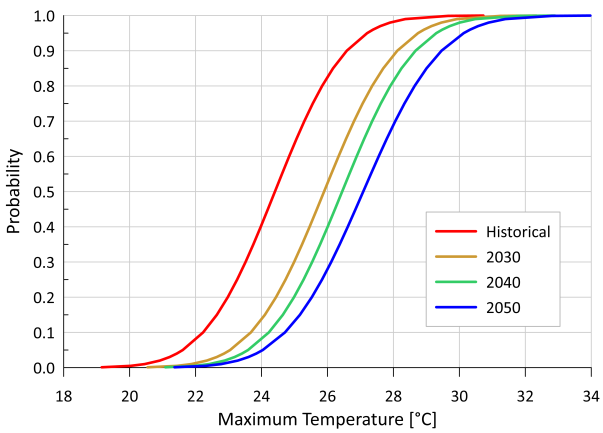
† These refer to first-level administrative boundaries within each country.

droughts and heatwaves) are especially being felt in the Yangtze River Basin (China) and Rhine River Basin (Germany).

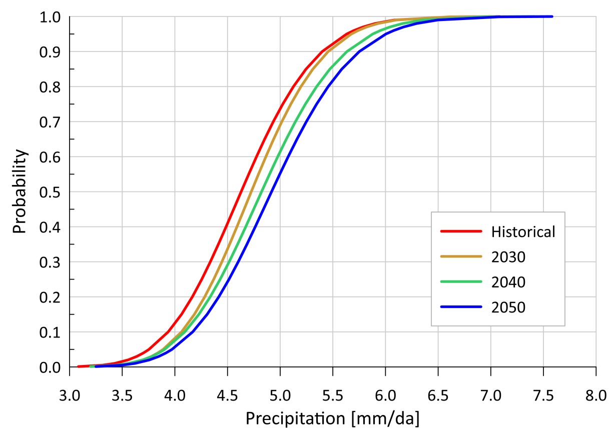
There are a number of limitations in the current study, many of which are driven by lack of data. Future work could consider a more systematic review of media coverage to understand the complex relationships between energy, water, and climate across both physical and social dimensions. Statistical evaluations of climate data could also be expanded to consider the likelihood of occurrence for compound events, for different time periods and for more targetted areas of interest. Such analyses will improve characterization of risk that better reflects the multiple pathways that water can impact energy activities.

Table 0-2 Key Climate Impacts across Nations

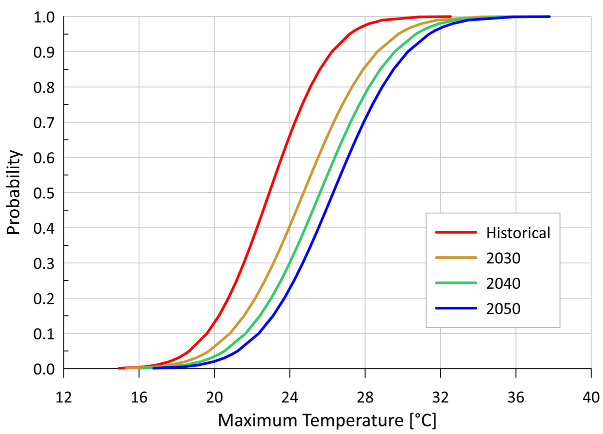
Climate Change Effect	China	Germany	France
Heatwaves	Increased electricity demands [1]	Reduced water availability [2]	Operational efficiency of power plants [3, 4]
Drought	Reduced hydropower generation in Sichuan; impacts to other provinces through electricity transmission [1]	Reduced river levels impacting inland shipping of fuels [5]	Low river levels and electricity shortages [6, 7]
Flooding	Disruptions to local industrial and manufacturing activities [8]	Disruptions to local industrial and manufacturing activities [2]	Flooding of nuclear plants [9]
Sea level rise	Damages to coastal shipyards [8]	-	Exposing coastal populations [10]
Glacier and Permafrost melt	Impact railways and pipelines carrying crude and natural gas [8]	-	-



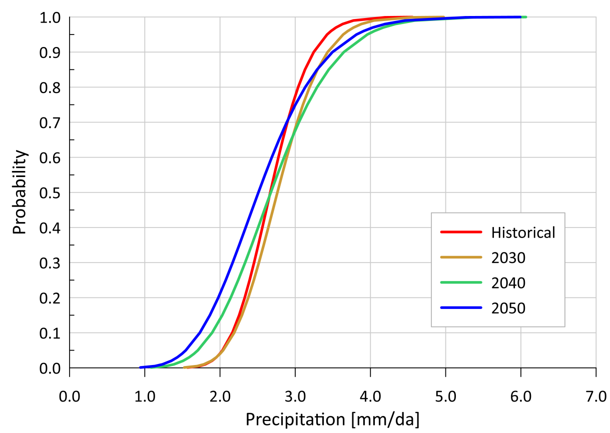
(a) China: Maximum Temperature



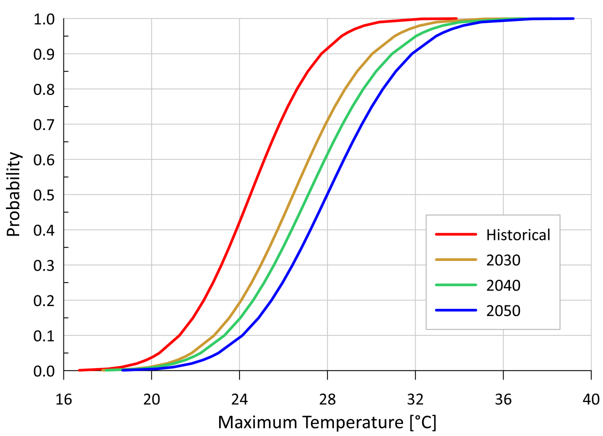
(b) China: Precipitation



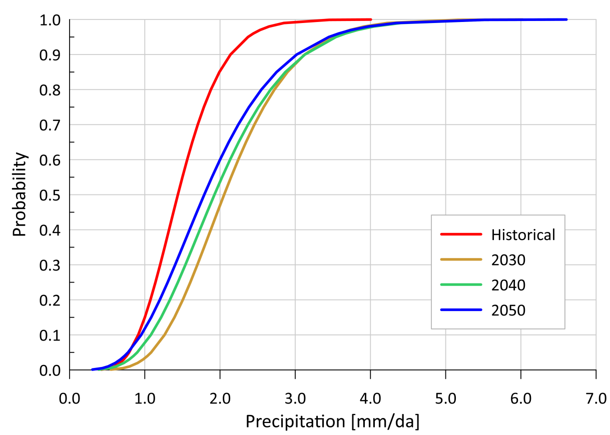
(c) Germany: Maximum Temperature



(d) Germany: Precipitation



(e) France: Maximum Temperature



(f) France: Precipitation

Figure 0-1 Probability Plots for daily maximum temperature the month of July (left-hand column) and daily precipitation (right-hand column) for China (top row), Germany (middle row), and France (bottom row).

ACRONYMS

AR5 Fifth Assessment Report

BNEF BloombergNEF

°**C** degrees Celsius

C-FIT Climate Futures Impact Tool

CMIP Coupled Model Intercomparison Project

GW gigaWatt

mm millimeter

m^3 cubic meter

MYSE Mingyang Smart Energy

1. INTRODUCTION

Multiple nations are actively exploring different energy transition strategies to support their security, development, and carbon emissions-related objectives [11]. As a part of these strategies, different technologies are being pursued to support energy efficiency, renewable energy generation (e.g., solar and wind), electrification, and hydrogen production [12]; the latter are intended to support shifting away from fossil-based fuel dependence. Current investments in clean energy technologies are approximately $1.7 trillion dollars globally, surpassing investments in fossil fuels [13].

Concurrently, there is increasing awareness of how changing climate conditions could influence these emerging energy technologies. This has motivated various research studies in energy transitions, spanning potentials, operations, and policies. For example, researchers are evaluating how climate could influence resource potentials for wind and solar as well as potentially accelerate degradation of the materials [14, 15, 16]. Others are researching how indirect greenhouse gas warming from hydrogen emissions could influence the effectiveness of decarbonization strategies [17]. Finally, impacts of different climate policies on the nature of technologies selected and rate of investments are also being studied [18].

Unfortunately, to date, relatively limited attention has been given to the water-climate nexus associated with the energy transitions. While some researchers are studying how operations of hydropower and thermoelectric plant operations could be impacted by changing water and climate conditions [19, 20], little is known about how water-related climate dynamics could impact current energy transitions. Recently, we published a report summarizing the current literature on water touchpoints to operations, manufacturing, and mining of emerging energy technologies [21]. This work extends those findings to consider regional nuances of water resources and potential climate impacts that could influence the roll-out of energy transitions, focusing on manufacturing-related activities.

2. SCOPE

A robust assessment of climate impacts on energy transitions-related manufacturing requires site-specific details regarding water requirements; local infrastructure to support collection, distribution, and treatment of water; and associated policies governing water accessibility. Unfortunately, water data for manufacturing is typically sparse and hard to ascertain without substantial deep dives and effort [22]. So, for the purposes of this analysis, we use a phased literature review approach to synthesize available details to understand possible climate impacts on water resources for energy transitions-related manufacturing. Manufacturing priorities for this report span four primary technologies (hydrogen, solar, wind, and batteries) as well as five associated minerals of interest (lithium, copper, nickel, cobalt, and graphite)[1].

Three countries were selected for this analysis: China, Germany, and France. China was selected due to its global dominance in manufacturing of solar panels, batteries, and electrolyzers as well as production of rare earth elements [23, 24, 25, 26, 27, 28, 29]. Additionally, China is recognized as a global leader in renewable energy expansion, building 75 gigawatts (GW) of wind and over 100 GW of solar annually; the scale of investments within China is comparable to the rest of the world combined [30, 31]. Germany and France, on the other hand, were selected due to their emerging leadership in manufacturing of energy transitions-related technologies within the European Union. Germany had the highest solar-, wind-, and battery-related manufacturing within the European Union while France is making significant investments in production of wind, battery, and hydrogen technologies [23, 32, 33, 34]. For each of these three nations, we begin with understanding where, within the nation, manufacturing is concentrated and then do an evaluation of water resources, with an emphasis towards areas[2] where manufacturing activities are concentrated. Finally, documented concerns about climate impacts that could influence water scarcity dynamics within the areas are captured. More information about the sources consulted for these activities is captured below.

Details about manufacturing activities were collected from multiple sources, including BloombergNEF (BNEF), international reports, industry sources, and corporate websites (in that order). BNEF contained highly-resolved details about solar manufacturing locations, including size and location of the plant [35]. These details were aggregated by area, to understand where solar manufacturing was concentrated. Some battery manufacturing details were also available in BNEF. However, the database did not categorize specific locations of plants. Thus, plant names from BNEF were used in combination with industry websites to identify the corresponding locations for each facility. For hydrogen and wind technologies as well as minerals, a combination of techniques and sources were consulted to gain insights into areas with high concentrations of associated manufacturing and mining activities. For hydrogen and wind, we began with compiling a list of possible manufacturers by consulting top entities from industry sources (e.g., Black Ridge for hydrogen [36]) and cross-referencing manufacturer details with

[1] More information about the selection of these technologies (including associated components, such as polysilicon for solar and nacelles for wind) as well as minerals can be found in our previous report [21]).

[2] Each of the evaluated countries use different nomenclatures for the first-level administrative boundaries, e.g., provinces (China), states (Germany), and regions (France). To reduce confusion, we use the term ‘area’ when referring to first-level administrative boundaries across multiple nations.

those provided in international reports (e.g., [23]). Then specific details about these manufacturer locations were sourced from associated corporate websites. Additional information from media reports about manufacturing as well as mining were used to augment these findings. Specific sources consulted are captured within each of the region-specific descriptions in the following sections. It should be emphasized that the purpose of this activity was to not generate a comprehensive list of manufacturing sites (which is beyond the scope of this work) but rather to help narrow down the specific geographies (if any) where water/climate-related impacts within a nation could be of import.

Details about water resources and climate impacts were sourced from a combination of peer-reviewed literature, climate data analysis, media coverage, and policy reports. Peer-reviewed literature and climate data analysis were used to help characterize the specific changes projected under climate change. For example, the Climate Futures Impact Tool (C-FIT) was used to help generate probabilities of observing specific climate variables (e.g., daily maximum temperature and precipitation). C-FIT uses the data from phase five of the Coupled Model Intercomparison Project (CMIP5) experiments developed for the Intergovernmental Panel on Climate Changes Fifth Assessment Report (AR5). We use the model-generated data of a statistically consistent ensemble (22 models) from CMIP5 to estimate uncertainty distribution functions at the country-level [37]. For this analysis, 30 years of record were used for both the historical period (from 1976 to 2005) and future period (2021-2050); the latter is organized into three decadal periods of 2030 (2021-2030), 2040 (2031-2040), and 2050 (2041-2050). A description of how to read the C-FIT plots is captured in Figure 2-1. The month of July was selected for C-FIT evaluations since the summer time reflects high stress conditions (i.e., when water resources are often the lowest and temperatures are often the highest). The information from the peer-reviewed literature and climate data analyses (about projected impacts under climate change) was supplemented by insights from media coverage (spanning international and national outlets) and policy reports to understand local priorities and concerns.

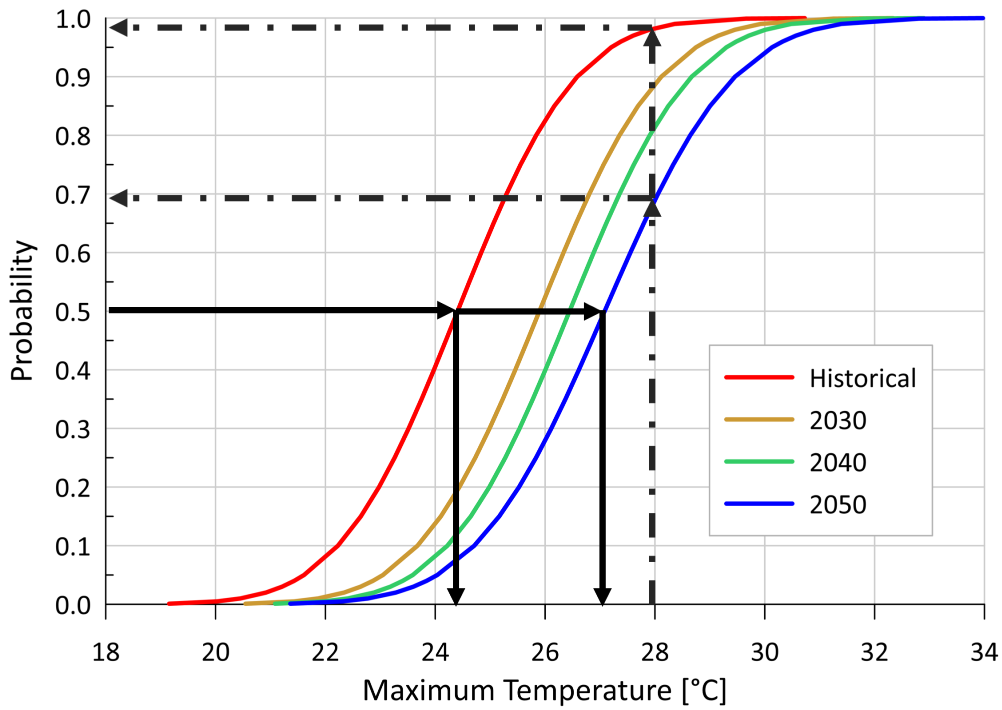


Figure 2-1 C-FIT plots show the probability of a variable (temperature in this example) being less than or equal to a particular value, and can be read in one of two ways: 1) understand how future values may change given a particular probability (solid black lines) or 2) understand how the probability changes for a given value (dashed black lines). In this example, the first method (shown by the solid black lines), indicates that for a probability equal to 50%, the mean temperature (being that value or lower) increases from 24.5°C historically, to 27.0°C by 2050. The second method (shown by the dashed black lines) indicates that a temperature of 28°C was historically exceeded only 3% of the time (less than or equal to 28° 97% of the time) whereas by 2050, it is expected to be exceeded 30% of the time (less than or equal to 28° 70% of the time).

3. CHINA

3.1. Manufacturing

As noted previously, China is home to a significant proportion of manufacturing associated with energy transition-related technologies. This manufacturing is distributed across multiple provinces of the country (Table 3-1). For example, within the solar sector, a total of 542.5 GW of solar manufacturing has been commissioned in China with another 72.2 GW under construction as of 2023 [35, 38]. Over three-quarters of the solar manufacturing is concentrated in three provinces: Jiangsu (39.2%), Zhejiang (21.0%), and Anhui (15.1%) [35]. There is also significant polysilicon production (approximately half of global supply) in the Xinjiang province [39].

Multiple manufacturers (e.g., LONGi, Sungrow, and Man Energy Solutions) have facilities manufacturing hydrogen electrolyzers within Anhui and Jiangsu provinces [40, 41, 42]. Other provinces with hydrogen-related manufacturing include Shanxi (headquarters for LONGi [40]), Hebei (PERIC [43]), and Jiangxi (Sungrow [41]); LONGi also has manufacturing plants located in Ningxia, Zhejiang, Yunan, and Hong Kong [40]. Jiangsu is also home to significant battery manufacturing [44]. More than 230 battery manufacturers are present within the country, but CATL and BYD comprise 21.5% of total nameplate capacity (7,702 GWh) [35]. Some estimates indicate that CATL may have a global market share of 37% while BYD has 16% [45]. CATL plants are distributed across 10 provinces, including Fujian (HQ) and Guangdong [46] while most of BYD's production base seems to be concentrated in Guangdong [47], with another large plant in Qinghai province [48]. Plans to build large factories in other provinces (e.g., Shandong Province by Great Power and Sichuan Province by CATL) have also been announced [49, 50].

Chinese manufacturers account for 60% of the installed capacity in wind worldwide [51], and is home to 7 of the top 10 wind turbine manufacturers [52]. Three of the leading providers are Goldwind, Envision, and Mingyang Smart Energy (MYSE) while other prominent ones include Shanghai Electric, Windey, CRRC, and Sany [52]. Envision's factory complex is located in Jiangsu [53] while maps of manufacturing facilities for Goldwind and MYSE indicate that their facilities are distributed throughout the country, including the northern Plateau and southeastern regions (e.g., Shanxi and Sichuan) [54, 55]. Tianjin is home to multiple western wind nacelle manufacturers (e.g., Siemens Gamesa and Vestas), although some of the production capacity may be unused [56].

Finally, China mines lithium, graphite, and copper, which are all critical minerals for energy production [25]. Sichuan province contains 57% of China's lithium ore reserves, mainly spodumene [57]. Other spodumene deposits are also found in Xinjiang and Henan while lepidolite is found in Jiangxi and Hunan provinces [58]. Majority of the world's graphite is in China; the nation is also involved in 90% of global graphite refinement [59]. Graphite production is traditionally centered in the Shandong Province but there has been some recent interest in transitioning to the Heilongjiang Province [60]. Copper mines in China are distributed across multiple provinces, including Fujian, Jiama, Julong, Yulong, and Yunnan [61].

Table 3-1 Energy Transitions-Related Manufacturing and Mining within Chinese Provinces

Province	Category	Notes	Source(s)
Anhui	Solar	15.1% of national production	[35]
Anhui	Hydrogen	LONGi, Sungrow, and Man Energy Solutions facilities	[40, 41, 42]
Fujian	Batteries	CATL headquarters	[46]
Fujian	Mining	Copper	[61]
Guangdong	Batteries	BYD and CATL plants	[46, 47]
Hebei	Hydrogen	PERIC facility	[43]
Heilongjiang	Mining	Emerging interest in graphite production	[60]
Hong Kong	Hydrogen	LONGi	[40]
Jiama	Mining	Copper	[61]
Jiangsu	Solar	39.2% of national production	[35]
Jiangsu	Hydrogen	LONGi, Sungrow, and Man Energy Solutions facilities	[40, 41, 42]
Jiangsu	Batteries	Most of nation's manufacturing	[44]
Jiangsu	Wind	Envision's factory complex	[53]
Jiangxi	Hydrogen	Sungrow facility	[41]
Julong	Mining	Copper	[61]
Ningxia	Hydrogen	LONGi	[40]
Qinghai	Batteries	Large BYD facility	[48]
Shandong	Batteries	Great Power facility planned	[49]
Shandong	Mining	Graphite production	[60]
Shanxi	Hydrogen	headquarters for LONGi	[40]
Shanxi	Wind	Goldwind and MYSE facilities	[54, 55]
Sichuan	Batteries	CATL facility planned	[50]
Sichuan	Wind	Goldwind facilities	[54]
Sichuan	Mining	Contains 57% of China's lithium ore reserves	[57]
Tianjin	Wind	Nacelle manufacturers (e.g., Siemens Gamesa and Vestas)	[56]
Xinjiang	Solar	Half of global polysilicon production	[39]
Yulong	Mining	Copper	[61]
Yunan	Hydrogen	LONGi	[40]
Yunnan	Mining	Copper	[61]
Zhejiang	Solar	21.0% of national production	[35]
Zhejiang	Hydrogen	LONGi	[40]

3.2. Water Resources

Water resources have long been considered both an opportunity and a challenge for China [62]. Comparable to the U.S. in land area[3], China experiences significant variations in the distribution of water resources across the country. For example, annual precipitation ranges from less than 50 millimeters per year (mm/yr) in the northwest provinces (e.g., Xinjiang and Qinghai) to over 2,000 mm/yr in the southeastern provinces (e.g., Guangxi, Guangdong, and Fujian) [64, 65]. The significant differences in precipitation are correlated with local water resource challenges. Flooding is a source of concern in the southeastern provinces [66]. In contrast, water scarcity is generally concentrated in the north and central provinces on the eastern side of the country, where precipitation is generally lower [67]. When water quality is taken into account, the region of water scarcity (e.g., around Shandong province) becomes larger [68].

To help manage the uneven distribution of these water resources, the country has introduced thousands of dams and diversions [69, 70, 66]. Multiple agencies manage these infrastructures, with governance often distributed by reservoir capacity and purpose of the dams [71]. For example, dams that are over 100 million cubic meters (m^3) in size are often managed by provincial or other higher level-agencies while those an order of magnitude smaller are managed by prefecture-level agencies, and so on through to the county and village levels [71]. Generally, there is a large diversity in surface water bodies present within the provinces, with some of the manufacturing areas (e.g., Anhui and Jiangsu) having more surface water bodies (by area) than others (e.g., Shanxi, Sichuan, Chongqing, and Fujian) [66]. Water contamination from mining has impacted reservoirs and food production in Guangdong province [72].

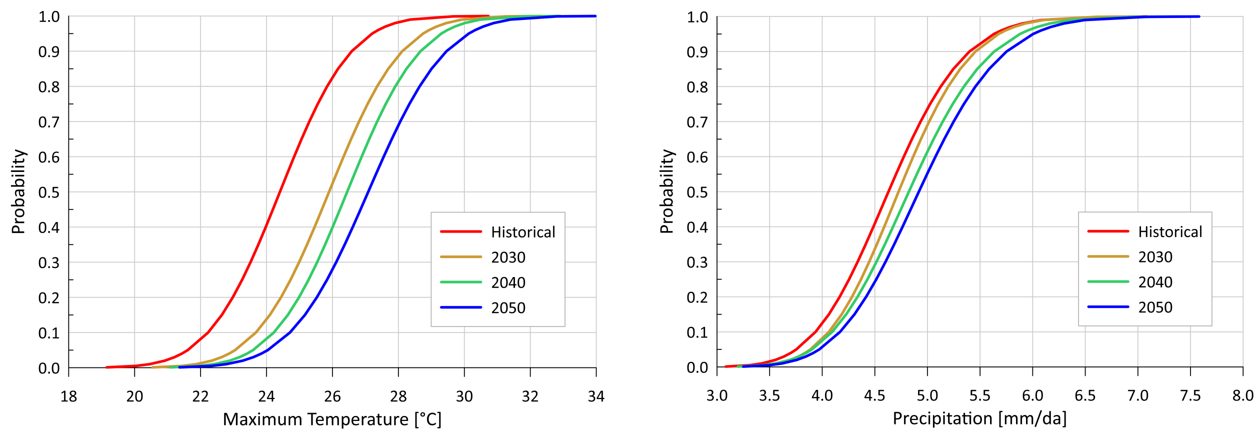
Generally, water data is considered highly sensitive in the nation, due to both national security concerns and regional hydro-geopolitics [73][4]. Recently, China has increased attention to water resources management through national policies. For example, the "Three Red Lines" effort in 2012 aimed to increase water efficiency practices and improve quality of major water sources [75]. The most recent 5-year National Water Security Plan (2021-2025) continues to emphasize prevention of floods/droughts, conservation, optimizing allocations, and strengthening ecological protection [76].

3.3. Climate Impacts

Climate change impacts on local water resources will occur through multiple pathways in China. These include: 1) changes in total and frequency of precipitation, 2) heatwaves, 3) sea level rise, and 4) melting of glaciers and permafrost. Changes in precipitation will increase both climatological drought (longer periods of low to no precipitation) as well as hydrological drought (due to increased evaporation from higher temperatures). C-FIT analysis of climate projections for the country indicate that daily precipitation values will likely increase in variability, from a maximum of 6 mm/day in historical time periods to over 7.5 mm/day by 2050 (Figure 3-1). Maximum temperature forecasts also indicate the higher prevalence of heatwaves. Historically,

[3]Both nations are approximately 9.5 million square kilometers [63].

[4]This has led to multiple energy-related studies often using statistics from other nations as a way to approximate water usage within China (e.g., [74]).



(a) Maximum Temperature in July **(b) Precipitation in July**

Figure 3-1 C-FIT Plots for China

27 degrees Celsius (°C) had a low probability of occurrence (i.e., 0.95 probability that temperatures were lower) but is a lot more likely (i.e., only 0.5 probability that temperatures were lower) in 2050 (Figure 3-1). Heatwaves are already causing buckled roads, blackouts, and emergency response issues, and are expected to cross the livable threshold by the end of the century [77, 78].

The specific impacts of these pathways will vary from region to region, with precipitation projected to occur in less frequent, more intense bursts in the southeast portions of the nation [79]. Sea level rise is of particular concern across coastal regions [8]. Permafrost and glacier melt, on the other hand, is mostly concentrated in the north and western provinces on the plateau, where prominent energy infrastructure (e.g., crude and natural gas pipelines and railways) are present [8, 80, 81, 82]. Accelerated glacier melting (from extreme precipitation and heatwaves) is also resulting in dam failure, flash flooding, and mudslides, which is damaging crops, ecosystems, and infrastructure [83, 84].

From a manufacturing standpoint, the Yangtze River Basin is emerging as a key hotspot. Yangtze River Basin is home to over 400 million people and spans multiple provinces (e.g., Anhui, Jiangsu, Sichuan, Shanghai; [85]) where there are significant economic and manufacturing activities as well as prominent coastal shipyards [8]. This region is experiencing flooding from record-breaking rainfalls, leading to significant economic loss, displacing people, and requiring military disaster relief missions [86]. In addition to flooding issues (that can impact the ability of manufacturing plants to continue to operate during extreme weather conditions), this area is also subject to sea level rise, which will impact accessibility to shipyards. Shipyards in the Yangtze River Basin are expected to be underwater by 2060 due to sea level rise [87, 88].

Electricity outages from water shortages is another concern within the Yangtze River Basin. In Summer 2022, a heatwave increased demands for air conditioning and led to power restrictions for multiple provinces (e.g., Sichuan, Chongqing, Jiangsu, Anhui, Zhejiang, and Shanghai) [1]. The local region was not able to keep up the demand because a drought impacted hydropower production within the Sichuan province. These shortages cascaded to other provinces since the Sichuan province exports electricity through the West-East electricity transmission project [1]. In addition to transmission between Sichuan and Jiangsu, other prominent electricity trades within China include Yunnan to Guangdong and Inner Mongolia to Jillin [89].

Although China has made prominent carbon neutrality-pledges [31], the imbalances in energy supply-demand from recent climate-driven heatwaves and drought has resulted in a large number of coal plant installations [30, 90]. Other regions of concern within the nation include the Beijing-Tianjin-Hebei provinces and the Yellow River Basin, where climate issues overlap with other local population and environmental resource concerns [8].

4. GERMANY

4.1. Manufacturing

Manufacturing within Germany is relatively well-distributed across its various states (Table 4-1). Solar and hydrogen manufacturing as well as mining occur in western to the eastern portions of the country whereas wind and battery production is concentrated in some of the northern and southeastern portions of the country. For example, over half of total solar manufacturing (3.8 GW) within Germany is concentrated in Saxony (57.3%), with another GW is distributed between the states of Rhineland-Palatinate (14.3%) and Brandenburg (10.5%) [35].

Germany is planning to significantly expand electrolyzer manufacturing for hydrogen (from 1.04 GW to 6 GW) [91]. Currently, large hydrogen manufacturers (e.g., Man Energy Solutions, Sunfire, and Seimens) all have facilities in Berlin, one of which is a 1 GW electrolyzer plant [42, 92, 93]. North Rhine-Westphalia and Bavaria also have significant electrolyzer manufacturing plants; Man Energy Solutions, Sunfire, and Thyssenkrupp Nucera have facilities in the former while Black Ridge, Man Energy Solutions, and H-TEC have facilities in the latter [36, 93, 42, 94, 95]. Other prominent manufacturing facilities are an H-TEC facility in Hamburg [95] and a McPhy facility in Brandenburg [96].

Wind-related manufacturing is distributed between Lower Saxony (e.g., for Enercon and Siemens Gamesa; [97, 98]) while Nordex is headquartered in Hamburg [99]. There are also wind generators being manufactured in Saxony-Anhalt [97]. Chinese manufacturers, like MingYang Smart Energy and CSSC are starting to set up manufacturing facilities capable of supplying up to 1 GW per year of turbines within the nation as well [100, 91].

A total of 343 GW of battery manufacturing nameplate capacity exists in Germany, with Berlin containing the largest concentration (29.1%) [35]. Battery manufacturing is also occurring in Hesse (17.5%), Lower Saxony (13.4%), and Rhineland-Palatinate (11.7%) [35]. Although Baden-Wuerttemberg only has 2% of the nation's capacity, there are 20 battery manufacturing facilities within this state [35]. CATL (the Chinese battery manufacturer) recently opened a plant in Thuringia [46] while Northvolt opened a plant in Heidi, Schleswig-Holstein [101]. In fact, "gigafactories" are emerging across the nation, from Brandenburg (Tesla and Microvast plants) to Thuringia (CATL plant) and Rhineland-Palatinate (SVOLT and PSA Groupe plants) [102].

Finally, mining activities are concentrated in the eastern states of Germany. Vulcan has started commissioning a lithium mining plant in Landau, Rhineland-Palatinate (in the Upper Rhine Valley) to process geothermal brines [103, 91] while an underground Zinnwald lithium project is also underway in Saxony [104]. Bitterfeld-Wolfen, Saxony-Anhalt has also emerged as an area of interest for lithium mining [105].

4.2. Water Resources

Given the distributed nature of energy transitions-related manufacturing within Germany, we evaluated water resources throughout the country. Precipitation is generally lower in the northeast

Table 4-1 Energy Transitions-Related Manufacturing and Mining within German States

State	Category	Notes	Source(s)
Baden-Wuerttemberg	Batteries	2% of the nation's capacity of nation's capacity	[35]
Bavaria	Hydrogen	Black Ridge, Man Energy Solutions, and H-TEC facilities	[36, 42, 94, 95]
Berlin	Hydrogen	Man Energy Solutions, Sunfire, and Seimens facilities	[42, 92, 93]
Berlin	Batteries	29.1% of nation's capacity	[35]
Brandenburg	Solar	10.5% of national production	[35]
Brandenburg	Hydrogen	McPhy facility	[96]
Brandenburg	Batteries	Tesla and Microvast "gigafactories"	[102]
Hamburg	Hydrogen	H-TEC facility	[95]
Hamburg	Wind	Nordex Headquarters	[99]
Hesse	Batteries	17.5% of nation's capacity	[35]
Lower Saxony	Batteries	13.4% of nation's capacity	[35]
Lower Saxony	Wind	for Enercon and Siemens Gamesa facilities	[97, 98]
North Rhine-Westphalia	Hydrogen	Man Energy Solutions, Sunfire, and Thyssenkrupp Nucera facilities	[42, 93, 94]
Rhineland-Palatinate	Solar	14.3% of national production	[35]
Rhineland-Palatinate	Batteries	11.7% of nation's capacity, SVOLT and PSA Groupe "gigafactories"	[35, 102]
Rhineland-Palatinate	Mining	Vulcan's lithium plant in the Upper Rhine Valley	[103, 91]
Saxony	Solar	57.3% of national production	[35]
Saxony	Mining	underground Zinnwald lithium project	[104]
Saxony-Anhalt	Mining	lithium	[105]
Saxony-Anhalt	Wind	Enercon facilities [97]	
Schleswig-Holstein	Batteries	Northvolt plant	[101]
Thuringia	Batteries	CATL "gigafactory"	[46, 102]

portion of Germany (< 500 mm/yr), whereas some of the mountainous regions can receive over 2,000 mm/yr [106]. These patterns in precipitation are heavily correlated with runoff patterns in the country and inversely correlated with dryness [107]. There is significant reliance on groundwater within Germany, for both public and non-public supply needs across the country [108]. However, water usage by non-public sectors is generally not collected [109]. This is, in part, because significant portions (at least 90%) of industrial water use (including mining) are self-supplied in the country [110]. Germany does have an application called Hochwasser-portal that is used to support monitoring of current water levels and flood warnings across the federal states [111]. A database of discharge and water quality data has also been developed by researchers at the Helmholtz Centre of Environmental Research [112].

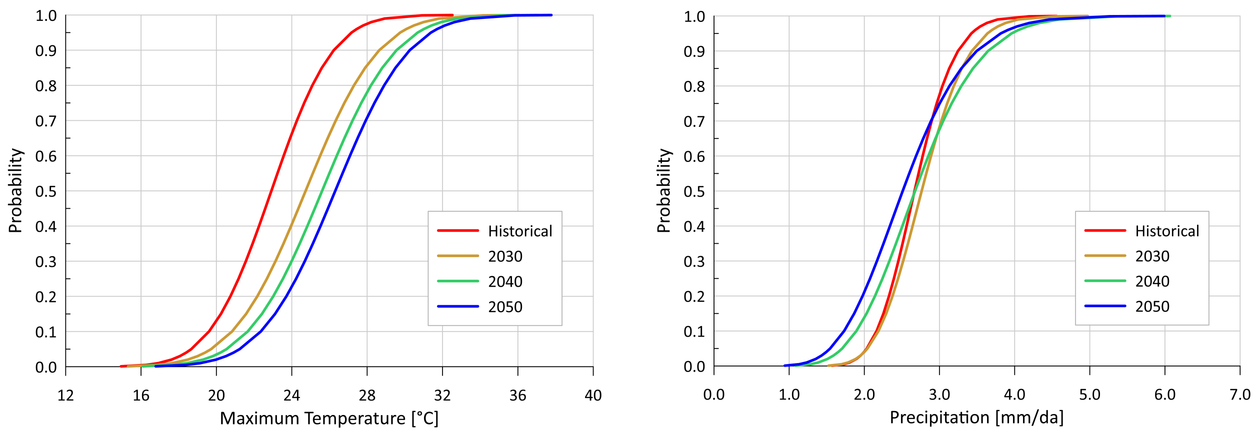
Drought maps indicate that multiple portions of the country are subject to water shortages at different times of the year [113, 114]. Groundwater scarcity is also becoming an increasing concern within the country, especially in the North Rhine-Westphalia as well as in Brandenburg and in Berlin [115]. North Rhine-Westphalia extracts significant groundwater resources to support mining activities [108] whereas notable energy transitions-related manufacturing in present within Berlin and Brandenburg (Table 4-1). Increasing concerns about water scarcity is triggering competition between users, including public, mining, and industry activities [114, 116]. These tensions have translated into litigation and public outcries that have impacted energy transitions-related manufacturing within the country, such as the Tesla's battery manufacturing plant [117, 118].

A majority of the rivers within Germany are significant internationally, including the Rhine, Danube, and parts of the Elbe [119]. So in addition to multiple local and regional agencies, Germany is also heavily involved in multiple international commissions to support protection of rivers that cross national borders [110]. Germany has generally used a decentralized approach to water management within the country. However, recent water scarcity concerns has motivated the nation to introduce its first national water strategy in 2023 [5, 120]. The national water strategy focuses mainly on flood prevention (by restoring vegetation in floodplains) and water scarcity (by developing priorities for water users). These activities are intended to support the nation cope with climate change impacts [120].

4.3. Climate Impacts

Prominent climate concerns in Germany are centered around heatwaves, low river levels, and flooding [121, 120]. Recent extreme weather events (e.g., heatwaves and droughts in 2018-2019 and floods in 2021) have caused multiple mortalities and significant economic damage [2]. Probabilities from C-FIT indicate higher frequencies for daily maximum temperatures are expected in the summertime in Germany (Figure 4-1). In contrast, the probabilities for daily precipitation are relatively similar between historical and future time periods, but there is a much larger range in precipitation values, spanning 1-6 mm/day in 2050 (versus 1.5-5 mm/day in the historical record) (Figure 4-1). Changes to precipitation intensity are expected to happen throughout Europe and underscore the concerns related to reducing river levels and flooding [122]. An analysis of major river basins within Germany (which cover 90% of the nation) indicates both extreme floods and higher deficits are expected for multiple basins [123]. All of the major basins were projected to have more extreme floods in the coming decades to 2100. Drought periods, however, are mostly concentrated in the Danube, the Elbe, and the Rhine basins in the next few decades, with the latter expected to face exceptional drought by 2100 [123].

The Rhine basin is emerging as a hot spot within the country [5]. The Rhine River serves as a shipping mechanism for close to 80% of their goods. In 2023, the water levels on the Rhine River were close to 50% of normal conditions. These low levels led to significant impacts to transportation of key goods, including coal, diesel, and heating oil [5]. Furthermore, the Rhine



(a) Maximum Temperature in July **(b) Precipitation in July**

Figure 4-1 C-FIT Plots for Germany

river passes through Rhineland-Palatinate and North Rhine-Westphalia states, which contain significant manufacturing and mining within the country (Table 4-1). Thus, any fuel and energy shortages in this basin could eventually cascade to influencing manufacturing activities within these states, especially as the nation starts to develop priority users during times of shortage.

5. FRANCE

5.1. Manufacturing

Energy transitions-related manufacturing occurs in multiple regions of France (Table 5-1). For example, solar manufacturing capacity of solar in France (total of 0.7 GW), is mostly concentrated in Brittany (67.2%) and Auvergne-Rhone-Alps (29.1%), with the remaining fraction in Occitania (3.6%) [35]. In contrast, battery manufacturing capacity in France (total of 117 GW), is concentrated in northern France, in Heights-of-France (97.6%) with some presence in New Aquitaine (1.8%) and Brittany (0.5%) [35]. Manufacturers (such as Prologium, Envision AESC, and Automotive Cells Company Consortium) are all being incentivized by the country in Heights-of-France [124, 125, 126]. France also recently opened a significant lithium mining project in Auvergne-Rhone-Alps that will leverage underground mining techniques [127, 91].

France is also home to some hydrogen manufacturing (e.g., by McPhy and Man Energy Solutions) and wind manufacturing (e.g., Vergnet) [91]. McPhy's facilities are located in Auvergne-Rhone-Alps and Burgundy-Free-Country [96]. Man Energy Solutions has a facility in Lands of the Loire [42]. The wind manufacturer, Vergnet, has facilities in Central-Vale of the Loire (for nacelle assemblies) as well as Occitania (for manufacturing of composite parts) [128].

Table 5-1 Energy Transitions-Related Manufacturing and Mining within France Regions

Region	Category	Notes	Source(s)
Auvergne-Rhone-Alps	Solar	29.1% of nation's production	[35]
Auvergne-Rhone-Alps	Hydrogen	McPhy Facilities	[96]
Auvergne-Rhone-Alps	Mining	Underground lithium mining project	[127, 91]
Brittany	Solar	67.2% of nation's production	[35]
Brittany	Batteries	0.5% of nation's production	[35]
Burgundy-Free-Country	Hydrogen	McPhy Facilities	[96]
Central-Vale of the Loire	Wind	Verget nacelle facility	[128]
Heights-of-France	Batteries	97.6% of nation's production	[35]
Lands of the Loire	Hydrogen	Man Energy Solutions facility	[42]
New Aquitaine	Batteries	1.8% of nation's production	[35]
Occitania	Solar	3.6% of nation's production	[35]
Occitania	Wind	Vergnet composite manufacturing	[128]

5.2. Water Resources

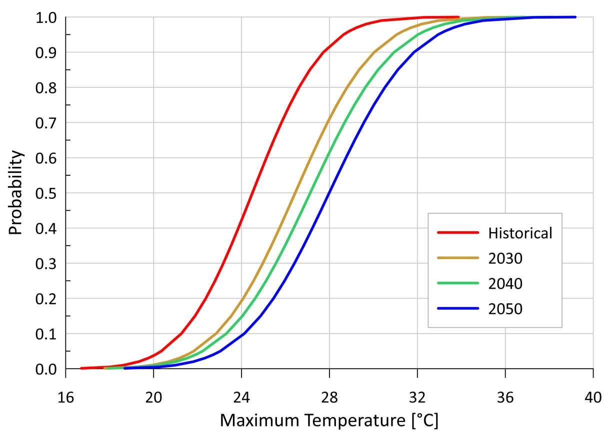
Rainfall and river flow are the two main sources of water within France. The country receives approximately 1,000 mm of annual precipitation [129], with most of the rainfall occurring during the autumn and winter months [130]. Over 100 rivers are present within the country, including three prominent international rivers (Rhine, Rhone, and Seine) [131, 132]. Almost half of the nation's freshwater use is for cooling of power plants, mostly nuclear systems [133]. Groundwater is also heavily relied upon within the country, comprising 66% of domestic water supply and 31% of industrial water supply [134]. Both surface and groundwater resources are considered "common heritage of the Nation" in France and multiple water management agencies are present to govern these resources [135, 136].

Although France is generally considered to have abundant water resources, there have been recent concerns about water scarcity, especially during summer months when supplies are the lowest and usage is the highest [130, 137]. Droughts in 2022 and 2023 have led to depleted resources, for both surface water and groundwater across the nation; almost three-quarters of the groundwater levels were below monthly normal in July 2023 [138]. In response, France has periodically placed temporary water restrictions in the country [130], but tensions over water usage and proposed plans for reservoirs have escalated over the last couple of years, leading to protests and some violence [139, 140, 141]. Industrial activities (including those related to energy) have also been targeted for water usage reductions [3]. The nation recently released a water plan, which aims to address water shortages, in part by promoting wastewater reuse and plugging water leaks [137].

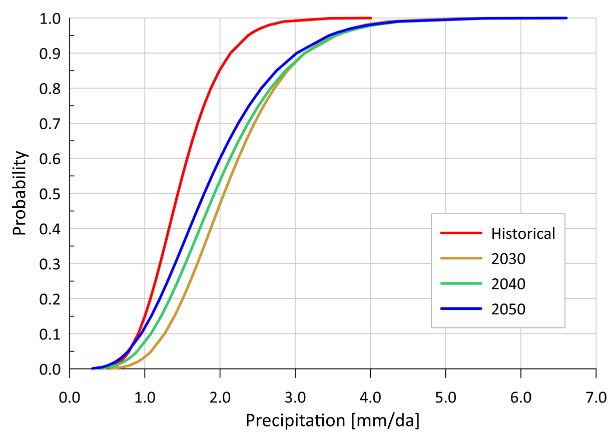
5.3. Climate Impacts

Changes in annual precipitation are forecasted to be relatively small for France [142]. However, 20% less annual precipitation is forecasted in southern France [142]. There is also a much larger range in precipitation values expected into the future, from a maximum of 4 mm/day (during the historical period) to up to 6.7 mm/day (by 2050) (Figure 5-1). The likelihood of higher daily maximum temperatures also increases in the summertime in France (Figure 5-1). These changes are expected to adversely impact streamflows, with some studies indicating the six coastal river basins in France could experience up to 88% reductions in annual water discharge [6]. Both reductions in water availability for cooling systems as well as flooding impacts are of particular concern for nuclear plants (e.g., in the Rhone Valley) within the country [9, 4]. Low water levels could also lead to reduced hydropower production, leading to possible electricity shortages within the nation [7].

A national report by the High Council for Climate indicates an increased risk of compounding extreme events (e.g., heatwaves and wildfires) are of particular concern for France [143]. The report highlights a number of impacts, from drinking water tensions to reduced hydroelectric production and damages to buildings from shrinkage that resulted from recent hot and dry spells [143, 144]. Additional concerns include potential exposure of 0.61 million people to floods (from a combination of sea level rise, coastal erosion, and changing storm patterns) as well as changes in the energy demand profiles within the country (from rising temperatures and heatwaves) [10]. France has released two National Adaptation Plans for Climate Change (one focused on 2011-2015 and the other focused on 2018-2022); the first plan devoted a lot more attention to climate resilience in the energy sector than the second plan [145]. Recent experiences with extreme weather events in 2022, however, has increased awareness among citizens, politicians, and scientists about climate change impacts within the nation [146].



(a) Maximum Temperature in July



(b) Precipitation in July

Figure 5-1 C-FIT Plots for France

6. DISCUSSION AND CONCLUSIONS

6.1. Synthesis of Findings

Our research identified that energy transitions-related manufacturing is distributed across multiple areas within the evaluated nations. Manufacturing within China was mostly concentrated in the eastern and southeastern provinces, such as Anhui, Jiangsu, and Sichuan (Table 3-1). In contrast, manufacturing in Germany was distributed throughout the country. Solar, hydrogen, wind, battery, and mining activities occurred across the western and eastern states (e.g., Rhineland-Palatinate, Saxony, and Brandenburg) as well as northern and southern states (e.g., Hamburg and Bavaria) (Table 4-1). Manufacturing within France was mostly concentrated in the northwestern and southeastern regions, with Heights-of-France containing almost all of the battery-related manufacturing. The Auvergne-Rhone-Alps region also has notable mining for lithium as well as solar- and hydrogen-related manufacturing (Table 5-1).

All three nations are experiencing concerns regarding availability and usage of water resources. In China, there is a general gradient in precipitation, with provinces in the southeast receiving much more rainfall (2000 mm/year) than provinces in the northwest (50 mm/year) [65]. This has led to significant infrastructure investments for dams and other water distribution efforts within the country [70]. In contrast, Germany and France are generally considered water abundant in terms of precipitation, receiving approximately 1,000 mm/year across the nations. Groundwater is also heavily relied upon within Germany and France, especially for industrial uses [108, 134]. Recent concerns about water resources has led to release of national water plans in all three countries, all of which aim to develop adaptations and mitigations to both scarcity and flooding issues [76, 120, 137]. There are differences in how these activities are being implemented locally within the countries. France, for example, is already targeting water use at industrial plants, including those pertaining to energy activities [3] while Germany is working on consolidating data and developing priorities for allocation during times of shortage [120].

There are some common climate risks that all three nations are facing while others are more country-specific (Table 6-1). For example, heatwaves, droughts, and flooding is impacting China, Germany, and France. C-FIT analysis of climate projections indicate that the likelihood for maximum daily temperatures and the range in precipitation values will be higher in all three countries (Figures 3-1, 4-1, and 5-1). The variability in precipitation is raising concerns over both drought and flooding, both of which can impact manufacturing. For example, droughts in the Sichuan province have led to reduced electricity production whereas droughts in Germany have led to low river levels that has impacted transportation of energy fuels [5]. Heatwaves can reduce the availability of water (e.g., through higher rates of evapotranspiration), which can compound the effects of drought. Furthermore, they can lead to an increase in energy demands for cooling, which can further stress existing infrastructure. Heatwaves in the summer of 2022, for example, led to power restrictions in multiple provinces in China [1]. Compounding effects (of droughts and heatwaves) are especially being felt in the Yangtze River Basin (China) [8] and Rhine River Basin (Germany) [5]. Sea level rise concerns are present in both China (where prominent coastal shipyard activities are present) and in France [8, 10].

Some energy-related climate impacts unique to China are glacier and permafrost melting, both of which are expected to impact existing energy-related infrastructure, such as railways and pipelines distributing fuels [80]. While this report focuses on energy transition-related manufacturing, it is worth noting that the regions discussed (e.g., Yangtze River Delta) coincides with large-scale manufacturing within China, including semiconductors [147, 148]. There are also a number of power plants (nuclear and natural gas) as well as hydrogen facilities and oil ports within these coastal regions [80].

Table 6-1 Key Climate Impacts across Nations

Climate Change Effect	China	Germany	France
Heatwaves	Increased electricity demands [1]	Reduced water availability [2]	Operational efficiency of power plants [3, 4]
Drought	Reduced hydropower generation in Sichuan; impacts to other provinces through electricity transmission [1]	Reduced river levels impacting inland shipping of fuels [5]	Low river levels and electricity shortages [6, 7]
Flooding	Disruptions to local industrial and manufacturing activities [8]	Disruptions to local industrial and manufacturing activities [2]	Flooding of nuclear plants [9]
Sea level rise	Damages to coastal shipyards [8]	-	Exposing coastal populations [10]
Glacier and Permafrost melt	Impact railways and pipelines carrying crude and natural gas [8]	-	-

6.2. Limitations

There are multiple limitations of this work, pertaining to all three topics that were researched. For example, there is a lot of variation in the information identified about manufacturing areas in this analysis. For some technologies (e.g., solar and batteries), information from BNEF helped to pin down not just the relevant sub-national areas but also the relative amount of manufacturing present in those areas. However, for other technologies, the research was heavily dependent on international, industry, and media sources, which may not have been as complete. Furthermore, details about the current production may not be indicative of future activities, since workforce and solvency issues may lead to factories being shut down [149]. Planned activities may also change as new discoveries of deposits (e.g., natural hydrogen) are made [150].

Information about water resources was generally easier to obtain. However, details about specific sources used for industrial and manufacturing activities were relatively sparse. Climate impacts in this analysis were generally limited to those relevant to the technologies associated with energy transitions. However, there are other concerns (e.g., radiological impacts) associated with flooding of nuclear plants in some of the regions (e.g., Rhone Valley of France [9]) that could warrant additional attention. Consideration of water quality issues (which can influence the availability of water for specific uses [68]) was also not considered. Finally, the climate data was analyzed at the national-level and could be resolved at a higher resolution to evaluate the impacts observed over a particular area of interest.

6.3. Future Work

Two possible directions for future work include: 1) more systematic review of media coverage and 2) further evaluation of compounding climate effects. In addition to providing insights into social priorities, media serves an agenda-setting function [151]. Thus, media information can serve as an important data source for understanding the complex physical and social interactions between energy, water, and climate. Resources consolidating news from around the world (e.g., [152]) could be systematically reviewed to characterize how and where attention is being given to these important topics. These sources could be used to understand other emerging dynamics (e.g., tighter export controls of graphite products [59]) as well as how the recent national water policies are influencing energy-water activities in the respective countries.

Finally, risks from climate change effects are likely to occur through multiple pathways at once (e.g., heatwaves and drought). Thus, statistical evaluations (such as C-FIT) could be expanded to consider the likelihood of occurrence for compound events, both during historical and future time periods. These analyses can be used to improve characterization of risk that better reflects the complex pathways through which water and climate can impact energy transitions.

REFERENCES

[1] Zhao Ziwen. China's power crisis: why is it happening and what does it mean for the economy? https://www.scmp.com/economy/china-economy/article/3190313/chinas-power-crisis-why-it-happening-and-what-does-it-mean, 2023.

[2] Trenczek, J. and Lühr, O. and Eiserbeck, L. and Sandhövel, M. and Ibens, D. . Estimation of costs resulting from climate change in Germany. https://www.prognos.com/en/project/estimation-costs-climate-change-germany, 2023.

[3] Paul Messad. France targets 12 industrial plants for radical water usage reduction. https://www.euractiv.com/section/politics/news/france-targets-12-industrial-plants-for-radical-water-usage-reduction/, 2023.

[4] Mihajlo Vujasin. Climate change, water scarcity jeopardizing French nuclear fleet. https://balkangreenenergynews.com/climate-change-water-scarcity-jeopardizing-french-nuclear-fleet/, 2023.

[5] The Local Germany. How the Rhine's low water levels are impacting Germany. https://www.thelocal.de/20220811/how-the-rhines-low-water-levels-are-impacting-germany, 2022.

[6] Camille Labrousse, Wolfgang Ludwig, Sébastien Pinel, Mahrez Sadaoui, Andrea Toreti, and Guillaume Lacquement. Declining water resources in response to global warming and changes in atmospheric circulation patterns over southern mediterranean france. *Hydrology and Earth System Sciences*, 26(23):6055–6071, 2022.

[7] The Local France. Warning that droughts may lead to electricity shortages in france. https://balkangreenenergynews.com/climate-change-water-scarcity-jeopardizing-french-nuclear-fleet/, 2023.

[8] Erin Sikorsky. China's climate security vulnerabilities. Technical report, Center for Climate and Security, 2022.

[9] F Eyrolle, C Duffa, C Antonelli, B Rolland, and F Leprieur. Radiological consequences of the extreme flooding on the lower course of the Rhone valley (December 2003, South East France). *Science of the total environment*, 366(2-3):427–438, 2006.

[10] CMCC. G20 Climate Risk Atlas: France. https://files.cmcc.it/g20climaterisks/France.pdf, 2023.

[11] IEA (International Energy Agency). Global Energy Transitions Stocktake Topics. https://www.iea.org/topics/global-energy-transitions-stocktake, 2023.

[12] IRENA (International Renewable Energy Agency). Energy transition outlook. https://www.irena.org/Energy-Transition/Outlook, 2023.

[13] IEA (International Energy Agency). World Energy Investment 2023. https://www.iea.org/reports/world-energy-investment-2023, 2023.

[14] Charles Fant, C Adam Schlosser, and Kenneth Strzepek. The impact of climate change on wind and solar resources in southern Africa. *Applied Energy*, 161:556–564, 2016.

[15] Mallory E Flowers, Matthew K Smith, Ara W Parsekian, Dmitriy S Boyuk, Jenna K McGrath, and Luke Yates. Climate impacts on the cost of solar energy. *Energy Policy*, 94:264–273, 2016.

[16] Michael T Craig, Ignacio Losada Carreño, Michael Rossol, Bri-Mathias Hodge, and Carlo Brancucci. Effects on power system operations of potential changes in wind and solar generation potential under climate change. *Environmental Research Letters*, 14(3):034014, 2019.

[17] Ilissa B. Ocko and Steven P. Hamburg. Climate consequences of hydrogen emissions. *Atmospheric Chemistry and Physics*, 22(14):9349–9368, 2022.

[18] Masahiro Suzuki, Jessica Jewell, and Aleh Cherp. Have climate policies accelerated energy transitions? Historical evolution of electricity mix in the G7 and the EU compared to net-zero targets. *Energy Research & Social Science*, 106:103281, 2023.

[19] Michelle T. H. van Vliet, David Wiberg, Sylvain Leduc, and Keywan Riahi. Power-generation system vulnerability and adaptation to changes in climate and water resources. *Nature Climate Change*, 6(4):375–380, 2016.

[20] Stuart M Cohen, Ana Dyreson, Sean Turner, Vince Tidwell, Nathalie Voisin, and Ariel Miara. A multi-model framework for assessing long-and short-term climate influences on the electric grid. *Applied Energy*, 317:119193, 2022.

[21] Thushara Gunda, Raquel Valdez, Dan Houck, and Lisa Linville. Critical Role of Water for Energy Transitions Technologies: A Literature Review. Technical Report SAND2023-14220, Sandia National Lab. (SNL-NM), Albuquerque, NM (United States), 2023.

[22] James McCall, Prakash Rao, Susana Garcia Gonzalez, Sachin Nimbalkar, Sujit Das, Sarang Supekar, and Joe Cresko. US manufacturing water use data and estimates: Current state, limitations, and future needs for supporting manufacturing research and development. *ACS ES&T Water*, 1(10):2186–2196, 2021.

[23] IEA (International Energy Agency). Energy Technology Perspectives 2023 – Analysis. https://www.iea.org/reports/energy-technology-perspectives-2023, 2023.

[24] IEA (International Energy Agency). Special Report on Solar PV Global Supply Chains. Technical report, IEA (International Energy Agency), 2022.

[25] IEA (International Energy Agency). The Role of Critical Minerals in Clean Energy Transitions - Analysis. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions, 2021.

[26] Govind Bhutada. Visualizing China's Dominance in Battery Manufacturing (2022-2027P). https://www.visualcapitalist.com/chinas-dominance-in-battery-manufacturing/, 2023.

[27] Peter Fairley. Making green hydrogen a reality down under: Proposals to make hydrogen from renewable electricity in australia exceed the country's generating capacity. *IEEE Spectrum*, 60(1):24–27, 2023.

[28] Carolyn Gramling. Rare earth mining may be key to our renewable energy future. but at what cost? https://www.sciencenews.org/article/rare-earth-mining-renewable-energy-future, 2023.

[29] AFP-Agence France Presse. US worries China will use supply chains as weapon. https://www.barrons.com/news/us-worries-china-will-use-supply-chains-as-weapon-413d5b2d, 2023.

[30] Sam Meredith. China's energy transition sees 'staggering' progress on renewables and a coal power boom. https://www.cnbc.com/2023/03/08/energy-chinas-renewables-progress-comes-alongside-a-coal-power-boom.html, 2023.

[31] IEA (International Energy Agency). An energy sector roadmap to carbon neutrality in China - Analysis. https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china, 2021.

[32] Vladimir Spasic. SolarPower Europe report - 2022, year when solar age truly began. https://balkangreenenergynews.com/solarpower-europe-report-2022-year-when-solar-age-truly-began/, 2023.

[33] Transport & Environment. Two-thirds of European battery production at risk analysis. https://www.transportenvironment.org/discover/two-thirds-of-european-battery-production-at-risk-analysis/, 2023.

[34] United Nations. UN Comtrade Database. https://comtradeplus.un.org/, 2023.

[35] BloombergNEF. Research and data. https://about.bnef.com/, 2023.

[36] BlackRidge Research & Consulting. Global top 20 hydrogen electrolyzer manufacturers [2023]. https://www.blackridgeresearch.com/blog/list-of-global-top-hydrogen-electrolyzer-manufacturers-companies-makers-suppliers-in-the-world, 2023.

[37] Thomas S. Lowry and George A. Backus. Using climate uncertainty for functional resilience. *Climate Services*, 23:100244, 2021.

[38] Michael A Woodhouse, David J Feldman, Ran Fu, Brittany Smith, Kelsey A Horowitz, Ashwin Ramdas, and Robert M Margolis. The international supply chain and manufacturing costs for photovoltaic modules, and project economics of systems including storage. Technical report, NREL, 2019.

[39] Department of Labor. Traced to Forced Labor: Solar Supply Chains Dependent on Polysilicon from Xinjiang. https://www.dol.gov/sites/dolgov/files/ILAB/images/storyboards/solar/Solar.pdf, 2020.

[40] LONGi. About us. https://www.longi.com/en/global-distribution/, 2023.

[41] Sungrow. Sungrow Powers World's Largest BIPV Project with a capacity of 120 MW and installed with Sungrow inverter solutions. https://en.sungrowpower.com/newsDetail/2765/sungrow-powers-world-s-largest-bipv-projectwith-a-capacity-of-120-mw-and-installed-with-sungrow-inverter-solutions, 2022.

[42] MAN Energy Solutions. Production & engineering network. https://www.man-es.com/company/production-locations, 2024.

[43] PERIC. Factory tour. https://english.peric718.com/factory/, 2023.

[44] Benchmark Source. The Chinese province producing more batteries than the rest of the world. https://source.benchmarkminerals.com/article/the-chinese-province-producing-more-batteries-than-the-rest-of-the-world, 2022.

[45] Statista. Global market distribution of lithium-ion battery makers in 2023. https://www.statista.com/statistics/235323/lithium-batteries-top-manufacturers/, 2024.

[46] CATL. Company profile. https://www.catl.com/en/about/profile/, 2024.

[47] BYD. BYD Group. https://bydeurope.com/byd-group, 2024.

[48] BYD. Press Release: BYD Builds the World's Largest Battery Plant in Lithium-Rich Chinese Province. https://en.byd.com/news/press-release-byd-builds-the-worlds-largest-battery-plant-in-lithium-rich-chinese-province/, 2018.

[49] EnergyTrend. Two More Billion-Yuan Battery Manufacturing Projects Have Landed in China. https://m.energytrend.com/news/20230608-32266.html, 2023.

[50] Limin An and Ciaxin Ding Yi. China's midtier cities vie for EV battery supremacy. https://asia.nikkei.com/Spotlight/Caixin/China-s-midtier-cities-vie-for-EV-battery-supremacy, 2023.

[51] Yasuki Okamoto. Chinese manufacturers dominate wind power, taking 60% of global market. https://asia.nikkei.com/Business/Energy/Chinese-manufacturers-dominate-wind-power-taking-60-of-global-market, 2023.

[52] EV Wind. China takes up 7 spots among the world's top 10 wind turbine manufacturers for wind power. https://www.evwind.es/2021/03/13/china-takes-up-7-spots-among-the-worlds-top-10-wind-turbine-manufacturers-for-wind-power/79787, 2021.

[53] Envision. Combine the Spirit of Art and Science Meet Our New Smart Wind Turbine. https://www.envision-group.com/en/windturbines.html, 2024.

[54] Goldwind. Corporate Brochure: Driving our Renewable Future. https://www.goldwindamericas.com/sites/default/files/GOLDWIND%20CORP%20BROCHURE.pdf, 2023.

[55] MingYang Smart Energy Group Limited. MingYang Smart Energy Group Limited. http://www.myse.com.cn/uploadfiles/2019/01/20190118231339505.pdf, 2024.

[56] Andrew David. China emerges as a major exporter of wind turbine nacelles. https://www.usitc.gov/publications/332/executive_briefings/ebot_wind_turbine_nacelles.pdf, 2021.

[57] Barry van Wyk. The future of china's lithium battery industry is in Sichuan Province. https://thechinaproject.com/2022/10/05/the-future-of-chinas-lithium-battery-industry-is-in-sichuan-province/, 2022.

[58] Dongni Zhao. Lithium industry in china: An overview. https://www.mondaq.com/china/mining/1289816/lithium-industry-in-china-an-overview, 2023.

[59] Siyi Liu and Dominique Patton. China, world's top graphite producer, tightens exports of key battery material. https://www.reuters.com/world/china/china-require-export-permits-some-graphite-products-dec-1-2023-10-20/, 2023.

[60] Northern Graphite Corporation. The graphite supply problem. https://www.northerngraphite.com/about-graphite/the-graphite-supply-problem/, 2023.

[61] GlobalData. The five largest copper mines in operation in china. https://www.mining-technology.com/marketdata/five-largest-copper-mines-china/, 2023.

[62] Jack Silvers. Water is China's greatest weapon and its Achilles heel. https://harvardpolitics.com/china-water-policy/, 2020.

[63] CIA. Country Comparisons: Area. https://www.cia.gov/the-world-factbook/field/area/country-comparison/, 2024.

[64] Runqiu Huang and Weile Li. Formation, distribution and risk control of landslides in China. *Journal of Rock Mechanics and Geotechnical Engineering*, 3(2):97–116, June 2011.

[65] Ang Zhang and Xinyi Zhao. Changes of precipitation pattern in China: 19612010. *Theoretical and Applied Climatology*, 148(3):1005–1019, 2022.

[66] Xinxin Wang, Xiangming Xiao, Yuanwei Qin, Jinwei Dong, Jihua Wu, and Bo Li. Improved maps of surface water bodies, large dams, reservoirs, and lakes in China. *Earth System Science Data*, 14(8):3757–3771, August 2022.

[67] Christine Chan. China's water woes. https://graphics.thomsonreuters.com/14/chinawater/index.html, 2014.

[68] Ting Ma, Siao Sun, Guangtao Fu, Jim W. Hall, Yong Ni, Lihuan He, Jiawei Yi, Na Zhao, Yunyan Du, Tao Pei, Weiming Cheng, Ci Song, Chuanglin Fang, and Chenghu Zhou. Pollution exacerbates China's water scarcity and its regional inequality. *Nature Communications*, 11(1):650, 2020.

[69] Jianguo Liu and Wu Yang. Water Sustainability for China and Beyond. *Science*, 337(6095):649–650, August 2012.

[70] Mark Mulligan, Arnout van Soesbergen, and Leonardo Sáenz. GOODD, a global dataset of more than 38,000 georeferenced dams. *Scientific Data*, 7(1):31, January 2020.

[71] Pu Wang, Shikui Dong, and James P. Lassoie. Large Dams in China: An Overview of History, Distribution, and Case Studies. In Pu Wang, Shikui Dong, and James Lassoie, editors, *The Large Dam Dilemma: An Exploration of the Impacts of Hydro Projects on People and the Environment in China*, pages 25–41. Springer Netherlands, Dordrecht, 2014.

[72] Nina Zheng, Nan Zhou, and David Fridley. Quenching china's thirst for renewable power: Water implications of china's renewable development. Technical report, Lawrence Berkeley National Laboratory, 4 2012.

[73] Jingyu Lin, Brett A. Bryan, Xudong Zhou, Peirong Lin, Hong Xuan Do, Lei Gao, Xinchen Gu, Zhifeng Liu, Luwen Wan, Shanlin Tong, Jiacong Huang, Qian Wang, Yuan Zhang, Hongkai Gao, Jiabo Yin, Zilong Chen, Weili Duan, Zheyu Xie, Tong Cui, Junzhi Liu, Mingqian Li, Xiaodong Li, Zhenwu Xu, Fei Guo, Lele Shu, Bin Li, Jingwen Zhang, Pingping Zhang, Bo Fan, Yanwen Wang, Yifan Zhang, Jinliang Huang, Xin Li, Yanpeng Cai, and Zhifeng Yang. Making China's water data accessible, usable and shareable. *Nature Water*, 1(4):328–335, April 2023.

[74] Yuan Yao, Yuan Chang, and Eric Masanet. A hybrid life-cycle inventory for multi-crystalline silicon PV module manufacturing in China. *Environmental Research Letters*, 9(11):114001, 2014.

[75] China Power Team. How Does Water Security Affect China's Development? https://chinapower.csis.org/china-water-security/, 2020.

[76] Genevieve Donnellon-May. China's five-year national water security plan. https://thediplomat.com/2022/12/chinas-five-year-national-water-security-plan/, 2022.

[77] Huopo Chen, Wenyue He, Jianqi Sun, and Lefeng Chen. Increases of extreme heat-humidity days endanger future populations living in china. *Environmental Research Letters*, 17(6):064013, 2022.

[78] Nectar Gan. China endures summer of extreme weather as record rainfall and scorching heat wave cause havoc. https://www.cnn.com/2022/07/20/china/china-summer-extreme-weather-climate-change-intl-hnk-mic/index.html, 2022.

[79] ShuangYe Wu, Yanjuan Wu, and Jiahong Wen. Future changes in precipitation characteristics in China. *International Journal of Climatology*, 39(8):3558–3573, June 2019.

[80] Elsie Hung. China manufacturing distribution breakdown. https://www.bakerinstitute.org/chinas-energy-infrastructure, 2023.

[81] Abrahm Lustgarten. Will global warming melt the permafrost supporting the China-Tibet Railway? https://www.scientificamerican.com/article/global-warming-china-tibet-railway/, 2009.

[82] Robyn Dixon. A huge Siberian pipeline binds Russia and China, as gas flows for the first time. *Washington Post*, 2019.

[83] Scott Moore and Michelle Melton. China's pivot on climate change and national security. https://www.lawfaremedia.org/article/chinas-pivot-climate-change-and-national-security, 2019.

[84] Wenfeng Hu, Junqiang Yao, Qing He, and Jing Chen. Changes in precipitation amounts and extremes across Xinjiang (northwest China) and their connection to climate indices. *PeerJ*, 9:e10792, 2021.

[85] Chu Penghao, Liu Pingkuo, and Pan Hua. Prospects of hydropower industry in the Yangtze River Basin: China's green energy choice. *Renewable Energy*, 131:1168–1185, February 2019.

[86] U.S. Department of Defense. Military and Security Developments Involving the People's of Republic of China. Technical report, Office of the Secretary of Defense, 2021.

[87] CSIS. China power project. https://www.csis.org/programs/china-power-project, 2023.

[88] Climate Matters. 2021 in review: Global temperature rankings. https://www.climatecentral.org/climate-matters/2021-review-global-temps, 2022.

[89] Hang Lei, Xin Zhang, and Xinyi Han. Exploring virtual water network dynamics of China's electricity trade: Insights into the EnergyWater Nexus. *Sustainability*, 15(22):15977, January 2023.

[90] Arendse Huld. China's energy transition - how far has the country come? https://www.china-briefing.com/news/earth-day-2022-whats-the-state-of-chinas-energy-transition/, 2022.

[91] IEA (International Energy Agency). Global Energy Transitions Stocktake Topics. https://iea.blob.core.windows.net/assets/a86b480e-2b03-4e25-bae1-da1395e0b620/EnergyTechnologyPerspectives2023.pdf, 2023.

[92] Siemens Energy. The future of hydrogen tech manufacturing. https://www.siemens-energy.com/global/en/home/stories/electrolyzer-gigawatt-factory.html, 2024.

[93] Sunfire. About sunfire. https://www.sunfire.de/en/about-us, 2024.

[94] thyssenkrupp nucera. Company. https://thyssenkrupp-nucera.com/, 2024.

[95] H-Tech Systems. Company. https://www.h-tec.com/en/company/, 2024.

[96] McPhy. Facilities. https://mcphy.com/en/mcphy/facilities/, 2024.

[97] Enercon. Production & sourcing. https://www.enercon.de/en/company/production-sourcing, 2024.

[98] Siemens Gamesa. Location finder. https://www.siemensgamesa.com/about-us/location-finder, 2024.

[99] Nordex. 06 - locations & addresses. https://www.nordex-online.com/en/company/, 2024.

[100] Igor Todorovic. Chinese company CSSC Haizhuang unveils world's largest wind turbine prototype. https://balkangreenenergynews.com/chinese-company-cssc-haizhuang-unveils-worlds-largest-wind-turbine-prototype/, 2023.

[101] Chris Randall. Northvolt commits to building its battery cell plant in Heide. https://www.electrive.com/2024/01/17/northvolt-commits-to-building-its-battery-cell-plant-in-heide/, 2024.

[102] En:Former. Battery boom: meet Germany's 'gigafactories'. https://www.en-former.com/en/battery-boom-meet-germanys-gigafactories/, 2021.

[103] Mining Technology. Vulcan begins commissioning of lithium extraction plant in Germany. https://www.mining-technology.com/news/vulcan-lithium-plant-germany/?cf-view, 2023.

[104] NS Energy. Zinnwald lithium project. https://www.nsenergybusiness.com/projects/zinnwald-lithium-project/, 2024.

[105] Lisa O'Carroll. The east German town at the centre of the new 'gold rush' ... for lithium. https://www.theguardian.com/business/2023/sep/23/the-east-german-town-at-the-centre-of-the-new-gold-rush-for-lithium, 2023.

[106] Christopher Jung and Dirk Schindler. Precipitation Atlas for Germany (GePrA). *Atmosphere*, 10(12):737, December 2019.

[107] Matthias Zink, Rohini Kumar, Matthias Cuntz, and Luis Samaniego. A high-resolution dataset of water fluxes and states for Germany accounting for parametric uncertainty. *Hydrology and Earth System Sciences*, 21(3):1769–1790, March 2017.

[108] BGR. Groundwater resources in Germany. https://www.deutsche-rohstoffagentur.de/EN/Themen/Wasser/grundwasser_deutschland_en.html, 2024.

[109] Statistisches Bundesamt. Water Supply Industry: GENESIS-Online. https://www.destatis.de/EN/Themes/Society-Environment/Environment/Water-Management/database-teaser.html, 2002.

[110] RUger Winnegge and Thomas Maurer. Water resources management: Country profile – Germany. https://www.bafg.de/GRDC/EN/02_srvcs/24_rprtsrs/report_27.pdf?__blob=publicationFile, 2002.

[111] Europa Data Team. How open data supports water management. https://data.europa.eu/en/publications/datastories/how-open-data-supports-water-management, 2024.

[112] Pia Ebeling, Rohini Kumar, Stefanie R Lutz, Tam Nguyen, Fanny Sarrazin, Michael Weber, Olaf Büttner, Sabine Attinger, and Andreas Musolff. QUADICA: water quality, discharge and catchment attributes for large-sample studies in germany. *Earth System Science Data*, 14(8):3715–3741, 2022.

[113] UFZ. Drought development (total soil column, depht 1.8m) in 2017. https://www.ufz.de/index.php?en=40990, 2017.

[114] Matthias von Hein. Water scarcity triggers fierce competition also in Germany. https://www.dw.com/en/water-scarcity-triggers-fierce-competition-also-in-germany/a-62942563, 2022.

[115] Benedikt Ahner. Assessing groundwater stress: An approach of measuring groundwater stress based on sub-national statistical data. https://www.deutsche-rohstoffagentur.de/EN/Themen/Wasser/grundwasser_deutschland_en.html, 2017.

[116] Annika Joeres, Gesa Steeger, and Katarina Huth. The biggest water guzzlers in Germany. https://correctiv.org/aktuelles/klimawandel/2022/06/24/wasser-verbrauch-unternehmen-private-haushalte/, 2022.

[117] Bobby Allyn. Tesla's first european factory needs more water to expand. drought stands in its way. https://www.npr.org/2022/11/03/1131695382/tesla-ev-electric-vehicles-europe-germany-drought-climate-change-factory, 2022.

[118] Weatherbed, Jess. The German Tesla plant fire is claimed by far-left 'Volcano Group'. https://www.theverge.com/2024/3/6/24092178/german-tesla-gigafactory-fire-arson-far-left-volcano-vulkan-group, 2024.

[119] Dennis MeiSSner, Bastian Klein, and Monica Ionita. Development of a monthly to seasonal forecast framework tailored to inland waterway transport in central Europe. *Hydrology and Earth System Sciences*, 21(12):6401–6423, December 2017.

[120] Riham Alkousaa, Markus Wacket, and Miranda Murray. Germany introduces national water strategy as climate change forces action. https://www.reuters.com/business/environment/germany-introduces-national-water-strategy-climate-change-forces-action-2023-03-15/, 2023.

[121] The Climate Reality Project. How climate change is affecting Germany. https://www.climaterealityproject.org/blog/how-climate-change-affecting-germany, 2018.

[122] Intergovernmental Panel On Climate Change (Ipcc). *Climate Change 2022 Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, 1 edition, June 2023.

[123] Shaochun Huang, Valentina Krysanova, and Fred Hattermann. Projections of climate change impacts on floods and droughts in Germany using an ensemble of climate change scenarios. *Regional Environmental Change*, 15(3):461–473, March 2015.

[124] Elizabeth Pineau, Gilles Guillaume, and Michel Rose. Insight: France rolls out the red carpet for EV battery factories. https://www.reuters.com/business/autos-transportation/france-rolls-out-red-carpet-ev-battery-factories-2023-06-05/, 2023.

[125] euronews. France to open first electric car battery factory in bid to catch up with china. https://www.euronews.com/next/2023/05/30/france-to-open-first-electric-car-battery-factory-in-bid-to-catch-up-with-china, 2023.

[126] Caroline Perrot. France opens its first electric car battery factory. https://www.barrons.com/news/france-to-open-its-first-electric-car-battery-factory-95e8d532, 2023.

[127] Charlotte Elton. France's massive new lithium mine could supply 700,000 electric car batteries a year. https://www.euronews.com/green/2022/10/24/frances-massive-new-mithium-mine-could-supply-700000-electric-car-batteries-a-year, 2022.

[128] Vergnet. About us. https://www.vergnet.com/en/about-us/, 2024.

[129] Jeroen Meersmans, Manuel Pascal Martin, Eva Lacarce, Sarah De Baets, Claudy Jolivet, Line Boulonne, Sébastien Lehmann, Nicolas Philippe Anthony Saby, Antonio Bispo, and Dominique Arrouays. A high resolution map of French soil organic carbon. *Agronomy for Sustainable Development*, 32(4):841–851, October 2012.

[130] Environmental Performance Review. Fact sheet: Water resources and use. Extract from France's 2021 Environmental Performance Review. https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2022-08/01_water_resources_and_use.pdf, 2022.

[131] Environmental Performance Review. Transboundary river basins: Status and trends. http://geftwap.org/publications/river-basins-technical-report, 2016.

[132] L. W. Lyde. The International Rivers of Europe. *The Geographical Journal*, 54(5):303–313, 1919.

[133] Cyrielle Cabot. Faced with summer restrictions, this is how France uses its water. https://www.france24.com/en/environment/20230306-faced-with-summer-restrictions-after-winter-drought-this-is-how-france-uses-water, 2023.

[134] Jean-Christophe Maréchal and Josselin Rouillard. Groundwater in France: Resources, Use and Management Issues. In Jean-Daniel Rinaudo, Cameron Holley, Steve Barnett, and Marielle Montginoul, editors, *Sustainable Groundwater Management: A Comparative Analysis of French and Australian Policies and Implications to Other Countries*, Global Issues in Water Policy, pages 17–45. Springer International Publishing, Cham, 2020.

[135] OECD Secretariat. France. https://www.oecd.org/france/Water-Resources-Allocation-France.pdf, 2015.

[136] Corentin Girard. Local groundwater management in France and California. https://californiawaterblog.com/2016/07/31/local-groundwater-management-in-france-and-california/, 2016.

[137] Luca Matteucci. France's growing water crisis. https://www.france24.com/en/tv-shows/down-to-earth/20230615-france-s-growing-water-crisis, 2023.

[138] BRGM. Groundwater tables as of August 1, 2023 (translated via google). https://www.brgm.fr/fr/actualite/communique-presse/nappes-eau-souterraine-au-1er-aout-2023, 2023.

[139] Marion Renault. French people are fighting over giant pools of water. https://www.theatlantic.com/science/archive/2023/06/water-mega-basins-reservoirs-france-drought/674313/, 2023.

[140] Michele Barbero. France's water war has no end in sight. https://foreignpolicy.com/2023/09/25/france-water-crisis-climate-environment-drought-agriculture/, 2023.

[141] Louise Guillot. Drought inflames France's water wars. https://www.politico.eu/article/drought-france-water-agriculture-environment-climate-change/, 2023.

[142] Gildas Dayon, Julien Boe, Eric Martin, and Joël Gailhard. Impacts of climate change on the hydrological cycle over France and associated uncertainties. *Comptes Rendus. Géoscience*, 350(4):141–153, 2018.

[143] Haut Conseil pour le Climat. Acter l'urgence engager les moyens. https://www.hautconseilclimat.fr/publications/rapport-annuel-2023-acter-lurgence-engager-les-moyens/, 2023.

[144] News Wires. France badly hit by climate change and ill-prepared for its effects, warns report. https://www.france24.com/en/france/20230628-france-badly-hit-by-climate-change-and-ill-prepared-for-its-effects-warns-report, 2023.

[145] IEA. France Climate Resilience Policy Indicator. https://www.iea.org/articles/france-climate-resilience-policy-indicator, 2022.

[146] Solenn de Royer. Climate change: The summer that ended indifference for the French. https://www.lemonde.fr/en/politics/article/2022/08/22/climate-change-and-the-french-the-summer-that-ended-indifference_5994354_5.html, 2022.

[147] Michelle Scheblein. China manufacturing distribution breakdown. https://www.berkeleysg.com/china-manufacturing-distribution-map/, 2016.

[148] China Water Risk. 8 Things You Should Know About Water & Semiconductors. https://chinawaterrisk.org/resources/analysis-reviews/8-things-you-should-know-about-water-and-semiconductors/, 2013.

[149] Marija Maisch. Meyer Burger prepares to shut down plant in Germany. https://www.pv-magazine.com/2024/02/23/meyer-burger-prepares-to-shut-down-plant-in-germany/, 2024.

[150] Sergio Matalucci. White hydrogen project sparks interest in France. https://www.pv-magazine.com/2023/12/18/white-hydrogen-project-sparks-interest-in-france/, 2023.

[151] Donald L Shaw and Shannon E Martin. The function of mass media agenda setting. *Journalism quarterly*, 69(4):902–920, 1992.

[152] GDELT. The GDELT project. https://www.gdeltproject.org/, 2024.

DISTRIBUTION

Email—Internal

Name	Org.	Sandia Email Address
Ben Cook	8930	bkcook@sandia.gov
Stephanie Kuzio	8932	spkuzio@sandia.gov
Technical Library	1911	sanddocs@sandia.gov

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.