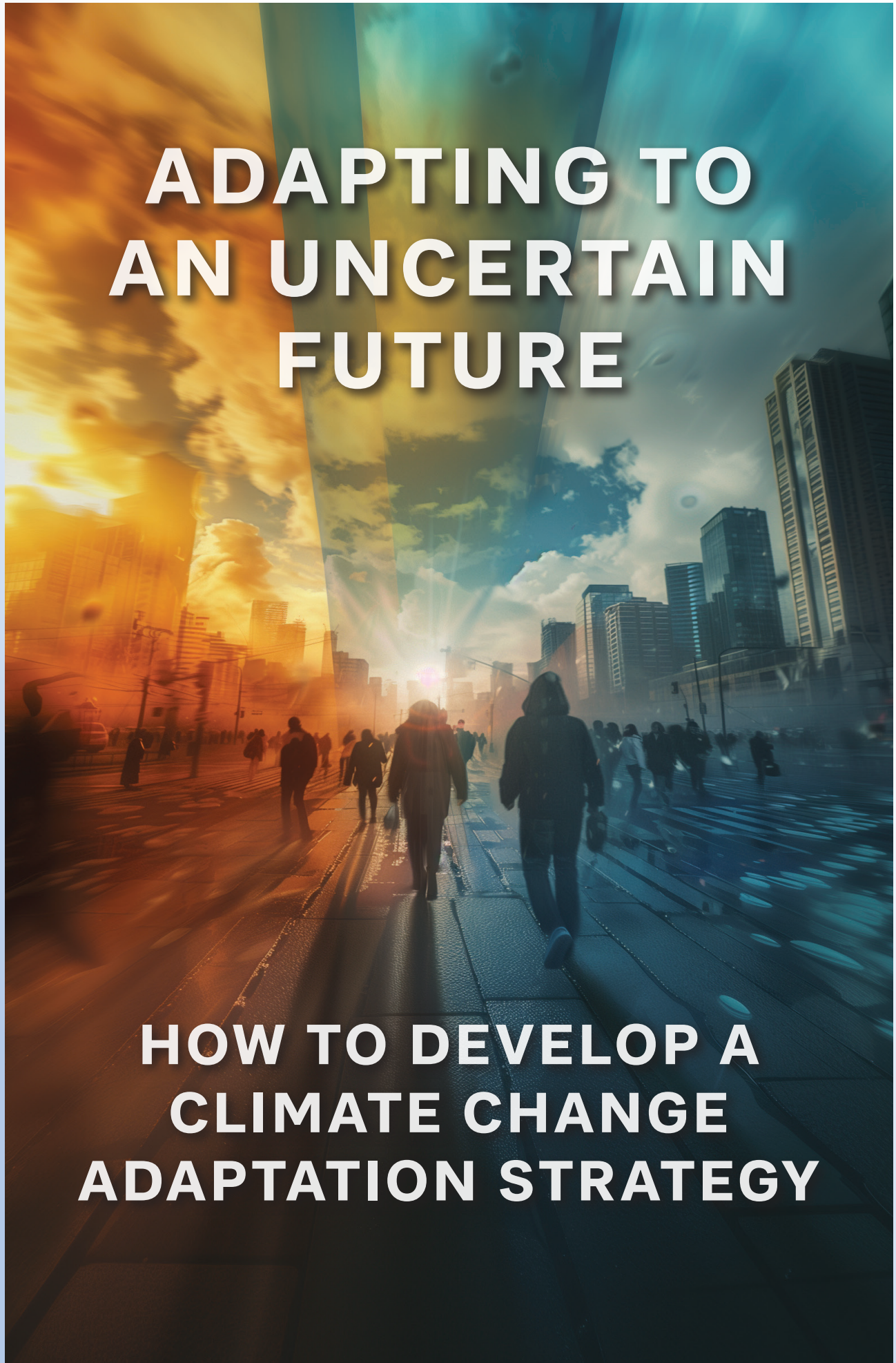


ADAPTING TO AN UNCERTAIN FUTURE

HOW TO DEVELOP A CLIMATE CHANGE ADAPTATION STRATEGY

AUTHORS

Dr. Albert Meige, Zoe Huczok, Rick Eagar

Mitigation gets most of the big headlines in the global discourse on the changing climate. However, no matter how successful — or not — the world is at mitigating global warming, many of the impacts of climate change are already underway and will greatly affect our future.

As well as efforts to reduce emissions and achieve net zero targets, businesses have an unavoidable need to adapt to climate change. Adaptation forms part of a broader set of sustainability goals, along with mitigation of climate impacts and improvement of resilience. Indeed, these concepts have many overlaps. For example, reducing water usage in a manufacturing process is an adaptation measure that also mitigates impacts. Protecting assets against severe weather events is an aspect of both adaptation and resilience. Businesses need to consider all three — being good at adaptation doesn't mean you can deprioritize mitigation, and vice versa. And there's more to adaptation than just becoming more resilient.

AS WELL AS EFFORTS TO REDUCE EMISSIONS AND ACHIEVE NET ZERO TARGETS, BUSINESSES HAVE AN UNAVOIDABLE NEED TO ADAPT TO CLIMATE CHANGE.

However, developing a strategy to help focus investment and development efforts for adaptation is particularly difficult. The technologies needed are, for the most part, specific, numerous, and fragmented. Adaptation solutions are diverse across different industries and often strongly driven by local circumstances, making scalability hard to achieve. At the same time, funding for adaptation tech remains low — less than 10% of all climate technology funding is estimated to have gone to adaptation in 2020–2021.

Furthermore, the suitability and viability of adaptation solutions in the future will be greatly affected by a range of uncertainties, such as competitive dynamics, regulation, and consumer behavior. This complexity leads all too often to decision paralysis or at least an extended "wait and see" philosophy, which many companies are pursuing today. Based on an in-depth study led by Arthur D. Little's (ADL's) Blue Shift institute, this article considers what adaptation means for businesses, future projections, some "no-regret" technology choices, and how to shape an adaptation strategy.

About the ADL Blue Shift study on climate change adaptation

The study was led by ADL's future technology institute, Blue Shift, in collaboration with the United Nations World Intellectual Property Organization (WIPO), which has established a green technology database comprising some 150,000 patents. It incorporated the results of 40 interviews with corporate executives, climate adaptation experts, venture capitalists, and start-ups, as well as two surveys covering 70 respondents.

One of the "elephants in the room" affecting the future course of adaptation is geopolitics, and clearly, issues such as international conflict and human migration will weigh significantly. Analyzing geopolitics is outside our expertise and mission, but we have sought to co-create a set of plausible projections together with our design fiction agency partners, Making Tomorrow, for which geopolitical events, both positive and negative, could be easily imagined as contributory factors.

4 KEY ASPECTS OF THE ADAPTATION CHALLENGE

A good place to start is to consider the range and extent of the challenges that adaptation poses for businesses. While these are many and diverse, they can be conveniently split into four generic business functions:

1. SOURCE: SECURING THE AVAILABILITY AND SUPPLY CHAIN OF CRITICAL RAW MATERIALS AND RESOURCES

Climate change will affect companies' raw materials and supply chains, such as decreasing agricultural yields and disruptions to supplies of critical materials due to severe climate events. For example, drought reduced the Panama Canal's capacity in 2023.

Companies need to consider how they can make their supply chains more resilient to disruptions.

2. MAKE: ADAPTING MANUFACTURING AND OTHER INDUSTRIAL PROCESSES TO A CHANGING CLIMATE

Energy and water shortages and grid instability are likely to be one aspect of climate that affects manufacturing processes. For example, in India, lower rainfall has reduced the efficiency of hydroelectric and nuclear power plants, causing greater grid instability. Fresh water is another critical resource with declining availability, hence the increased importance of solutions for water treatment, reuse, and recycling — or, in certain cases, desalination plants. Working conditions for employees, such as extreme heat, will also need to be addressed. Companies need to ensure that their processes can continue delivering the required product/service quality, volume, and continuity in a more extreme climate environment.

3. PROTECT: PROTECTING INDUSTRIAL SITES AND ASSETS FROM CLIMATE CHANGE IMPACTS

First, organizations must ensure they have better capabilities for prediction and early warning of climate-related disruptions. Second, they need to take physical measures to better protect their assets from floods, storms, and sea level rise, including new shielding or designs with built-in resilience. Third, they must improve their ability to respond rapidly to sudden damage or losses. Finally, they may need to consider wholescale relocation of assets away from high-risk locations, such as parts of China, Vietnam, and Bangladesh, which are vulnerable to sea level risk and flooding, or parts of sub-Saharan Africa, India, and Southeast Asia, which are vulnerable to droughts and heatwaves.

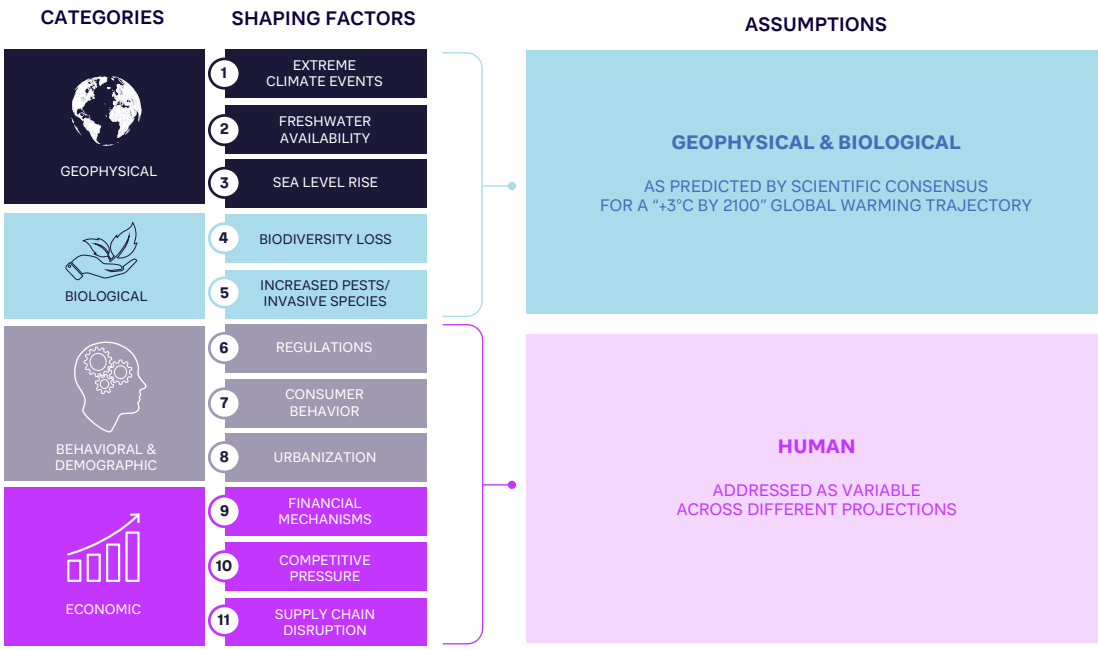
4. SELL: MARKETING COMPETITIVE AND DIFFERENTIATED GOODS AND SERVICES TO MEET THE NEEDS OF A CHANGING CLIMATE

Climate change will alter customers' needs for certain products and services and create new needs. For example, in late 2023, tire manufacturer Michelin started marketing a range of inflatable solutions for sun protection in large areas, including inflatable parasols to reduce heat islands in cities. New consumer expectations and sales and delivery channels may need to be considered, especially if consumer behaviors change because of ongoing climate-related events. Thus, social listening supported by natural language processing may help track changing and increasingly localized consumer preferences. Circularity and more sustainable ways of consumption may also become a higher priority, especially for B2B organizations.

Considering each of these generic business functions systematically helps ensure that an adaptation strategy is comprehensive, though some industries may be disproportionately affected by specific challenges (e.g., agrifood is particularly exposed to "Source").

DEALING WITH FUTURE UNCERTAINTIES

One of the biggest challenges in shaping an adaptation strategy is dealing with the significant uncertainties about the future environment. Our study identified 11 "shaping factors" that determine these uncertainties across four categories (see Figure 1).



Source: Arthur D. Little

FIGURE 1: SHAPING FACTORS FOR CLIMATE CHANGE ADAPTATION

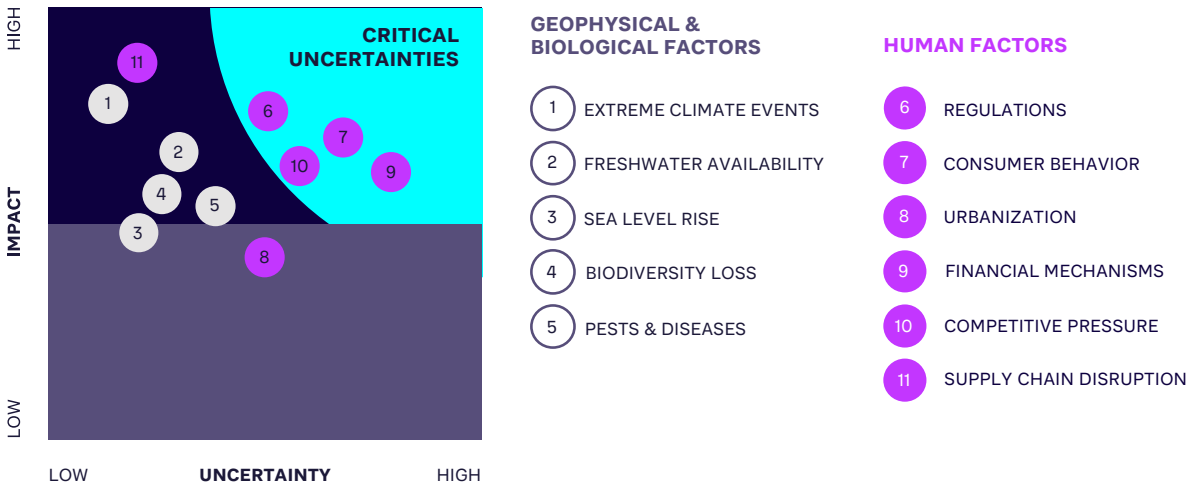
For geophysical and biological factors, we adopted a "+3°C by 2100" trajectory. This falls within the confidence interval for the Intergovernmental Panel on Climate Change's (IPCC's) Representative Concentration Pathway (RCP) 6.0, which predicts a temperature increase of ~+2.8°C versus pre-industrial levels, with a possible range between +2.0° and +3.7°C. This trajectory considers the likely target gap in 2030 based on the current delay in policy and climate action at large. Therefore, it allows for a cautiously pessimistic but realistic outlook against which to consider adaptation challenges. To understand what this future means, it is worth considering some representative impacts across our five relevant shaping factors (see Figure 2).

Source: Arthur D. Little

FIGURE 2: LIKELY CLIMATE IMPACTS FOR A "+3°C BY 2100" TRAJECTORY

Of course, uncertainties still exist regarding how these geophysical and biological factors will react and develop over time, but even at the most optimistic end of the range (+2°C by 2100), the need to adapt will be unavoidable.

Turning to the behavioral and economic factors (factors 6-11 in Figure 1), we can collectively consider these "human shaping." Using our survey of 70 experts, we ranked these in terms of level of uncertainty and impact on a 1-5 scale (see Figure 3).



Source: Arthur D. Little

FIGURE 3: HUMAN SHAPING FACTOR RANKING AND CRITICAL UNCERTAINTIES

Four factors emerge as the most critical because they have both high potential impact and high uncertainty on how adaptation will evolve:

1. Regulations refer to the extent to which new regulations will enforce or encourage adaptation, similar to how they drive mitigation today. It is by no means certain that this will happen for adaptation.

2. Consumer behavior means how far consumers will shift toward a preference for adaptation-related goods and services.

3. Financial mechanisms refer to public and private finance availability for adaptation. While adaptation finance for climate change hit a record US $63 billion in 2021/2022, increasing by 28%, it is still significantly below the $212 billion yearly need projected by 2030 for developing countries alone.

4. Competitive pressure is the extent to which market forces will drive adaptation. It is led by big industry leaders requiring all suppliers to comply. For example, today, Apple is demanding that its entire value chain reduce its impact on global warming.

By considering each "on/off" combination of these four factors, we generated 24 future projections, of which the following five are the most plausible, differentiating, and technologically relevant:

- **Green Communities:** This projection features a strong consumer behavior shift but limited finance. It characterizes a resource-scarce world where grassroots adaptation initiatives flourish without large-scale projects. It could happen if climate catastrophes start to change consumer opinion, yet ROIs for adaptation projects continue to be poor, and geopolitical or economic constraints limit public finance.
- **Lonely at the Top:** This projection features no consumer behavior shift but high competitive pressure. Here, adaptation is driven by global industry market leaders with deep pockets within a two-speed economy. Most less affluent consumers cannot support the higher price levels associated with adaptation, focusing instead on surviving in a tight economic environment.
- **Wild Green West:** This projection features strong finance but little regulation. There is a creative chaos in which adaptation initiatives sprout up everywhere, fueled by private capital but lacking any regulatory backbone. In this essentially neoliberal projection, governments fear imposing further heavy costs on industries to enforce adaptation, especially with the already huge mitigation costs, leading to a lack of globally agreed regulations and standards.

- **Don't Look Up:** This projection features limited finance and no consumer behavior shift. It is a pessimistic future in which neither customers nor financial institutions have adjusted to the new climate reality. This could be, for example, due to more pressing economic or geopolitical crises that have taken precedence over adaptation.
- **Adaptation Surge:** In this projection, all variables favor adaptation. It represents a relative utopia in which adaptation is the norm, resetting expectations, creating new markets and new needs, attracting finance, and being supported by appropriate national and international regulations.

The projections don't seek to describe a full world but rather illustrate a set of plausible tensions that may partly coexist in different regions or industries. Projections such as these are useful tools for companies wishing to develop long-term strategic plans.

FINDING YOUR WAY THROUGH ADAPTATION STRATEGIES

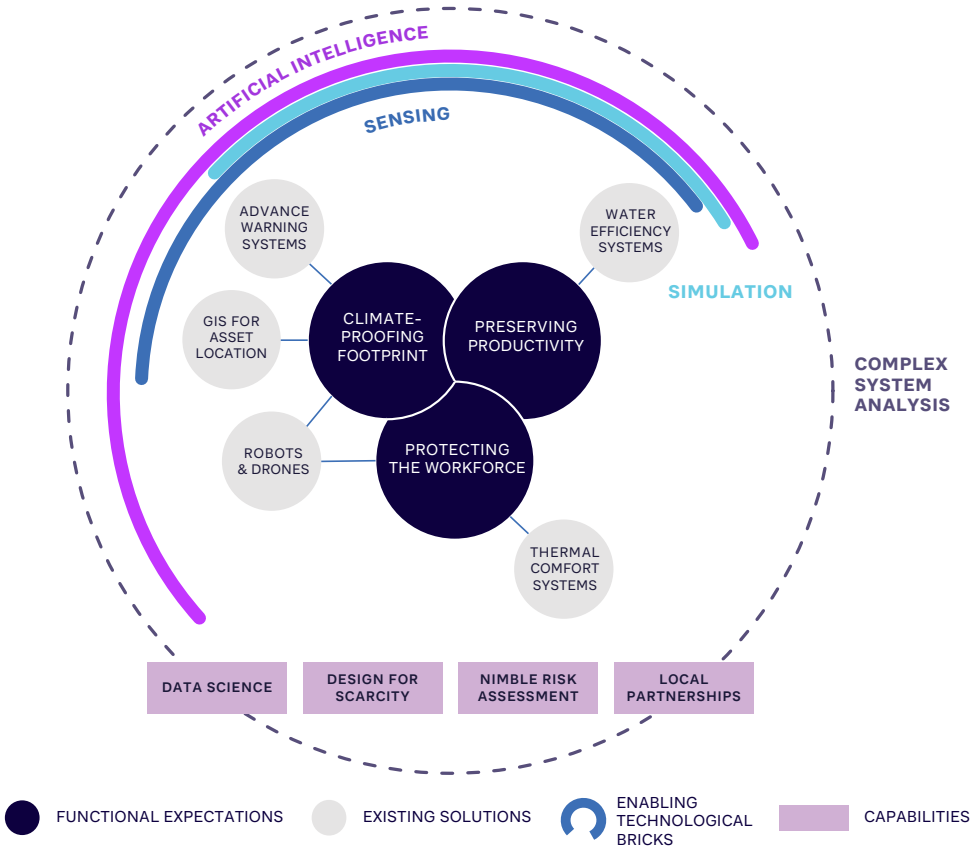
One of the challenges of developing an adaptation strategy is deciding which technologies to focus on: what will be needed, where and when, and what could be the best solution. Because adaptation is highly local, multivariate, and multidisciplinary, a huge range of technologies must be considered. Undoubtedly, this is one reason adaptation technologies have, up to now, remained in the shadow of mitigation technologies in terms of public debate.

Considering future projections such as those above is one way to help prioritize. Each future projection implies a partly different set of functional needs and priorities for which particular technological solutions are more or less relevant. For example, a Wild Green West future would favor less mature solutions with high potential ROI, such as synthetic biology for critical materials manufacturing and crop production and digital twinning for improving productivity and limiting vulnerability to climate events. Conversely, in a Green Communities future, the emphasis would be on low-cost, local solutions with more mature technologies, such as mini desalination plants for water supplies and modular designs for consumer products to reduce costs and improve reuse. In the full Blue Shift Report, we identify almost **100** of the most relevant technology families, mapped across the five future projections and the four key business functions (Source, Make, Protect, and Sell), all ranked by maturity and impact. (Readers wishing to understand in detail what is most relevant for their industry are urged to consult the main report.)

BECAUSE ADAPTATION IS HIGHLY LOCAL, MULTIVARIATE, AND MULTIDISCIPLINARY, A HUGE RANGE OF TECHNOLOGIES MUST BE CONSIDERED.

Overall, the value of adaptation technologies lies less in cutting-edge performance or breakthroughs than in applying existing technologies to solve specific and local problems **at an acceptable financial, environmental, and social cost** for all stakeholders involved. This is the key area for innovation. For example, reef balls, concrete structures that mimic marine reefs, are valuable because of their low cost, shape, marine-friendly material, and arrangement, which interact with local marine ecosystems to improve their resilience. Nevertheless, many technologies not developed for adaptation have a key role in this space, from advanced consumer sentiment analysis to digital twinning. There is no single best approach to solving adaptation challenges. Instead, a nuanced consideration of a business's ecosystem on its operations, and vice versa, is needed. Adaptation strategy is, therefore, best approached as an integral part of company strategy.

Looking across the whole adaptation technology space, some "no-regret" candidates are relevant for most industries, regardless of the projection. They address three major recurring functional expectations: **risk-proofing the industrial footprint, preserving productivity, and protecting workers** (see Figure 4).



Source: Arthur D. Little

FIGURE 4: NO-REGRET CAPABILITIES, SOLUTIONS, AND ENABLING TECHNOLOGIES

Existing no-regret solutions include advanced warning systems, thermal comfort systems, geographic information systems (GIS) for site location and relocation, drones for aerial imaging, robots for maintenance and automation of production, and water efficiency and recycling systems.

As with any technology forecast, it is valuable to consider not only technology solutions but also the key **enabling technology bricks** and underlying capabilities necessary to realize them.

From the study, three enabling technological bricks emerged as overall most relevant for these no-regret adaptation solutions:

1. Sensing technologies, including the Internet of Things (IoT), multispectral imaging, and light detection and ranging (LiDAR), provide granular, instant insights into specific metrics of interest without accessing locations — increasing safety and efficiency.

2. Deep neural networks, especially graph neural networks (GNN) — a branch of AI — have proven particularly apt at weather forecasting and, more broadly, identifying patterns across large numbers of variables. However, deep neural networks require large training data sets, and we only have one climate history.

3. Simulation via generative AI helps feed the training of neural networks by providing instances of climate events that could have happened (but did not). Digital twins allow the creation of a rich data set fully representing an asset or business. Augmented and virtual reality help visualize simulations, aiding decision-making and creating a sense of urgency.

Ultimately, the interaction of these technologies gives rise to a critical tenet of adaptation: **complex system modeling**. Complex systems are composed of many interacting units displaying emergent properties that cannot be understood in terms of the properties of their individual isolated components. Climate and human-climate interactions can be described as complex systems. Holistically modeling a company's interactions with its environment (including assets, operations, and people) and vulnerabilities to climate change will be a critical input into a sound adaptation strategy. Supply chain optimization is a proven use case. We predict that complex system modeling expertise will become increasingly important as companies have to make difficult choices and investment decisions in their adaptation strategies.

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At the level of boosting or building underlying capabilities, four emerged as critical: **data science** because deep learning expertise will be critical to accurately predicting local climate phenomena and quantifying their impact; **design for scarcity** because the ability to design solutions in a resource-constrained environment will be key; **responsive risk assessment** because dynamic sensing and responding to rapidly changing risks will be important; and **local partnership** capabilities because climate adaptation solutions often have to be tailored to the local environment.

TAKING ACTION

Should companies take action now, or can it be postponed for a few years? In fact, some companies are already moving fast in adaptation strategy for good reasons. First, the no-regret solutions and technologies outlined above all deliver productivity and adaptation benefits. For example, IoT can help optimize the use of raw materials and utilities regardless of climate adaptation. Second, because climate adaptation is inevitable, early movers making carefully calculated investments are likely to build competitive advantage versus those who are forced to act in crisis mode. Adaptation is not just a matter of avoiding downsides — businesses with the right strategy have major opportunities. Finally, implementing many adaptation solutions requires long development lead times not least because climatic conditions cannot be controlled. In many cases, commitments to new technology development and testing must be made many years ahead of when they will be needed.

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A survey conducted as part of the study confirmed that lack of knowledge on the best course of action is the biggest hurdle to business adaptation, followed by resistance to change, lack of funds, and technology limitations. To move forward with adaptation strategies, companies need to consider four key questions:

1. How to predict: Decision makers should begin by creating their own global warming trajectory assumptions and identifying the shaping factors most critical for their industry and global footprint. They need to conduct site-by-site assessments of potential risks, both acute and chronic, and pilot improved risk-monitoring and modeling approaches, leveraging digital technologies such as digital twinning and AI.

2. How to decide: A suitable governance approach is needed to oversee the adaptation agenda, which often spans several functions. New metrics will likely be needed. Approaches such as heat maps can help allocate priorities. The key is thinking globally, acting locally, and enhancing customer listening.

3. How to finance: Mobilizing funding for adaptation requires updating financial metrics, including pricing climate-risk vulnerabilities in terms of damage to assets, production loss, and possible reputational effects. It may also involve the complex task of pricing positive externalities (productivity gains and employee retention) and potential market opportunities from adaptation (market share gains or new product-market fit). It also requires working with longer timelines (more than 15 years) than is customary for most corporate decision-making. Blended finance solutions, which combine concessional public funds with private capital, can be leveraged when corporate adaptation investments impact communities. Adopting a portfolio approach, balancing risks and returns, means various project types can be accommodated.

4. How to build: Because adaptation problems require local solutions, developing local ecosystems of partners is essential. As with any collaborative innovation effort, setting clear ground rules for intellectual property is important.

Ultimately, the effectiveness of adaptation to climate change will depend on how governments, businesses, local communities, and individuals collaborate to meet local, national, and global challenges. Climate change will become an increasingly consequential constraint on business strategy and forward planning. By 2040 and beyond, we may already be in a situation where “adaptation strategy” has become almost inseparable from “business strategy.”

DR. ALBERT MEIGE
is the Director of Arthur D. Little's Blue Shift Institute, based in Paris, France.

ZOE HUCZOK
is a Program Manager of Arthur D. Little's Blue Shift Institute, based in San Francisco, USA.

RICK EAGAR
is a Partner Emeritus of Arthur D. Little, based in Cambridge, UK.