DP WORLD

CLIMATE-PROOFING THE SUPPLY CHAIN

Using data to enhance infrastructure resilience

CONTENTS

TIEMEN MEESTER

GROUP CHIEF OPERATING OFFICER, PORTS & TERMINALS, DP WORLD

"Trade will be vital for the world's continued economic success, so taking proactive steps today to evaluate and manage the risks associated with climate change is paramount. Advances in climate modelling can significantly enhance private sector involvement in building resilience, promoting a sustainable and strong future for global trade. Given the long-term nature of our industry, we strongly support adopting a forward-looking, data-driven approach to tackle upcoming challenges proactively."

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"As we decarbonise our operations and contribute to mitigating global temperature rise, we also understand the need to proactively prepare for climate risks that the trade sector may be susceptible to in the future. Our Global Asset Resilience Study offers a scalable first step to building collective resilience across the trade value chain; charting a path to mobilise considered, targeted and evidence-based action for climate adaptation."

ANDY TAM

GLOBAL DIRECTOR OF ENERGY MANAGEMENT

"This exercise revealed that while we stand strong in most of our operations, not all are equally resilient. Recognising potential risks now allows us ample time to proactively plan and implement mitigation and adaptation strategies, ensuring the continued success of our operations. More importantly, our proactive risk identification has helped to ensure long-term resilience, even in our most vulnerable locations. While similar studies are yet to be widely adopted across the supply chain, we are optimistic that our initiative will inspire industry-wide action, leading to a united, data-driven effort to enhance the resilience of global trade."

1 | INTRODUCTION

Our world is already suscept to the impacts of climate change and while ambitions to limit global temperature rise to 1.5 °C continue, it is increasingly likely that the irreversible impacts of global warming to our natural and physical world will become more pronounced. While climate mitigation solutions, such as alternative energy, reforestation and other deep decarbonisation initiatives, are essential to limiting climate change; we must also prepare to manage the likely fallout that will come with global temperature rise. Fires, floods, droughts, heat and cold will leave our planet especially vulnerable to the consequences of a changing climate.

The uptick in slow-onset phenomena like droughts, desertification and sea-level rise, resulting in the ensuing destruction of physical infrastructure and natural habitats present one side of the problem- a more human face to the climate issue lies behind this veneer. Livelihood loss, community health impacts and climate-induced migration compound these more visible climate consequences and impede climate change preparedness efforts.

Trade – the lifeblood of the global economy - stands to benefit from climate resiliency planning. There is a need for considered, proactive and strategic action to help ensure that the sector responds appropriately to evolving climatic hazards. A thorough, data-driven analysis of the industry, and the network of supply chains that support it, is a good first step to quantifying the relative risk exposures of a changing climate.

As a global end-to-end supply chain solutions provider, managing risk proactively is integral to DP World's responsible business operations. Considering our roots in the Ports and Terminals (P&T) industry, risk associated with extreme weather is not a new consideration. P&T infrastructure, like coastal settlements, has long been a nexus of natural, physical and human interaction, as well as a hotbed for the socio-economic vulnerabilities that are driven by climate change. The rapid rise in the frequency and severity of extreme weather events has exacerbated the overall adverse economic impacts attributable to climate change in this sector[1], with a total of US$81 billion of global trade and at least US$122 billion of economic activity being at-risk on average annually due to P&T disruptions from climate extremes[2]. This is before considering the impact on ancillary infrastructure and communities which will only serve to multiple these estimates.

[1]IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 33-3, doi:9781009325844.001/10.1017.

[2]Verschuur, J., Koks, E.E., 1,2 & Hall, J.W. (2023). Systemic risks from climate-related disruptions at ports, Nature Climate Change, https://doi.org/10.1038/s01754-023-41558-w

Given this potential for disruptions, downtime across port operations and regional instability, DP World identified the need for a systematic and methodologically sound approach to assess our operational asset resilience against the pending impacts of climate change. Working with Guidehouse and Jupiter Intelligence, we have looked at the direct physical climate risks to business disruption across our P&T operations and have come to understand the benefits of a scientific approach to measuring, monitoring and pre-empting best practices for climate adaptation.

Ultimately, we believe the entire trade sector must also find a way to consider the broader vulnerabilities that may hinder the mid to long-term health of the industry, while also aiming to safeguard the four billion people, globally, who are increasingly susceptible to climate shocks[3]. Conducting a series of similar asset resilience studies is a scaleable first step to mapping adaptation efforts. It will also enable the global trade community to functionally allocate roles and responsibilities around managing the knock-on effects of climate-related disruptions.

Growing public and political awareness in the last decade has shown an appetite to improve current adaptation approaches, with 170 countries and many cities beginning to include adaptation in their climate planning and approach[4].

Global campaigns such as the "Race to Resilience", financial instruments like the Adaptation Fund and voluntary mechanisms for accountability (including corporate reporting standards and National Adaptation Plans (NAPs)) offer a set of moving parts through which the public and private sector can play a pivotal role in establishing a more unified approach to managing cascading climate impacts.

This paper highlights how, if equipped with a mosaic of data, the logistics industry and wider trade community (including governments) will be able to demonstrate a practicable pathway to achieving collective climate resiliency - one that considers the socio-economic consequences and societal vulnerabilities that are routinely under researched and overlooked.

[3]UNFCCC Climate Champions, 2021. Race to Resilience: Catalysing a step-change in global ambition to build the resilience of 4 billion people by 2030, Race to Resilience - Climate Champions (unfccc.int)

[4]IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 33-3, doi:9781009325844.001/10.1017.

DP WORLD GLOBAL ASSET RESILIENCE STUDY - A TIMELINE

1 IDENTIFY THE NEED FOR CHANGE

- Recognized the impact of acute climate volatility and business disruption on operations

2 PROACTIVE PROJECT INITIATION

- Started the project proactively in response to business impacts before requests from investors and customers for climate-related resiliency plans

3 ENGAGE INTERNAL STAKEHOLDERS

- Involved internal stakeholders: Global Operations & Engineering, Group Health, Safety & Environment, Group Audit (Risk), Group Insurance, and Group Planning & Project Management.
- Defined the scope of the engagement collaboratively.

4 PUBLIC TENDERS FOR CONSULTANCY

- Conducted public tenders for risk consultancy proposals
- Evaluated proposals based on criteria such as climate experience and data depth.

5 PARTNERED WITH GUIDEHOUSE

- Partnered with Guidehouse for their breadth of climate-related experience.
- Partnered with Jupiter for their depth of climate-related data

6 CONTINUOUS DATA REFRESHMENT

- Refresh the underlying data every couple of years.
- Ensure ongoing relevance of the insights developed.

7 ENGAGEMENT AND OUTCOMES

- Shared outcomes from the Asset Resliency Study with senior management for approval
- Agree upon the outcomes with senior management.

8 INTEGRATION INTO PRACTICES

- Integrate findings into asset management, risk, and port construction practices.

2 | RESEARCH AND ASSESSMENT

Ports already routinely manage extreme weather and climate risks are readily considered in design and operational procedures. This includes accounting for the potential impact of high wind speeds on terminal operations, or the importance of designing quay walls mindful of past storm surge occurrences. However, the changing climate and increasing frequency and severity of extreme weather, has resulted in unmitigated risks that remain unaddressed. There is a pressing need to ensure equipment is adapted to changing climate patterns and that P&T operators leverage available climate forecast data to revise operational processes.

Climate modelling has seen significant advancements in recent decades and if leveraged effectively can vastly improve private sector participation in resilience building[5]. Various academic and commercial research groups have enhanced the accuracy of climate projections with new and improved climate-model experiment protocols, standards, data distribution mechanisms and artificial intelligence technology entering the fold. As a result, it is now possible to predict the frequency and severity of a range of climate hazards, for specific locations, under different climate scenarios.

In 2022, we at DP World started working with Jupiter Intelligence, a global leader in climate risk analytics, to better understand how this forward-looking data could help understand climate change risks across our P&T operations. The consultancy Guidehouse, then helped DP World to interpret this climate forecast data, allowing us to underscore its potential business implications.

[5]Hallegatte, Stephane; Rentschler, Jun; Rozenberg, Julie. 2020. Adaptation Principles: A Guide for Designing Strategies for Climate Change Adaptation and Resilience. © World Bank, Washington, DC. http://hdl.handle.net/34780/10986 License: CC BY 3.0 IGO

2.1 DP WORLD'S CLIMATE RISK ASSESSMENT

Assessing climate change risk for a port requires an understanding of:

1. Hazards: what climate hazards are likely to occur in the port?
2. Exposure: what assets and operations are exposed?
3. Vulnerability: when will hazards do damage and/or disrupt operations?

Together with Jupiter Intelligence and Guidehouse, we investigated these 3 dimensions of climate risk for our port and terminal operations through a comprehensive global study covering our P&T portfolio.

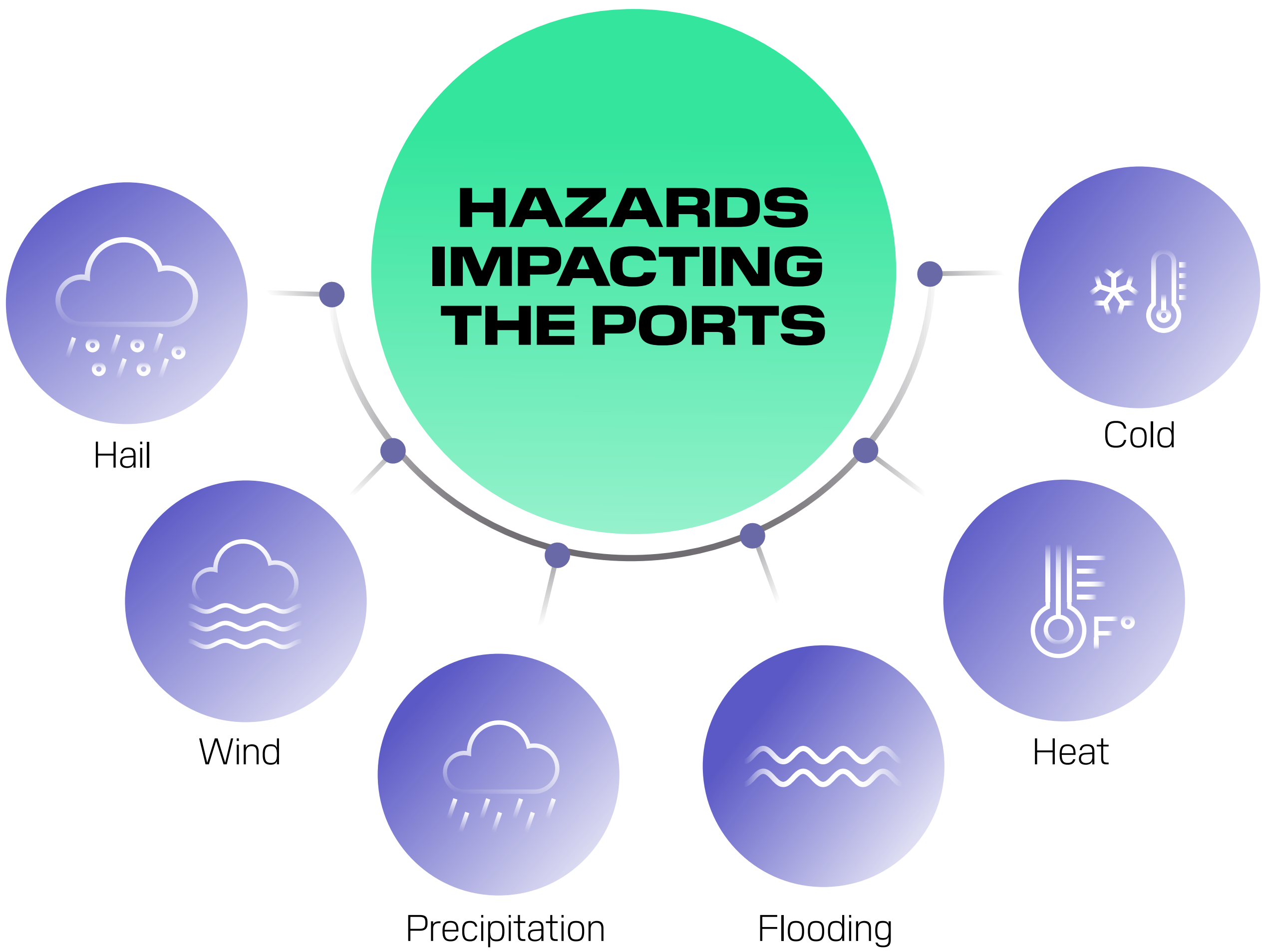
Dimensions	Description
Hazards	The data from Jupiter Intelligence provided insights into 6 different climate hazards (flooding, precipitation, wind, heat, cold, and hail). For 50 selected ports and terminals (P&Ts) hazards were then modelled for three different IPCC climate scenarios[6]. The three scenarios were selected to capture impacts ranging from the greatest to least global temperature rise. Jupiter's data included a range of metrics, such as wet-bulb globe temperature (WBGT - a heat metric that takes humidity into account to better assess impact on people) and wind speeds at different return periods (wind speed of 1-in-10 year event, 1-in-20 year event, 1-in-50 year event, etc.). These metrics were provided for 5-year intervals until 2100.
Exposure	DP World's Asset Resilience Working Group developed a list of 24 asset categories that are most important and relevant for most ports (including cranes and quay infrastructure, but also workers as extreme temperatures and high humidity create unsafe working conditions that can prevent outdoor operations).
Vulnerability	The vulnerability of exposed assets to climate hazards was first mapped qualitatively by Guidehouse, and failure modes per hazard and asset were validated by DP World. However, assets and operations differ between ports. For example, a heat wave in a colder port (e.g. in the UK) will have more impact than in a hot port (e.g. in India) where staff is used to the heat and equipment is better suited. To account for these differences, the ports were requested to report maximum operating threshold for each hazard. For example, maximum operating wind speed threshold for a quay crane is typically around 70 km/hr, because at higher wind speeds operations are ceased to avoid incidents.

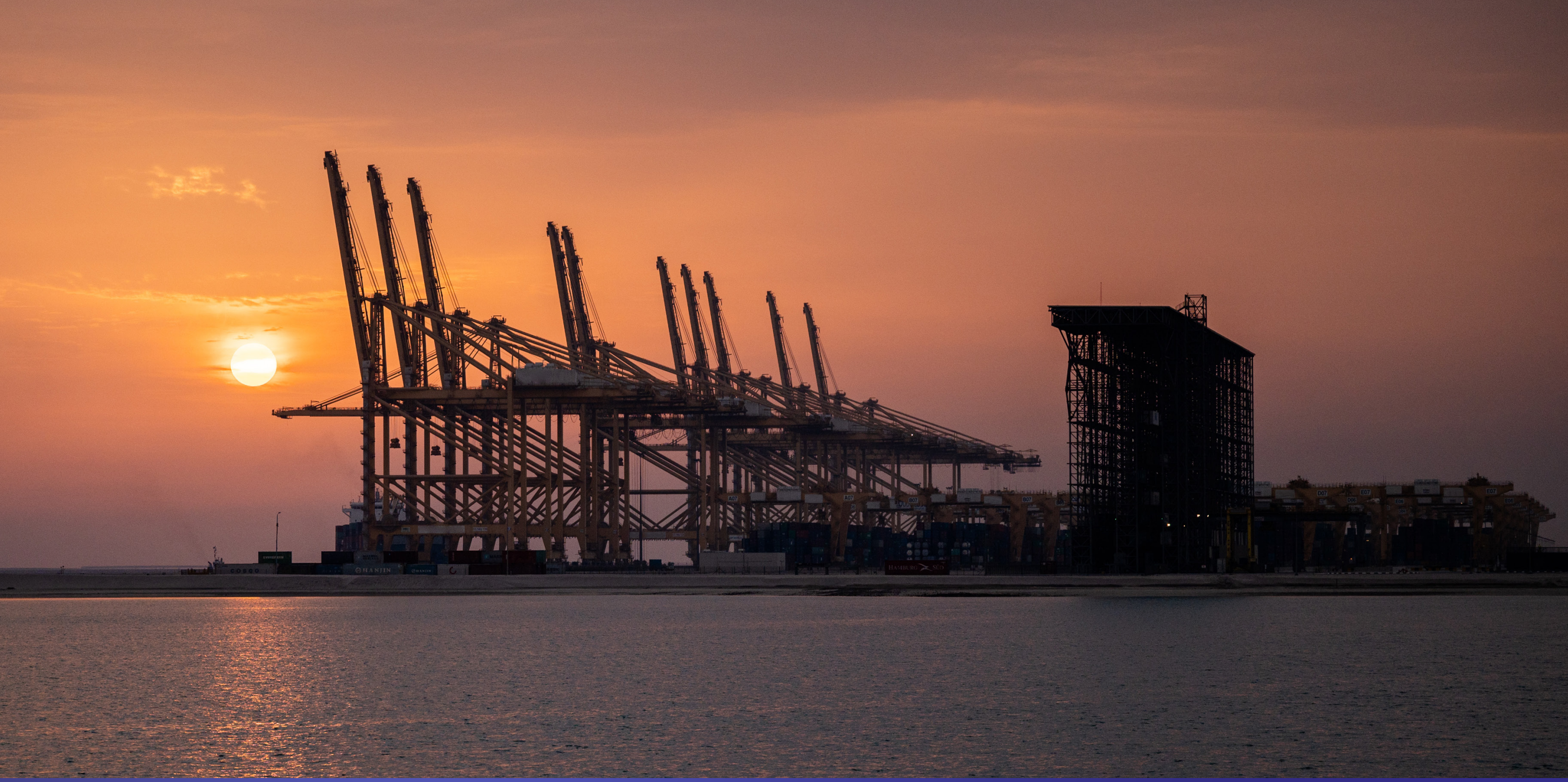
[6]Low-Carbon Scenario (warming of 1.8°C by 2100) - SSP1-2.6
Medium-Carbon Scenario (warming of 2.7°C by 2100) - SSP2-4.5
High-Carbon Scenario (warming of 4.4°C by 2100) - SSP5-8.5

Climate risk model

Based on this available information on material hazards, exposure, and vulnerability from Jupiter Intelligence, Guidehouse developed a risk model. The methodology adopted was used to interpret the climate hazard information; integrating data on asset-level maximum operating thresholds to help estimate the downtime experienced at port facilities due to weather related disruptions. This took into consideration asset criticality (percentage of P&T revenue lost when the asset cannot be operated) and the extent of downtime experienced per extreme weather event. The modelling focused exclusively on disrupted operations and associated loss in revenue; it considered that 'damages' to assets, including safety hazards to workers, are largely avoided (by ceasing activities in case of extreme weather) and thus negligible for the purposes of this analyses.

Over time, new or better asset data may become available and our P&T portfolio will likely change; so, the climate models we employ will need to evolve. DP World intends to regularly update the assessment to account for changes, leveraging the most recently available forecast data. Additionally, future updated studies will include the remedial actions we will have already taken to increase asset resilience.





2.2 CLIMATE RISKS FOR DP WORLD

The assessment considered decadal variabilities and found that total climate risk for the 50 P&Ts is relatively stable until 2050 (see figure1). In fact, a slight decrease in total risk across DP World's P&T portfolio is expected until 2050, primarily driven by diminished disruption from cold events in DP World's Canadian P&Ts. This finding was consistent for all three climate scenarios.

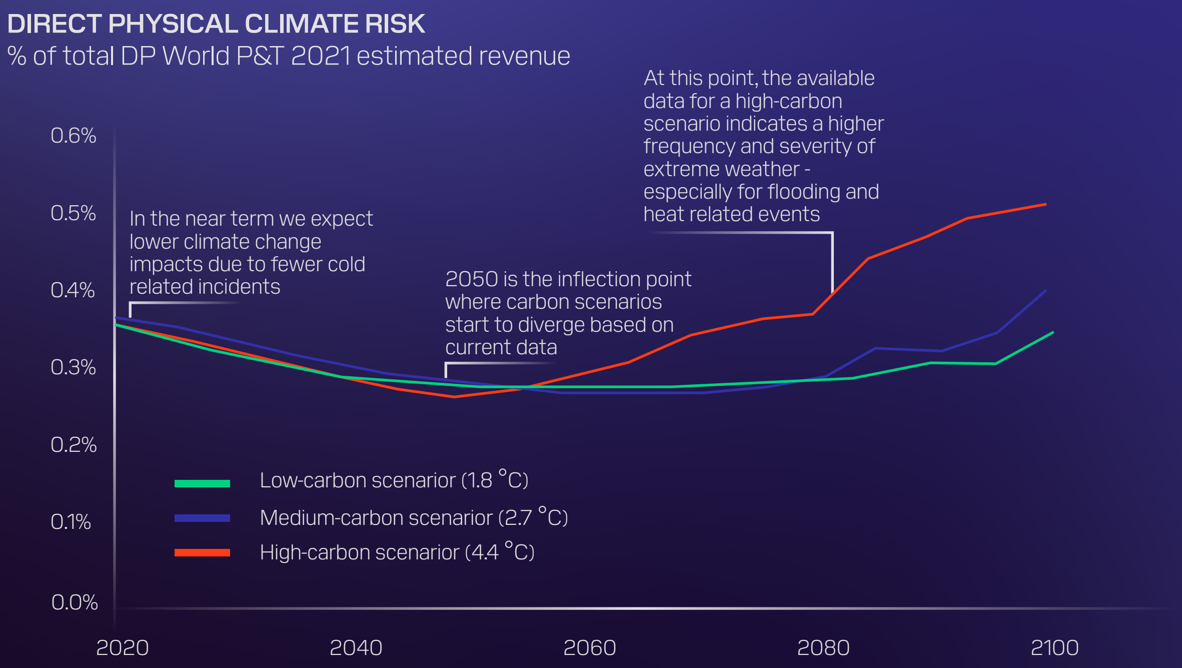


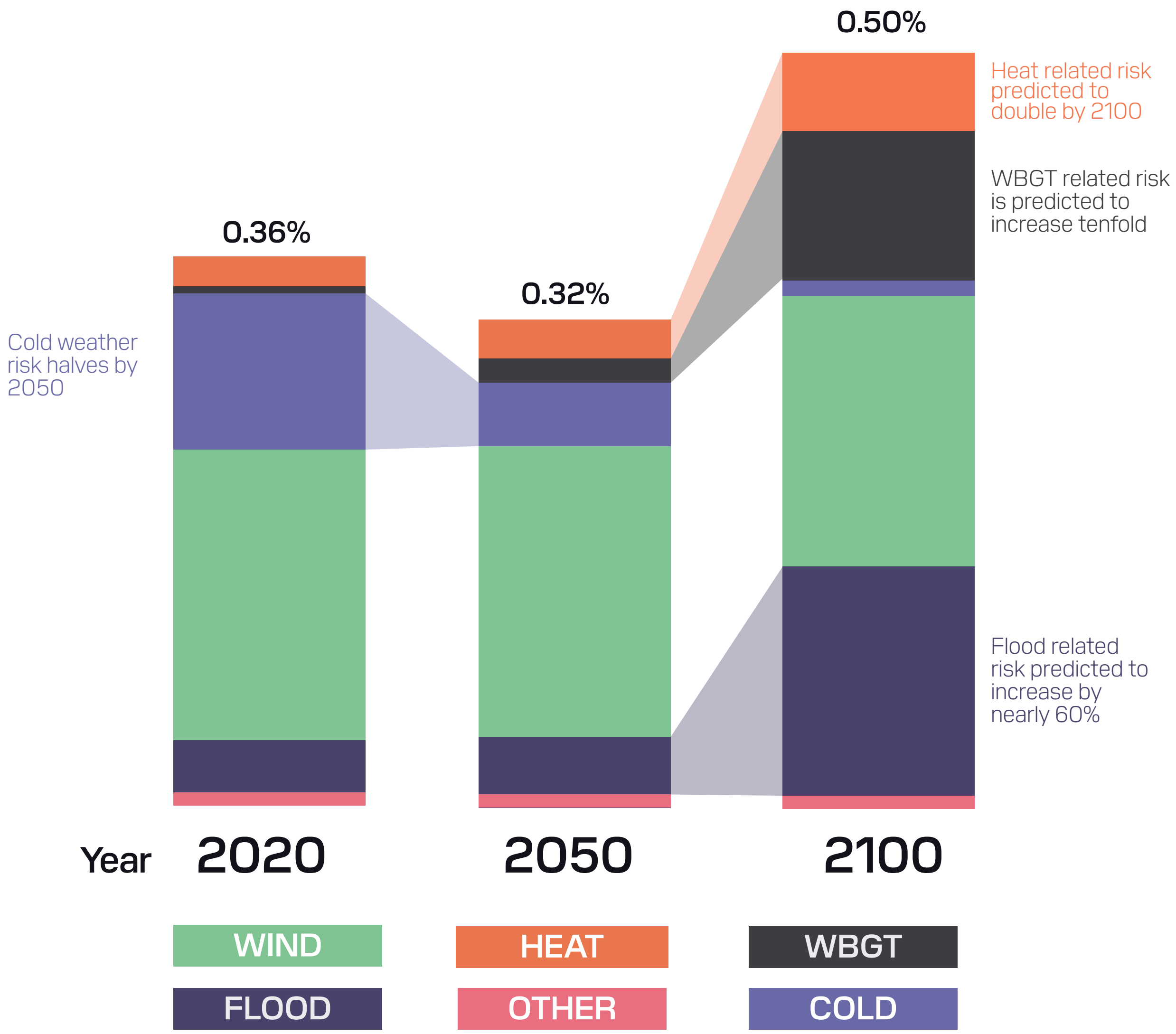
Figure 1: Direct physical climate risk as a % of total DP World Ports & Terminals 2021 revenue

After 2050 the climate scenarios show a more pronounced difference on direct physical climate risk. While under the low-carbon scenario the total risk in 2100 remains similar to 2020 levels, under both the medium-carbon scenario and high-carbon scenario, the total risk in 2100 is expected to be higher, albeit still relatively small, with the overall climate risk only impacting up to %0.50 of total DP World P&T 2021 estimated revenue.

While the outcomes of this resilience study have largely given us comfort in that DP World's P&T operations are not projected to be substantially impacted by climate change, it was notable for us that seven out of the fifty ports (Paramaribo, Dakar, Limassol, Santos, Yarimca, Mundra, and Paita) included as part of this study are still expected to experience increased downtime in the years leading up to 2050, and in the absence of action, more so thereafter. When analysed from a hazard perspective (see figure 2), as per the high-carbon climate scenario, we observed that ~%50 of the current total direct physical climate risk is driven by wind, followed by cold (~%30), and flooding (~%10). However, cold risk is expected to decrease by half before 2050, and become insignificant by 2100, whereas flood risk is expected to increase significantly after 2050, as is heat and WBTG. This indicates looming challenges for certain locations, seemingly concentrated around our operations in the emerging markets.

In response to these outcomes our Asset Resilience Working Group has registered potential risks and will subsequently be working with respective operating entities to develop strategic action plans that help to alleviate anticipated stresses, protecting business continuity in the short-to-medium term. Risk exposure at our P&T infrastructure was shown to be most sensitive to assumptions made for quay wall height and downtime per flooding event, stressing the importance of investing in resources to improve the performance of port-specific assets (e.g., maximum operating thresholds). Importantly, this early intervention into physical climate change defences will significantly improve the overall resilience of our P&T infrastructure systems, generating large longer-term benefits at markedly lower costs[7].

IMPACT OF CLIMATE CHANGE ON ASSETS AS A % OF DP WORLD'S P&T 2021 ESTIMATED REVENUES



[7]Hallegatte, Stephane; Rentschler, Jun; Rozenberg, Julie. 2020. Adaptation Principles: A Guide for Designing Strategies for Climate Change Adaptation and Resilience. © World Bank, Washington, DC. http://hdl.handle.net/10986/34780 License: CC BY 3.0 IGO

CASE STUDIES

The climate risk model enabled port-level and asset-level analysis of climate change impacts over time. Here we show a few examples of notable ports and key findings.

HIGH CARBON IMPACT ON PORTS BY 2100

- **Key Hazards:** Cold
- **Business Impacts:** Reduced disruption of port activities caused by freezing due to increasing average temperature.
- **Development - High Carbon Scenario:** Days with temperatures below -10 degrees decreasing from 5 today to 2 by 2050 and <1 by 2100.
- **Development - Medium Carbon Scenario:** Days with temperatures below -10 degrees decreasing from 5 today to 3 by 2050 and 1 by 2100.
- **Development - Low Carbon Scenario:** Days with temperatures below -10 degrees decreasing from 4 today to 3 by 2050 and 3 by 2100.

- **Key Hazards:** Heat
- **Business Impacts:** Disruption of port activities due to heat stress on workers and assets.
- **Development - High Carbon Scenario:** Days with temperature exceeding 35°C increasing from 7 today to 8 by 2050 and 19 by 2100.
- **Development - Medium Carbon Scenario:** Days with temperature exceeding 35°C increasing from 7 today to 8 by 2050 and 8 by 2100.
- **Development - Low Carbon Scenario:** Days with temperature exceeding 35°C increasing from 7 today to 8 by 2050 and 8 by 2100.

- **Key Hazards:** Heat, Flooding
- **Business Impacts:** Disruption to port activities due to flooding beyond 2050 (protected by quay wall until 2050).

  - Disruption to port activities due to heat stress on workers.
- **Development - High Carbon Scenario:** Flood depth (from sea level rise and storm surge) at 100 year return period increases from 0.5m today to 0.9m by 2050 and 1.9m by 2100.

  - Days with temperature exceeding 35°C (heat stress threshold) increases from 3 today to 9 by 2050 and 72 in 2100.
- **Development - Medium Carbon Scenario:** Flood depth (from sea level rise and storm surge) at 100 year return period increases from 0.4m today to 0.8m by 2050 and 1.4m by 2100.

  - Days with temperature exceeding 35°C (heat stress threshold) increases from 4 today to 9 by 2050 and 23 in 2100.
- **Development - Low Carbon Scenario:** Flood depth (from sea level rise and storm surge) at 100 year return period increases from 0.4m today to 0.7m by 2050 and 1.2m by 2100.

  - Days with temperature exceeding 35°C and causing heat stress increases from 4 today to 7 by 2050 and 7 by 2100.

- **Key Hazards:** Heat
- **Business Impacts:** Disruption of port activities due to heat stress on workers.
- **Development - High Carbon Scenario:** Days with temperature exceeding 35°C increasing from 38 today to 137 by 2050 and 319 by 2100.
- **Development - Medium Carbon Scenario:** Days with temperature exceeding 35°C increasing from 41 today to 111 by 2050 and 207 by 2100.
- **Development - Low Carbon Scenario:** Days with temperature exceeding 35°C increasing from 38 today to 84 by 2050 and 91 by 2100.

2.3 LIMITATIONS OF THE STUDY

Our climate risk assessment focused on direct downtime impacts and highlights the value of forward-looking physical risk analysis to identify hotspots and areas that need investment to improve resilience within our P&T operations. The assessment did not consider indirect impacts and therefore disruption to port facilities from failing ancillary infrastructure has not been accounted for and remains a key area of uncertainty. In addition, business impacts from climate hazards at other ports, some of which have close trade ties to DP world's facilities and may be less prepared for climate related stresses, were not captured.

This lack of available complementary forecast data from our supply chain partners on ancillary infrastructure, including hinterland connectivity, energy grids, urban and informal settlements, does compromise the overall effectiveness of the global study. Extreme weather impacts will not concentrate around select ports & terminals; collective climate resilience will depend on the overall design of the wider spatial footprint of urban infrastructure. Furthermore, uncoordinated improvements to infrastructure will introduce the risk of maladaptation, complicating protective efforts in the long term.

There is substantial benefit to similar exercises being deployed by our industry peers, government partners and civil society actors. It would allow for the interconnectedness of global trade routes to be appropriately considered in independent risk-appraisal exercises, thus facilitating a wholescale evidence-based approach to resilience building for the trade sector.

3 | LANDSCAPE ANALYSIS

Climate change poses numerous challenges to the global trade landscape that extend beyond the direct impacts on infrastructure and company assets that have been explored in our resilience study. While rising sea levels, more frequent storms, and altered precipitation patterns directly threaten the viability of these vital modes of trade and distribution[8], it is crucial to also consider the indirect impacts tangential to the P&T industry. These evolving climatic hazards have the potential to be detrimental to supporting critical infrastructure and the health and well-being of a large portion of the global population.

Our P&T climate risk assessment presents a scalable first step to collectively managing climate adaptation and resiliency building. Indirect risks to the industry, including impacts to vulnerable external systems like people, are a persistent threat that remains under-researched within commercial climate risk analyses. These hidden vulnerabilities are particularly relevant for the trade sector, considering the global reach of supply chains and the socio-economic importance of the industry. By conducting a series of similar asset resilience studies, the sector will build a robust repository of information that will allow both public and private sector actors to engage in a targeted adaptation strategy that is conscientious of the interdependent nature of climate change risks.

[8] IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 33-3, doi:9781009325844.001/10.1017.

3.1 INDIRECT CLIMATE CHANGE RISKS

Indirect vulnerabilities span a range of issues, from the robustness of in-land logistics infrastructure to the fragility of regional power supplies[9]. The reliance on infrastructure networks, such as nationally maintained roadways or rail systems, government-funded emergency response and recovery resources, or city water supplies and infrastructure leave private entities susceptible to an abundance of unforeseen economic and organizational impacts that cannot be individually managed. Climate hazards such as drought, heat waves, extreme precipitation, and tropical storms can disrupt any of these support systems, leading to interruptions to business planning, strategy, and continuity.

Furthermore, given the dependency the sector has on external raw material sourcing, suppliers and manufacturing, indirect climate impacts will affect the access and availability of transport cargo. These will manifest as unexpected delays across major trade corridors and result in ensuing negative economic multiplier impacts around the world. In turn, these will also cascade into socio-economic disruptions. As access to basic institutional, technical and financial services are compromised, a web of heightened shocks are likely to appear. Unemployment, loss of community infrastructure and wider social unrest will begin casting a shadow over even the most comprehensive climate risk strategies.

[9] Ghadge, A., Wurtmann, H., & Seuring, S. (2020). Managing climate change risks in global supply chains: a review and research agenda, International Journal of Production Research, 64-44 ,58:1, DOI: 10.1080

3.2 ANCILLARY INFRASTRUCTURE

DP World, and other private actors, have direct control over specific aspects of the global trade ecosystem. Therefore, there is a clear delineation around which critical assets we can implement adaptation strategies for and a defined range of climate risks that can be managed as part of such an individualised approach.

Given that global trade relies on cross-border collaboration, multi-sectoral cooperation and institutional governance, there is a limit to the overall adaptive capacity private sector actors can influence through individual action alone. DP World's ports and terminals also rely on secure transportation, hinterland connectivity, access to energy and an array of other complementary infrastructure often managed by the public sector.

The Suez Canal obstruction in 2021 is a useful example of the relative interdependence of global trade networks and the susceptibility the industry has to knock-on delays: a single bottleneck, over 6 days, held up nearly $60 billion in global trade[10]. Considering the degree to which climate-related extreme weather events will increase the overall probability of such disruptions, the need for governments, civil society and private corporations to clarify respective roles and responsibilities and align on resilience building is self-evident.

As with our own assets, these crucial complementary parts of the wider trade network must be able to continue to function successfully if climate resilience within the trade sector is to be achieved. A transparent understanding of potential vulnerabilities in-the-face of more frequent extreme weather events is a necessary first step to actioning an inclusive approach to climate adaptation and resilience building. Importantly, an understanding on the extent of existing disaster preparedness and the ability of this broader infrastructure to manage climate stresses will inform the extent to which we, as individual trade facilitators, must contribute to adaptation and resilience measures.

[10] Gladstone, R. & Specia, M. (2021). What to Know About the Suez Canal and the Cargo Ship That Was Stuck There, The New York Times/00207543.2019.1629670

3.3 COMMUNITIES AND WORKFORCE

The Intergovernmental Panel on Climate Change (IPCC) has unequivocally outlined the growing list of adverse impacts of climate change on societal stability, especially within economically disadvantaged coastal communities of the global south[2]. Many of these vulnerable economies share similar characteristics: a reliance on raw commodities, an absence of industry and increasing rural-to-urban migration[11]. Across these countries, critical infrastructure, such as ports and terminals, play a disproportionate role in driving not-only economic growth, but also addressing the skill-labour gap divide and catalysing access to industrial forms of employment[12].

As climate change proliferates the impacts of slow onset phenomena like droughts, floods and tropical storms, these countries are susceptible to significant economic shocks. Heavy losses will likely be borne hardest by marginalised workers and their wider community networks who are reliant on the economic opportunities generated by the global trade industry.

In addition to inducing systemic impacts, climate change will have more immediately tangible adverse impacts to human health and well-being, particularly for these vulnerable subsets of the global population[13]. The IPCC's assessments underscore the likelihood of heat stress amplifying in the workplace, most significantly within industries relying on manual labour. The effects will be further intensified by a lack of equitable access to climate-proofed infrastructure and thus a growing inability to find relief from incremental temperature rises[2]. Marginalized communities, especially those without access to cooling systems, are likely to suffer most from this issue[6].

Furthermore, flooding and changes in storm activity could result in contaminated water supplies from the accidental discharge of hazardous oil and chemical reserves, subsequently leading to agricultural and food supply destruction[2]. Such disparities would exacerbate migration trends and leave behind a burdened, vulnerable population further beholden to the impacts of climate change[14]. Without inclusive resilience building, workers, who are an essential part of the wider trade community, will be trapped in a cycle of "disaster loss, a lack of capacity to recover, and reduced resilience when the next shock strikes"[15].

[11] Zilli, M., Scarabello. M., Soterroni, A. C., Valin, H., Mosnier, A., Leclère, D., Havlík, P., Kraxner, F., Lopes, M. A., Ramos, F. M. (2020) .The impact of climate change on Brazil's agriculture, Science of The Total Environment, Volume 139384 ,740, ISSN 9697-0048, https://doi.org/10.1016/j.scitotenv.2020.139384.

[12] Luke, D., Macleod, J. & Ogunkola, O. LSE Firoj Lalji Institute for Africa. White Paper on Sustainable Industrialisation in Africa: The Art of Upgrading Industrial Policymaking Itself (2023)

[13] King, A. D., & Harrington, L. J. (2018). The inequality of climate change from 1.5 to 2°C of global warming. Geophysical Research Letters, 5033–5030 ,(10)45. https://doi.org/2018/10.1029gl078430

[14] Shayegh, S. Outward migration may alter population dynamics and income inequality. Nature Clim Change (2017) 832–828 ,7. https://doi.org/10.1038/nclimate3420

[15] Hallegatte, Stephane; Rentschler, Jun; Rozenberg, Julie. 2020. Adaptation Principles: A Guide for Designing Strategies for Climate Change Adaptation and Resilience. © World Bank, Washington, DC. http://hdl.handle.net/34780/10986 License: CC BY 3.0 IGO

3.4 MANAGING INDIRECT CLIMATE RISKS

Quantifying these indirect impacts remains a difficult task. There is a lack of comprehensive data, especially within communities of the global south[16]. It's here that the global trade sector is confronted with a dilemma: how to capture and address collective disruptions triggered by climate change. The answer lies in a collaborative approach that recognizes the interdependence of multiple stakeholders.

Companies, governments, civil society, non-profits, and non-governmental organizations must coordinate their efforts, pooling resources to strategically fortify the global trade network. For the private sector this must also include contributing to actively managing community and workforce related impacts. Partnering with entities entrusted with maintaining community well-being, from local governments to public health organizations, will enable the private sector to play a pivotal role in strengthening global resilience and addressing both the physical and societal risk aspects of climate change.

Where global approach should leverage private actors' expertise in infrastructure development and supply chain management; nations, intergovernmental organisations and regulatory bodies must simultaneously be relied on to govern action by setting out policies, mobilising regulatory measures and improving institutional capacity to allow for such targeted adaptation responses to succeed in the long term[17].

The Dutch government offers a working example of this approach, by having taken responsibility for providing threshold protections from floods and publishing maps outlining residual flood risks, all private actors have access to a blueprint for where to invest in additional adaptation infrastructure[18]. Functionally, this has helped to prevent maladaptive measures from being adopted and induces a commitment to shared responsibility around climate resilience building.

Just as there are clear pathways for the public and private sector to work together to maintain the resilience of physical infrastructure, there must be efforts made to improve social protections as a part of these measures. Scaling-up existing approaches will require an in-depth understanding of the specific challenges vulnerable communities stand-to-face as climate-related shocks become more frequent. Working with local governments, civil society and non-governmental organisations to better understand societal networks and their relative emergency preparedness is an effective starting point. This should include community-centred resilience studies that help to highlight existing socio-economic vulnerabilities within wider urban infrastructure and/or informal settlement areas. In doing so, people will be given an opportunity to build resilience in a systematic manner, addressing specific weaknesses in the context of livelihoods, healthcare and resources.

[16] Mehmood, H. (2021). Data Drought in the Global South, Our World: United Nations University, https://ourworld.unu.edu/en/data-drought-in-the-global-south

[17] IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 33-3, doi:9781009325844.001/10.1017.

[18] Hallegatte, Stephane; Rentschler, Jun; Rozenberg, Julie. 2020. Adaptation Principles: A Guide for Designing Strategies for Climate Change Adaptation and Resilience. © World Bank, Washington, DC. http://hdl.handle.net/34780/10986 License: CC BY 3.0 IGO

Although, the direct financial returns of these indirect climate adaptation efforts may be challenging to quantify accurately, the value collaborative adaptation solutions will provide in terms of preserving trade operations, protecting communities, and preventing wider infrastructure decline is substantial. By acknowledging the significance of climate hazards and taking proactive steps to adapt, the global trade sector has an opportunity to showcase how a cooperative approach, that takes actions beyond self-interest, can help to initiate inclusive resilience-building that contributes to the well-being of sectors and societies on a global scale.

4 FRAMEWORK FOR ACTION

Global adaptation and climate resilience planning will rely on a varied group of public and private sector actors to work in collaboration across borders, sectors and institutions. Close cooperation between these organisations, in-spite of any differing vested interests, will be integral to overcoming the climate adaptation implementation gap.

Our Global Asset Resilience Study has helped to not only better understand the long-term health of our assets and highlight potential vulnerabilities across DP World's P&T portfolio, but has also indicated how the absence of complementary adaptation information has limited our overall understanding of the trade industry's broader climate-change preparedness. This has made it difficult to comprehend the overall risk exposure to trade across all 3 carbon scenarios, leaving questions of roles and responsibility unanswered. Such uncertainty around resilience building has contributed to the observed financial constraints and limited interest in mobilising action. Systematic risk and vulnerability assessments are essential, and they will necessitate our industry peers, governments, local authorities and civil society partners to develop their own key asset inventories[19]. Ultimately, this will facilitate transparent knowledge sharing around prospective vulnerabilities and help determine a way-forward for targeted adaptation.

[19] Hallegatte, Stephane; Rentschler, Jun; Rozenberg, Julie. 2020. Adaptation Principles: A Guide for Designing Strategies for Climate Change Adaptation and Resilience. © World Bank, Washington, DC. http://hdl.handle.net/34780/10986 License: CC BY 3.0 IGO

4.1 GOVERNANCE AND ACCOUNTABILITY

A good governance approach that promotes accountability will help to drive results-oriented, collective action. The trade sector is multi-sectoral and transnational; therefore, it requires a combination of participatory, climate-related corporate reporting frameworks and mandatory national reporting directives to help coerce a targeted response to resilience building. These will help to enfranchise a network of local and global regulatory bodies to collate information, mandate prescriptive action and monitor progress.

Since the "Who Cares Wins" report[20] was first published in 2004, a seminal document introducing the concept of non-financial reporting to the mainstream, voluntary mechanisms for corporate accountability have significantly matured. This has seen more macro-facing, quantitatively driven reporting standards (such as the ISSB's IFRS S1 & S2) entering into force, while still maintaining inter-operability with established counterparts (like the GRI). As these newer standards continue to drive a collaborative, interdependent and increasingly evidence-based approach to environmental and social disclosures, the actions of the entire supply chain are becoming better incorporated when assessing non-financial performance. In the context of climate action, this will deliver a channel of accountability conducive for adaptation planning.

[20] United Nations, The Global Compact (2004). Who Cares Wins: Connecting the Financial Markets to a Changing World? United Nations. https://www.unglobalcompact.org/docs/issues_doc/Financial_markets/who_cares_who_wins.pdf

The EU's Corporate Sustainability Reporting Directive (CSRD) will further improve institutional and technical capacities by introducing a level of mandated cohesion between private sector best practice and national requirements. In the context of resilience building, formalised requirements and target setting like this will help to set clear boundaries on responsibilities for both the public and private sector operating as part of the trade value chain. This will include managing impacts to nature, the labour force and wider community.

To meet these increasingly stringent environmental, social and governance targets, the public and private sector will need to improve bilateral cooperation and assist each other in resource and capacity building. This will catalyse inclusive adaptation strategies that leverage comparative advantages and allow for a more comprehensive mapping of overall risk exposures - highlighting priority investment areas for resilience building. If taken up in-kind, we will see major improvements to overall institutional governance and improve collective adaptive capacity.

4.2 CAPACITY BUILDING AND MOBILISATION

Good climate change action is difficult to attribute to individual actors or country-specific initiatives. Global trade resilience building is a sum of its parts, and our collective adaptation response is only as strong as its weakest aspects. The trade value chain benefits from two types of collaborative action: horizontal coordination (integrated action across the sector) and vertical coordination (interplay between different levels of governance)[21]. Improving the operability of both these components is essential to overcoming the social, technical and financial constraints that contribute to the adaptation implementation gap.

Establishing transparency in information through data-driven resiliency exercises sit at the foundation of this process; improving channels of communication and initiating a strategic approach to target setting, information collection and monitoring, builds out the structural framework; and response coordination plays the role of facilitating action, dictating the overall capacity of the sectors' approach to climate adaptation. Therefore, managing both the horizontal and vertical coordination of resilience building necessitates public-private partnership, but more importantly mandates a synchronised approach between local, regional and national government bodies. This difficulty is historically defined by a systemic failure to engage in a multi-stakeholder approach to adaptation, especially at the local level[22].

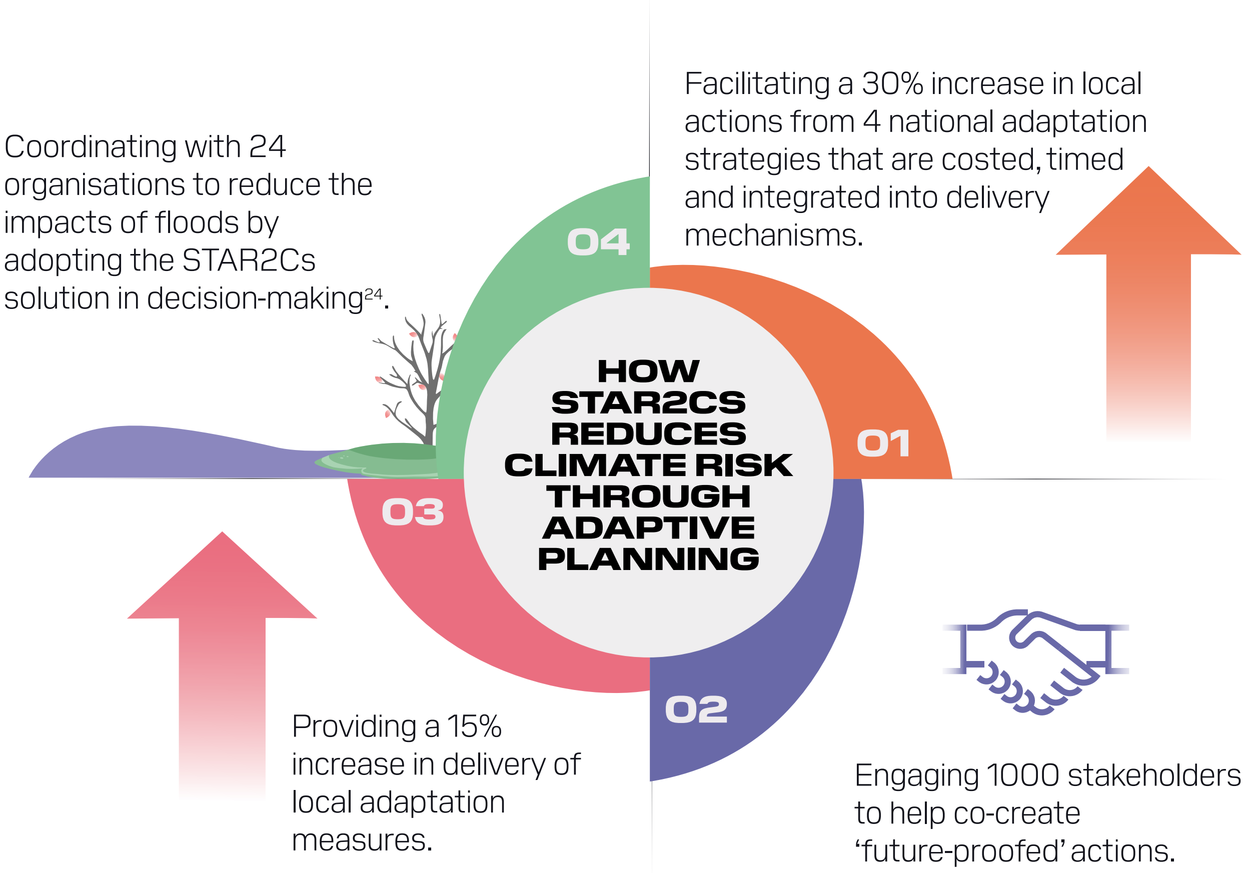
Innovative, transferable and scalable solutions must engage a wide variety of stakeholders and take responsibility for catalysing knowledge dissemination, institutional development and the ability of local entities to better participate in future-proofed decision making. An approach that engages with such a heightened level of capacity building, across a value chain as all-encompassing as global trade is difficult, but doable. The Short Term Adaptation for Long Term Resilience to Climate Change (STAR2Cs) is a working example of this and showcases how a cross-border solution to implementing adaptation measures can reduce climate risk through adaptive planning, while also actively building-up on-the-ground capacity[23]. Siloed, stand-alone initiatives are not conducive for a successful resilience building strategy and will not overcome the adaptation implementation gap, largely defined by the lack of access to financial capital.

[21] United Nations Environment Programme (2021). Adaptation Gap Report 2020. https://unepccc.org/wp-content/uploads/01/2021/adaptation-gap-report-2020.pdf

[22] Short Term Adaptation for Long Term Resilience to Climate Change. https://www.interreg2seas.eu/en/star2cs

[23] European Regional Development Fund. 2020. Star2Cs Routes to Resilience: Reducing climate risk through adaptive planning

STAR2Cs involves eight organisations and over two thousand stakeholders from England, France, Belgium-Flanders and the Netherlands. By doing so, it has identified social, financial, technical and ecosystem-based approaches to deliver cost-effective adaptation, delivering a 15% reduction in future costs from flooding by:



Star2Cs is replicable. Multi-sectoral, inter-governmental, yet localised, approaches like it will help to address some of key the underlying challenges that have contributed to a growing adaptation finance gap[25]. Well planned, collaborative large-scale climate resilience solutions will help to mobilise capital by giving governments an opportunity to anchor investment opportunities, reducing perceived and real risks and thus crowding-in further private sector investment. In turn, this will strengthen both horizontal and vertical response coordination and the ability for resiliency efforts to permeate across the trade sector.

[24] Short Term Adaptation for Long Term Resilience to Climate Change. https://www.interreg2seas.eu/en/star2cs

[25] United Nations Environment Programme (2021). Adaptation Gap Report 2020. https://unepccc.org/wp-content/uploads/01/2021/adaptation-gap-report-2020.pdf

5 | CONCLUSION

Effective climate action comprises of two twin pillars: climate mitigation and climate adaptation. As efforts across the global trade sector are made to strengthen deep decarbonisation, particularly in areas of renewable energy transition, low-carbon fuel alternatives and equipment electrification, resilience in the short to medium term will depend on improving the overall adaptive capacity of the institutions, infrastructure and social networks that drive trade's day-to-day operations.

Our global Asset Resiliency Study, as explored in this whitepaper, centres DP World's roots in the P&T industry to illustrate the growing importance of taking a systematic, data-driven and science-based approach to managing the increasingly erratic impacts of extreme weather events - as driven by a changing climate. Together with our partners from Jupiter Intelligence and Guidehouse, DP World has been able to better understand our climate risk exposure across several IPCC-aligned climate scenarios. While it has been heartening to note that our P&T portfolio is not projected to be substantially impacted by climate change, the exercise has highlighted the potential for increased downtime across the trade sector in the years leading up to 2050, and in the absence of action, certainly in the years leading up to 2100.

As showcased, global trade is an interdependent network comprising not only of the ports and terminals industry, but also shipping, logistics, construction and a wider array of other upstream and downstream supply chain partners. Downtime disruptions across any of these segments will have systemic impacts on the sector at large[26]. Given that DP World's operations rely on the long-term health of the complete trade value chain; susceptibility to knock-on delays and other business impacts, due to gaps in the sectors collective climate-change preparedness, present hidden vulnerabilities that cannot be accounted for in independent assessments.

Appropriately considering potential risks to ancillary infrastructure, workers and communities that make up our wider urban or peri-urban spatial footprint will require buy-in from industry peers, government partners, civil society and local authorities. Transparency and a willingness to collaborate is an essential aspect of the way forward.

By leveraging readily available climate modelling and forecast data, we, as the global trade community, can work together to comprehensively map our present level of adaptation readiness. In taking this first step, we will have set out a baseline from which to respond in a targeted manner, promoting collective responsibility and preventing siloed, uncoordinated efforts that will only serve to increase the risk of maladaptation.

Moreover, in collating such a comprehensive data set, the trade sector will be better poised to address the social, technical and financial barriers to adaptation. This will inform better governance practices that empower local-level participation, improve channels of accountability between public and private sector entities and assume an evidenced-based approach to monitoring and pre-empting collective best practice; allowing us to pave the way to climate change resilience.

[26] Verschuur, J., Koks, E.E., 1,2 & Hall, J.W. (2023). Systemic risks from climate-related disruptions at ports, Nature Climate Change, https://doi.org/10.1038/s01754-023-41558-w

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Guidehouse is a leading global provider of consulting services to the public sector and commercial markets, with broad capabilities in management, technology, and risk consulting. By combining our public and private sector expertise, we help clients address their most complex challenges and navigate significant regulatory pressures, focusing on transformational change, business resiliency, and technology-driven innovation. Across a range of advisory, consulting, outsourcing, and digital services, we create scalable, innovative solutions that help our clients outwit complexity and position them for future growth and success. The company has more than 16,500 professionals in over 55 locations globally. Guidehouse is a Veritas Capital portfolio company, led by seasoned professionals with proven and diverse expertise in traditional and emerging technologies, markets, and agenda-setting issues driving national and global economies.

Jupiter is the trusted leader in climate risk analytics for organizations looking to strengthen their climate resilience. The increasing frequency and severity of extreme weather events across the globe are having a major impact on economies, businesses, and communities. With forward-focused, rigorous methodologies, and analytics delivered by some of the best scientists in the industry, Jupiter turns gold standard climate science into actionable data. Customers proactively assess the physical risks in their portfolios, address regulatory requirements and evaluate potential reputational concerns.