CLIMATE RISKS

Near-term transition risks and longer-term physical climate risks of greenhouse gas emissions pathways

climateworks FOUNDATION

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CLIMATE RISK

Policy, business, finance, and civil society stakeholders are increasingly looking to compare future emissions pathways across both their associated physical climate risks stemming from increasing temperatures, and their transition climate risks stemming from the shift to a low-carbon economy. Here we present an integrated framework to explore near-term (to 2030) transition risks and longer-term (to 2050) physical risks.

This deck is a companion to an article in Nature Climate Change and part of a wider collaboration between:

- Grantham Institute - Climate Change and the Environment, Imperial College London
- Center for Global Sustainability, University of Maryland
- Joint Global Change Research Institute, Pacific Northwest National Laboratory
- Department of Meteorology, University of Reading
- Met Office Hadley Centre
- ClimateWorks Foundation

TRANSITION RISKS

can occur when moving toward a less polluting, greener economy. Such transitions could mean that some sectors of the economy face big shifts in asset values or higher costs of doing business.

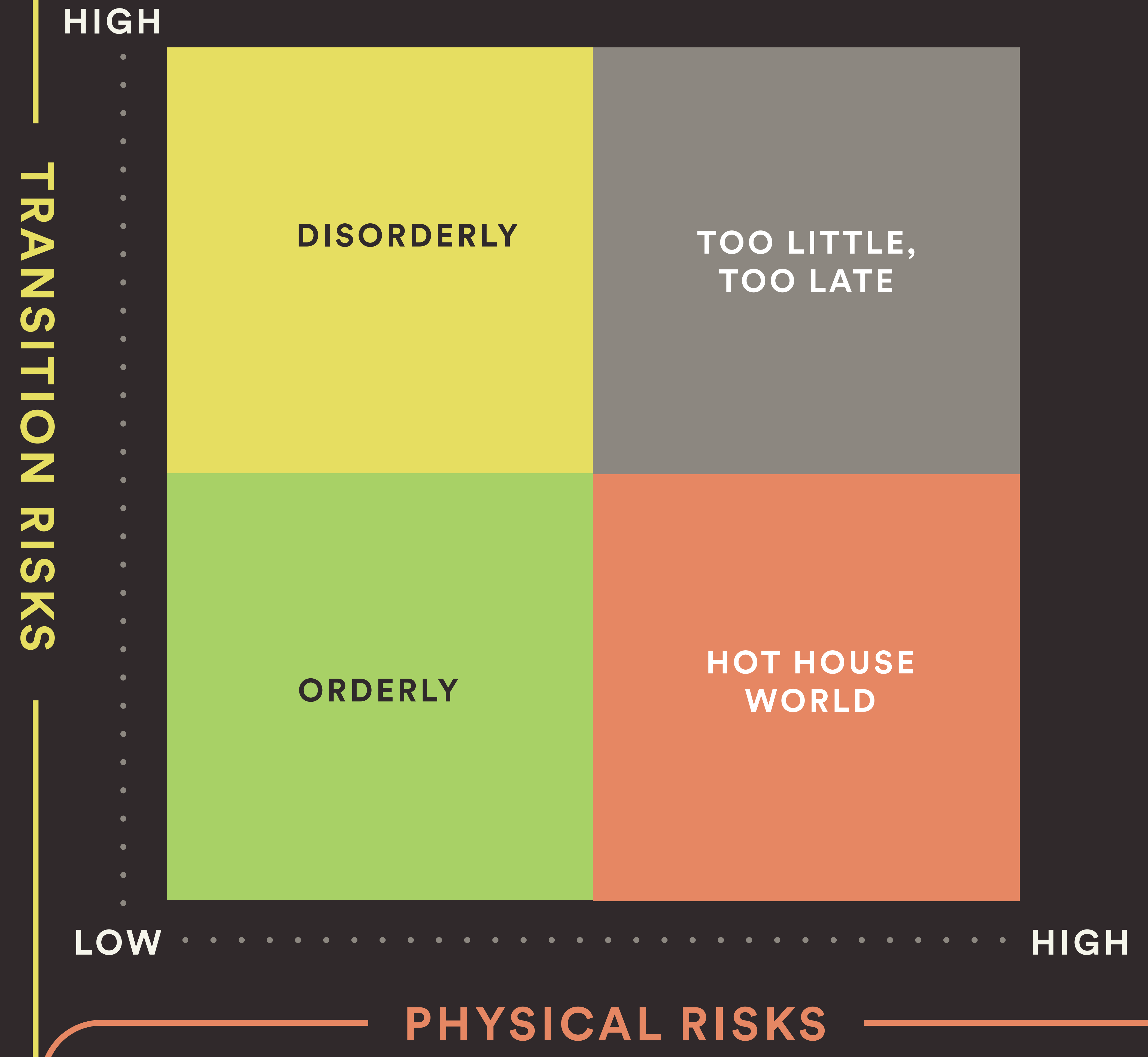
PHYSICAL RISKS

result from climate change, which means we may face more frequent or severe weather events like flooding, droughts, and storms.

In 2019, the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) published its first comprehensive report with a call to action to financial players to consider both transition and physical risk as they relate to climate change. The June 2020 report provided a conceptual framework and a call to create analytical toolsets for assessing these risks, as well as an initial set of climate scenarios.

The scenarios presented here fall within this framework while carrying the research further by adding more scenario variants, particularly around intended temperature change outcomes, as well as around the technological, socio-economic, policy, and orderliness aspects of scenarios. These new scenarios therefore help broaden the exploration of the future of climate risk.

RISK WITHIN NGFS



FRAMEWORK

Measuring physical and transition climate risks

We combine a technology-rich, regionally disaggregated, integrated assessment model (IAM) representing energy systems, agricultural and land-based greenhouse gas emissions, a simplified climate model to simulate probabilistic global temperature changes over the 21st century, and a suite of impact models to estimate regional climate-related physical hazards deriving from the temperature change pathways and their underlying socio-economics.

Together, these models allow for evaluation of the regional hazard and impact attributes of physical hazard indicators, and a set of transition-risk indicators related to transitions to different long-term temperature outcomes. Each metric is evaluated across an ensemble of scenarios used to explore a range of temperature outcomes as well as socio-economic and technological choices for a set of pathways to 2ºC of warming by 2100. This provides a holistic, self-consistent assessment of physical and transition risk across each of a wide range of plausible scenarios.

SEE METHODS SECTION ▶
for more detail

SCENARIOS IN CONTEXT

11 scenarios are used to explore a range of temperature outcomes as well as socio-economic and technological choices for a set of pathways to 2ºC of warming.

NO POLICY

No new policies from a 2010 baseline mirroring a "hothouse world" reaching ~4ºC of warming by 2100.

NDC PLEDGES

Includes nationally determined pledges (NDC) from 2015 to 2030 and continued trend to 2100 reaching ~3ºC.

2.5ºC

Same as the 2ºC Central but orderly, coordinated transition to higher temperature outcome of 2.5ºC.

2ºC CENTRAL

A transition starting in 2025 that is compliant with 2ºC of warming, with full technology portfolio using Middle of the Road, SSP2.

2ºC NDC

An enhanced NDC Pledges scenario with rapid mitigation toward a 2ºC target after 2030.

2ºC FRAGMENTED

Different start dates of 2ºC with early action for some regions and later action for others.

2ºC SSP1

Alternative underlying socio-economics to 2ºC Central and focus on greater resource efficiency and energy efficiency.

2ºC SSP3

Alternative underlying socio-economics to 2ºC Central with more challenging mitigation entailing greater disruption and transition risk.

2ºC RES

Same as 2ºC Central but with higher renewables (wind and solar).

2ºC NUC CCS

Same as 2ºC Central but with higher utilization of nuclear and carbon capture and sequestration technology.

1.5ºC

An orderly, ambitious, and coordinated transition to 1.5ºC of warming, using a range of options. See report for details.

SCENARIOS IN CONTEXT

For ease of communicating the results, we focus on a subset of the scenarios in order to illustrate our key findings. More analysis of the fuller set can be found in the publication.

1.5°C

An orderly, ambitious, and coordinated transition to 1.5°C of warming, using a range of options. See report for details.

2°C CENTRAL

A transition starting in 2025 that is compliant with 2°C of warming, with full technology portfolio using Middle of the Road, SSP2.

2.5°C

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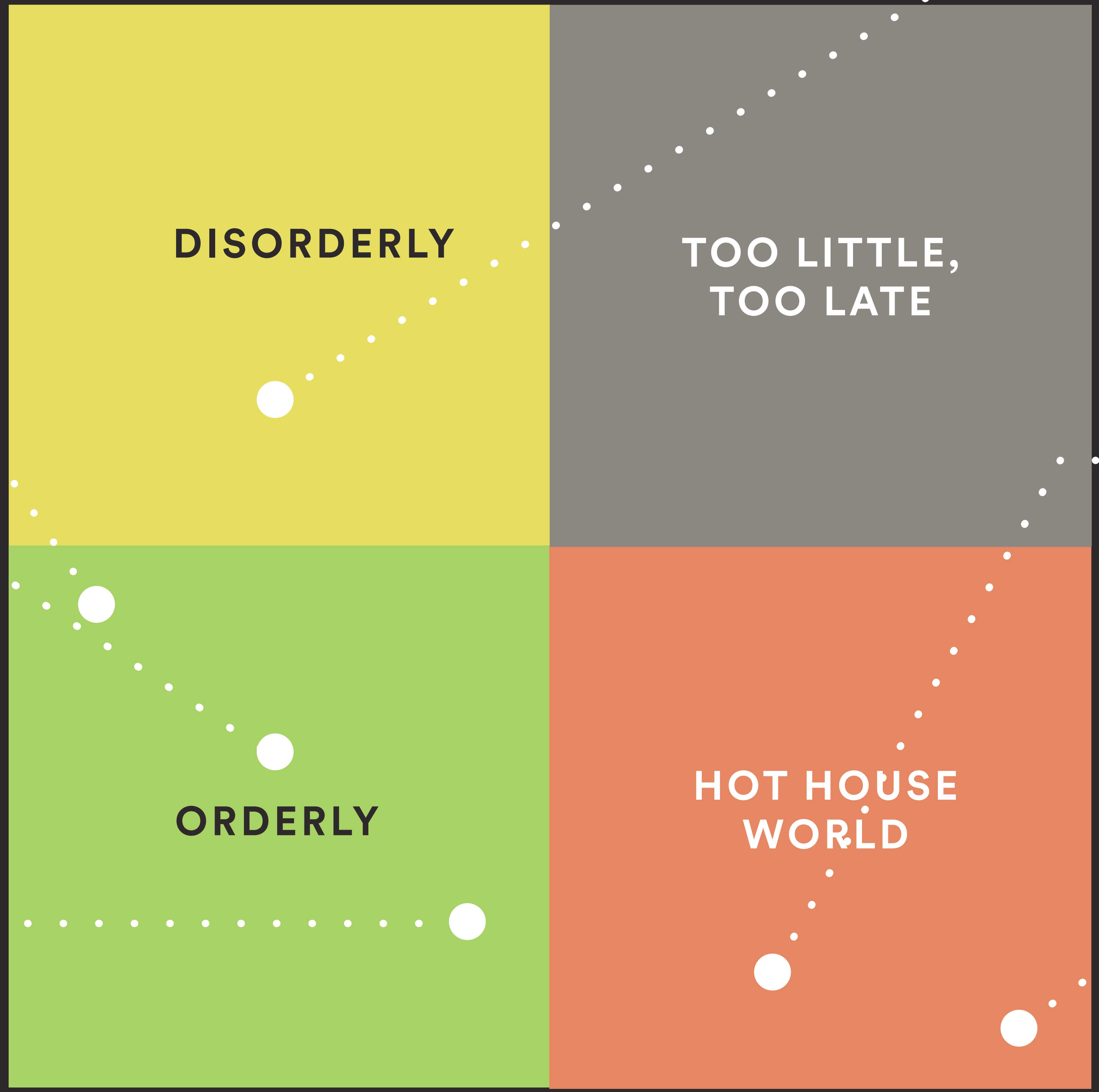

2°C FRAGMENTED

Different start dates of 2°C with early action for some regions and later action for others.

NDC PLEDGES

Includes nationally determined pledges (NDC) from 2015 to 2030 and continued trend to 2100 reaching ~3°C.

NO POLICY

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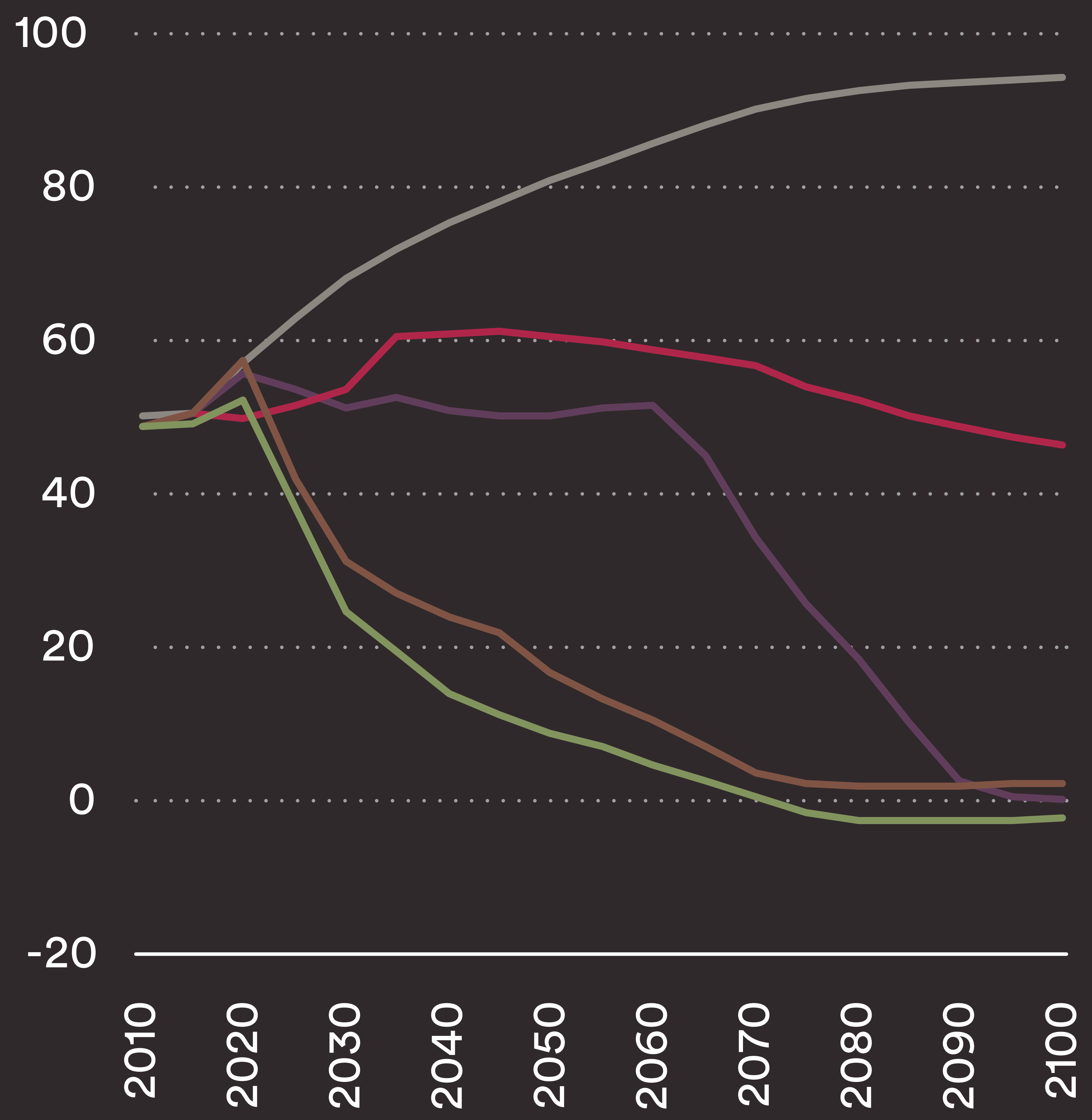
TRANSITION RISKS

TRANSITION RISKS

SCENARIO KEY: No Policy | NDC Pledges | 2.5°C | 2°C Central | 1.5°C

Global annual GHG emissions ($Gt\ CO_2e/year$)



Future transitions can differ in myriad ways. For transition risks, we utilize readily available metrics from IAMs to capture the most salient transition risk-related variables. We draw from a range of low-carbon transition indicators as well as those that track the feasibility of the transition (see next slide for descriptions). And while IAMs offer numerous additional metrics, we see these seven chosen metrics as illustrative of this wider transition. Ultimately, any risk assessment would need to narrow on more granular data, so these results should be seen as a start to this process.

We focus on the 2030 time horizon because emissions pathways of the various scenarios diverge in the near-term so that by 2030 there are significant differences in the values of metrics used to assess transition risk (see figure). And though differences exist across all time periods, nearer-term actions set in motion path dependencies for physical risks that might be assessed in later time periods. It is important to note that, while these example measure are indicative of the overall additional resource cost of decarbonizing by 2030, these abatement costs alone do not capture all macro-economic consequences, if, for example, it results in a net investment, innovation, and growth stimulus to the economy. After all, while there is certainly risk involved in a global economic transition, there is also opportunity.

TRANSITION RISKS

ECONOMY-WIDE ABATEMENT COST

A measure of macro-economic risk affecting all production and consumption activities.

CARBON PRICE

A high carbon price will place additional production costs on carbon-intensive industries, reducing profits.

REDUCTIONS IN GHG EMISSIONS INTENSITY OF GDP

A rapid reduction in emissions intensity indicates a potentially disruptive transition.

FOSSIL FUEL DEMAND REDUCTIONS

If this decreases rapidly, it signals a disruptive shift away from established industries.

COAL PLANT CAPACITY REDUCTIONS

An indicator of lost capital and lost jobs in coal power and upstream sectors (i.e., mining, distribution).

ELECTRICITY PRICES

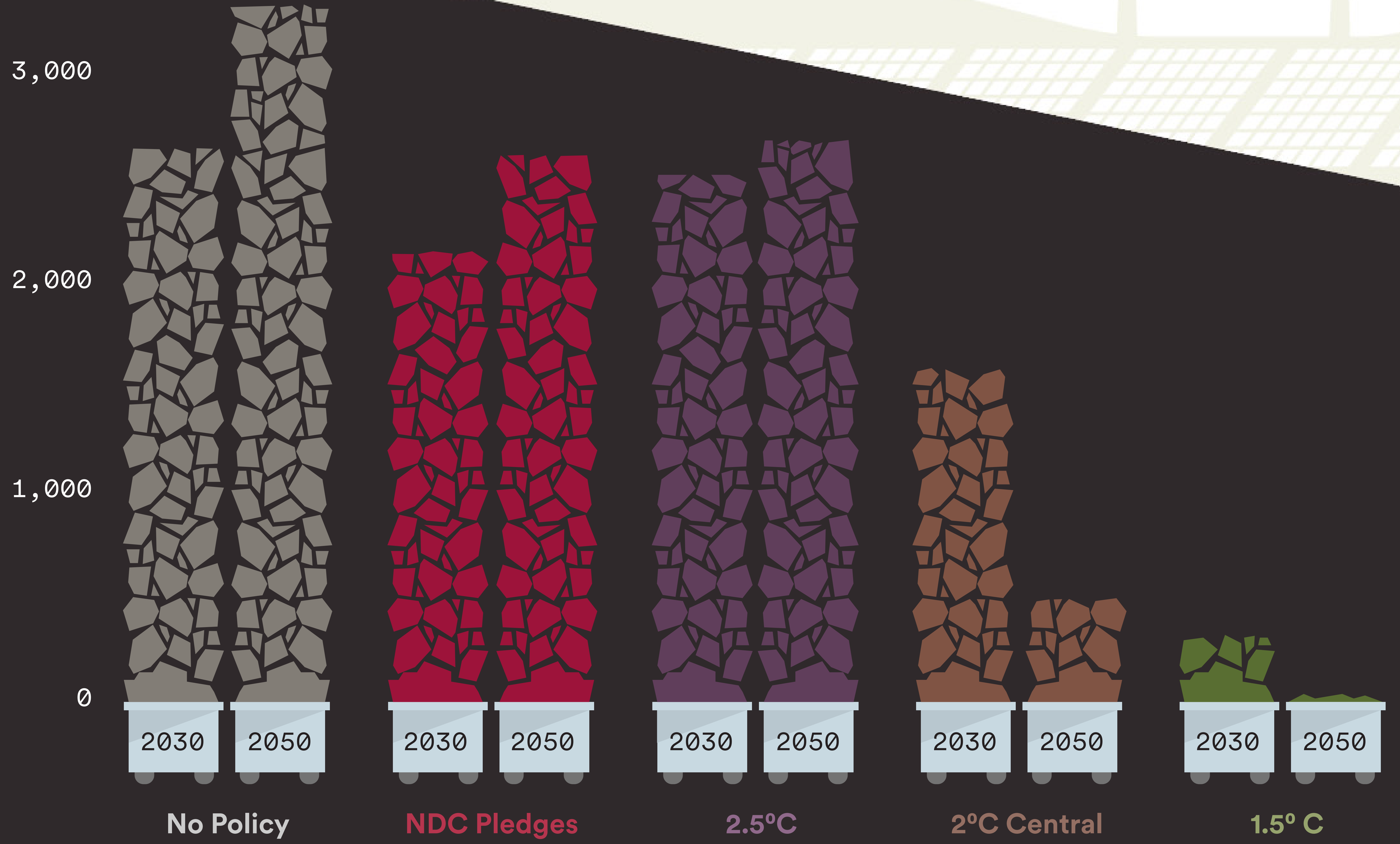
A rapid increase in electricity price could be associated with rising business and household energy bills and disruption.

CROP PRICES

Rising household food prices indicate lower ability to service debt.

TRANSITION RISKS: GLOBAL COAL PLANT CAPACITY (GW)

Significant near-term transition risks to specific business sectors could result from carbon prices, regulations, and potential stranding of carbon-intensive assets such as coal-fired power stations. This would have a ripple effect due to lost capital and jobs in the coal power and upstream distribution and mining sectors, as well as impacts to those communities where such activity occurs. Here we see the global decline of coal plant capacity by 2030 and how that sets in motion further reductions by mid-century.



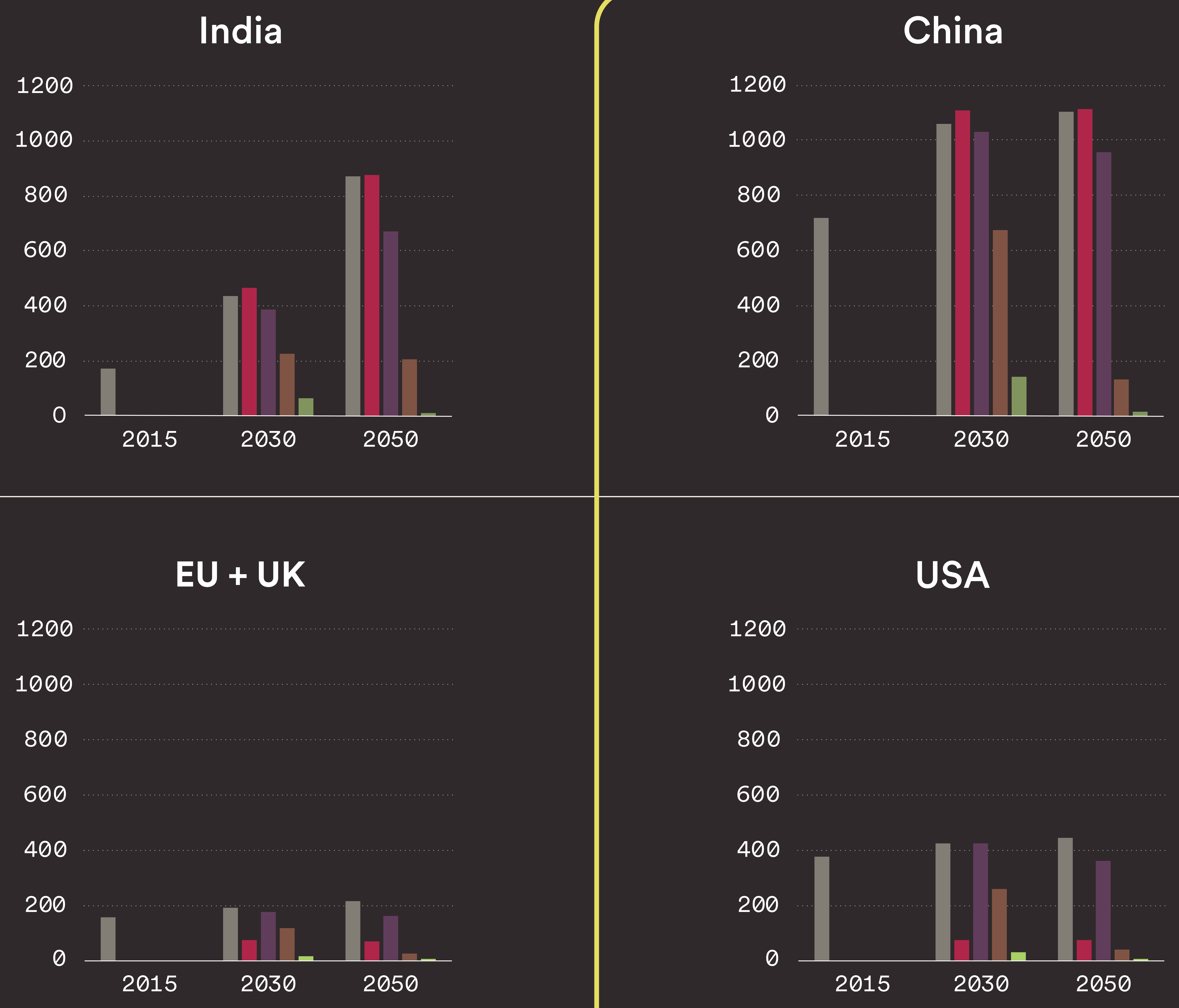
COAL PLANT CAPACITY BY COUNTRY (GW)

However, global estimates hide the nuance seen within individual geographies.

- For traditional thermal coal, in 2030 it is slightly more persistent in some regions (e.g., India and China in a 2°C Central scenario).
- But in a 1.5°C scenario, these are wiped out by 2050.
- Other regions see declines at a faster pace.

SCENARIO KEY

- No Policy
- NDC Pledges
- 2.5°C
- 2°C Central
- 1.5°C



TRANSITION RISKS

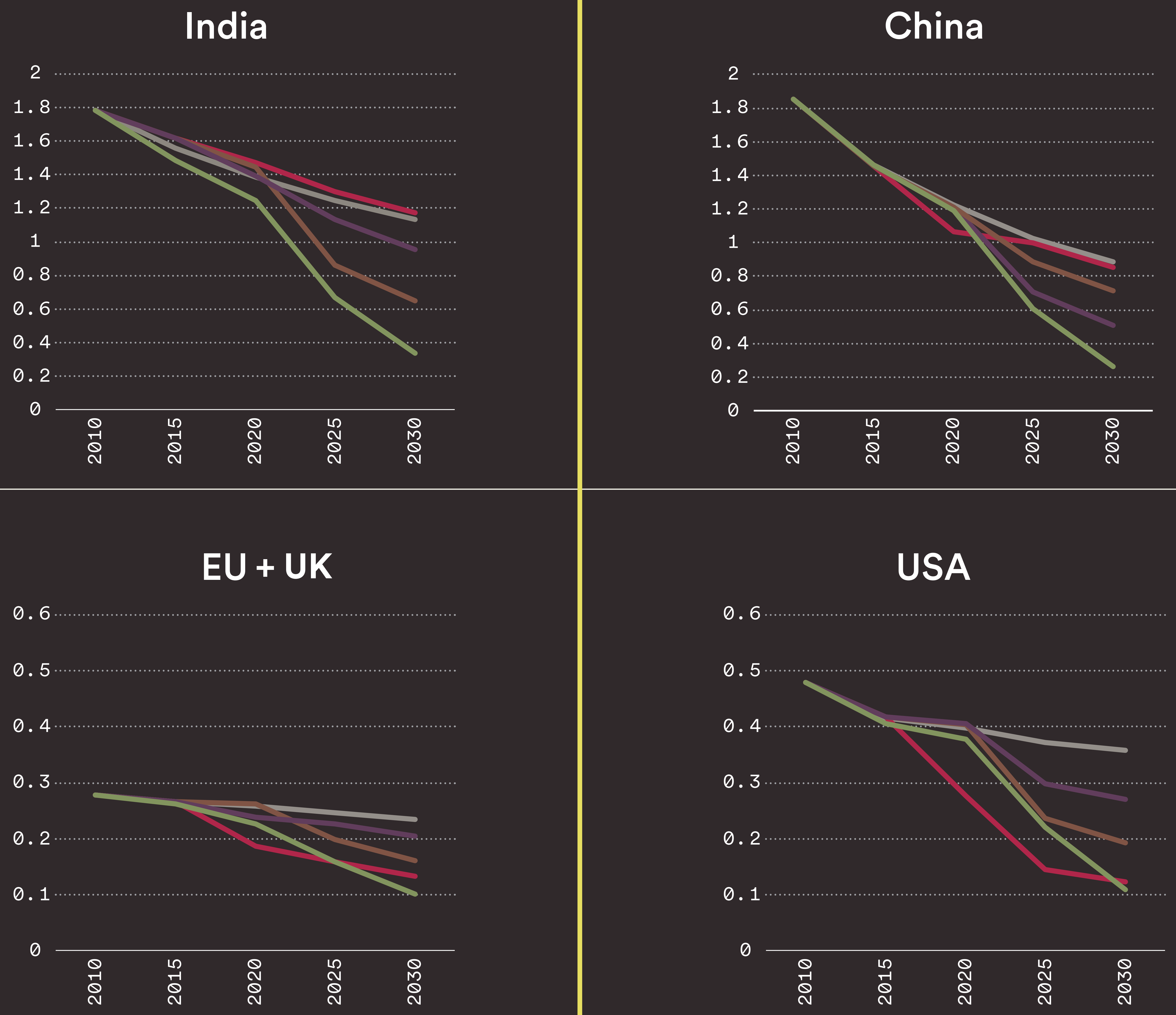
EMISSIONS INTENSITY OF GDP (MT CO_2-E / BILLION USD2010)

The change in emissions intensity of GDP is illustrative of the overall transition of an entire economy. It is a measure of macro-economic risk affecting all production and consumption activities.

- Regions can vary significantly when compared to historical values.
- While useful as a macro-economic metric, it can hide nuance of the pace of the transition seen in individual sectors (e.g., service sector-oriented economies look very different from more industrial economies).

SCENARIO KEY

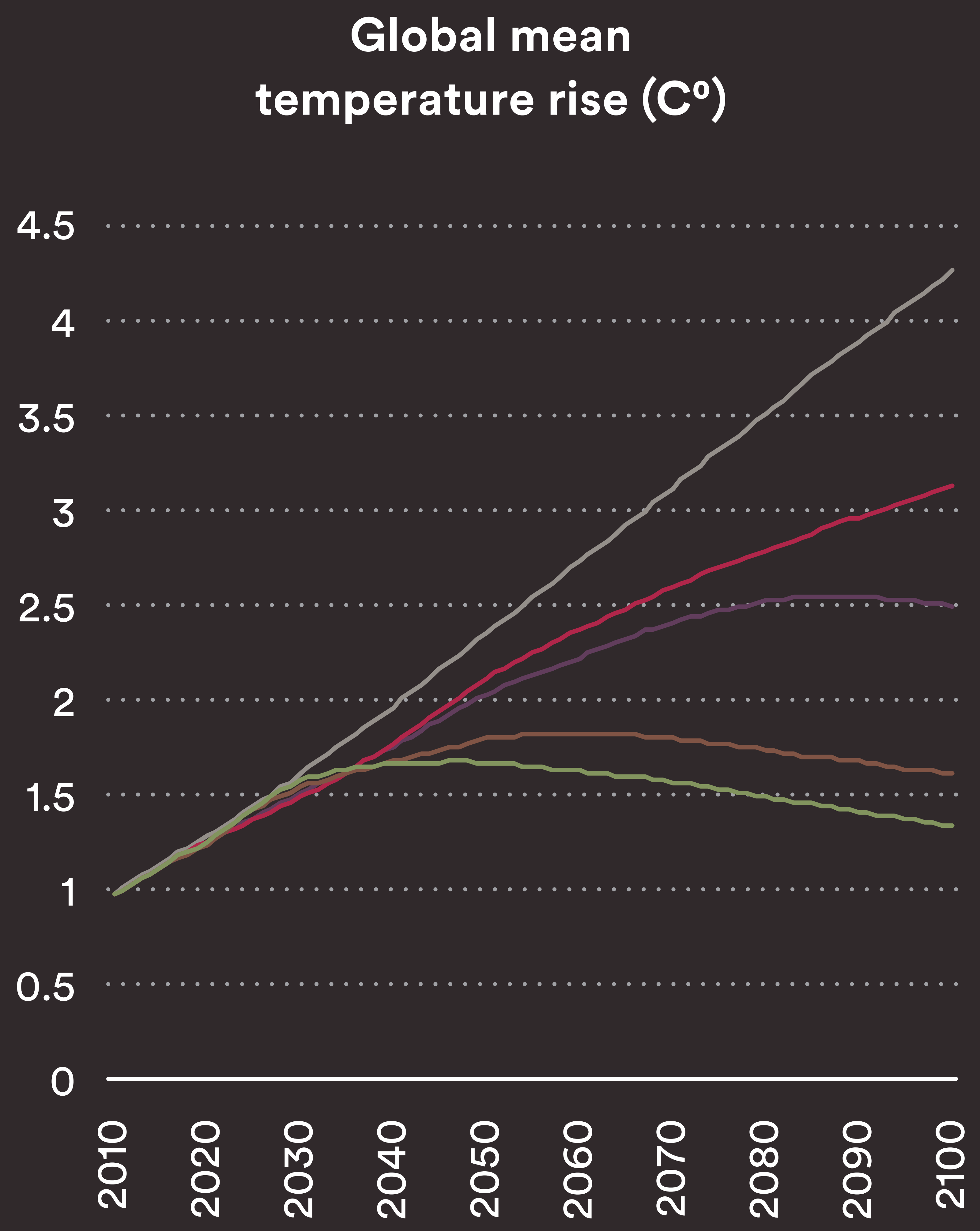
- No Policy
- NDC Pledges
- 2.5°C
- 2°C Central
- 1.5°C



PHYSICAL RISKS

PHYSICAL RISKS

SCENARIO KEY: No Policy | NDC Pledges | 2.5°C | 2°C Central | 1.5°C



Potential exposure to future physical risks can also widely differ between scenarios. Metrics of physical risk have been presented in the climate change literature, relating to major impacts from climate change, categorized as either gradual and chronic, or acute and extreme event-driven. We utilize regional hazard and impact attributes of seven physical hazard indicators (see next slide). These indicators are calculated using a suite of impact modeling at a high resolution (0.5x0.5°) and then averaged to the regional scale – thus representing the regional average likelihood or change in duration at a point in the region. Most indicators are expressed as likelihoods and can be interpreted as acute risks, since they characterize the chance of an extreme event happening each year, but average annual change in crop growth duration is a chronic risk.

As with transition risks, a thorough risk assessment would need to narrow on more granular data included in the more detailed high-resolution modeling, and we first display such results and later provide the geographic averages.

For physical risks, we focus on 2050 because, unlike transition risks that can vary widely in the nearer term, physical risk variations between scenarios become apparent later on. This is due to inertia. Essentially, nearer-term temperature increases between scenarios differ only slightly by 2030, but by 2050 (and thereafter), there are big enough differences to evaluate physical risk (see figure on temperature outcomes).

PHYSICAL RISKS

HEAT WAVE

Heatwaves adversely impact human health and wellbeing. The heatwave definition used here currently occurs in around 35% of years.

MAJOR HEAT WAVE

The major heatwave definition used here currently occurs in around 5% of years.

RIVER FLOOD

River flooding causes direct and indirect losses to health, livelihoods, and economic assets. The flooding defined here currently occurs in 2% of years.

HYDROLOGICAL DROUGHT

Water resource droughts affect supplies of water to people and industry. The drought defined here currently occurs in around 6% of years.

AGRICULTURAL DROUGHT

Agricultural droughts affect crop yields, farmer livelihoods, and food security. The drought defined here currently occurs in around 10%-12% of years.

HEAT STRESS FOR MAIZE

High temperatures at critical points in the growing season can adversely affect crop yields. The current chance varies considerably.

GROWTH DURATION

Reduction in time to crop maturity due to higher temperatures would result in lower yields.

PHYSICAL RISKS: MAJOR HEAT WAVES

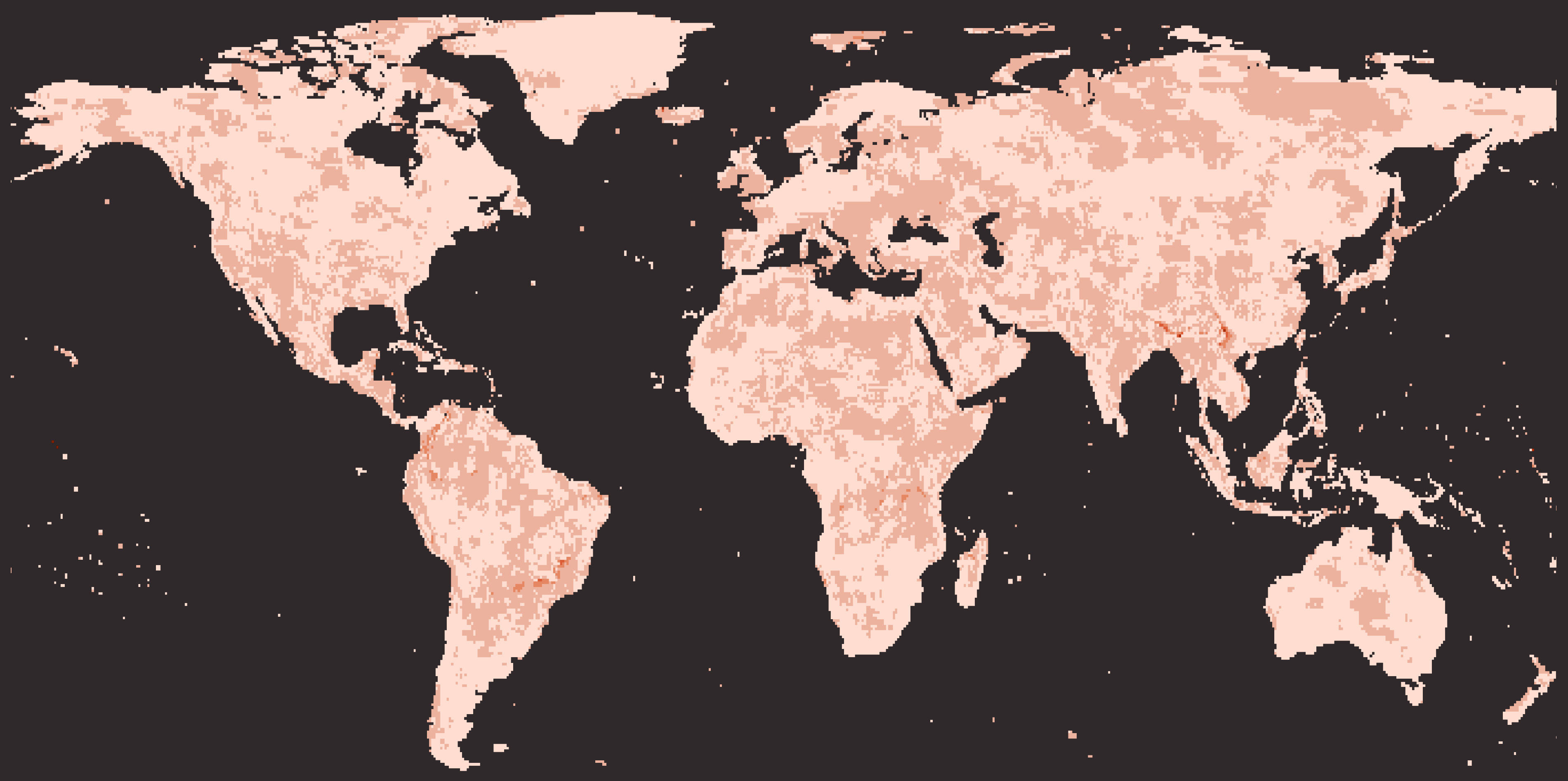
These maps shows the annual likelihood in 2050 of major heatwaves in each region, which occur with a global average likelihood of 5% today.

- All scenarios see a rise in risk for heat waves.
- Globally, the average is increased to 32% in a 1.5ºC scenario, and greater than 50% in an No Policy scenario.
- Significant differences exist within regions and global medians can hide these.

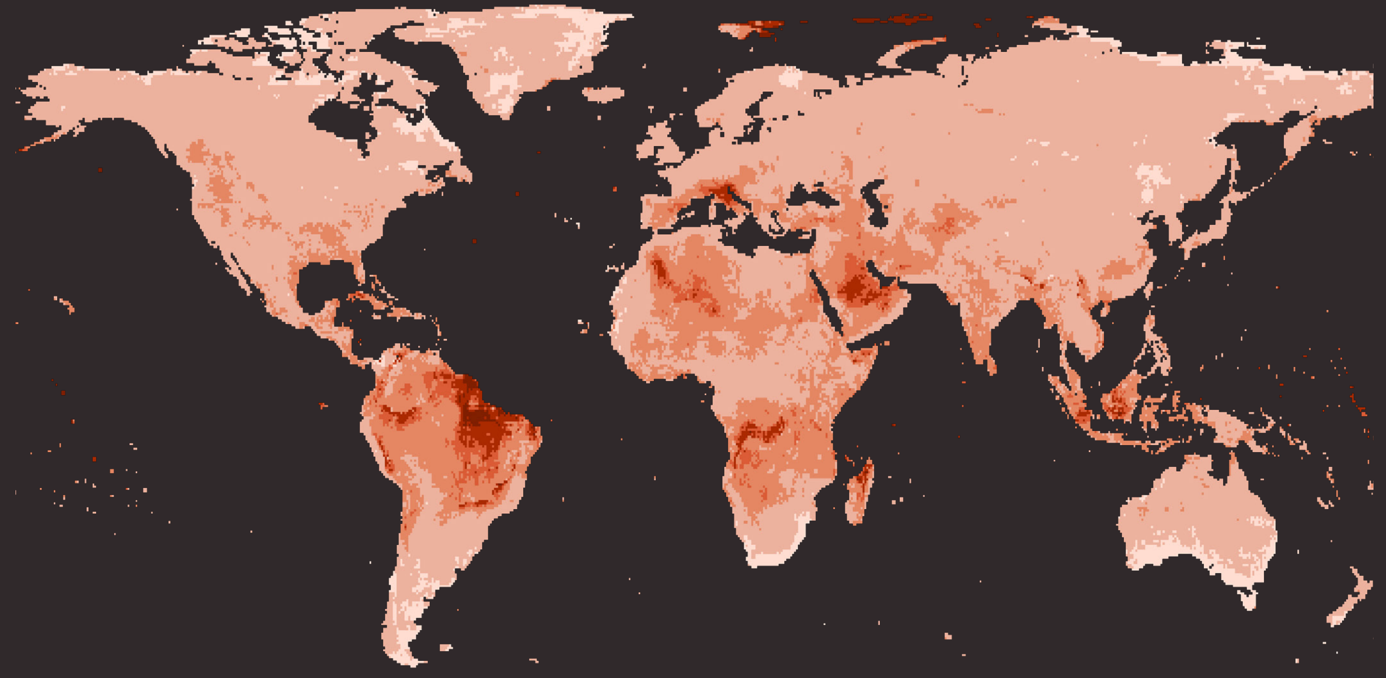
SCENARIO KEY

- 0 - 25%
- 35 - 50%
- 50 - 65%
- 65 - 80%
- 80 - 95%
- 95 - 100%

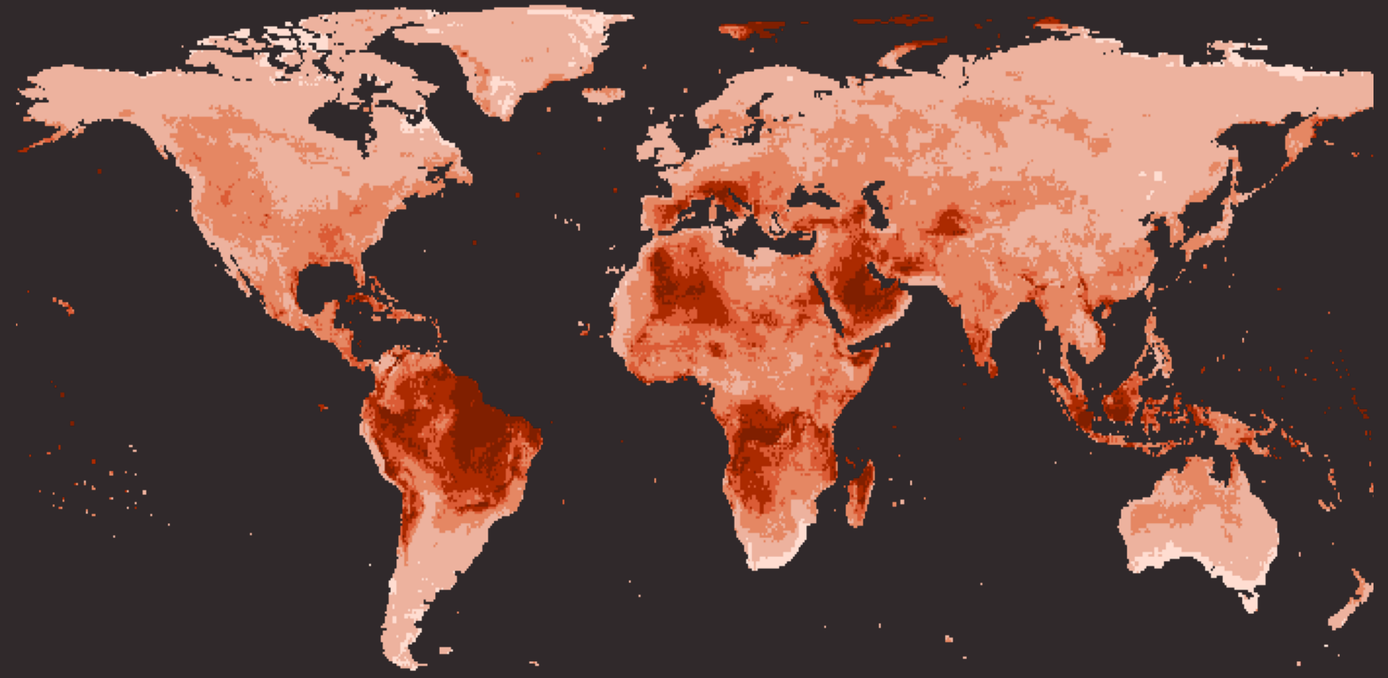
Chance of major heatwave today



Chance of major heatwave in 2050 in a 1.5ºC Scenario



Chance of major heatwave in 2050 in a No-Policy Scenario



PHYSICAL RISKS: AGRICULTURAL DROUGHT

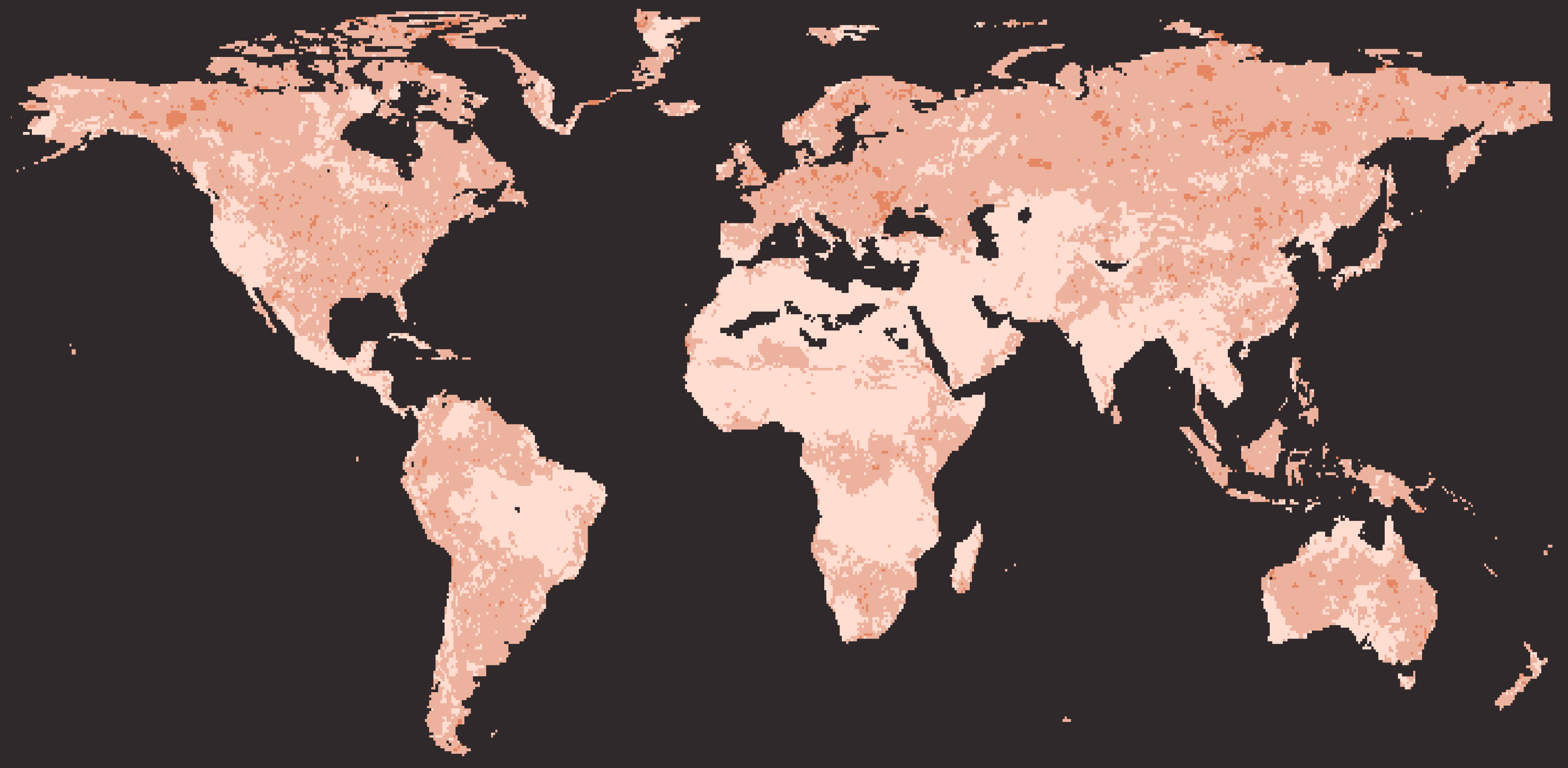
The maps show percent change in occurrence for agricultural drought (compared to a benchmark average from today of 10-12%).

- All scenarios see a rise in risk for drought.
- All regions and sub-regions see a rise in risk for drought.
- Globally, the average is increased to 25% in a 1.5ºC scenario, and to 39% in an No Policy scenario.

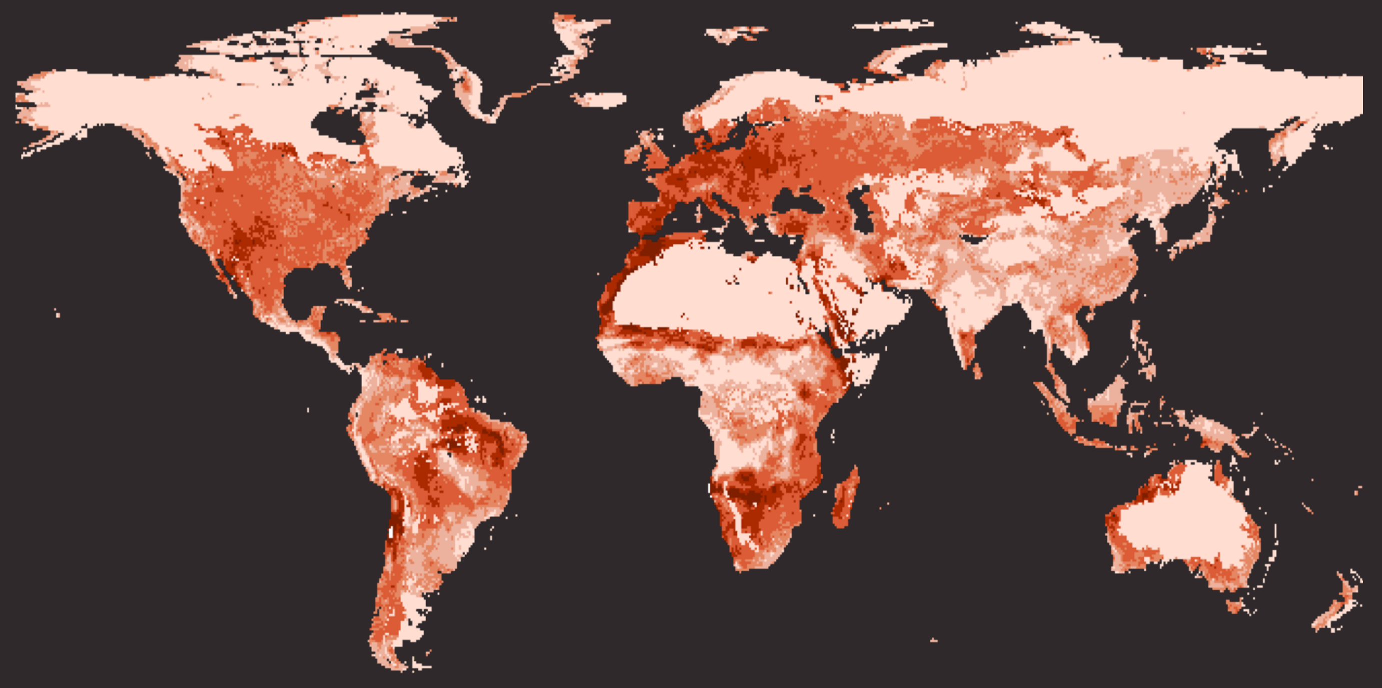
SCENARIO KEY

- 0 - 10%
- 10 - 20%
- 20 - 30%
- 30 - 50%
- 50 - 70%
- 70 - 100%

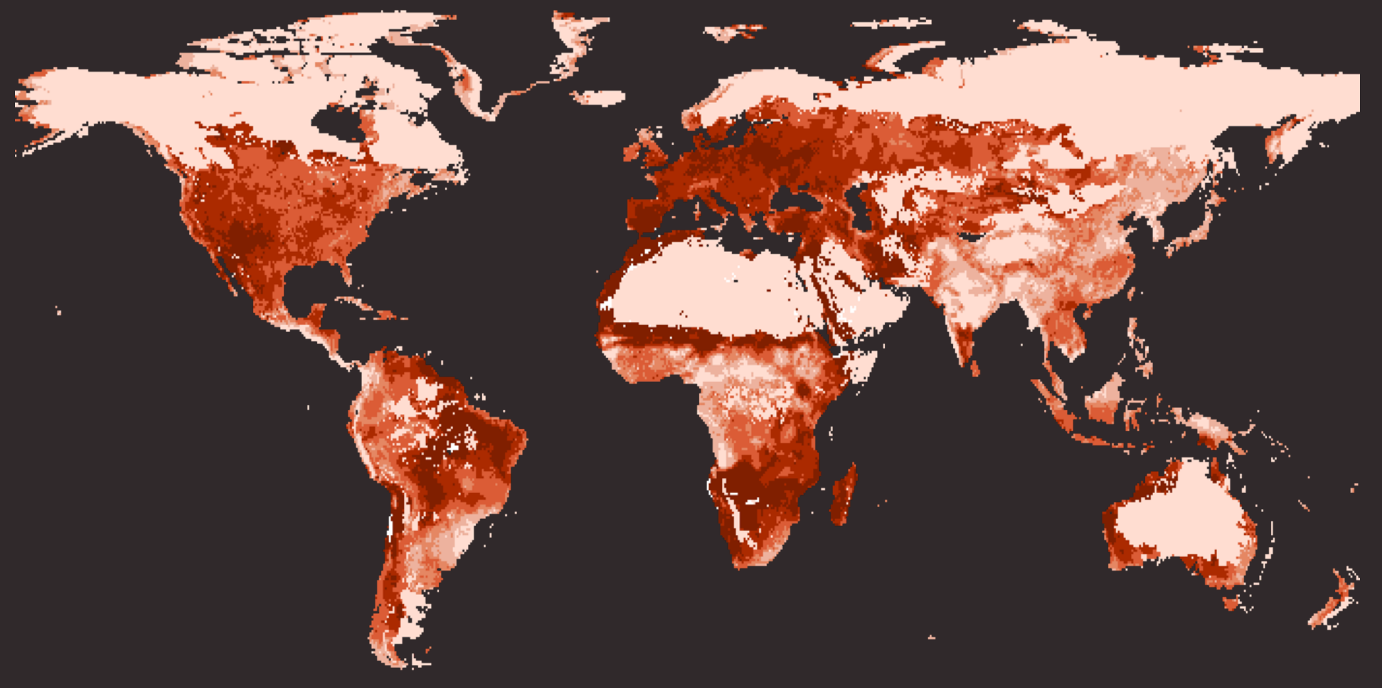
Chance of drought today



Chance of drought in 2050 in a 1.5ºC Scenario



Chance of drought in 2050 in a No-Policy Scenario



GEOGRAPHIC INSIGHTS

Moving from the global to regional data reveals variation across both transition risk in 2030 and physical risk in 2050. Though complicated, viewing the full set of metrics side by side allows one to take into account a wider set of insights that might be overlooked while evaluating a metric in isolation.

NORMALIZED METRICS

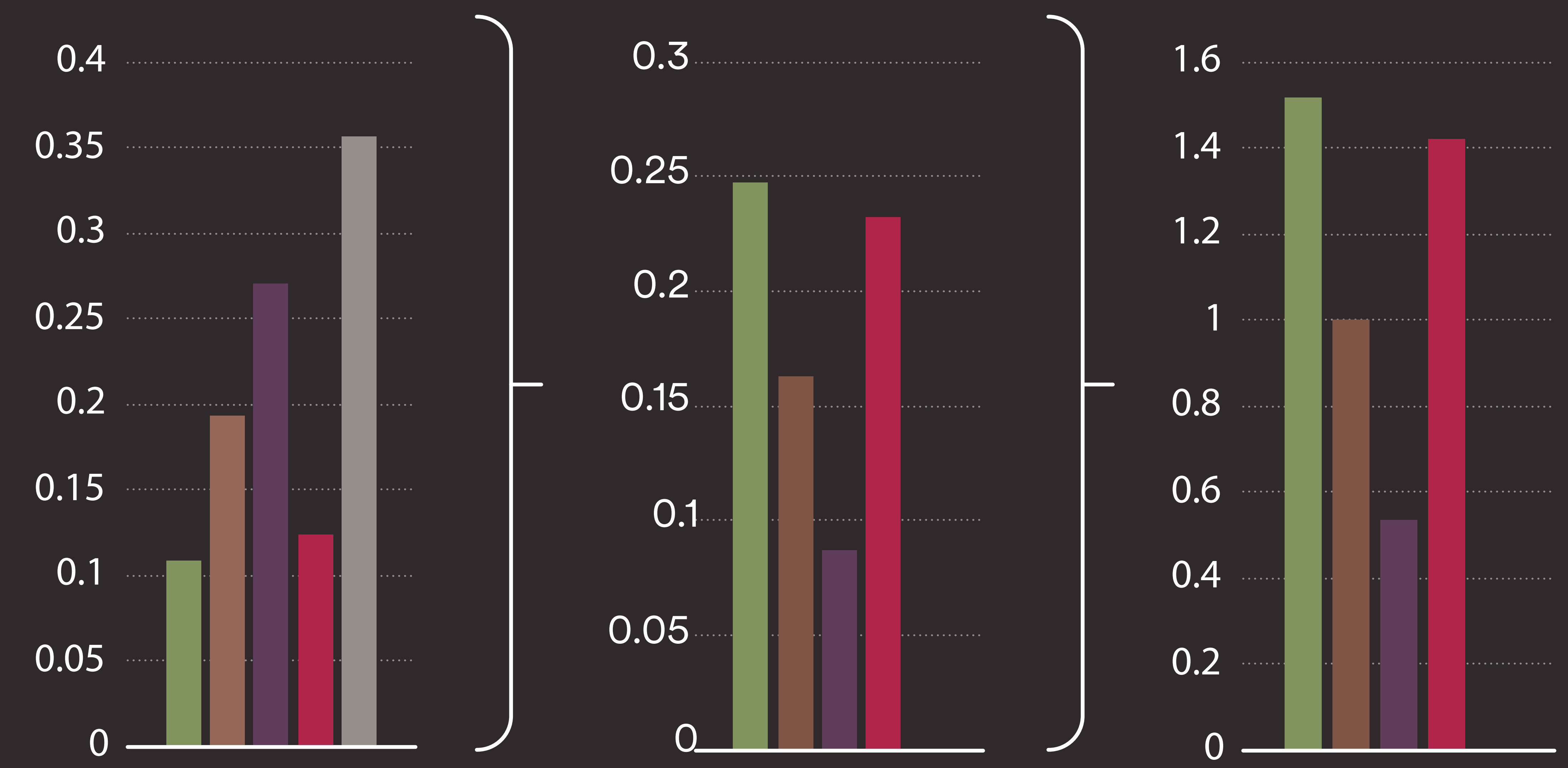
SCENARIO KEY:
No Policy | NDC Pledges | 2.5°C | 2°C Central | 1.5°C

TRANSITION METRICS

The outputs from the integrated assessment model are downscaled for a particular region for the year 2030 (a time period with significant divergence in outcomes). Each outcome is then compared to what might occur in a No-Policy scenario, which is considered lower risk in the sense that it implies a business-as-usual pathway and thus has a value of zero. These are then normalized by comparing the differences to the 2°C Central pathway. This is repeated across metrics.

In the case below, the normalized USA GHG Intensity comparison shows higher risk for both the NDC Pledges and the 1.5°C scenarios and lower risk for 2.5°C and No-Policy scenarios, in comparison to the 2°C Central scenario.

2030 USA GHG Intensity | **Difference to No-Policy** | **Normalized: (2°C =1)**

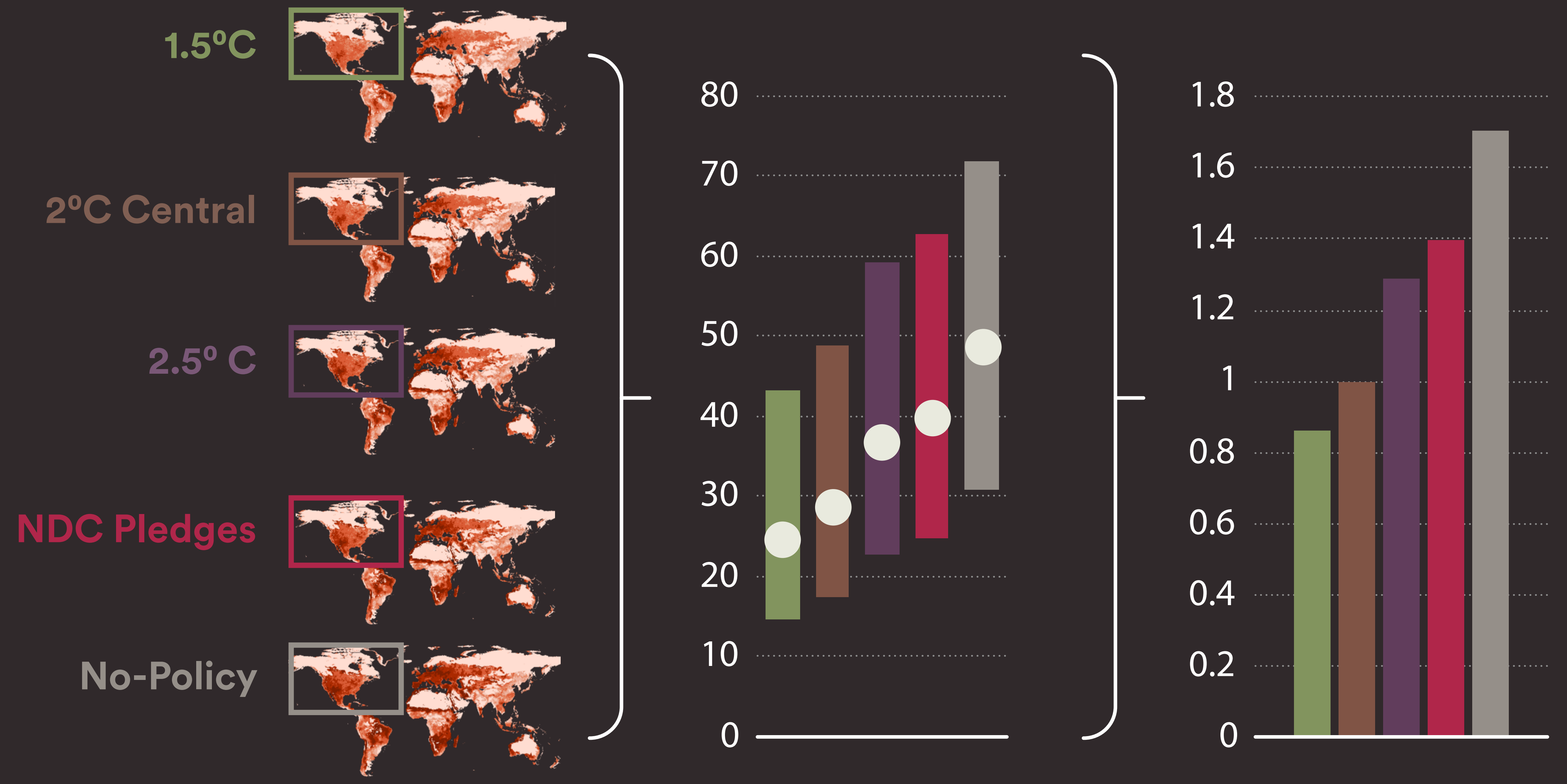


PHYSICAL METRICS

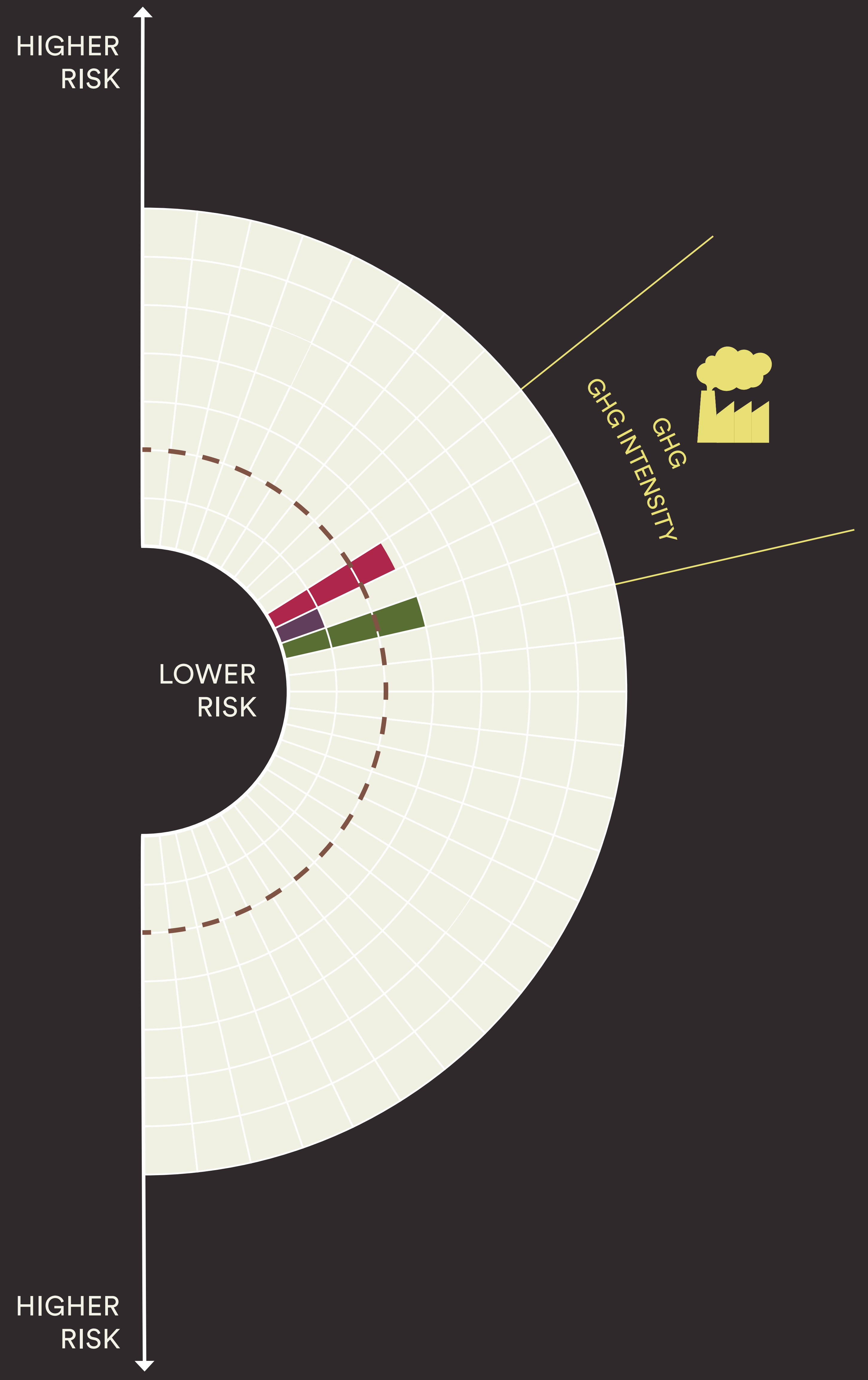
The outputs from the impact models are downscaled for a particular region for the year 2050 (note that earlier time periods see little divergence and later years see greater). These are then normalized by comparing the ratio outcomes to the Central 2°C pathway so that the value shows the percent change in comparison to this scenario. This is repeated across all physical impact metrics.

In the case below, the normalized chance for drought comparison shows higher risk for the No-Policy, NDC, and 2.5°C scenarios and lower risk for 1.5°C scenario, in comparison to the 2°C Central scenario.

2050 Global -%Chance drought | **2050 USA - %Chance** | **Normalized: (2°C =1)**



TRANSITION RISKS
in 2030



HOW TO READ CHARTS

SCENARIO KEY:

No Policy | NDC Pledges | 2.5°C | 2°C Central | 1.5°C

IMPORTANT:
Results are compared to the 2°C Central scenario

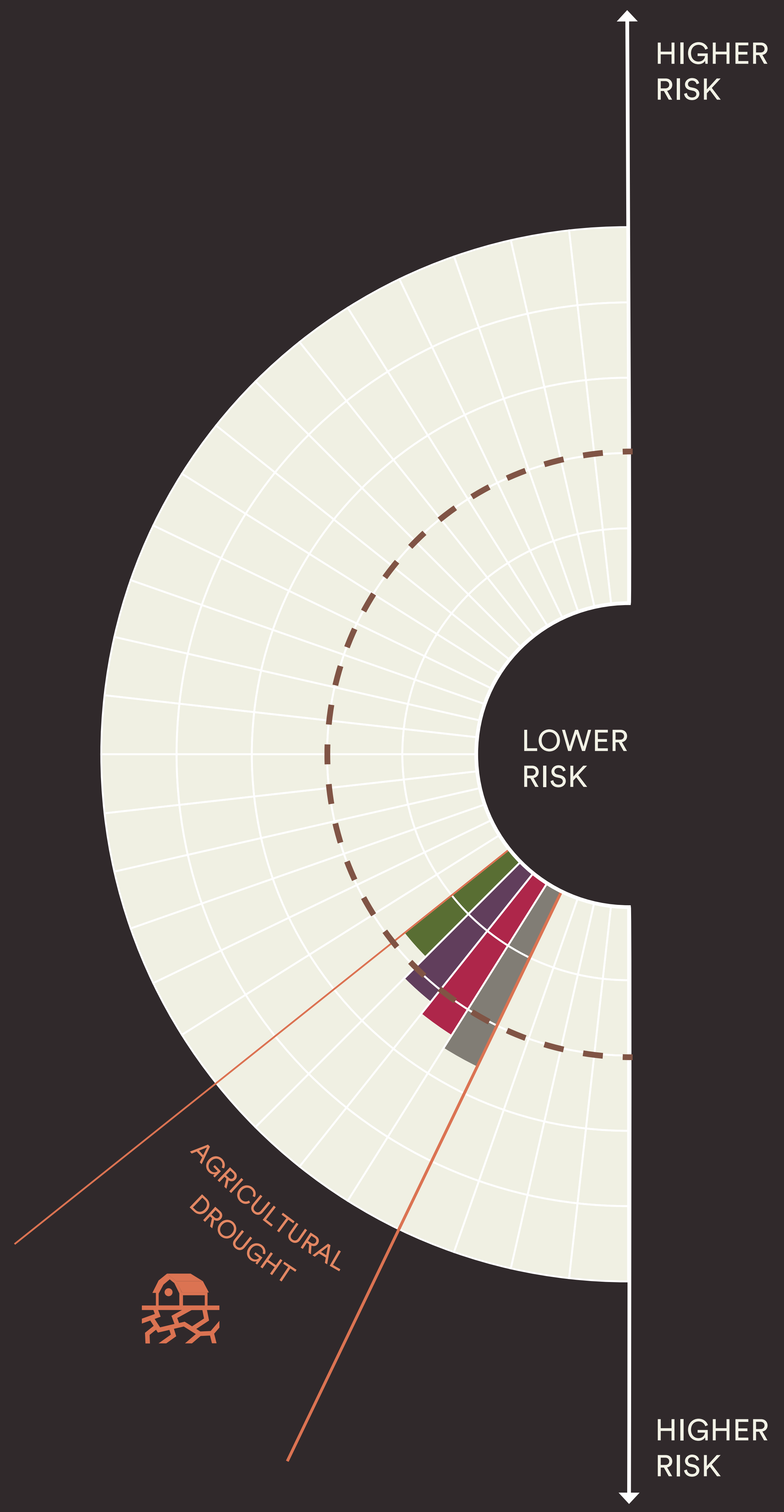
The metrics (for both the physical and transition risk metrics) are expressed as a ratio of each scenario's value compared to the value for the 2°C Central scenario. This means that the 2°C scenario always has a value of 1 (or 100%) and a value for another scenario that is higher or lower corresponds with an increase or decrease in potential risk.

These plots provide a sense of the relativity between scenarios of the severity of risk for each individual metric but shouldn't be compared across metrics. A more detailed analysis would be required for such an assessment. Instead, showing all metrics at once allows one to identify areas for further exploration.

Each ring represents a 50% change in value, in comparison to the 2°C Central scenario. For transition risks, we show values for 2030 where there is significant divergence in the scenario spread due to early versus delayed or limited action. For physical risk, we show values for 2050 where there is also significant spread in outcomes for different emissions and associated temperature pathways.

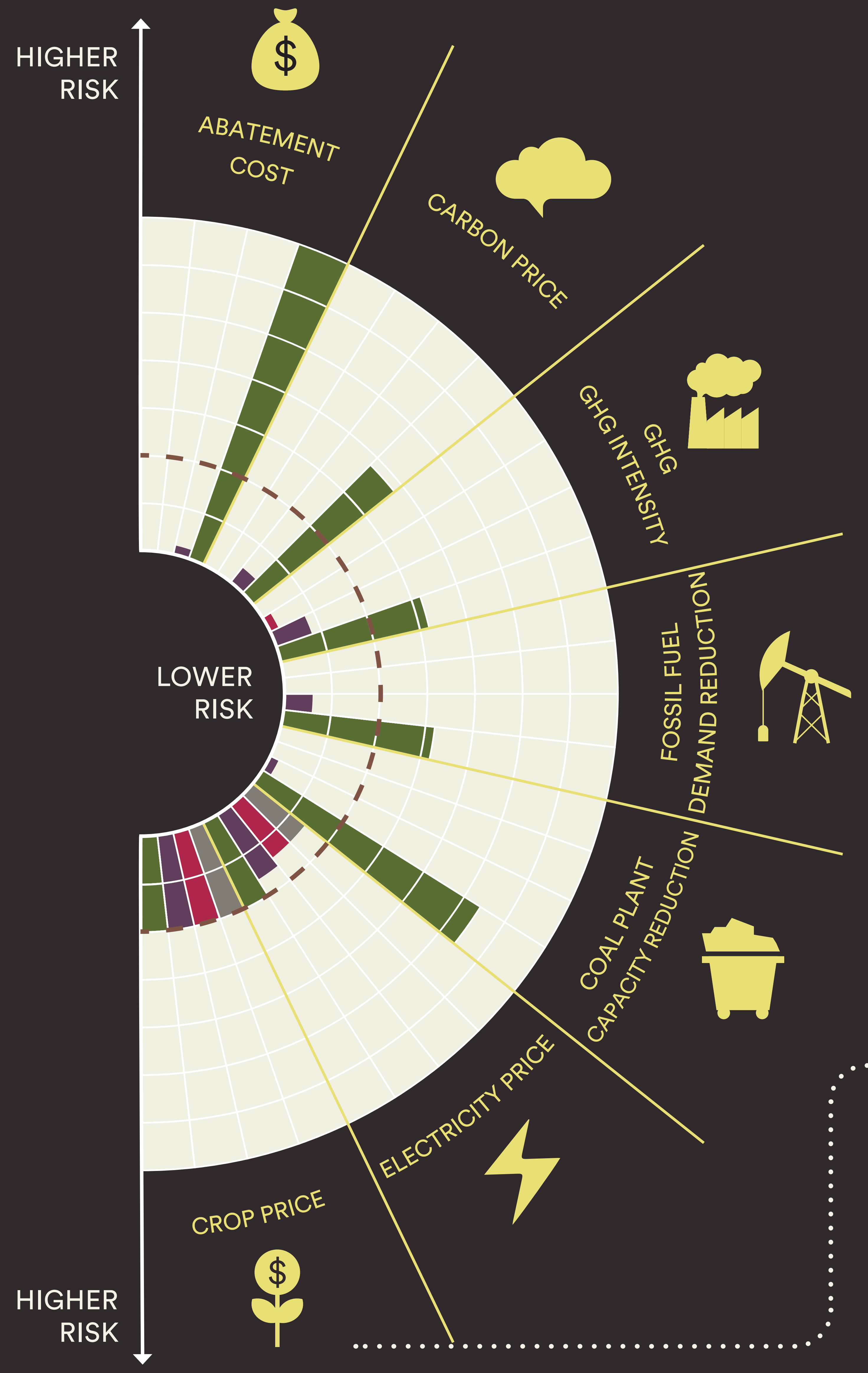
In these examples, the GHG intensity on the left shows that in a 1.5°C scenario (in green) the reduction in intensity by 2030 is around 50% greater that the 2°C scenario (brown dashed line). And for drought, on the right hand side, we see a different outcome as the 1.5°C scenario corresponds with a roughly 15% decrease in potential drought in 2050, in comparison to this 2°C scenario.

PHYSICAL RISKS
in 2050



CHINA

TRANSITION RISKS
in 2030

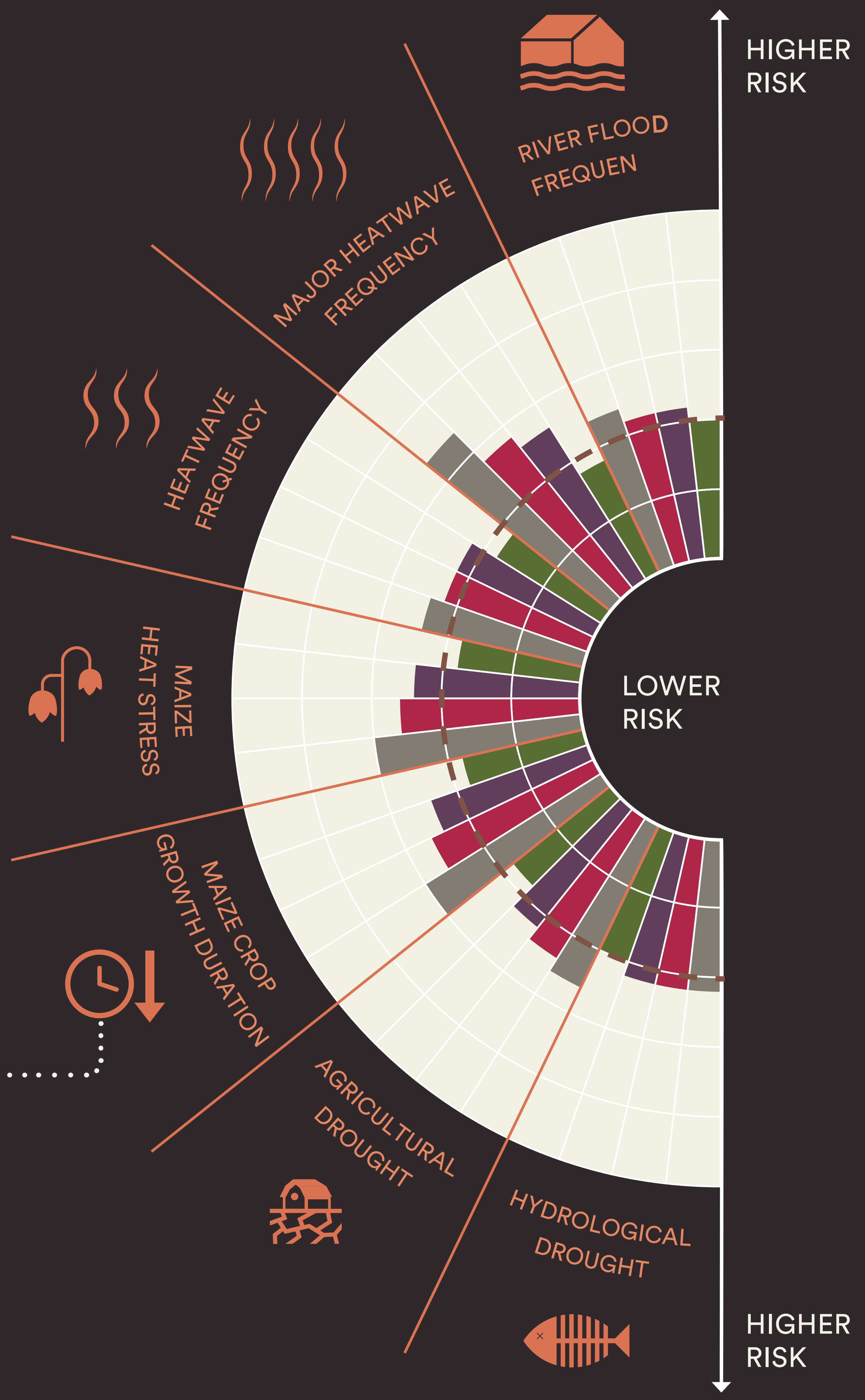


While most transitions are higher in a 1.5°C scenario, agricultural prices are reasonably uniform.

SCENARIO KEY:

- No Policy
- NDC Pledges
- 2.5°C
- 2°C Central
- 1.5°C

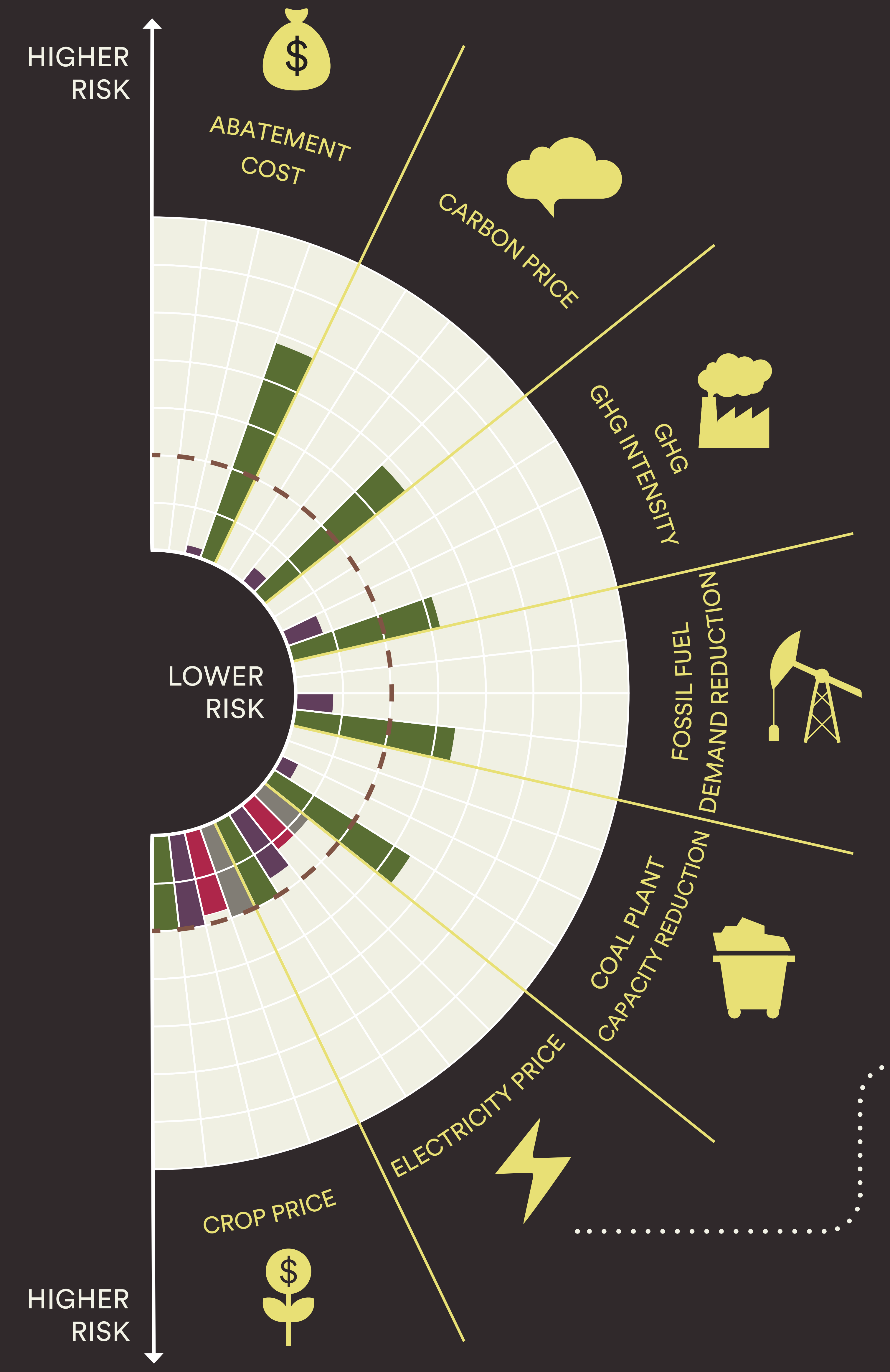
PHYSICAL RISKS
in 2050



Higher risk is associated with higher temperatures, and for China, a shorter growing season could be a major concern.

INDIA

TRANSITION RISKS
in 2030

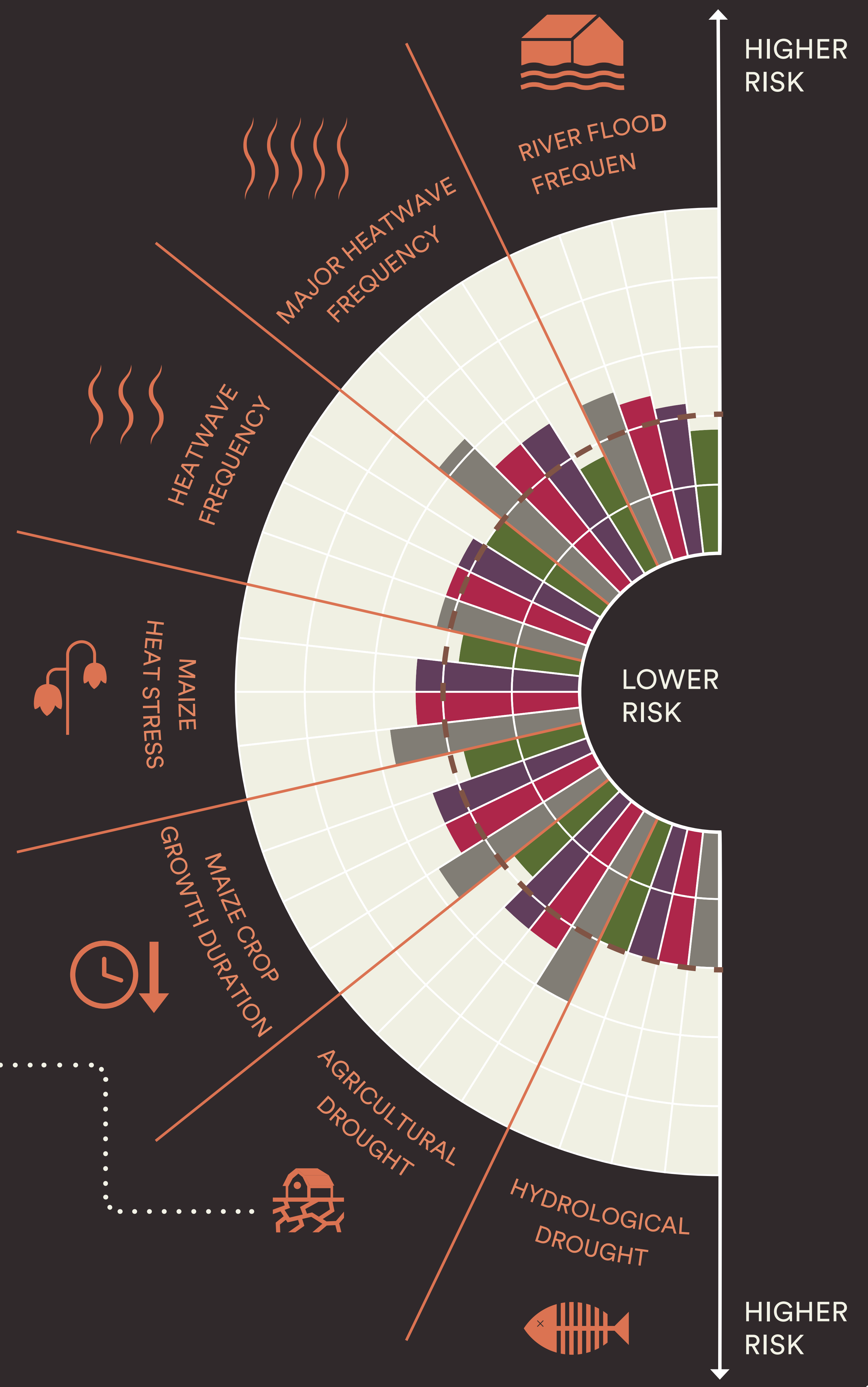


SCENARIO KEY:

- No Policy
- NDC Pledges
- 2.5°C
- 2°C Central
- 1.5°C

Electricity prices are only moderately lower in No Policy and NDC Pledge sceanrios.

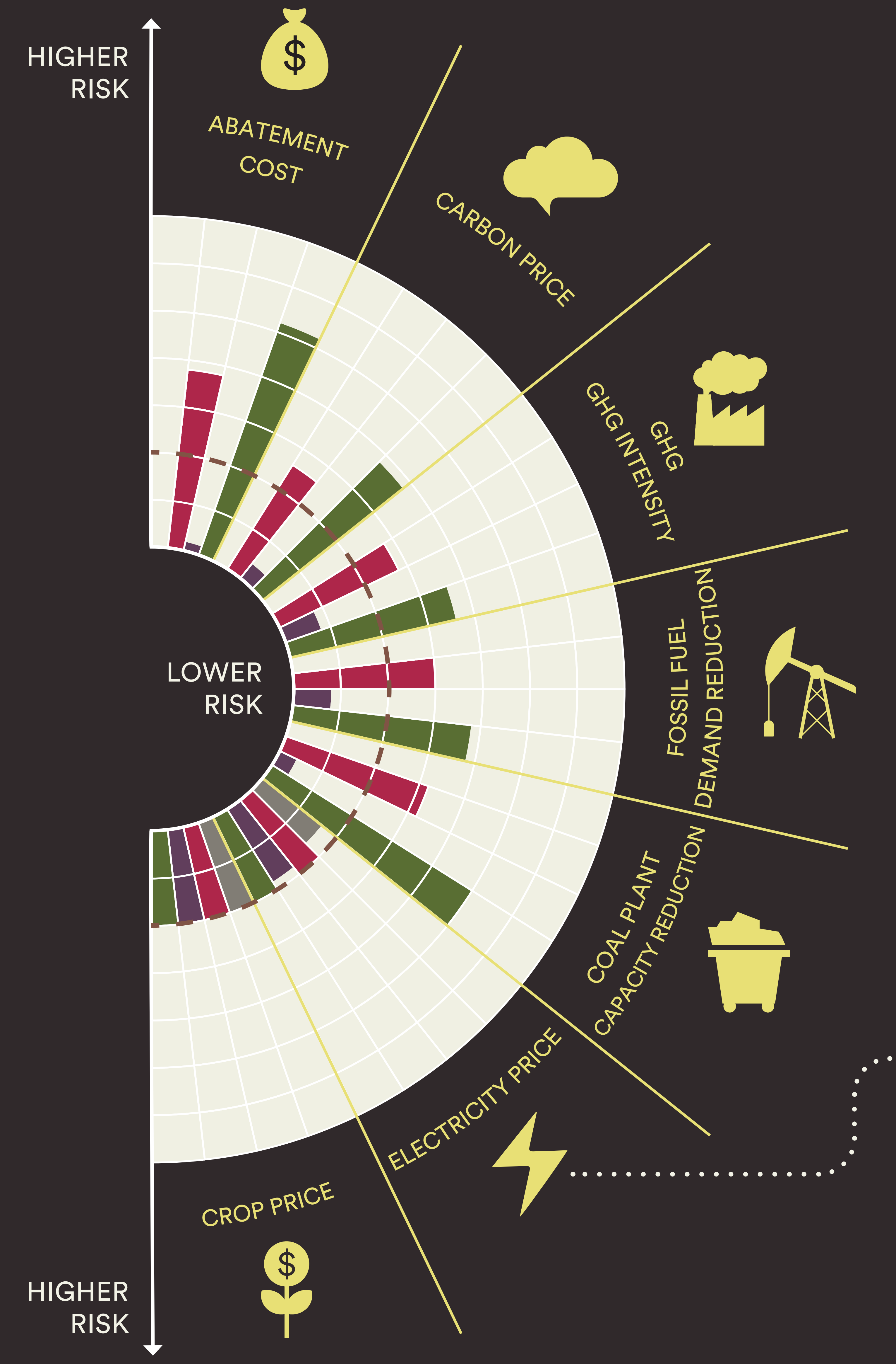
PHYSICAL RISKS
in 2050



Higher risk is associated with higher temperatures, and for India, a growing risk of agricultural drought could be a major concern.

EU+UK

TRANSITION RISKS
in 2030

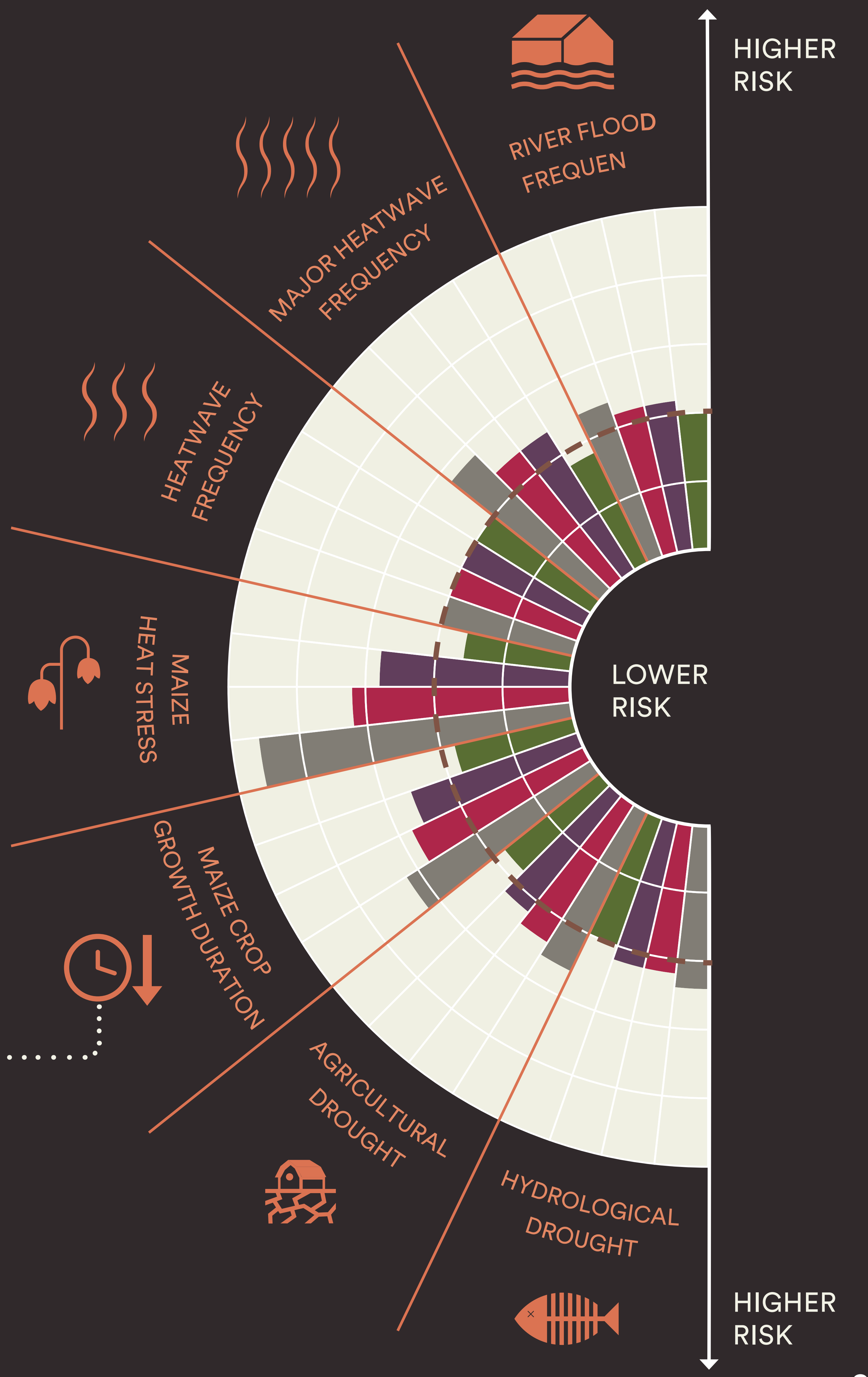


SCENARIO KEY:

- No Policy
- NDC Pledges
- 2.5°C
- 2°C Central
- 1.5°C

Electricity prices are only moderately lower in No Policy and 2°C Central scenarios.

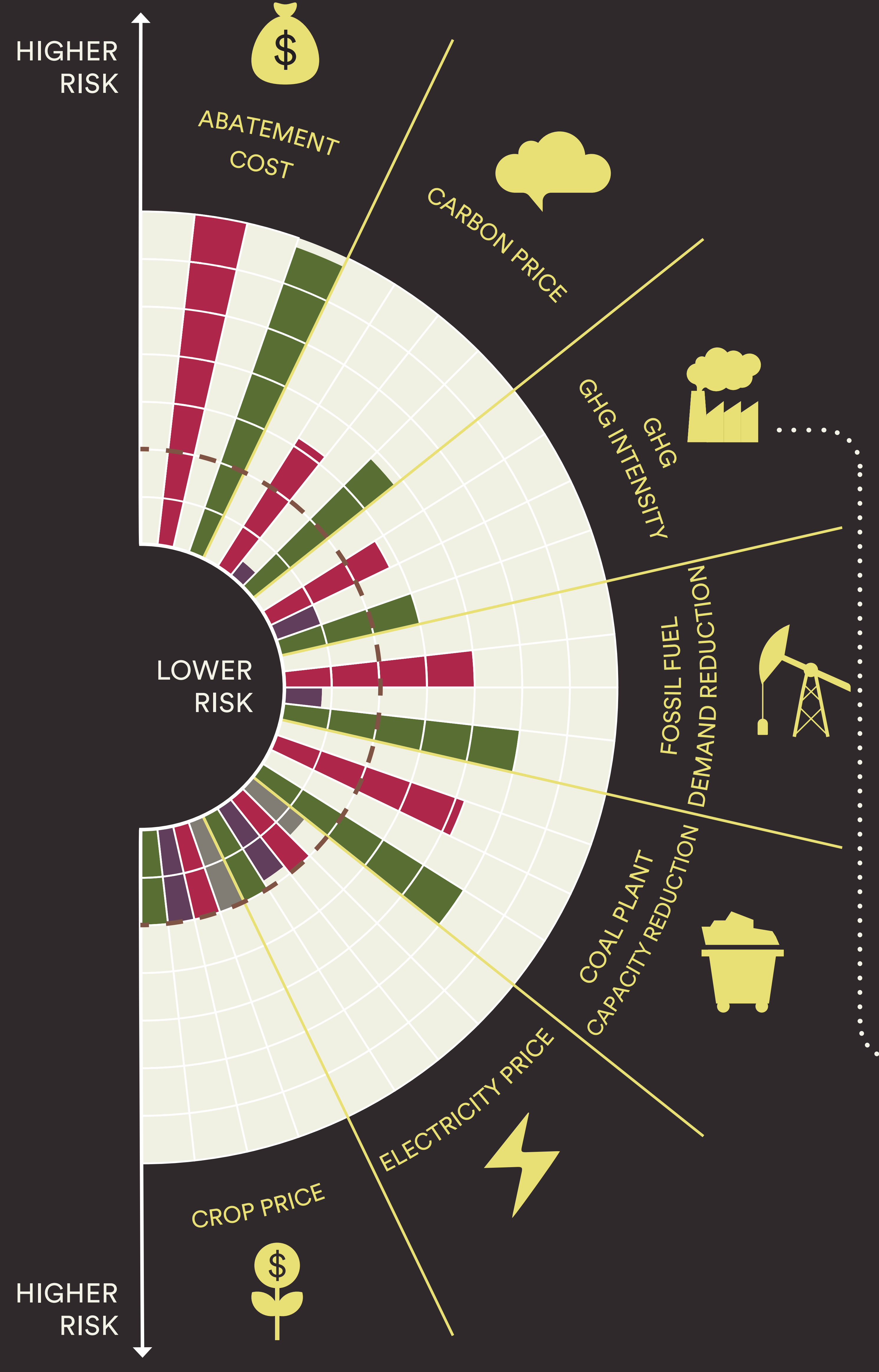
PHYSICAL RISKS
in 2050



Higher risk is associated with higher temperatures, and for the EU+UK, a shorter growing season could be a major concern.

USA

TRANSITION RISKS
in 2030



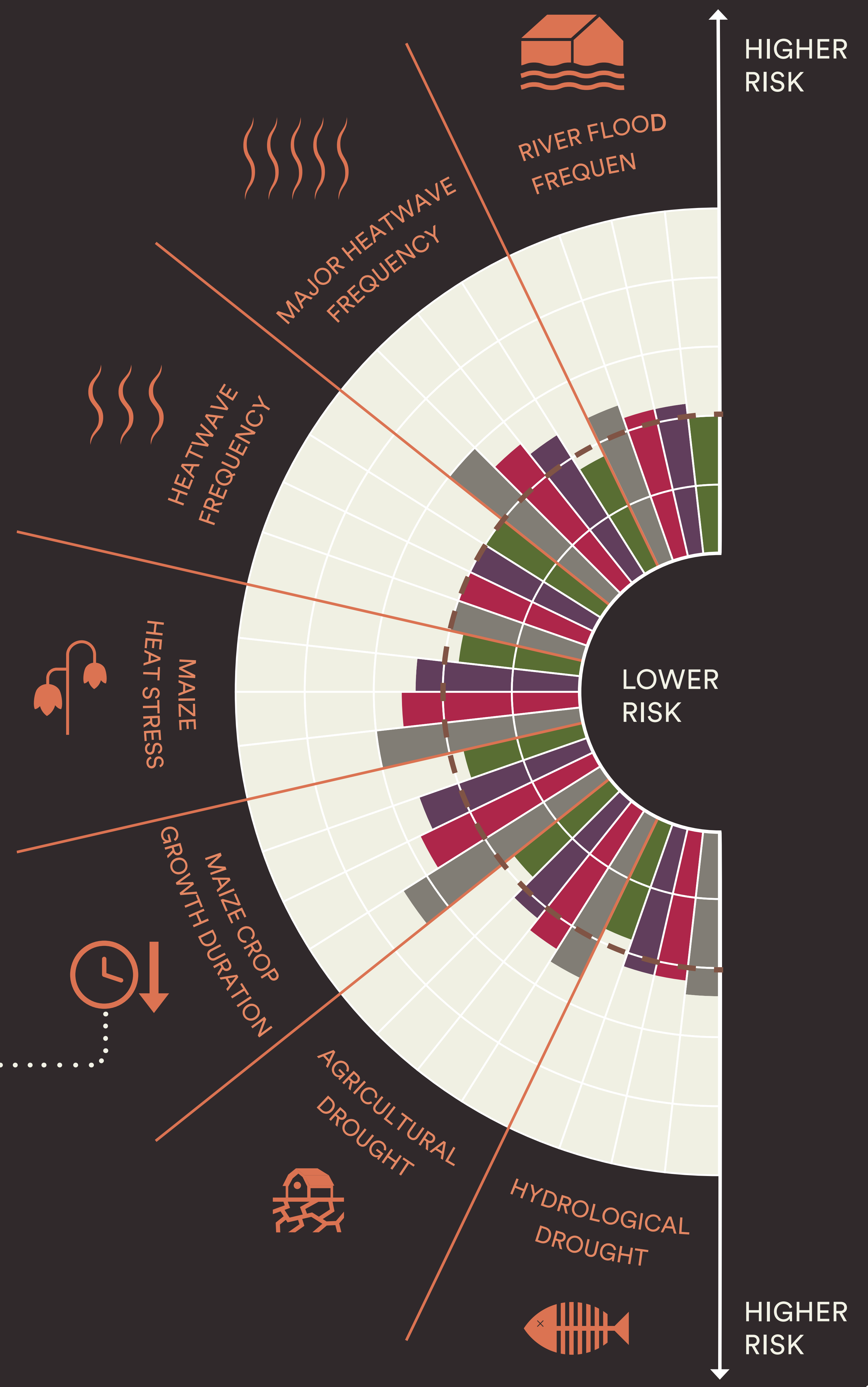
SCENARIO KEY:

- No Policy
- NDC Pledges
- 2.5°C
- 2°C Central
- 1.5°C

While most transitions are higher in a 1.5°C scenario, the USA NDC Pledges are similar in scale.

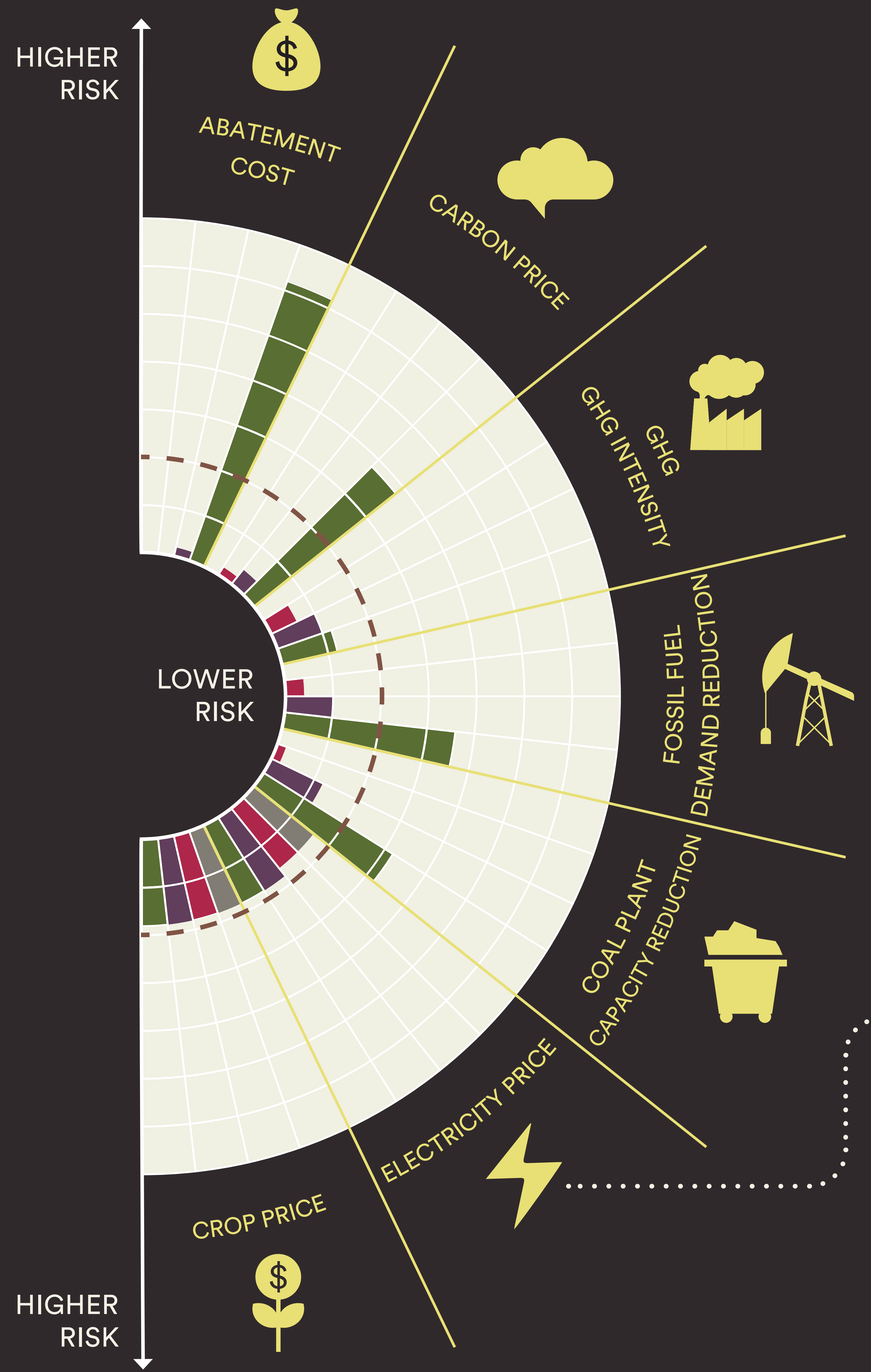
Higher risk is associated with higher temperatures, and for the USA, a shorter growing season could be a major concern.

PHYSICAL RISKS
in 2050



BRAZIL

TRANSITION RISKS
in 2030

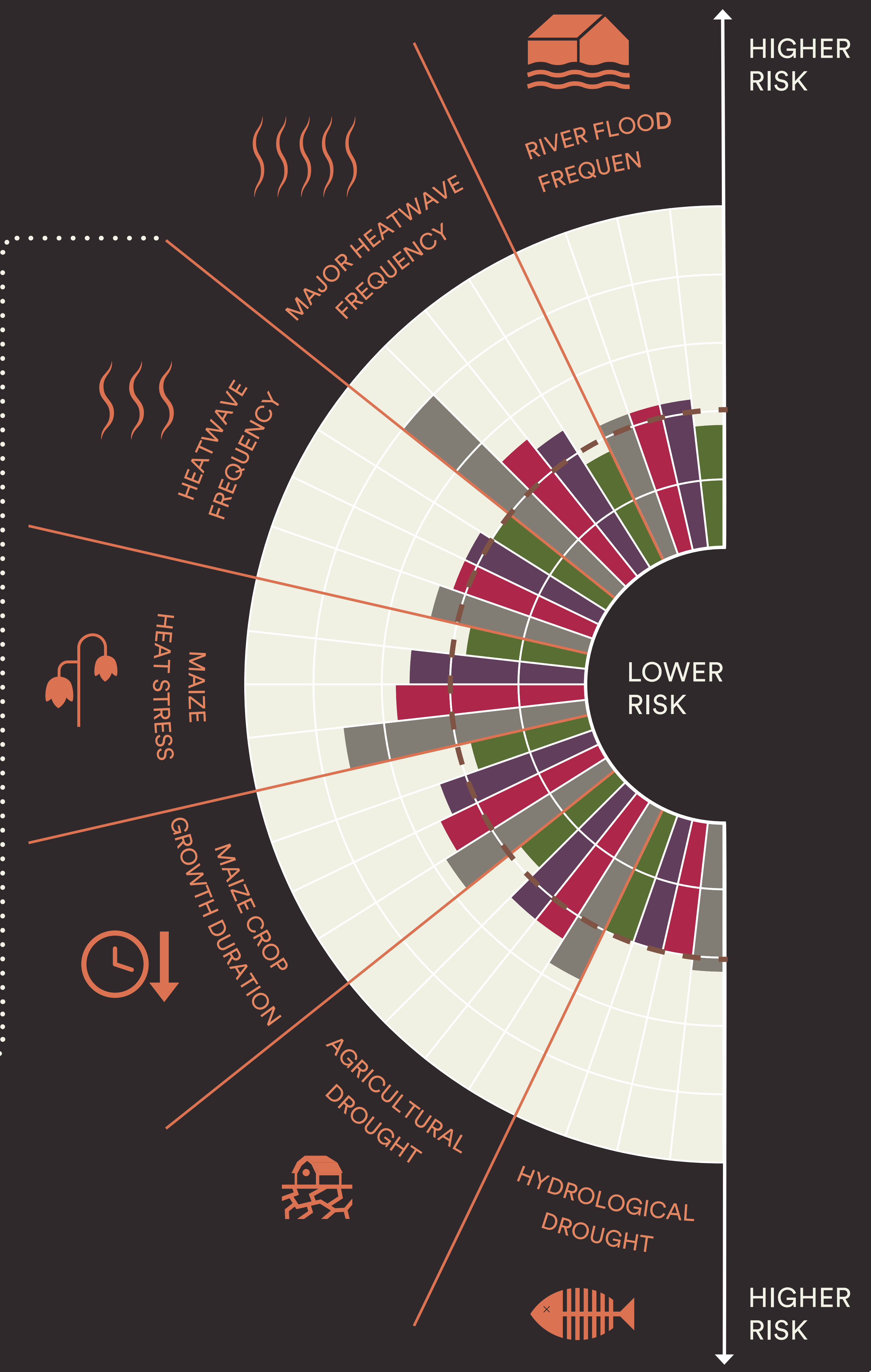


SCENARIO KEY:

- No Policy
- NDC Pledges
- 2.5°C
- 2°C Central
- 1.5°C

Electricity prices are only moderately lower in No Policy and NDC Pledges scenarios.

PHYSICAL RISKS
in 2050



Higher risk is associated with higher temperatures, and for the Brazil, exposure to heatwaves could be major concern.

DISCUSSION: A FRAMEWORK TO CARRY FORWARD

This integrated scenario analysis framework can be built upon by stakeholders across business, finance, household, and government sectors. This figure indicates sample implications for a range of key economic sectors. For example, the framework serves as a first step toward a full "scenario expansion" toward financial risk estimates, which would involve quantitatively downscaling sector-level and economy-wide outputs from IAMs to firm- and household-level financial risks.

A critical consideration in undertaking such financial risk analysis is systemic risk, deriving not just from first-round exposure of investors to carbon-intensive sectors, but also to second-round effects from financial firms' investment in each other, creating networks of exposure to losses, as well as the extent of insurance against losses. More detailed analysis is therefore required to understand the full financial system and wider economic risks.

And yet, insights gleaned from comparing physical and transition risks in a consistent scenario framework provides a clear basis for building such analysis, including identifying underlying drivers of economic changes that result from them. In essence, we provide the first chapter in this storyline of global and regional physical and transition consequences of different plausible emissions pathways.

Scenario analysis / Sector implications

TRANSITION RISKS	RELATED IAM OUTPUTS	AGRICULTURE	ENERGY SUUPLY	BUSINESS AND INDUSTRY	HOUSEHOLDS	FINANCE
Economy-wide mitigation cost leading to GDP losses	Policy, abatement or system lost changes, GDP losses	Reduced demand	Reduced demand	Potentially reduced demand	Potential employment loss or restructure	Impact on risk and return across assets
Higher carbon taxation	Carbon price	Potentially higher cost e.g. meat	Higher operating cost for fossil energy supplies	Higher operating cost for fossil reliant businesses	Higher goods and service prices	Greater business and household credit default risk
Energy prices	Electricity and other fuel prices	Higher energy input cost	Higher energy input cost	Higher energy input cost	Higher energy bills	Greater business and household credit default risk
Food prices	Food price	Changes to sales and revenue		Changes to input costs e.g. food retailers	Higher food prices	Greater business and household credit default risk
Stranded assets	Stranded asset (mostly in power sector)		Sunk costs of premature asset closure			Asset investment write-offs
Sectoral transition pathways	Sectoral carbon intensity	Higher cost to reduce intensity faster	Higher cost to reduce intensity faster	Higher cost to reduce intensity faster		Lower carbon-intensive asset values

PHYSICAL HAZARD RISKS	RELATED IMPACT MODEL OUTPUTS	AGRICULTURE	ENERGY SUUPLY	BUSINESS AND INDUSTRY	HOUSEHOLDS	FINANCE
Heatwaves	Loss of work hours	Lower productivity	Lower output / higher wages	Lower outputs / higher wages	Health and lost income	Lower asset values across sectors
Floods	Asset damages	Lower productivity	Asset replacement costs	Asset replacement costs	Household damage / higher insurance costs	Business and household asset devaluation
Droughts	Lower crop productivity and loss	Lower productivity	Lost output e.g. hydro, water-reliant plants	Lost production for firms reliant on water input	Health and water supply impacts	Lower asset values from lost production
Crop heat stress and duration	Lower crop productivity and loss	Lower productivity	Loss of bioenergy resource	Potentially higher food input costs	Higher food prices	Lower agricultural sector asset values

METHODS

The different scenarios are set up in the Global Chance Analysis Model (GCAM), an integrated assessment model, considering the specific GDP and population growth characteristics of the scenarios, the temperature goals, the scenario variants in terms of policy action, and any technological and behavioural constraints or availability.

The GCAM model outputs a range of energy, agricultural, and land system metrics that are used to specify the transition risk indicators. The emissions (spanning all greenhouse gases, aerosols, and other climate forcers) are fed into the probabilistic climate model MAGICC, whose range of temperature outputs are then fed into the suite of impact models. These produce measures of physical hazard that form the physical risk metrics. When combined with the population from the specific scenario, these hazards are used to generate impact indicators (e.g., population exposed to heat waves).

For more information on methods, and results across more geographies, please see the supplemental material to the article in:

Nature Climate Change

Scenario design

- Socio-economics
- Temperature goal
- Mitigation timing
- Technological choices
- Behaviours

Integrated assessment model: GCAM

- Energy system
- Agriculture
- Land use

TRANSITION RISK INDICATORS

- Abatement cost
- Carbon price
- GHG intensity
- Fossil fuel demand
- Coal plant capacity
- Electricity price
- Crop price

Climate model: MAGICC

Resulting GHG emissions and other climate-related forcers are fed through a climate model resulting in probabilistic temperature pathways

Impact models

Probabilistic temperature outcomes are run through an ensemble of impact models

PHYSICAL RISK INDICATORS

- River flood
- Major heatwave
- Heatwave
- Maize heat stress
- Crop duration
- Agricultural drought
- Hydrological drought

Near-term transition and longer-term physical climate risks of greenhouse gas emissions pathways

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Access the full report in Nature Climate Change

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