The Ongoing IAMC and IPCC Socio-Economic Scenarios Processes

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Pacific Northwest
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Office of Science
U.S. DEPARTMENT OF ENERGY

The Scenario Matrix Approach and SSPs—A work in progress

▶ The first and most important thing to say is: **THIS IS ALL A WORK IN PROGRESS**.

▶ And, if you think you have questions, they pale in comparison to the questions that arise when you actually try to implement these ideas.

A Thread Through the Assessment Process

▶ The basic idea of the scenarios process that began in Noordwijkerhout, was to develop a set of scenarios that could provide some common points of reference that would pervade an assessment.

- They are not intended to be the only scenarios developed.
- They are simply intended to provide a reference between three climate research communities:
    - Integrated assessment modelers
    - Climate modelers, and
    - Impacts, adaptation and vulnerability researchers.

▶ They were also intended to facilitate IAV research

- Providing a point of reference for national, regional & local researchers, and
- Facilitating IAV intercomparison.

NORDWIJKERHOUT AND THE PREPARATORY PHASE

The Noordwijkerhout process: RCPs were developed by the IAM community for the climate modeling community.
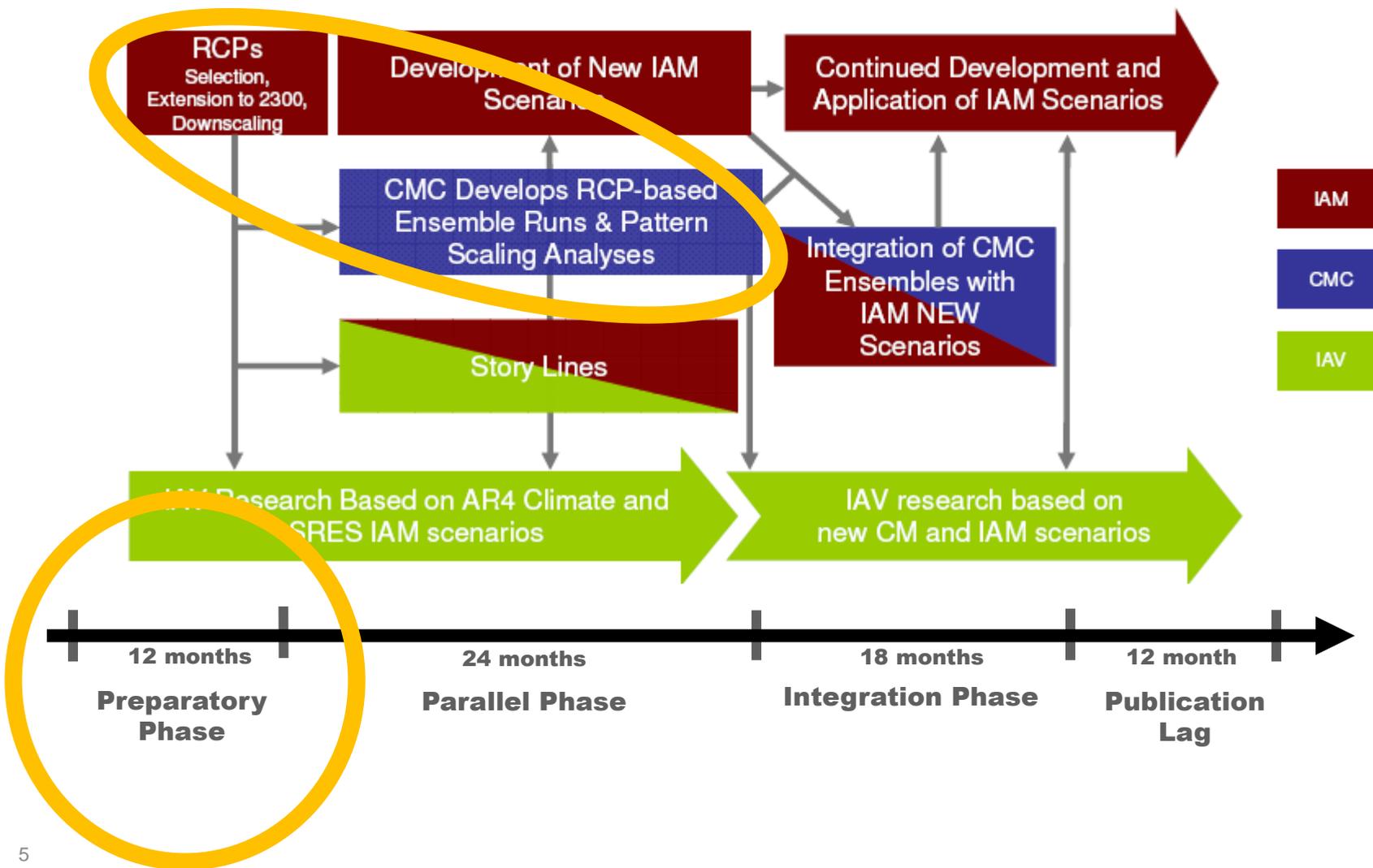
FOUR RCPs developed by the IAMC to provide emissions scenarios to the climate/Earth system modeling (ESM) community to jumpstart the assessment process.

- **RCP8.5 (IIASA/MESSAGE)**
  - >8.5 W/m^2 in 2100,
  - Rising

- **RCP6.0 (NIES/AIM)**
  - ~6 W/m^2 at stabilization after 2100
  - Stabilization without exceeding target

- **RCP4.5 (PNNL/MiniCAM)**
  - ~4.5 W/m^2 at stabilization after 2100
  - Stabilization without exceeding target

- **RCP2.6 (PBL/IMAGE)**
  - <3 W/m^2 in 2100
  - peak & decline stabilization
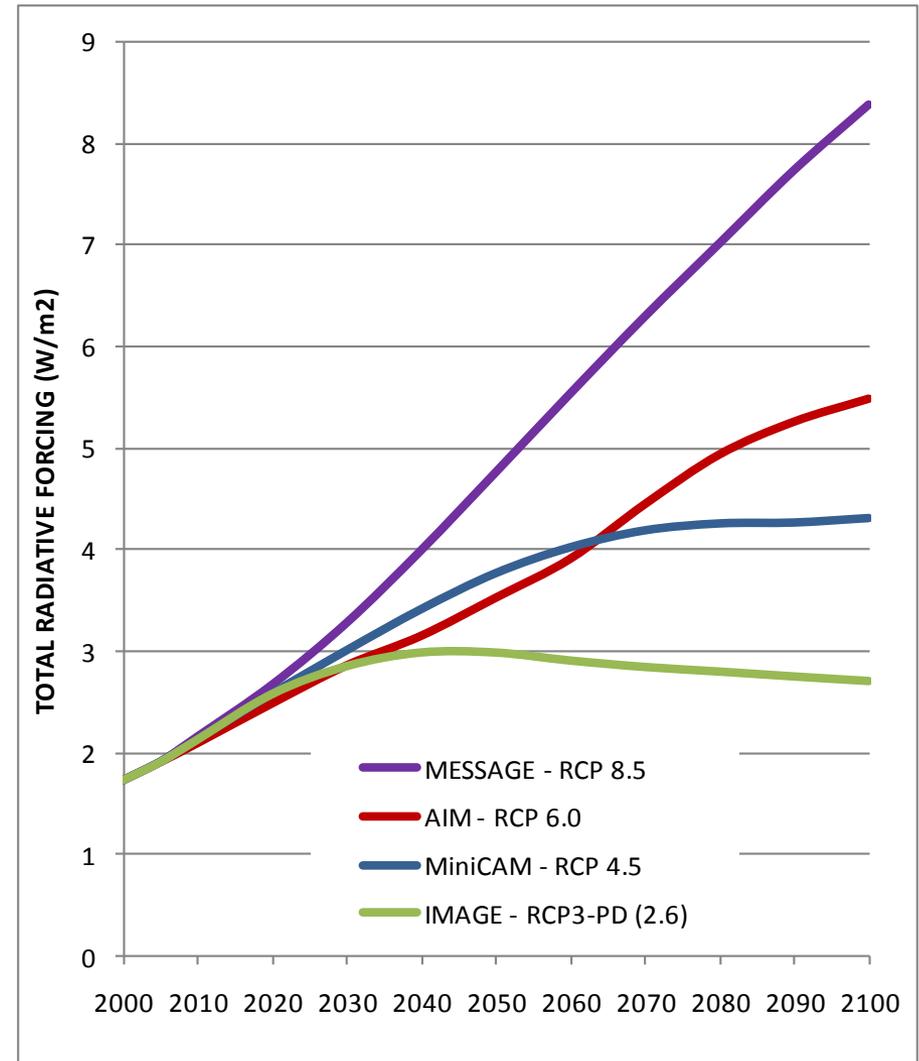
THE PARALLEL PHASE

The PARALLEL phase in the Noordwijkerhout process
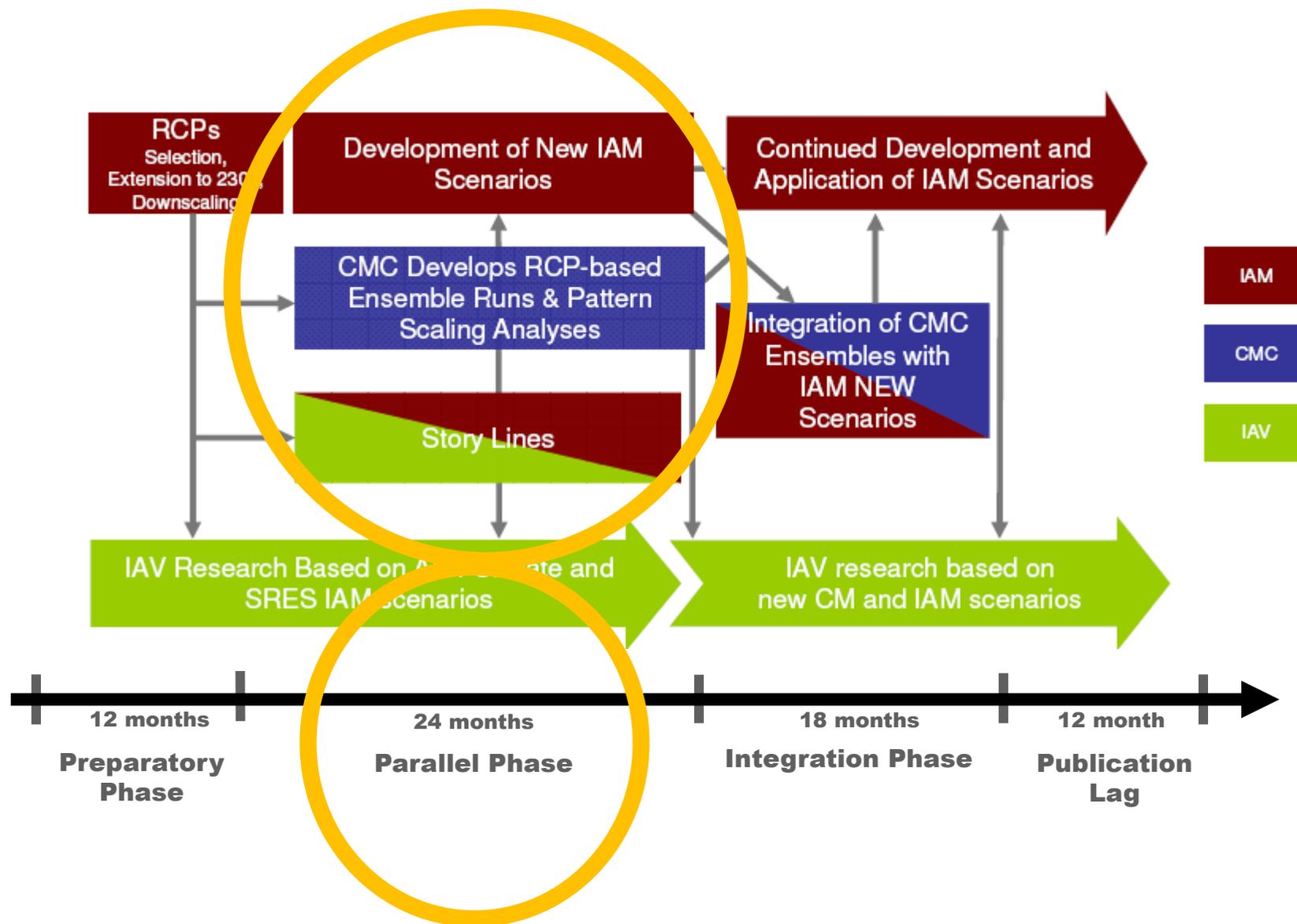
The Parallel Phase

► The parallel phase of the assessment process defined in Nordwijkerhout calls for the development of new scenarios and storylines useful to the impacts, adaptation and vulnerability community (IAV).

  ■ Though there will be thousands of other scenarios developed for other reasons.

► **The two key ideas were:**

  ■ **Development of new scenarios useful to the IAV community AND**

  ■ **Capable of providing a link across all 3 research communities.**

The Framework Document

► This architecture is incorporated in something called the Framework Document, that is almost ready to go out for general review.

A NEW SCENARIO ARCHITECTURE

The New Scenario Matrix Architecture: Two Matrices

▶ Matrix 1: Reference Scenarios and Mitigation

▶ Matrix 2: Reference Scenarios—adaptive versus mitigative challenges

The New Scenario Matrix Architecture: Two Matrices

▶ Matrix 1: Reference Scenarios and Mitigation

■ There are many variations on this theme, but all have the following character.

■ Reference scenarios are described by a set of characteristics that are referred to as SSPs.

		SSP 1	SSP 2	SSP 3	SSP4	SSP5
	Reference	X	X	X	X	X
RCP Replication	8.5 Wm^{-2}				X	X
	6.0 Wm^{-2}		X	X	X	X
	4.5 Wm^{-2}	X	X	X	X	X
	2.6 Wm^{-2}	X	X	X		X

■ Note that some combinations may not exist.

SSPs

► **The SSPs**: Assumptions about the state of global and regional society and ecosystems as they evolve over the course of the 21st century defined in terms of their reference scenario values.

► SSP stands for either:

- Shared Socio-economic Pathways

- Shared Socio-ecosystem Pathways

- Depending on whether you talk to me or someone else.

The New Scenario Matrix Architecture: Two Matrices

► Matrix 2: Reference Scenarios Mitigative and Adaptive Challenges.

Matrix 2: Reference Scenarios Mitigative and Adaptive Challenges.

		SSP 1	SSP 2	SSP 3	SSP4	SSP5
	Reference	X	X	X	X	X
RCP Replication	8.5 Wm^{-2}				X	X
	6.0 Wm^{-2}		X	X	X	X
	4.5 Wm^{-2}	X	X	X	X	X
	2.6 Wm^{-2}	X	X	X		X
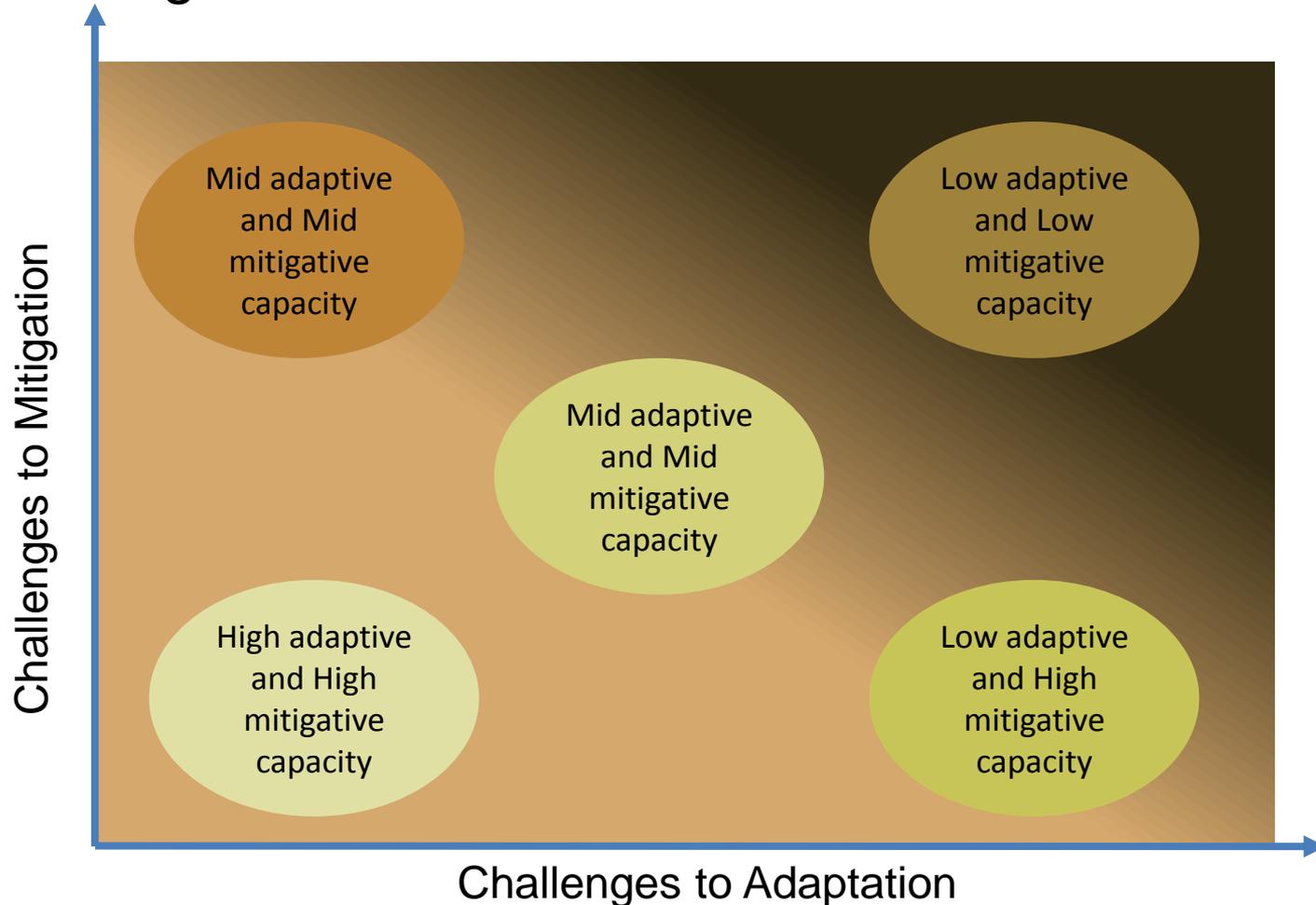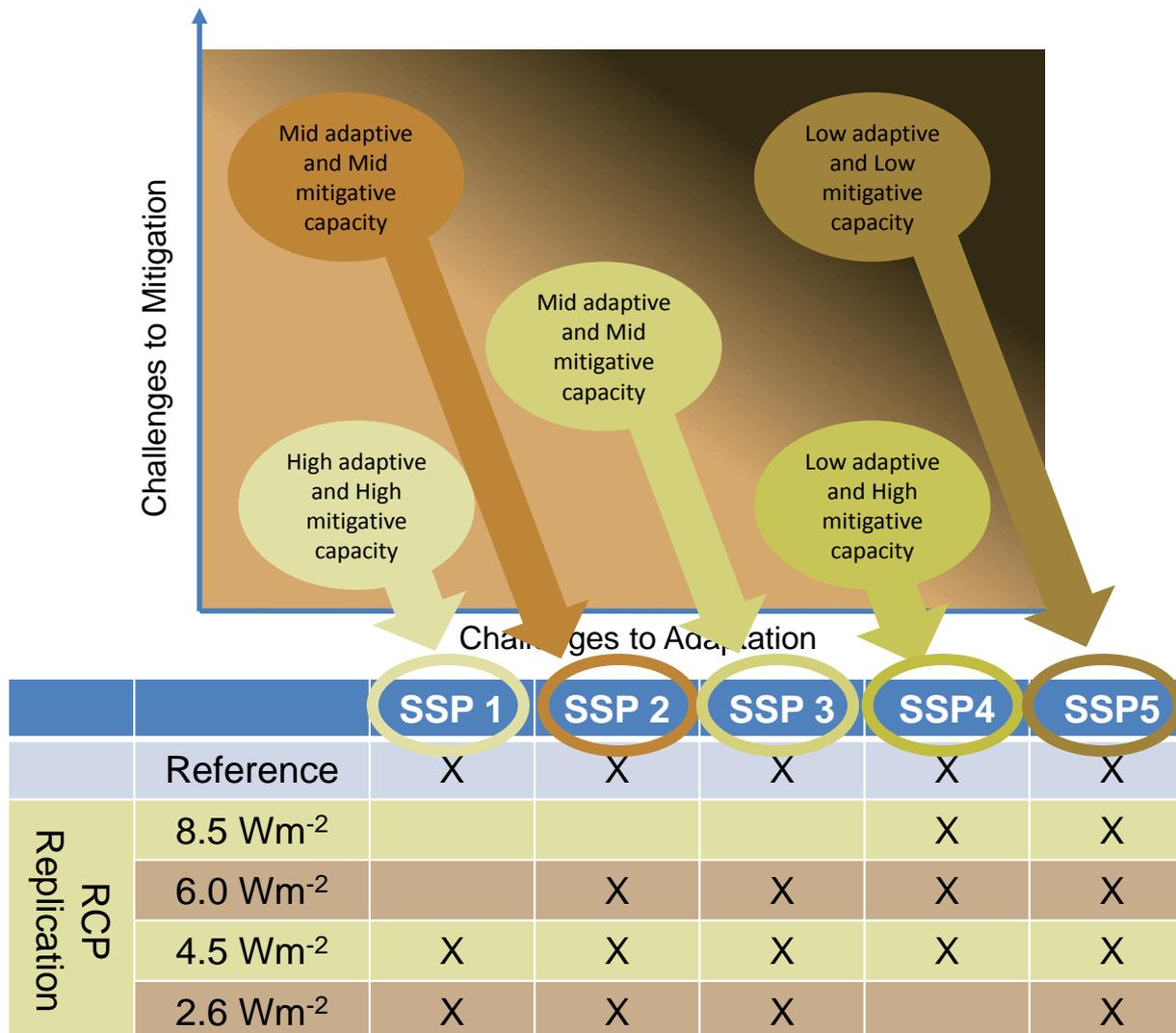
Implementation of the new SSPs

▶ Several groups have tried begun experiments on the development of a set of SSPs.

▶ Major question: *How do you measure challenges to mitigation and challenges to adaptation?*

The Matrix Vocabulary

▶ **The Scenario Matrix Architecture (SMA)**: The concept of multiple scenarios, clustered into families defined by

▶ **Shared socio-ecosystem pathway (SSP)** assumptions,

▶ **Shared policy assumptions (SPA)** about mitigative stringency, and

▶ **Shared climate assumptions (SCA) the missing piece of the research design.**

Through Basic and Extended: Timing and Products

▶ Desire for the first scenarios early in 2012—"Basic"

▶ Continued work to add details—"Extended"

THE SSP'S

The Shared Socioecosystem Pathways (SSPs)

▶ An SSP consists of a set of descriptions of the state of the world as it evolves over time in a **reference, "no-climate-policy" scenario**.

▶ Each SSP implies a different reference scenario.

  ■ There are a virtually infinite number of such potential worlds.

  ■ Many variables that are contained in the definition of the SSP will change in response to either climate change and/or emissions mitigation.

  ■ But, the definition of the SSP is unique and cleanly defined.

▶ The reference scenarios themselves may or may not be interesting.

  ■ For example, the worlds that are of interest may be only worlds in which emissions mitigation occurs, as in the RCPs.

Components of the SSPs

▶ There are three parts to each SSP

  ■ **Storyline**: The qualitative description of a reference, "no-climate-policy" scenario, e.g. social commitment to sustainability. All elements of the SSP that are non-quantitative are part of the storyline.

  ■ **Quantitative reference scenario values that are IAM drivers**, e.g. population, labor productivity growth rates.

  ■ **Other quantitative reference scenario values** for important variables, e.g. governance, ecosystem vulnerability.

▶ **All three elements of the SSP are to be crafted so as to be consistent.**

SSPs

Storylines   **Quantitative IAM Inputs**   **Quantitative non-IAM Variables**

SSP1

Storyline 1: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

Quantitative Variables that define IAM reference "no-climate-policy" scenario 1. E.g. reference scenario population by region by year.

Quantitative Variables that define reference "no-climate-policy" scenario 1, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.

SSP2

Storyline 2: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

Quantitative Variables that define IAM reference "no-climate-policy" scenario2. E.g. reference scenario population by region by year.

Quantitative Variables that define reference "no-climate-policy" scenario 2, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.

Etc.

MITIGATIVE STRINGENCY

Mitigative Stringency

▶ Defined to be consistent with RCP replication.

▶ This creates consistency and comparability across climate modeling, integrated assessment modeling, and IAV research.

▶ Should the same assumptions of globally harmonized mitigation be employed? Or, should a less than perfect world be assumed?

▶ The degree of **mitigative capacity** is assumed to be matched to the degree of **mitigative stringency**.

■ While this need not necessarily be the case, for example societies with high mitigative capacity might choose to undertake little mitigation.

Shared Climate Policy Assumptions

SPA2.6

Storyline 2.6: The storyline is a verbal description of the degree of mitigation in the scenario. All non-quantitative aspects of the climate mitigation scenario are included in the storyline. For example, the storyline might include information about the nature of climate policy instruments including inefficient or second-best policies and measures, and the timing of emissions mitigation activity with regard to nations and sectors.

Quantitative Variables that would be used as inputs to an IAM, e.g. radiative forcing is limited to 2.6 W/m^2.

SPA4.5

Storyline 4.5: The storyline is a verbal description of the degree of mitigation in the scenario. All non-quantitative aspects of the climate mitigation scenario are included in the storyline. For example, the storyline might include information about the nature of climate policy instruments including inefficient or second-best policies and measures, and the timing of emissions mitigation activity with regard to nations and sectors.

Quantitative Variables that would be used as inputs to an IAM, e.g. radiative forcing is limited to 4.5 W/m^2.

Etc.

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Radiatively important constituents

▶ Many gases play a role in determining radiative forcing, but are also associated with local and regional air quality.

  ■ Sulfur—strong aerosol effect on radiative forcing, but also strong role in acid deposition.

  ■ NMHA—important role in determining concentrations of chemically active greenhouse gases, but also strongly associated with local air pollution.

▶ To the extent that these gases are being controlled under reference scenarios, that information is contained in the SSP and not the SPA.

▶ To the extent that these gases are controlled due to a concern for climate change, that information is contained in the SPA.

THE SCENARIOS

The Reference Scenario for an SSP

▶ The reference scenarios contain information from four sources: the Storyline, The IAMs, other Quantitative Information and associated climate change.
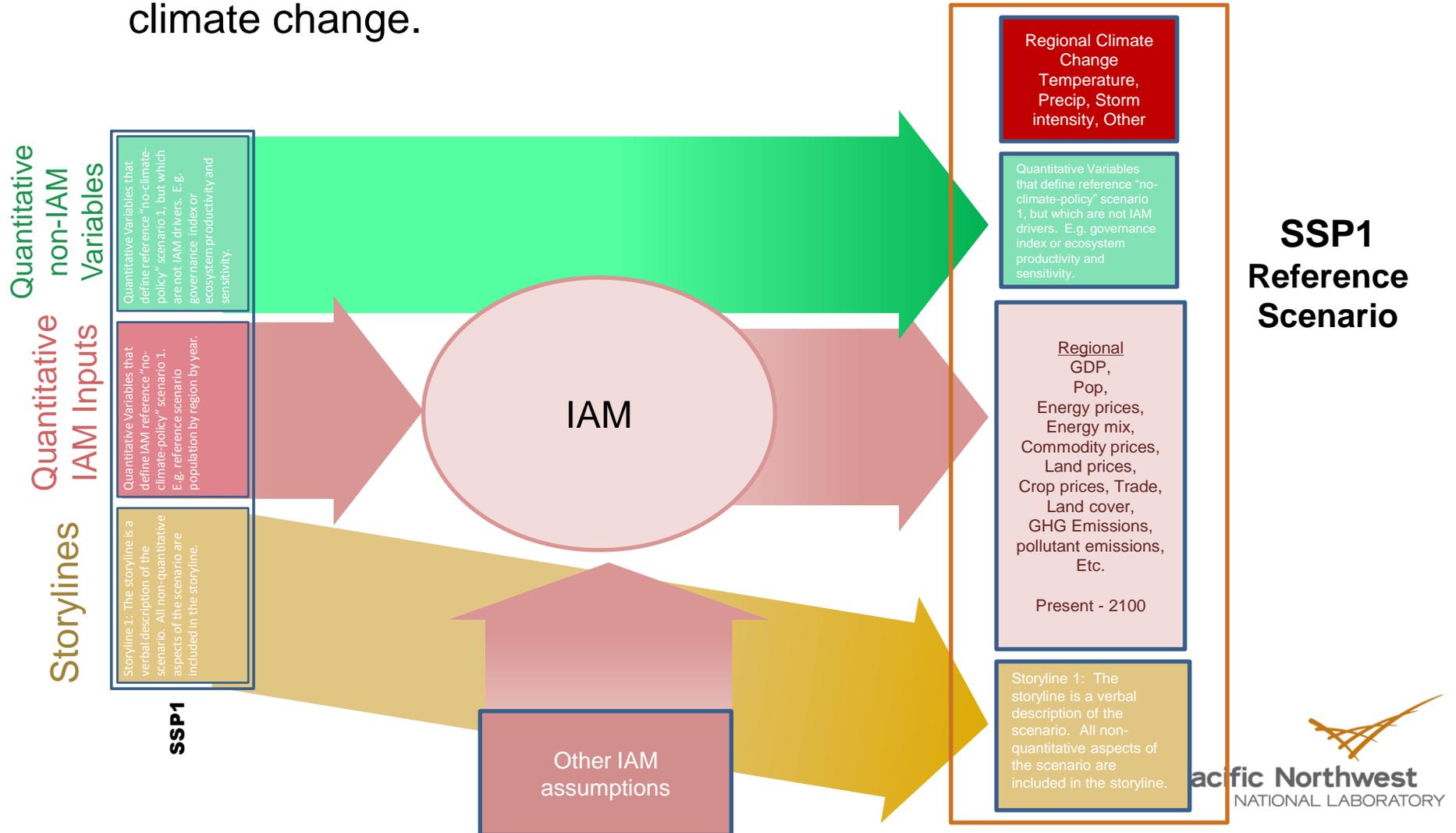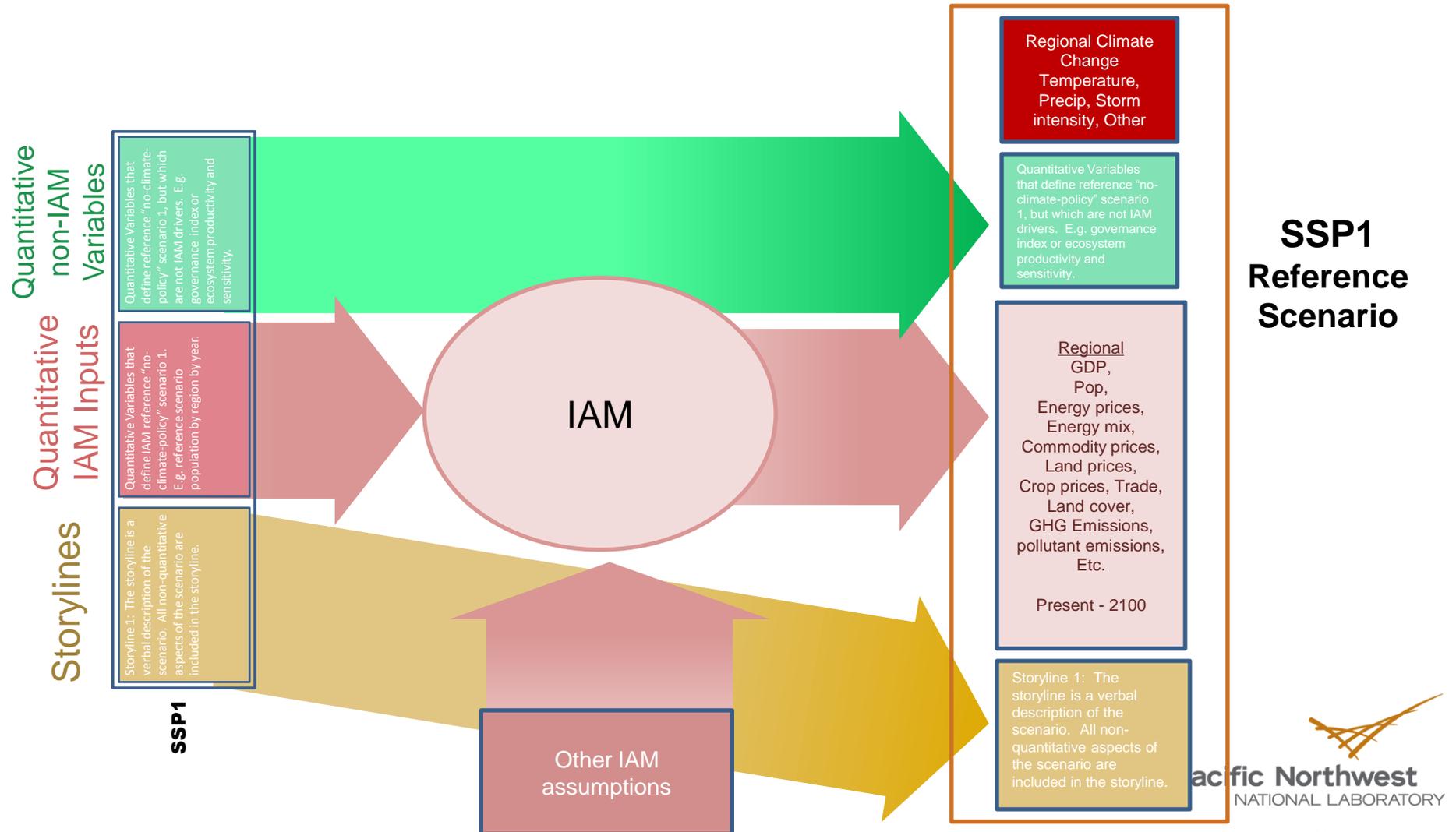
The Reference Scenario for an SSP

▶ This bundle of information constitutes a REFERENCE scenario.

The Reference Scenario for an SSP

► We will depict this bundle of information as a scenario "cube".

**SSP1
Reference
Scenario**

**SSP1
Reference
Scenario**

Regional Climate Change Temperature, Precip, Storm intensity, Other

Quantitative Variables that define reference "no-climate-policy" scenario 1, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.

Regional
GDP,
Pop,
Energy prices,
Energy mix,
Commodity prices,
Land prices,
Crop prices, Trade,
Land cover,
GHG Emissions,
pollutant emissions,
Etc.

Present - 2100

Storyline 1: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

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Climate Policy

Imposing climate policy assumptions to achieve a prescribed level of mitigative stringency changes the scenario but not the SSP.

Climate Policy

We refer to the set of assumptions associated with the mitigative scenarios as Shared Climate Policy Assumptions (SPAs).

Climate Policy

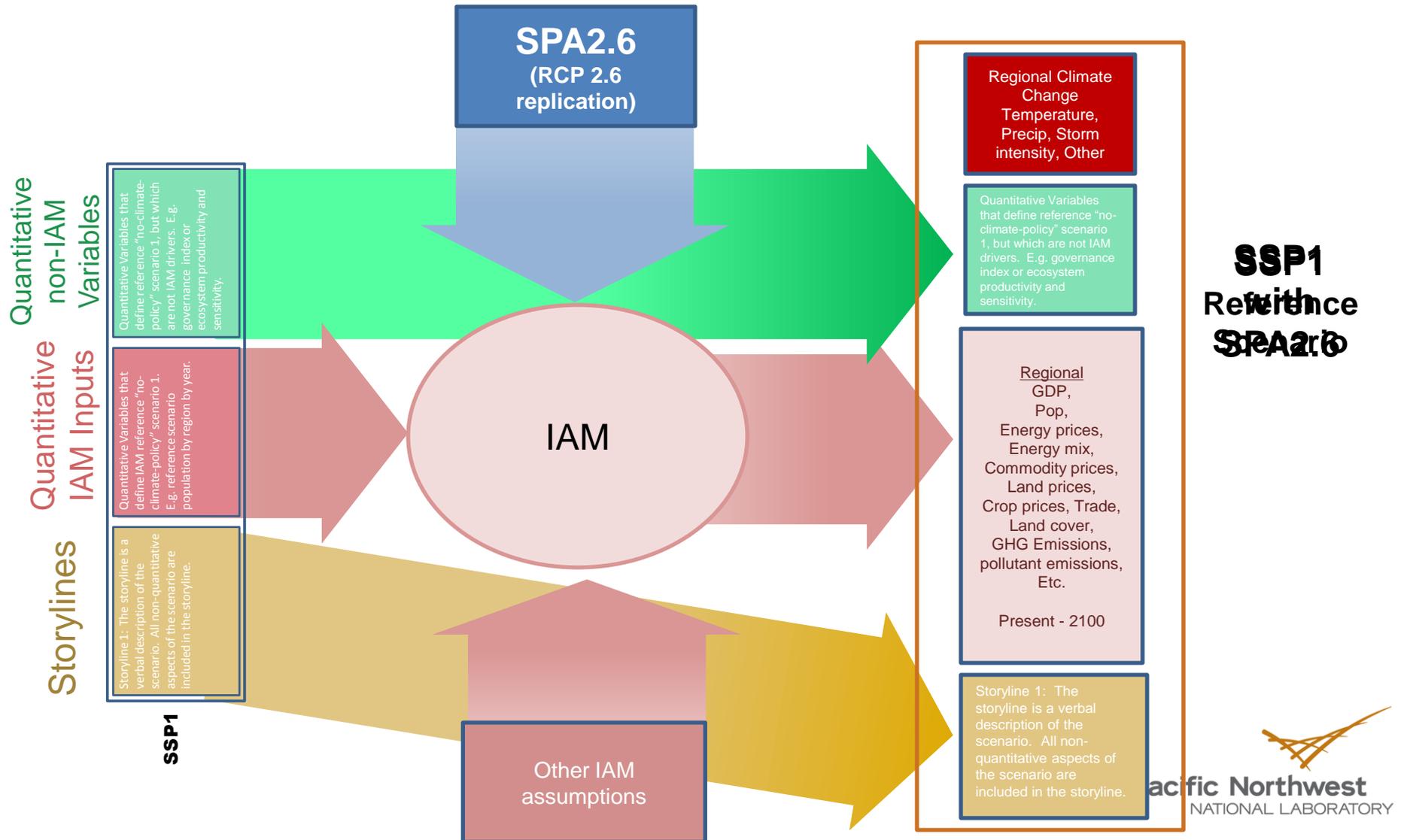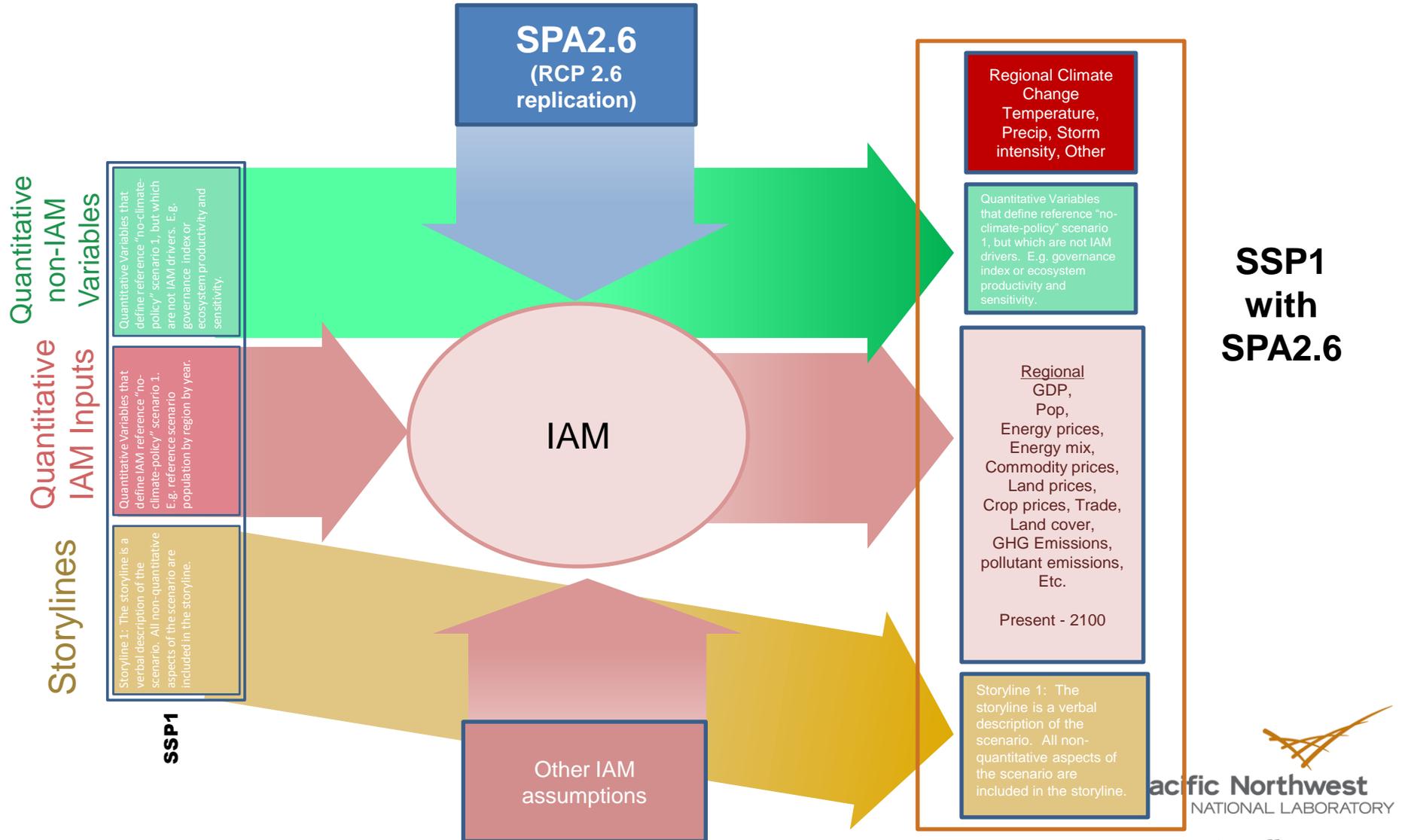SPAs contain information about the **<u>climate</u>** policy environment including the limit, e.g. 2.6 Wm^{-2}, the timing of participation by regions, the nature of the climate policies imposed to achieve that goal, taxes or regulation, and the nature of policies to respond to climate change.

(R

Quantitative non-IAM Variables

Quantitative Variables that define reference "no-climate-policy" scenario 1, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.

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Quantitative IAM Inputs

Quantitative Variables that define IAM reference "no-climate-policy" scenario 1. E.g. reference scenario population by region by year.

IAM

Regional
GDP,
Pop,
Energy prices,
Energy mix,
Commodity prices,
Land prices,
Crop prices, Trade,
Land cover,
GHG Emissions,
pollutant emissions,
Etc.

Present - 2100

Storylines

Storyline 1: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

SSP1

Other IAM assumptions

Storyline 1: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

SSP1 with SPA2.6

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Climate Policy

ALL IAM outputs--Emissions, GDP, prices, land use, the energy mix, etc.—will change as a consequence of climate policy. So too, will climate change.

SPA2.6
(RCP 2.6 replication)

Quantitative non-IAM Variables

Quantitative Variables that define reference "no-climate-policy" scenario 1, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.

Quantitative IAM Inputs

Quantitative Variables that define IAM reference "no-climate-policy" scenario 1. E.g. reference scenario population by region by year.

Storylines

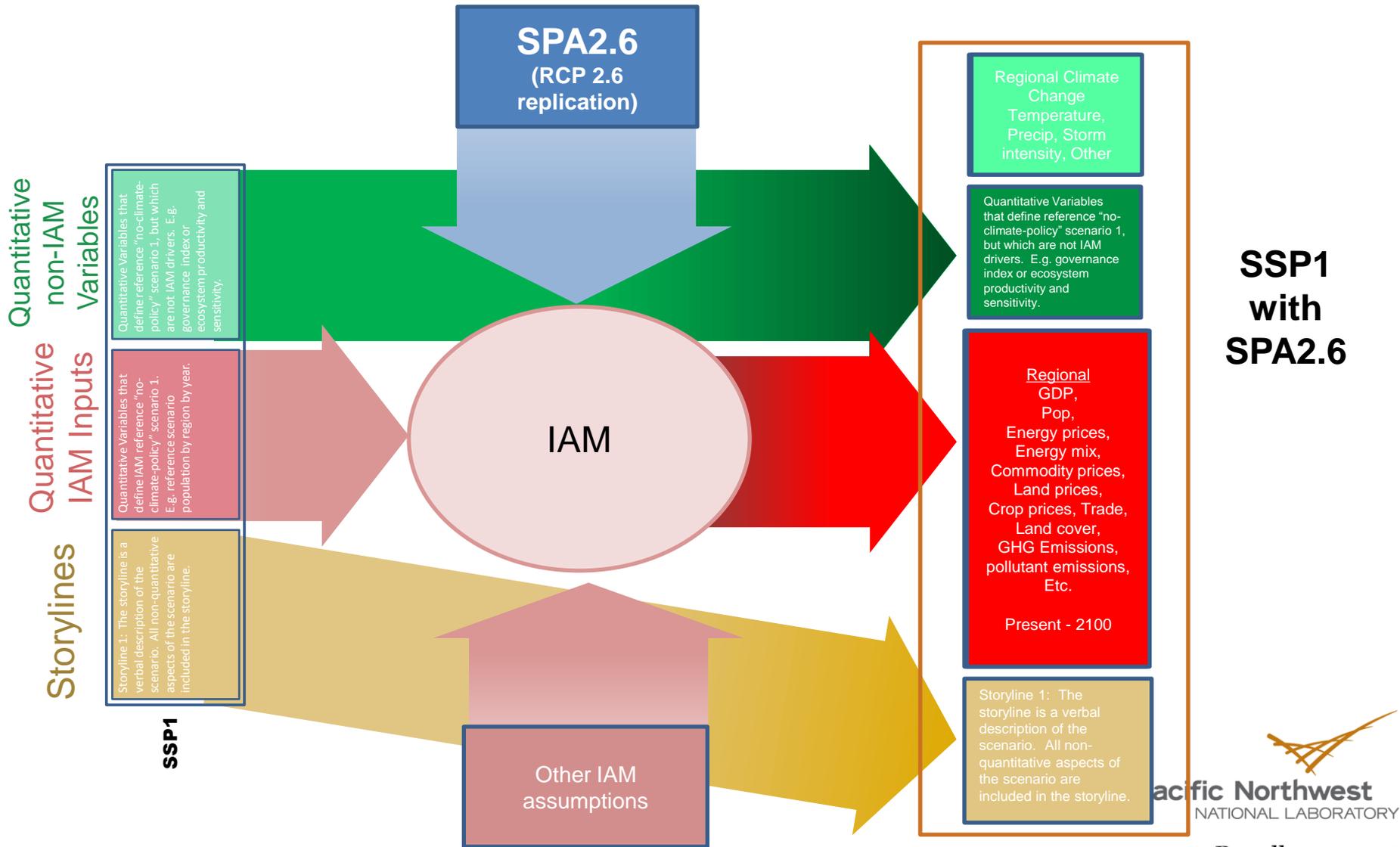Storyline 1: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

SSP1

IAM

Other IAM assumptions

Regional Climate Change Temperature, Precip, Storm intensity, Other

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Etc.

Present - 2100

Storyline 1: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

SSP1
with
SPA2.6

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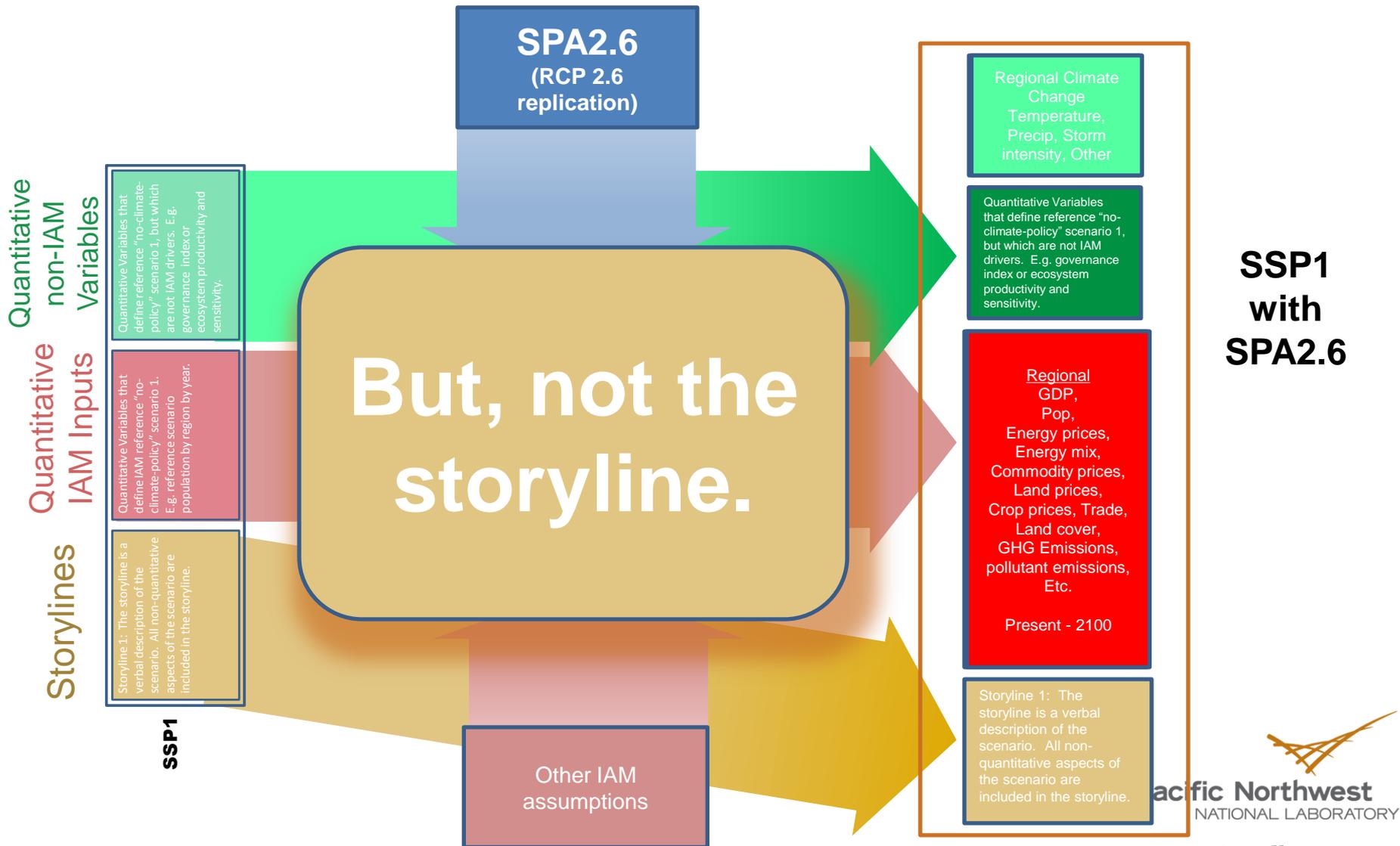*Proudly Operated by* **Battelle** *Since 1965*

Climate Policy

The quantitative—but non-IAM—social and ecosystem indicators could also be expected to change.
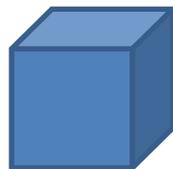
Climate Policy

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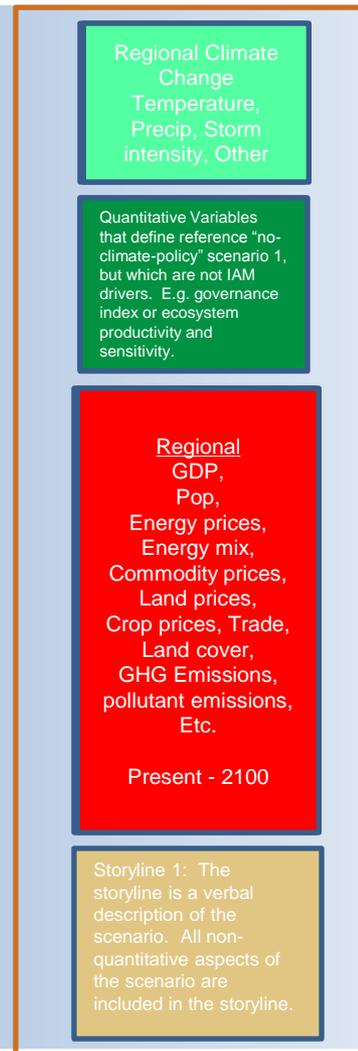
Climate Policy

This bundle of information constitutes a **policy intervention** scenario in the SSP1 family.
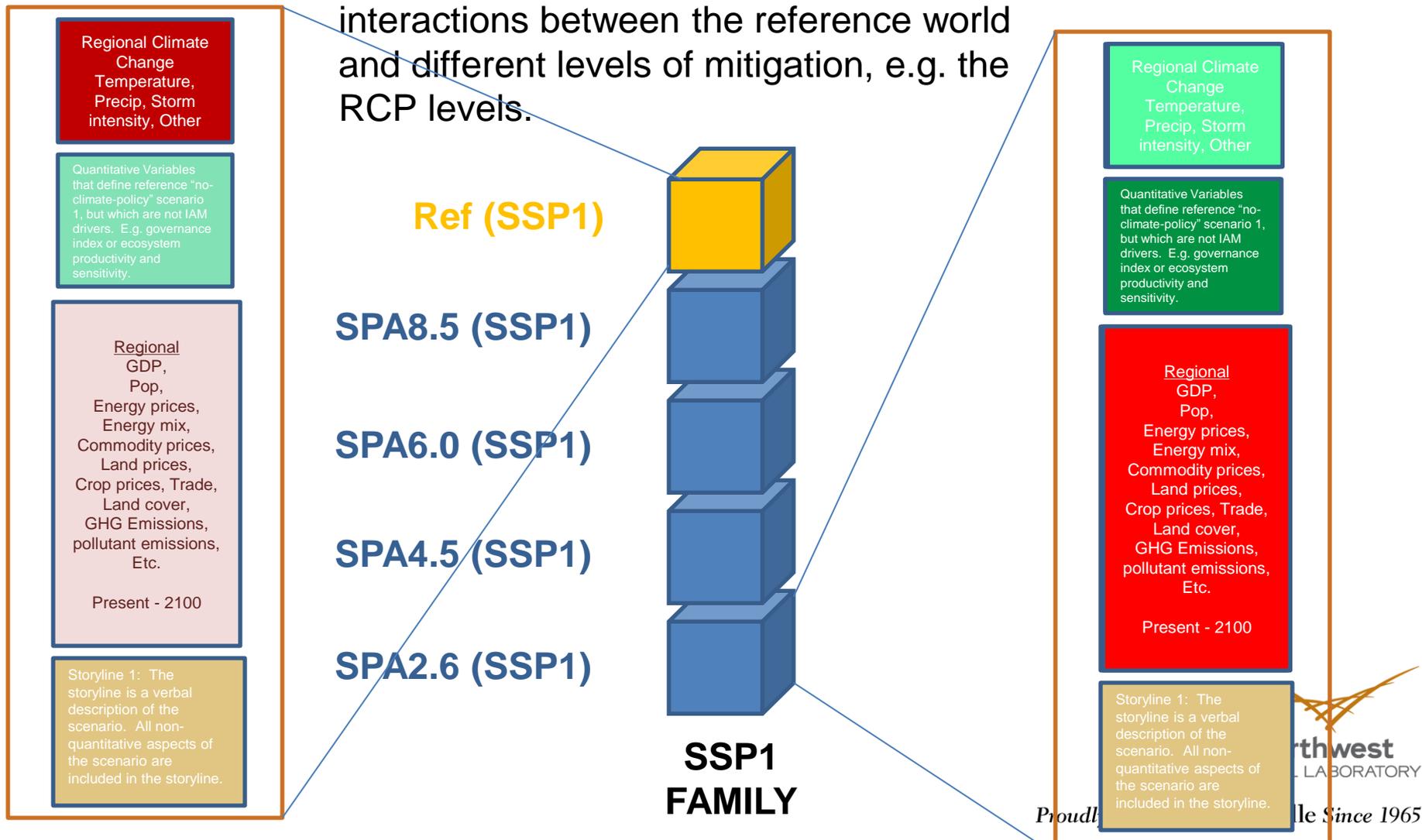
SPA2.6) ⊗ (SSP1)

SSP1 FAMILY

SSP1 with SPA2.6

Regional Climate Change Temperature, Precip, Storm intensity, Other

Quantitative Variables that define reference "no-climate-policy" scenario 1, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.

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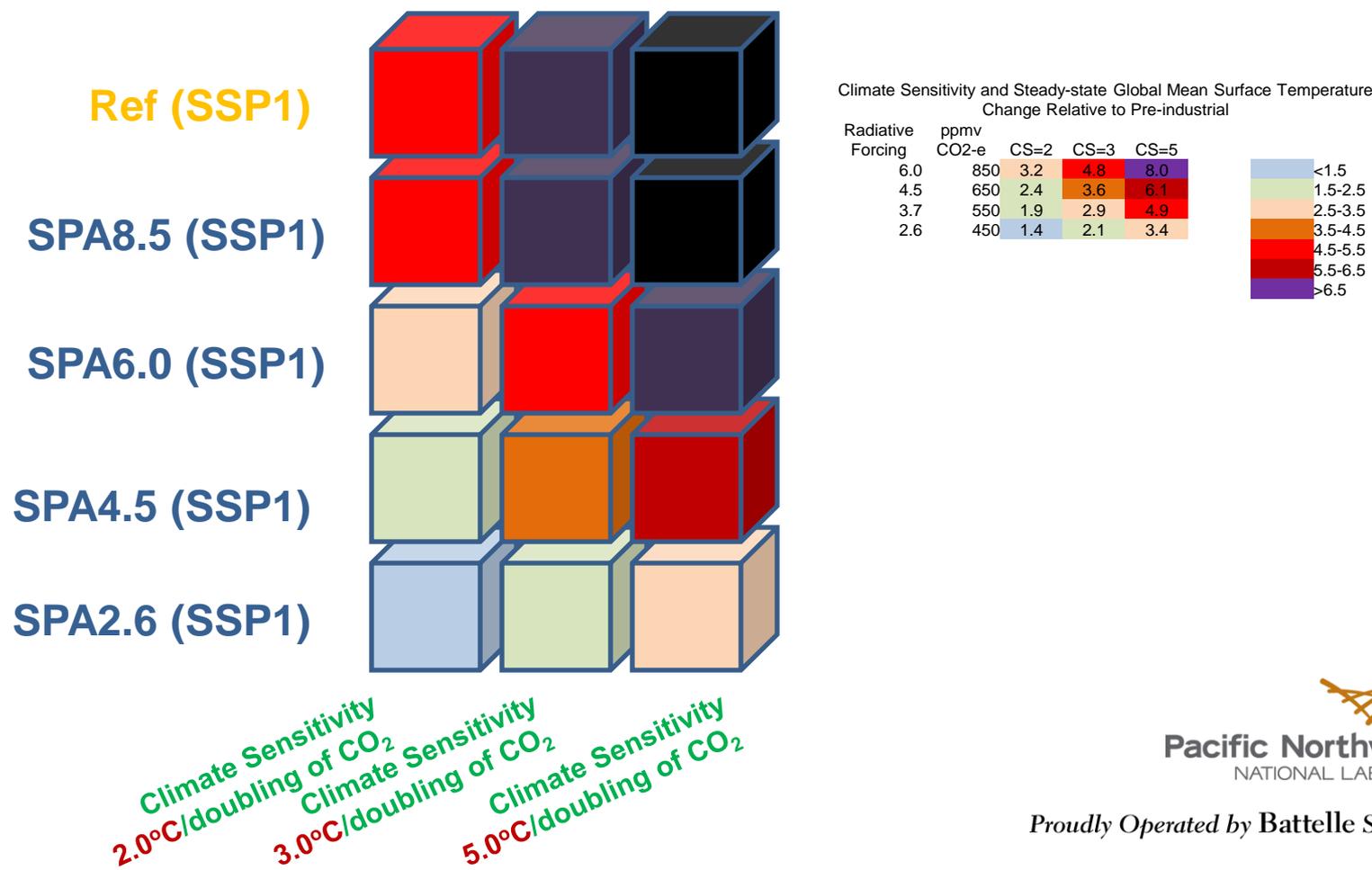
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Three Elements of the New Scenarios: SSPs, Climate Change, and Mitigation

► For a given SSP one could explore interactions between the reference world and different levels of mitigation, e.g. the RCP levels.

Regional Climate Change Temperature, Precip, Storm intensity, Other

Quantitative Variables that define reference "no-climate-policy" scenario 1, but which are not IAM drivers. E.g. governance index or ecosystem productivity and sensitivity.

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Land cover,
GHG Emissions,
pollutant emissions,
Etc.

Present - 2100

Storyline 1: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

Ref (SSP1)

SPA8.5 (SSP1)

SPA6.0 (SSP1)

SPA4.5 (SSP1)

SPA2.6 (SSP1)

SSP1 FAMILY

Regional Climate Change Temperature, Precip, Storm intensity, Other

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Present - 2100

Storyline 1: The storyline is a verbal description of the scenario. All non-quantitative aspects of the scenario are included in the storyline.

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Each combination of SSP, Mitigation, and Climate defines a SCENARIO

▶ Each scenario will have a different set of global and regional values for all of the different outputs of IAMs.

  ■ Energy and commodity prices,

  ■ GDP and population,

  ■ Land use and land cover.

▶ Other variables that relate to vulnerability would also be expected to change.

▶ Note also, that each IAM will yield different quantitative values for each scenario element.

Why use RCP levels to define the level of mitigative stringency?

▶ Using RCP levels to define mitigative stringency has one potentially very useful feature. It provides a direct link to the climate modeling community's ensemble calculations.

▶ This could incorporate shared policy assumptions (SPAs) if desired.

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Three Elements of the New Scenarios: SSPs, Climate Change, and Mitigation

▶ One could then expand that to consider different climate regimes, e.g. different climate sensitivities.

Ref (SSP1)

SPA8.5 (SSP1)

SPA6.0 (SSP1)

SPA4.5 (SSP1)

SPA2.6 (SSP1)

Climate Sensitivity 2.0°C/doubling of CO_2

Climate Sensitivity 3.0°C/doubling of CO_2

Climate Sensitivity 5.0°C/doubling of CO_2

Climate Sensitivity and Steady-state Global Mean Surface Temperature Change Relative to Pre-industrial

Radiative Forcing	ppmv CO_2-e	CS=2	CS=3	CS=5
6.0	850	3.2	4.8	8.0
4.5	650	2.4	3.6	6.1
3.7	550	1.9	2.9	4.9
2.6	450	1.4	2.1	3.4

	<1.5
	1.5-2.5
	2.5-3.5
	3.5-4.5
	4.5-5.5
	5.5-6.5
	>6.5

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Three Elements of the New Scenarios: SSPs, Climate Change, and Mitigation

▶ Beyond that, however, one needs to consider different SSPs.
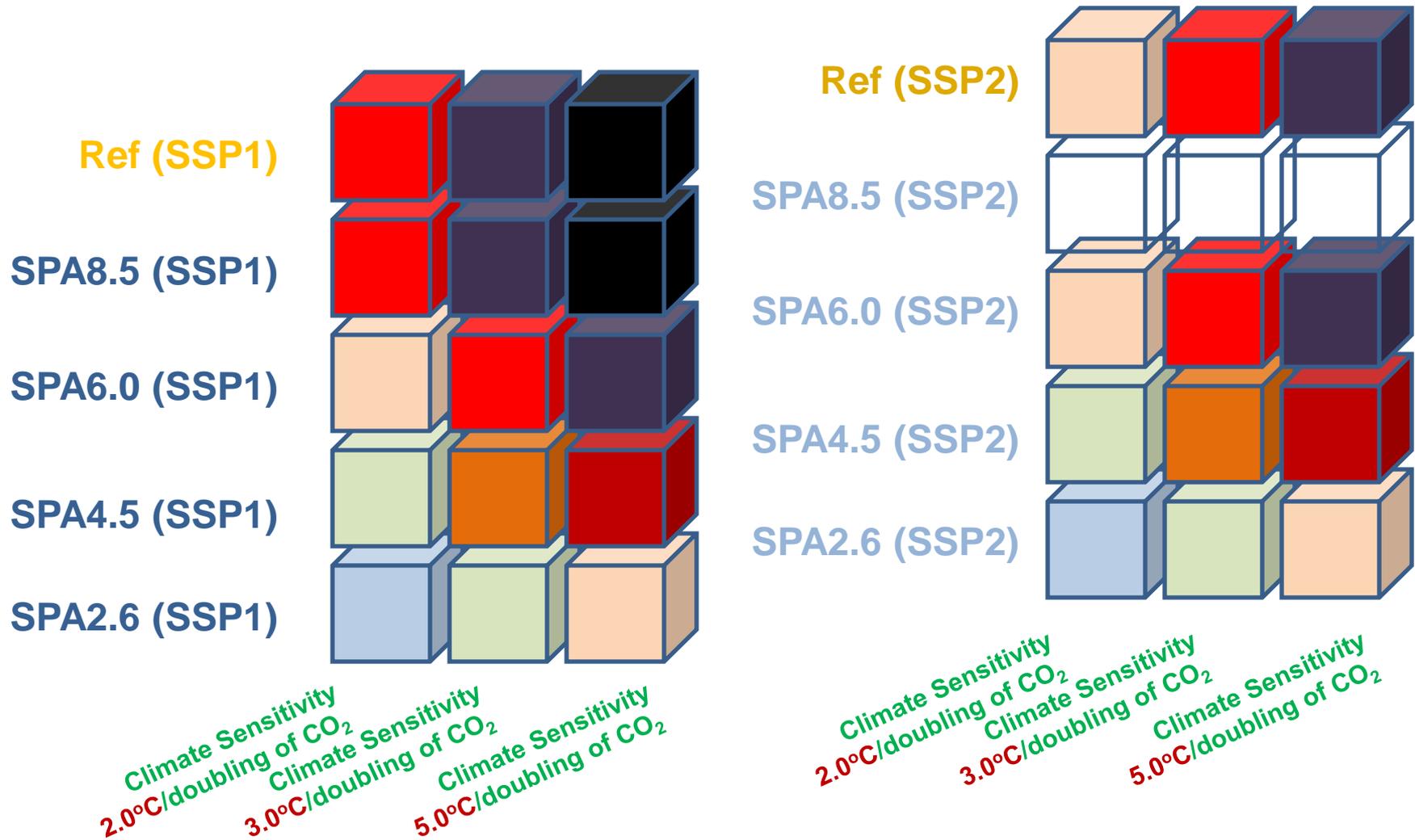
Three Elements of the New Scenarios: SSPs, Climate Change, and Mitigation

▶ Note that for a given SPA and climate sensitivity, the aggregate climate change is fixed for a given RF, but NOT for the reference scenario.
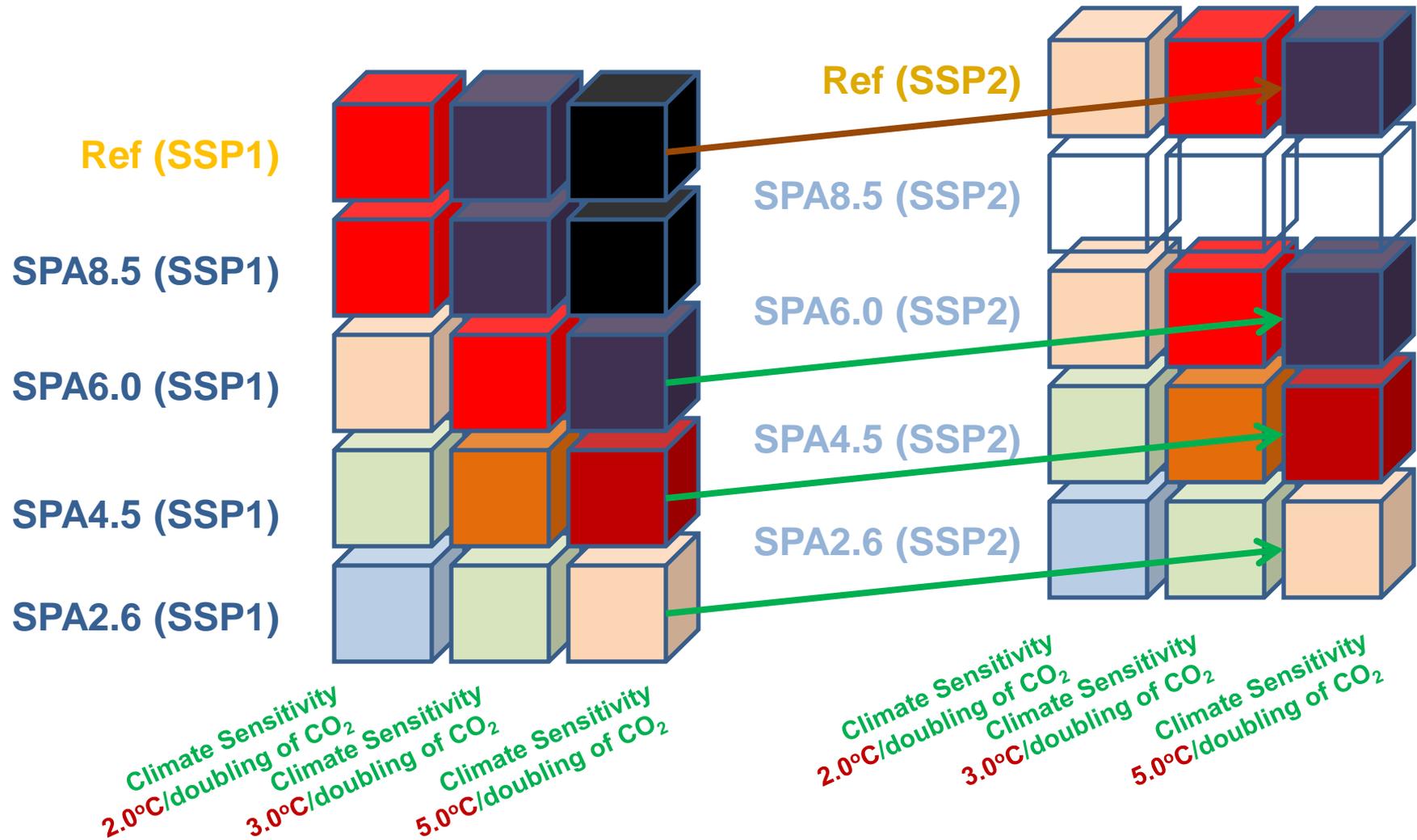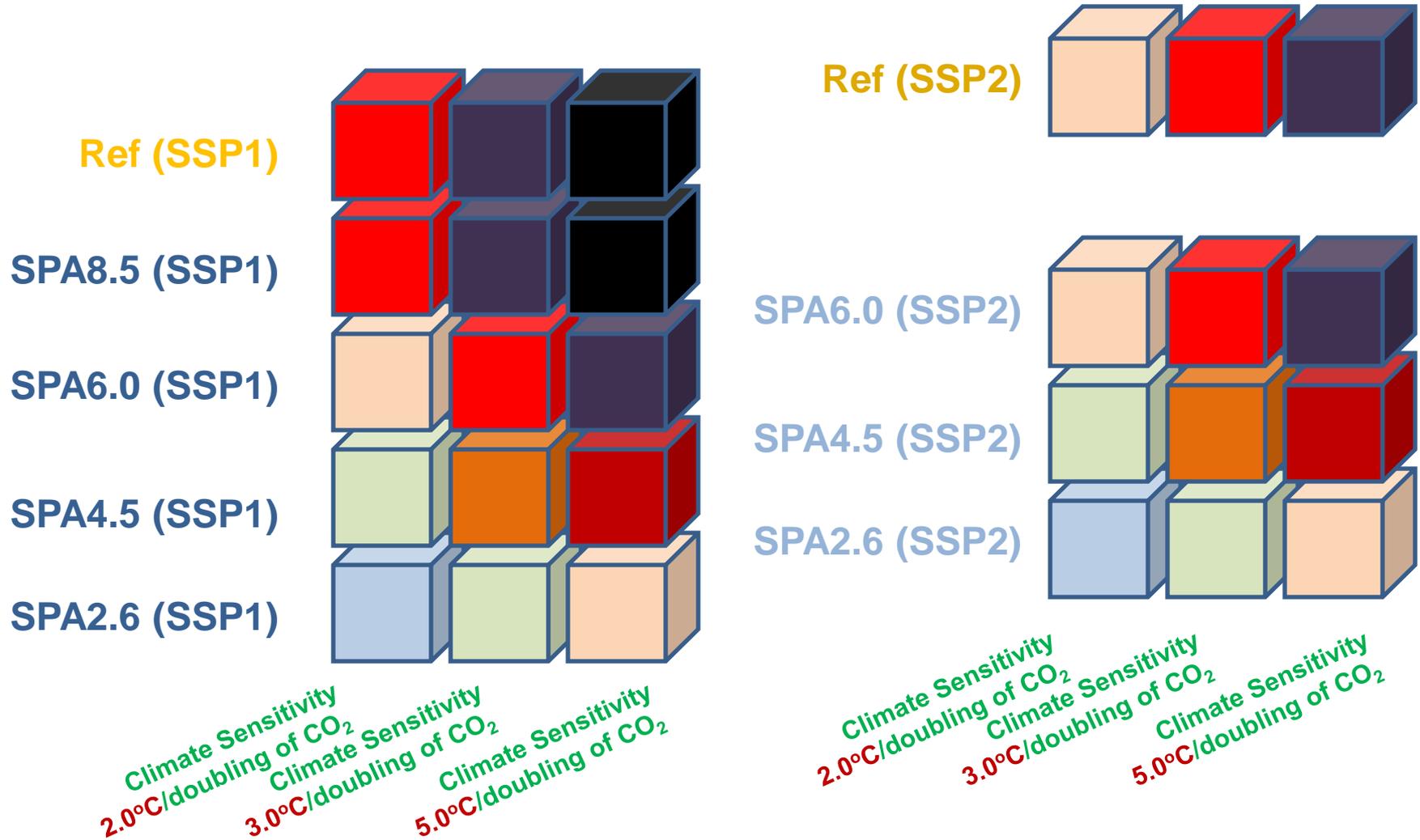
Three Elements of the New Scenarios: SSPs, Climate Change, and Mitigation
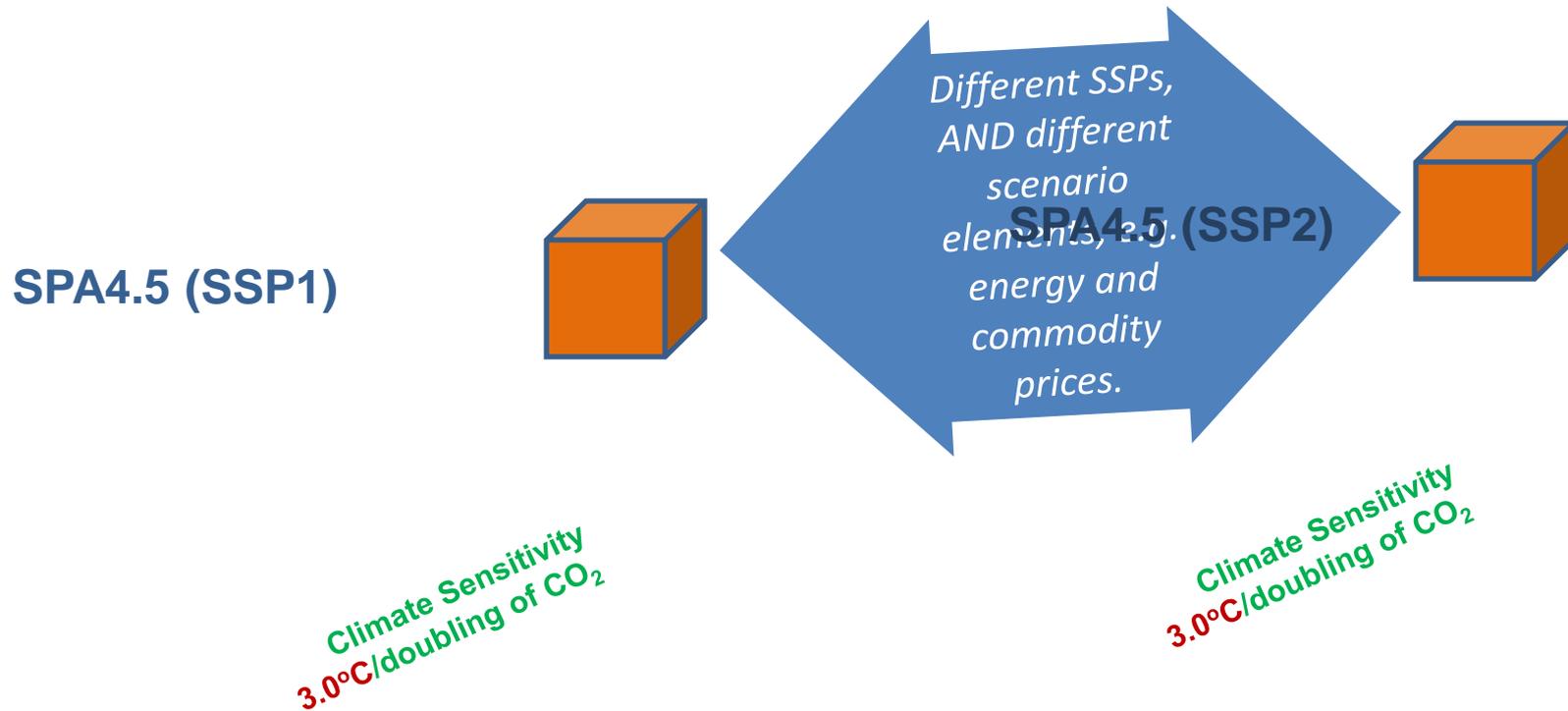
▶ Note also that some RF levels may not exist for a given SSP.
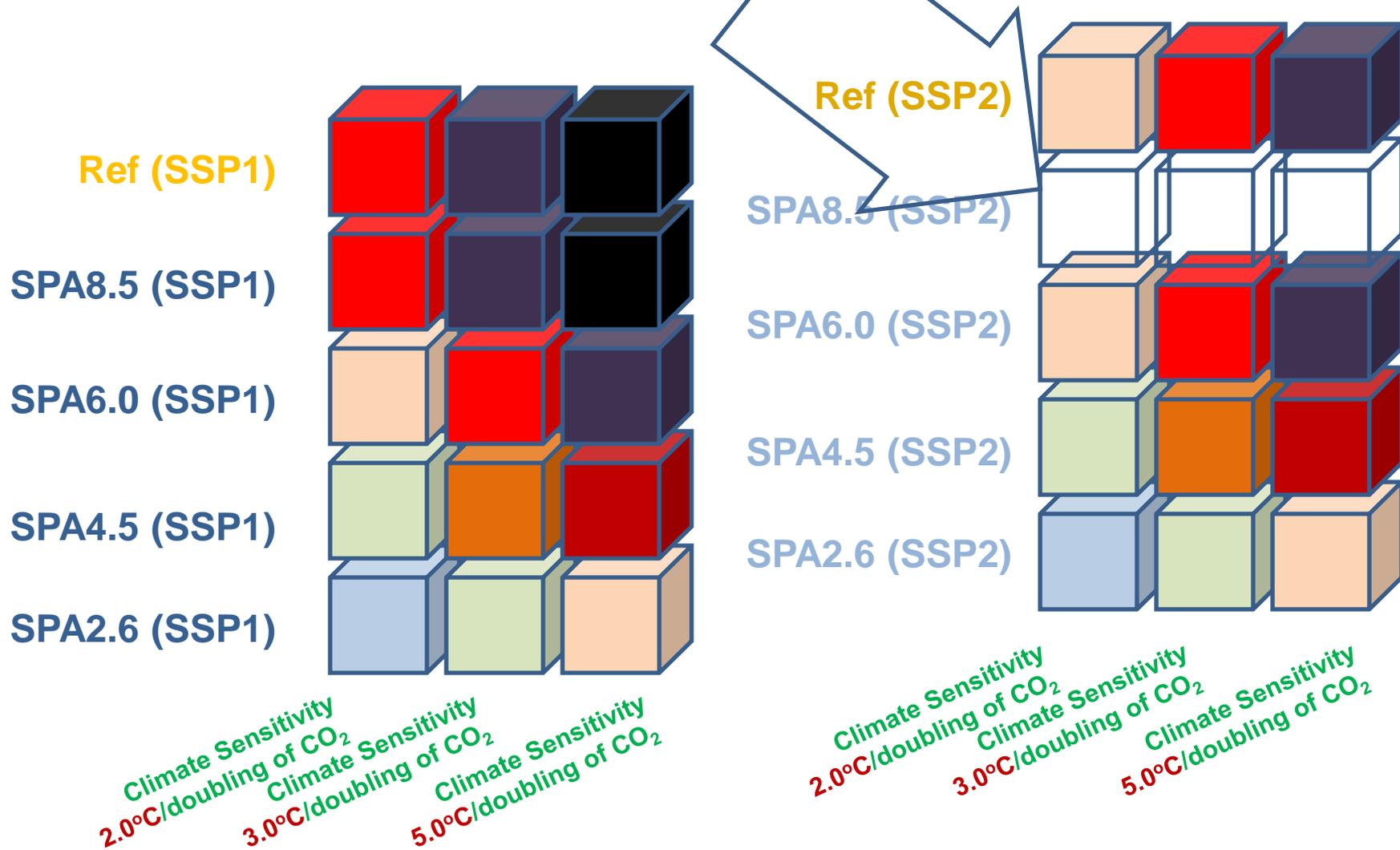
Three Elements of the New Scenarios: SSPs, Climate Change, and Mitigation

▶ Even though the climate will be the same for a given climate sensitivity and radiative forcing regardless of the SSP, the other scenario elements will vary.

Three Elements of the New Scenarios: SSPs, Climate Change, and Mitigation

▶ Even though the climate will be the same for a given climate sensitivity and radiative forcing regardless of the SSP, the other scenario elements will vary.

▶ Both scenarios below share the same climate sensitivity and degree of mitigative stringency.

▶ They do not share the same SSP.

▶ Therefore the will have different scenarios.

SPA4.5 (SSP1)

Different SSPs, AND different scenario elements, i.e. energy and commodity prices.

SPA4.5 (SSP2)

Climate Sensitivity
3.0^{o}C/doubling of CO_2

Climate Sensitivity
3.0^{o}C/doubling of CO_2

COMPARABILITY

Comparability

▶ Perhaps the most important feature of the new scenario architecture is that it facilitates comparison in at least two very useful ways:

- Across research communities: *Climate modeling, Integrated Assessment, and IAV.*
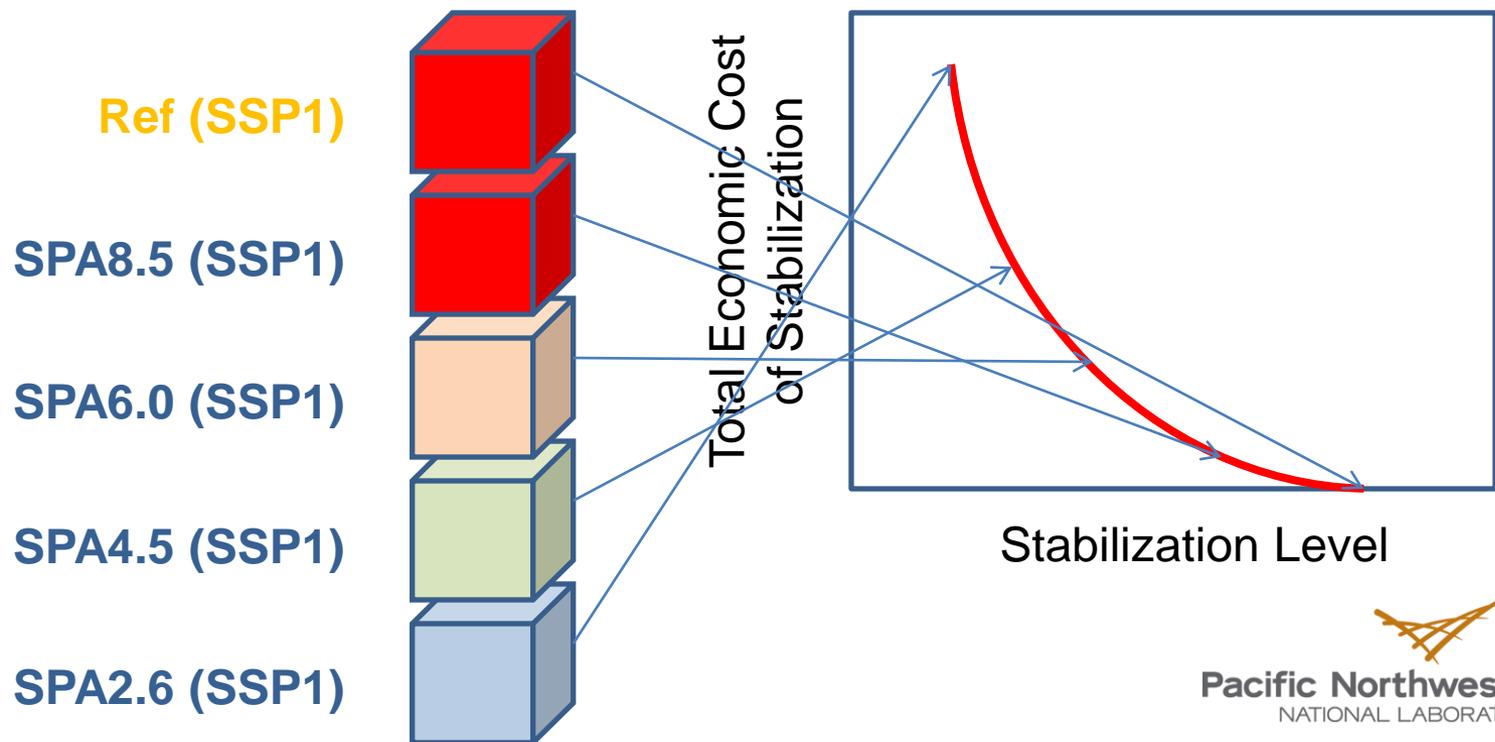
- Across IAV studies.

Comparability Across Research Communities

▶ The climate community started with the RCPs.

▶ It is producing ensemble calculations based on those emissions scenarios.

▶ Using RCP replications as part of the definition of the shared policy assumptions would make it easier for research results to be compared across the three climate research communities.

  ■ Ensemble calculations could be matched with emissions limitation scenarios in the new scenarios. So climate change results could be directly used by the IAV community (in combination with SSPs)

Comparability across mitigation studies

▶ Like RCP replications, using a common SSP would facilitate the comparison of the consequences of the mitigation.

▶ For example, total cost.

Ref (SSP1)

SPA8.5 (SSP1)

SPA6.0 (SSP1)

SPA4.5 (SSP1)

SPA2.6 (SSP1)

Total Economic Cost of Stabilization

Stabilization Level

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Multiple models will yield multiple results

▶ See for example, EMF 22 model inter-comparison results.
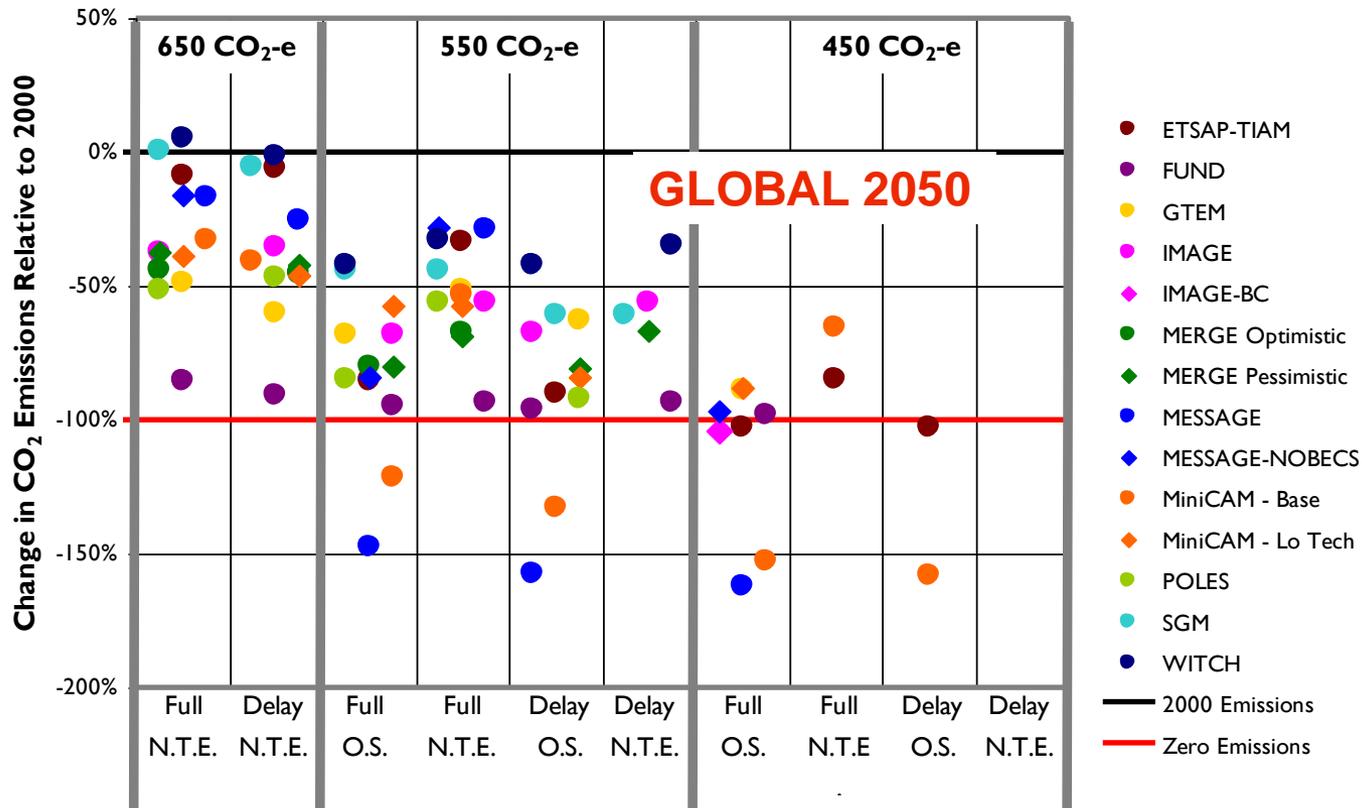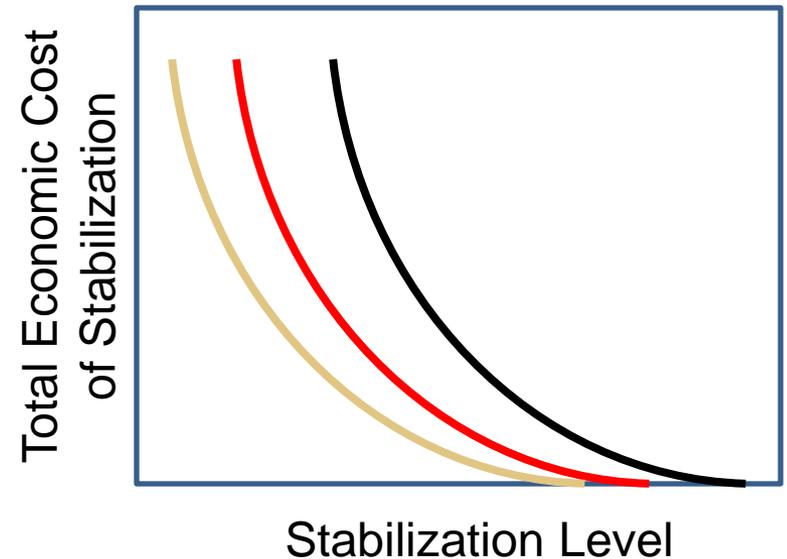
Comparability across mitigation scenarios

▶ Adding climate change may alter mitigation costs.
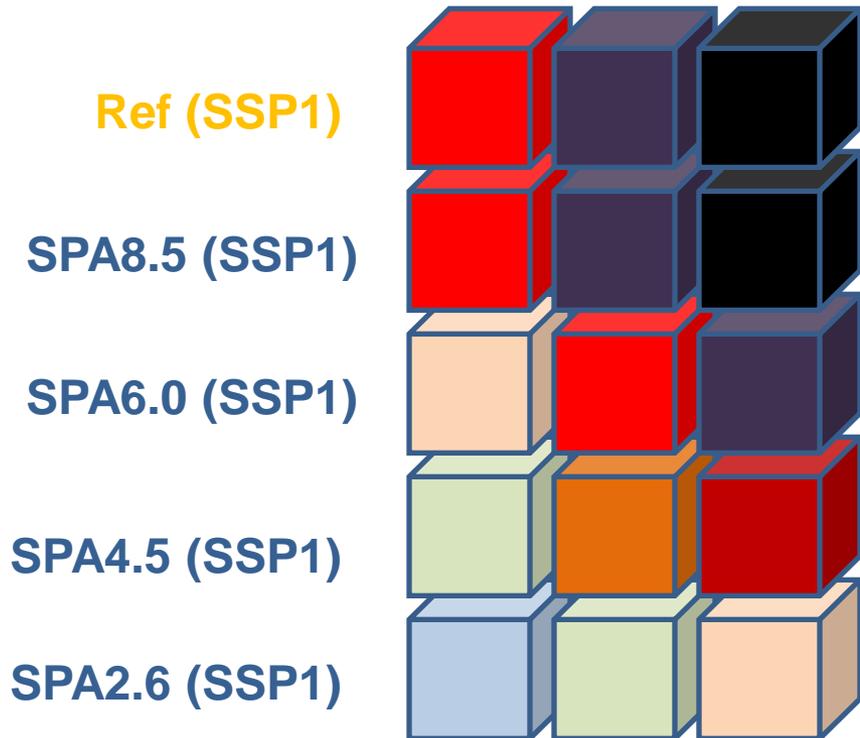
Ref (SSP1)

SPA8.5 (SSP1)

SPA6.0 (SSP1)

SPA4.5 (SSP1)

SPA2.6 (SSP1)

Climate Sensitivity
2.0°C/doubling of CO_2

Climate Sensitivity
3.0°C/doubling of CO_2

Climate Sensitivity
5.0°C/doubling of CO_2

Total Economic Cost of Stabilization

Stabilization Level

Comparability across mitigation scenarios and SSPs

▶ Changing from one SSP to another may alter the nature of emissions mitigation.

▶ E.g. EMF 24 looks at alternative technology regimes.

Ref (SSP1)

SPA8.5 (SSP1)

SPA6.0 (SSP1)

SPA4.5 (SSP1)

SPA2.6 (SSP1)

Ref (SSP2)

SPA8.5 (SSP2)

SPA6.0 (SSP2)

SPA4.5 (SSP2)

SPA2.6 (SSP2)

Total Economic Cost of Stabilization

Stabilization Level

Pacific Northwest
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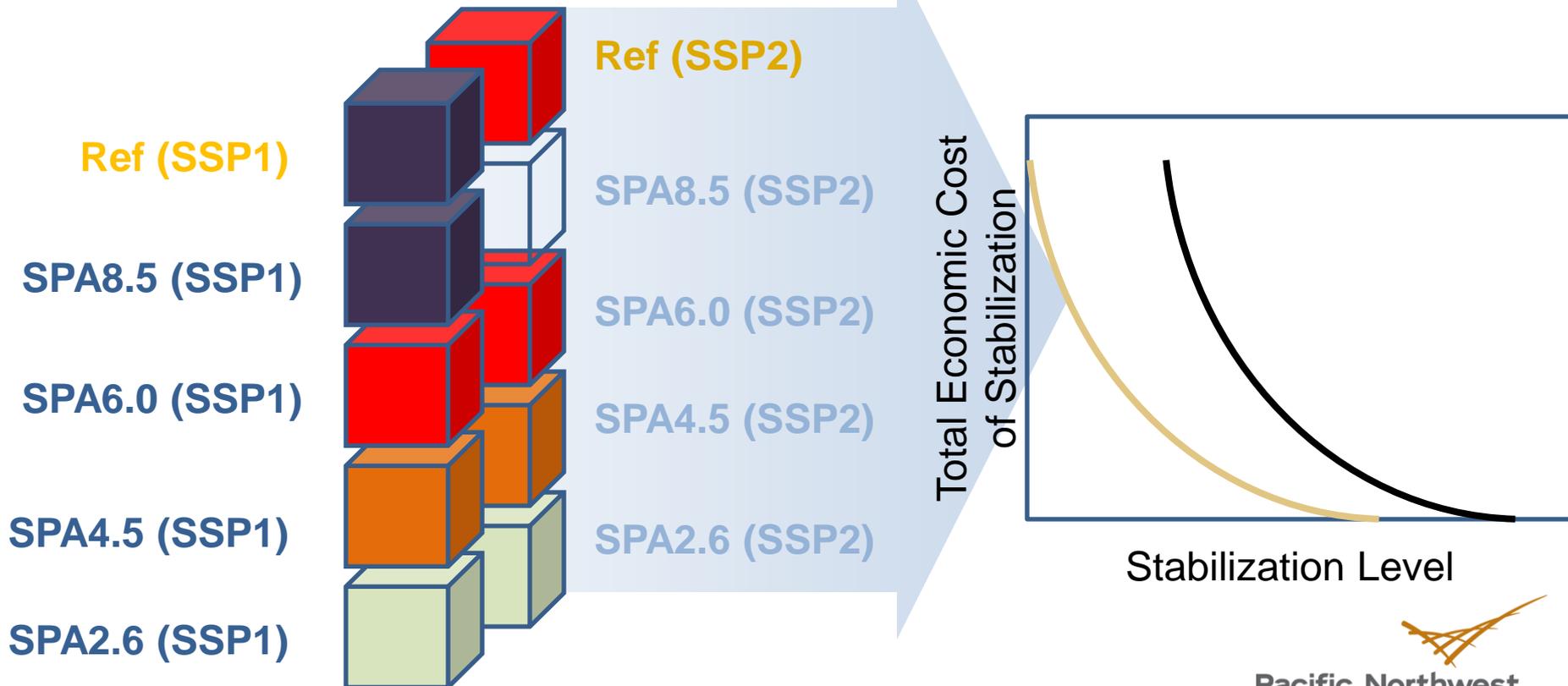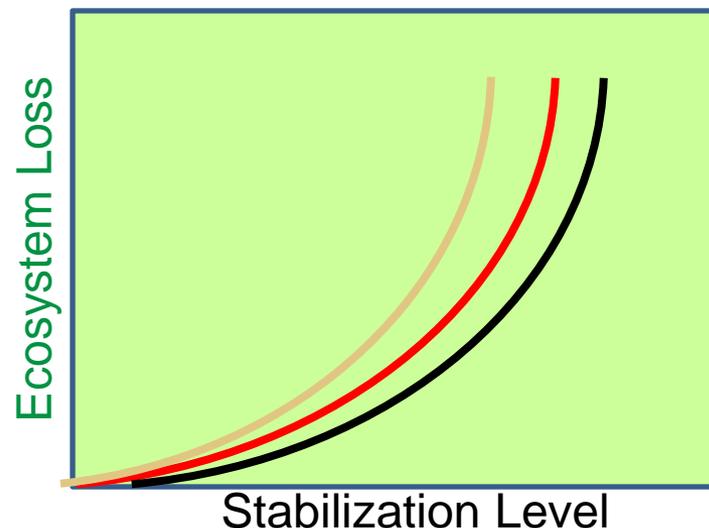
Comparability across IAV scenarios for an SSP

▶ These scenarios allow comparison of impacts, adaptation and vulnerability across alternative stabilization levels.

▶ And climate scenarios.
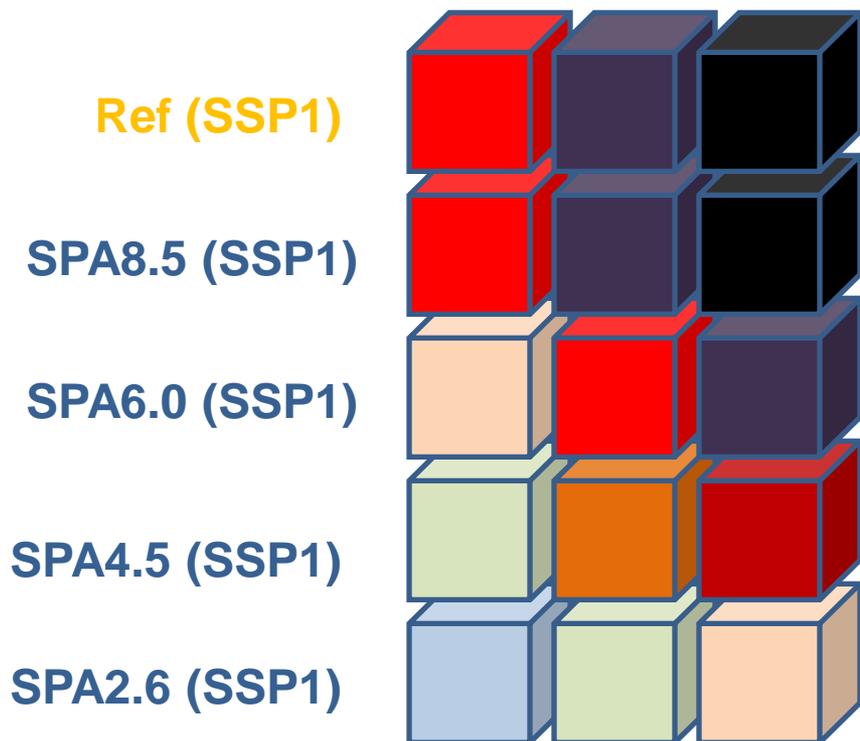
Ref (SSP1)

SPA8.5 (SSP1)

SPA6.0 (SSP1)

SPA4.5 (SSP1)

SPA2.6 (SSP1)

Climate Sensitivity
2.0°C/doubling of CO_2

Climate Sensitivity
3.0°C/doubling of CO_2

Climate Sensitivity
5.0°C/doubling of CO_2

Ecosystem Loss

Stabilization Level

Pacific Northwest
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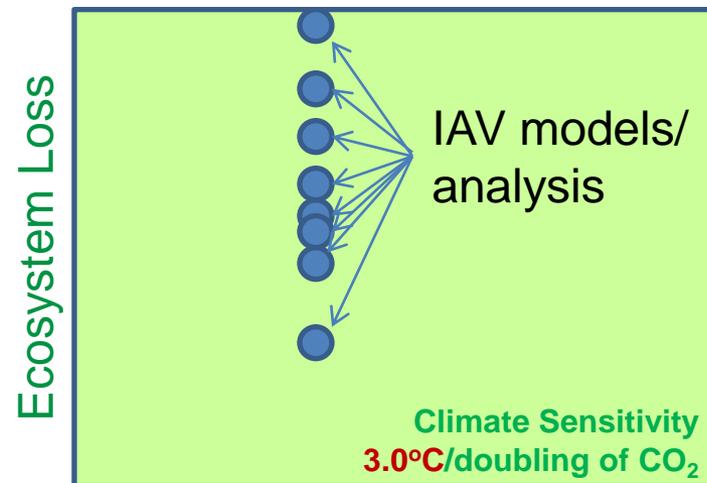
The new architecture can also facilitate comparison of IAV models and analysis

▶ For a given degree of mitigative stringency and a climate scenario, **and a given IAM**, the new SMA could facilitate model/analysis intercomparison.

▶ To understand how much change traces to differences in underlying scenarios and how much traces to IAV modeling an analysis.

SPA6.0 (SSP1)

Climate Sensitivity
$3.0^{\circ}C$/doubling of CO_2

Ecosystem Loss

IAV models/
analysis

Climate Sensitivity
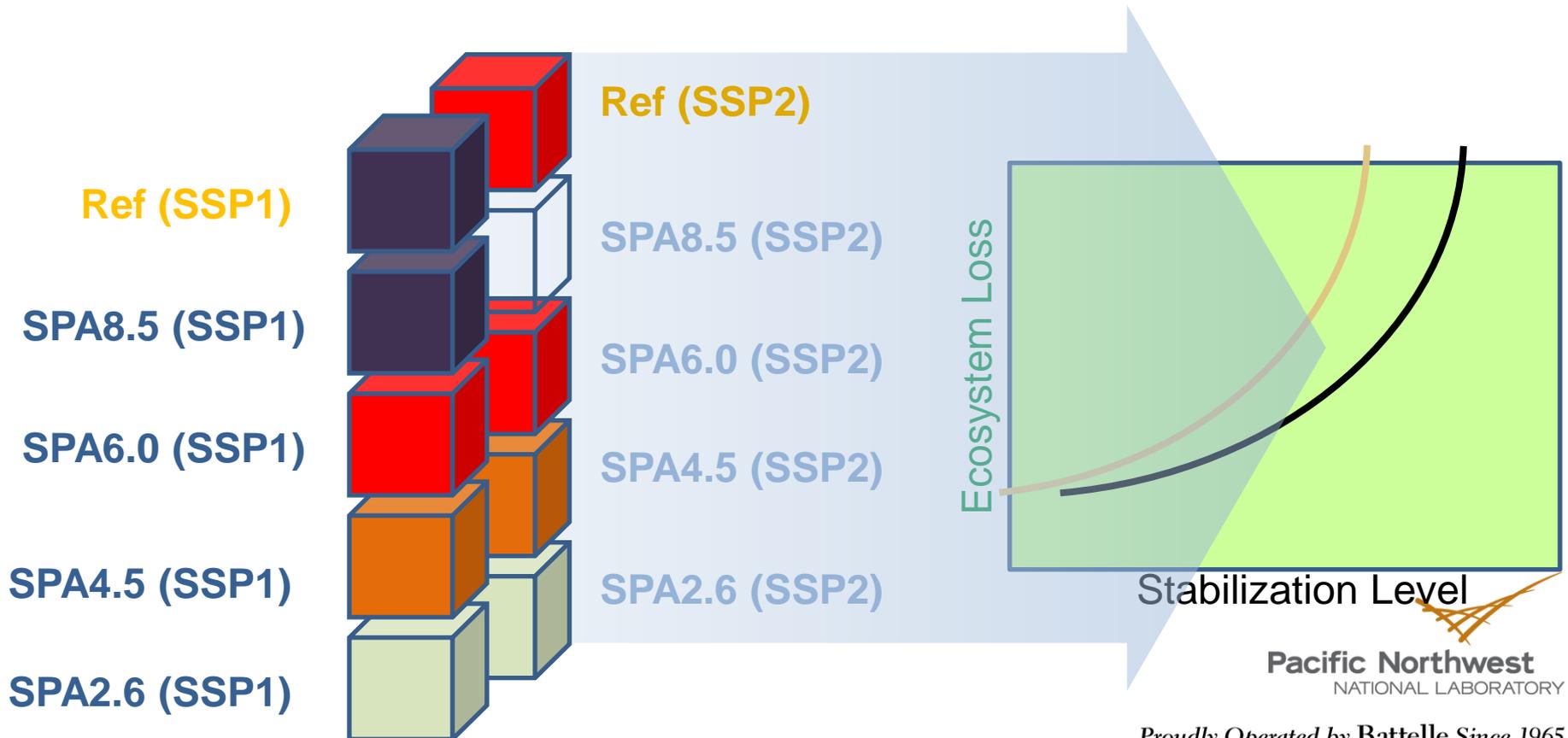$3.0^{\circ}C$/doubling of CO_2

SPA6.0
(SSP1)

Stabilization
Level

The new architecture can also facilitate comparison of IAV models and analysis

▶ IAV model intercomparison is impossible without fixing at least two components:

  ■ The climate scenario, AND

  ■ The IAM, because each IAM will have its own models of human and natural systems, which in turn carry implications for potentially vulnerable sectors, e.g. land use and land cover.

RCP 6.0 (SSP1)

Climate Sensitivity
3.0°C/doubling of CO_2

Ecosystem Loss

IAV models/ analysis

Climate Sensitivity
3.0°C/doubling of CO_2

RCP 6.0 (SSP1)

Stabilization Level

Pacific Northwest
NATIONAL LABORATORY

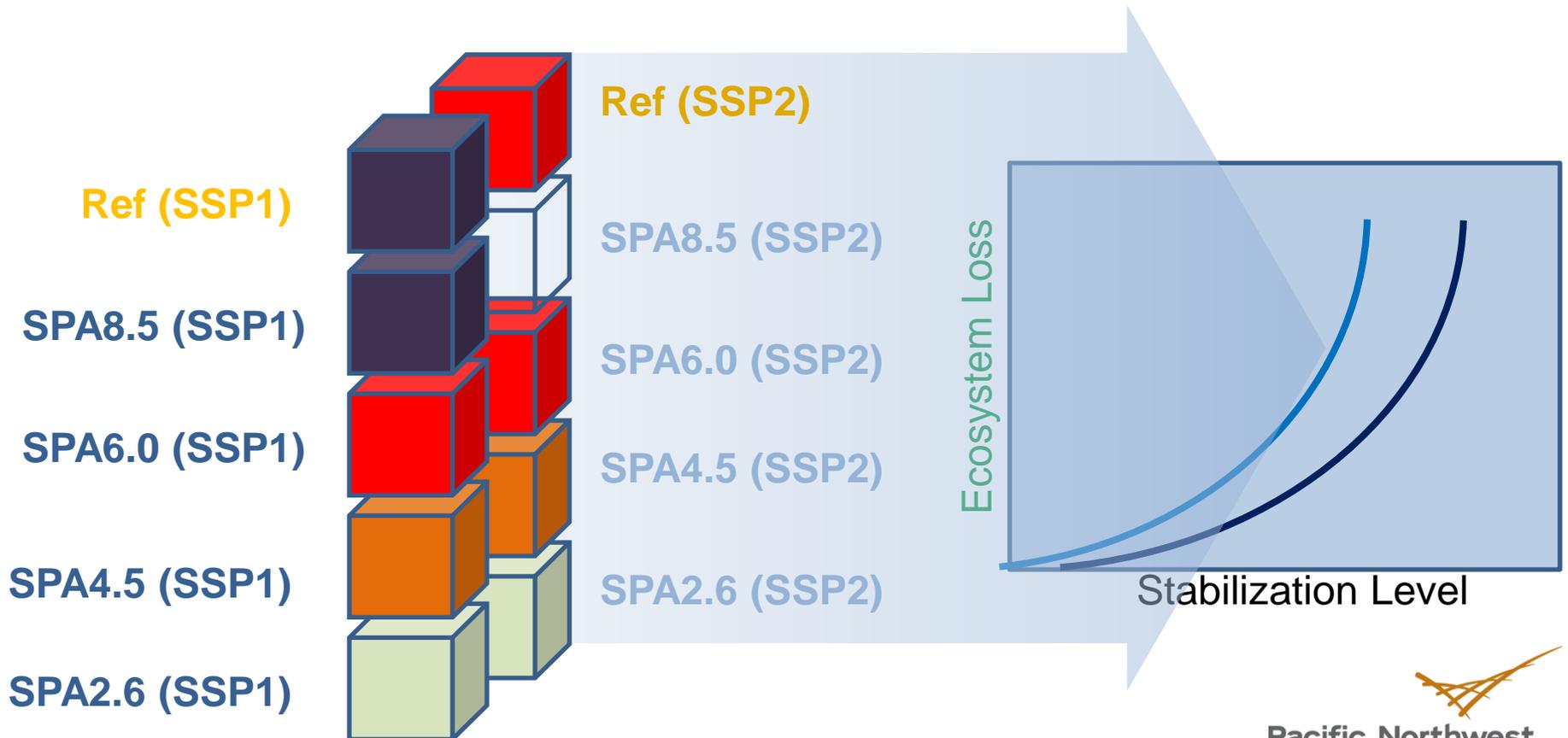*Proudly Operated by* **Battelle** *Since 1965*
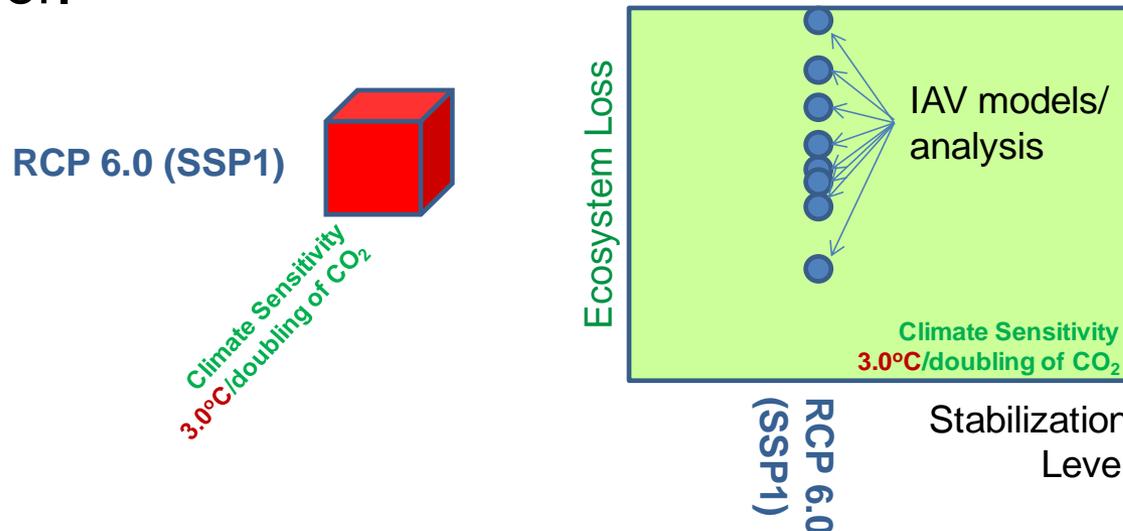
Comparability across mitigation scenarios and SSPs

▶ **Similarly, comparison of impacts and adaptation across SSPs will be clouded if the comparison uses a different IAM for the second SSP, because you won't know if the different climate impact is because the underlying SSP was different or because the way it was modeled was different.**

Ref (SSP2)
Ref (SSP1)
SPA8.5 (SSP2)
SPA8.5 (SSP1)
SPA6.0 (SSP2)
SPA6.0 (SSP1)
SPA4.5 (SSP2)
SPA4.5 (SSP1)
SPA2.6 (SSP2)
SPA2.6 (SSP1)

Ecosystem Loss

Stabilization Level

Comparability across SPAs and SSPs

▶ **Comparison of impacts and adaptation across SSPs will be clouded if the comparison uses a different climate model for the second SSP.**

Ref (SSP2)

Ref (SSP1)

SPA8.5 (SSP2)

SPA8.5 (SSP1)

SPA6.0 (SSP2)

SPA6.0 (SSP1)

SPA4.5 (SSP2)

SPA4.5 (SSP1)

SPA2.6 (SSP2)

SPA2.6 (SSP1)

Ecosystem Loss

Stabilization Level

THE CHANGWON CITY WORKSHOP

The SMA/SSP Workshop was held in Changwon City, Korea July 16 & 17

▶ *The goal of this workshop was to bring together researcher, who are exploring specific options for implementation of the SMA/SSP concepts, and to exchange information and results from their exploratory research, both positive and negative.*

▶ No decisions were taken—it was a "Show-and-Tell".

▶ Feeds into a longer-term process still under development.

- Laxenburg, Austria—the IAMC meeting October 6-7 (update on progress).

- NCAR SMA/SSP meeting November 3-4.

DISCUSSION