INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
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Energy, Water and Food under Climate Change: Tradeoffs and Policies

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Outline

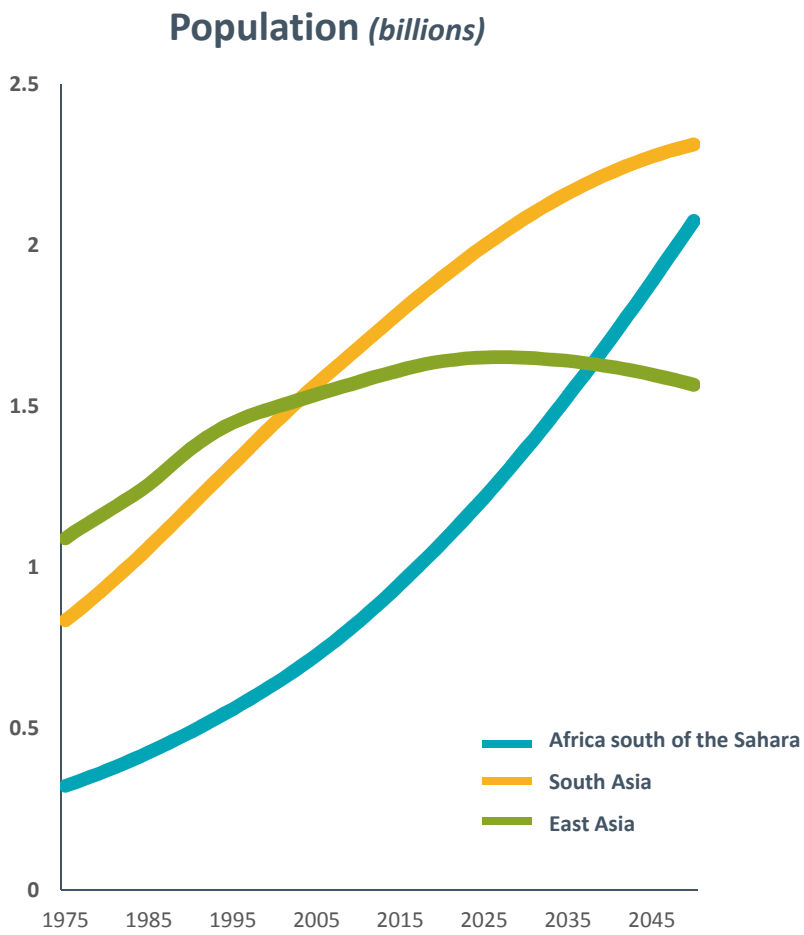
- Trends and Challenges for Food Security, Water Scarcity, and Energy Use
- Impact of Energy Taxes and Policy on Food Security and Water Scarcity: Scenarios to 2050
- Conclusions

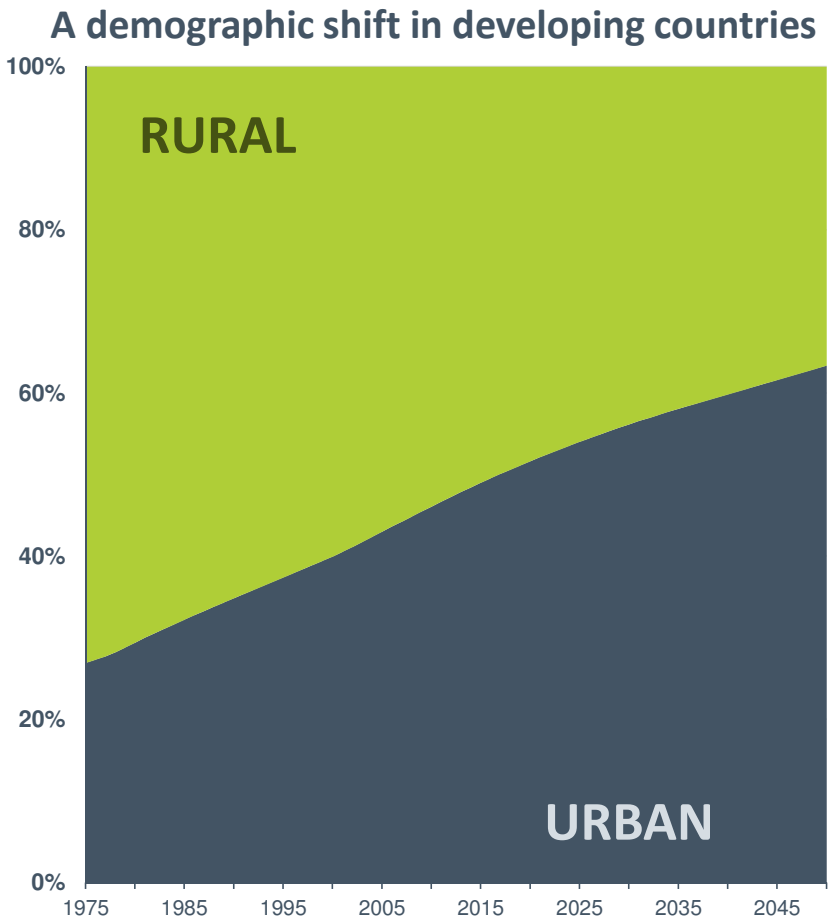
Trends and Challenges for Food Security, Water Scarcity, and Energy Use

Background and Objective

- In September 2015, UN members adopted the Sustainable Development Goals
  - access to food, nutrition, safe water and modern energy for all
  - strong environmental protection, including reductions in greenhouse gas emissions (GHG)
- Potential tradeoffs between these goals, related targets and indicators
- Need to identify policies that achieve win-win solutions
- To assess the impact of energy (carbon) taxes on food security and water scarcity under climate change: can such taxes reduce GHG without damaging food and water security?

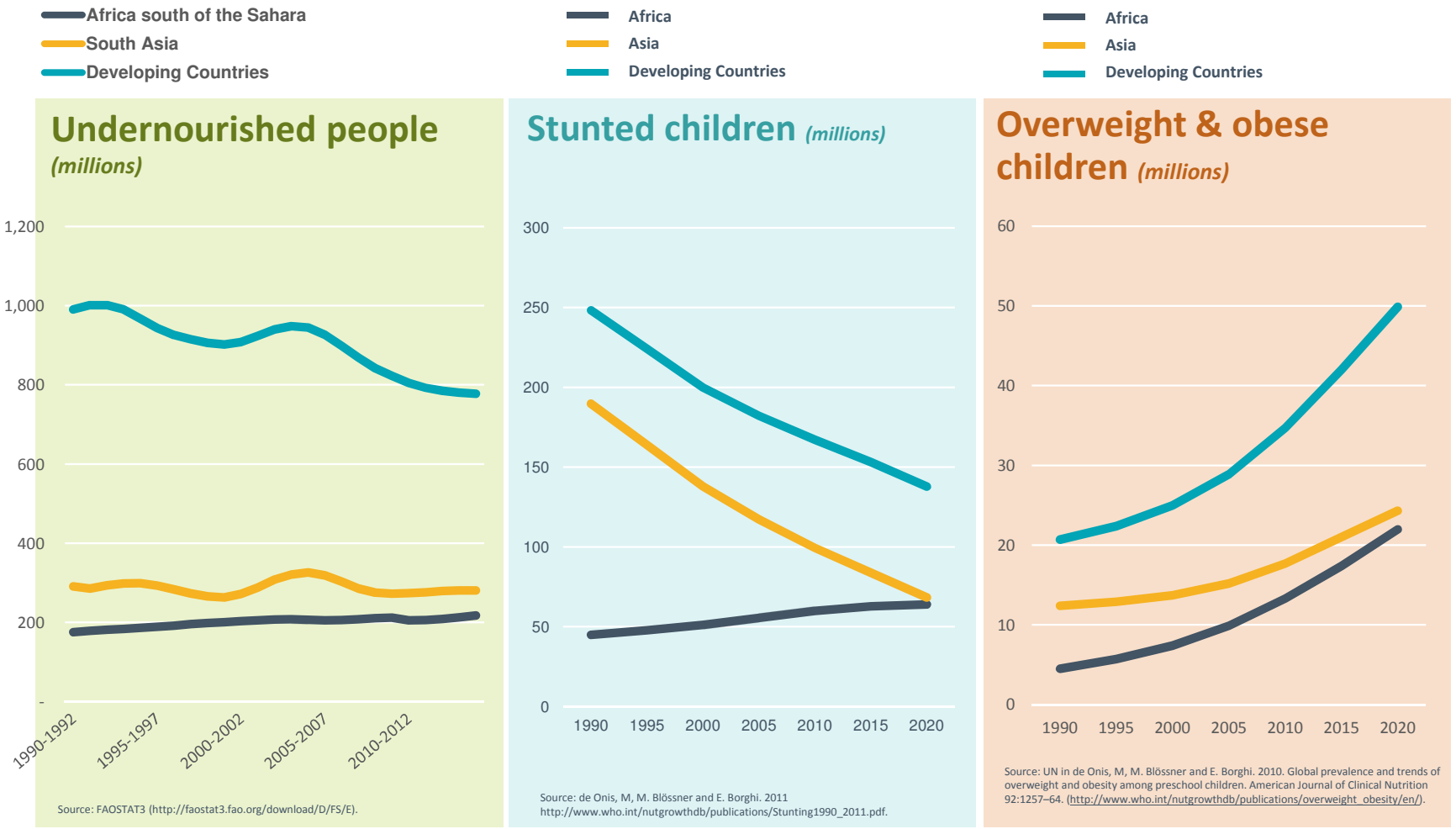
Population: Rapid growth in Africa. Developing world urbanizes.





Source: United Nations, Department of Economic and Social Affairs, Population Division (2014). World Urbanization Prospects: The 2014 Revision, CD-ROM Edition.

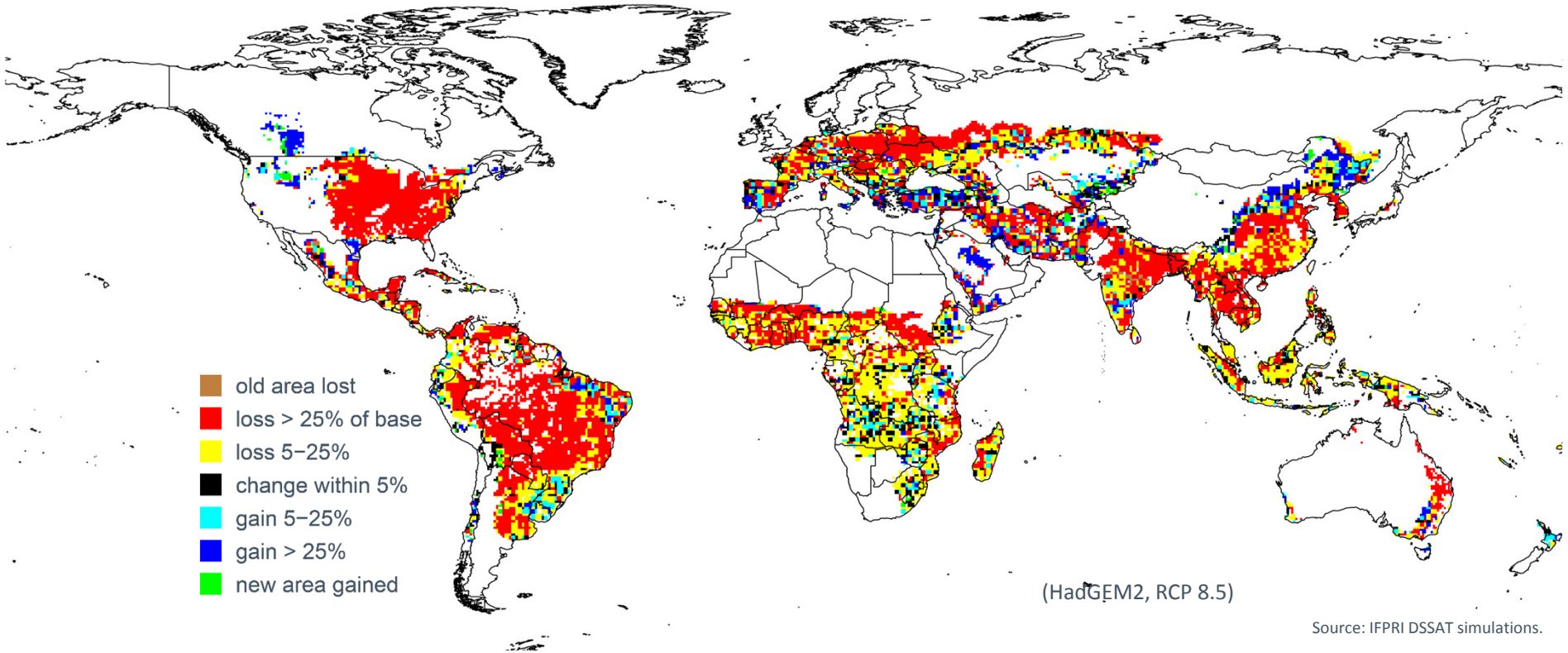
Slow decline in malnourishment. Alarming increase in obesity.



Heavy toll on rainfed maize with climate change.

Global yields projected

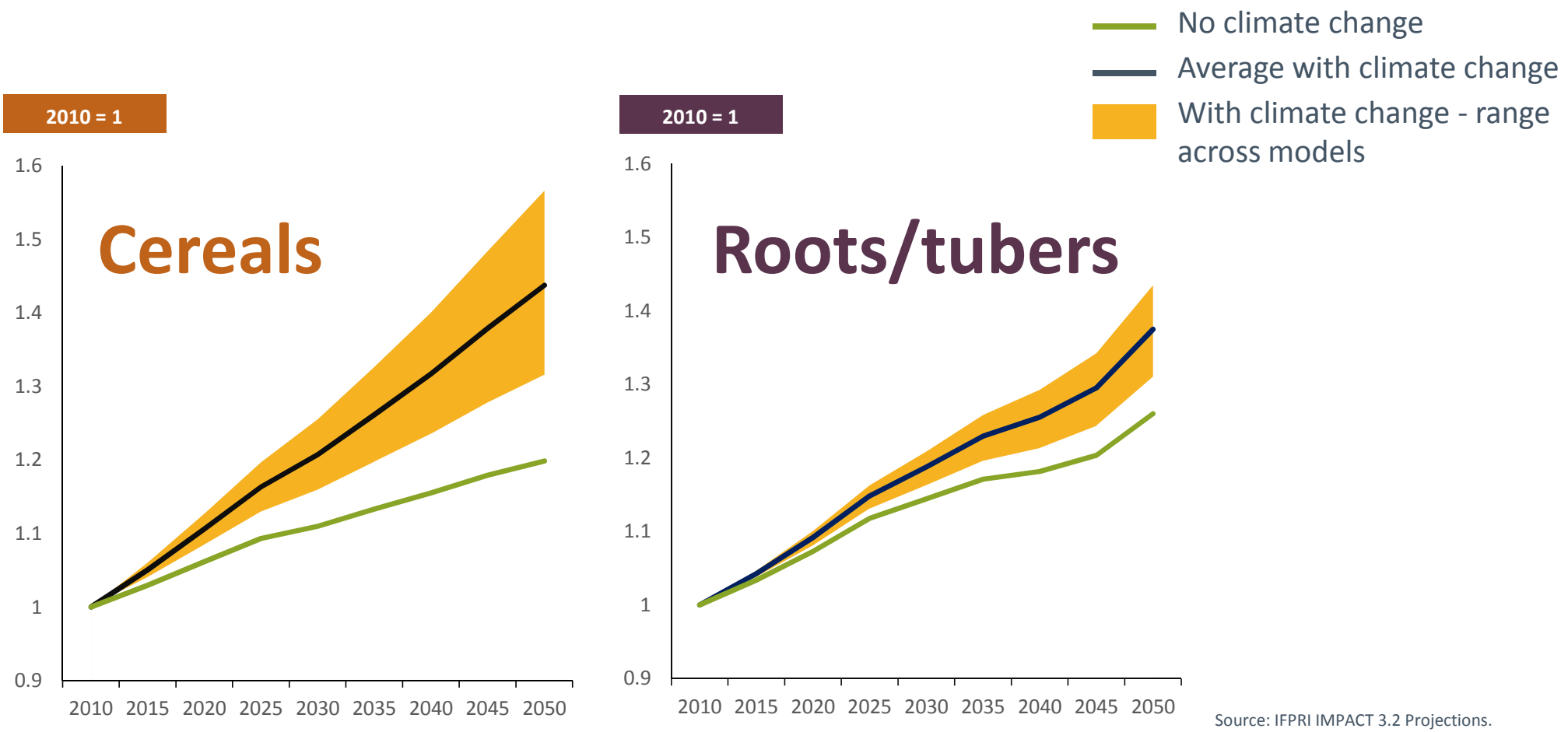
30% lower in 2050 compared to no climate change



(HadGEM2, RCP 8.5)

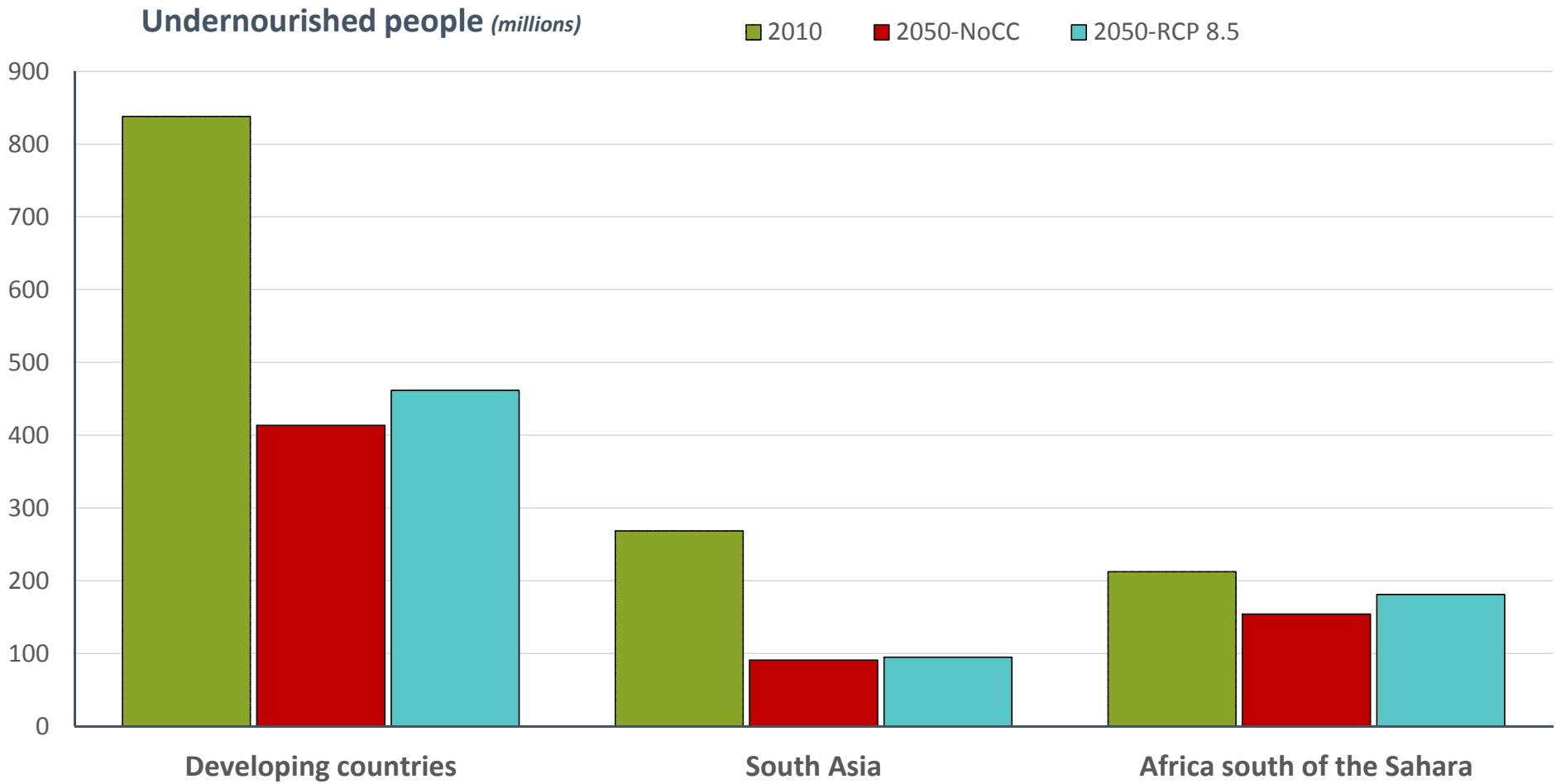
Source: IFPRI DSSAT simulations.

Food prices increase without climate change; even higher with climate change.



Source: IFPRI IMPACT 3.2 Projections.

Improved progress on hunger, but too slow.
Climate change increases hunger.



Source: IFPRI IMPACT 3.2 Projections.

Water stress risk

36%	population	52%
39%	grain production	49%
22%	global GDP	45%

TODAY

Total population living in water scarce areas

2.5 BILLION PEOPLE

Global GDP generated in water scarce regions

US$9.4 TRILLION

By 2050

Total population living in water scarce areas

4.7 BILLION PEOPLE

90%

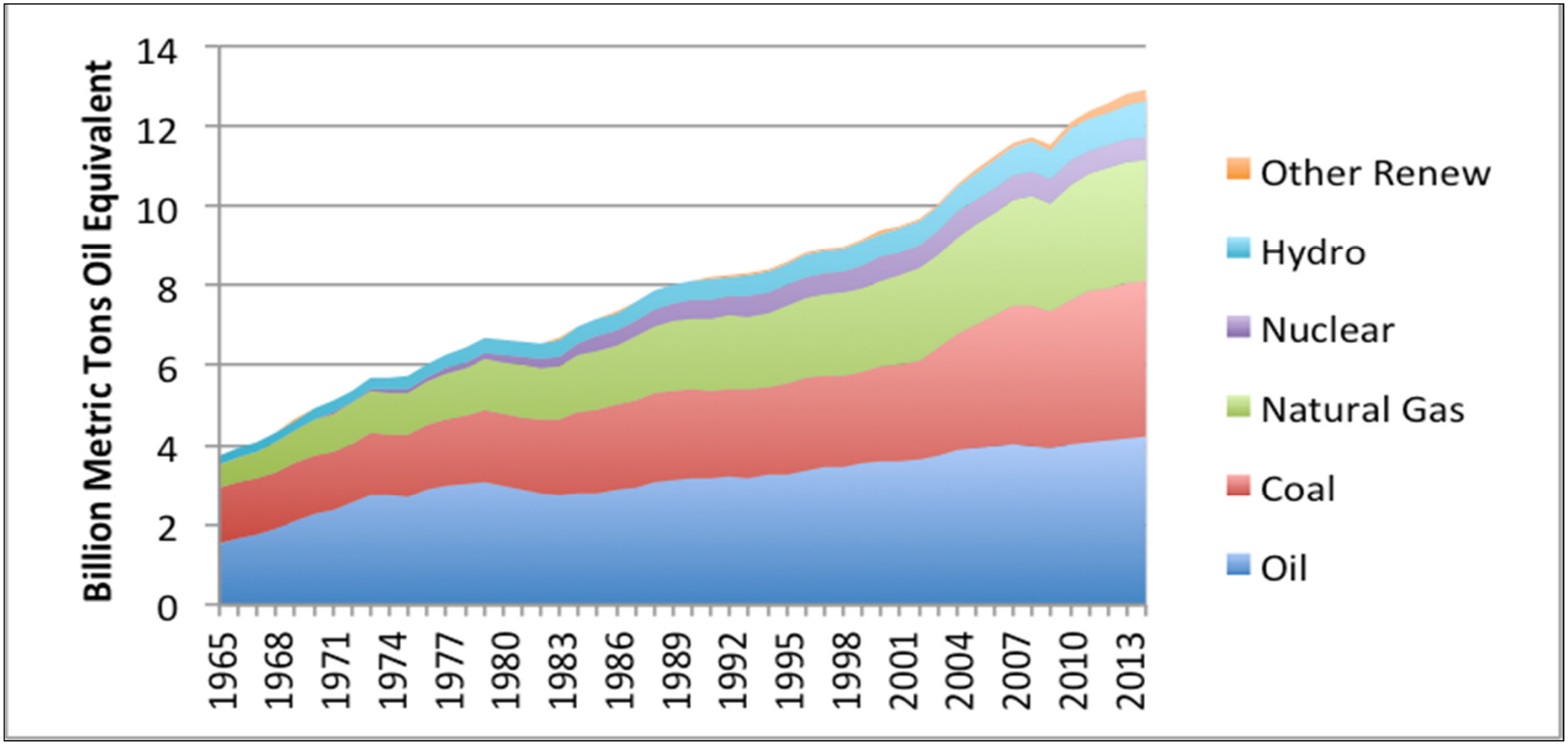
Global GDP generated in water scarce regions

US$63 TRILLION

570%

Source: Veolia Water and IFPRI 2011.

Fossil fuels continue to dominate energy consumption



• ~60 percent of biomass is traditional biomass

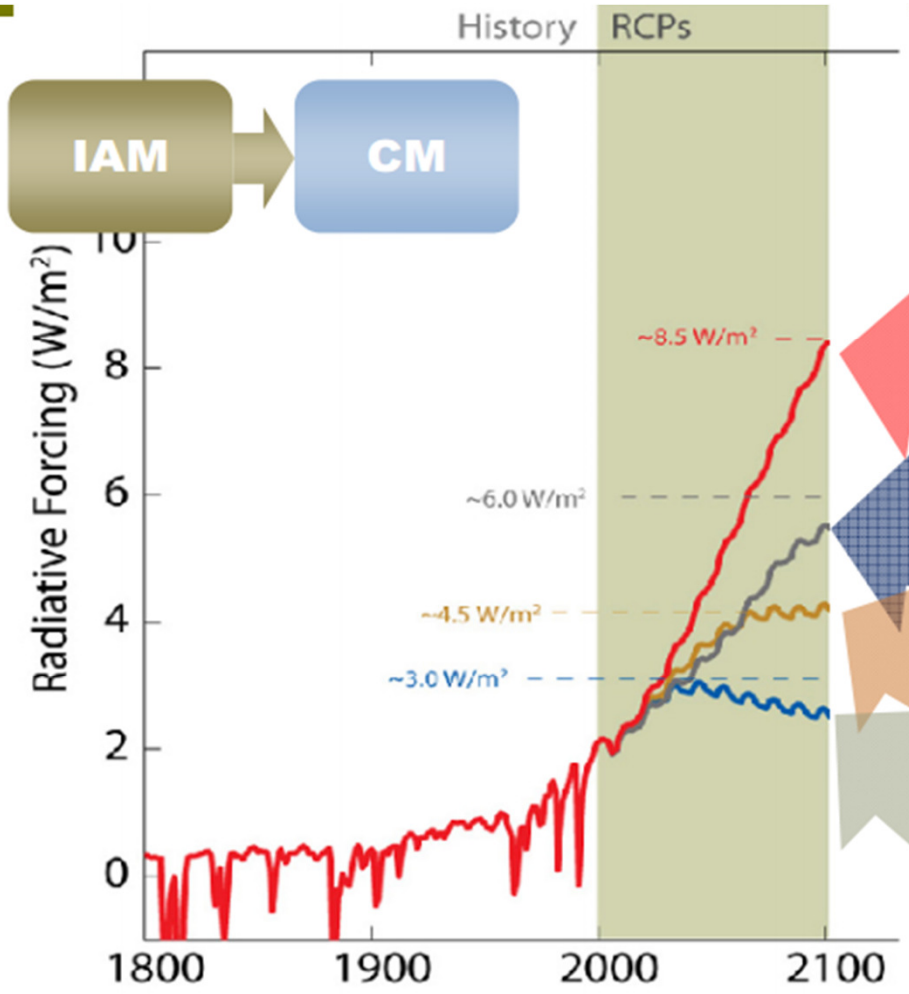
Source: BP Statistical Review of World Energy 2015

Impact of Energy Taxes on Food Security and Water Scarcity: Scenarios to 2050

Terminology in IPCC Fifth Assessment (AR5) climate scenarios

- SSPs – Shared Socioeconomic Pathways, alternative scenarios for income growth and population growth
- RCPs – Representative Concentration Pathways, alternative scenarios for increase in greenhouse gas emissions and temperature increases via radiative forcing

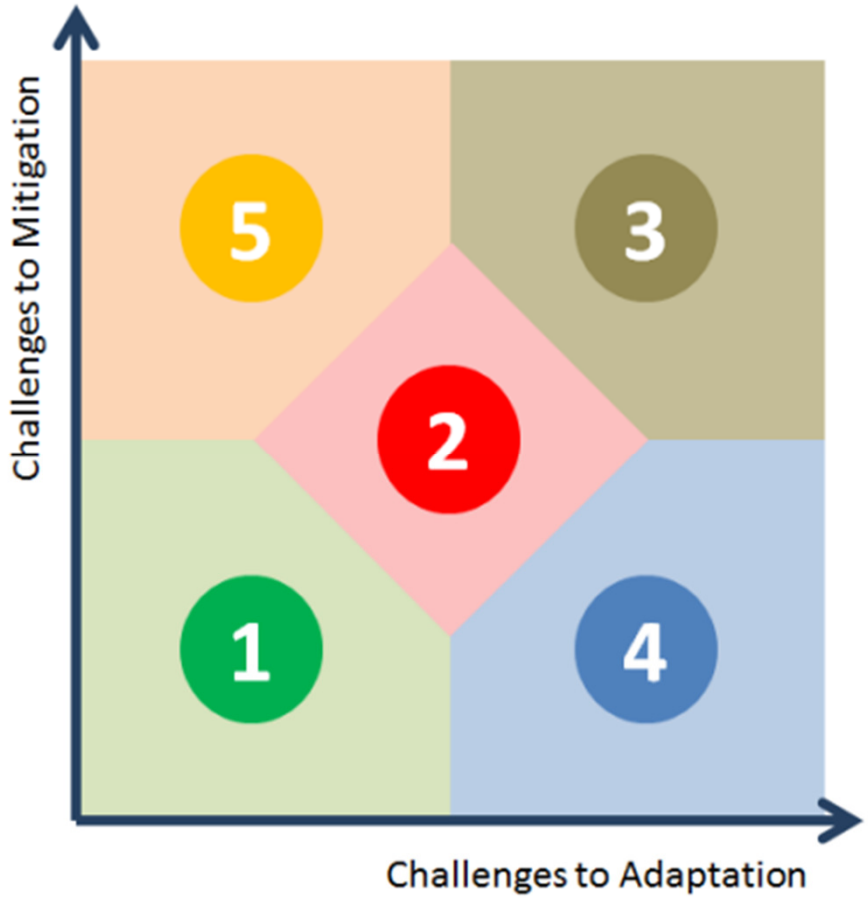
Representative Concentration Pathways (RCPs)



- The CM community wanted 4 levels of RF that span the literature.
  - 8.5 Wm^{-2} (RCP 8.5, *1350ppm CO_2-e*)
  - 6.0 Wm^{-2} (RCP 6.0, *850ppm CO_2-e*)
  - 4.5 Wm^{-2} (RCP 4.5, *650ppm CO_2-e*)
  - 2.6 Wm^{-2} (RCP 2.6, *450ppm CO_2-e*)

Shared Socioeconomic Pathways (SSPs)

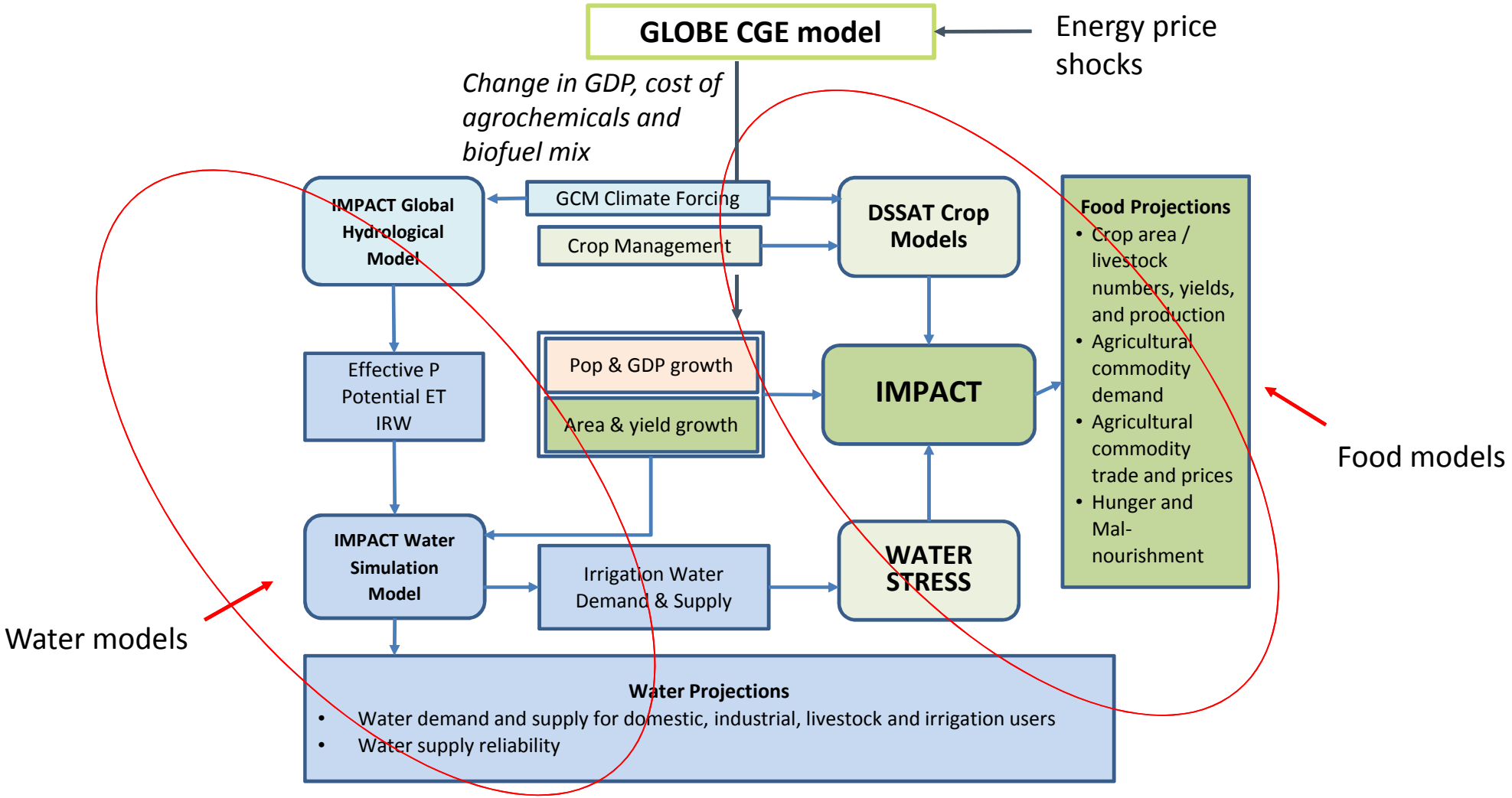
- SSP1 – Low Challenges
- SSP2 – Intermediate Challenges, business as usual (med-med)
- SSP3 – High Challenges
- SSP4 – Adaptation Challenges Dominates
- SSP5 – Mitigation Challenges Dominates



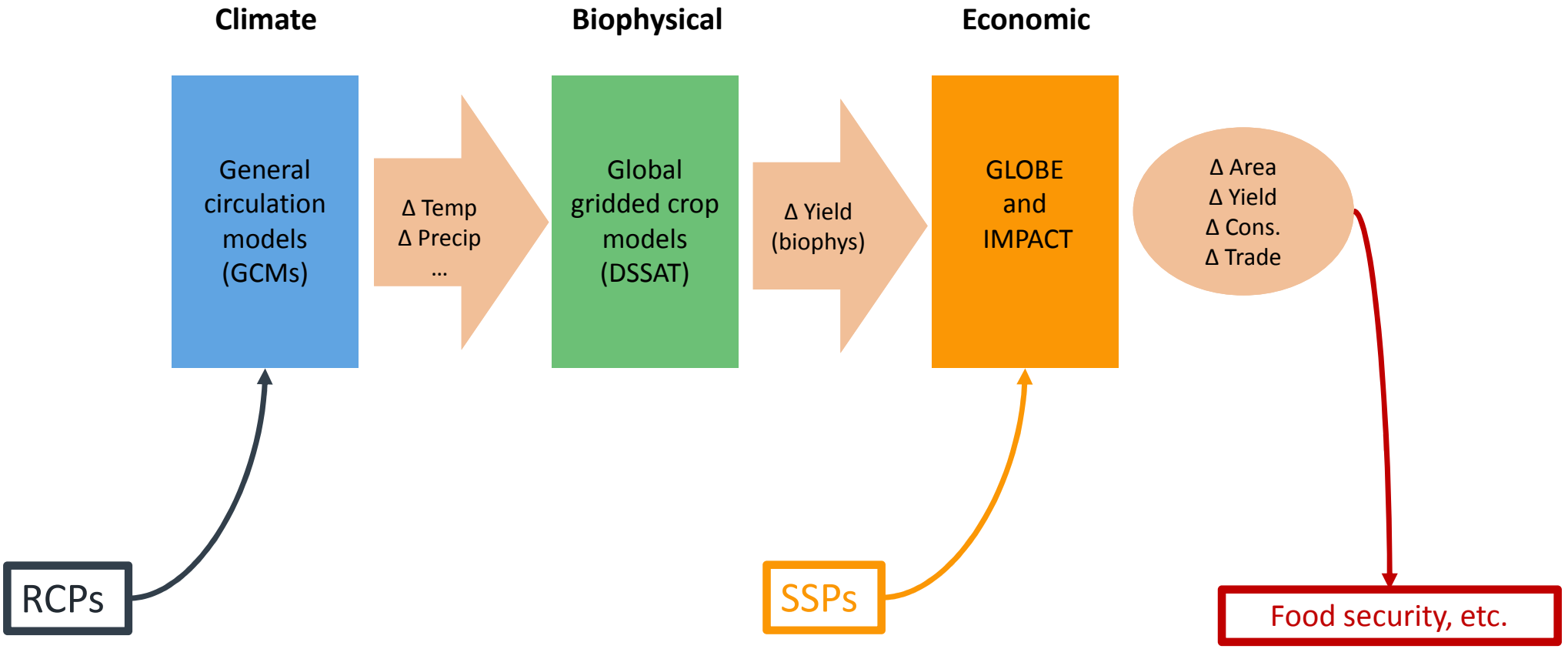
SSP2 – Annual Growth rates by region (2010-2050)

Region	GDP	Population	Per capita GDP
Africa and Middle East	3.4%	1.3%	2.0%
East Asia, Southeast Asia, and Oceania	2.9%	0.1%	2.8%
South Asia	4.1%	0.7%	3.3%
Former Soviet Union	2.3%	-0.0% (slightly negative)	2.3%
Latin America and Caribbean	2.4%	0.5%	1.9%
North America	1.5%	0.5%	0.9%
Europe	1.3%	0.1%	1.1%
World	2.5%	0.6%	1.9%

Method: IMPACT with CGE linkage



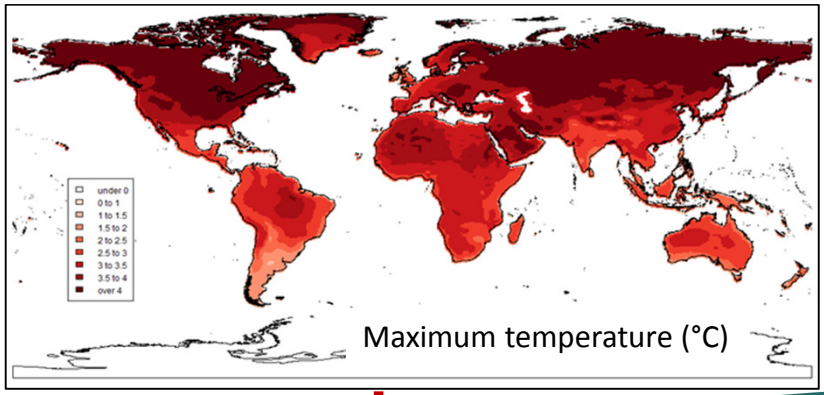
Modeling climate impacts on agriculture: biophysical and economic effects



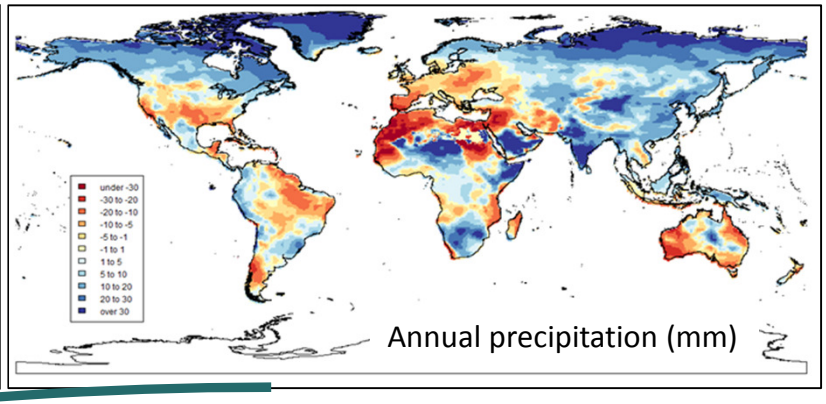
Adapted from Nelson et al., *Proceedings of the National Academy of Sciences* (2014)

Climate change impacts in 2050

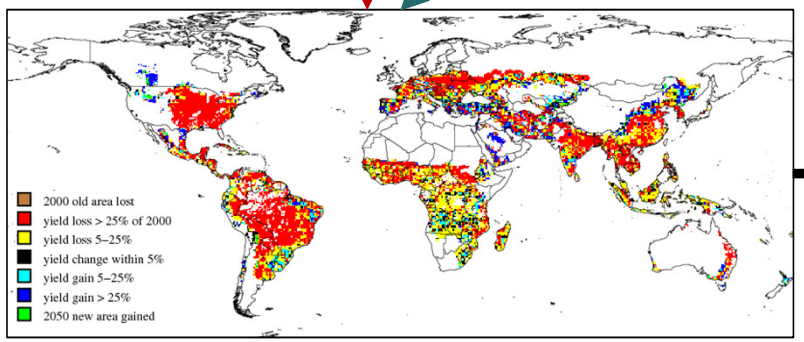
The case of maize yields using HadGEM (RCP8.5), DSSAT, and IMPACT (SSP2)



Maximum temperature (°C)

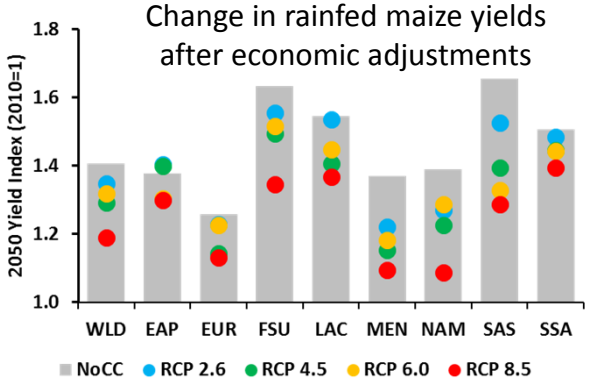


Annual precipitation (mm)



Change in rainfed maize yields before economic adjustments

Change in rainfed maize yields after economic adjustments



Source: IFPRI, IMPACT version 3.2, November 2015

Analytical Framework: GLOBE CGE model

- Trade: Nested Armington specification: Imperfect substitutability between domestic goods and imports, and between imports by origin
- Product differentiation between output for domestic markets and exports, and between exports by destination (nested CET)
- Consumer demand derived from maximization of Stone-Geary utility functions => LES demand
- Producers maximize profits subject to CES-Leontief technologies and price taking behaviour in input and output markets
- Calibration to GTAP 8.1 database (2013) and GTAP elasticities
- Aggregation 22 sectors – 22 regions – 5 primary factors

Analytical Framework: IMPACT Model

- Global partial equilibrium agricultural sector model
- Disaggregated agricultural commodities (56 commodities)
- Disaggregated spatial allocation of crop production at sub-national level (159 countries, and 320 food production units)
- Log-linear demand and supply functions
- Detailed structure of technology, land and water, and climate change
- World food prices are determined annually at levels that clear international commodity markets, demand, and supply

GLOBE-IMPACT linkage

- Model baselines are calibrated on agricultural productivity, GDP and prices and economy-wide gross domestic product (GDP)
- Climate shocks on agricultural productivity and prices are transmitted from IMPACT to GLOBE, with further iteration back to IMPACT for economy-wide feedbacks to agriculture
- Energy tax shocks on household income and GDP are transmitted from GLOBE to IMPACT

Scenarios

Scenario	Specification
1a Baseline without climate change (BasenoCC)	BAU (SSP2): 9.1 billion people in 2050
1b Baseline with climate change (BaseCC)	BAU (SSP2) with high emissions scenario (RCP8.5); HadGEM2-ES
2 High fossil fuel price with CC); run with RCP8.5 for macro impact (HEPPCC); then with RCP6, to reflect endogenous reduction in GHG emissions (HEP-6CC)	Fossil fuel taxes in GLOBE (70% tax on coal, 50% on crude oil; 30% on natural gas)—reduce producer price and increase consumer price Reduction of GW withdrawal by 20% relative to baseline due to adverse impacts of higher fuel prices on GW pumping
3 High fossil fuel price with increased biofuel use and increased HP production with CC (HEPadapCC)	Same as Scenario 2 plus Increase in First GEN biofuel demand to compensate for reduced fossil fuel availability, doubled by 2050 Gradual, linear increase in hydropower production (10% by 2050) with associated 10% increase in storage and SW withdrawal capacity

Source: Ringler, C., Willenbockel, D., Perez, N., Zhu, T., Rosegrant, M.W., Matthews, N., Global Linkages among Water, Energy and Food: An Economic Assessment. Draft paper, 2015

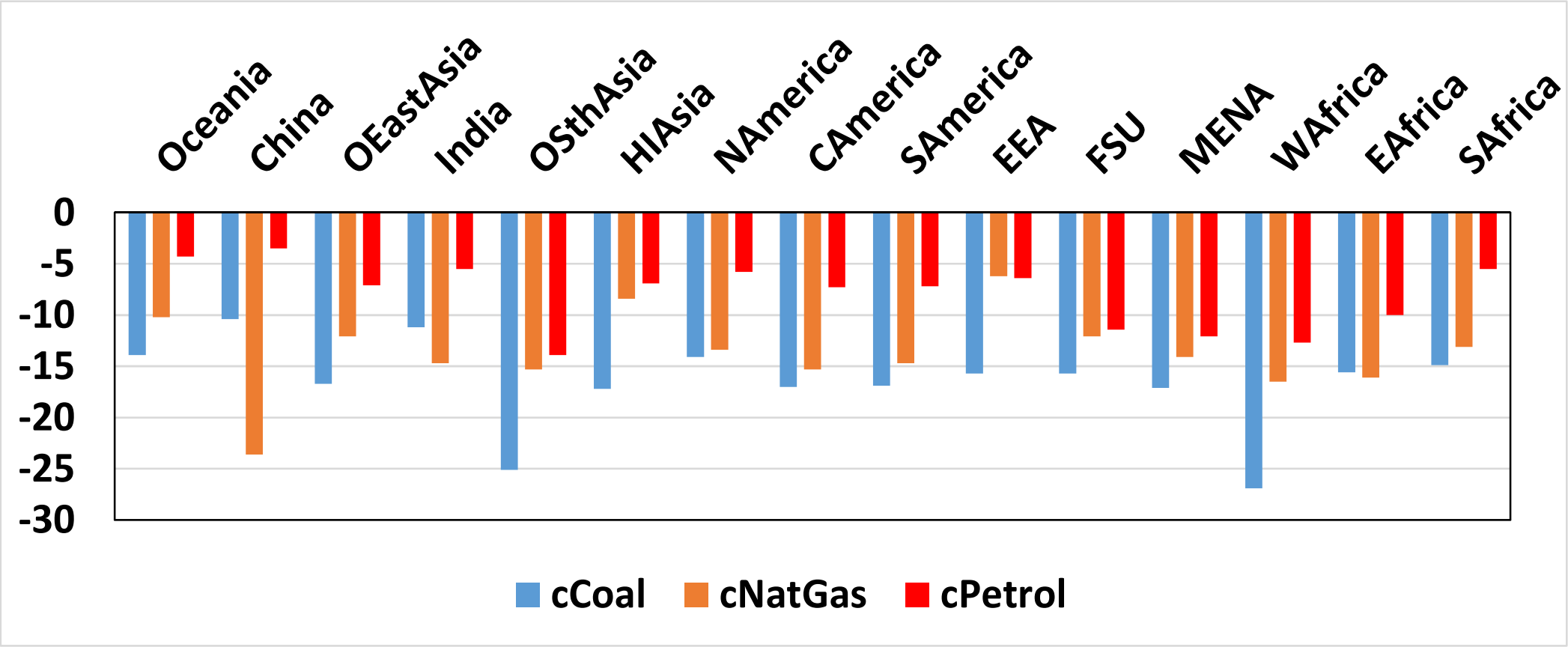
Terms-of-Trade Effects (GLOBE)

	No Climate Change		With Climate Change	
	HEP	HEPadap	HEP	HEPadap
Oceania	(2.7)	(2.6)	(2.7)	(2.5)
China	0.9	0.9	0.9	0.8
O EastAsia	(1.2)	(1.2)	(1.2)	(1.2)
India	6.6	6.6	6.5	6.5
O SouthAsia	(3.9)	(3.9)	(3.9)	(3.9)
HIAsia	5.2	5.1	5.1	5.0
N America	2.0	2.0	2.0	2.1
C America	(2.2)	(2.2)	(2.1)	(2.1)
S America	(1.1)	(0.9)	(1.1)	(0.8)
MENA	(6.0)	(6.1)	(5.9)	(6.0)
W Africa	(10.8)	(10.8)	(10.7)	(10.7)
E Africa	(5.1)	(5.1)	(5.1)	(5.1)
S Africa	1.6	1.6	1.5	1.5

- Energy price shifts cause terms-of-trade
  - gains for regions that are net importers of the primary fossil fuels
  - losses for the net exporters of these fuels (MENA)
- Regions that are simultaneously net importers of primary fossil fuels and net exporters of refined petrol enjoy the largest terms-of-trade gains (India and High-Income Asia)
- Regions that are both net exporters of primary fossil fuels and net importers of refined petrol (East and West Africa) have the biggest losses

Source: Ringler et al., 2015

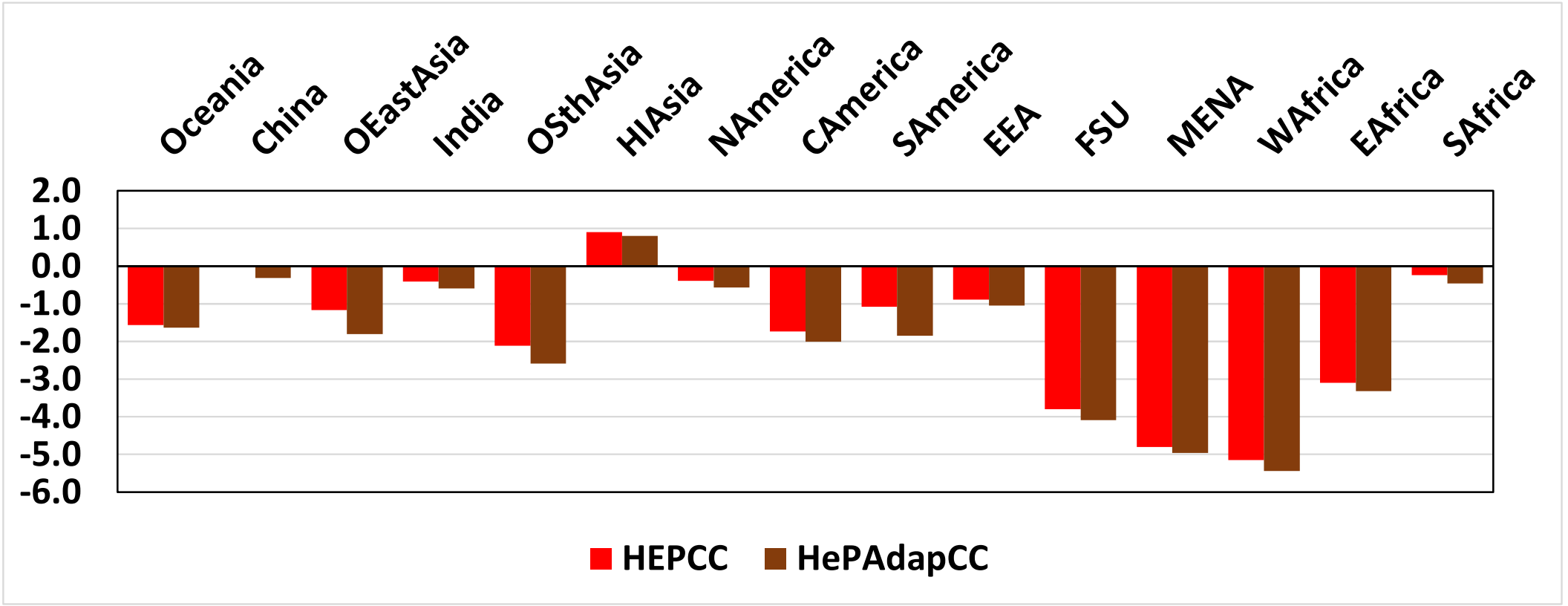
Change in fossil fuel use in electricity sector, HEPCC compared to BaseCC *(%-change, 2050)*



Note: Oceania: Australia, New Zealand and Other Oceania; OEastAsia – Other East Asia; OSthAsia – Other South Asia; HIAsia – High-income Asia; NAmerica – North America; CAmerica – Central America and Caribbean; SAmerica – South America; EEA – European Economic Area; FSU – Former Soviet Union; MENA – Middle East and North America; WAfrica – West Africa; EAfrica – East and Central Africa; SAfrica – Southern Africa

Source: Ringler et al., 2015

Impact of energy price increase on real household income *(% deviation from baseline scenario)*



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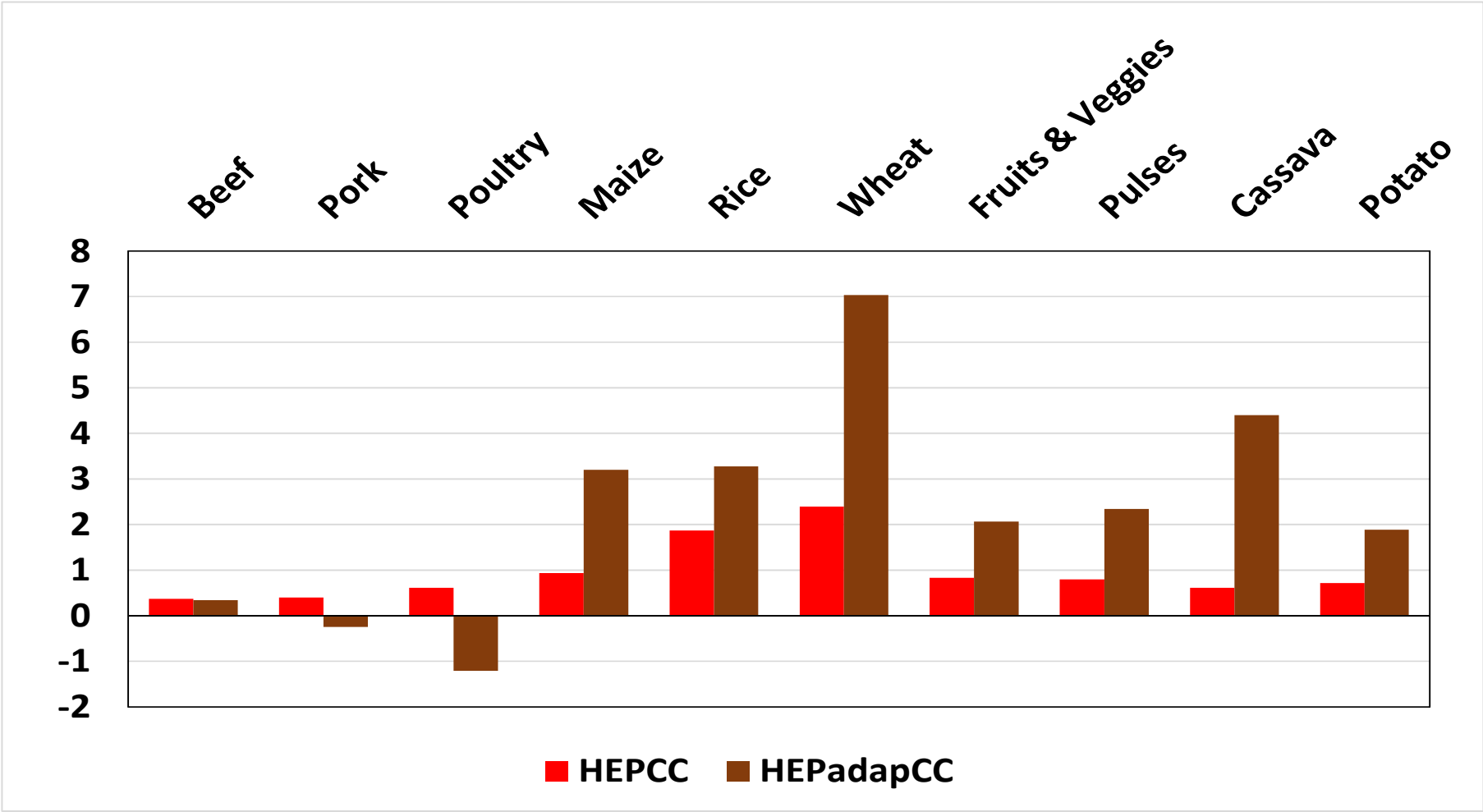
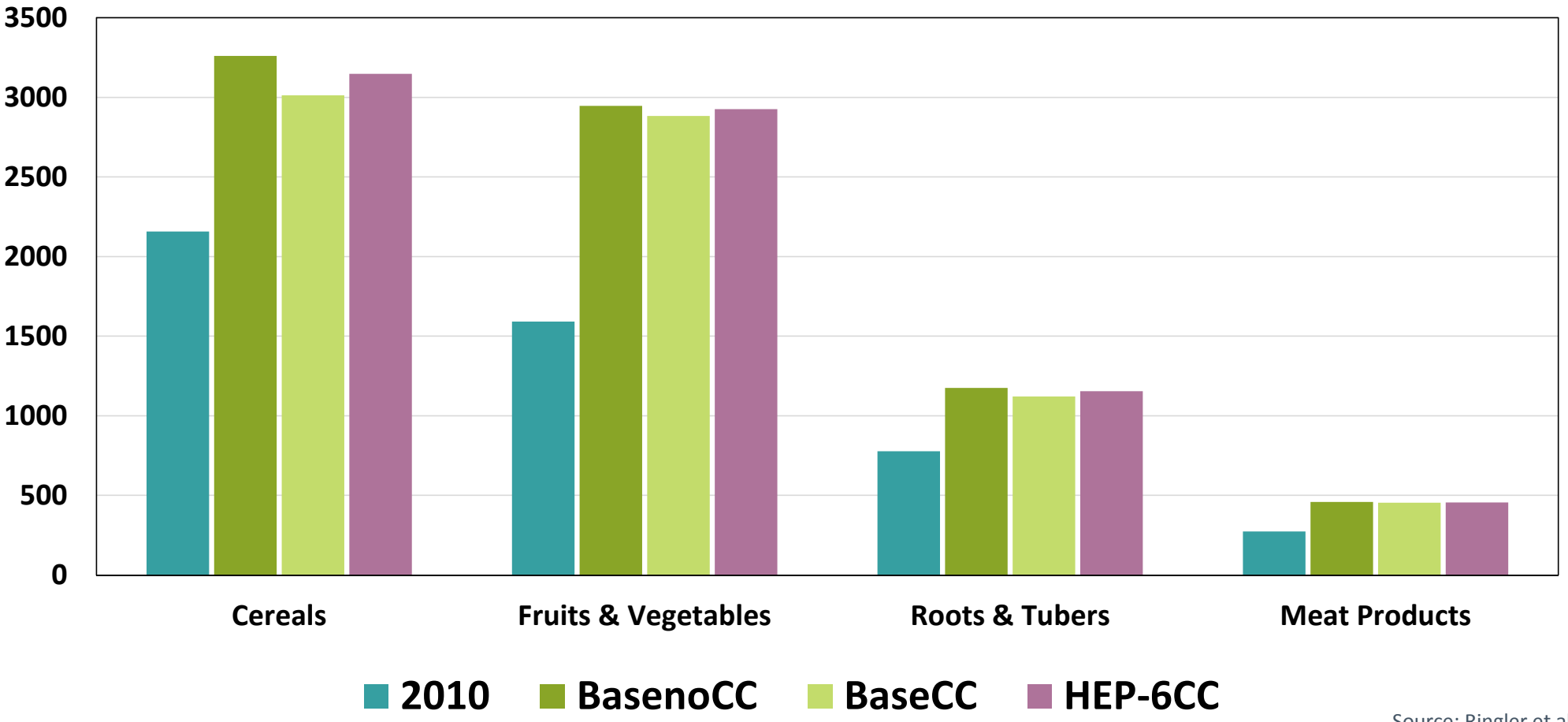
Source: Ringler et al., 2015

Changes in global food prices, alternative energy price scenarios *(%-change in 2050, compared to BaseCC)*



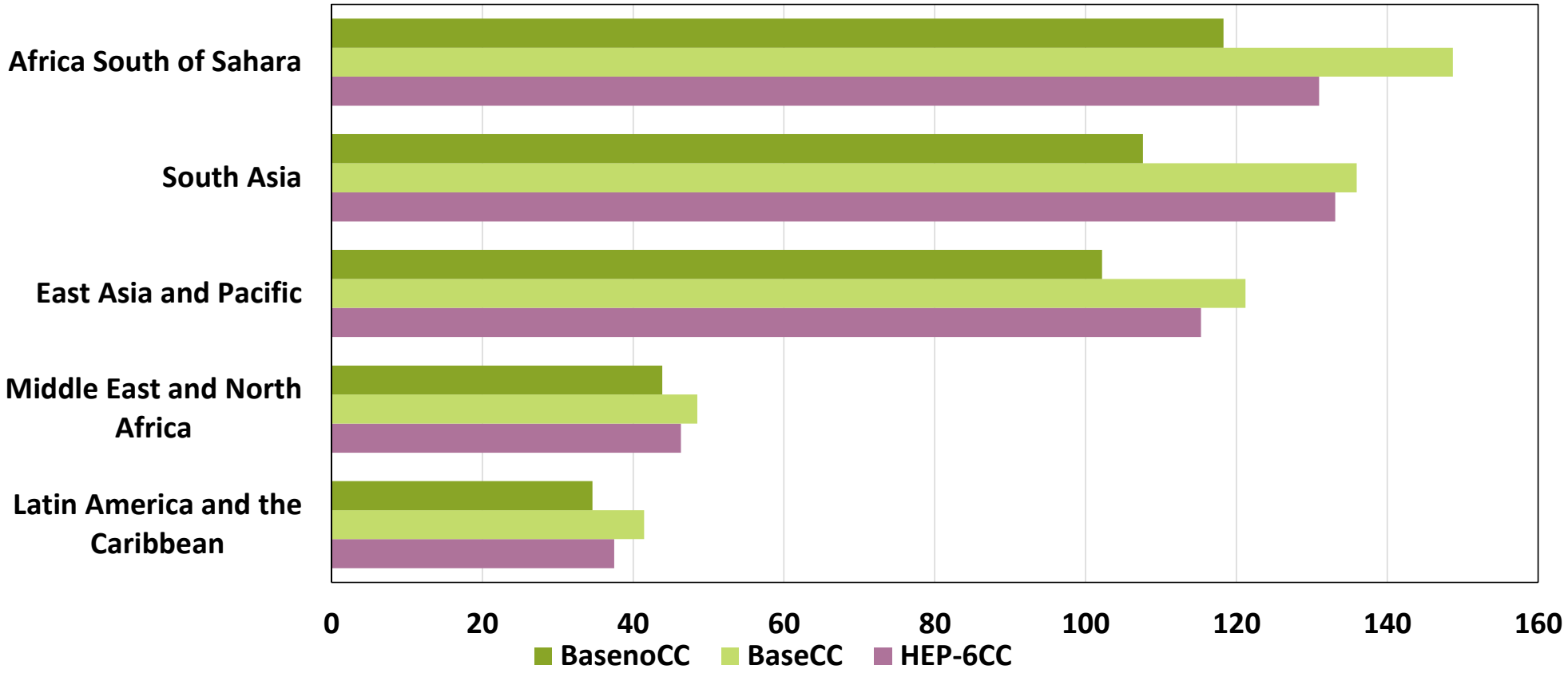
gler et al., 2015

Global agricultural production, alternative energy scenarios *(million mt)*



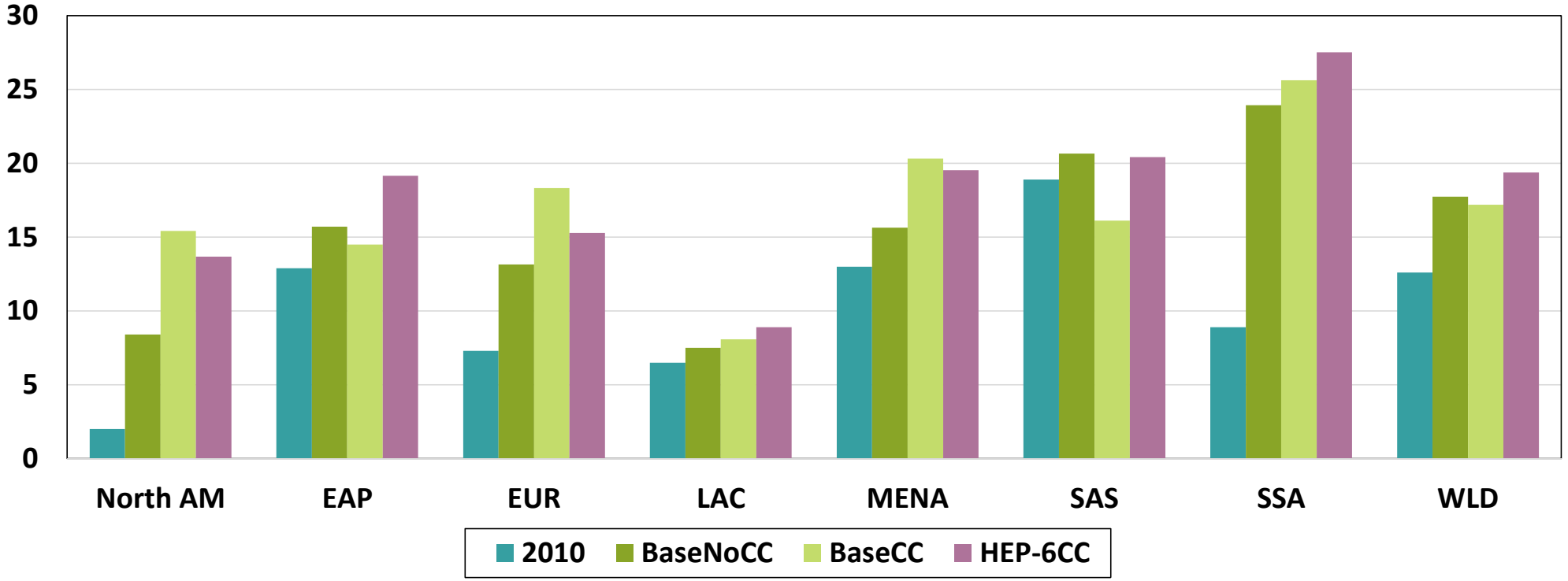
Source: Ringler et al., 2015

Number of people at risk of hunger, 2050, alternative scenarios *(million people)*



Source: Ringler et al., 2015

Share of unmet water demands, 2010 and 2050 under alternative energy scenarios *(%)*



Share of consumptive use of water in all sectors that is not met either due to the lack of water availability, lack of investment or access (1 minus the ratio of total water supply to total water demand across the agriculture, livestock, industrial, and domestic sectors)

Note: North AM - North America; EAP - East Asia and Pacific; EUR - Europe; LAC - Latin America and Caribbean; MENA - Middle East and North Africa; SAS - South Asia; SSA - Sub Saharan Africa; WLD - World

Source: Ringler et al., 2015

Conclusions

Conclusions

- Climate change increases food prices and food insecurity
- Expansion of biofuel production increases the number of food insecure people
- Energy taxes
  - Significantly reduce fossil fuel consumption
  - Slightly reduce food supply due to higher agricultural chemical prices and reduced groundwater pumping

Conclusions

- Energy taxes
  - Cause small reductions in household income, particularly in countries that are net exporters of fossil fuels or net importers of refined petrol
  - Slightly decrease food demand due to lower household income, leading to little or no change in food prices
  - Have variable impacts on water scarcity across regions depending on relative impacts on climate change and groundwater use
  - ***Improve food security with reduction in climate change intensity due to lower fossil fuel use***