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UNECE Pathways to Sustainable Energy: GCAM Scenario Results

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Review of GCAM scenarios

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We explore Energy Sustainability using scenarios

We explore two dimensions

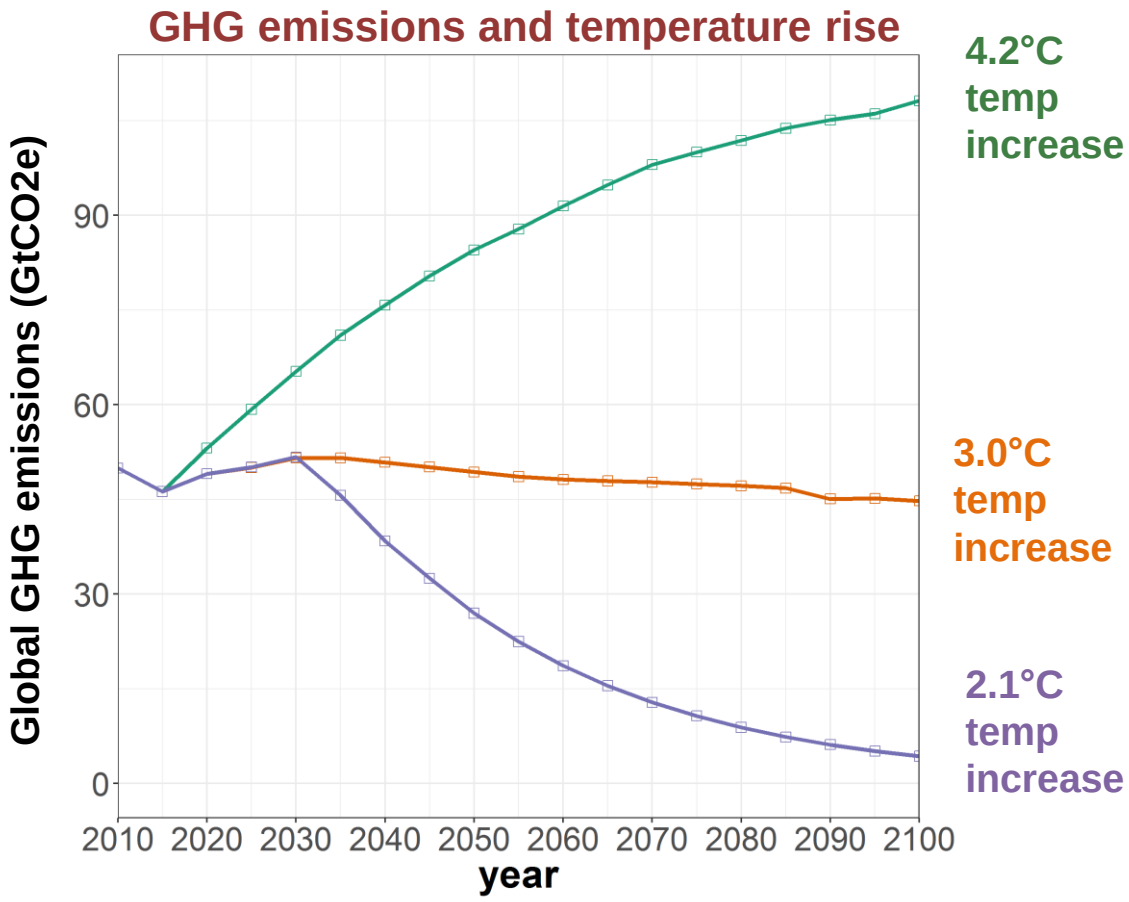
POLICY

TECHNOLOGY

Review of GCAM scenarios: The Policy Dimension

3 Alternative Policy Assumptions

- **Reference**: SSP2 assumptions
  - Reference technology
- **NDCs continued ambition***
  - Regional GHG emissions caps based on national Paris pledges
  - Continued ambition post-2030
- **Paris to 2C:**
  - Regional GHG emissions caps based on national Paris pledges
  - Enhanced ambitions post-2030 to achieve 2ºC goal



* Fawcett AA *et al.* (2015) Can Paris pledges avert severe climate change? *Science (80)*

Review of GCAM scenarios: The Technology Dimension

4 Alternative Technology Assumptions

Technology		Reference assumptions	Advanced assumptions
Renewables	Solar	• Capital costs decline about 25% by 2050	• Capital costs decline more than 60% by 2050
	Wind	• Capital costs decline about 20% by 2050	• Capital costs decline more than 60% by 2050
	Geothermal	• Capital costs less than 10% by 2050 • Only hydrothermal resources	• Capital costs decline about 20% by 2050 • New enhanced geothermal system (EGS) resources (regional specific supply curves)
Nuclear		• 2010 $5,501/kw • 2030 $5,307/kw • 2050 $5094/kw	• Lower capital costs that reflect the small module reactors (SMR) • Advanced assumption is about 35% lower than the reference assumption
CCS		• CO2 capture rate: 85% in 2020, increase to 95% by 2100	• Higher CO2 capture rate: 99% • Lower costs of carbon storage (region-specific) that are in line with SSP5 assumptions

1 SSP2

Review of GCAM scenarios: The Technology Dimension

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Review of GCAM scenarios: The Technology Dimension

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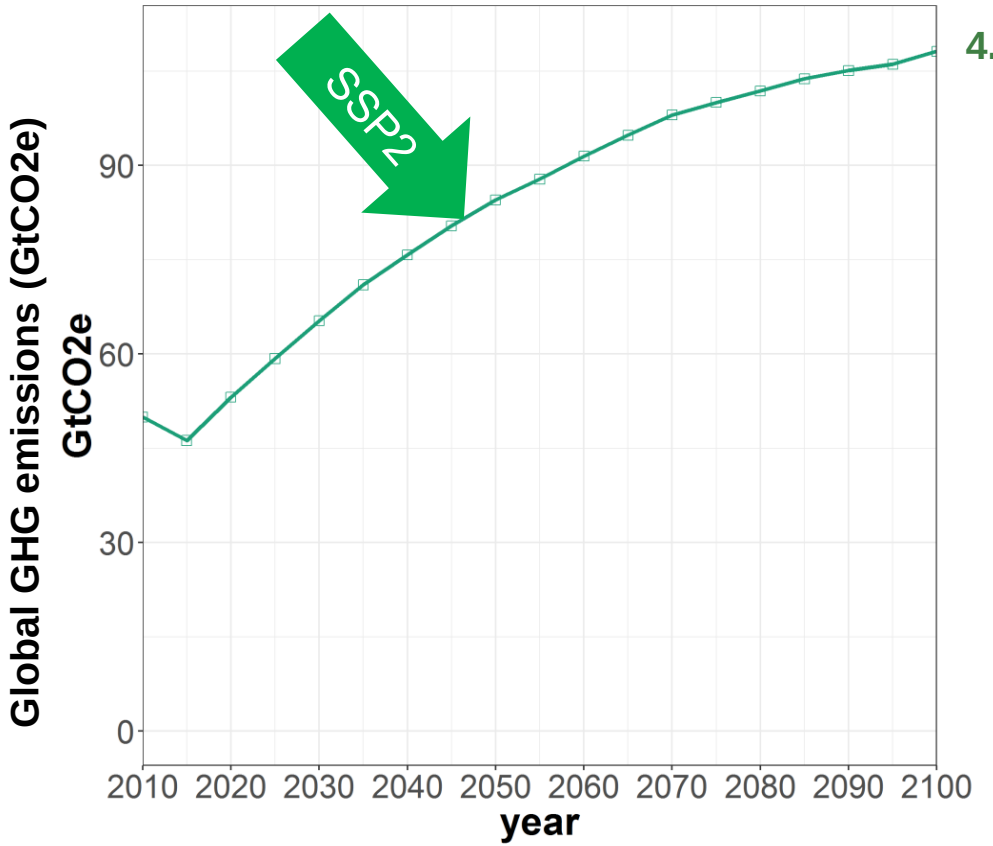
GCAM: Preliminary Modeling Results—Four Technology Sensitivities

GHG emissions and temperature rise

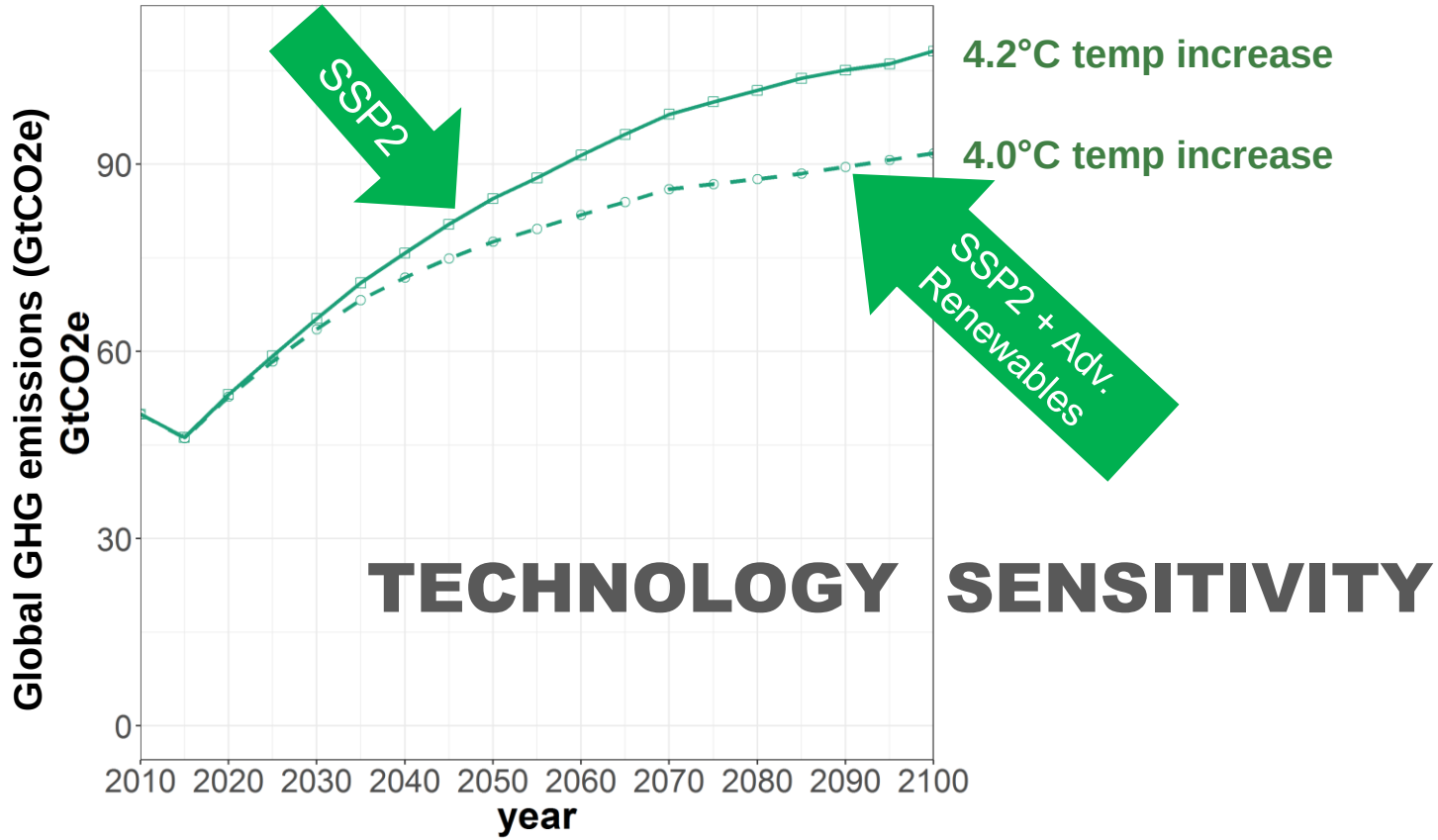


4.2°C temp increase

Reference: SSP2 assumptions

GCAM: Preliminary Modeling Results—Four Technology Sensitivities

GHG emissions and temperature rise



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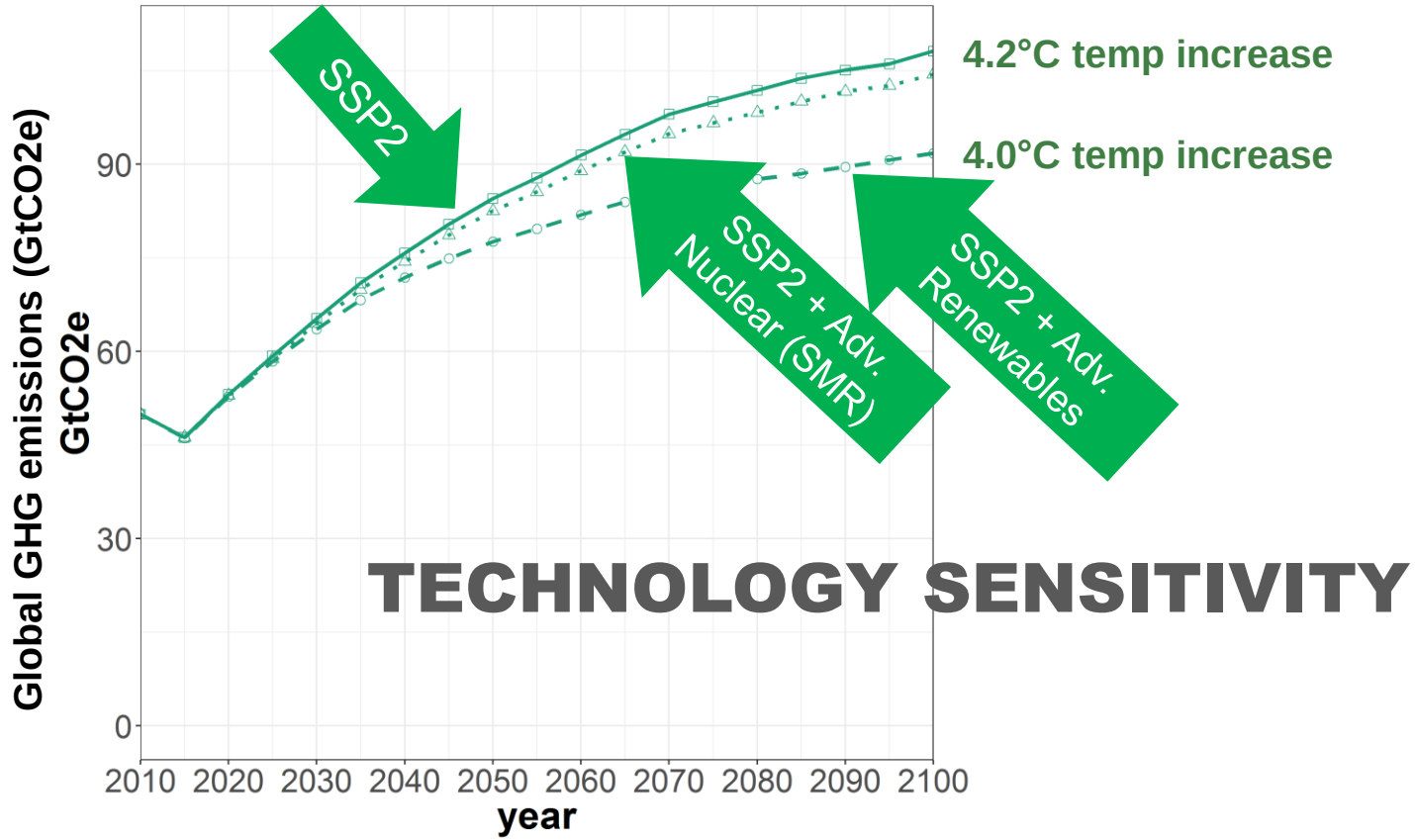

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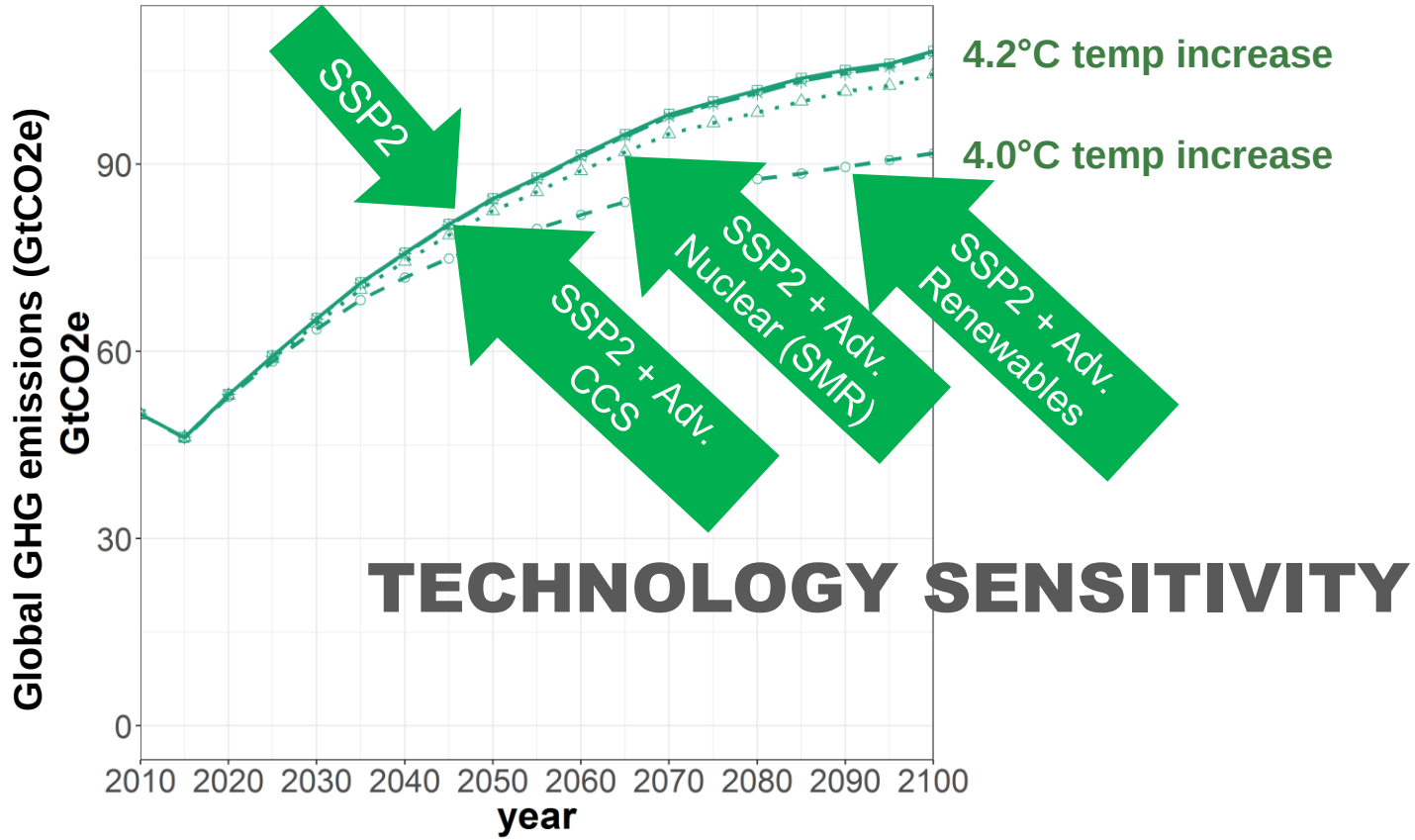
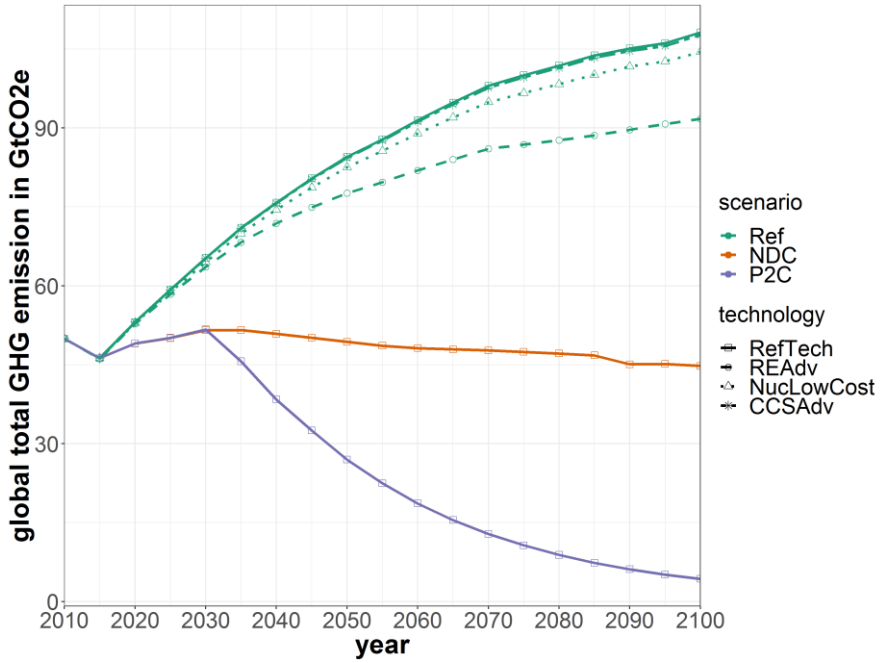


Review of GCAM scenarios—Policy and Technology Sensitivities

Technology \ Scenario	Reference	Paris NDC continued ambition*	Paris to 2C
Reference Technology	Ref-RefTech	NDC-RefTech	P2C-RefTech
Advanced Renewables	Ref-REAdv		P2C-REAdv
Low-cost Nuclear (SMR)	Ref-NucLowCost		P2C-NucLowCost
Advanced CCS	Ref-CCSAdv		P2C-CCSAdv

- **Reference**: SSP2 assumptions
- **Paris NDC continued ambition**: regional GHG emissions caps based on national Paris pledges plus continued actions post-2030
- **Paris to 2C**: regional GHG emissions caps based on national Paris pledges plus enhanced ambitions post-2030 to reach the 2C goal



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ENERGY SUSTAINABILITY METRICS

Review of Energy Sustainability metrics

Pillar	Metric	Measurement	
Energy Security	Energy Self-Sufficiency	Import Dependence: net imports of energy as share of total consumption	M1
	Energy Efficiency	Energy Intensity of Economy: final energy per unit of GDP	M2
	Renewable Energy	Share of RE in total final energy consumption	M3

Review of Energy Sustainability metrics

Pillar	Metric	Measurement	
Quality of Life	Access to Services	Energy services (i.e. electricity consumption, passenger transportation service) per capita	M1
	Energy Affordability	Energy expenditure as share of GDP	M2
	Food Security	Share of calories from non-staple food	M3

Review of Energy Sustainability metrics

Pillar	Metric	Measurement	
Environmental Sustainability	Climate Change	Total (and per capita) global GHG emissions in MtCO2eq Change in average earth surface temperature	M1
	Local Air Pollutions	Total and per capita air pollutant emissions: Sulphur Dioxide (SO2), Nitrogen Oxides (NOx)	M2
	Water Stress	Ratio of water withdrawal to renewable water availability	M3
	Natural Land Cover	Natural forest area	M3

Review of Energy Sustainability metrics

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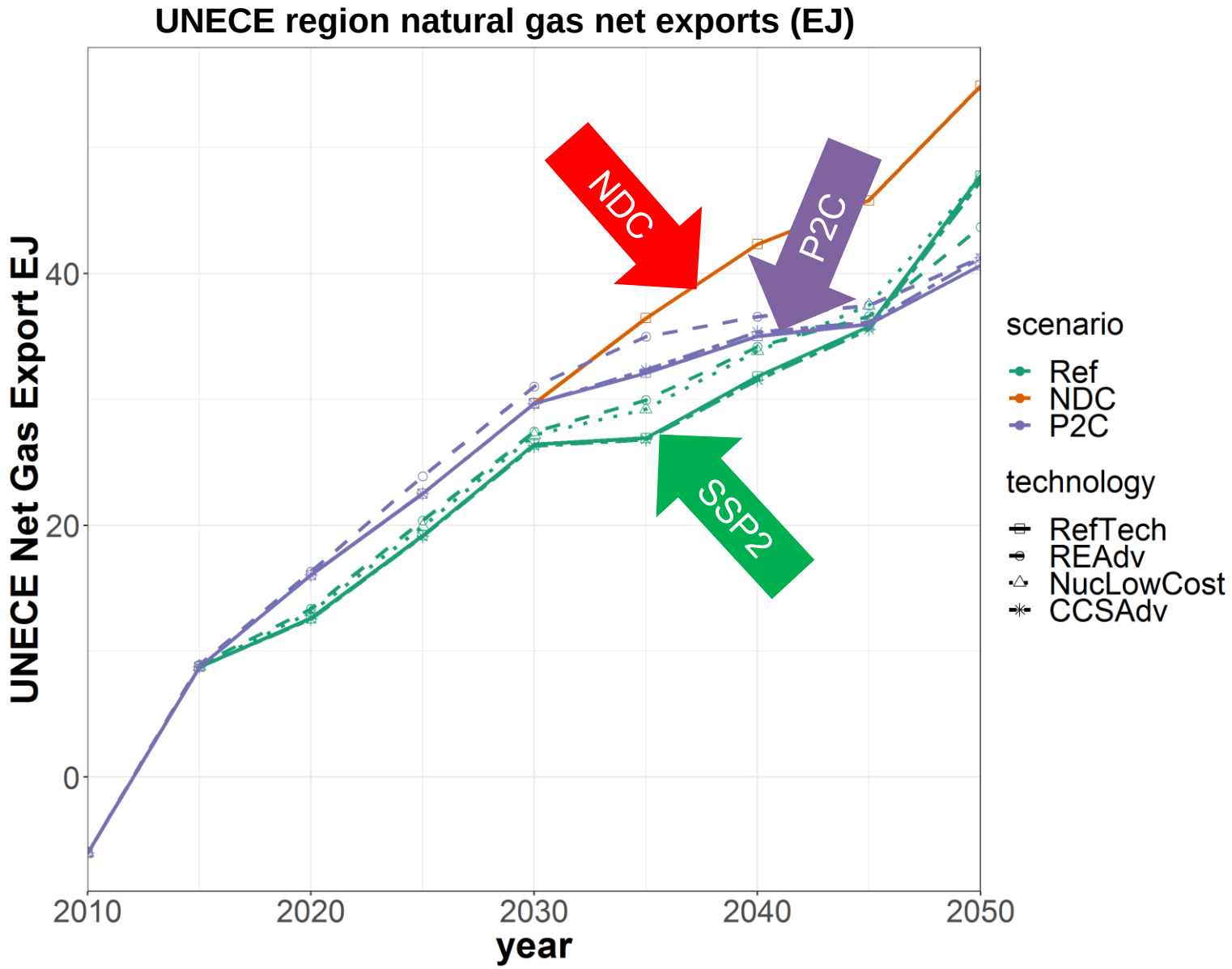
	Natural Land Cover	Natural forest area	M3

MEASURING ENERGY SECURITY

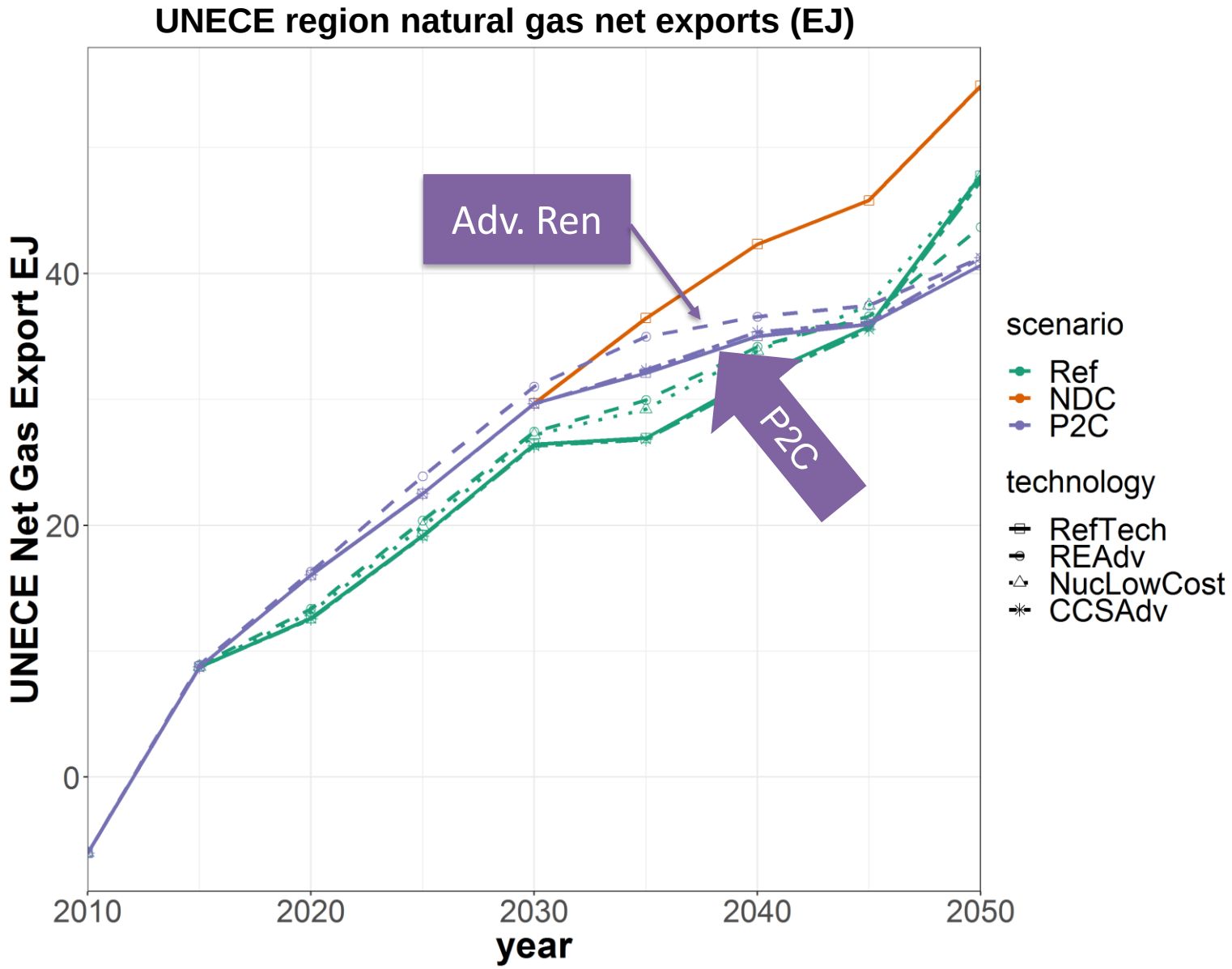
Energy Security-M1: Energy Self-Sufficiency

- **Net Exports of Natural Gas**
- Overall UNECE net exports of natural gas increase through 2050, higher under policy scenarios.



Energy Security-M1: Energy Self-Sufficiency

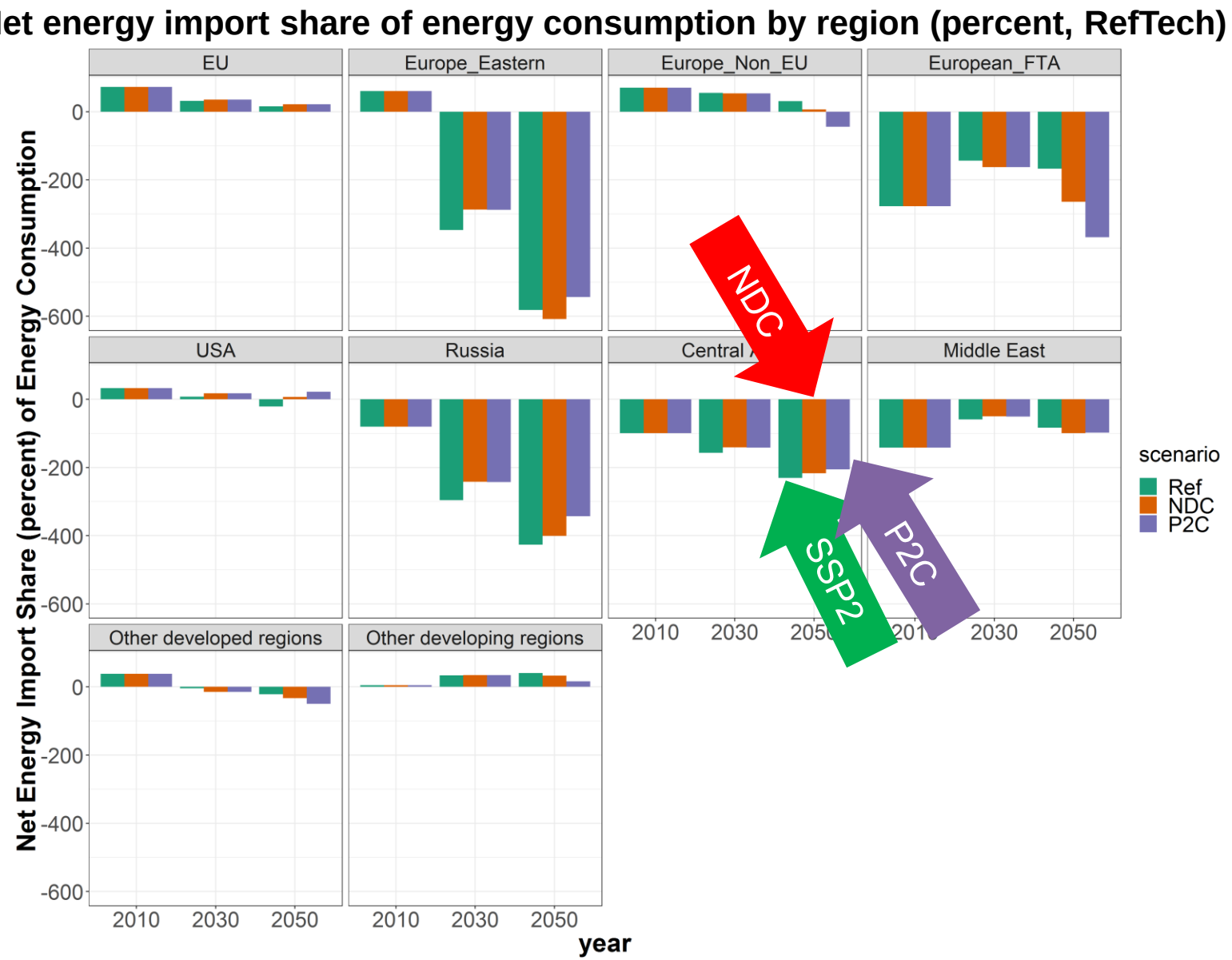
- **Net Exports of Natural Gas**
- Advanced RE decreases gas imports in UNECE non-exporting regions, e.g. EU, making more gas available for export to non-UNECE regions



Energy Security-M1: Energy Self-Sufficiency

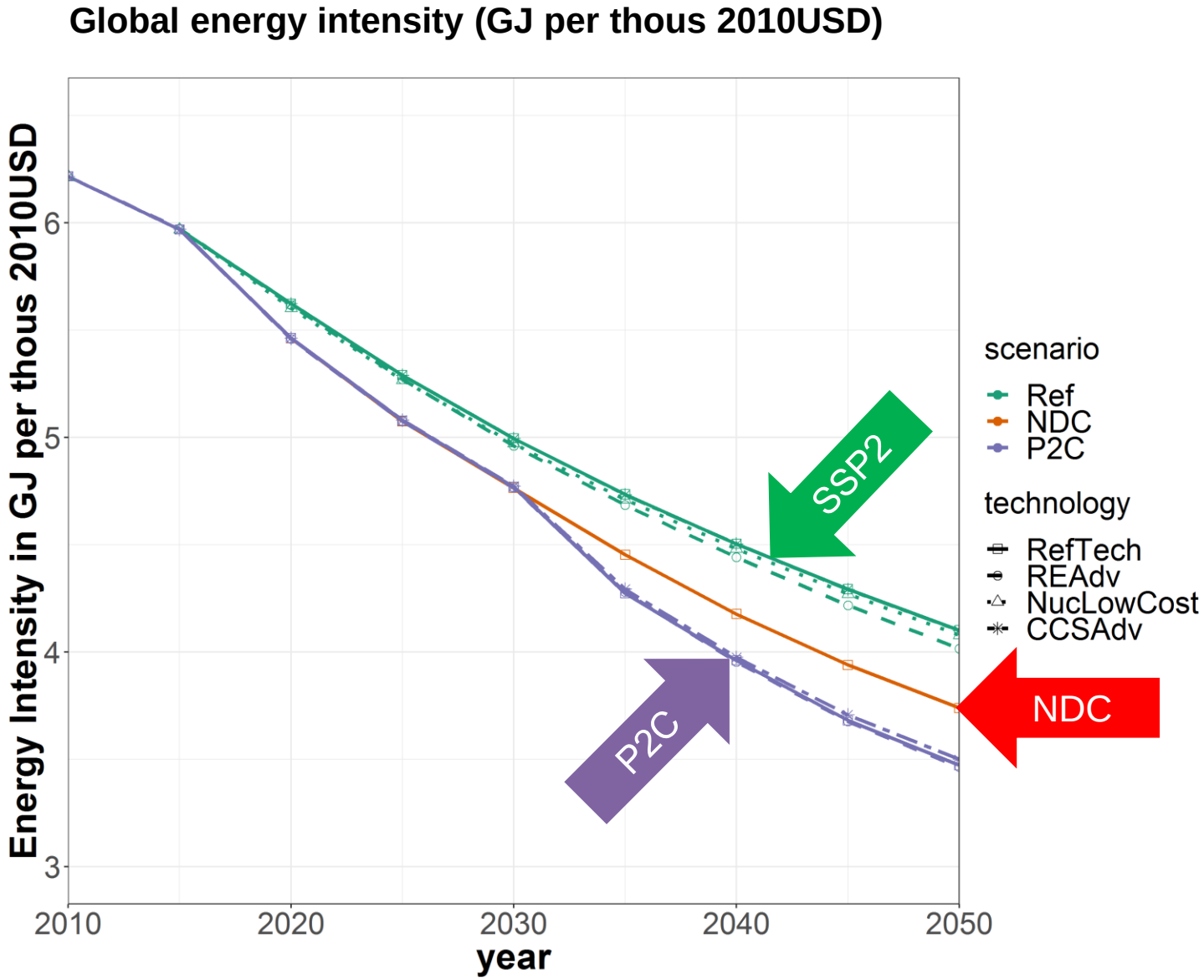
- **Net Energy Imports Share of Final Consumption**

- Mixed trends for net energy imports relative to final consumption over time and across policies



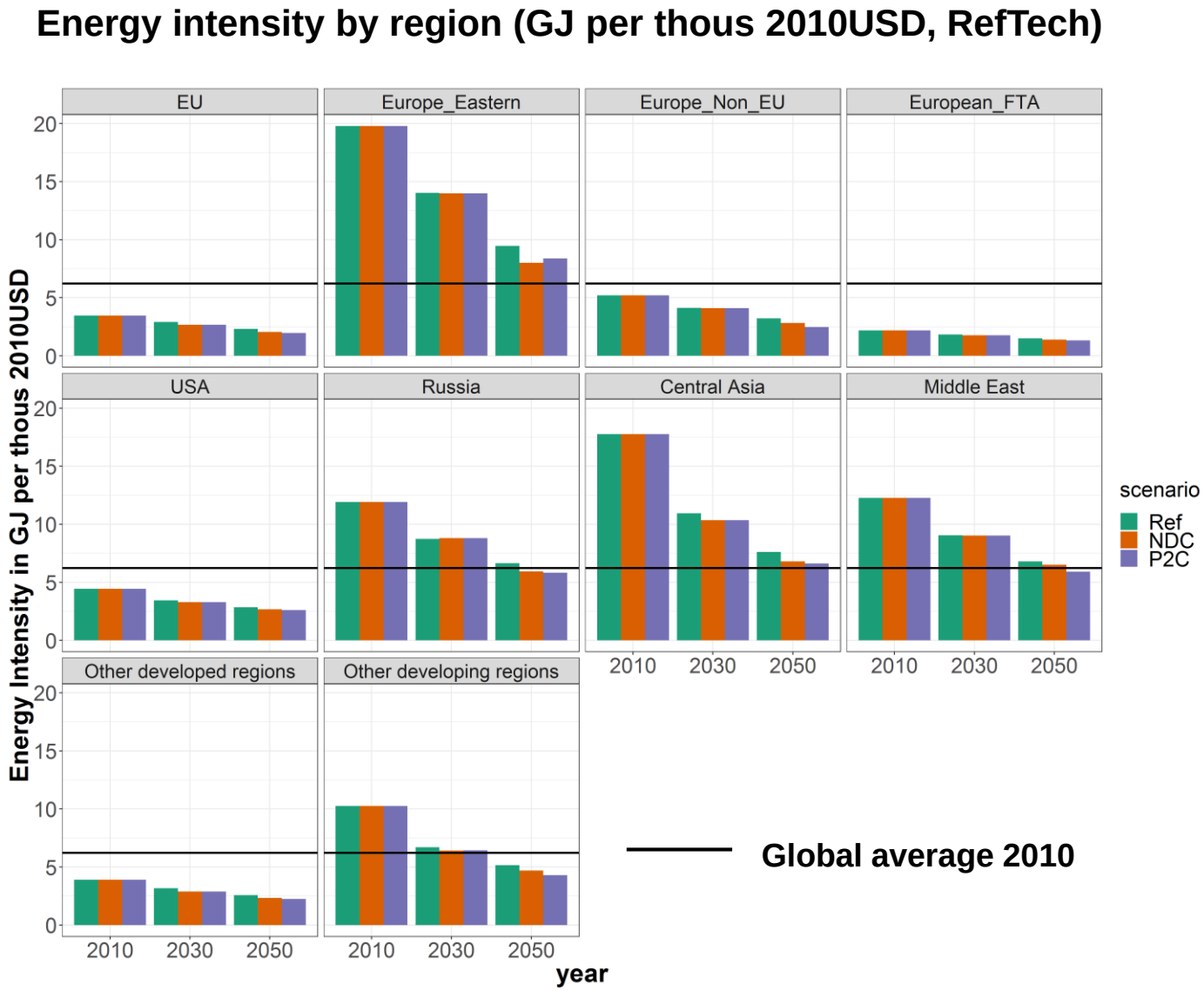
ES-M2: Decrease Energy Intensity of Economy

- **Energy-GDP Ratio**
- Energy consumption per unit of GDP decreases, with higher rates under policy scenarios.
- Technology variations have marginal impact.



ES-M2: Decrease Energy Intensity of Economy

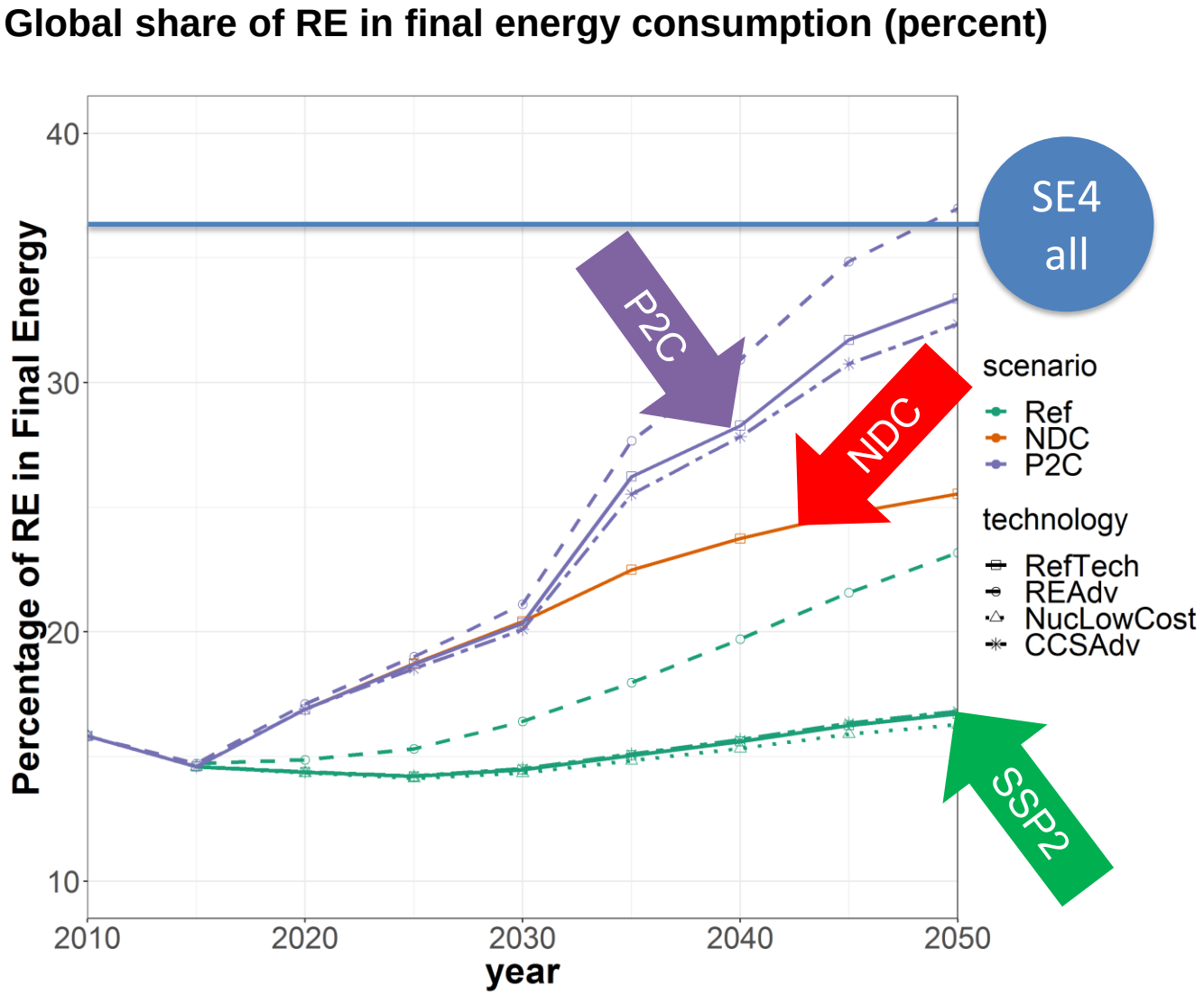
- **Energy-GDP Ratio**
- Several regions (i.e. Eastern Europe, Russia, Central Asia) may still be above the 2010 global average level by 2050.



ES-M3: Increase Renewable Energy

- **Renewable Energy Share of Final Energy Use**

- Renewable energy use rises with mitigation ambition
- None of the scenarios meet the SE4all 2030 target (36%).
- Advanced RE has significant impact on SSP2, current policies.

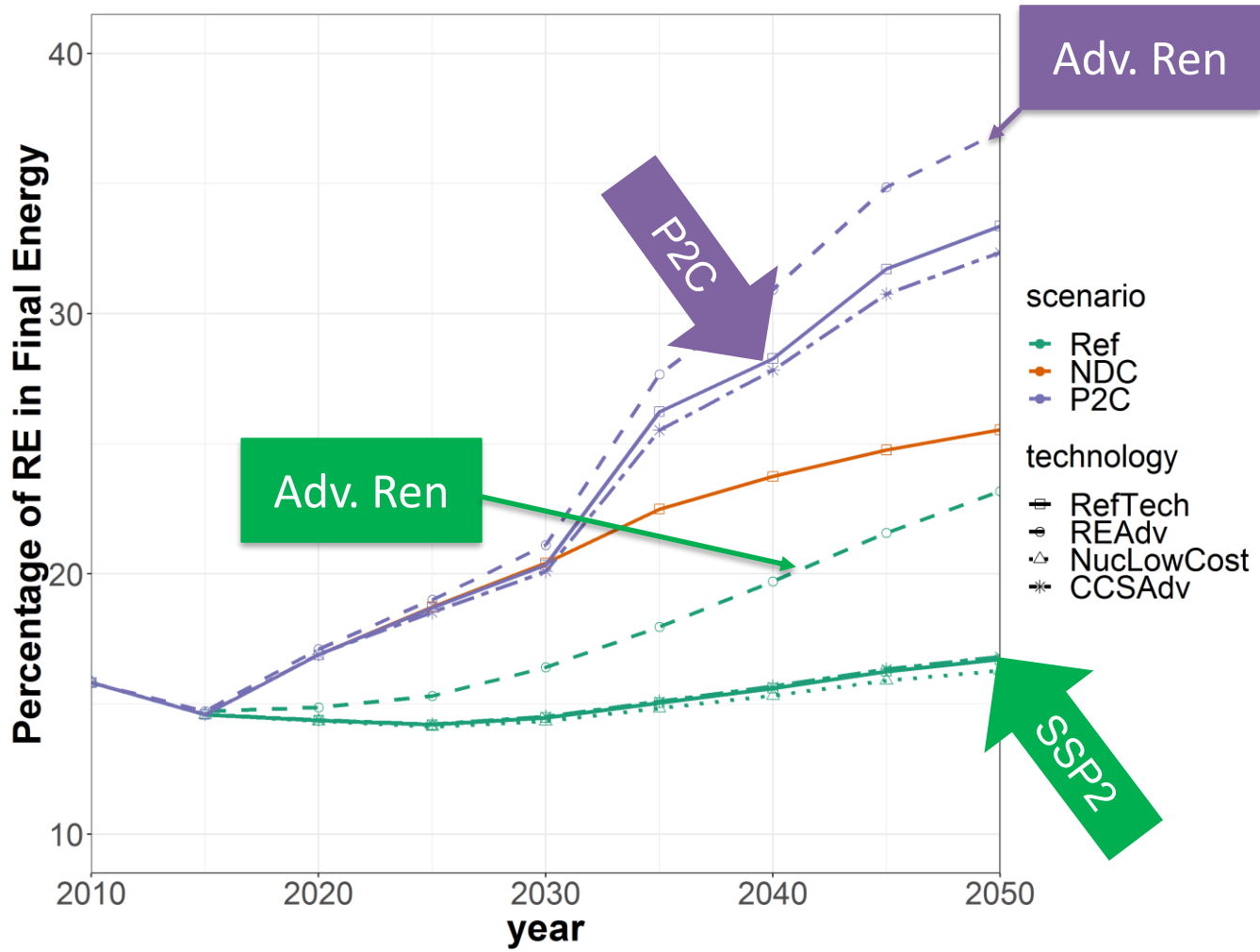


ES-M3: Increase Renewable Energy

- **Renewable Energy Share of Final Energy Use**

- Advanced RE increases the RE share of final energy in the SSP2 and P2C scenarios
- Other technologies have minor impact on the RE share of final energy in the Reference (SSP2) scenario

Global share of RE in final energy consumption (percent)

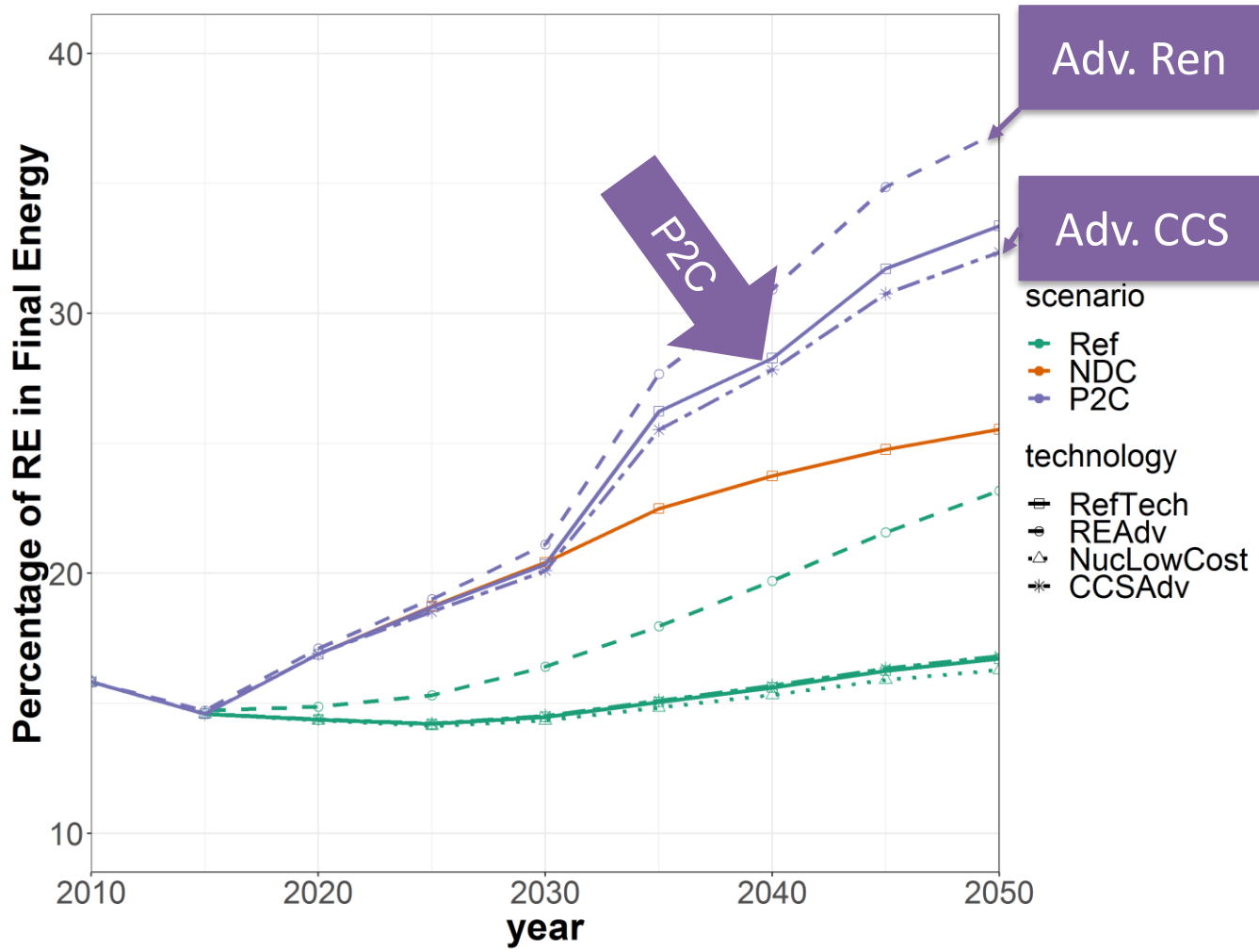


ES-M3: Increase Renewable Energy

- **Renewable Energy Share of Final Energy Use**

- Low-cost nuclear and advanced CCS technologies would lower RE share in the P2C scenario.

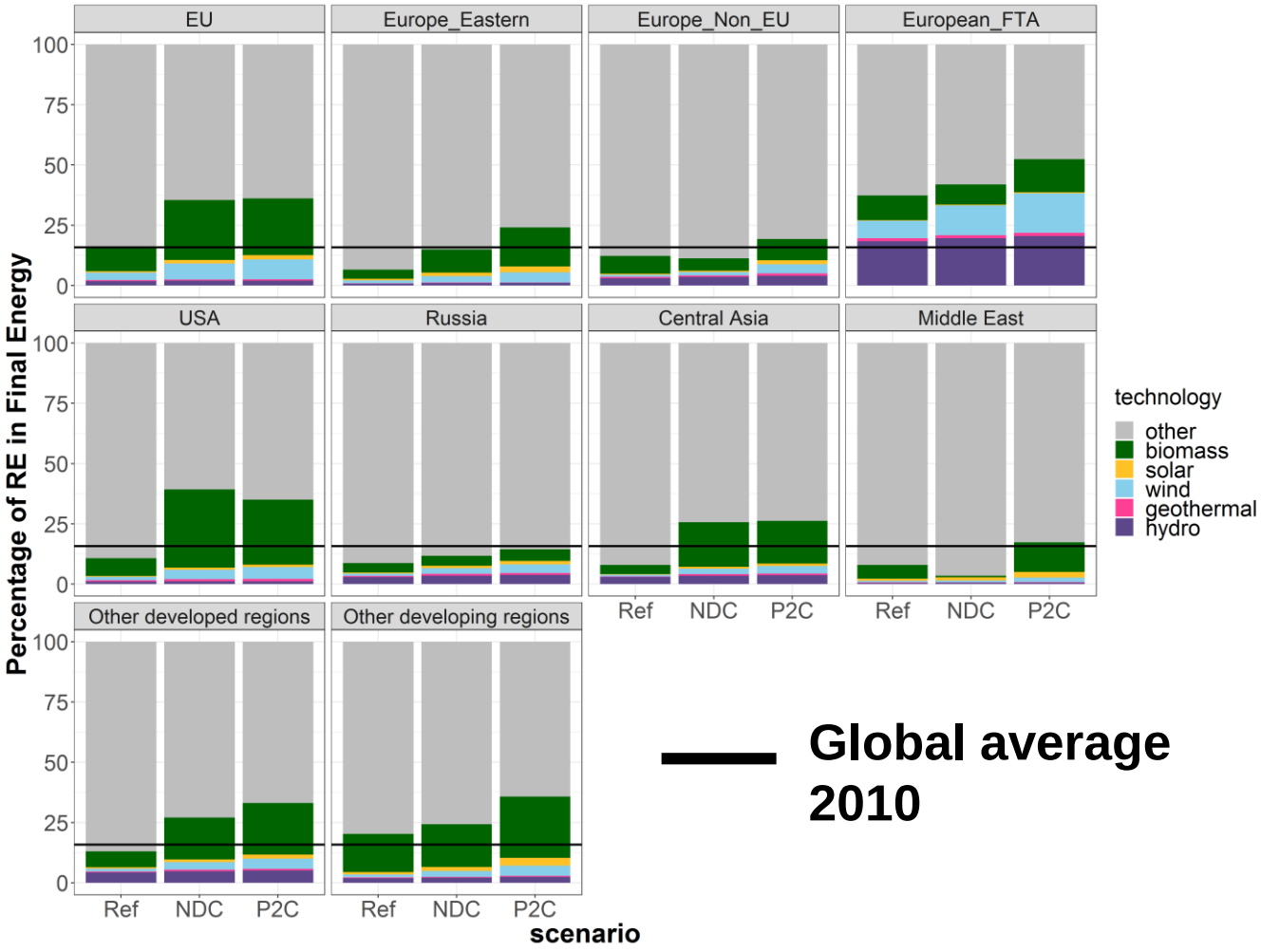
Global share of RE in final energy consumption (percent)



ES-M3: Increase Renewable Energy

- **Renewable Energy Share of Final Energy Use**
- All regions surpass 2010 Global Average in 2050 in the P2C scenario

Share of RE in final energy consumption by region in 2050 (percent, RefTech)

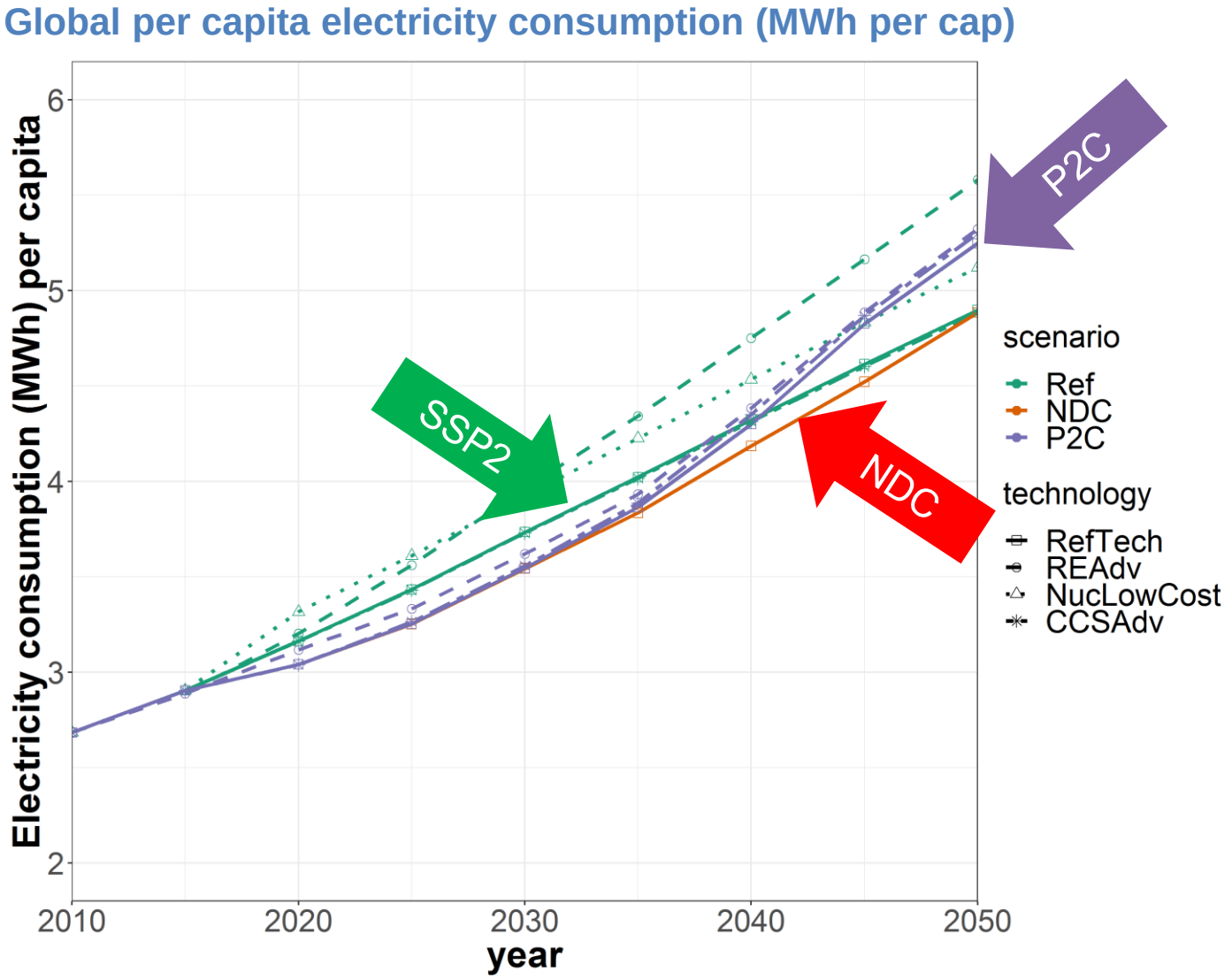


MEASURING QUALITY OF LIFE

Quality of life-M1: Access to Services—Electricity per capita

- **Per capita electricity consumption**

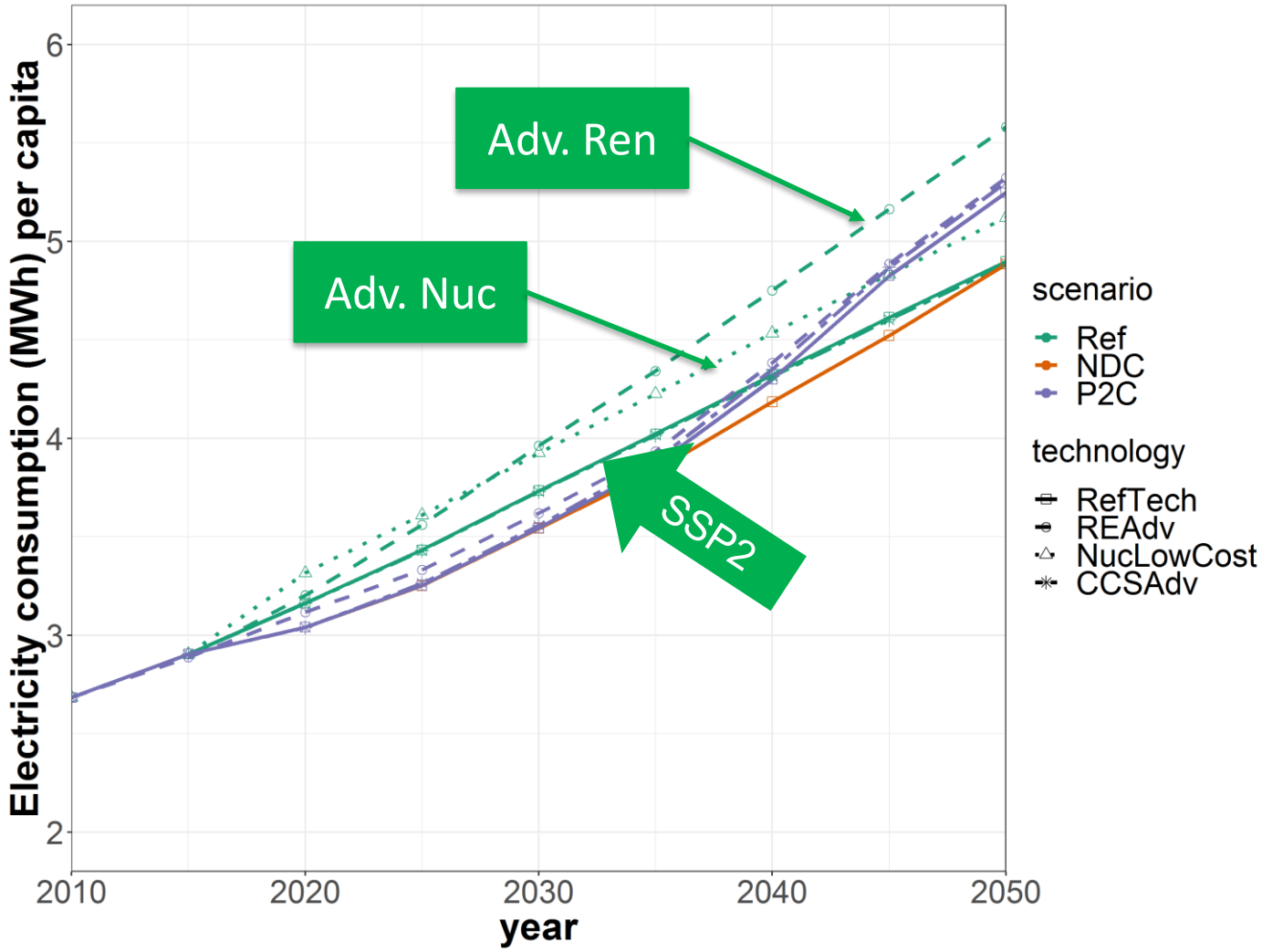
- Increases over time.
- Although it increases at lower rate under policy scenarios in the near-term, the long-term effect tends to be more positive.



Quality of life-M1: Access to Services—Electricity per capita

- **Per capita electricity consumption**
- Advanced technology scenarios raise the electrification rate per capita.

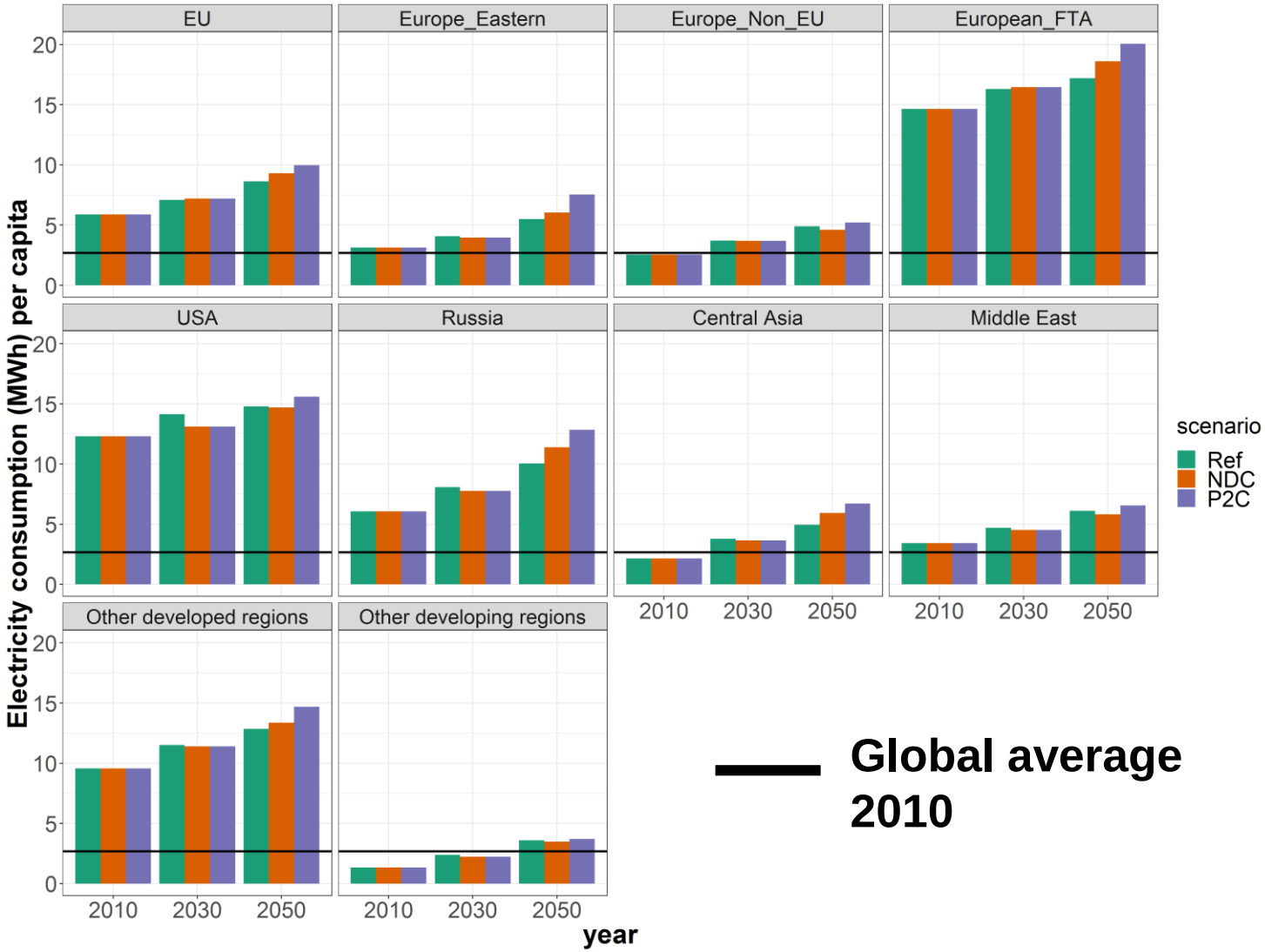
Global per capita electricity consumption (MWh per cap)



Quality of life-M1: Access to Services—Electricity per capita

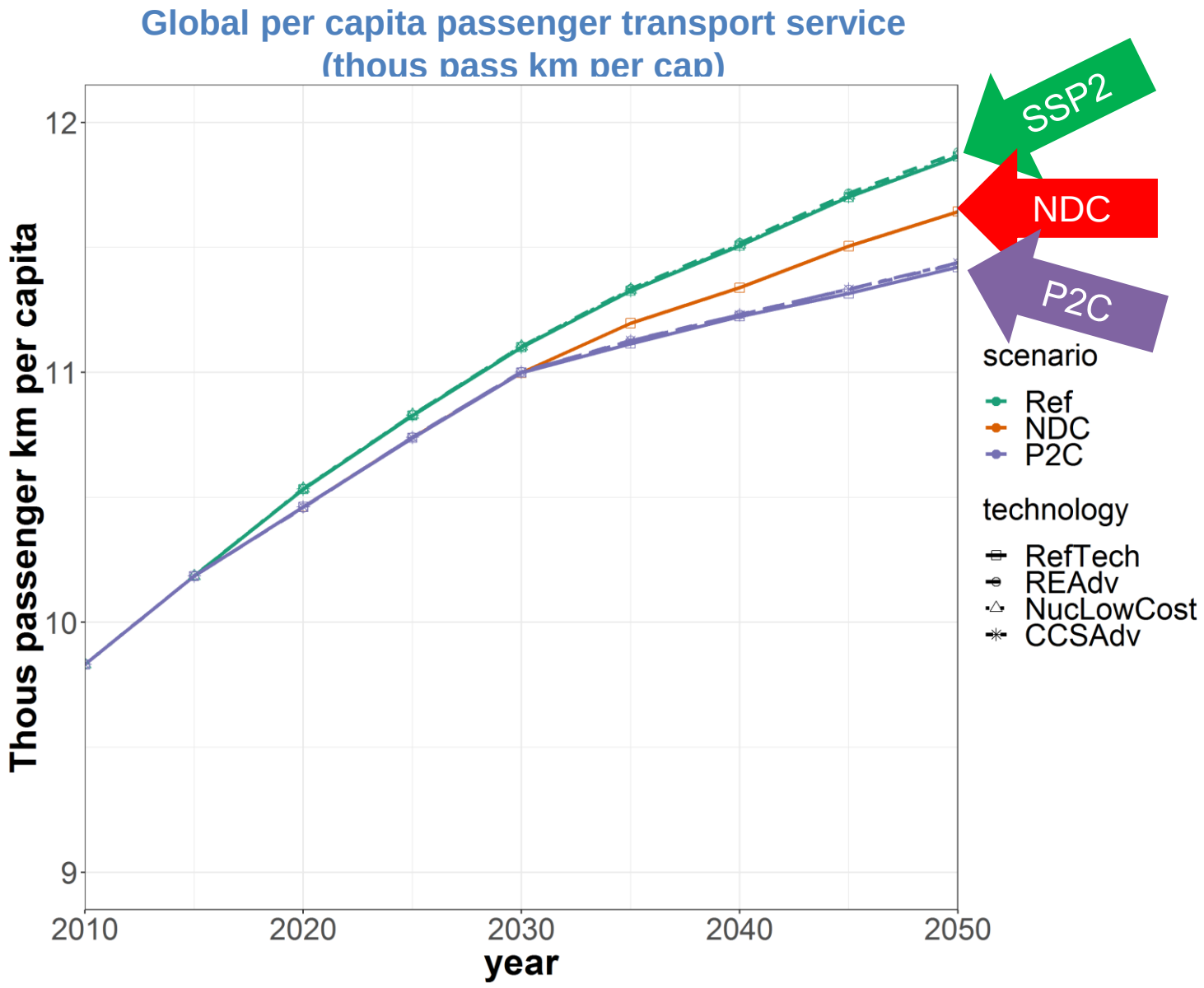
- Most regions surpass 2010 Global Average

Per capita electricity consumption by region (MWh per cap, RefTech)



Quality of life-M1: Access to Services—Pass Transport per capita

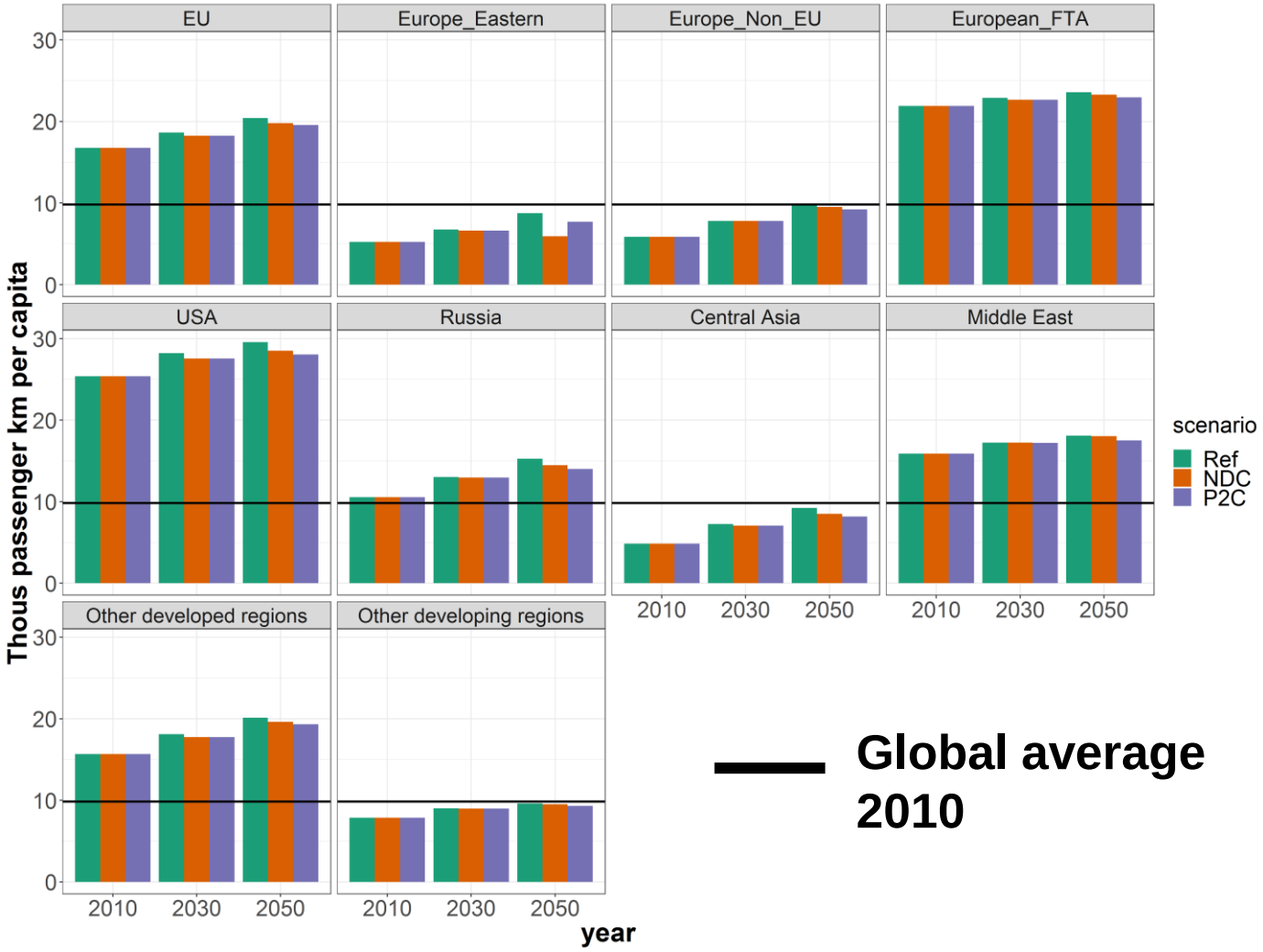
- **Passenger Transport per Capita**
- Per capita passenger transport service increases over time, but at lower rates under policy scenarios.
- Little sensitivity to power sector technology assumptions



Quality of life-M1: Access to Services—Pass Transport per capita

- **Passenger Transport per Capita**
- Several regions (i.e. Eastern Europe, Central Asia) may not achieve the 2010 global average level by 2050.

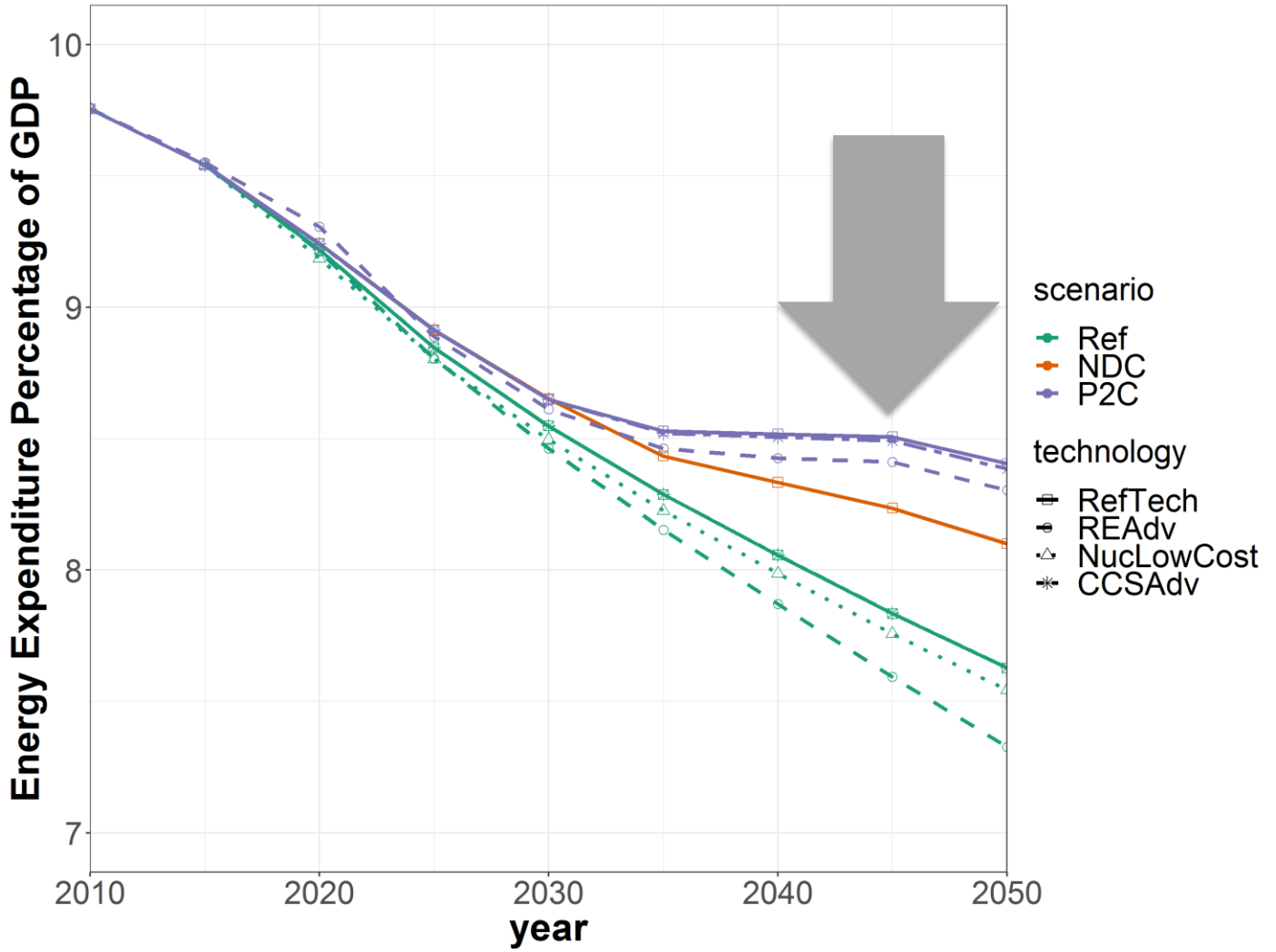
Per capita passenger transport service by region (thous pass km per cap, RefTech)



QL-M2: Energy Affordability

- **Energy Expenditure Relative to GDP**
- Energy expenditure share of GDP decreases through 2050.

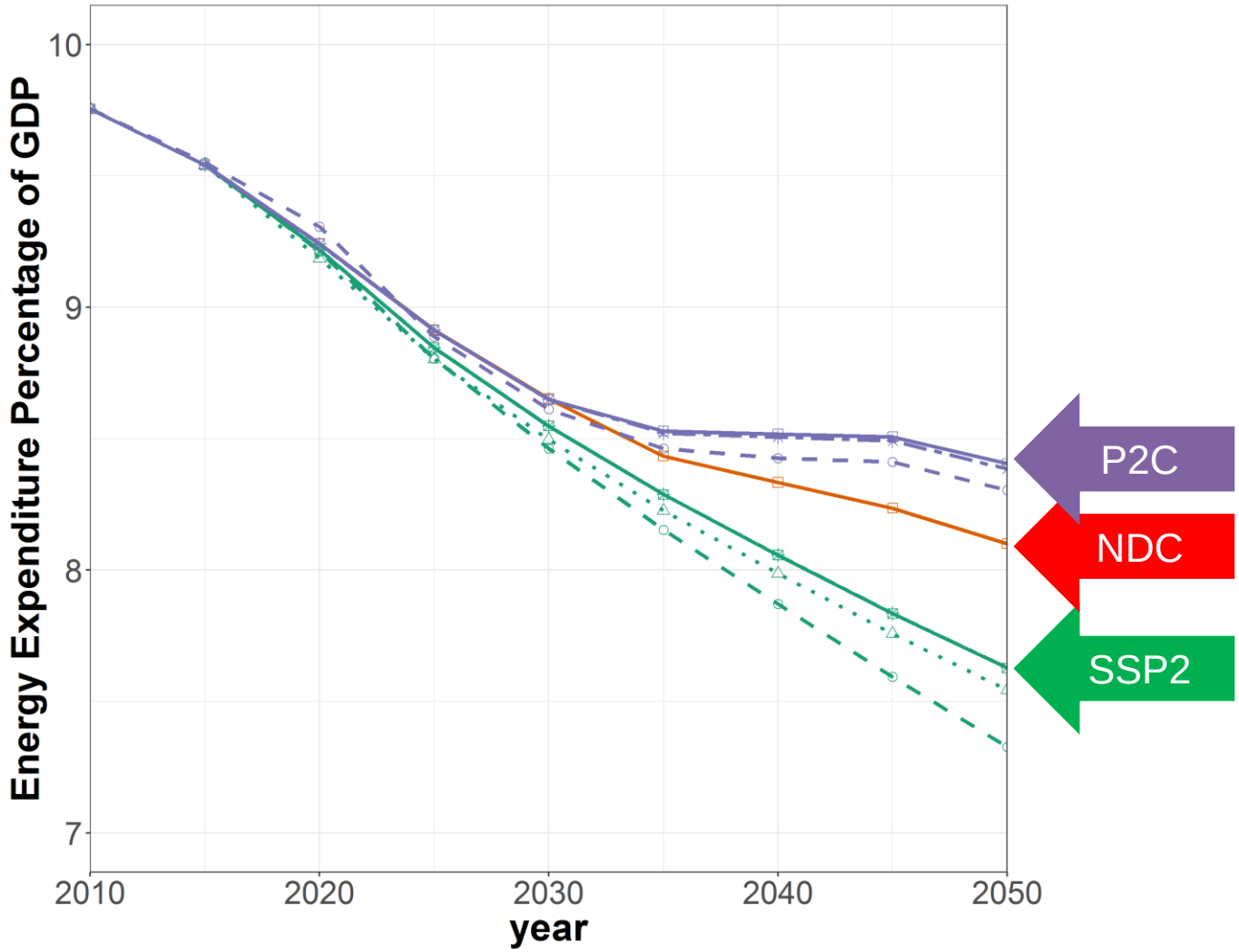
Global energy expenditures as share of GDP (percent)



QL-M2: Energy Affordability

- **Energy Expenditure Relative to GDP**
- Although energy intensity (ES-M2) is lower under policy scenarios, energy expenditure share of GDP is higher due to increasing prices.

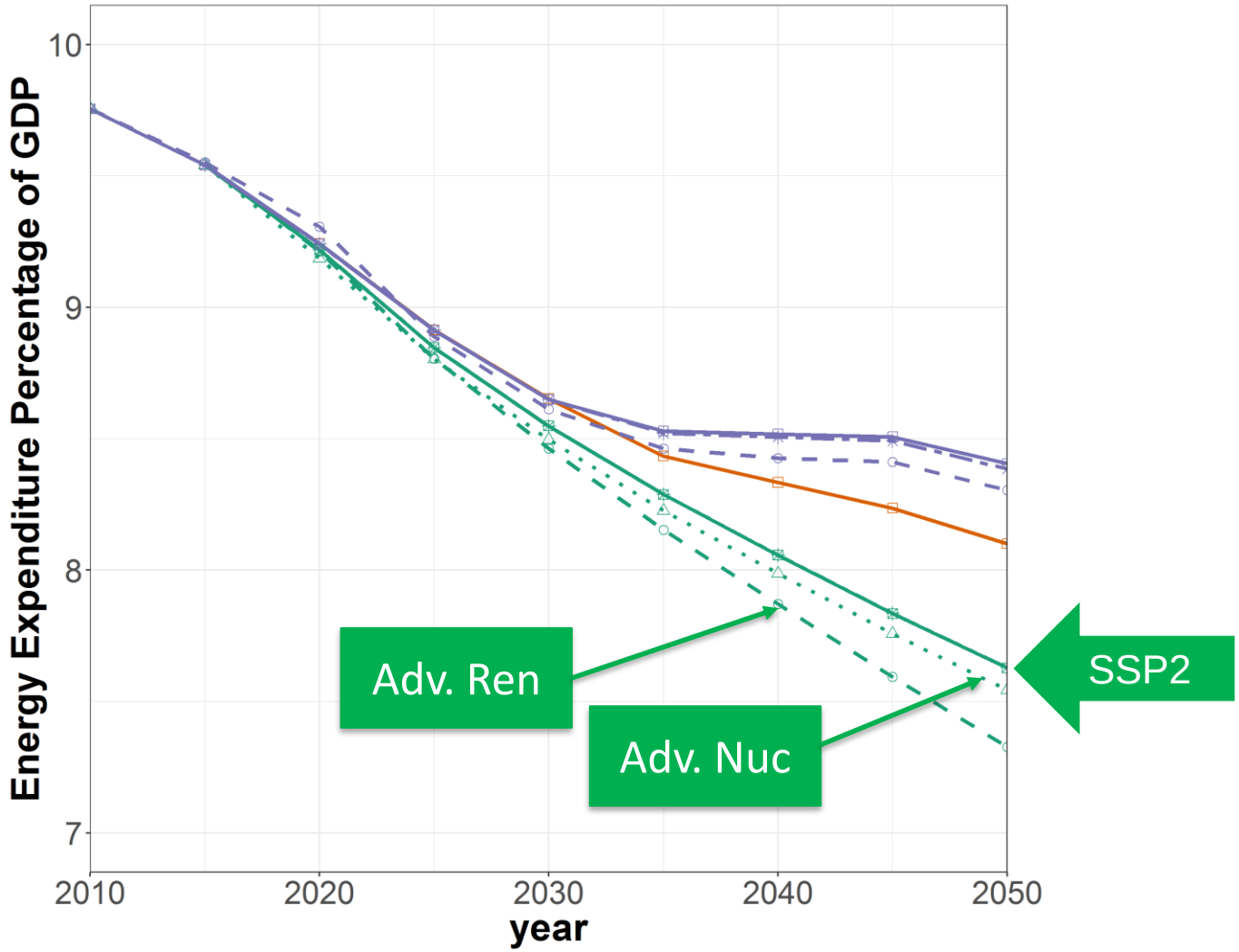
Global energy expenditures as share of GDP (percent)



QL-M2: Energy Affordability

- **Energy Expenditure Relative to GDP**
- Advanced technologies help reduce the policy impact.

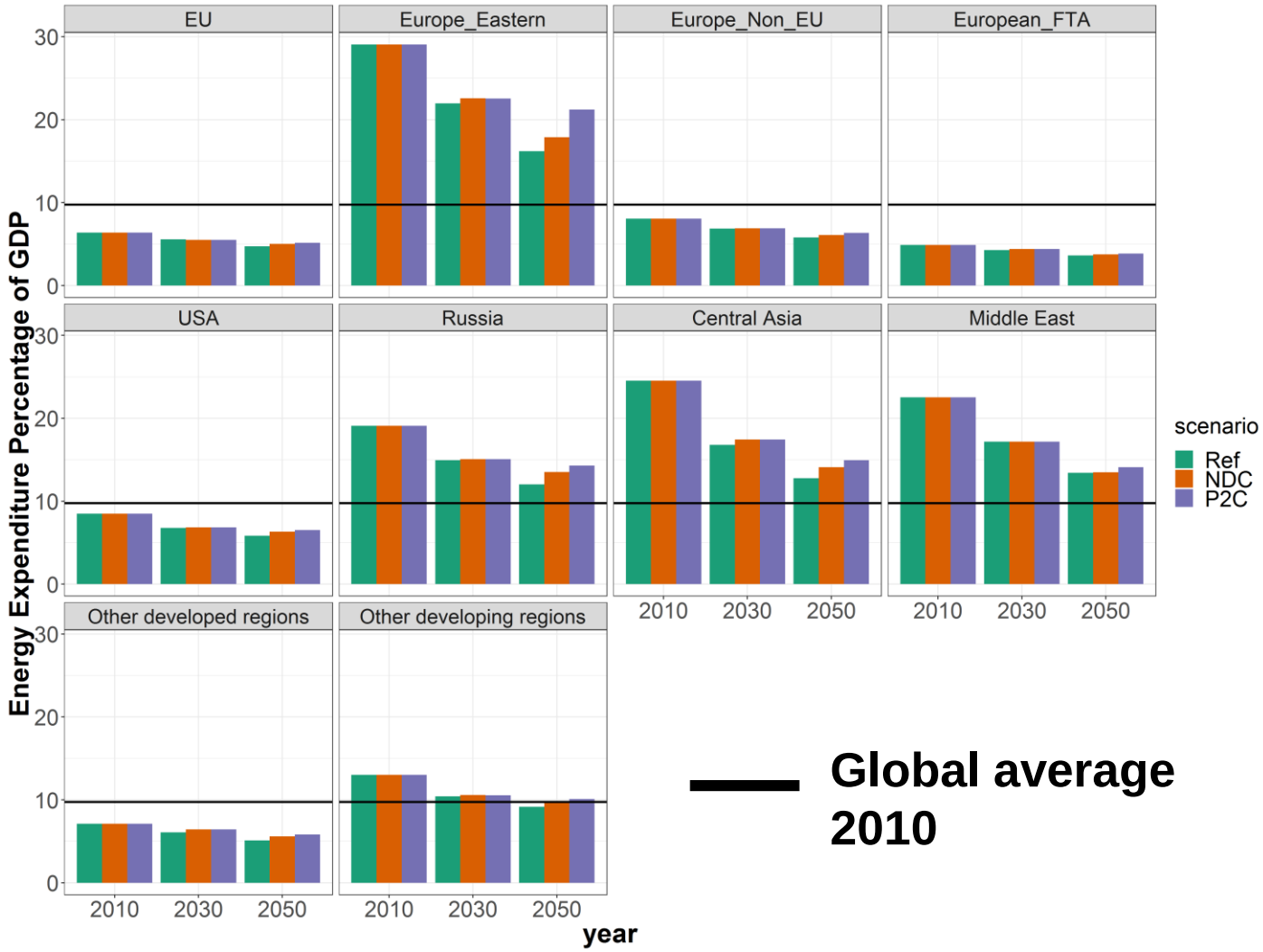
Global energy expenditures as share of GDP (percent)



QL-M2: Energy Affordability

- **Energy Expenditure Relative to GDP**
- In 2050 energy expenditure share of GDP is higher than the 2010 Global Average for many regions.

Energy expenditures as share of GDP by region (percent, RefTech)

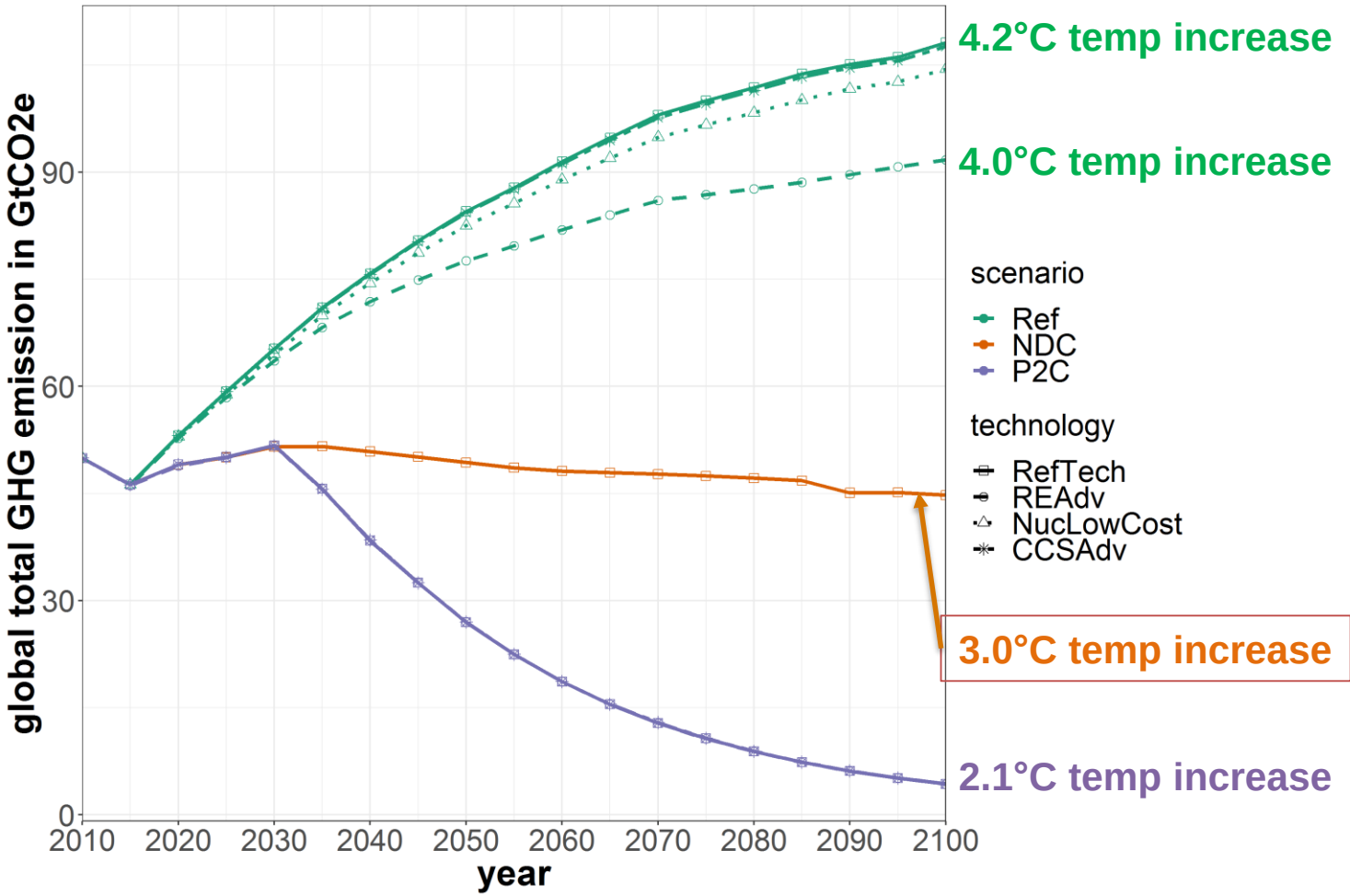


MEASURING ENVIRONMENTAL QUALITY

Environment-M1: Climate Change

- Global GHG emissions stay flat under continued NDC, but need to decrease sharply in post-2030 to achieve the 2°C goal.
- Advanced technologies help lower GHG emissions, but they alone do not archive the climate goal.

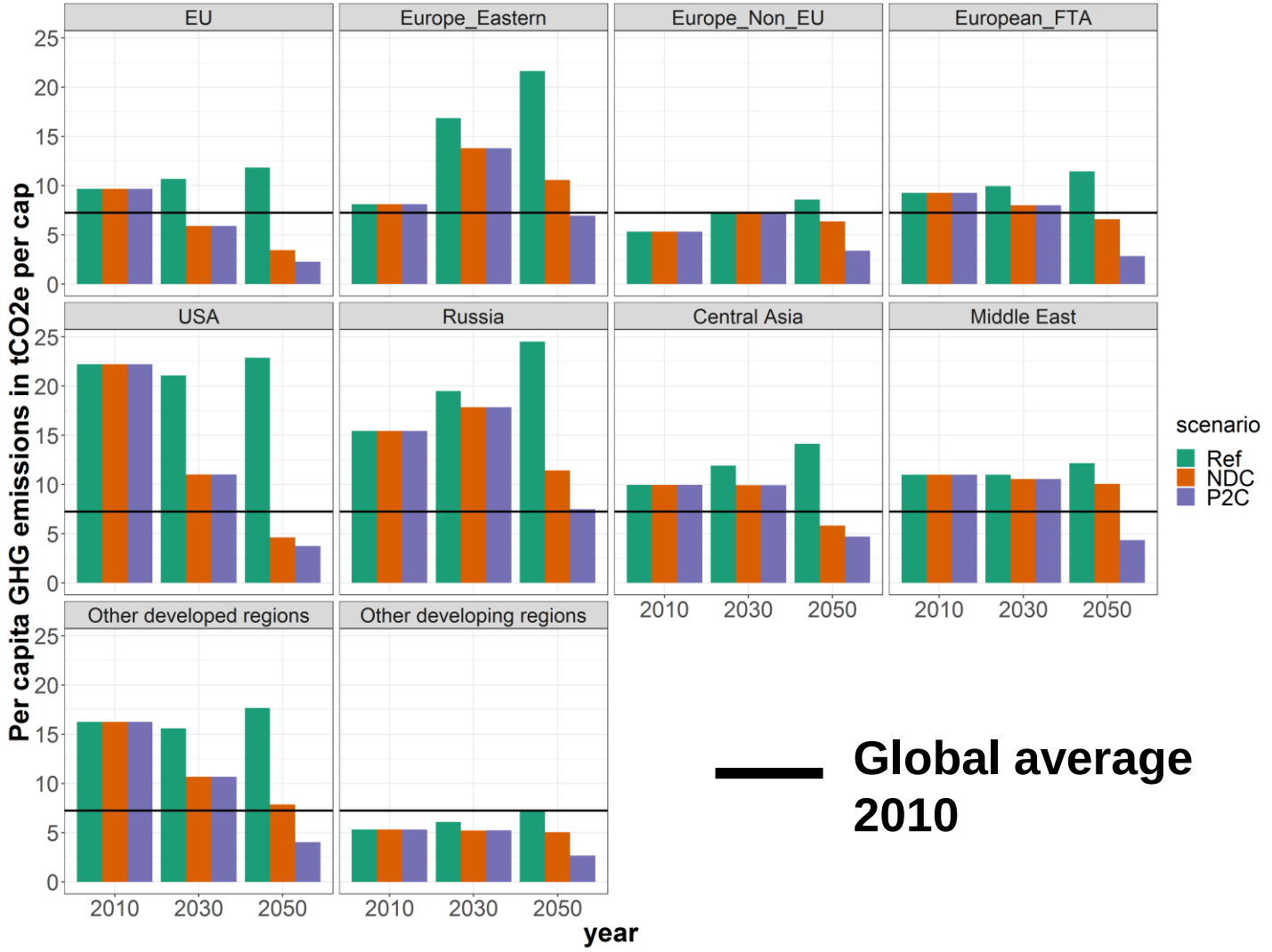
Global total GHG emissions (GtCO2e) and Average Earth Surface Temp Change in 2100



Environment-M1: Climate Change

- Regional emissions tend to rise in the Reference (SSP2) Scenario
- Regional emissions decline as policy stringency increases

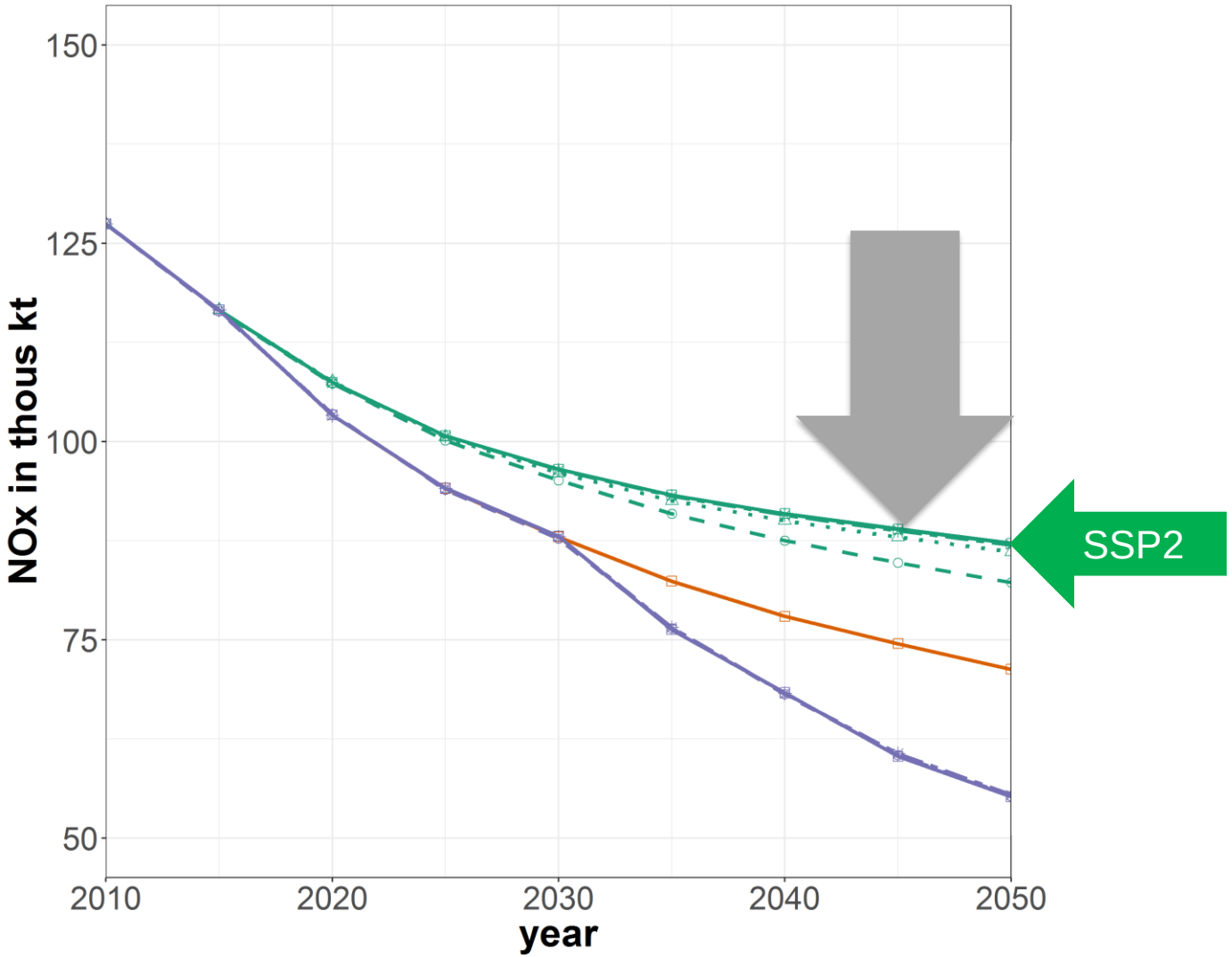
Per capita GHG emissions by region (tCO2e per cap, RefTech)



Enviroment-M2: Local Air Pollutants

- Total and per capita NOx emissions both decrease overtime.

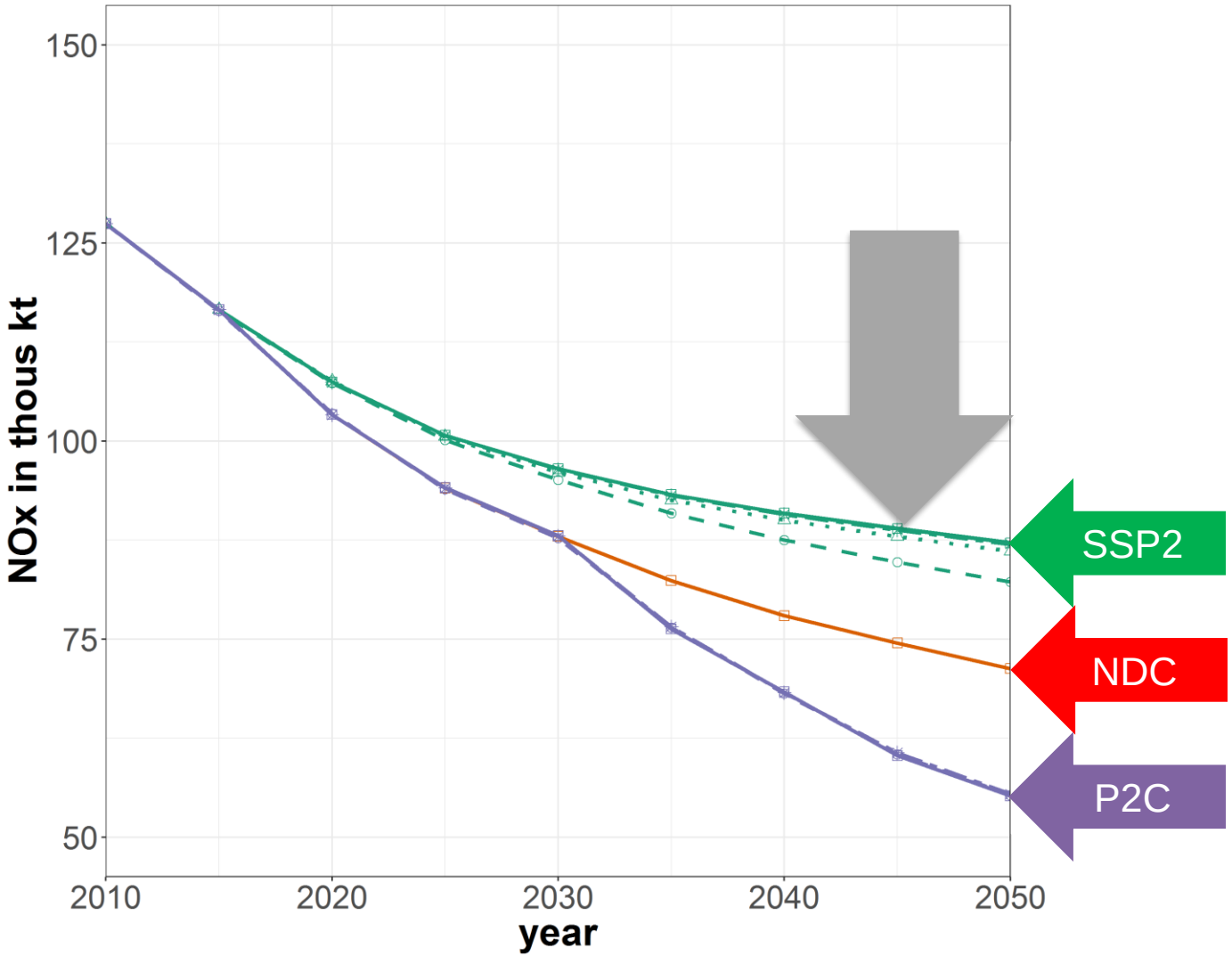
Global total NOx emissions (thous kt)



Enviroment-M2: Local Air Pollutants

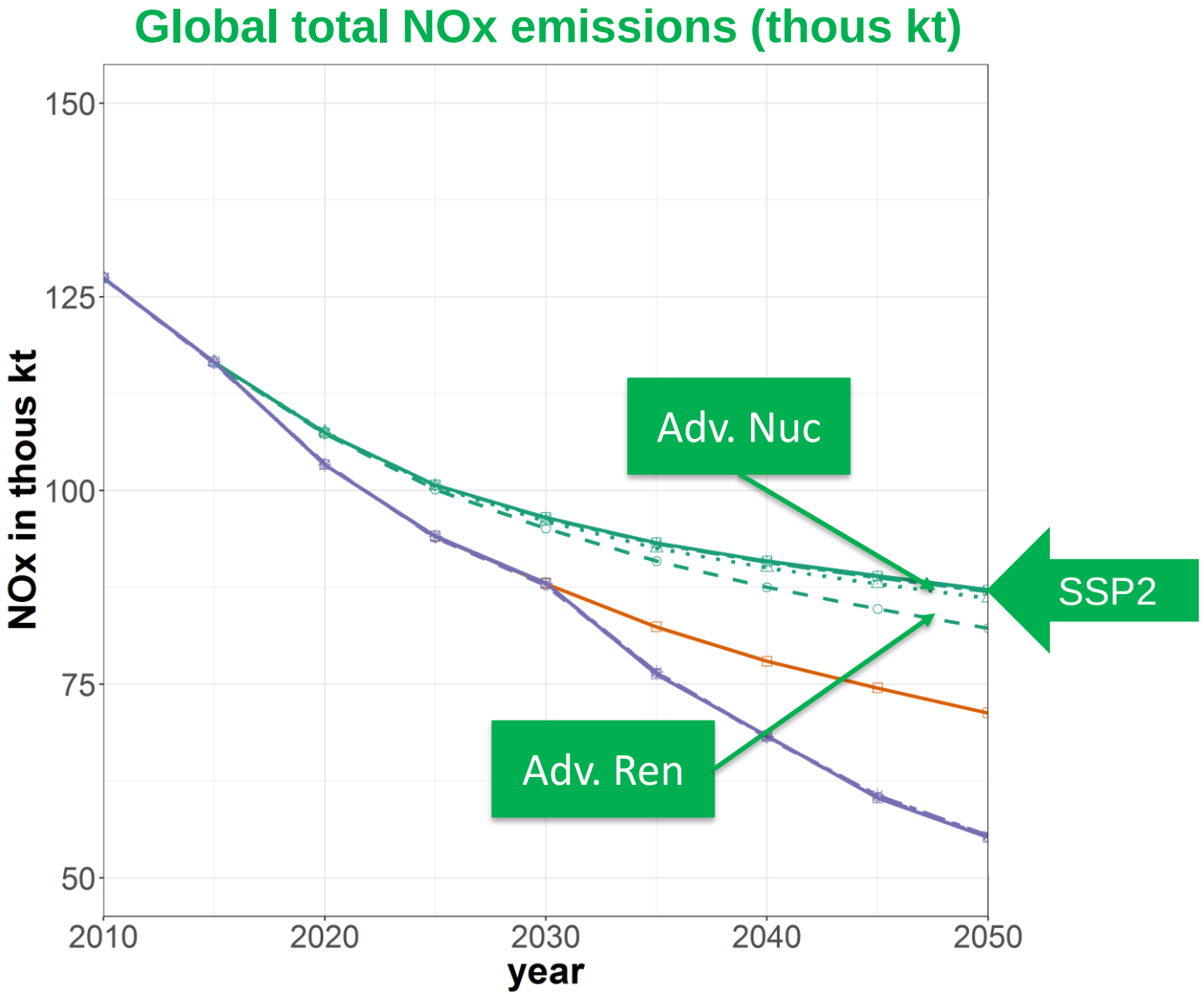
- Total and per capita NOx emissions both decrease overtime.
- Larger reduction is achieved under policy scenarios.

Global total NOx emissions (thous kt)



Enviroment-M2: Local Air Pollutants

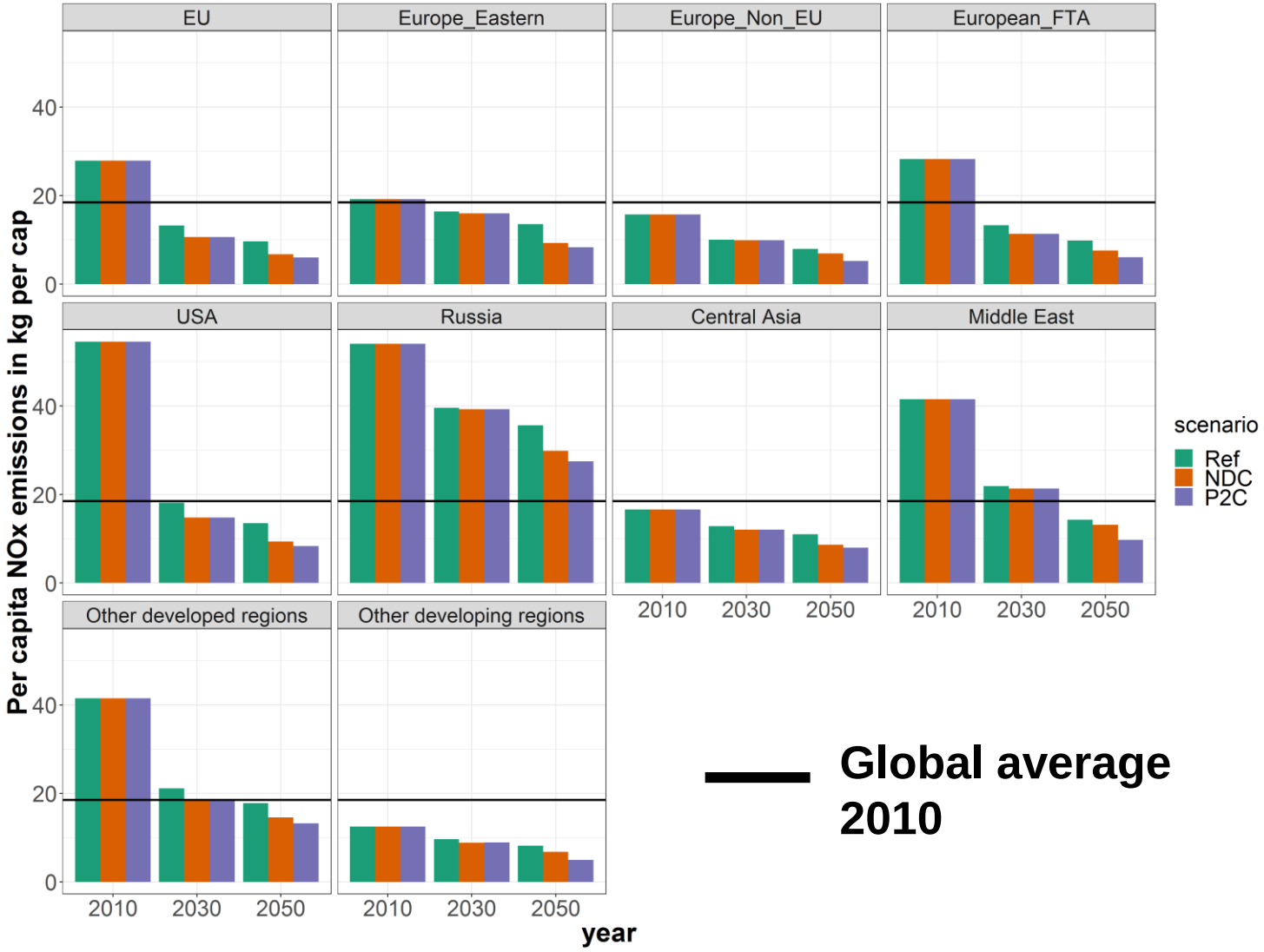
- Advanced RE and low-cost nuclear technologies help lower local air pollutants.



Enviroment-M2: Local Air Pollutants

- Regional patterns are similar to global trends.
- Per capita emissions decline with time and policy stringency
- Most regions are below 2010 global average in 2050

Per capita NOx emissions by region (kg per cap)



DISCUSSION

BACKUP SLIDES

SSP Input Assumptions

	SSP1 Sustainability	SSP2 Middle of the Road	SSP3 Fragmentation	SSP4 Inequality	SSP5 Development First
NEW SSP Pop & GDP					
2100 Population [billion] (IIASA)	6.9 (5th)	9.0 (3rd)	12.6 (1st)	9.3 (2nd)	7.4 (4th)
2100 GDP [trillion 2005 USD, PPP] (OECD)	565 (2nd)	537 (3rd)	278 (5th)	352 (4th)	1,015 (1st)
Technology					
Energy Service Demands	Low	Medium	High	Medium	High
End-Use Technology	High	Medium	Low	Low / High	Medium
Nuclear / CCS	Low	Medium	Medium	Mixed	Medium
Renewable Technology	High	Medium	Low	High	Medium
Fossil Fuel Extraction	Low	Medium	High	Medium	High
Crop Yield Improvement	High	Medium	Low	Low / Medium	High

GCAM Technology Building Blocks

	High Tech	Med Tech	Low Tech	Lower Tech
Nuclear Power	Lower capital recovery factor wi capital and O&M costs declining 0.3% per year	Base capital recovery factor with capital and O&M costs declining at 0.1% per year	igher capital recovery factor with fixed capital and O&M costs	No new nuclear power plant
Carbon Capture & Storage (CCS)	Lower-cost non-tradable regional l d-based storage with larger capaci expensive global-access offshor storage	Non-tradable regional land-based storage combined with expensive global-access offshore storage	tal available resource to 5% of the edium case. Cost scales up rapidly without offshore storage	No deployment
Fossil Fuel Extraction	Extraction costs of coal, oil, and g resource drop by 0.75% per yea	Extraction costs of coal, oil, and gas resource drop by 0.5% per year	xtraction costs of coal, oil, and gas esource drop by 0.25% per year	NA
Advanced Grid for Renewable Tech	1:1 backup required when renewa es supply 50% of capacity	1:1 backup required when renewables (central PV, CSP, rooftop PV, wind) supply 25% of capacity	1 backup required when renewables supply 15% of capacity	NA
Solar Tech	Capital and O&M costs decline a faster rate (double)	Capital and O&M costs decline	apital and O&M costs decline at a slower rate (50%)	NA
Wind Tech	Capital and O&M costs drop at 0. per year	Capital and O&M costs drop at 0.25% per year	apital and O&M costs do not drop	NA
Geothermal Tech	Faster improvement in hydrotherm / EGS available with the improvem rate of 0.5% per year or more	Base improvement in hydrothermal / EGS available only after the exhaustion of hydrothermal resource / EGS improves at 0.25% per year or more	N mprovement in hydrothermal / EGS not available	NA
Building Tech	Faster improvements in end-us efficiencies	Base improvements in end-use efficiencies	lower improvements in end-use efficiencies	NA
Transportation Tech	Faster declines in fuel intensities i ll modes	Base declines in fuel intensities in all modes	S wer declines in fuel intensities in all modes	NA
Industry Tech	Faster improvements in end-us efficiencies	Base improvements in end-use efficiencies	lower improvements in end-use efficiencies	NA
Crop Production	Crop yield improvements convergi to 0.5% per year by 2050	Crop yield improvements converging to 0.25% per year by 2050	C p yield improvements converging to 0% per year by 2050	NA