China's Methane Mitigation Potential:

An Assessment of Costs and Uncertainties through 2060

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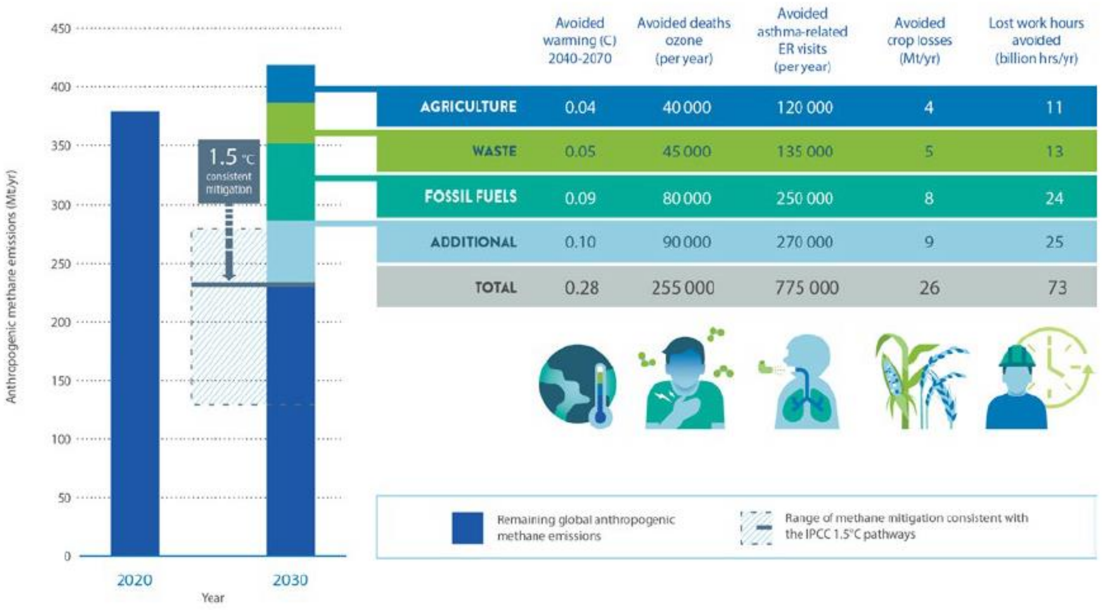
Introduction

- Methane, a potent short-lived climate pollutant, has contributed to ~30% of the current rise in global average temperatures
- Reducing methane emissions contributes significantly to reducing near-term climate change impacts, by avoiding 0.3°C temperature increase by the 2040s
- Additional co-benefits in improved air quality and health conditions and crop yields
- China, the world's largest methane emitter, is increasing policy focus on methane mitigation:
  - U.S.-China Joint Glasgow Declaration
  - Endorsement in 14th Five-Year Plan
  - National Methane Action Plan (just released)
  - 2023 Sunnylands Statement



Source: 2021 Global Methane Assessment Report

Overview of Model Development & Earlier Analysis

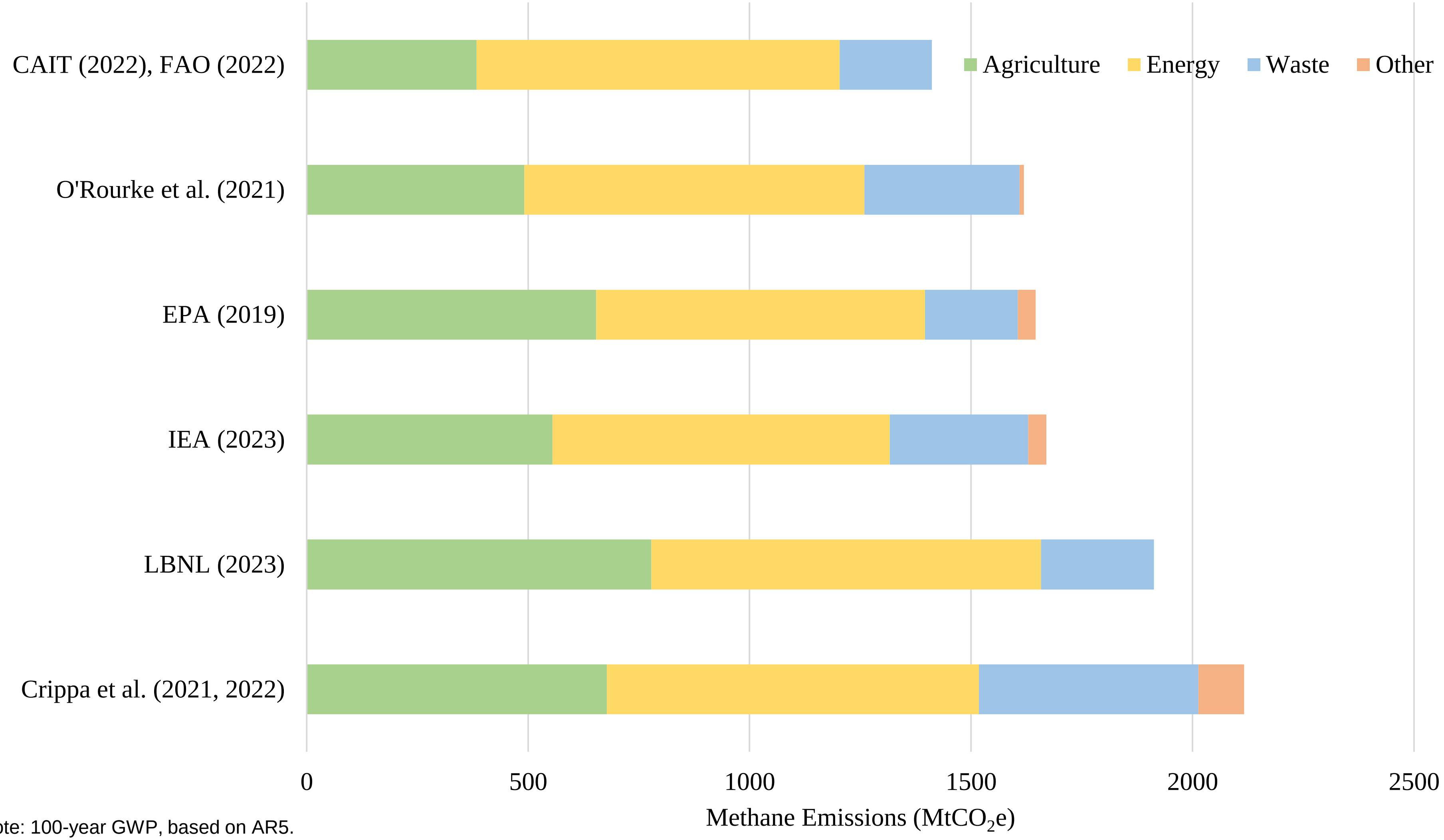
- We developed a bottom-up model of non-CO_2 GHGs and modeled cost-effective mitigation potential for China, covering:
  - Methane, F-gases and N_2O
  - Energy, agriculture, waste and wastewater, and industrial processes
- Previous work identified 1040 $MtCO_2e$ of non-CO_2 GHGs, including half from methane reductions, could be reduced in 2030 at average abatement costs of ~US$10/$tCO_2e$
- By 2050, 57% reduction in non-CO_2 GHGs from a BAU scenario is possible

See Lin et al. 2019, “China’s Non-CO2 Greenhouse Gas Emissions: Future Trajectories and Mitigation Options and Potential” https://www.nature.com/articles/s41598-019-52653-0 and Lin et al. 2022, “Opportunities to Tackle Short-lived Climate Pollutants and other GHGs for China”, https://www.sciencedirect.com/science/article/pii/S0048969722039390 for more information

Methane Mitigation Modeling

- We used a bottom-up modeling approach with **updated activity driver projections** for methane sources (e.g., population, coal production) through 2060 that:
  - accounts for additional emission sources: **abandoned coal mines, aquaculture**
  - incorporates new mitigation opportunities: **biochar** and straw applications in rice cultivation, **aquaculture mitigation**, emerging **enteric fermentation measures**
- We also address **areas of uncertainties** in emission sources, including:
  - regionalized emission factors and uncertainty ranges for coal mine methane
  - biochar methane mitigation efficiency and uncertainty ranges for rice cultivation
  - sensitivity analysis for less certain, emerging enteric fermentation measures

We estimate 1913 $MtCO_2e$ of methane emissions in 2020, with higher estimate that accounts for additional emission sources of abandoned coal mine and aquaculture



Note: 100-year GWP, based on AR5.
Sources: CAIT (2022), FAO (2022), O'Rourke et al. (2021), EPA (2019), IEA (2023), Crippa et al. (2021, 2022). Other category varies by different data sources and includes chemicals, metals and fossil fuel fires in O'Rourke et al. (2021), manufacturing, other transport, chemical and metal industries and fires in Crippa et al. (2021, 2022), stationary and mobile sources in EPA (2019), and average of other estimates from four key sources in IEA (2023).

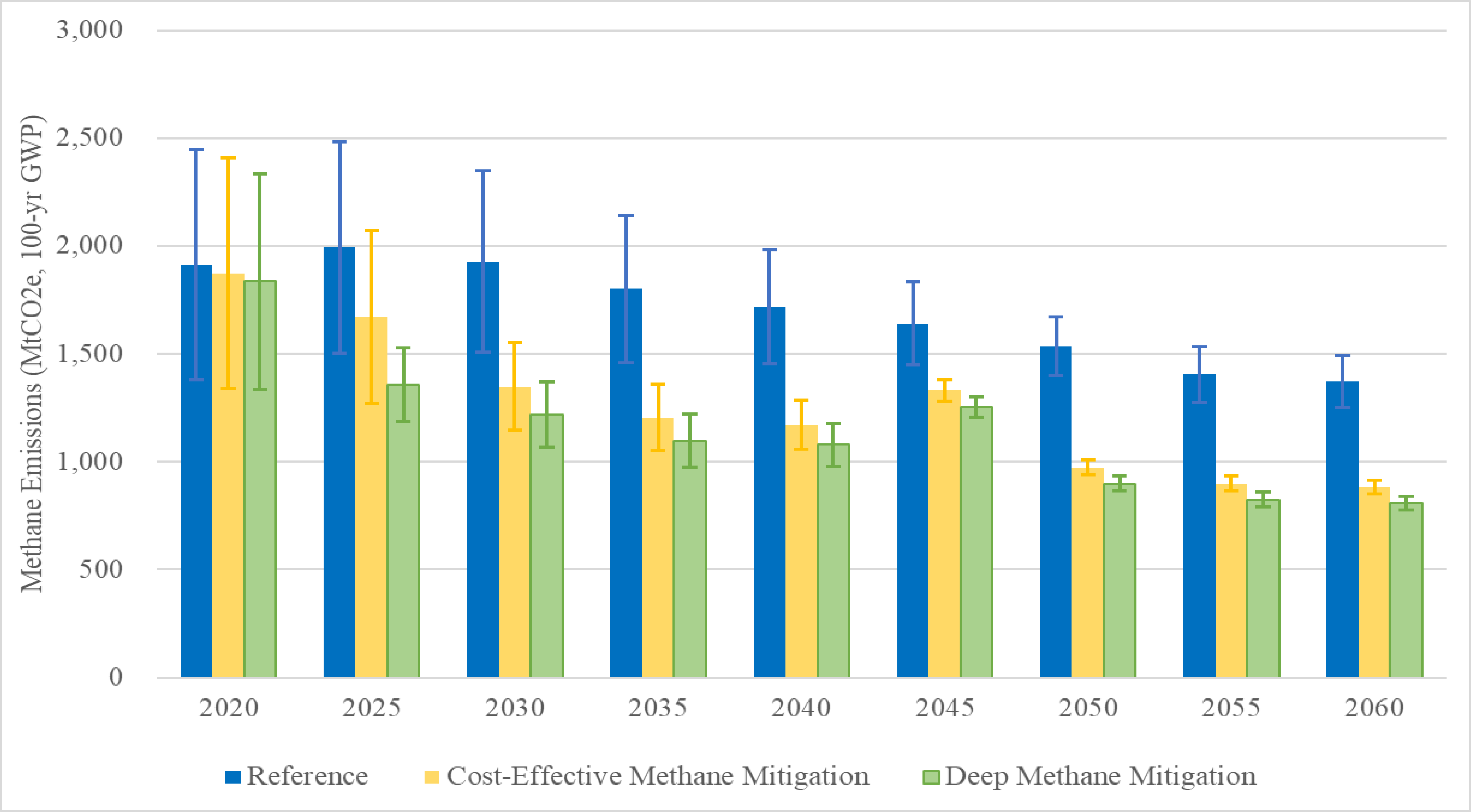
Scenario analysis

Reference scenario of clean energy transition and decarbonization consistent with current policies to serve as a baseline scenario that does not consider any methane mitigation measures,

Cost-effective Methane Mitigation scenario that assumes full adoption of individual cost-effective methane mitigation measures below $10/t$CO_2$e prior to 2050 and,

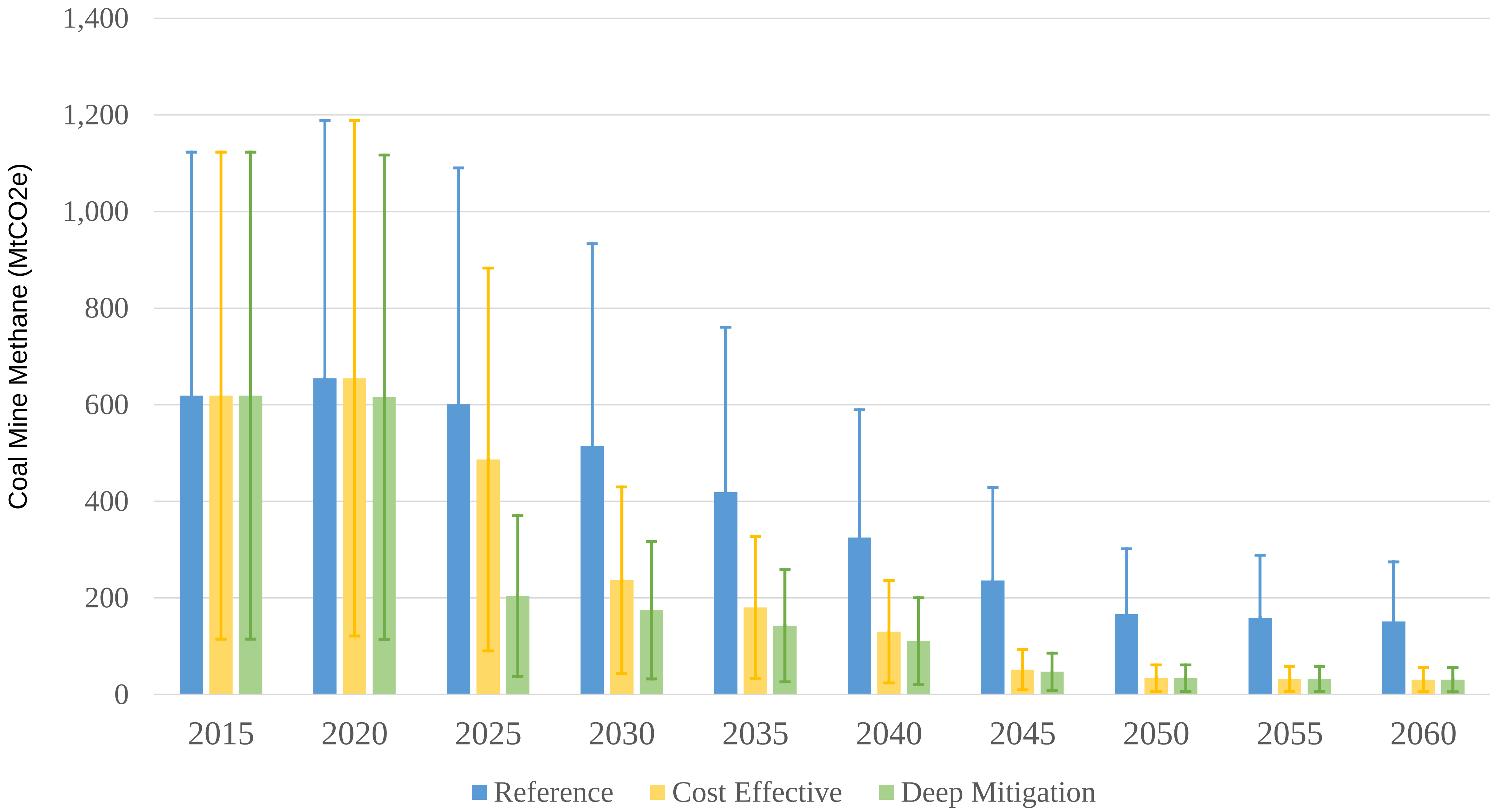
Deep Methane Mitigation scenario that assumes accelerated clean energy transition, faster adoption of cost-effective methane mitigation measures by 2025 and application of additional, higher-cost individual mitigation measures below US$100/t$CO_2$e.

Significant uncertainty ranges in total methane emissions from coal mine methane and agriculture uncertainties

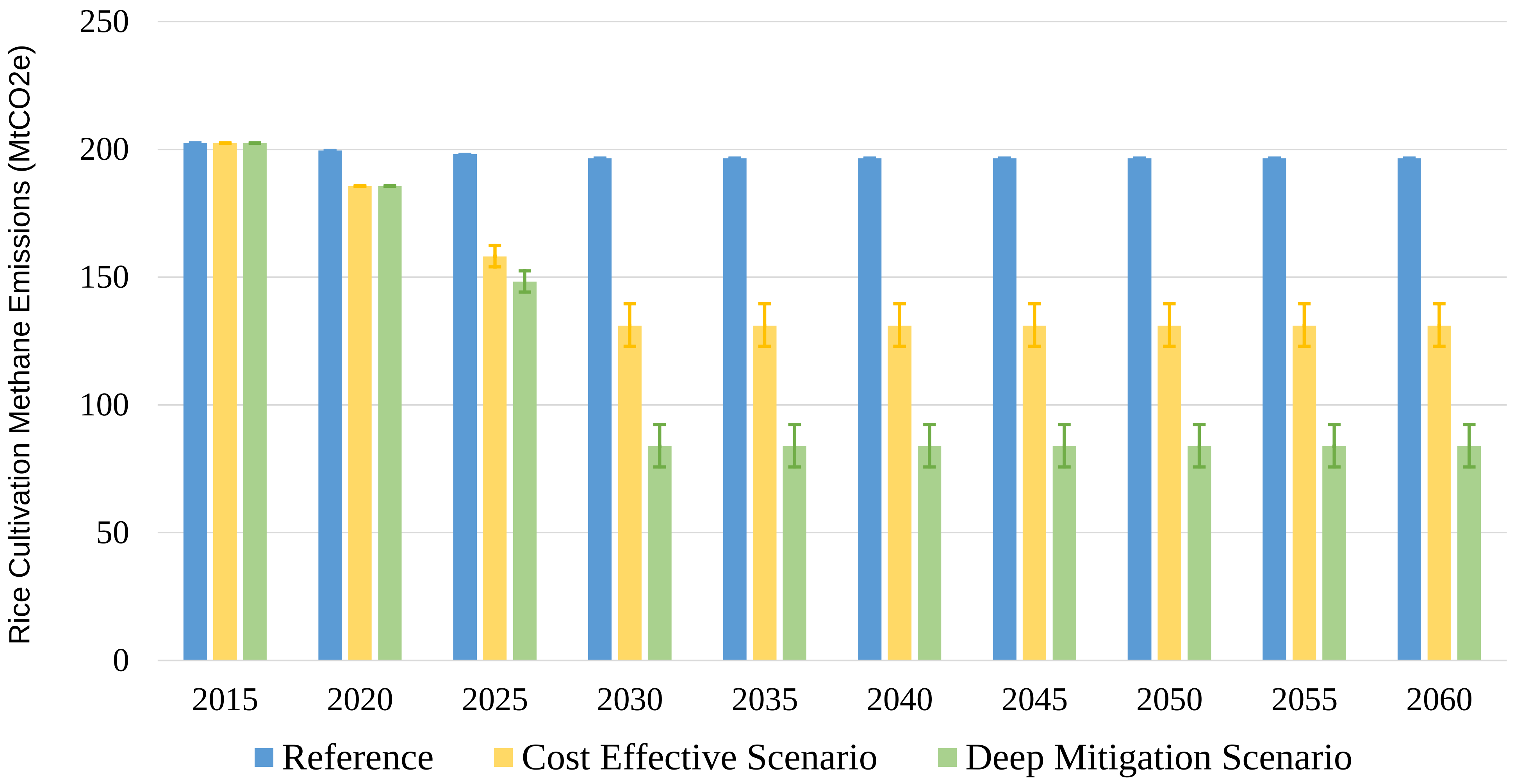


Note: error bars represent the high and low range values for uncertainties in coal mine methane and rice cultivation

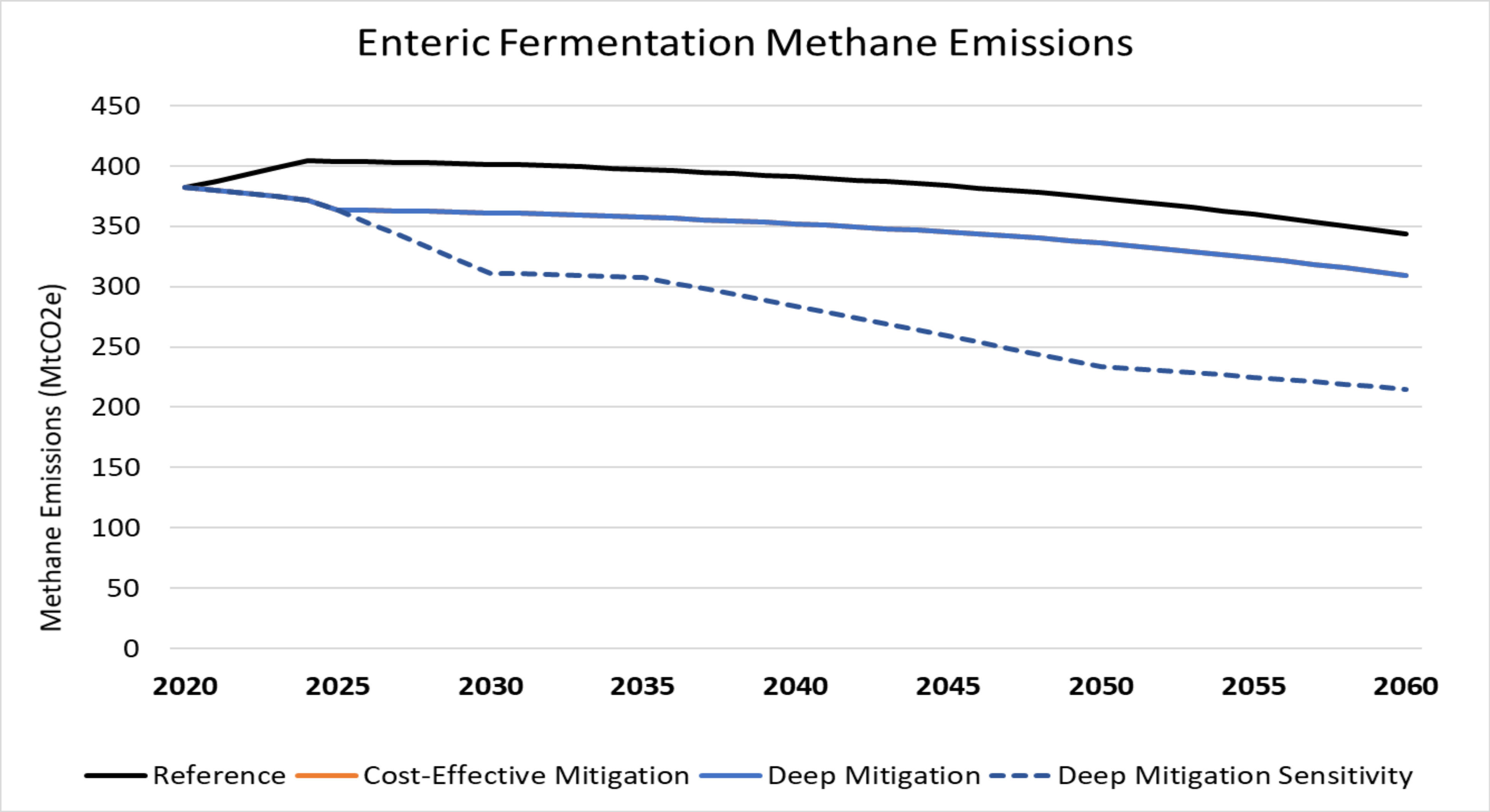
Uncertainties in coal mine methane emissions significant, but decrease over time



Uncertainty in rice cultivation methane emissions primarily due to efficacy of biochar application, which is assumed to be fully deployed by 2030

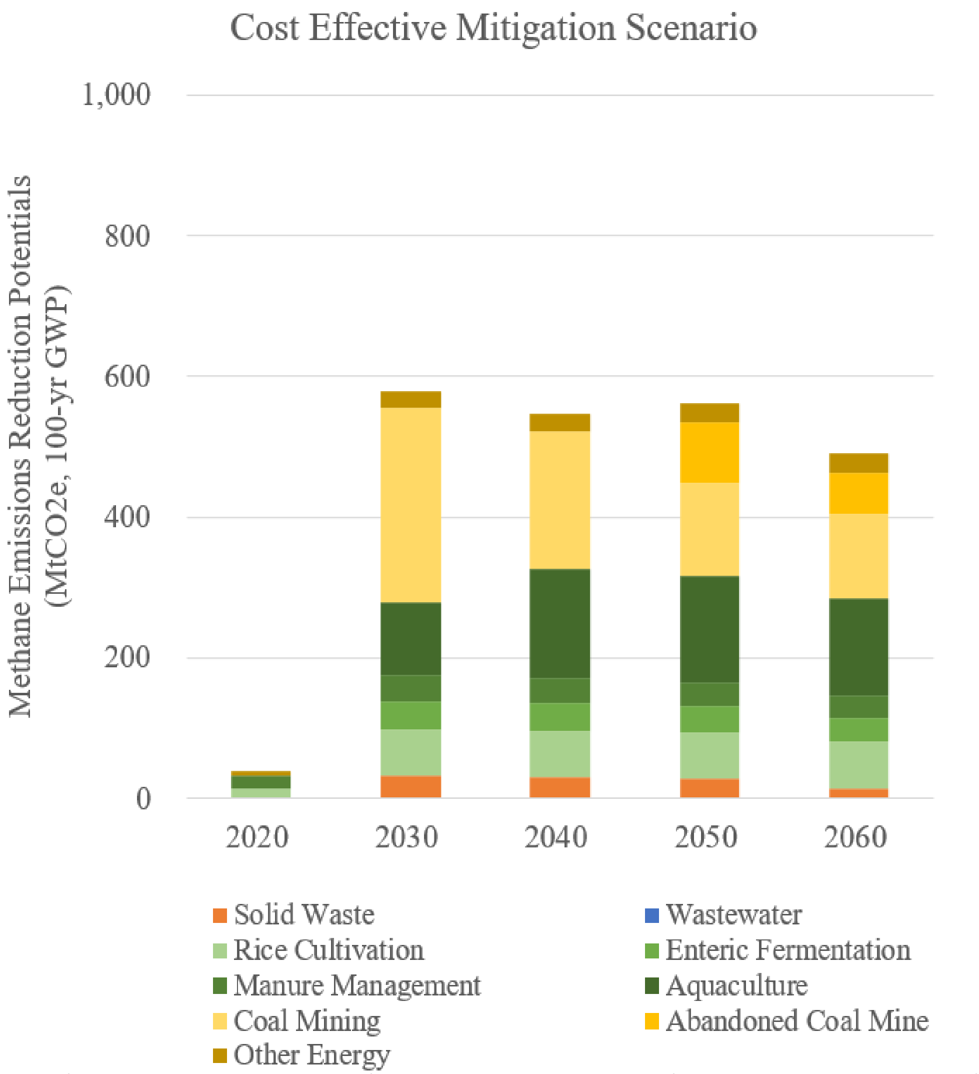


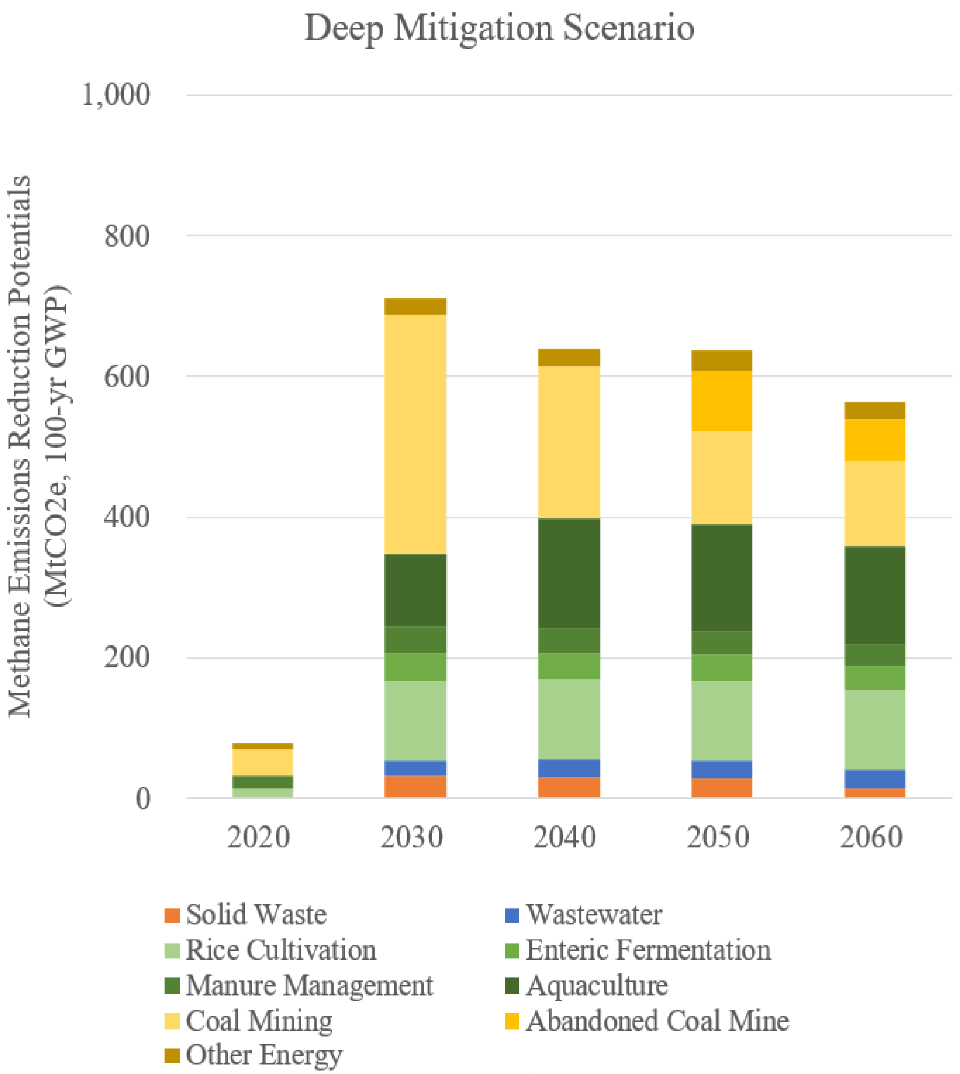
The phased adoption of emerging enteric fermentation measures can further reduce methane emissions by 13% in 2030, and by 27% in 2060



Note: Deep Mitigation Sensitivity assume additional adoption of emerging mitigation measures of methane inhibitors and vaccines, based on Reisinger et al. 2021.

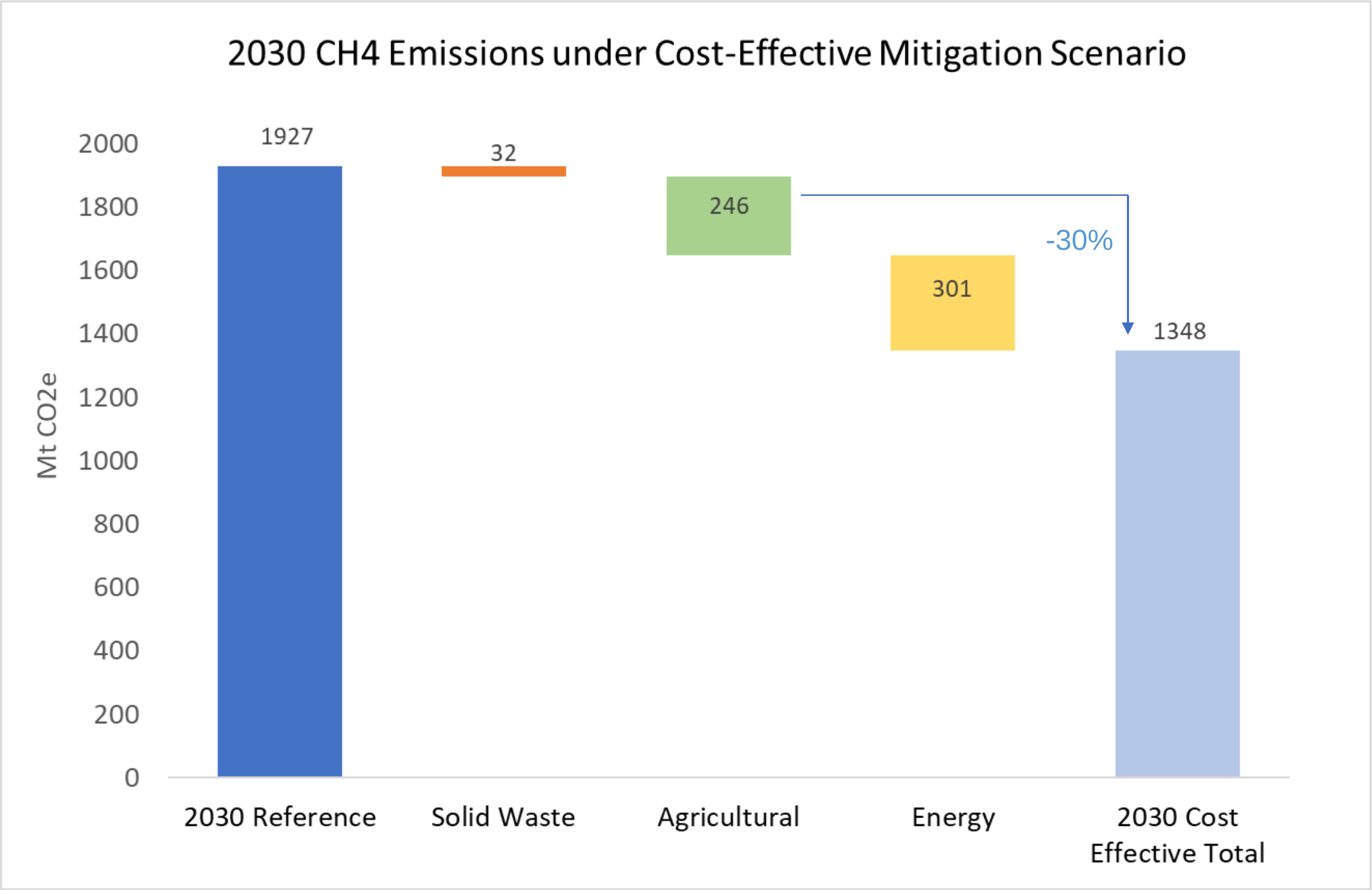
Under both scenarios, most reduction potential will be from the energy sector in early years, but shifts to agriculture sector as China shifts away from coal



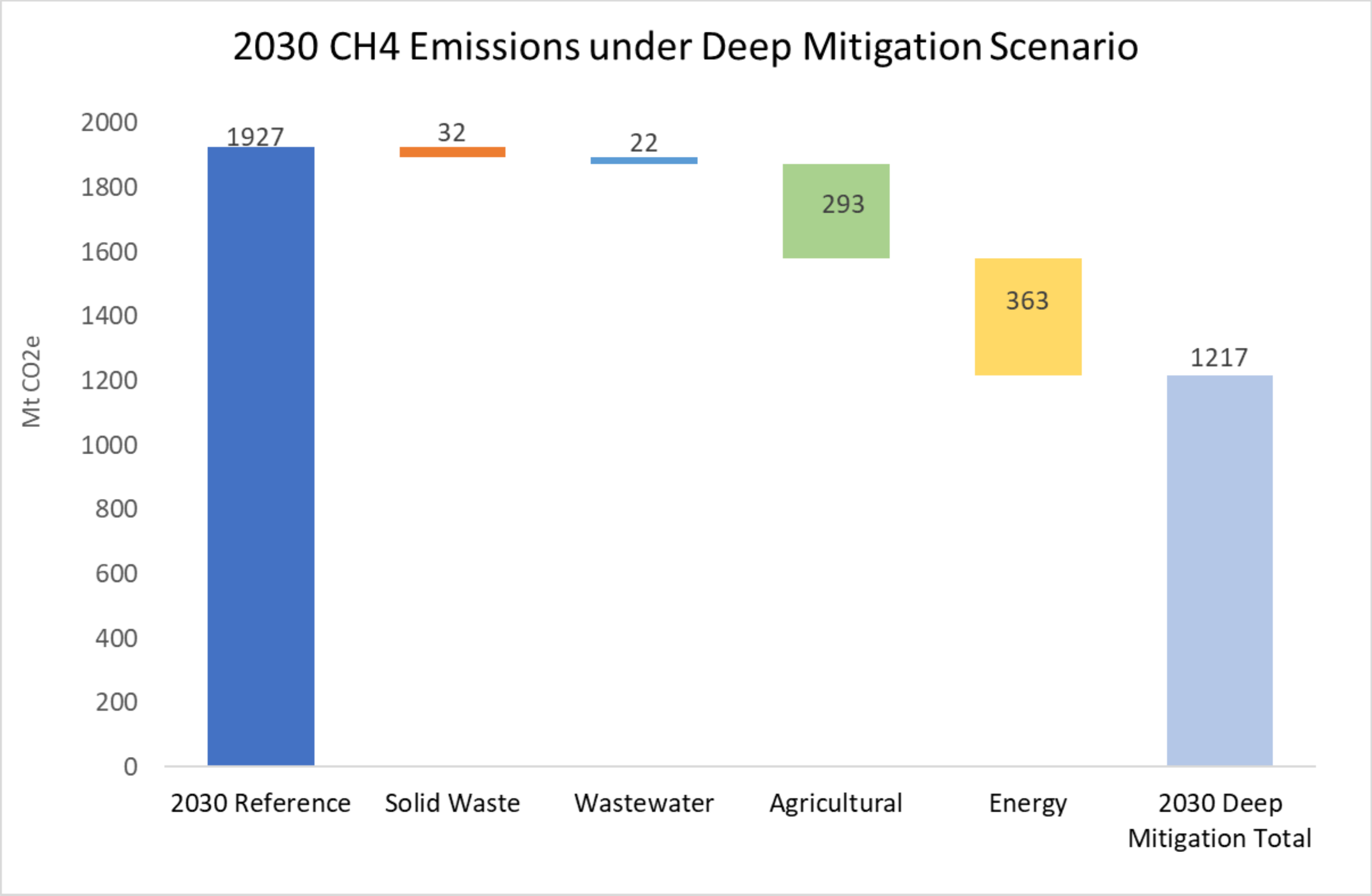


Note: reductions shown are relative to Reference scenario

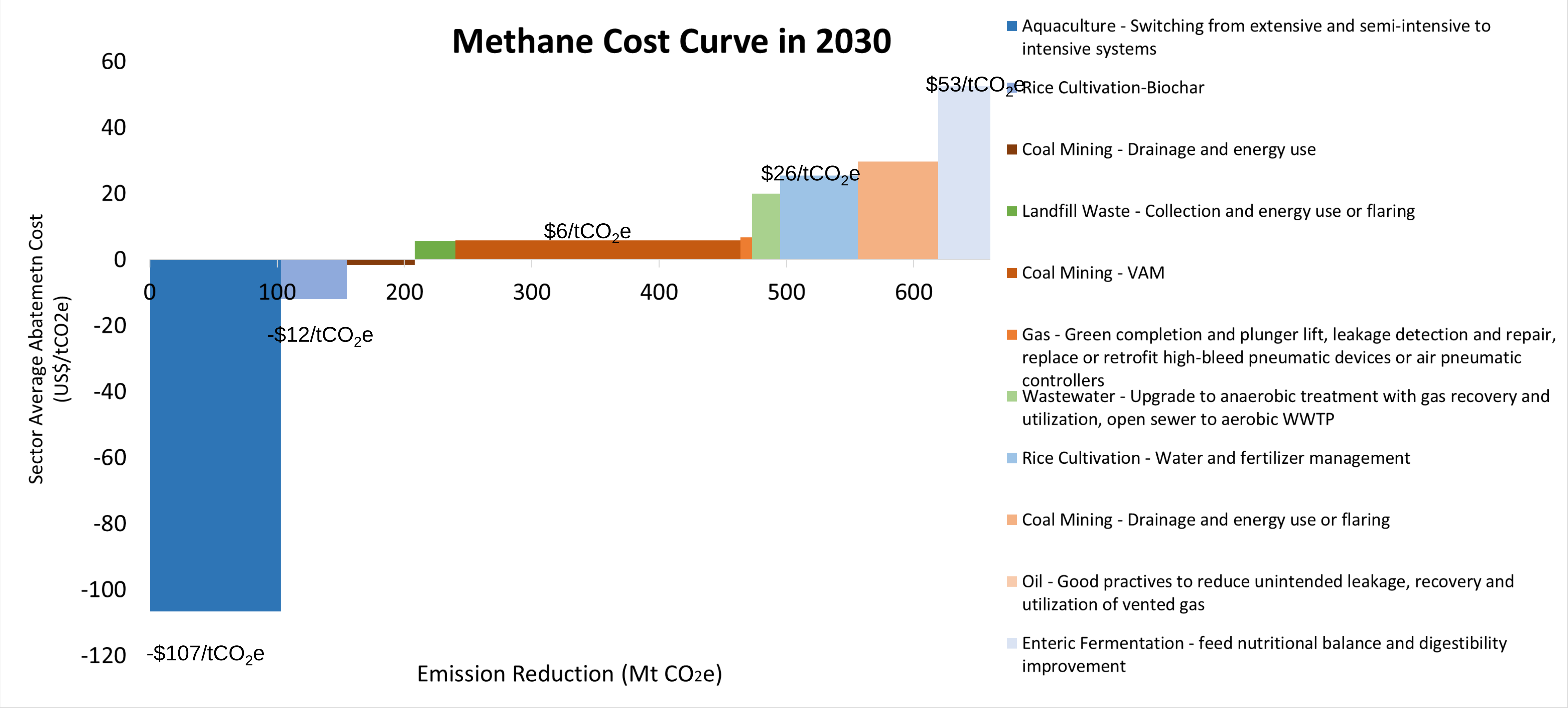
In 2030, most methane mitigation potential exists in the energy sector, which accounts for 63% of total potential under the Cost-Effective Scenario



Under the Deep Mitigation Scenario, half of methane mitigation potential is from the energy sector, followed closely by the agriculture sector

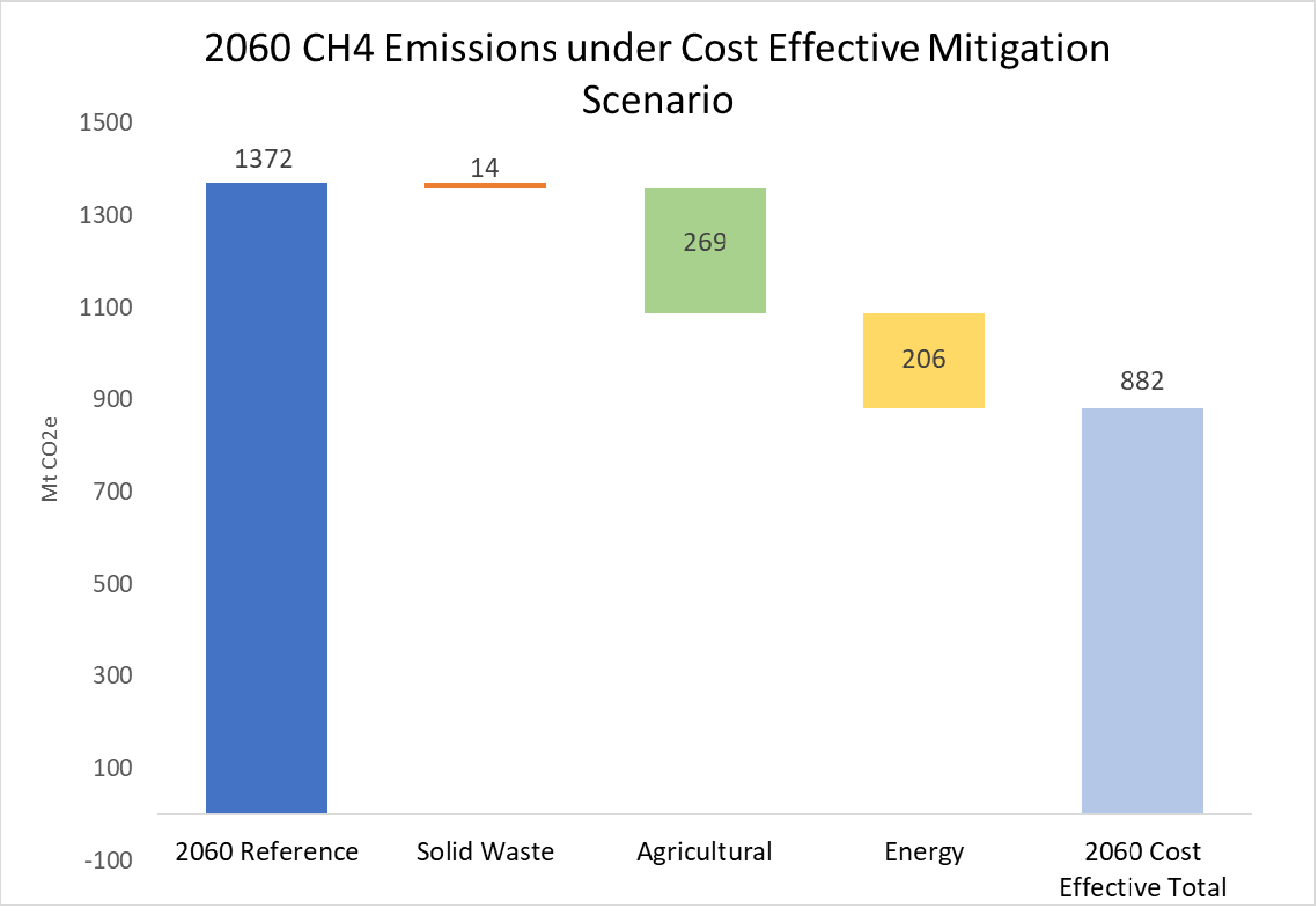


Under the Deep Mitigation Scenario, we identified 660 $MtCO_2e$ reductions (34% reduction relative to Reference scenario) possible in 2030 with average abatement costs of US$6.40/$tCO_2e$

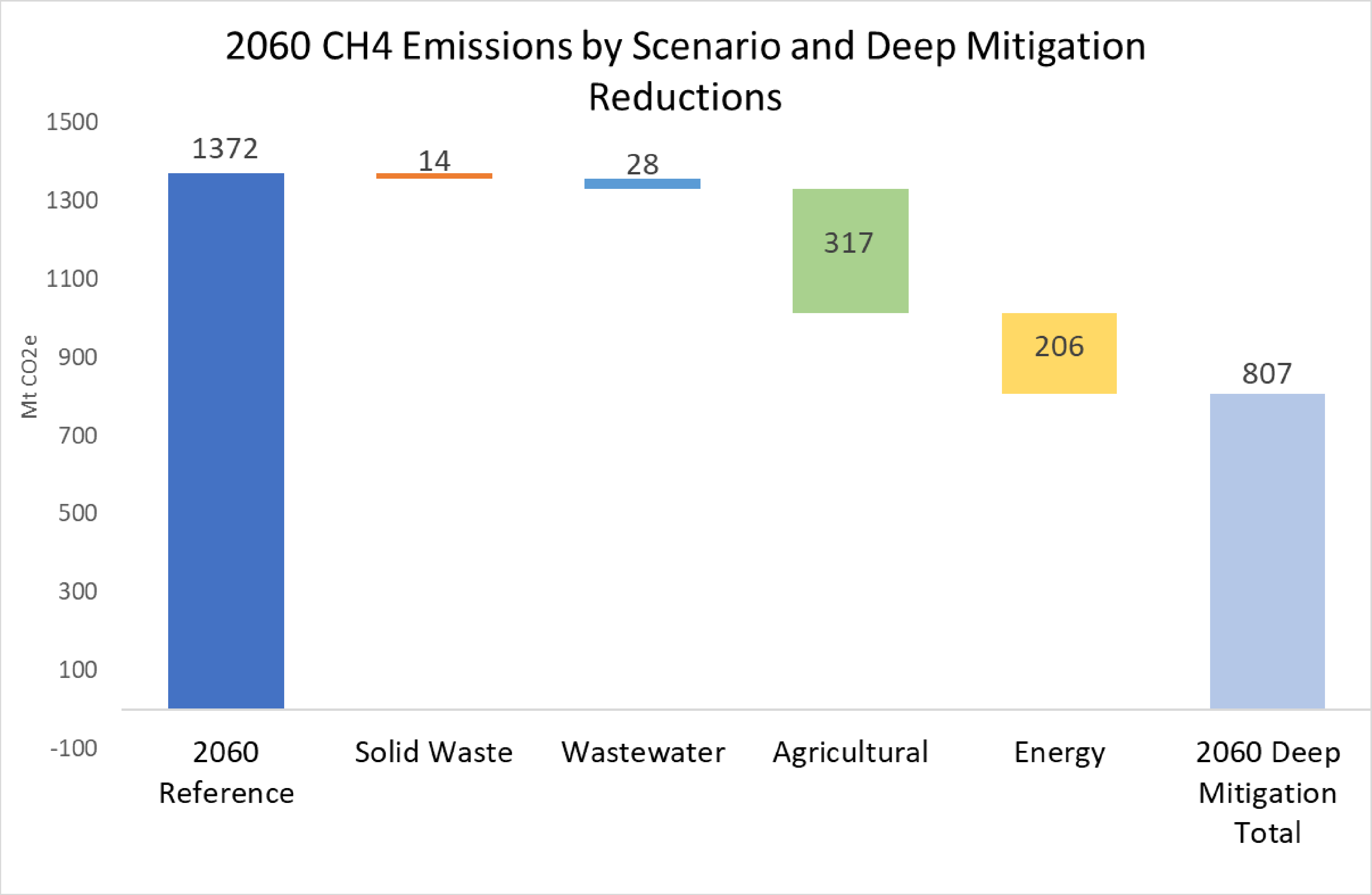


Note: highly uncertain and costly manure management and biomass combustion measures are not shown in above cost-curve, but could provide additional 50 $MtCO_2e$ of methane reduction

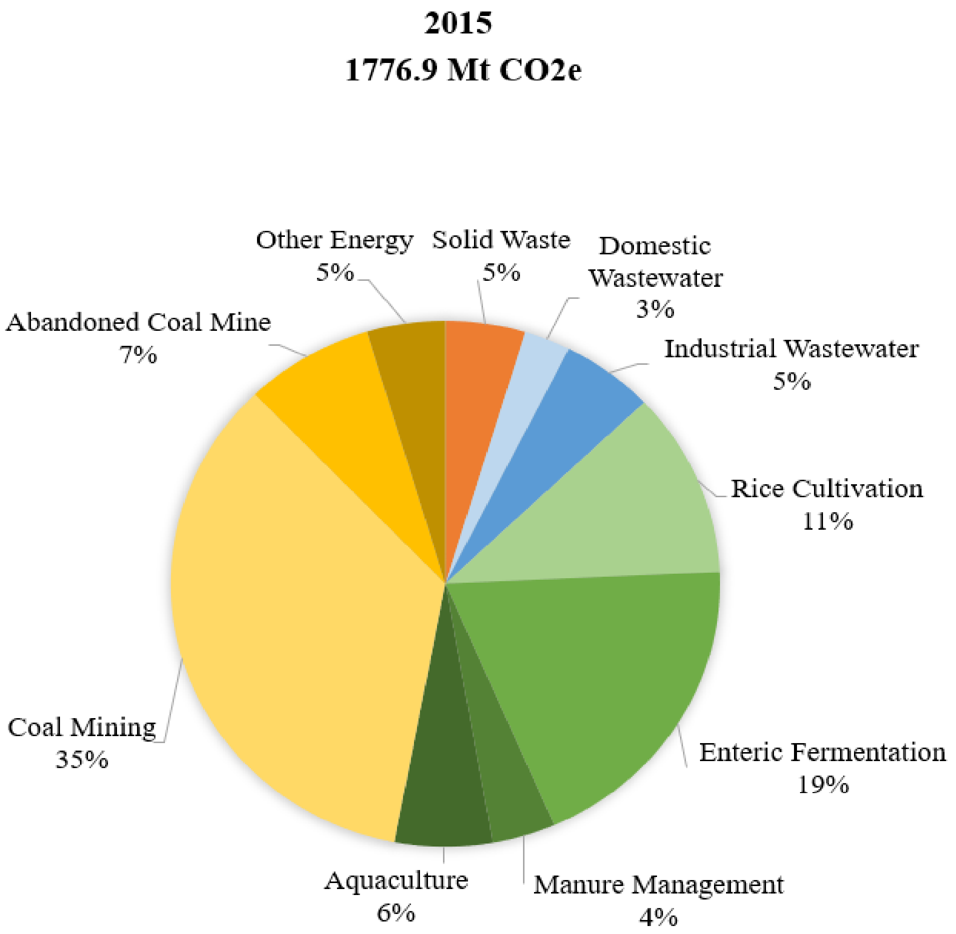
By 2060, 36% reduction in methane emissions possible under the Cost-Effective Mitigation Scenario

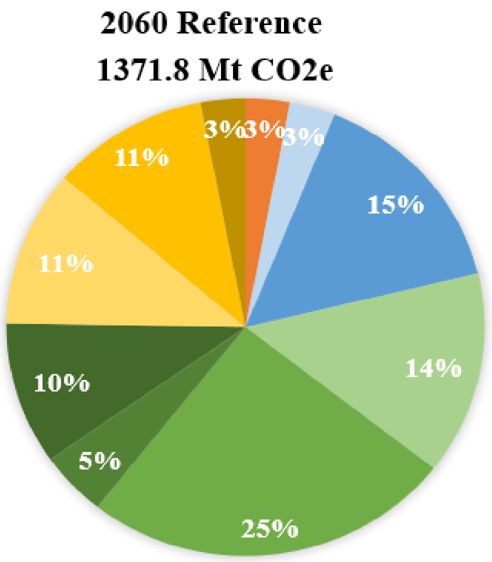


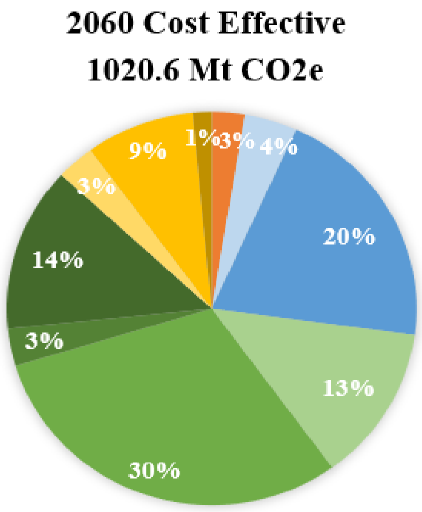
Under the Deep Mitigation Scenario, additional 75 $MtCO_2$ of methane reduction is possible by 2060, resulting in 42% reduction

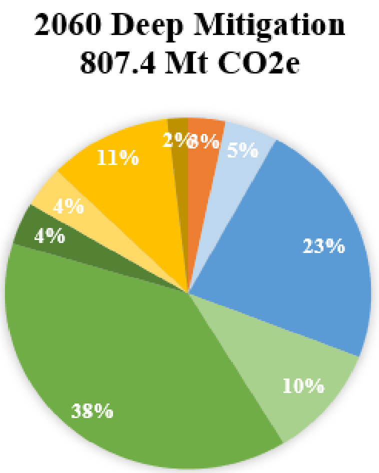


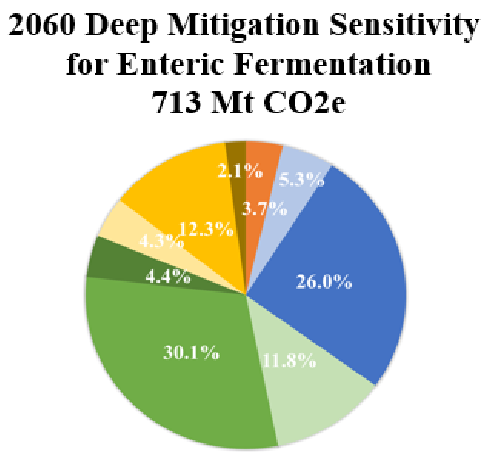
By 2060, up to 55% reduction in methane emissions *from 2015 levels* is possible under the Deep Mitigation Scenario, but with large remaining emissions in agriculture











Sensitivity includes emerging mitigation measures of methane inhibitors and vaccines.

Conclusions

- We identified significant potential for reducing methane emissions in China by 2030, with 660 $MtCO_2e$ reductions (34% reduction relative to Reference scenario) possible with average abatement costs of US$6.40/$tCO_2e$
- If more uncertain and costly manure management, biomass and emerging enteric fermentation measures are included, total reduction potential of 760 $MtCO_2e$ (39% reduction) is possible by 2030
- Coal mining remains a key source of methane emissions but there are high uncertainties around coal mine methane emissions in the near term, and abandoned coal mine methane is not well studied
- In agriculture, aquaculture and biochar applications in rice cultivation could reduce methane emissions at negative cost (i.e., net benefit) but will need more support to be pursued more rigorously in both research and development and implementation
- Additional research is needed to better understand emerging measures in enteric fermentation and addressing remaining methane emissions in agriculture and wastewater sectors in 2060, including behavior-based measures