
Technology Portfolio

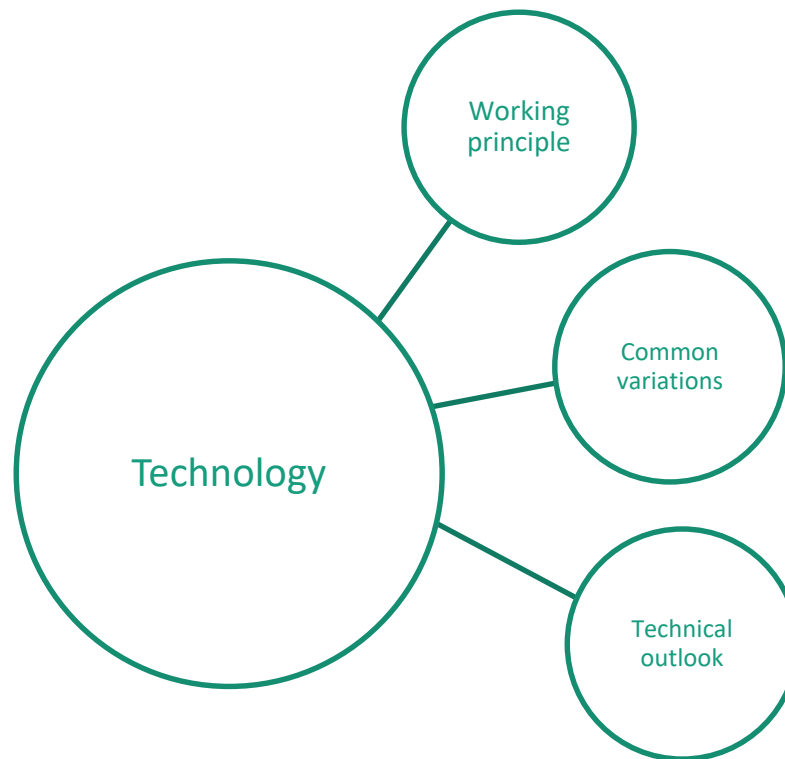
Comparison of technology cost assumptions from MESSAGE and GCAM
(Preliminary Results)

Objective

- **Characterizing the main power generation technologies**
- **Creating transparency for the Pathways project**
 - Detailing the techno-economic input assumptions (CapEx, O&M, Efficiency, Lifetime)
 - Comparing the models with each other and with literature values
 - Displaying annualized cost for each technology to consider all factors simultaneously (CapEx, O&M and Lifetime)

Activities: Technology Description

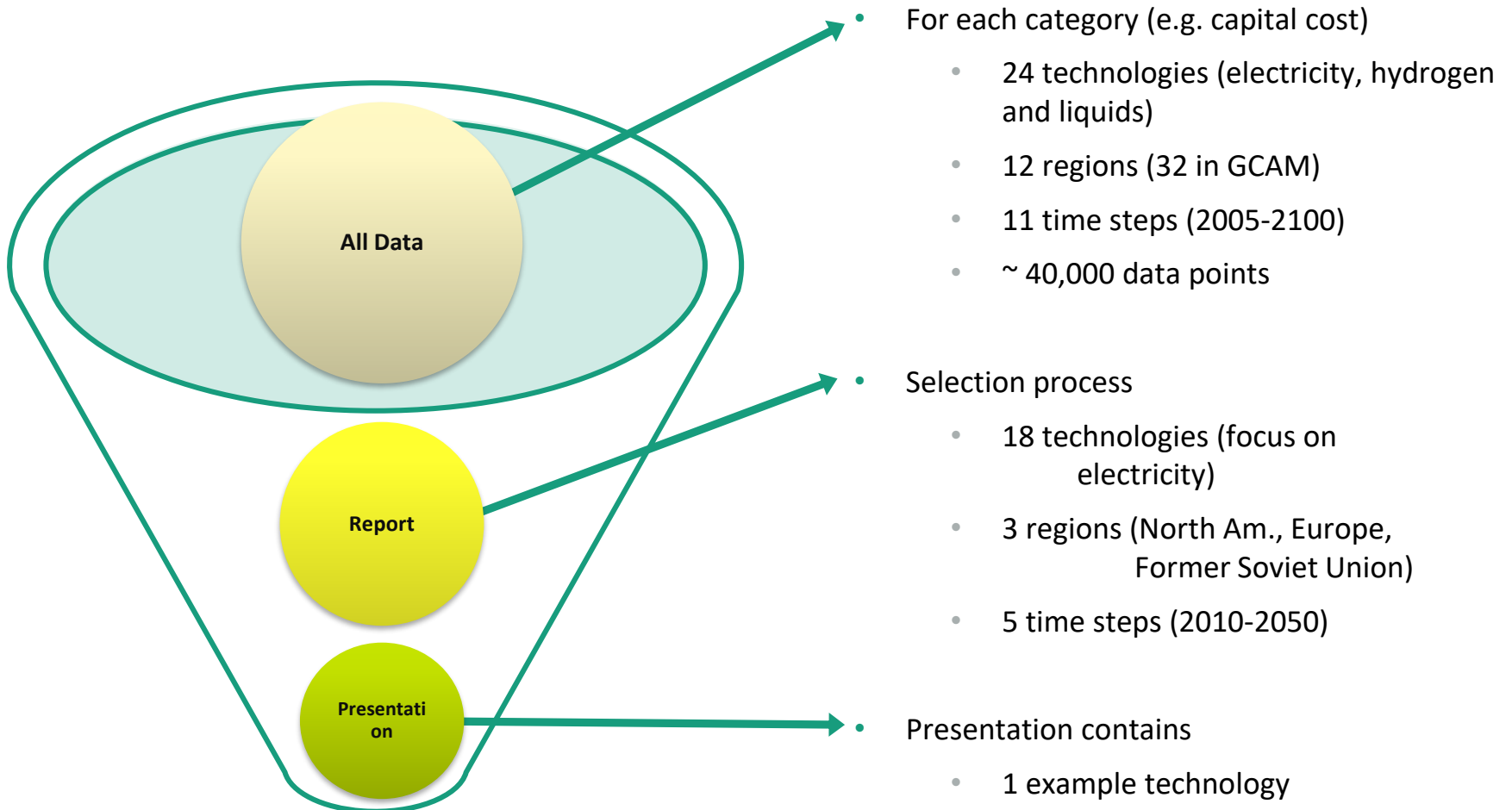
- Descriptions of each technology to provide reader with a brief overview (details are in the report):



Activities: Technology Description

- Renewable technologies:
 - Photovoltaics
 - Concentrated solar power
 - Wind power
 - Hydro power
 - Biomass
- Conventional technologies:
 - Coal-fueled power plants (IGCC, subcritical, supercritical)
 - Gas combustion (CCGT, gas steam power)
 - Nuclear power

Activities: Data Comparison



Activities: Data Comparison

Literature Comparison

- Values from open literature
- Studies including capital cost and O&M cost for the time period from 2010 to 2050 were prioritized

Visualization

- Literature values were cumulated into cost ranges (light grey areas)
- Overlapping ranges with darker grey shade
- Model assumptions were added on top of the literature ranges

Adding Annualized Cost

- Complimenting the direct comparison of capital cost, O&M cost and efficiencies
- This approach allowed a comparison that takes into account both cost factors and lifetime

Activities: Data Comparison

Adding Annualized Cost

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- The calculation including interest rates has been conducted with the following formulae:

- Calculation of the Annuity factor: $A(t, r) = \frac{1 - (1/(1+r)^t)}{r}$

- Calculation of annualized cost: $AC = \frac{\text{Capital cost}}{A(t, r)} + \text{O\&M cost}$

t = lifetime

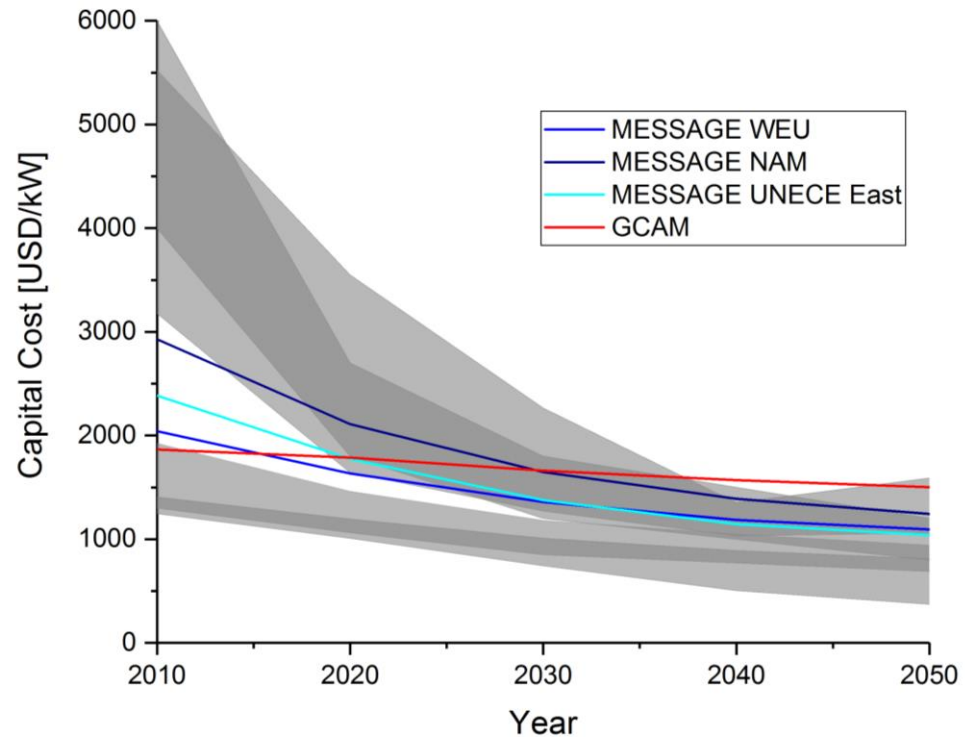
r = interest rate

Discount Rates

- GCAM and MESSAGE use different methods to annualize their CapEx for technology cost calculations
- GCAM uses a Fixed Charge Rate (**13%**), which includes multiple discounting factors such as: depreciation, interest rate, taxes and return on equity
- MESSAGE works with the interest rate to discount the investment costs over the lifetime of the technology (**5%**) while the other mentioned factors are considered at different stages
- This leads to large differences in calculated annualized cost
- **Differences due to different methodologies**

Results – Example Renewable: Solar PV

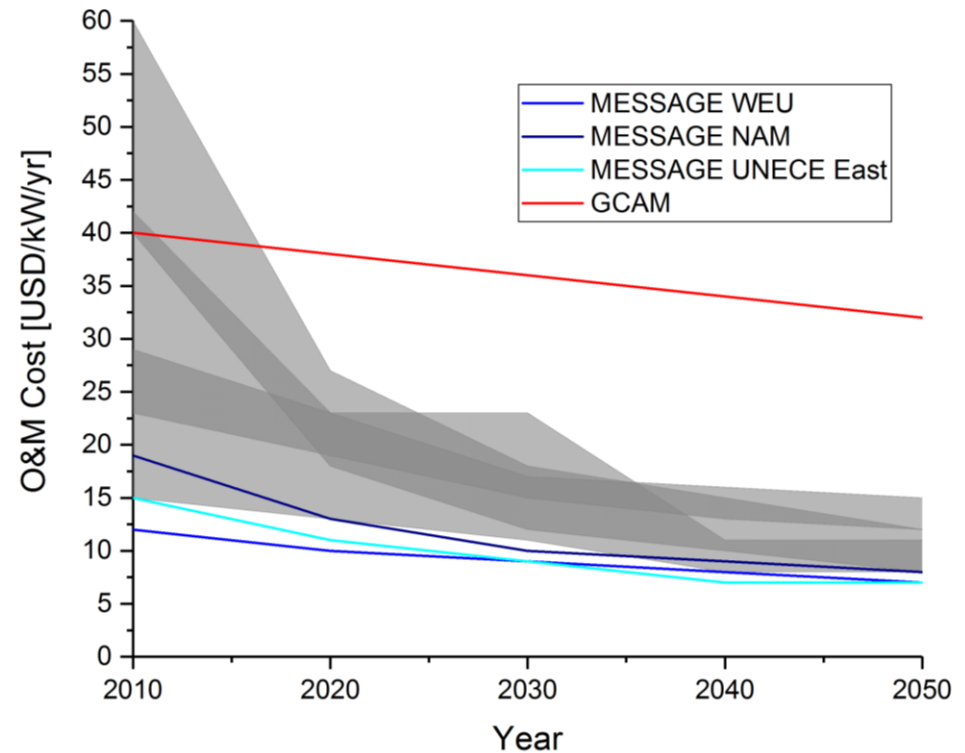
- **Capital Cost**
 - General trend among models and literature is similar
 - GCAM more conservative, smaller overall cost decline
 - MESSAGE with similar development for all regions



Comparison of literature values (grey area) and the regional assumptions from MESSAGE (WEU – Western Europe, NAM – North America, UNECE East – includes Russia and Central Asia) (blue lines) and GCAM (red line)

Results – Example Renewable: Solar PV

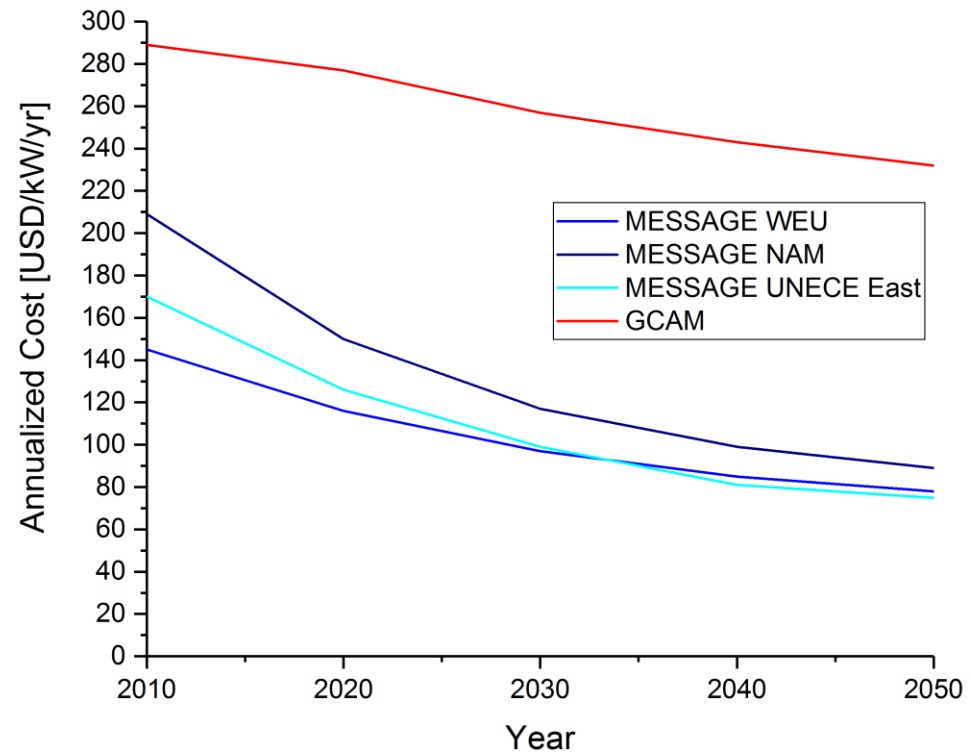
- **Operation and Maintenance Cost**
 - Greater difference between MESSAGE and GCAM
 - GCAM more than 100% higher than MESSAGE



Comparison of literature values (grey area) and the regional assumptions from MESSAGE (WEU – Western Europe, NAM – North America, UNECE East – includes Russia and Central Asia) (blue lines) and GCAM (red line)

Results – Example Renewable: Solar PV

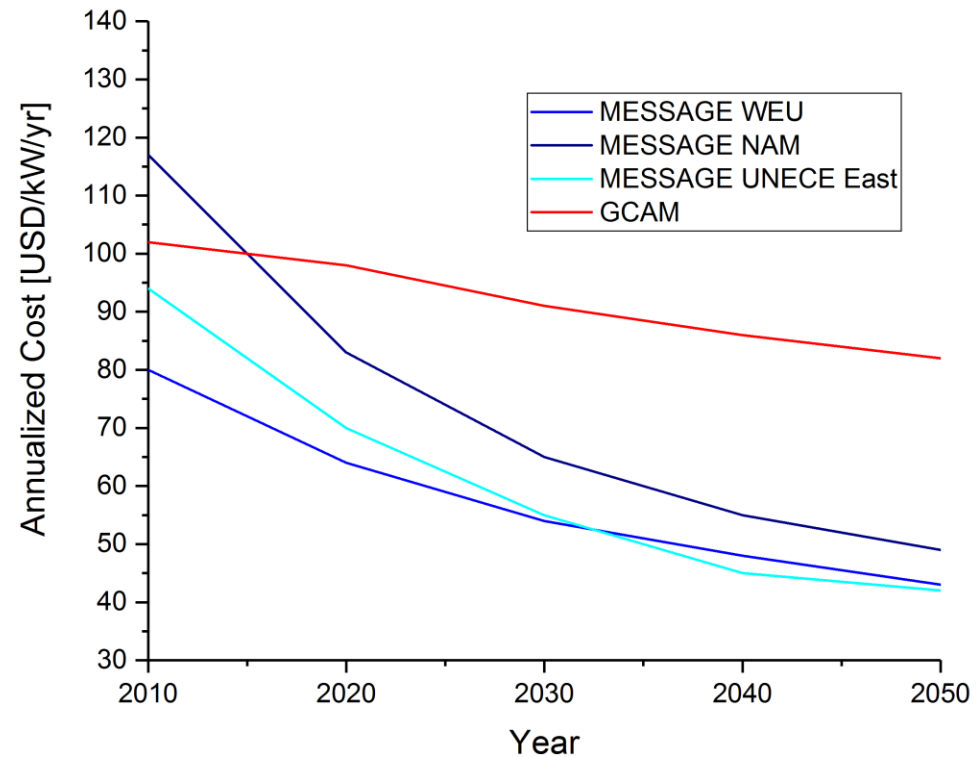
- **Annualized Cost with discount rates**
 - Discount Rates:
 - MESSAGE **5%**
 - GCAM **13%**
- Large difference in discount rates pulls GCAM and MESSAGE further apart



Comparison the regional assumptions from MESSAGE (WEU – Western Europe, NAM – North America, UNECE East – includes Russia and Central Asia) (blue lines) and GCAM (red line)

Results – Example Renewable: Solar PV

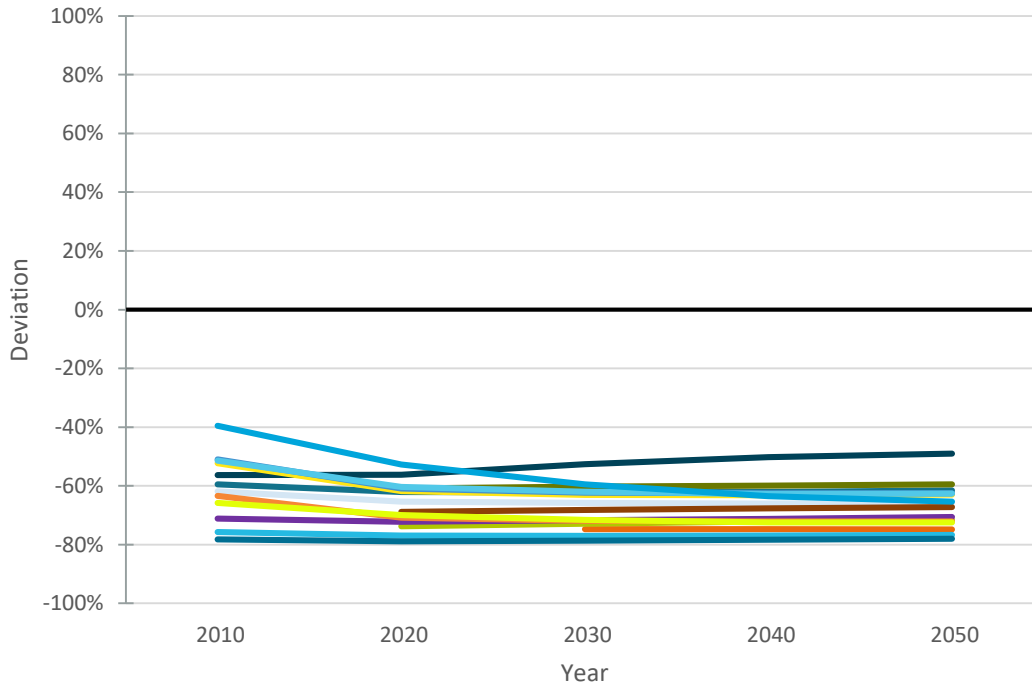
- **Annualized Cost without discount rates**
 - Not including discount rates brings GCAM and MESSAGE closer together
 - Main difference because of high O&M cost in GCAM
 - Lifetime of 30 years in both models



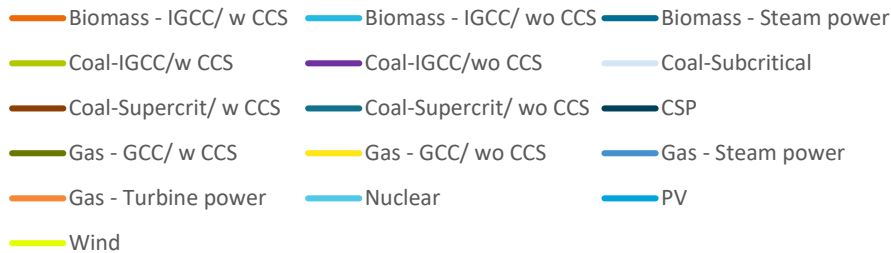
Comparison the regional assumptions from MESSAGE (WEU – Western Europe, NAM – North America, UNECE East – includes Russia and Central Asia) (blue lines) and GCAM (red line)

Results-Comparing Annualized Costs directly

MESSAGE/GCAM Deviation Annualized Cost (incl. discount rates)

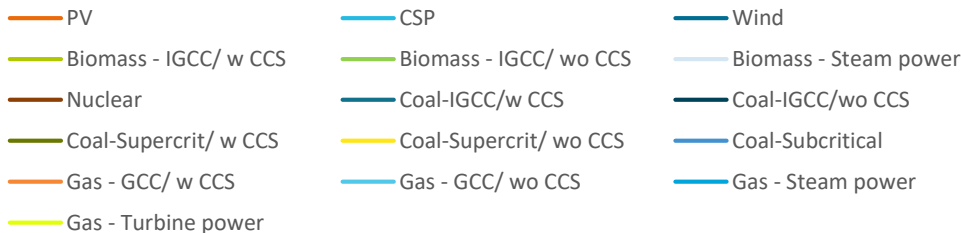
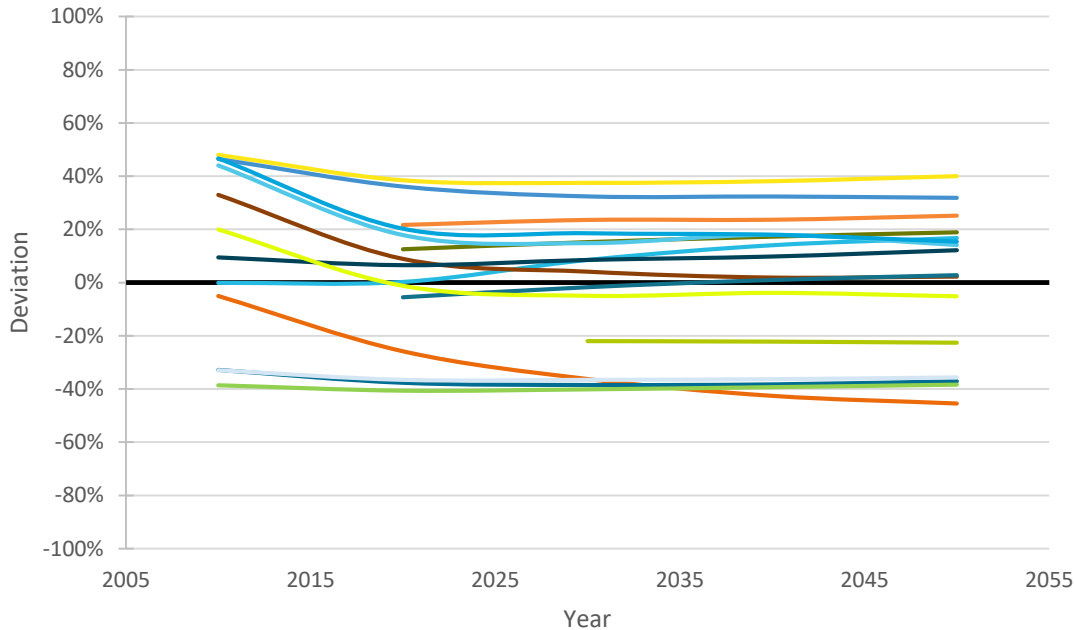


- + deviation → MESSAGE X% higher than GCAM
- - deviation → MESSAGE X% lower than GCAM
- Comparison not very meaningful due to the different approaches behind the discount rate
- GCAM's high discount rate makes all MESSAGE technologies 40%-80% cheaper



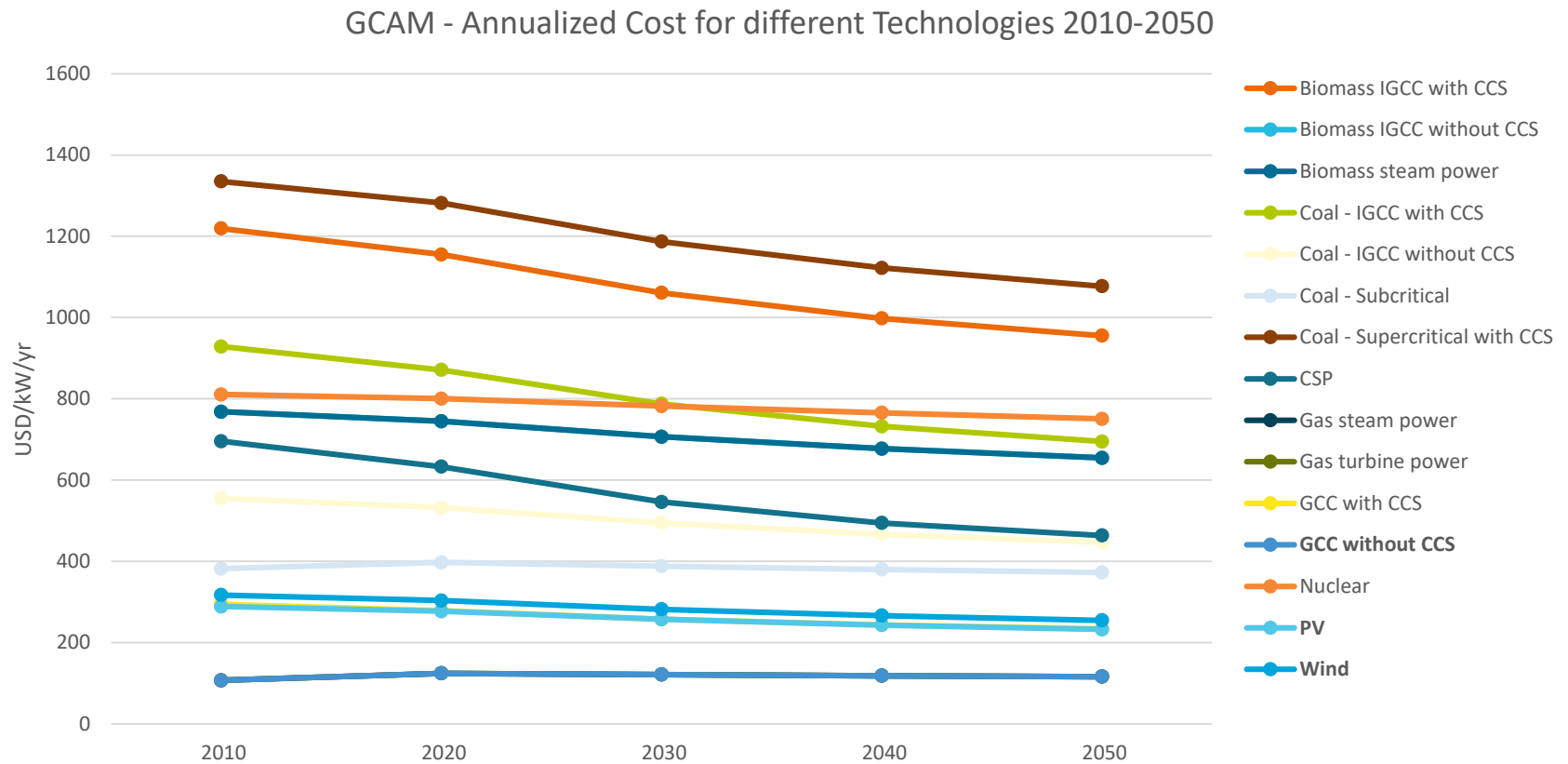
Results-Comparing Annualized Costs w/o discount rate

MESSAGE/GCAM Deviation Annualized Cost (w/o discount rates)

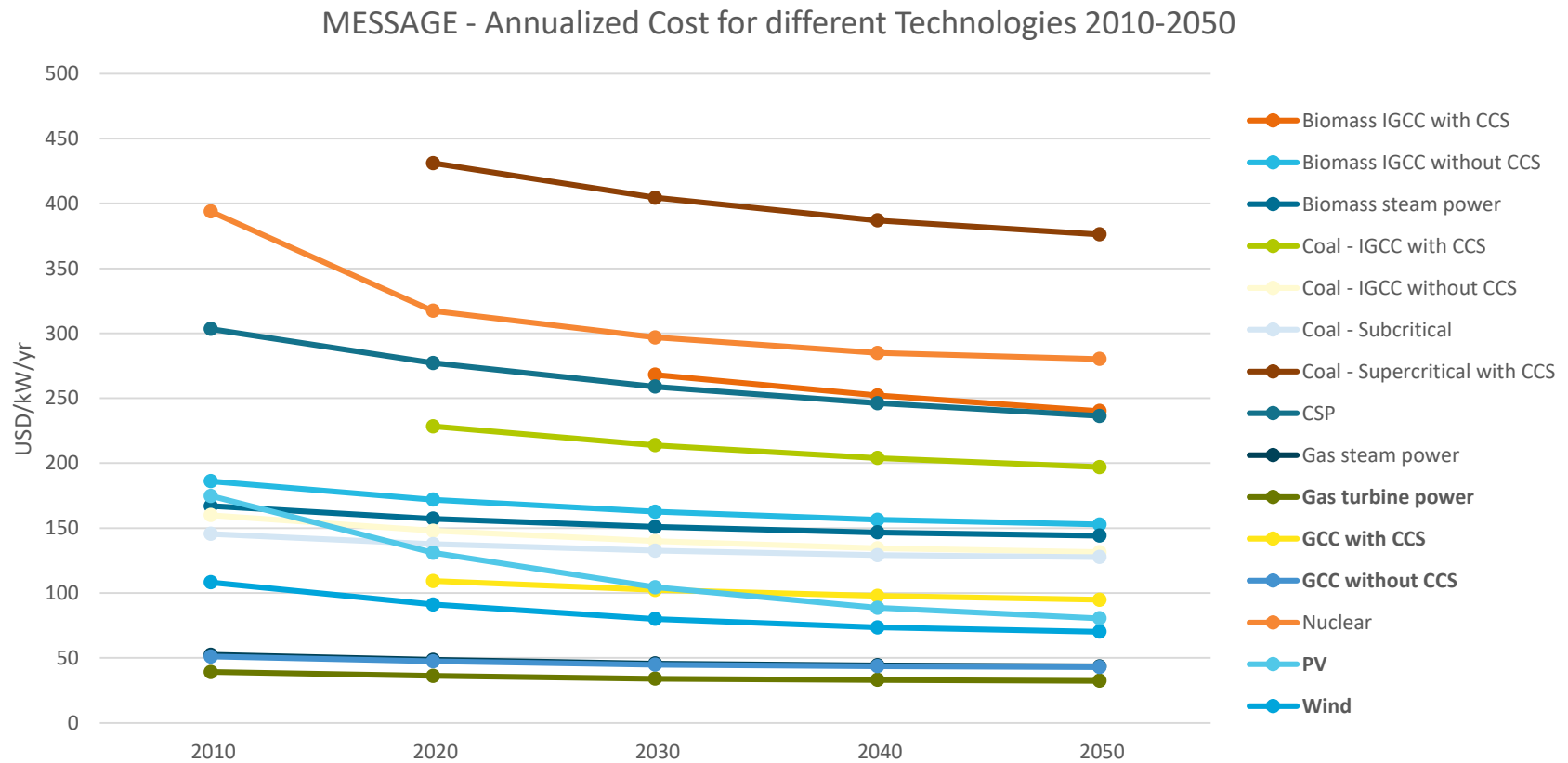


- *+ deviation* → MESSAGE X% higher than GCAM
- *- deviation* → MESSAGE X% lower than GCAM
- Simplified method that does not include discount rates. However, it provides a better overview
- Technologies are all within $\sim \pm 40\%$ of each other
- Cost differences not as large and not as unidirectional as previous chart suggested

Results: GCAM Annualized Costs (with discount rate)



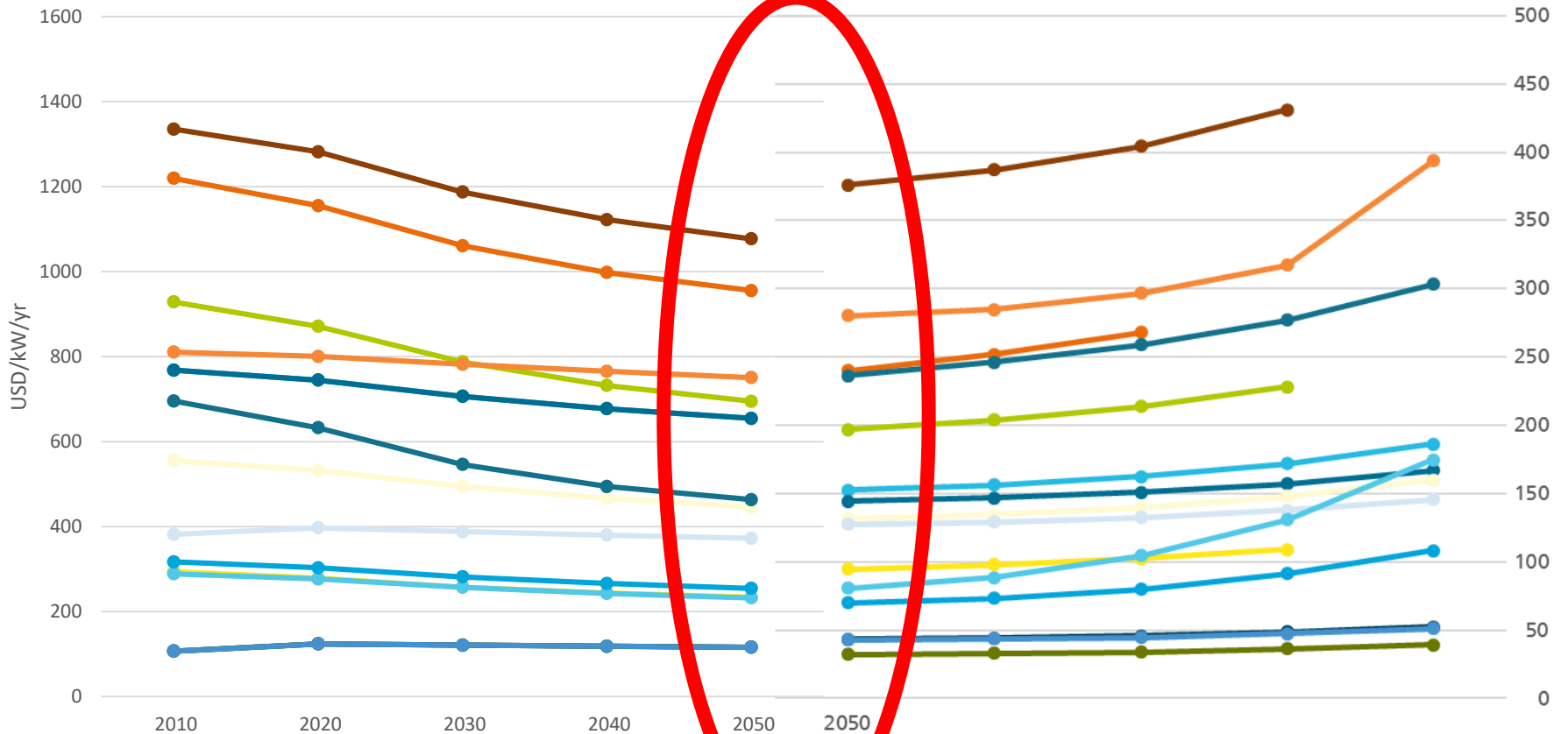
Results: MESSAGE Annualized Costs (with discount rate)



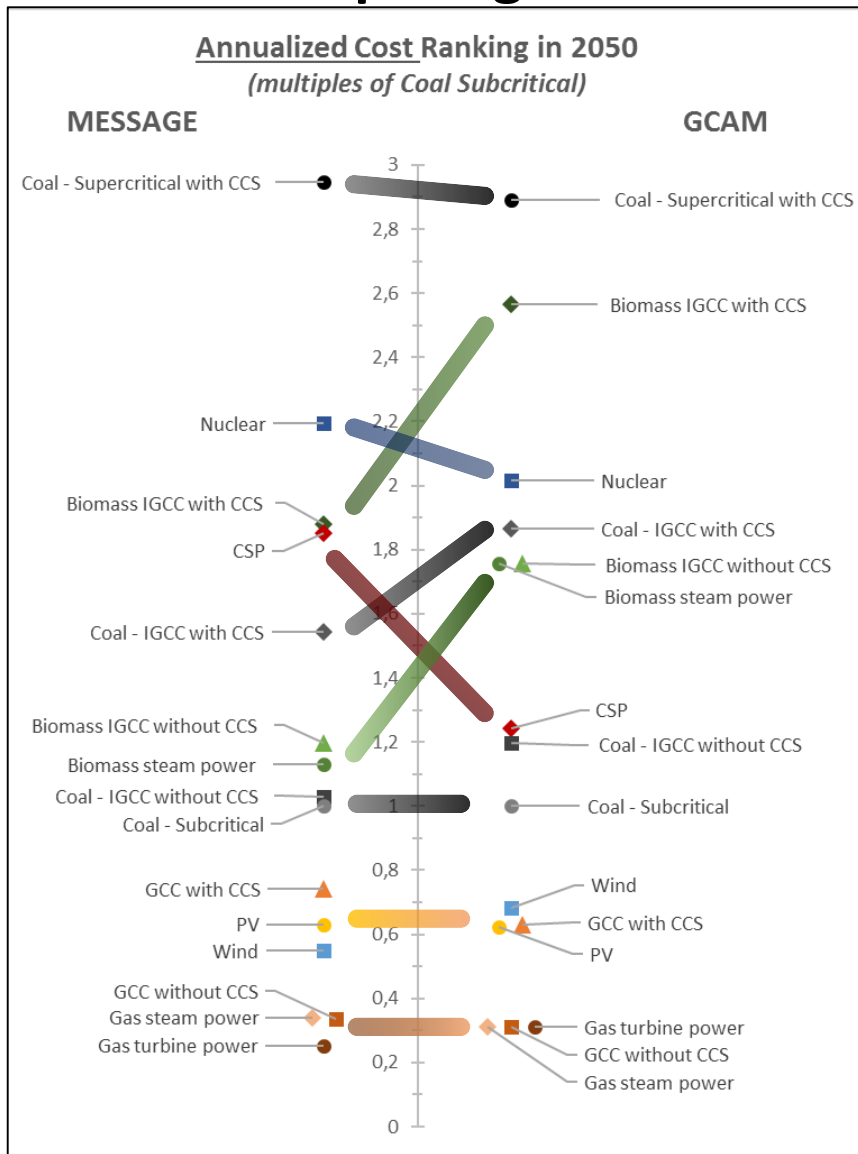
Results: Comparing the Annualized Costs

GCAM - Annualized Cost for different Technologies 2010-2050

MESSAGE - Annualized Cost for different Technologies 2010-2050



Results: Comparing the Annualized Costs



- Annualized costs are shown as multiples of coal subcritical
- Standard technology with very limited expected development
- Most technologies compare well between the models (PV, Wind, Coal and Gas technologies)
- Some variation in Biomass, CSP and Nuclear

Results - Summary

- For some technologies widely spread literature data was found. Uncertainty in the future development of a specific technology leads to higher variations in the projected costs.
- MESSAGE and GCAM do vary in their assumptions but are generally not outside the ranges found in literature. Different approaches to the discount rates make direct comparisons difficult but their internal cost structures are similar.
- Lowest annualized technology costs:
 - **GCAM:** Wind, PV, GCC without CCS
 - **MESSAGE:** Gas turbine power, GCC without CCS, Wind, PV (by 2050), GCC with CCS
- Highest annualized technology costs:
 - **GCAM:** Coal supercritical with CCS, Biomass IGCC with CCS
 - **MESSAGE:** Coal supercritical with CCS, Nuclear, Biomass IGCC with CCS

Q & A