Title: Analyzing the economic impacts of low-energy demand pathways based on CGE analysis[1]

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Abstract:

The importance of demand-side responses is gaining recognition as a complementary strategy to supply-side actions in meeting climate mitigation goals. Despite their potential, studies and modeling of demand-side impacts are still relatively underdeveloped. The IPCC Sixth Assessment Report highlights the critical role of demand management, demonstrating its substantial mitigation potential across different sectors. However, comprehensive quantitative studies on demand-side scenarios are sparse, and modeling efforts that incorporate these scenarios often focus primarily on the power sector. This research aims to explore trends in low-energy demand (LED) scenario discussions and to develop a global Computable General Equilibrium (CGE) model to analyze these scenarios. The study utilizes a recursive dynamic CGE model to assess the economic impacts of LED scenarios. The research applies a climate module and a damage function for estimating the additional expenditure for cooling and heating energy consumption based on the FUND model, which is an Integrated Assessment Model. The research identifies the key components constructing the low energy demand scenarios as Energy Efficiency Improvement, Energy Consumption Changes due to climate change, Lifestyle Change, Net Zero carbon pricing, and the Impact of COVID-19. The different rates of energy efficiency improvements and reductions in household's energy-related consumption are applied to Global South and Global North regions. Also, NGFS Phase 4 Net Zero 2050 Carbon Pricing is considered to assess the impacts of carbon pricing, and the updated SSP2 Scenario from EU NAVIGATE Project, which considered the economic impacts of COVID-19, is used for calibration.

Keywords: Global CGE Model, Energy Demand, Scenario Analysis

As the results of the Global Stocktake (GST) come in, it is anticipated that discussions around national and regional goals for mitigating climate change will grow more urgent in order to meet worldwide temperature targets. By 2025, countries must finalize their Nationally Determined Contributions (NDCs) for 2035, and the pressure to cut emissions will likely rise. Given this scenario, there is an imperative to explore demand-side strategies to alleviate the reliance on expensive low-carbon technologies that are necessary for swift and extensive decarbonization. While there is significant interest in transforming energy systems and developing novel, low-carbon technologies like Direct Air Capture (DAC), Carbon Capture, Utilization, and Storage (CCUS), and hydrogen solutions, many of these options are technically limited, still uncertain, or not cost-effective in several instances. With the pressing need for rapid and profound decarbonization to mirror the implications of the GST, relying solely on supply-side solutions becomes challenging and often too expensive. Consequently, demand-side

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measures are increasingly seen as crucial.

Research focusing on low-energy-demand scenarios is becoming crucial for achieving Nationally Determined Contributions (NDCs) and Net Zero targets. Changes on the demand side of energy, such as increased electrification, resource efficiency, and behavioral shifts, have significant potential to impact various key sectors including buildings, industry, and transport. These changes can expedite mitigation efforts by reducing the pressure on supply-side measures. The importance of demand-side responses is gaining recognition as a complementary strategy to supply-side actions in meeting climate mitigation goals. Despite their potential, studies and modeling of demand-side impacts are still relatively underdeveloped. The IPCC Sixth Assessment Report highlights the critical role of demand management, demonstrating its substantial mitigation potential across different sectors (Creutzig et al, 2022, pp.505-571). The IMP-LD pathway, noted for its emphasis on demand-side strategies, advocates for reducing resource use through efficient practices and consumption shifts, while ensuring high service levels and meeting basic needs (Riahi et al, 2022, pp.309-340).

However, comprehensive quantitative studies on demand-side scenarios are sparse, and modeling efforts that incorporate these scenarios often focus primarily on the power sector. This includes modifications to electricity demand forecasts, peak load adjustments, or the application of sensitivity analyses. More extensive research that includes demand-side changes in a broader range of sectors using both top-down and bottom-up models is needed to fully understand and harness the potential of these strategies.

This research aims to explore trends in low-energy demand (LED) scenario discussions and to develop a global Computable General Equilibrium (CGE) model to analyze these scenarios. The study utilizes a recursive dynamic CGE model to assess the economic impacts of LED scenarios. The global CGE model is built around a system of equations that produce a set of equilibrium conditions for factor and commodity markets (Jung, Kim, and Moon, 2021; Kim et al, 2023, pp.16-22). The model employs the latest GTAP 11 Power Database, released in December 2023, which includes comprehensive data on 12 distinct power technologies, along with transmission and distribution technologies (Aguiar, Angel et al, 2023, pp.7-13). The research integrates 160 country/region into 17 aggregated regions as shown in [Table 1].

Table 1. Regional Classification

Label	Description
KOR	Republic of Korea
JPN	Japan
EAS	China, Hong Kong, Macau, North Korea, Mongolia
USA	United States of America
CAN	Canada
WEU	Western Europe
ANZ	Australia and New Zealand
CEE	Central and Eastern Europe
FSU	Former Soviet Union
MDE	Middle East
CAM	Central America
SAM	South America
SAS	South Asia
SEA	Southeast Asia

NAF	North Africa
SSA	Sub-Saharan Africa
SIS	Small Island States

In this study, the analysis consolidates 76 sectors into 21 composite sectors. The sectors for coal, oil, gas, and petroleum and coal products remain distinct due to their specific impacts and characteristics. Within the electricity sector, the study categorizes 12 power technologies into three main groups: renewable, nuclear, and non-renewable electricity. Here, renewable electricity encompasses solar, wind, and hydro technologies. Nuclear power is classified on its own due to its unique properties and role in energy strategies. All other power technologies are grouped under non-renewable electricity, which typically includes sources that are less favorable for environmental sustainability.

Sector	Description
Ely	(non-renewable) Electricity
COA	Coal
OIL	Oil
GAS	Gas
P_C	Petroleum and coal products
AGR	Agriculture
REN	Renewable electricity
NUC	Nuclear electricity
Mineral	Extraction
Food	Food (meat, vegetables, dairy products, food products, beverages)
Cloth	Textiles, apparel, leather
Paper	Wood products, Paper products
Chemical	Chemical products, basic pharmaceuticals, rubber and plastics, mineral products
Metal	Iron and steel, non-ferrous metals, manufacture of fabricated metal products
ICT	Manufacture of computer, electronic, optical products, and electric equipment
Vehicle	Manufacture of motor vehicles, trailers, semi-trailers, and other transport equipment
Machine	Manufacture of machinery and equipment, and other manufacturing
Construct	Construction
Service	Service
Trans	Transport (land, water, air transport)
Dwell	Dwellings (ownership of dwellings)

The global CGE model utilized in this study forms a complex system of equations to establish equilibrium conditions for macroeconomic aggregates as well as for factor and commodity markets. It incorporates a dynamic capital structure that distinguishes between "old" and "new" capital, applying different elasticities of substitution. The model considers Constant Elasticity of Substitution (CES) production functions.

Source: The author.

Parameter	Value
Substitution between Output and non-CO2 emissions	0.02~0.1 depending on sectors
Substitution between unskilled labor and KTRE Bundle	GTAP (esubva): (for new) 0.2 for coal, oil, and mineral; 1.26 for ely, p_c, ren, and nuc; 0.48 for gas; 0.254 for agr; 1.363 for service; 1.4 for construct; 1.68 for trans; 1.12 for food; 1.26 for cloth, paper, chemical, metal, ICT, vehicle, machine, and dwell
Armington elasticity (domestic vs. import)	GTAP (esubdm): (for new) 0.9~6.35 depending on sectors
Armington elasticity (Import sources)	GTAP (esubm): (for new) 1.8~34 depending on sectors
Substitution among KTR bundle, energy, and skilled labor	0.535 for coal, oil, p_c; 0.396 for gas, ely, ren, nuc; 0.029 for agr; 0.35 for mineral; 0.391 for food; 0.17 for cloth; 0.372 for paper; 0.038 fo chemical; 0.29 for metal; 0.246 for ICT; 0.091 for vehicle; 0.118 for machine; 0.105 for construction; 0.404 for service; 0.449 for trans; 0.654 for dwell
Substitution among capital, land, and natural resources	0.2 for new vintage; 0.06 for old vintage
Substitution between electricity and other energy inputs	2 for new vintage; 0.6 for old vintage 0 for fossil fuel
Substitution between coal and liquid	0.55 for new vintage; 0.06 for old vintage 0 for fossil fuel
Substitution between oil and gas	1 for new vintage; 0.125 for old vintage 0 for fossil fuel
Note: For old vintage, the elasticities of new vintage are multiplied by 0.3	

The model categorizes electricity generation technologies into three groups: non-renewable electricity, renewable electricity, and nuclear electricity. It specifically applies a 15% learning rate to the productivity improvements of renewable energy technologies, capturing the cost reductions and efficiency gains as deployment scales up.

To analyze the impact of changes in energy consumption resulting from global and regional temperature variations, the research integrates a climate module from the FUND model, which is an integrated assessment model. This integration follows the regional classifications provided by the FUND model but makes an exception for Korea, treating it as a distinct region. The parameters used for the climate module, including those that apply to Korea and Japan, are assumed to be the same within this context.

The climate module of the FUND model is essential for calculating the concentrations of carbon dioxide in the atmosphere. C refers to concentrations in ppm, E represents global carbon emissions, t stands for time, and pre indicates pre-industrial levels. Initially, the FUND model used a baseline concentration of 310.75 ppm; however, this figure has been updated to 405.22 ppm as of 2017, reflecting more recent findings by Lan, Tans, and Thoning (2024).

$$c_t = c_{t-1} + E_{t-1} - \beta(c_{t-1} - c_{pre})$$

The module then applies the 5-box model to compute carbon dioxide concentrations, taking into account the different decay rates of carbon dioxide boxes. Each box has a decay rate, symbolized as ρ, which influences how quickly CO2 levels decrease in that box. The total concentration of carbon dioxide in the atmosphere is determined by the sum of the concentrations from all five boxes.

$$BOX_{i,t} = \rho_i BOX_{i,t-1} + 0.000471 a_i E_t$$

$$C_t = \sum_{i=5}^{5} a_i BOX_{i,t}$$

After determining the concentrations of carbon dioxide, the climate module assesses radiative forcing, which accounts for the impact of various greenhouse gases on the earth’s energy balance. These gases include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and sulfur hexafluoride (SF6). The emissions data for these gases are provided by the global CGE model. The equation used to calculate radiative forcing is as follows:

$$\begin{aligned}
RF_t = {} & 5.35\ln\left(\frac{CO2_t}{274}\right) + 0.036 \times 1.4\left(\sqrt{CH4_t} - \sqrt{790}\right) + 0.12\left(\sqrt{N2O_t} - \sqrt{285}\right) \\
& - 0.47\ln\left(1 + 2.01 \times 10^{-5} CH4_t^{0.75} 285^{0.75} + 5.31 \times 10^{-15} CH4_t^{2.52} 285^{1.52}\right) \\
& - 0.47\ln\left(1 + 2.10 \times 10^{-5} N2O_t^{0.75} 790^{0.75} + 5.31 \times 10^{-15} N2O_t^{1.52} 790^{2.52}\right) \\
& + 2 \times 0.47\ln\left(1 + 2.01 \times 10^{-5} 790^{0.75} 285^{0.75} + 5.31 \times 10^{-15} 790^{2.52} 285^{1.52}\right) \\
& + 0.00052\left(SF6_t - 0.04\right) + rfSO2_t
\end{aligned}$$

Based on radiative forcing information, the climate module is used to estimate global mean temperature changes.

$$T_t = \left(1 - \frac{1}{\varphi}\right) T_{t-1} + \frac{1}{\varphi} \frac{CS}{5.35\ln 2} RF_t$$

$$\varphi = \max\left(\alpha + \beta^l CS + \beta^q CS^2, 1\right)$$

$$RT_t = REG \times T_t$$

Information on greenhouse gas emissions—including carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulfur hexafluoride (SF6), nitrogen trifluoride (NF3), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs)—is derived from the global CGE model and subsequently integrated into the climate module. This module calculates radiative forcing and the resulting global mean temperature change. Additionally, it applies regional multipliers to determine temperature changes specific to various regions. This helps to evaluate the effectiveness of policy interventions like carbon pricing in curbing global temperature rises.

This study incorporates a damage function to estimate the additional energy consumption required for heating and cooling as a result of climate change. The damage function, sourced from the FUND model, is integrated into the global CGE model, enabling the analysis of how temperature variations influence energy demand.

X denotes additional expenditure on space heating and cooling, a is the parameter for the impact of climate change on heating and cooling expenditure, ϵ_h is the parameter for the impact of economic growth on demand for heating, ϵ_c is the parameter for the impact of economic growth on demand for cooling, $cumAEEI_{t,r}^{1990}$ is the cumulative value of AEEI since 1990, γ is parameter for the impact of the global temperature changes on cooling expenditures.

$$X_{t,r}^{heating} = a_r^{heating} Y_{1990,r} \left(\frac{\mathrm{atan}(Temp_{t,r} - Temp_{1990,r})}{\mathrm{atan}\,1.0}\right)\left(\frac{y_{t,r}}{y_{1990,r}}\right)^{\epsilon_h}\left(\frac{pop_{t,r}}{pop_{1990,r}}\right)/cumAEEI_{t,r}^{1990}$$

$$X_{t,r}^{cooling} = a_r^{cooling} Y_{1990,r} \left(\frac{Temp_{t,r} - Temp_{1990,r}}{1.0}\right)^{\gamma}\left(\frac{y_{t,r}}{y_{1990,r}}\right)^{\epsilon_c}\left(\frac{pop_{t,r}}{pop_{1990,r}}\right)/cumAEEI_{t,r}^{1990}$$

This study utilizes the initial Autonomous Energy Efficiency Improvement (AEEI) and cumulative AEEI (cumAEEI) values from the FUND model to assess changes in the impacts on heating and cooling up to the year 2017. Post-2017, the study applies its assumed rate of energy efficiency improvements to update the cumAEEI calculations. This method helps in tracking and evaluating the efficiency gains in energy use for heating and cooling over time.

The structure of the global CGE model is such that it calculates global mean temperature changes using the climate module, which then helps determine the additional energy expenditure for cooling and heating due to these temperature changes. This additional energy consumption is factored back into the global CGE model, influencing production levels and market equilibrium. Consequently, this feeds into the overall calculations of global greenhouse gas emissions and further temperature changes, creating a feedback loop that highlights the interdependencies between climate change, energy use, and economic activity. This cyclical process is crucial for understanding the broader economic impacts of temperature changes and the potential benefits of policy measures such as improved energy efficiency or carbon pricing.

To integrate changes in energy consumption for cooling and heating, the research initially calculates the total quantity of energy-related bundles (TQENL). This calculation includes the aggregation of QENL, which represents the combined energy bundle used across various sectors, and electricity and other energy input consumption by households.

$$TQENL_r = \sum_{i,v} QENL_{r,i,v} + \sum_{i \in ely} QC_{r,i} + \sum_{i \in e} QC_{r,i}$$

The study assesses the additional spending on cooling and heating in relation to the total amount of energy-related bundles (TQENL). To account for these impacts, the study modifies the share parameter of the KTRE bundle, which comprises the combined bundle of energy, capital, and skilled labor. The share parameter for the energy bundle within the KTRE bundle is accordingly adjusted. To ensure that the sum of all share parameters remains equal to one, these modifications are offset by the share attributed to the skilled-labor bundle within the

KTRE bundle. Essentially, the increase in expenditures for cooling and heating comes at the expense of the allocation for skilled labor.

$$A\_KTRE_{ENL,r,i,v} = A\_KTRE0_{ENL,r,i,v}(1-(\frac{X_{t,r}^{heating} - X_{2017,r}^{heating} + X_{t,r}^{cooling} - X_{2017,r}^{cooling}}{TQENL_r}))$$

$$A\_KTRE_{LB,r,i,v} = A\_KTRE_{LB,r,i,v} + (A\_KTRE0_{ENL,r,i,v} - A\_KTRE_{ENL,r,i,v})$$

Based on our review of relevant literature, it is evident that scenarios involving low-energy demand necessitate modifications in individual consumption behaviors. These behavioral changes include curtailing excessive consumption, modifying habits related to energy use, and adopting lifestyles that are less energy-intensive. However, there is minimal evidence supporting the effectiveness of these behavioral changes in significantly reducing energy consumption at the aggregated level. Most of the demand analysis has been performed at individual or community levels, or with only a few actions considered simultaneously. Given the complexity of integrating such wide-ranging behavioral adjustments into a global CGE model, this study treats these changes as exogenous shocks. This approach simplifies the incorporation of behavioral dynamics into the model, acknowledging the difficulty of directly modeling these changes due to their diverse and dispersed nature.

There is no straightforward method to incorporate the demand changes discussed in low-energy demand (LED) scenarios into models, and such changes are typically represented by adjusting the elasticities in Constant Elasticity of Substitution (CES) functions. However, reflecting altered consumer preferences as outlined in LED scenarios proves challenging. To address this over time, our study opts to gradually modify the share parameter, drawing on approaches from Chepeliev et al. (2022, pp.6-11) and van der Mensbrugghe (2024, pp.66-69). These studies implement a "phantom tax" as a mechanism to achieve targeted reductions in demand by simulating the effect of a tax that alters consumer and producer behavior without actually imposing a fiscal levy. Furthermore, they incorporate a strategy known as ‘redesign’, which involves reducing the intermediate use of materials while increasing other types of consumption, fitting the principles of a circular economy. For our purposes, we adapt the method these studies used to adjust the share parameter, applying it to household consumption to mimic the 'redesign' concept in the circular economy framework outlined by Chepeliev et al. (2022, pp.10). This approach allows us to shift consumption patterns without the need for a phantom tax, thereby avoiding the complexities associated with setting specific targets or pathways for energy demand changes.

Given the limitations placed on household energy consumption, the share parameter for energy—which includes the electricity and energy bundle—decreases annually at a predetermined rate (1.25% per year for the Global South and 1.5% per year for the Global North). This rate of reduction, denoted as RatioCRi, represents the consumption constraints in place at time t. As the share parameter for energy sources declines, the adjustments in the shares of all energy types are cumulatively redistributed to the non-energy sectors. This redistribution means that while the proportion of spending on energy commodities will decrease, there will be a corresponding increase in the share of spending on other, non-energy commodities. This reallocation reflects a strategic shift in consumption patterns, aimed at reducing energy use while enhancing expenditure in other sectors of the economy.

	CPZ30	CPZ40	CPZ50
ANZ	45.0	213.0	528.1
SIS	59.1	185.2	346.5
EAS	52.1	112.9	230.1
JPK	80.3	165.7	414.8
KOR	121.7	265.2	651.3
SEA	66.0	207.0	387.2
SAS	83.4	180.7	390.0
CAN	87.8	227.6	510.6
USA	65.9	179.9	430.8
CAM	66.0	207.0	387.2
SAM	103.4	262.6	537.4
WEU	51.1	165.0	406.7
CEE	56.4	181.8	446.7
FSU	65.8	206.3	388.8
MDE	66.0	207.0	387.2
NAF	66.0	207.0	387.2
SSA	58.3	188.4	424.2

Note: The study utilized the NGFS Below 2-degree (GCAM) Carbon Prices by Region and Year.
Source: Richters et al. (2023.11.7), "NGFS Climate Scenario Dataset (4.1)", accessed on November 15, 2023.

Scenario	Description
Business-as-Usual (BAU)	- Baseline scenario without energy expenditure changes
Energy Expenditure (E_EXP)	- BAU scenario with changes in cooling and heating energy demand changes due to temperature changes
Low Energy Demand in Industry (LED_ind)	- In addition to the E_EXP Scenario, energy efficiency improvements in industrial sectors are considered - Energy efficiency improvements in all sectors by 1% per year in Global North and 1.5% per year in Global South
Carbon Pricing (CP)	- E_EXP scenario with GCAM Below 2-degree carbon pricing
Low Energy Demand in Industry with CP (LED_ind_CP)	- Follows CP scenario's emissions pathways - In addition to E_EXP Scenario, energy efficiency improvements in industrial sectors are considered - Energy efficiency improvements in all sectors by 1% per year in Global North and by 1.5% per year in Global South
Low Energy Demand in Industry and Household with CP (LED_all_CP)	- Follows CP scenario's emissions pathways - In addition to the LED_ind_CP Scenario, efficiency improvements to household energy consumption households, reductions in household energy consumption, and reductions in transport sector energy consumption are considered. 1.25% energy and 1.5% energy consumption reductions in Global South and Global North, respectively

Source: The author.

In the Business-as-Usual (BAU) scenario, economic and population growth are aligned with the GDP and population estimates provided by the updated Shared Socioeconomic Pathways 2 (SSP2) from the EU NAVIGATE project. Carbon pricing is set to match the 2020 levels specified in the NGFS scenario by the year 2020 and is projected to maintain a level of 30% above the 2020 carbon price. The Energy Expenditure (E_EXP) scenario builds upon the BAU assumptions but additionally incorporates variations in energy consumption for cooling and heating as a response to rising temperatures. This scenario is designed to reflect how the global economy and greenhouse gas (GHG) emissions projections might adjust by 2050 when changes in energy needs due to temperature increases are considered. Following this, the Low Energy Demand in Industry (LED_ind) scenario introduces an increment in energy efficiency on top of the E_EXP scenario's framework. It presumes an annual increase in energy efficiency of 1% in the Global North and 1.5% in the Global South, consistent with the rates discussed previously. This scenario focuses on enhancing energy efficiency, which is a key component often highlighted in various studies and policy formulations. The aim here is to evaluate the impact of systematic energy efficiency improvements on the industry sector's energy consumption and the broader implications for global GHG emissions.

The next scenario, the Carbon Pricing (CP) scenario, is based on the carbon price projections from the NGFS 2-degree scenario (using the GCAM model) for the years 2030, 2040, and 2050. This scenario examines the economic and environmental outcomes if a net-zero carbon pricing strategy is implemented, alongside adjustments for changes in energy demand due to rising temperatures. Essentially, the CP scenario extends the Energy Expenditure (E_EXP) scenario by incorporating net-zero carbon pricing. The subsequent scenarios focus on increased energy efficiency and reduced energy consumption in households, critical factors for achieving low-energy demand. Low Energy Demand in Industry with Carbon Pricing (LED_ind_CP) Scenario builds on the CP scenario by assuming an annual increase in energy efficiency of 1% in the Global North and 1.5% in the Global South. It reflects the impact of improved energy efficiency in the industrial sector under the condition of net-zero carbon pricing. Low Energy Demand in Industry and Households with Carbon Pricing (LED_all_CP) Scenario incorporates energy efficiency improvements in both industry and households. Specifically, it assumes household energy efficiency improvements and consumption reductions of 1% per year and 1.5% per year, respectively, in the Global North, and 1.5% per year and 1.25% per year, respectively, in the Global South. This scenario is designed to capture the full spectrum of low-energy demand measures discussed in the study, under a net-zero carbon pricing framework. In all scenarios, a 15% learning rate is applied to enhance the adoption of renewable energy technologies, which facilitates faster electrification and aids the transition to a low-carbon economy. The introduction of carbon pricing policies causes a divergence in carbon prices between scenarios with and without the carbon pricing starting from 2022. Additionally, changes such as increased energy efficiency will commence in 2024, aligning with the broader strategic goals of reducing energy consumption and greenhouse gas emissions effectively.

These scenarios provide a framework to explore various outcomes. Initially, this study evaluates the potential global temperature increase under different emission trajectories and considers how changes in energy demand due to rising temperatures could influence this. The study specifically looks at the impacts of energy efficiency improvements in the industrial sector. This includes analyzing the effects of implementing industrial energy efficiency improvements alone, without a carbon price, and investigating the potential for a rebound effect, where the expected gains in energy efficiency may lead to an increase in energy use. Furthermore, the study examines the role of energy efficiency improvements as primary measures for reducing industrial energy demand and assesses the impacts of combining these improvements with reductions in household energy consumption as part of the net-zero transition pathway. The Carbon Pricing (CP) scenario facilitates an analysis of how emissions, economic impacts (by country and sector), and global temperature increases could be moderated under a regime of carbon pricing. Additionally, the study explores the economic effects of low-energy demand strategies in both industry and households under scenarios with carbon pricing. This includes evaluating their potential to alleviate the burden of greenhouse gas (GHG) mitigation. Overall, these scenarios allow for a comprehensive analysis of how energy demand management and carbon pricing could collectively contribute to limiting global warming in a cost-effective manner.

Results:

To be updated

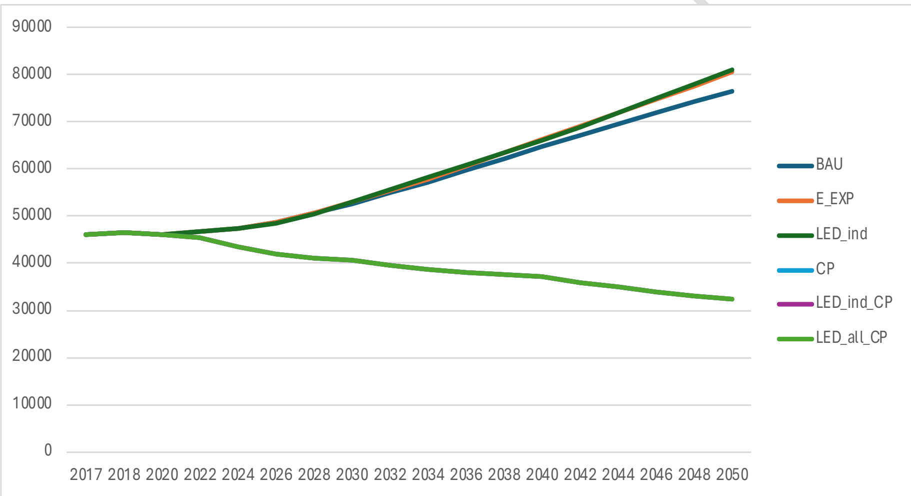

Figure 1. Global Greenhouse Gas Emissions (unit: MtCO2eq)

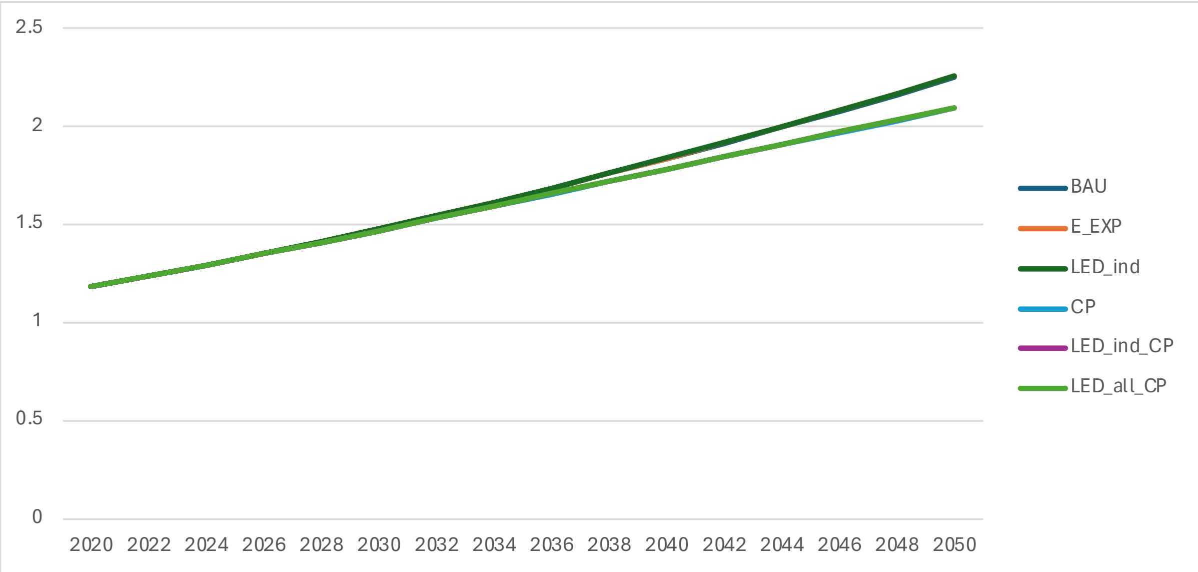

Figure 2. Global Temperature Change above Pre-industrial Levels (Unit: Degree Celsius pre-industrial levesl)

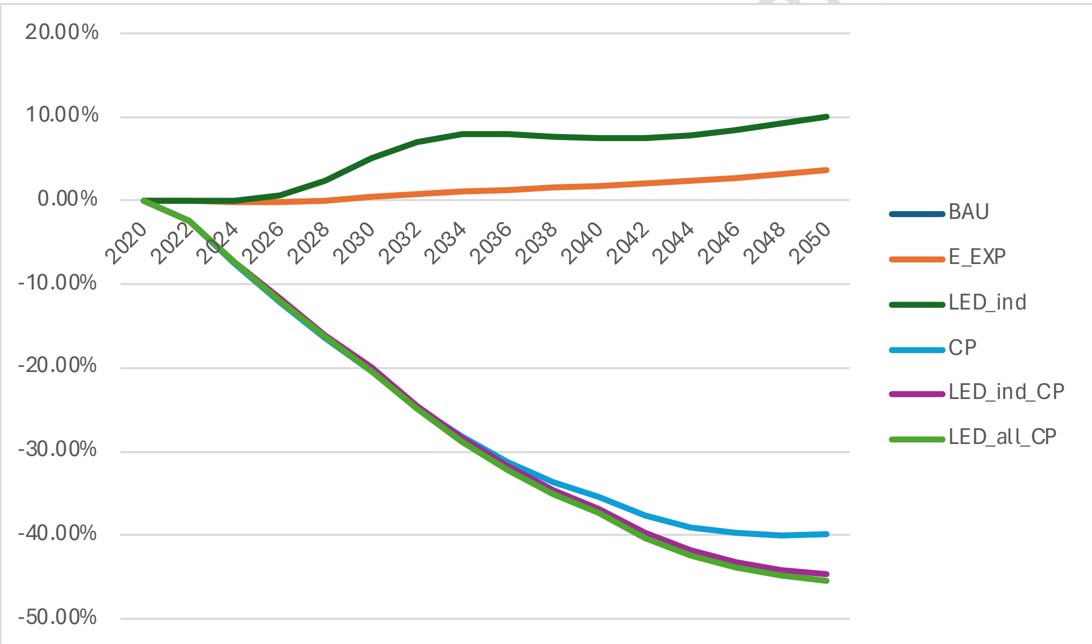

Figure 3. Changes in Global Final Energy Demand by Scenario (relative to BAU) (unit: %)

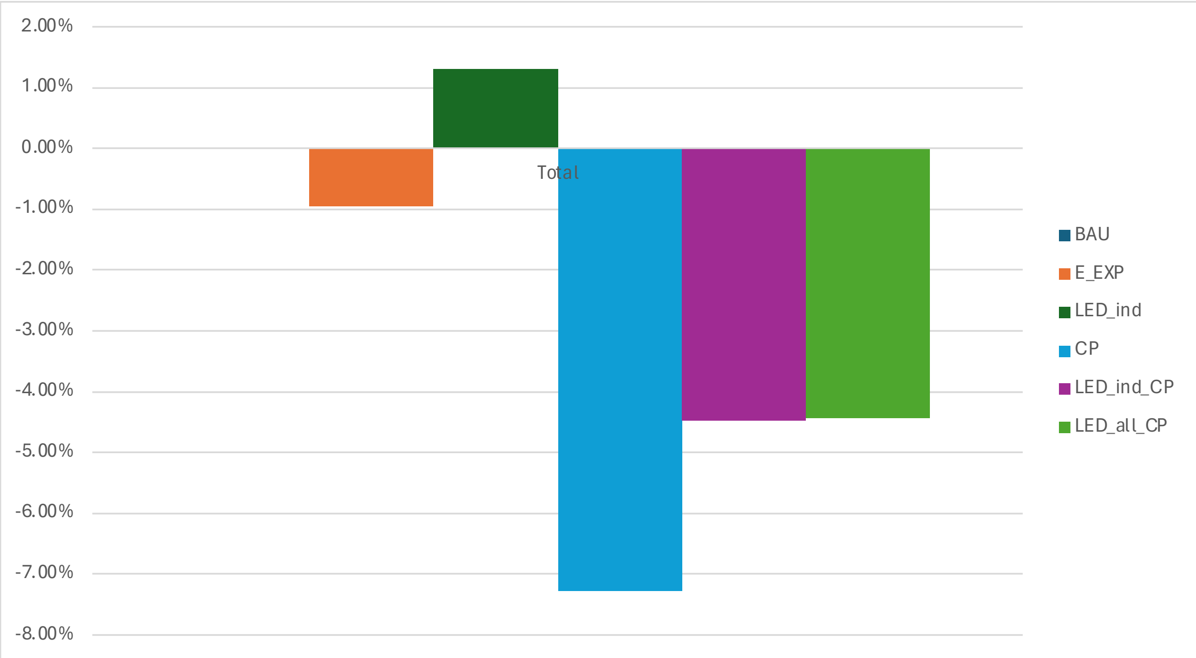

Figure 4. Changes in Global Real GDP (2022-2050) (Relative to BAU) (unit: %)

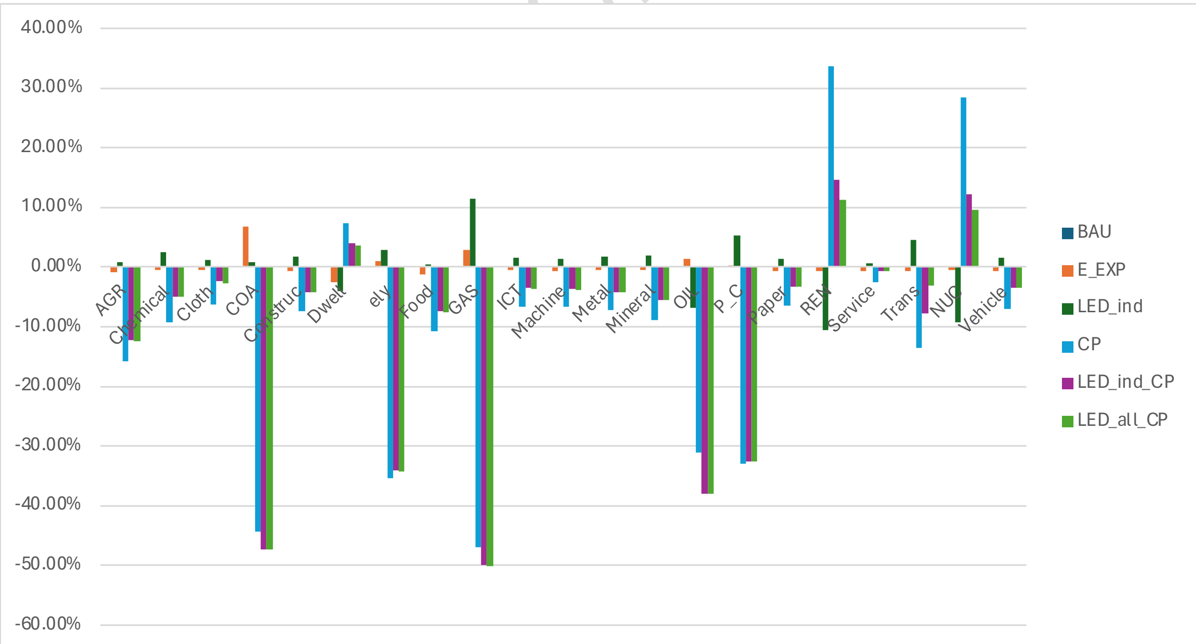

Figure 5. Changes in Global Production by Sector (2021-2050) (Relative to BAU) (unit: %)

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