# The Earth Bill:
# A Lever for the U.S. to meet its Paris Climate Commitments

**An Analysis Report of *Regenerative Intelligence, Public Benefit LLC***

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## Executive Summary

The United States of America has set high standards to cut its greenhouse gas emissions in half by 2030 below 2005 levels by its updated Paris Agreement commitment. To help meet this goal, President Biden signed into law the Inflation Reduction Act (IRA), one of the most ambitious and potentially impactful climate policies in US history so far. However, the U.S. needs more ambitious actions like the Earth Bill to achieve the Paris target (50-52% total U.S. emissions reductions by 2030 compared to 2005) and any Zero emission targets by 2050. The Earth Bill aims to achieve 100% renewable electricity in utilities, zero-emission vehicles from manufacturers, and regenerative agriculture by industrial plant and animal corporations in order to stop U.S. greenhouse gas pollution and thereby avert 1.5 degree warming in line with the Paris Accord. In this study, we present the climate mitigation potential of the Earth Bill by 2030 and 2050. We used a systematic approach to analyze the climate mitigation impacts of the Earth Bill on the U.S. three economic sectors; Electric Power, Transportation, and the Agriculture sector.

We first identified the Business as Usual developments and associated emissions referred as the “Reference” emissions in the present study. We then modeled the Earth Bill scenario-based developments and associated emissions in each sector and finally analyzed the combined Earth Bill scenario’s emission reduction.

The projected climate mitigation impacts show that the implementation of the Earth Bill can reduce or sequester up to 74% of the U.S. greenhouse gas emissions by 2050 in comparison with the 2005 values. This includes reduction of virtually all grid emissions from 2030 onwards, and reduction of hundreds of millions of tons of $CO_2$-eq each from transportation and agriculture yearly, especially after 2030 after vehicles are replaced.

Though our analysis suggests that the Earth Bill is unable to push the US to achieve zero emissions by 2050 in isolation, it sets the course to achieve the Paris targets, and lays the foundation for more ambitious future action that may achieve zero emissions.

Key Insights from the Earth Bill Climate Analysis:

1. The proposed interventions of the Earth Bill can cause the U.S. to achieve a reduction of greenhouse gas emissions by an additional 41% by 2030, and 51% by 2050 compared to 2005 levels.
    a. These reductions include roughly 15% and 11% from nature-based sequestration in 2030 and 2050 respectively. This represents 100% adoption of regenerative agriculture in cropland and grassland in the US (1.19 billion acres).
2. The U.S. emissions have been trending down since 2005, but not fast enough to meet climate targets or avoid catastrophic warming.
    a. The 2021 emissions were already 17% lower than 2005.

   b. The reference projection indicates a further reduction of 4% by 2030 and 6% by 2050.
   c. Published estimates of the impact of other climate policies, like the IRA clean energy incentives, indicate that they can help the U.S. achieve an additional 9% reduction by 2030, much of which overlaps with, and is made more certain by, pollution-source mandates in the Earth Bill.
3. In summary, in addition to the current policies, the emissions reduction due to The Earth Bill (compared to 2005) are:
   a. 41% + 17% + 4% = 62% by 2030
   b. 51% + 17% + 6% = 74% by 2050
4. Specifically, the bill would reduce the U.S. GHG emissions from 5,983 MMT CO2-eq (2022) to 2,494 MMT CO2-eq (2030) and to 1,735 MMT CO2-eq (2050).

## Background

The Earth Bill Network, an open association of activists, organizations and coalitions, has drafted a proposal for a radical shift in U.S. Domestic policy to respond to the climate crisis. This draft being proposed for laying in the U.S. Congress aims "***To ensure by 2030 the transition to 100% renewable electricity in utilities, zero-emission vehicles from manufacturers, and regenerative agriculture by publicly-traded land and livestock corporations in order to stop U.S. greenhouse gas pollution and thereby avert 1.5 degree warming in line with the Paris Accord***".

The Earth Bill Network has asked Regenerative Intelligence PBLLC (RegenIntel) to assess the climate impacts of their proposals on the US domestic greenhouse gas emissions and on its ability to meet its climate targets.

## Scope of Work

To model the climatic impact of the proposed Earth Bill interventions (listed below) by 2050 under the given Earth Bill Scenario.[1]

*Set in place policy to mandate that, by 2030, and following a defined schedule, there will be:*
1. *100% Renewable electricity provided by all utilities*
2. *100% Zero-emission vehicles sold by all vehicle manufacturers*
3. *100% Regenerative agriculture by publicly-traded land and livestock corporations*

[1] *This study is based on Earth Bill Scenario which is a highly ambitious one. It is assumed that all the required policies will be in place for the implementation of the solutions described in this study.*

## Analytical Framework

To analyze the impact of the proposed initiatives we took a scenario-based approach. We created 1) the Reference scenario ("REF") to project the development that would have happened without the Earth Bill and 2) the Earth Bill Scenario to project the development that would occur under the Earth Bill. Scenarios are not predictions of the future, but projections of what may happen if certain conditions are true. The Reference scenario assumes that the slow rate of clean energy and climate-adaptive changes that are being observed across the U.S. will continue. This is what the International Energy Agency (IEA) for example considers on the Stated Policies scenario - or the current *real* trajectory as a result of actual policy action, not just a *political* goal without supporting implemented *policy*. Sectors that are not directly affected by the Earth Bill proposals (industry, aviation, buildings etc.) continue to operate under these assumptions in both the REF and the Earth Bill scenarios. The reference emissions values were taken from two sources. The historical data (2005-2020) was taken from the U.S. Environmental Protection Agency, whereas the future reference emissions values were taken from The Energy Policy Simulator (EPS) developed by Energy Innovation (2022) LLC as part of their Energy Policy Solutions project.

Each of the three sectors directly affected by the Earth Bill is modeled separately and the results of all three are summed to report the total impact. Large systemic interactions between the targeted sectors (such as a reduced electricity grid emissions making transport electrification cleaner) are accounted for in our modeling. Nevertheless, emissions reductions impact sectors that are not referred to in the Earth Bill (e.g. Buildings), and they should indirectly benefit from the proposed changes but are not calculated herein.

## Section I - 100% Renewable Electricity in Utilities

### Earth Bill Proposal

*The minimum annual percentage of the quantity of electricity sold by a retail electric supplier that must be generated from renewable energy resources shall be—*

*(1) in 2027, 80 percent; and*

*(2) in 2030, and every year following, 100 percent.*

**Objective**

1. Identify the current status of electricity generation from renewable energy sources in the U.S.
2. Review and collect international studies with electricity total and renewable energy sources (RES) generation scenarios for the U.S. for 2030 and 2050.
3. Develop an Earth Bill scenario for 100% renewable electricity in utilities.
4. Analyze the climate impact based on the proposed Earth Bill in comparison to a Reference Scenario.

**Methodology**

Renewable energy sources are key in clean energy transitions, and the adoption of renewable power solutions is one of the most powerful enablers for keeping the rise in average global temperatures below 1.5°C. At a global scale, recent progress has been positive: estimates suggest that 2022 is a record year for renewable capacity additions, with annual capacity expected to amount to about 340 GW (IEA, 2022a). In spite of this progress, global energy-related carbon dioxide emissions increased by 6% in 2021 to 36.3 billion tons, and are on course to rise by almost 1% in 2022 compared to the previous year. That's nearly 300 million metric tons of $CO_2$ more than in 2021 (IEA, 2022b).

This corroborates the hypotheses that most of the government's plans and targets around the world will not do more than stabilize global emissions instead of drastically reducing them. Despite an increase in widespread support for renewable energy technologies over the past several years, global energy-related $CO_2$ emissions have increased an average of 1.3% annually between 2014 and 2019 (IRENA, 2022).

1. Total current electricity generation and renewable energy sources

The renewable energy sources share in the power sector has grown from 10% in 2010 (0.07% solar PV and 2.8% wind) to around 20% in 2020 of a total of 4,243 TWh of electricity generated (IEA, 2021).

In 2021, around 61% of U.S. utility-scale electricity generation was produced from fossil fuels (coal, natural gas, and oil), 19% was from nuclear energy, and only about 20% was from renewable energy sources, with a nationwide net generation of 4,165 TWh of electricity from both utility and small-scale technologies (EIA, 2022a). Furthermore, the U.S. imports 1.2% (2021) of electricity from Canada and Mexico and exports 0.3% (2021).

2. Projections of electricity generation and renewable energy sources

Modeling future energy scenarios is a powerful tool in energy and climate debates. Different organizations within the energy sector community publish their updates for the future on a regular basis. The publications reviewed herein for this study have multiple sources: energy agencies, academia, utilities, non-profit organizations, and others (Ram *et al*., 2019; IEA, 2021, Shell, 2021; DNV, 2021; Total, 2021; Equinor, 2021; BP, 2022). The main outputs considered from these future scenarios modeled in the literature are energy-related $CO_2$ emissions, total electricity generation, and fossil fuels and renewable energy shares of the energy mix.

Few international energy and emissions projection studies portray a strong renewable energy adoption that enables the regional or global power sector to be aligned with 100% renewable in the medium (2030) and long term (2050). Penetration of renewables into the power sector is not just a matter of replacing hydrocarbons with zero-carbon energy sources, but it represents a significant improvement in resource efficiency.

Most electricity generation scenarios projections for both the global and U.S. scales show a significant growth of electricity generation (TWh) as a result of an increase in electricity use on demand-side sectors (e.g. due to fuel shifting/electrification). Usually coupled with an overall growth of electricity generation, there is a strong increase in onshore wind and solar photovoltaics as they are deemed to dominate the technological transition in the power sector. On the other hand, the shares of fossil fuels and nuclear power are expected to have a declining trend (e.g. Ram *et al*., 2019; IEA, 2021).

The IEA Sustainable Development Scenario (IEA, 2021) projects a total generation of 4,874 TWh in the U.S- a 15% growth from the current electricity generation- in 2030 from all sources. By 2050, the U.S. is projected to generate 7,435 TWh of electricity - a 71% increase from 2020 figures. Under this IEA scenario, $CO_2$ emissions from the entire energy system could be reduced from 4,303 Mt $CO_2$ to 2,817 Mt $CO_2$ (in 2030), to 107 Mt $CO_2$ in 2050, justified not only by a deep change in the methods of electricity production but also strong fuel shifting and emissions reductions in demand-side energy sectors (buildings, industry, transportation, etc.).

Despite being very ambitious, unfolding an average growth of 12%/year of RES generation increase, this scenario still only considers a share of renewable energy sources in the electricity generation mix of 54% by 2030 and 85% by 2050, far below Earth Bill planned targets.

## 3. Earth Bill Scenario Development

Based on our external review of international studies, there are not any models/studies that consider renewable energy sources adoption and growth as strong as the proposed targets on Earth Bill. Thus, to develop an Earth Bill scenario with the 2027 and 2030 onwards set objectives, we build upon the current electricity generation mix (IEA, 2021) and related GHG emissions details (EPA, 2022), two scenarios (i.e. IEA Stated Policies Scenario and Sustainable Development Scenario (SDS)) from the World Energy Outlook 2021 (IEA, 2021) for future electricity generation projections. The Energy Innovation (2022) BAU GHG emissions scenario is used as a Reference Scenario for annual emissions for this assessment. The scenarios and final sources considered reflect detailed data availability, and the presented results go beyond electricity generation to consider carbon dioxide emissions for all demand-side energy sectors (buildings, transportation, power, etc.).

The methodology followed for this modeling exercise encompasses, therefore, five key steps:

1) Firstly, to retrieve annual values between 2020, 2030, and 2050 data points for total electricity generation (TWh) presented by IEA (2021) scenarios, we make an interpolation using a best fit 3rd polynomial.
3) Secondly, we consider the two targets of the Earth Bill for renewable energy share in the power sector mix (2027, 2030) to understand the yearly average growth required. The amount of electricity generated by renewables in the U.S. in the medium and long term is also calculated based on the aforementioned IEA SDS (2020) scenario.
3) Thirdly, the 2005-2020 annual GHG emissions for the electricity generation sector (US EPA, 2022) and the assumption of 0% emissions by 2030 (aligned with the Earth Bill 100% RES adoption by that year) are used to calculate the resulting annual GHG emissions for the power sector. Indirect greenhouse gas emissions related to renewable energy technologies, lifecycle from cradle to cradle e.g. impact of manufacturing, materials used, and transportation, are not specifically accounted for, since they are not considered in the historical emissions used. Nevertheless, a rough estimation for comparison purposes between direct and indirect emissions shares will be provided. Indirect emissions factors are collected from an extensive review of Lifecycle Analysis (LCA) data to include in the modeling all the greenhouse gas emissions impacts that renewable energy technologies implementation can have.
4) Fourthly, we calculate the emissions reduction derived from this tested Earth Bill scenario from 2020 to 2050; and compare them to a REF scenario following BAU scenario trends for the power sector from Energy Innovation (2022).
5) Finally, we calculate electricity grid emissions factors using the outputs of the previous steps, to understand the improvements in emissions per TWh generated and supplied to consumers. Electricity grid emissions factors are used by the demand side electricity technologies modeled in the other sectors explained below for impact calculations.

**Results and Analysis**

The results of our Earth Bill scenario show that increased adoption of renewable energy sources for electricity generation of 80% by 2027 and 100% by 2030, as proposed on Earth Bill, entails the need for a 20% average annual growth from renewable energy until 2030. Afterward, from 2030-2050, renewable electricity would need to grow on average by just over 2% a year to keep pace with electricity demand. Electricity generation by 2030 would be around 4,874 TWh based on IEA Sustainable Development Scenario overall electricity generation value (IEA, 2022a).

On a similarly ambitious path, a 100% RES electricity generated by 2030 would result in zero direct greenhouse gas emissions in that year. From 2005 to 2020, the historical annual average GHG emissions reduction was just over 3.2%/year. To align with the Earth Bill targets, the average annual reduction will need to be around 12.6%/year until 2030. This requires stronger

RES technological adoption efforts closer to the 2030 objective when technologies will be cheaper and more efficient, with annual reductions growing from around 4%/year to 30-50%/year around 2027-2030.

This Earth Bill scenario, with significant growth of renewable energy sources, may result in direct GHG emissions of 7,731 million metric tons $CO_2$-eq over the 2021-2050 period (zero after 2030). This compares to a 37,822 million metric tons $CO_2$-eq under a Reference scenario for the same period. Indirect GHG emissions estimates might reduce these figures between 5% to 10% depending on the technological mix of renewable energy sources (Figure 1).

This would mean that the very ambitious scenario proposed on the Earth Bill could result in around 5,702 million metric tons of avoided cumulative $CO_2$-eq emissions from 2021-2030 and 30,091 million metric tons of avoided $CO_2$-eq in the 2021-2050 timeframe.

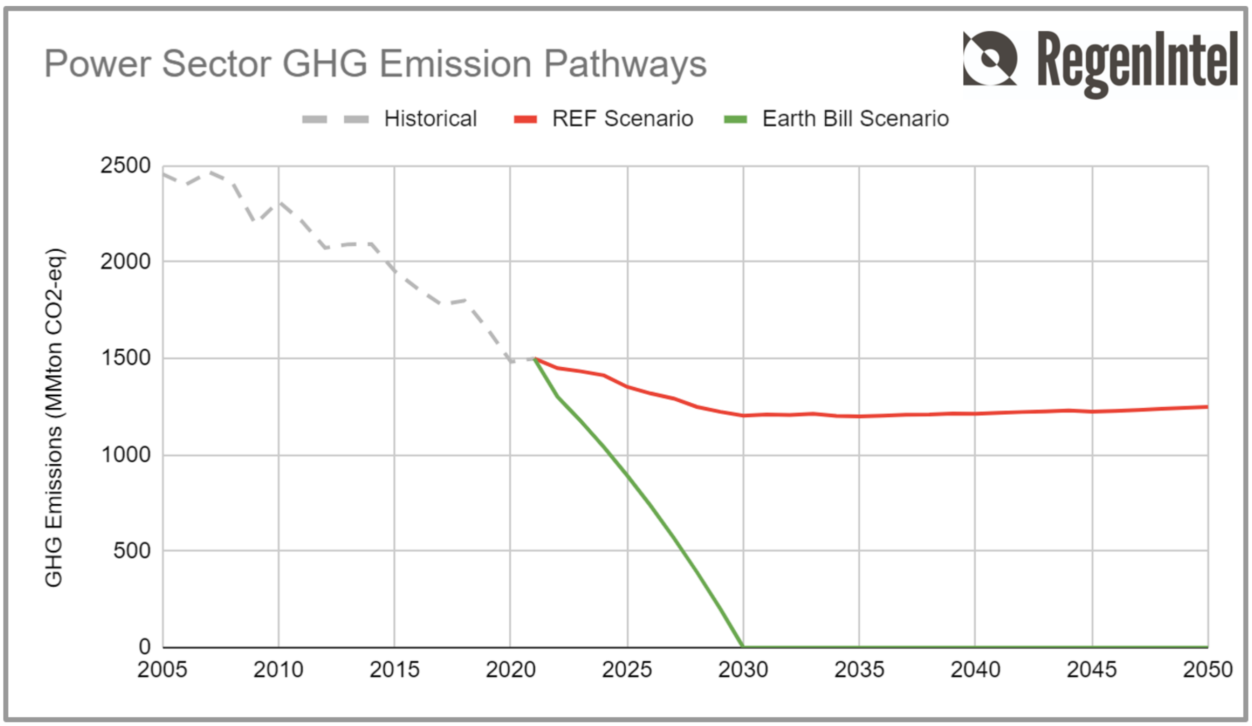


Figure 1: Power Sector GHG Emissions Pathways to 2050

On a related trend, electricity grid emissions factors under this Earth Bill scenario would entail a reduction on average of 30%/year up to 2030, compared to a 3%/year reduction on a REF scenario.

It is clear that renewable electricity needs to grow at a significantly higher rate to reach the milestones in the Earth Bill of having 80% of electricity generation be renewable in 2027, and 100% from 2030 onwards. The US Inflation Reduction Act will help accelerate renewable electricity adoption; however, a lot more technological, financial, and regulatory changes are needed to achieve the Earth Bill milestones.

## Section II - 100% Zero-emissions Vehicles from Manufacturers

### Earth Bill Proposal

*[T]he minimum annual percentage of the quantity of new motor vehicle sales of a vehicle manufacturer that shall be zero-emission vehicles shall be—*

*(A) in 2027, 80 percent; and*

*(B) in 2030 and every year following, 100 percent.*

**Objective**

1. Identify status of U.S. transport fleet and projections as they relate to battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEV/hydrogen)
2. Collect latest data on total vehicle and transport service demand out to 2050
3. Collect data on the BEV and hydrogen vehicle technologies and other data on the U.S. fleet
4. Analyze the climate impact based on the proposed Earth Bill

**Methodology**

1. Status of Fleet and Projections

Light Duty Vehicles (LDVs)
The U.S. LDV fleet sits at around 253 million vehicles which includes 105 million cars and 148 million light trucks (includes sport utility vehicles, and pickups) both for mainly private passenger use. The share of light trucks has been increasing for some time. Total sales hover around 14-17 million vehicles per year and no major growth is expected in these annual sales figures (EIA, 2022b).

The share of Battery-powered Electric Vehicles (BEVs) is under 1% of the stock (just over 1 million BEVs on U.S. roads), but 3% (466,000) of the annual sales of LDVs in 2020. Sales growth has advanced greatly in the last few years due to media attention, announced emissions targets (both from the public and private sectors), fiscal incentives, high fuel prices, and the roll out of more charging stations. Sales of BEVs in leading countries is as high as 16% (Germany) and in 2021 68% of all LDVs in Norway were BEVs (IEA, 2022c). *Reference projections* of BEVs suggest that the U.S. could see as few as 680,000 and as many as 5 million units sold annually by 2030 (4.5%- 30% increase in the proportion of LDV sales) (EIA, 2022b; Energy Innovation, 2022).

Hydrogen vehicles have received much less interest and are estimated to number no more than 12,400 total in the U.S. in 2021. The hydrogen vehicle market is expected to take much longer to grow since the technology is still very expensive and the charging must be done at a station, of which there are only 67 in the entire U.S. (compare that to 120,000 EV charging points) (IEA, 2022).

Trucks

The term “truck” has been classified in different ways by the Federal Highways Administration (FHWA) and the Environmental Protection Agency (EPA). This includes light trucks (analyzed in the light duty vehicle sections), medium and heavy trucks that are used for urban and long-distance freight deliveries, buses, and specialist trucks like emergency vehicles and cement mixers. Although far less numerous than some other classes of trucks, the heaviest trucks (classes 7 and 8 trucks weighing at least 26,000 pounds gross weight, as defined by the FHWA) are the largest users of medium and heavy truck fuel annually accounting for around 60-70% of all medium and heavy truck fuel, and therefore a sizable portion of all direct truck emissions (Davis & Boundy, 2022). This segment is the focus of this section.

There are around 2-3 million trucks on the roads in this class, and a vanishingly small number of them (likely fewer than a couple thousand) are not fossil-powered. The number of available medium and heavy truck BEV and hydrogen vehicle models is small, though it is growing. Most of the vehicle models at present are designed for shorter regional trips or those in controlled environments like port operations. Battery capacities and driving range are also growing as many manufacturers go through their product development phases in the U.S. and abroad.

2. Demand for Transport to 2050

Light duty vehicle emissions analysis is performed in units of passenger-miles (pass-mi) which represents the transport of one average person over 1 mile (and ton-miles is used for freight trucks). These units take into account that moving the same people (or freight) a greater distance and moving more people (or freight) the same distance both require more energy and can generate more emissions. Most variables are normalized to these units and often need some conversion from pure vehicle miles traveled using an estimated average number of persons carried or freight carried.

Light Duty Vehicles

The total land passenger transport is estimated at 2,870 billion vehicle-miles in 2021 (U.S. Bureau of Transport Statistics 2021). Assuming an average passenger load of 1.67 (average number of drivers + passengers in a vehicle), this is a total demand of 4,800 billion passenger-miles. The projected total growth in land passenger transport by 2040 (in terms of passenger-miles) is under 1% annually (OHPI, FHWA 2021).

Heavy Trucks

Total land freight transport by combination class 7 and 8 trucks is estimated at 180 billion vehicle-miles in 2021 and freight transport annual growth is estimated to be on the order of 2% (U.S. Bureau of Transport Statistics, 2021; OHPI, FHWA 2021). Additionally, the average real-world payloads for heavy freight trucks is estimated at 36,000 lbs. - this is incorporated into the transport market projection.

3. State of Technology and Fleet Data

Light Duty Vehicles

According to the latest survey data, passenger (LD) vehicles in the U.S. are driven an average of 11,200 vehicle miles annually (Davis & Boundy, 2022). This doesn't change drastically across normal years (during COVID years, the figure did drop noticeably). Vehicles are kept for longer than in the past. On average, after 16 years of ownership, a light duty truck has a 50% chance of still being in use (that is, the median lifetime is 16 years; that for cars is lower, but cars are a declining share of the light duty vehicle fleet, so we used the truck figure). We assume that LDV's are replaced after 16 years.

Light duty battery electric vehicles consume around 29.4 kWh per 100 vehicle-miles, and are compared to an average fuel economy of 20.8 and 28.6 mpg for light trucks and cars respectively (Gohlke & Zhou, 2021; Davis & Boundy, 2022). We assume that these figures are constant as passengers are added since, 1) on average, only 2 passengers are taken on every 3 vehicle trips in the U.S., 2) passenger weights are small compared to vehicle weights, and 3) vehicle efficiency depends on vehicle speed and other factors.

However, BEV's do require large batteries and it has been estimated that construction on a BEV generates more emissions than construction of a comparable internal combustion engine (ICE) vehicle (10.5 compared to 6 metric tons). The emissions saved by a BEV during the driving/use phase far exceeds the emissions from constructing the vehicle however. Notably, generating 10.5 metric tons of emissions from a typical gasoline LDV only occurs after around 4 years of use, so keeping *existing* LDV's for a few more years could generate fewer emissions than replacing a working older ICE vehicle with a new BEV.

Hydrogen vehicles also generate more emissions than a typical ICE during the manufacturing stage and are far behind BEVs in passenger vehicle development.

Heavy Trucks

Trucks form the backbone of the U.S. freight industry (carrying 76% of all goods either alone or in combination with other modes) (Davis & Boundy, 2022). The average heavy truck in the US travels almost 60,000 miles annually (Davis & Boundy, 2022). For comparison, that's over 10 return road trips between New York and Los Angeles. Limited truck survival and scrappage research suggests a median heavy truck lifetime of around 28 years before replacement (Davis & Boundy, 2022) and we assume the same will be true for a zero-emissions truck.

For energy consumption, diesel trucks have a fuel economy of 6.2 mpg on average, and electric trucks are expected to consume around 200 kWh per 100-veh-miles (Sripad & Viswanathan, 2018; Davis & Boundy, 2022). Emissions from electric trucks include battery production and electricity generation (described in earlier sections). Some heavy EV truck models from manufacturers like BYD, Peterbilt, Volvo, Nikola, and Lion8 are already in production and offering 120-330 miles range on a single charge.

Hydrogen trucks are still at the development stage and suffer from high costs, low availability of charging infrastructure, and low availability of renewably-generated hydrogen (most hydrogen is generated from natural gas that releases GHG- gray hydrogen). These barriers mean EV truck adoption will outpace hydrogen trucks for some time. In the future, hydrogen trucks could catch up since they have the advantage of rapid refueling.

4. Earth Bill Scenario Development

Light-duty zero-emissions vehicles (ZEVs) (battery and hydrogen powered cars and light trucks) and heavy-duty truck ZEVs (class 7 and 8) are modeled separately in this analysis. Other vehicle classes are not modeled. These two groups of vehicles account for 92% of all road fuel use (Davis & Boundy, 2022). The results give us the scale of impact of the EB policies, and since they exclude the medium trucks, act as a conservative estimate for modeling to 2050.

The total number of vehicles sold of each type (LDVs and trucks) is assumed the same in the Earth Bill Scenario compared to the reference since no major effect on LDV sales is noted in the Earth Bill proposal. Projections from the Energy Information Administration (EIA) indicate decreasing annual sales of heavy trucks to 2050 (EIA, 2022b). Energy Innovation's projected reference sales are higher than those of the EIA (Mahajan et al 2022), and were used since comparing the Earth Bill scenario to them would constitute a more conservative approach. This way, we are more confident that the real results are *at least as high* as those published.

The vehicle shares defined in the Earth Bill proposal (80% of sales in 2027, 100% in 2030 onwards) are applied to these sales projections, and the sales of vehicles are aggregated into the stock of vehicles in the national U.S. fleet which also accounts for the retirement of vehicles over a fixed average lifetime. We, therefore, have the total zero emissions vehicles (mainly BEV's) in each year for the Earth Bill Scenario and the Reference scenario.

Total annual emissions of a single vehicle are calculated based on the fuel consumption (for fuel vehicles) and electricity consumption multiplied by the average grid emissions factors of the given scenario (for electric vehicles). The emissions generated by manufacturing are included in the calculations for LDV, but not heavy trucks because the limited research in that area suggest that it's minimal compared to overall emissions (Machado et al 2021).

No hydrogen vehicle adoption is modeled since it is far behind the development of BEV's in both light-duty and heavy-duty vehicles (EIA, 2022b; Energy Innovation, 2022; IEA, 2022c; Samsun et al, 2022). Results with hydrogen vehicles taking a noticeable share of the heavy truck market in the future (post-2030) shouldn't differ much from that of heavy truck BEVs since both are projected to depend on clean electricity (for electrolysis-generated hydrogen and for manufacturing and charging batteries). Thus, results here are indicative of a future with or without heavy hydrogen vehicle vehicles in the medium/long term.

The grid emissions factors used in the Earth Bill scenario and the Reference Scenario are based on those calculated in the electricity sector above.

**Results and Analysis**

The climate analysis of the transportation element of the Earth Bill Scenario shows that, collectively it can avoid 17,400 Million Metric tons of $CO_2$-eq emissions total from 2020 to 2050 (10,600 from LDVs and 6,800 from heavy trucks). The Emissions reduction of these initiatives vs U.S. 2005 Transportation Emissions is 53%. When compared to the Reference emissions (which already takes into account reductions in the transportation sector), these proposals facilitate 89% reductions in emissions. This should be seen as a conservative estimate.

The breakdown of emissions avoided is shown below on table 1.

Table 1: Annual Emissions Reductions from Transportation Sector

| Transportation Segment | Annual Emissions Reduction from 2030 Onwards (Million Metric Tons $CO_2$-eq) |
|---|---|
| LDV | 160 - 640 |
| Trucks | 100 - 450 |
| Total | 260 - 1,070 |

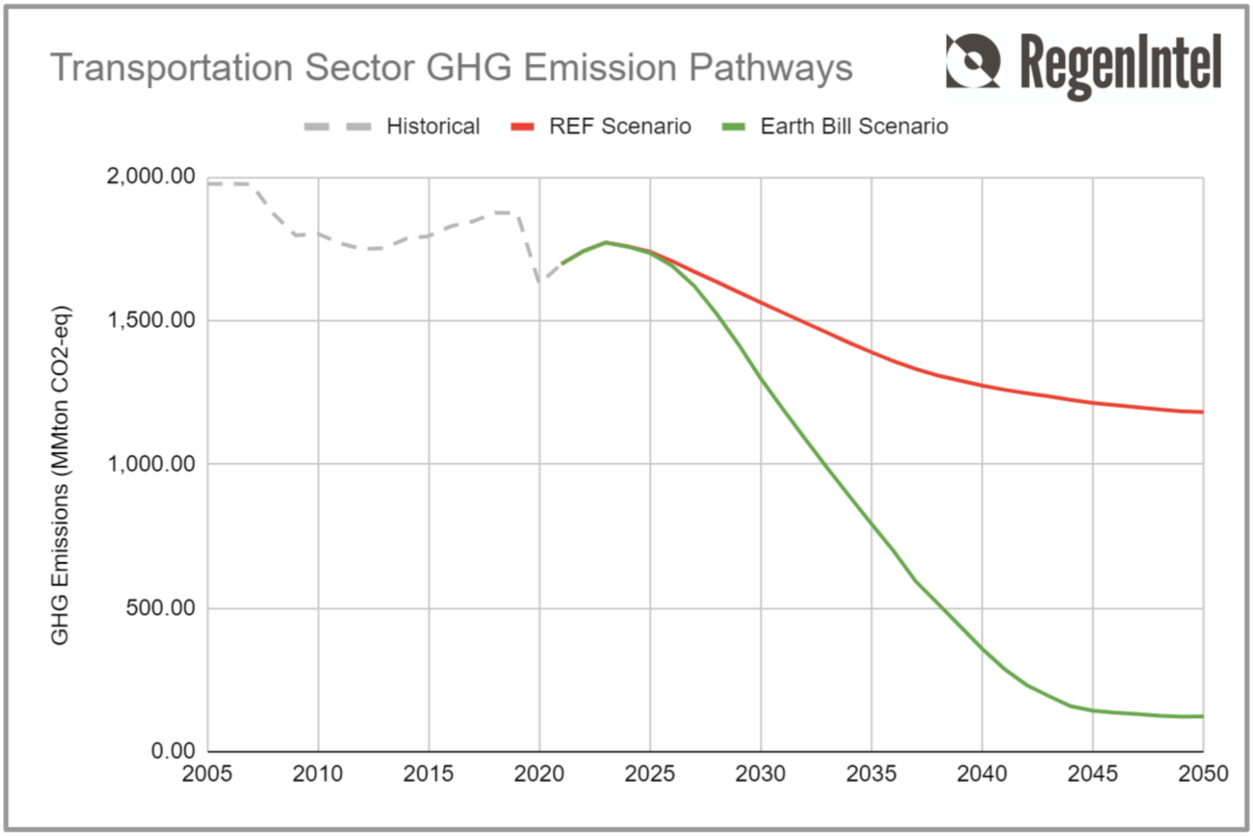


Figure 2: Transportation Sector GHG Emissions Pathways to 2050

The results above should be taken as conservative (or a minimum impact) since:

1. The Reference/BAU car and light truck projection chosen from among a few authoritative sources projects quite a high adoption of BEVs in the U.S. by 2030 (on the order of 5 million/yr.). Other sources suggest much lower levels, but this source was selected to align with the other BAU projections used.
    a. The car/light truck emissions savings could be 4,500 million metric tons $CO_2$-eq higher and result in a 70% reduction in 2050 compared to 2005 transportation emissions. This additional emissions reduction is already included in the Reference Scenario, and so is not included in the results above to avoid double counting.

2. The analysis only included light-duty vehicles and heavy freight trucks - which account for 92% of on-road fuel consumption. Medium trucks and specialist applications were ignored; they would have an additional impact on the analysis.

Note, however, that hydrogen cars (fuel cell vehicles) were not modeled since they take up a minuscule portion of both the car and truck markets now, have limited commercial data, and can only become really competitive for very long-distance freight travel (a small portion of all freight), and are likely to be far behind for many years (Samsun et al, 2022). Hydrogen vehicles may improve the results, but they could also worsen them since hydrogen generation can release emissions if the $H_2$ source is not via electrolysis, a currently expensive process. It is a reasonable expectation that when hydrogen vehicles become a competitive option, the majority of hydrogen would be generated by electrolysis or other zero-emissions alternatives.

## Section III - 100% Regenerative Agriculture by Industrial Corporations

### Earth Bill Proposal

*The minimum annual percentage of land and livestock managed with regenerative agricultural practices, as defined in this act, for a covered land or livestock corporation shall be -*

> *(1) In 2025, 50 percent; and*
>
> *(2) In 2027, 75 percent; and*
>
> *(3) in 2030, 100 percent.*

### Objective

1. Identify U.S.-based regenerative agricultural interventions for climate analysis
2. Estimate the maximum area available for each intervention in the U.S. using information available in the public domain
3. Collect U.S.-specific climate data for these interventions as well as for the conventional practices
4. Analyze the climate impact based on the proposed Earth Bill scenario

### Methodology

1. <u>Identify U.S.-based regenerative agricultural interventions for climate analysis</u>

The agriculture sector in the U.S. emits close to 635 Million Metric tons of $CO_2$-eq emissions per year (EPA 2020). Nearly 56% of these emissions come from crop cultivation - primarily from agricultural soil management (95%) and the remaining 5% from rice cultivation. The livestock sector, on the other hand, contributes to 43% of the total agricultural emissions, with a major contribution coming from enteric fermentation (70%) and the remaining 30% from manure management. The remaining 4% of the total agricultural emissions is attributable to urea fertilization, liming, and crop residue burning (EPA 2020). The detailed information is provided in Figure 3.

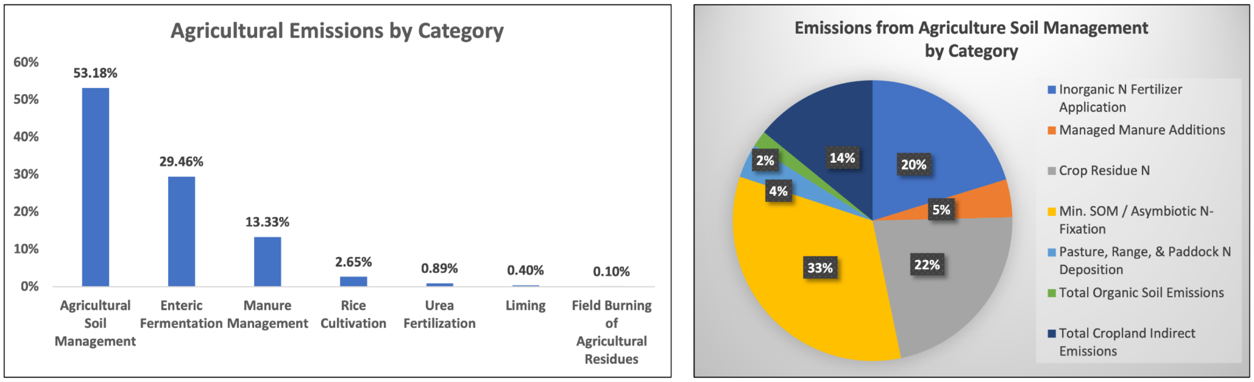


Figure 3 - Agriculture sector emissions in the United States

Source: EPA

To identify U.S.-based regenerative agricultural interventions, we began by mapping the regenerative agricultural practices listed on Earth Bill to the following climate solutions.

Table 2: List of Regenerative Agriculture Solutions

| RegenIntel Climate Solutions for the Regenerative Agriculture System by Category | RegenIntel Climate Solutions for the Regenerative Agriculture System | Earth Bill - Regenerative Agricultural Practices |
|---|---|---|
| Regenerative cropland practices | Regenerative Annual Cropping | Conservation cover, Conservation crop rotation, Contour farming, Cover crops, Residue and tillage management with no till, Residue and tillage management with reduced till, Strip-cropping, Alley cropping, Contour buffer strips, Critical area planting, Cross wind trap strip, Field borders, Field strips, Herbaceous wind barriers, Vegetative barriers, Windbreak renovation, Windbreaks, and shelterbelts |
| | Improved Rice Cultivation | Same as above |
| | Nutrient Management | Nutrient management |
| Regenerative livestock practices | Silvopasture | Silvopasture establishment, Range planting, Riparian forest buffers, Riparian herbaceous buffers |
| | Managed Grazing | Grassed waterways, Prescribed grazing, Range planting |

| RegenIntel Climate Solutions for the Regenerative Agriculture System by Category | RegenIntel Climate Solutions for the Regenerative Agriculture System | Earth Bill - Regenerative Agricultural Practices |
|---|---|---|
| | Improved Livestock Feed | Regenerative livestock feed practices |
| | Improved Manure Management | Regenerative livestock manure practices |
| Regenerative agroforestry practices | Multistrata Agroforestry | Multistory cropping, Tree and shrub establishment |
| | Tree Plantation | Critical area planting, Forage and biomass planting, including the use of native prairie and seed mixtures, Forest stand improvements, Hedgerow planting, Tree and shrub establishment |
| | Perennial Bioenergy Cultivation | Forage and biomass planting, including the use of native prairie and seed mixtures |
| Regenerative restoration practices | Peatland restoration | Wetland restoration |

**Upland wildlife habitat, Woody residue treatment, biochar incorporation, and coastal wetland restorations are the practices which are listed on the Earth Bill but not analyzed under the current study*

2. Estimate the maximum area available for each intervention in the U.S. using information available in the public domain

After mapping the Earth Bill listed practices to the above-listed climate solutions, we used information available in the public domain, especially at the Global Solution Alliance platform and with the United States Department of Agriculture, to estimate the maximum land area available for these solutions in the U.S. A total of 159 million hectares of U.S. cropland and 323 million hectares of U.S. grassland area is considered in the present analysis.

3. Collect the U.S. specific climate data for these interventions as well as for the conventional practices

Next, we collected U.S. specific climate data for these solutions to perform the climate analysis of these solutions. The current analysis includes data collection on the following climate variables;

a. Avoided $CO_2$ emissions in $CO_2$/ha/yr.
b. Avoided $CH_4$ emissions in $CH_4$/ha/yr.
c. Avoided $N_2O$ emissions in $N_2O$/ha/yr.
d. Avoided $CO_2$-eq emissions in $CO_2$-eq/ha/yr.
e. Carbon sequestration in C/ha/yr.

4. Analyze the climate impact based on the proposed Earth Bill scenario
    a. Earth Bill Scenario Development

The Reference/BAU adoption for each solution was based on the best available information in the literature in the U.S. The climate impact of each solution was projected based on the Earth Bill future adoption targets, i.e. 50% by 2050, 75% by 2027, and 100% by 2030. These adoption rates were also compared with the best estimates available in the literature. We have extended this analysis to 2050, assuming similar adoption rates post-2030.

b. Status of regenerative agriculture practices in the U.S.

Regenerative cropland practices
With a range of diverse definitions for regenerative agriculture, it is difficult to accurately describe the status of regenerative agriculture in the U.S. For the purposes of this study, we have referred to the regenerative agriculture practices provided by Earth Bill and have mapped RegenIntel climate solutions to those practices. Conservation agriculture has increased in area by 40% between 2008-2018 (Kassam et al., 2019) and is currently being practiced on nearly 45 million hectares in the U.S. Based on this growth rate, the continued adoption of conservation agriculture seems promising in the near future. However, the transition from conservation agriculture to regenerative annual cropping is not as promising and would require greater investment. Rice is marginally cultivated in the U.S., and the adoption of improved rice cultivation builds on regenerative agriculture principles also followed in conservation agriculture. The U.S. is the fourth largest consumer of synthetic fertilizers; therefore, the adoption of nutrient management practices not only helps in reducing significant agricultural greenhouse gas emissions, but also ensures the safety of a lot of nature and people.

Regenerative livestock practices
Livestock production and consumption is a major contributor to agricultural greenhouse gas emissions in the U.S. Adoption of practices like silvopasture and managed grazing is slowly increasing, but not at the pace required to achieve the required emission reduction targets of the U.S. Though the exact area on silvopasture and managed grazing is unknown, the best estimates suggest an area of 10.50 and 9.96 million hectares respectively (Smith et al., 2022a, Henderson et al., 2015).

Regenerative agroforestry practices
Adoption of agroforestry practices, especially on degraded grassland and cropland, is also slowly increasing in the U.S., but clear evidence of the current state of adoption is unavailable. At present, nearly 1.5% of all U.S. farms are classified as "agroforestry" (Smith et al., 2022b).

Regenerative agroforestry practices
Restoration of the wetland areas, especially in the existing cropland and grassland landscapes is extremely important as these soils are highly rich in soil organic carbon and drainage of these soils results in significant amounts of greenhouse gas emissions.

**Results and Analysis**
The climate analysis of the above-listed regenerative agriculture solutions shows that collectively these solutions avoid 8,220 Million Metric tons of $CO_2$-eq emissions, with 100% adoption by 2030. The 2050 annual emissions reduction vs the U.S. 2005 Agricultural Emissions of these initiatives is 51.6% (Figure 4, Table 3).

Table 3: Annual Emissions Reductions from Agriculture Sector

| Regenerative Agriculture | Annual Emissions Reduction from 2030 Onwards (Million Metric tons $CO_2$-eq/year) |
|---|---|
| Crop Cultivation | 156 |
| Livestock | 155-167 |
| Total | 311-323 |

The annual emissions reduction 2030 onwards are given in the above table, broadly for crop cultivation and livestock production. This is a conservative estimate for the following reasons:

1. These estimates do not include the emissions reduction associated with crop residue burnings (0.617 Million Metric tons $CO_2$-eq), which will be used in a regenerative system to cover the soil or be converted into biochar.
2. The emission associated with the mineralization of soil organic matter and the asymbiotic fixation of nitrogen gas, representing 33% of agricultural soil management, is unavoidable. However, the overall adoption of regenerative agricultural practices with carbon sequestration yields net carbon benefits.
3. The crop residue Nitrogen emissions, representing 22% of the agricultural soil management, also decrease with reduced/no tillage (Feng et al., 2018). However, we could not account for this emissions reduction due to the lack of data.
4. Improving cattle feed reduces enteric fermentation to a certain extent. Our estimates show a 36% reduction in methane emissions in the U.S. Prathap et al., 2021 has found the application of different feed alternatives on a global scale could lead to a methane

emission reduction potential ranging from 6%-76%. We erred on the low side of the scale of the methane emissions reduction potential as a result of feed alternatives.

The adoption of these solutions would reduce 5% of the U.S. total annual greenhouse gas emissions by 2050. In addition, these solutions could sequester 727 Million Metric tons of $CO_2$-eq by 2050 compared to the Reference scenario. Taken together, these solutions can mitigate up to 16% of the total 2005 U.S. greenhouse gas emissions.

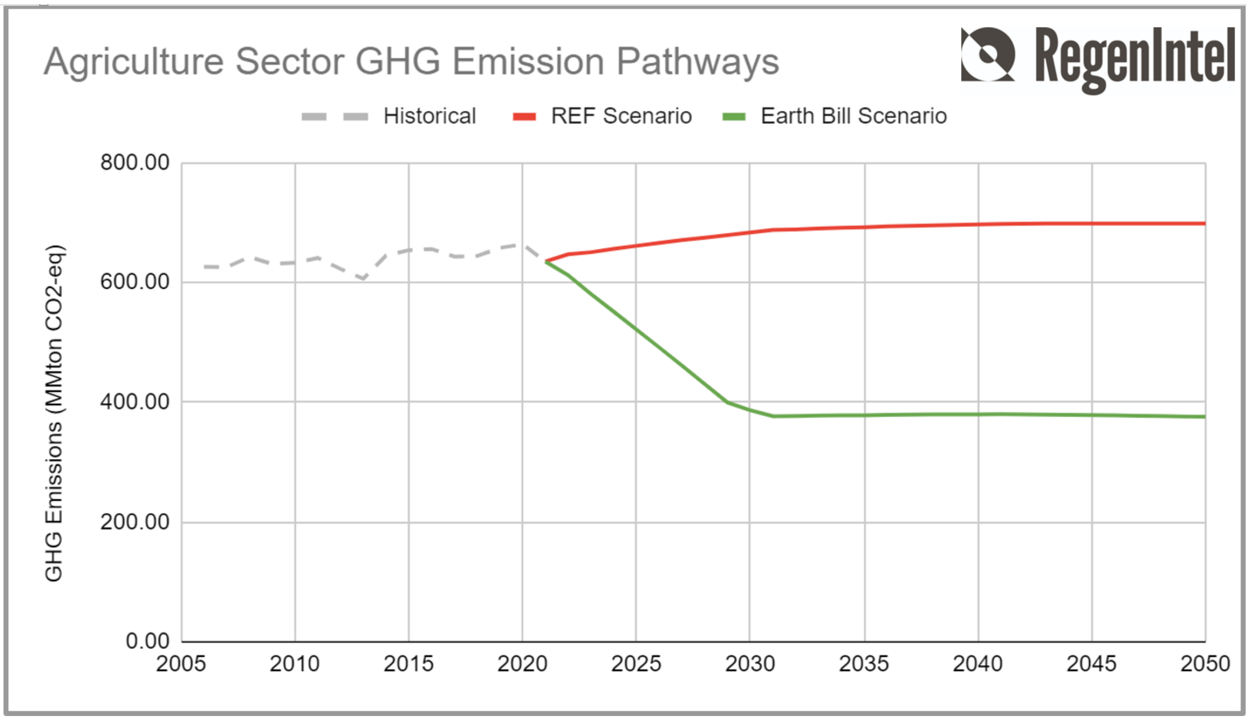


Figure 4: Agriculture Sector GHG Emissions Pathways to 2050

## Section IV - Overall Result

**Summary and Analysis**

The combined analysis from the above three sectors under the Earth Bill scenario shows that the proposed interventions of the Earth Bill can avoid up to 74% of U.S. greenhouse gas emissions by 2050 compared to 2005 emissions (Figure 5). Some of additional key insights are listed below:

1. The proposed interventions of the Earth Bill can cause the U.S. to achieve a reduction of greenhouse gas emissions by an additional 41% by 2030, and 51% by 2050 compared to 2005 levels.

   a. These reductions include roughly 15% and 11% from nature-based sequestration in 2030 and 2050 respectively. This represents 100% adoption of regenerative agriculture in cropland and grassland in the US (1.19 billion acres).
2. The U.S. emissions have been trending down since 2005, but not fast enough to meet climate targets or avoid catastrophic warming.
   a. The 2021 emissions were already 17% lower than 2005.
   b. The reference projection indicates a further reduction of 4% by 2030 and 6% by 2050.
   c. Published estimates of the impact of other climate policies, like the IRA clean energy incentives, indicate that they can help the U.S. achieve an additional 9% reduction by 2030, much of which overlaps with, and is made more certain by, pollution-source mandates in the Earth Bill.
3. In summary, in addition to the current policies, the emissions reduction due to The Earth Bill (compared to 2005) are:
   a. 41% + 17% + 4% = 62% by 2030
   b. 51% + 17% + 6% = 74% by 2050
4. Specifically, the bill would reduce the U.S. GHG emissions from 5,983 MMT CO2-eq (2022) to 2,494 MMT CO2-eq (2030) and to 1,735 MMT CO2-eq (2050).

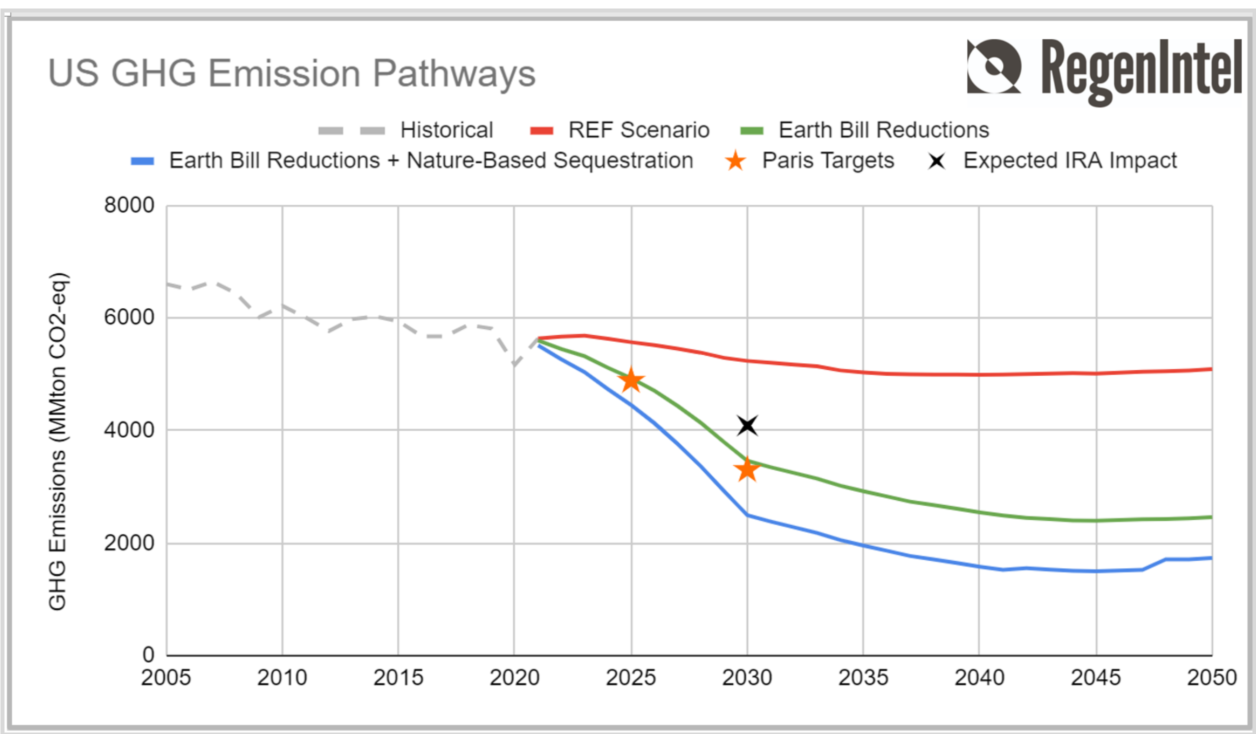


Figure 5: U.S. GHG Emissions Pathways to 2050

Table 4: U.S. GHG Pathways to 2050

| U.S. Annual GHG Emissions (Million Metric tons $CO_2$-eq/year) | 2005 | 2022 | 2030 | 2050 |
|---|---|---|---|---|
| Historical | 6604 | NA | NA | NA |
| REF Scenario | NA | 5668 | 5237 | 5093 |
| Earth Bill (only emission reductions) | NA | 5668 | 3460 | 2462 |
| Earth Bill (emission reductions with nature-based sequestration) | NA | 5668 | 2494 | 1735 |

What is not included in the EB analysis report

1. This report only includes the climate analysis of the three sectors as proposed by the Earth Bill. This report doesn't estimate the financial impact of the Earth Bill proposal.
2. The climate analysis doesn't include the Imported and exported emissions. However, all retail sales of power, sales of vehicles, agricultural lands, are covered in the climate analysis.
    a. The U.S. imports 1.2% (2021) of electricity from Canada and Mexico and exports 0.3% (2021).
3. This report doesn't include the climate analysis of the impact of 100% renewable energy in utilities on the industry and household/commercial emissions.
4. This report presents a conservative estimates for the given three sectors. The details are provided in each sector's result description.

**Frequently Asked Questions**

Relationship with the Inflation Reduction Act (IRA) and the Bipartisan Infrastructure Law (BIL)

The largest act for infrastructure spending ever ($1.2 trillion) was passed in 2021 as the BIL. This included several elements that relate to climate change, and in fact it helps facilitate many elements of the Earth Bill like paying for electric vehicle charging infrastructure, hydrogen power generation, and funding research on advanced nuclear power. The IRA is a landmark act passed in August 2022 in the US Congress to provide $369 billion for, among other things, expanding clean energy and electric vehicles. This has been estimated to have a projected impact of an additional 9% (or an additional 1,150 million metric ton beyond the reference) $CO_2$e reduction in US emissions in 2030 compared to 2005 (US DOE, 2022). Since ⅔ of these reductions are estimated to be from the power generation, agriculture and transportation sectors, and they are expected to be of similar type to those expected under the Earth Bill[2], *most* of the IRA and BIL impacts are covered in the Earth Bill estimates above. Additional impacts of the IRA and BIL, like buildings and industrial emissions reduction may be in addition to the results of our analysis.

Is the Earth Bill in line with a 1.5 Degree warming Scenario?

According to the UN Intergovernmental Panel on Climate Change (IPCC), emissions pathways that are consistent with 1.5 degrees of warming have rapid emissions decline to zero by around 2050 (IPCC, 2018). This may be achieved by reductions in energy consumption alone or in combination with carbon dioxide removal (whether natural/afforestation/bioenergy or technological). Since our analysis does not show the Earth Bill adoption in isolation leading the US to a zero emissions future by 2050, it does not put the US in line with a 1.5-degree pathway. However, comparing this analysis with global estimates, it was observed that the world needs to reduce annual GHG emissions by 17.1 Gt CO2-eq in 2030 to limit the global temperature anomaly to 1.5°C (UNEP 2022). The U.S. under the Earth Bill scenario can reduce up to 3.49 Gt CO2-eq in 2030, thereby contributing nearly 20% of the global 1.5°C target for 2030. Moreover, with the Earth Bill, the U.S. contribution towards the global 2°C target would be nearly 38%.

Can the Earth Bill lead the U.S. to a zero emissions path by 2050?

Yes! The Earth Bill is an important step in the gradual increase of ambition for the US to reduce its national emissions and lead the world in climate action while maintaining a strong economy. The climate ambition from the Bipartisan Infrastructure Law to the Inflation Reduction Act to the Earth Bill increases significantly and lays the foundation for even more ambitious action post 2030. That action can include reductions that lead to a zero emissions nation by 2050.

What might be some impacts of the Earth Bill's adoption on other Sectors or Countries?

The changes called for in the Earth Bill require a massive shift in finance, and policy at federal and state levels. Manufacturing of renewable energy and clean vehicle technologies would require massive increases to meet the targets laid out and the supportive supply chains, which are global, would also have to be expanded to focus on this major national initiative. This means that several of the trading partners of the US would necessarily be involved in this transition.

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[2] Transportation consideration of the IRA include non-zero emissions vehicle impacts, so these are not perfectly substituted by the zero-emissions vehicle requirements of the Earth Bill

Many more clean energy workers would be needed and policies that facilitate the growth of the sector (approvals for land for renewable infrastructure etc.) would need to adapt to the federal goals.

Some important unmeasured impacts of the Earth Bill could include a drop in costs of the technologies and approaches supported by the Earth Bill that result in wider adoption in other sectors or countries. So for instance, as renewable energy prices dropped worldwide in the past, adoption grew significantly. This multi-decadal process can be accelerated by the Earth Bill's adoption. This also applies to zero emissions vehicles, and regenerative agriculture practices (especially in temperate countries where the Earth Bill's impact would mostly apply). Similarly, other sectors that may use the technologies that constitute the Earth Bill solution may see some greater access to them as their prices drop. Onsite renewable energy for manufacturing industries might become cheap enough for it to replace incumbent technologies for generating heat and electricity for manufacturing.

Less direct impacts could also include an acceleration in sustainability and climate commitments and actions of business leaders in other industries as their colleagues in the Earth Bill-affected industries implement their solutions. Activists may use those solution implementations to highlight that change is possible.

**Recommendations**

1. The Earth Bill should include all economic sectors, including the Industry and Commercial/Residential sectors in order to drive towards zero emissions by 2050.

2. The Earth Bill should include the protection and restoration measures for all land types.

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