



## Strategic Roadmap to Net-Zero Emissions in Taiwan's Agriculture Sector by 2040

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### ABSTRACT

*None of us is considered an outsider when it comes to facing global climate change. Taiwan's agriculture-related greenhouse gas (GHG) emissions accounted for as low as 2.1% of the country's total GHG emission. Countries around the world successively made commitments and taken actions towards the target of achieving "Net-Zero Emissions by 2050." In 2022, a declaration was made indicating the strong determination of the agriculture sector to reach the goal of net-zero emissions by 2040. In response to the trends of climate change and environmental sustainability, the Council of Agriculture (COA) underwent an organizational restructuring and was elevated to the status of the Ministry of Agriculture (MOA) on August 1<sup>st</sup>, 2023. Notably, a significant development was the establishment of the "Department of Resources Sustainability" as the authority to formulate climate change adaptation and net-zero emissions policy. Tens of conferences had been held for stakeholders from various agriculture sectors to collect opinions and suggestions dealing with climate-related crisis, which contributed to the formulation of the roadmap to Net-Zero Emissions in the agriculture sector. The roadmap consists of four pillars: (1) reducing carbon emissions, (2) enhancing carbon sinks, (3) encouraging circular agriculture and (4) promoting green trend. With an estimate of 7,630 kt CO<sub>2</sub>-e GHG reduction, and 6,159 kt CO<sub>2</sub>-e carbon sink, MOA declared confidently that the net-zero emissions in the agricultural sector will be targeted by 2040, surpassing the global schedule. The country will invest a total of more than NT\$3 billion (about US\$93.8 million) in the following 4 years to support the measures covered by the strategies. Talent training and experience exchanging programs are conducted for boosting the ability and capacity for reaching the goal of net-zero emissions.*

Keywords: global climate change, GHG emissions, carbon sink, and net-zero emissions

### CURRENT STATUS OF AGRICULTURE AND ITS GHG EMISSIONS

#### An overview of Taiwan's agriculture

According to the farmland database made by the Ministry of Agriculture (MOA), Taiwan has 701,351 hectares of arable land (Ministry of Agriculture, 2023), accounting for 19.3% of the total land area. This includes 472,233 hectares for crop cultivation, 385,106 hectares for fisheries, and 8,139 hectares for livestock farming (Council of Agriculture, 2023a). At the end of 2021, the number of agricultural and livestock households in Taiwan was 759,000, accounting for 8.5% of the total resident households. Most farms are small-scale operations, and based on the previously mentioned arable land, the average land operated by each household is approximately 1 ha (Council of Agriculture, 2023a). The total value of Taiwan's agriculture production in 2022 was NT\$562.6 billion (about US\$16.6 billion), of which crops was NT\$275.9 billion (about US\$8.6 billion) occupied 49.1%, forestry was NT\$0.24 billion (about US\$7.4 million), fisheries NT\$82.2 billion (about US\$2.5 billion), livestock was NT\$204.2 billion (about US\$6.3 billion), accounting for 0.04%, 14.6%, 36.3% of the total agriculture production, respectively.

Besides, Taiwan has a high forest coverage rate, 60.7% of the total land area, which was 2.2 million ha of land (Council of Agriculture, 2023a) and most of the forest is operated by the government (Council of Agriculture, 2020).

The food self-sufficiency ratio (as calculated by calories) maintains around 30-34% in the past 5 years. The reason for such a low food self-sufficiency ratio was that Taiwan imports more than 9 million tons of wheat, soybean, maize and sugar every year. The result was very different, if the main items were considered separately and calculated by calories. Rice is the staple food of the Taiwanese, and its self-sufficiency ratio was 103.9%. Other items and its corresponding self-sufficiency ratio are as follows: vegetables 85%, fruits 82.9%, meat 73.5%, eggs 99.7%, fisheries 131%, milk 34.6%. As for the major imported items, its self-sufficiency ratio is as follows: wheat 0.0%, corn 3.5%, sorghum 2.6%, potato 17%, sugar 7.6%, soybean 0.2%, beef 4.6%, mutton 5.9%, shrimps and crabs 19.8% (Council of Agriculture, 2023a).

Agricultural GDP accounted for 4.0% of national GDP in 1990, and decreased gradually to 1.41% in 2022. However, if the processed agricultural products and the food and beverage were included, the share would be more than 6% (Council of Agriculture, 2023a).

### Taiwan's GHG emissions in agriculture sector

Taiwan has compiled a national GHG inventory in accordance with the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories proposed by Intergovernmental Panel on Climate Change (IPCC) in 2006. Taiwan has established a greenhouse gas inventory database covering the period from 1990 to 2020. According to the country's latest published National Greenhouse Gas Inventory Report 2023, total GHG emissions increased during the first 17 years, from 137,881 kt CO<sub>2</sub>-e (excluding land use, land use change and forestry, abbreviated as LULUCF) in 1990 to 301,665 kt CO<sub>2</sub>-e in 2007, then decreased to 297,007 kt CO<sub>2</sub>-e (excluding LULUCF) in 2021 (Figure 1), with emissions decreased by 1.5% at a negative average annual growth rate of -0.12% since 2007. Among the GHG emissions in 2021, the proportion of CO<sub>2</sub> emissions is 95.32% and that of non-CO<sub>2</sub> is 4.71%. The total emissions in 2021 saw an increase of 4.68% from 2020 (Ministry of Environment, 2023).

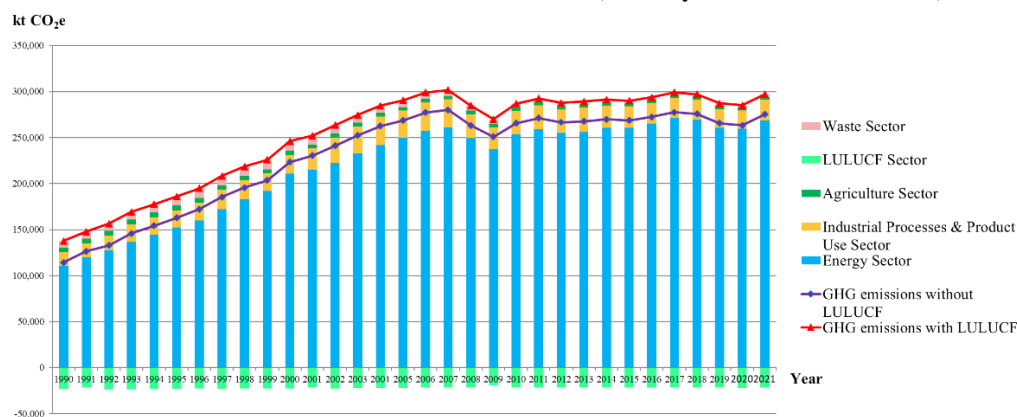


Figure 1. Trends in greenhouse gas emission by sector in Taiwan from 1990 to 2021

Agriculture isn't the major emission source of GHGs in Taiwan. The total GHG emissions in the agriculture sector (including energy related and non-energy related emissions) was 6,238 kt CO<sub>2</sub>-e in 2021, accounting for 2.1% of the total emissions. GHG emissions in agriculture sector shows a negative annual growth, from 8,669 kt CO<sub>2</sub>-e in 1990 to 6,238 kt CO<sub>2</sub>-e in 2021. It decreased by 28.04% during the past 3 decades. The non-energy related GHG emission was 5,049 kt CO<sub>2</sub>-e in 1990, which decreased annually to 3,231 kt CO<sub>2</sub>-e in 2021. It shows a similar trend with the total agricultural GHG emissions. Methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) are the 2<sup>nd</sup> and 3<sup>rd</sup> greenhouse gases in the agriculture sector, with the global warming potential of 25, and 298, respectively. Methane mainly came from livestock enteric fermentation, manure management and rice cultivation. Its emission in 2021 was 1,883 kt CO<sub>2</sub>-e, accounting for 42% of the total CH<sub>4</sub> emission 4,453 kt CO<sub>2</sub>-e. The CH<sub>4</sub> emission decreased by 58% compared to 10,705 kt CO<sub>2</sub>-e in 1990. Agriculture soil and manure management are the main sources of N<sub>2</sub>O in the agriculture field. It shows a significant reduction during the past 3 decades. In 1990, N<sub>2</sub>O

emission from agriculture was 1,994 kt CO<sub>2</sub>-e, accounting for about 67% of the total N<sub>2</sub>O emission of 2,992 kt CO<sub>2</sub>-e. As for the fuel combustion of energy related emission, also reveals a negative annual growth. The GHG emissions from agricultural fuel combustion decreased from 2,963 kt CO<sub>2</sub>-e in 1990 to 1,323 kt CO<sub>2</sub>-e in 2021, a sharp decrease of 55% in the past 30 years which was mainly due to a huge reduction of fishery fuel using. In contrast, the emission from electricity use nearly tripled in the past 3 decades, from 657 kt CO<sub>2</sub>-e in 1990, which increased annually to 1,682 kt CO<sub>2</sub>-e in 2021 (Figure 2). The sharp increase of electricity mainly due to the transformation and development of production and marketing structure in agriculture sector, such as cold supply chain systems, equipment and machineries used in post-harvest treatment, smart environment-controlled systems, etc. (Ministry of Environment, 2023).

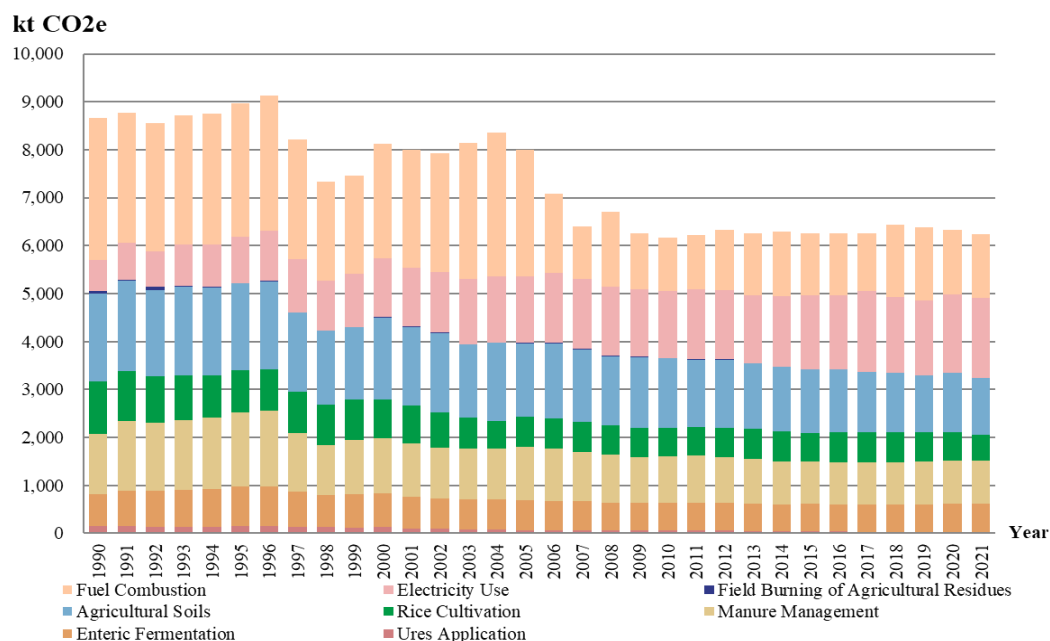


Figure 2. Trend of agriculture emissions in Taiwan from 1990 to 2021

Nature-based solution is a popular issue while discussing actions to tackle climate change. Carbon dioxide captured by means of photosynthesis and stored in natural carbon sinks, forest, soil and marine, could offset parts of global GHG emissions. According to the National Greenhouse Gas Inventory Report 2023, Taiwan's LULUCF contains only forest land. The CO<sub>2</sub> sequestration in LULUCF was 21,850 kt CO<sub>2</sub>-e in 2021 (Ministry of Environment, 2023). Compared with the amount of 23,386 kt CO<sub>2</sub>-e in 1990, decreased by 6.5%, mainly because small part of the forest covered land was adapted to grow crops. However, due to Taiwan had relatively strict land and forest related regulations, the trend of forest carbon sink in the past 3 decades shows a stable situation. An evident decrease in 2009 was due to a natural disaster which was Typhoon Morakot.

### THE INTENSITY AND FREQUENCY OF NATRUAL DISASTER INCREASED YEAR BY YEAR DURING THE PAST THREE DECADES

According to the climate scientist Maximiliano Herrera, who specializes in extreme weather, it was reported that in 2021, more than 400 weather stations globally broke their daily historical high-temperature records. Additionally, Taiwan's eastern Taimali weather station recorded a temperature of 40.6 °C on August 11<sup>th</sup>, 2021, earning it a spot on the list of countries with record-breaking high temperatures (The Guardian, 2022). The Central Weather Bureau's statistics on Taiwan's average temperature over the past 100 years indicate a rise of 0.11°C every 10 years, and in the recent 30 years, an increase of 0.25 °C every 10 years. This is in sharp contrast to the global average temperature increase of 0.08°C and 0.21°C every 10 years. Taiwan's rate of warming is notably faster (Central Weather Bureau, 2022).

Experts anticipate that in the future, Taiwan will experience an increased frequency of extreme rainfall events, resulting in drier conditions during dry periods and wetter conditions during wet periods. The uneven distribution of droughts and floods is expected to be more severe in Taiwan compared to the global average.

The annual total precipitation was 2,244.6 mm in 2022, slightly higher than the climatological value (2,161.1 mm) by approximately 3.9%. The total precipitation in 2022 did not differ a lot from the past 3 decades. However, the distribution was not even across regions and months. By region, precipitation was below normal levels in most parts of Taiwan except in the southwest area. By timeline, above-normal precipitation that mainly came from the Meiyu (plum rainy season, plums are usually ripe in the duration of late spring and early summer) in June and typhoons in summer (Central Weather Bureau, 2023). Besides, Taiwan just experienced extreme drought conditions and severe water shortages during June 2020 and May 2021 (Vision Project, 2023). When the water levels in reservoirs are at their lowest, farmlands in severely drought-affected areas are forced to lie fallow. In 2021, the statistics show that the fallow area reached 74,370 ha (Liberty Times Net, 2021).

As mentioned above, Taiwan experienced significant climate abnormalities and extreme events in these years compared to the past decades. The annual mean agriculture loss caused by natural disasters was NT\$11 billion (about US\$341 million) from 1996 to 2022, and NT\$12 billion (about US\$372 million) from 2016 to 2022, respectively (Council of Agriculture, 2023a). The data shows that annual agriculture loss fluctuated during the past 3 decades. However, as the timeline moved, the peak and annual mean loss increased significantly. In 2020, the loss rose sharply to more than NT\$16 billion (about US\$496 million) due to the severe drought in the first half and torrential rain caused by a typhoon in August (Figure 3). As agriculture production is vulnerable to weather factors, Taiwan had made *Agriculture Natural Disaster Relief Act* which farmers could apply for cash relief or low interest loan. The MOA had been inputting a large investment to cope with the impacts of climate change since 1990s, with 6 adaptation strategies which include protection of water resources and the environment, doing research work on climate-smart agricultural technology, building early warning and adjustment mechanisms of business model, establishing disaster warning and response system, and developing disaster relief and agriculture insurance.

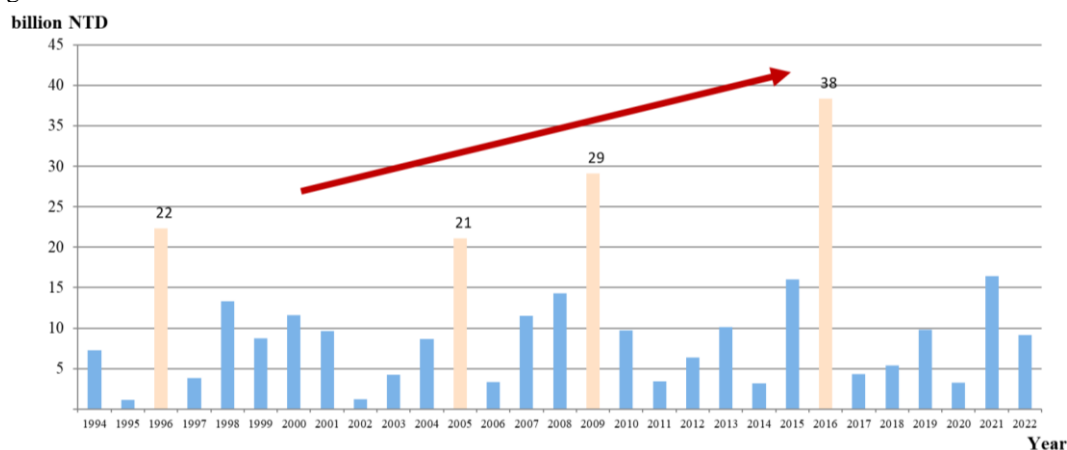


Figure 3. Agriculture loss from climate disasters in Taiwan from 1994 to 2022

#### FOUR PILLARS SUPPORTING THE AGRICULTURE SECTOR TOWARDS NET-ZERO EMISSIONS

Climate change and its impacts have long been hot issues in seminars, forums, workshops, symposiums, and Conference of the Parties (COPs). Nevertheless, only a few countries really did fast and specific reactions to fight or slowdown the impacts caused by climate change. According to Working Group III Contribution to *The IPCC Sixth Assessment Report (AR6)*, global net GHG emissions were 59±6.6 Gt CO<sub>2</sub>-e in 2019, about 12% higher than in 2010 and 54% higher than in 1990. The annual average during the decade 2010–2019 was 56±6.0 Gt CO<sub>2</sub>-e, which is 9.1 Gt CO<sub>2</sub>-e higher per year than that of 2000–2009. This is the highest increase in average decadal emissions on record (Intergovernmental Panel on

Climate Change, 2022). Currently, there are more than 130 countries that have declared their determination to reach net-zero emissions by 2050. Taiwan is of course one of them. In March 2022, Taiwan officially published *Taiwan's Pathway to Net-Zero Emissions in 2050*, which provides the action pathway to achieve "2050 Net-Zero Emissions." The blueprint aims to promote technology research and development (R&D) and innovations in key areas, facilitate the green transition of the industry, and drive a new wave of economic growth. At the same time, it looks forward to promoting green financing and increasing investments at various key milestones.

In the agriculture sector, the COA had set up the Climate Change Program Office (CCPO) on September 1, 2021, in order to specialize in adaptation and mitigation issues of climate change. February in 2022, Taiwan's agriculture sector proposed an ambitious goal that agriculture sector will reach net-zero emissions by 2040, which is 10 years earlier than the national goal. The roadmap to achieving Net-Zero Emissions in the agricultural sector consists of four pillars: reducing carbon emissions, enhancing carbon sinks, promoting circular agriculture, and encouraging green trends. These pillars encompass a total of 19 strategies with 59 measures. To address the challenges posed by climate change and the need for environmental sustainability, the COA initiated an organizational restructuring, officially becoming the MOA on August 1, 2023. A noteworthy aspect of this transformation was the creation of the "Department of Resources Sustainability." This department plays a central role in devising policies and strategies aimed at tackling climate change and advancing sustainable development. Its primary mission revolves around attaining the objective of achieving net-zero emissions in the agricultural sector, while simultaneously laying the groundwork for resilient agricultural practices.

### **Reduce Carbon emissions**

5 strategies have been identified to reduce the GHG emissions from agriculture sector, though the development of agricultural industry needs more and more input of electricity and fuel. The goal of 50% reduction of agriculture GHG emissions by 2040 is expected from the baseline of 7,994 kt CO<sub>2</sub>-e in 2005.

### ***Complete GHG statistics of agriculture industry***

The agriculture sector works hard to reduce GHG emissions, even if the sector isn't the main source of GHG emissions in Taiwan. A GHG information platform is expected to be well-constructed by 2024. The detailed GHG statistics and information are scheduled to be included in the platform. Researchers, officials, as well as stakeholders will be able to access GHG emission data related to agriculture, crops, livestock, and fisheries from the platform. Estimates, such as mitigation potential and carbon footprint, can then be derived using sectoral approaches wherever data is available.

### ***Establish low-carbon crop cultivating models***

Measures including organic and eco-friendly farming, smart use of chemicals and pesticides, integrated pest management (IPM), low or no tillage farming, energy-saving machinery and greenhouse are encouraged in Taiwan to reduce CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub> emissions through farm practices. Milestones are also set as follows:

1. Reach 45,000 of organic and eco-friendly farming area by 2040, with an annual reduction in the usage of 200 tons pesticides and 20,000 tons of chemical fertilizers is expected.
2. Use half the quantity of chemical fertilizers and pesticides by 10 years, by means of promoting the use of organic fertilizers and biological control of insects and microorganisms.
3. Adopt low or no tillage approaches on more than 50,000 ha of farmlands by 2040.
4. Use more power electricity for main farm machineries instead of fossil fuel.
5. Adopt adjusted water management practice to more than 40,000 ha of rice cultivation for methane emission reduction by 2040.

### ***Establish low-carbon animal raising models***

A series of studies on the feasibility of low GHG emission animal raising models through changing feed formulations and management have been conducted, hence measures such as the use of feed rice instead of imported corn in feed formulation; the replacement of grains by digestible agricultural byproducts; the application of probiotics; the adoption of water saving livestock housing have been promoted.

### ***Establish low-carbon fishing models***

Aquaculture fishers are encouraged to replace the traditional aerator to an energy saving type. The Fishery Agency has scheduled to subsidize fishermen for more than 5,000 energy saving aerators in the coming years. Fish attracting lamps are also encouraged to be replaced by high energy efficient type, with a milestone of more than 80% of the attracting lamps to be replaced in the coming few years.

### ***Conduct science research in carbon reduction***

R&D budgets for carbon reduction have been allocated in the coming years. The major fields include:

1. Breeding of varieties suitable for low input and low carbon cultivation systems;
2. The development of low GHG emission fertilizers, and their practices;
3. Precision nutrition feed formulation with high efficiency and better performance for livestock husbandry; and
4. Development of energy saving machineries and devices.

### **Enhance Carbon sinks**

Agricultural land and ecosystem are powerful carbon sink sources for absorbing anthropogenic CO<sub>2</sub> emissions. Both nature-based and technology-based solutions are important on the way toward net-zero emission. Nowadays, more and more industries are trying their best to reduce GHG emissions. However, GHG reduction has its limitations. It's impossible to expect a product that has zero GHG emission during the process of manufacturing and processing. Therefore, carbon capture, utilization and storage (CCUS) maybe one of the solutions to offset the remaining GHGs that are difficult to reduce. Photosynthesis is an elaborated designed carbon capture system made by nature. Agriculture can be a unique sector with a high power of natural carbon sinks, when the carbon captured by photosynthesis can be effectively used and stored in forests, soil and marine life. Seven strategies with 16 measures have been identified for targeting 10 megatons CO<sub>2</sub>-e carbon sink additionally (the currently existed 21,905 kt CO<sub>2</sub>-e carbon sink is excluded) by 2040.

### ***Enhance forest area***

Forest is one of the most familiar options to offset emissions or sequester CO<sub>2</sub> from the atmosphere. Under careful investigation, marginal rural farmlands with low productivity will be encouraged to afforest. Urban forests are also encouraged in public work. A total increase of 12,600 ha forest with 107 thousand tons of CO<sub>2</sub> absorbing potential annually is expected by 2030.

### ***Increase usage of domestic timber***

Wood used in construction may reduce GHG emissions associated with steel and concrete use. Wood is also an ideal carbon storage sink. In Taiwan, domestic timber is now only supplied less than 2% corresponding to the annual demand. By introducing the “Domestic Timber and Bamboo Certification Mark (the “Taiwan Wood” mark)”, a traceable Taiwan wood system, and other co-benefit measures, it is expected that the self-sufficiency of domestic timber will reach 10% by 2040. This implies an annual supply of at least 200,000 cubic meters of certified Taiwan wood.

### ***Improve management of forests***

Measures of protecting forests involve reducing drivers of deforestation and forest degradation, which can be achieved by establishing well designed management system, including improvement of law enforcement, forest governance and management. Besides, bamboo is also an important forest type in Taiwan, with high CO<sub>2</sub> removal potential which comes from efficient photosynthesis. In order to further strengthen the carbon sink capability of bamboo, Taiwan is promoting the renewal of old bamboo forests. By 2040, the well designed and managed forest area is expected to increase to more than 66,000 ha and the renewed bamboo forest area to reach 80,000 ha.

### ***Improve management of agricultural soil***

Agriculture provides another carbon removal avenue with high potential through good management of cropland and grassland soil. Increasing soil organic matter in croplands is critical, practices include crop management, fertilization with organic amendments / green manures, reducing tillage intensity, residue retention, and even biochar application.

### ***Negative emission farming models***

Promotion of improved crop varieties, crop rotation, use of cover crops, deep rooted grasses, perennial cropping systems and integrated production systems are farming models for negative carbon emission. Appropriate use of agricultural residues and byproducts can increase soil organic matter and productivity. Soil carbon management as a carbon sink in croplands is a low-cost option at a high level of practical readiness, but with difficulty in monitoring and verification proving as a barrier to implementation.

### ***Improve management of ocean & wetland***

This strategy aims at (1) the development of approaches to increase carbon sink in maritime space, (2) the conservation of wetlands and (3) the development of approaches which are under the Measurement, Reporting and Verification (MRV) principle for marine fisher and aquaculture fishery.

### ***Science research in carbon sink***

The research focuses on (1) the improvement of soil carbon sink and development of carbon-negative cropping system, (2) the evaluation of marine and fishery carbon sink, (3) promotion of carbon sink by forest management and (4) the methodology of marine and wetland conservation. A four-year project has been approved for the aforementioned researches.

### ***Encourage the adoption of circular agriculture***

Bio-energy and bio-based options could be important opportunities for mitigation potential. The solid wastes generated from agriculture sector amounted to 5.069 million ton (Mt) with well-treatment rate of 100 % in 2021. The treatment rate increased by 4.7 % compared with 10 years ago, according to the data announced in Taiwan's Environmental-Economic Account (Council of Agriculture, 2023b). The wastes will be no longer wastes if they can be reused and recycled appropriately, they will become renewable resources. Most of the wastes from agricultural sector are bio-derived resources. They could be recycled as ingredients, raw material of other products, or transformed into bio-energy. Bio-energy and bio-based products provide additional mitigation by the substitution of fossil fuels and fossil-based products. Under this pillar, 3 strategies with 12 measures have been identified for a zero-waste agriculture in Taiwan by 2040.

### ***Change agricultural wastes into resources***

Appropriate reuse of agricultural wastes possesses high mitigation potentials. The MOA encourages livestock farmers to reuse the pig droppings for power generation and help them to enhance the conversion efficiency. The biogas residues were recycled as organic fertilizer. Crop and forestry residues are also ideal ingredients for organic fertilizers or the feedstocks of biochar. Biochar is produced by heating organic matter in oxygen-limited environments with byproducts such as wood gas, pyrolygneous acid and tar. It is estimated to persist from decades to thousands of years when biochar is applied into soil. Soil application plus bioenergy gives a greater mitigation contribution than bioenergy alone. Taiwan is now conducting a guideline for biochar quality control and its application.

### ***Promote economically viable cross-industry circular agriculture***

Circular agriculture should be a co-benefit and economically viable before its scaled application. This strategy tries to build cross-industrial business models for reusing the agricultural residues efficiently and economically. More than one thousand plants/factories are expected by 2040.

### ***Science research in circular agriculture***

Detailed calculation of the mitigation contributions and benefits of circular agriculture is very important for its application and promotion, especially when the carbon credits are considered. This strategy focused on the calculation of carbon flux during the process of residues that were reused or recycled. The development of science-based and technology-based approaches are also concerned. For example, climate change brings extreme weather disasters like drought, thus water treatment and management models for livestock and aquaculture fishery are critical. These approaches not only have mitigation potential but can also improve the efficiency of water use and improve resilience in facing climate change.

### **Promote green trend**

A concrete, sustained and effective mechanism for all stakeholders is the prerequisite for achieving net-zero emissions. In Taiwan, more than 97% of energy used was imported in 2022 (Energy Administration, 2023a). Transformation of energy structure has been taken place for a decade, in order to increase the share of indigenous energy and shift the energy composition. Renewable energy is on the top priority in Taiwan, not only for energy structure transformation but also a critical option toward net-zero emissions. In addition to renewable energy, policies and regulations play a necessary role in carrying out long term practicable projects. The agriculture sector or rural areas are potential main territories for carbon sinks, agricultural circulation, biofuel and renewable energy. Significantly, the agriculture sector is also responsible for food security, ecosystem services, and farmers' interest that must be guaranteed while assisting toward the goal of net-zero emissions. Rural areas provide lots of crops and forestry residues which are good sources for energy generation as well as biochar. Besides, it's crucial to construct a net-zero-emissions-friendly environment in order to lead farmers, consumers and even industries into a greener pathway. Related measures include carbon pricing, green finance, product carbon footprint, education, etc.

### ***Increase renewable energy from rural villages***

The combination of farm production and green energy generation is a promising way targeting net-zero emissions. Agricultural facilities, fish farms and farmlands with low productivity are the main fields for photovoltaics. Nevertheless, land resources are not rich in Taiwan, so how to maintain agriculture and aquaculture productivity must be carefully considered in advance. Related acts stipulate that productivity must maintain more than 70% when compared with conventional farming both in agro-photovoltaics and symbiosis of fishery and electricity. Policies encourage farmers to install photovoltaics on the top of greenhouses, livestock house and indoor aquaculture. The installed photovoltaics capacity in agriculture sector have reached 2.16 Gw, 22.5% of the total Taiwan solar power generation in 2022 (Energy Administration, 2023b). Rural villages are also encouraged to use natural flow of moving water to generate electricity.

### ***Promote carbon pricing scheme in agriculture***

Agriculture and forestry account for large share of emission reduction and carbon offset. Nature-based solutions play a key role in coping with climate challenges currently and in the future. *The GHG Offset Project* promulgated by the Ministry of Environment, Taiwan gives an opportunity for the agriculture sector. Farmers could get additional benefits if they adopt operations with carbon reduction or carbon sink increase credits. Methodologies and their corresponding MRV mechanisms are currently under construction.

### ***Promote green finance and green consumption***

The Financial Supervisory Commission, Taiwan stipulates that the listed companies have to make an inventory of GHGs since 2023 and be verified since 2027. Those companies are also required to announce their environment, social, governance (ESG) activities in their sustainability report. Agricultural authority is conducting packages that are fit for ESG requirements, and inviting enterprises to join together for a win-win achievement. Green consumption is becoming more and more important and popular in now and future. Carbon Footprint-Product Category Rule for a wide range of agricultural products are currently being developed to provide guidance on calculating the GHG emissions of products. Businesses are encouraged to apply for carbon footprint tags for their products. Consumers are also encouraged to change their consumption behavior by choosing products with a low carbon footprint, in order to implement lifestyle transition.



### Science research in green trend

Supply chain management is very important for agriproducts. The policy instruments must be based on feasible science and technology. This strategy focuses on innovations for providing opportunities to lower emissions and reduce emission growth in the process of supply chain management, and create social and environmental co-benefits. Besides, talent training programs are also included.

The aforementioned strategies to address climate change include existed and emerging technologies with low emission or carbon removal potential. It needs public-private entities' cooperation from all stakeholders. According to the scheduled measures to be adopted, Taiwan's agricultural sector is able to target net-zero emissions by 2040. The annual reduction is estimated to reach 7,630 kt CO<sub>2</sub>-e, which includes 1,135 kt CO<sub>2</sub>-e energy related reduction, 1,344 kt CO<sub>2</sub>-e reduction from crop & animal cultivation and 5,151 kt CO<sub>2</sub>-e from renewable energy & waste recycle. The total carbon sink will be 6,159 kt CO<sub>2</sub>-e, from forest, soil and ocean with 1,411, 4,716 and 32 kt CO<sub>2</sub>-e, respectively (Figure 4).

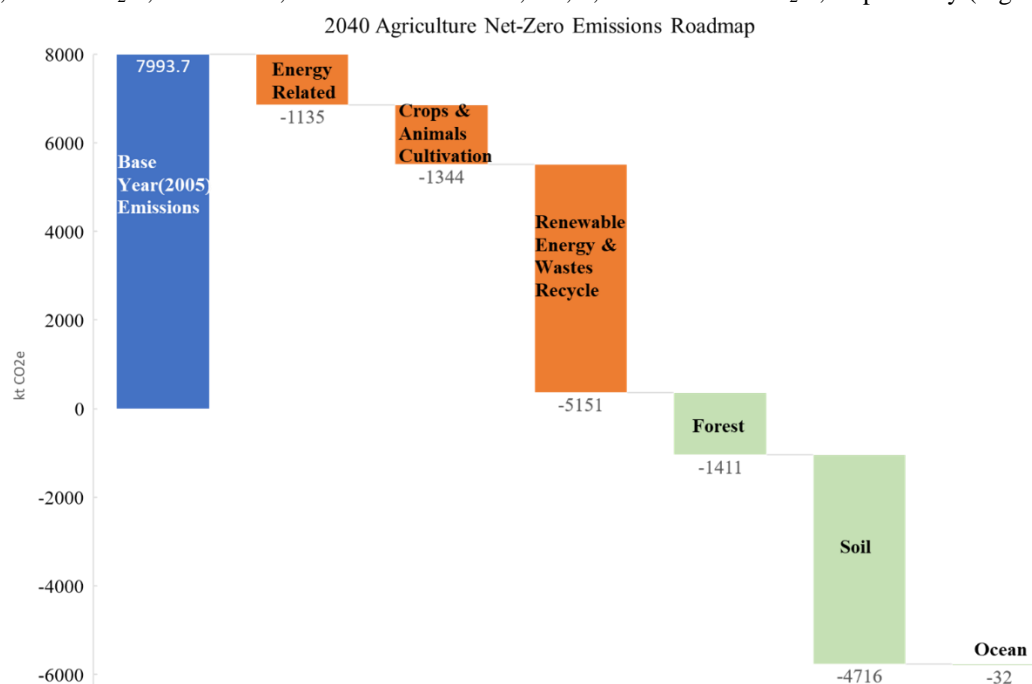


Figure 4. Agriculture net-zero emissions roadmap in 2040

## CONCLUSION

Growth in GHG emissions has persisted across almost all countries, sectors and groups of emission sources during the past few decades. President Tsai declared on the Earth Day on April 22, 2021 that the “2050 Net-Zero Transition” is Taiwan’s goal as well as a global consensus. Taiwan’s pathway to net-zero in 2050 has been officially published following the said declaration. Furthermore, the MOA has announced the roadmap to net-zero in the agriculture sector by 2040, depends on the potential of nature-based solutions in the agriculture sector. Taiwan is striving to make contributions on global climate change crisis. The agriculture sector has been allocated a total of more than NT\$3 billion (about US\$93.8 million) for the following 4 years for supporting the measures covered by the 4 pillars and 19 strategies mentioned above. A series of training courses are also well designed and scheduled for enabling stakeholders across agricultural industries. Moreover, talents in public and private departments are encouraged to exchange opinions and share their experiences with sectors involved in facing climate challenges, both domestically and internationally.

## REFERENCES

Special issue: Synergies of Adaptation and Mitigation for Sustainable Climate-Resilient Agriculture:  
Perspectives and Policy Implication

- Central Weather Bureau. (2022). Taiwan's climate in 2021. Annual Climate Report 2021. Taipei, Taiwan.
- Central Weather Bureau. (2023). *Taiwan's climate in 2022*. Annual Climate Report 2022. Taipei, Taiwan.
- Council of Agriculture, Forestry Bureau. (2020). *The Fourth Forest Resource Survey Report*. Retrieved from <https://www.forest.gov.tw/0002393> (Nov. 8, 2023)
- Council of Agriculture. (2023a). *AG. STATISTICS YEARBOOK 2022*. Taipei, Taiwan.
- Council of Agriculture. (2023b). *Agricultural statistics query - Green national income account agricultural solid waste annual table*. Retrieved from <https://agrstat.moa.gov.tw/sdweb/public/common/Download.aspx> (Nov. 8, 2023)
- Energy Administration. (2023a). *Energy Statistics Information System*. Retrieved from [https://www.esist.org.tw/publication/monthly\\_detail?Id=1b14a5cffb2d](https://www.esist.org.tw/publication/monthly_detail?Id=1b14a5cffb2d) (Nov. 8, 2023)
- Energy Administration. (2023b) *Various types of renewable energy device capacity*. Retrieved from [https://www.moeaea.gov.tw/ECW/populace/opendata/wHandOpenData\\_File.ashx?set\\_id=253](https://www.moeaea.gov.tw/ECW/populace/opendata/wHandOpenData_File.ashx?set_id=253) (Nov. 8, 2023)
- Intergovernmental Panel on Climate Change. (2022). *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, Eds.). Cambridge University Press, Cambridge, UK and New York, NY, USA. doi:10.1017/9781009157926
- Liberty Times Net. (2021). *Taoyuan: 28,000 hectares of suspended irrigation, marking the largest area in 20 years, with 74,000 hectares in the first phase*. Retrieved from <https://news.ltn.com.tw/news/life/breakingnews/3401972> (Nov. 8, 2023)
- Ministry of Agriculture. (2023). *Agricultural and Agricultural Land Resources Survey Results Inquiry Map - 2022 National Survey Results Statistical Table*. Taipei, Taiwan.
- Ministry of Environment. (2023). *National Greenhouse Gas Inventory Report 2023*. Taipei, Taiwan.
- The Guardian. (2022). *More than 400 weather stations beat heat records in 2021*. Retrieved from <https://www.theguardian.com/world/2022/jan/07/heat-records-broken-all-around-the-world-in-2021-says-climatologist> (Nov.8, 2023)
- Vision Project. (2023). *Scorching Water: A Chronicle of Water Scarcity in Taiwan" and "The Ordeal of Mother River*. Retrieved from <https://visionproject.org.tw/story/6669> (Nov. 8, 2023)