# Zhejiang Carbon Neutrality Planning Research

# Executive Summary

## 1. Current economic development and foundations for emissions reduction

Zhejiang Province is one of the most dynamic and promising regions in China. In 2023, the province's GDP reached RMB 8.26 trillion, ranking fourth nationwide, with a year-on-year growth rate of 6.0%. The industrial structure has shifted toward a service-oriented economy, with the primary, secondary, and tertiary sectors accounting for 2.8%, 41.1%, and 56.1% of GDP, respectively. By the end of 2024, the province had a permanent population of 66.7 million, and its urbanization rate rose to 75.5%. In terms of living standards, the per capita disposable income reached RMB 67,013, while per capita consumption expenditure amounted to RMB 45,107, both indicators placing Zhejiang among the leading provinces nationwide.

In recent years, Zhejiang Province has continued to optimize its industrial structure, with accelerated upgrading of the manufacturing sector and the rapid rise of the digital economy and high-tech industries as new drivers of economic growth. From the perspective of shifts within the manufacturing sector, the top six subsectors remained relatively stable during 2017 to 2022: electrical machinery and equipment manufacturing, chemical raw materials and chemical products manufacturing, computer, communications, and other electronic equipment manufacturing, general equipment manufacturing, automobile manufacturing, and textiles. Together, these six subsectors account for more than half of the province's total manufacturing output, forming the core foundation of Zhejiang's industrial competitiveness.

Electrical machinery and chemical production are the two pillar industries of Zhejiang Province, with their combined share of manufacturing output increasing from 19.9% in 2017 to 23.7% in 2022, reflecting a further strengthening of their strategic position. In response to China's "dual-carbon" goals, the traditional electrical machinery sector is undergoing a transition toward new energy equipment and intelligent electrical manufacturing. As a fundamental and pillar industry of the national economy, the chemical sector, which is characterized by its large scale, high inter-industry linkage, and strong driving effects, is advancing toward greener and more environmentally friendly development. Zhejiang is prioritizing the growth of new chemical materials and high-end specialty chemicals while upgrading traditional fine chemical production. The equipment manufacturing industry, especially high-end equipment manufacturing, has made a substantial contribution to provincial economic growth and has become an essential pillar of Zhejiang's industrial system. Meanwhile, textiles, one of Zhejiang's traditional competitive industries and a key livelihood sector, have an annual output exceeding RMB 1 trillion. However, textile enterprises still face challenges associated with high energy consumption and emissions, making low-carbon transformation and upgrading imperative under the carbon peaking and carbon neutrality agenda.

From 2017 to 2022, Zhejiang Province's total energy consumption increased from 210 million to 270 million tons of coal equivalent. In terms of the energy mix, the shares of coal and oil in primary energy consumption declined by nearly 10 percentage points, while the proportion of non-fossil energy, primarily electricity, rose by 6.7 percentage points. Coal experienced the largest drop, falling from 48.6% to 42.9%, and oil declined from 17.9% to 13.7%. Natural gas, as a relatively cleaner fossil fuel, increased its share to 8.8%. Although Zhejiang's dependence on fossil fuels has gradually decreased in recent years, the share of coal consumption remains relatively high, and the province's electricity demand has become increasingly reliant on power imports from outside the region. From the perspective of the electricity supply structure, Zhejiang's electricity consumption grew steadily from 403.7 TWh in 2017 to 563.4 TWh in 2022. The gap between electricity demand and in-province generation has widened over time, leading to a rising dependence on imported electricity.

According to Zhejiang Province's 2020 greenhouse gas emissions inventory, the province's net $CO_2$ emissions reached 400 million tons. Of this total, energy-related

$CO_2$ emissions accounted for 389 million tons, industrial process emissions, which primarily come from cement production, amounted to 34 million tons, and land use and forestry contributed a carbon sink of 27 million tons.

From 2017 to 2020, carbon emissions from fossil fuel combustion in Zhejiang Province remained relatively stable. After 2021, emissions began to rise rapidly, reaching 475 million tons in 2022[1] (Fig. 1). Structurally, the shares of carbon emissions from coal and oil combustion declined significantly, while the contribution from natural gas increased slightly. Notably, the share of emissions embodied in imported electricity rose markedly. Zhejiang's dependence on external electricity supplies has continued to deepen, with most of the incremental imports in recent years originating from coal-fired power in provinces such as Ningxia and Anhui. Reflecting the changes in the province's energy mix, the sharp increase in energy-related carbon emissions in recent years has been driven primarily by rising in-province coal consumption and higher volumes of imported coal-fired electricity. Overall, Zhejiang's energy consumption structure remains dominated by coal, indicating that the province has yet to fully transition away from coal-intensive energy use.

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[1] This dataset includes carbon emissions associated with imported electricity. Based on historical data from Zhejiang's provincial energy balance sheets, emissions from purchased electricity are estimated using a $CO_2$ emission factor of 0.5422 kg/kWh. According to the annual provincial power balance sheets, the composition of Zhejiang's imported electricity varies considerably across years. The volume of imported clean hydropower and nuclear power has remained relatively stable at more than 70 billion kWh, while the remaining imported electricity is primarily coal-fired power from provinces such as Anhui and Fujian, as well as the Ningxia and Xinjiang regions. To account for interannual differences in the actual structure of imported electricity, the calculation of $CO_2$ emissions in each year uniformly deducts 70 billion kWh of clean electricity from the total imported electricity. The resulting net coal-based imported electricity is then converted to $CO_2$ emissions using the latest province-level average power-sector $CO_2$ emission factor for Zhejiang, as reported in the national guideline *"China's Power Grid Average CO2 Emission Factors 2021"*.

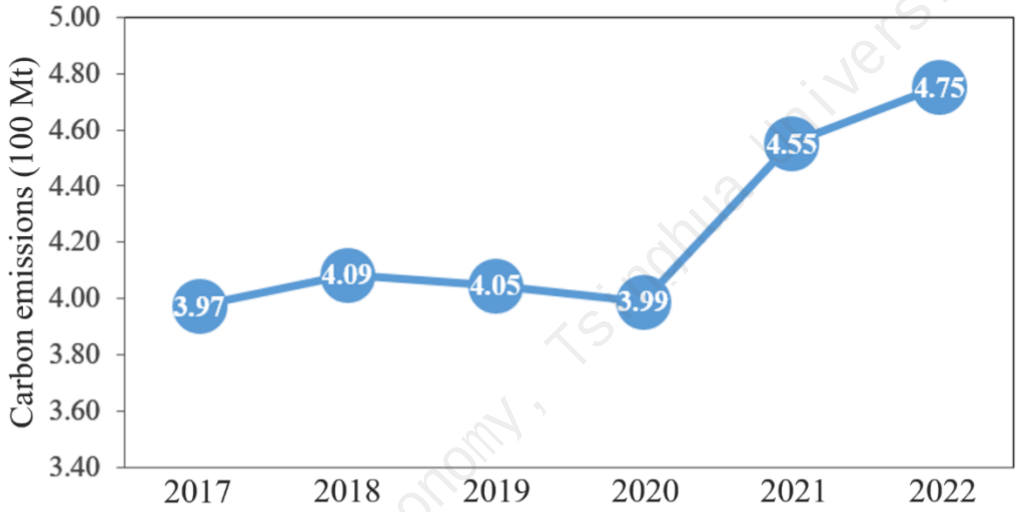


**Fig. 1 Changes in carbon emissions from energy consumption in Zhejiang Province, 2017 to 2022.**

*Source: Compiled from the Zhejiang Province energy balance sheets in the "China Energy Statistical Yearbook".*

In pursuit of its carbon peaking and carbon neutrality goals, Zhejiang Province faces a challenging emissions reduction outlook, primarily reflected in three aspects: high abatement costs, limited capacity for low-carbon transition, and the considerable difficulty of achieving carbon neutrality. As a coastal economic powerhouse dominated by light industry, Zhejiang has relatively high energy efficiency and low energy intensity per unit of GDP. This leaves limited room for further efficiency gains, meaning additional emissions reductions will increasingly rely on technological upgrades and equipment replacement, which are both associated with higher marginal abatement costs. Zhejiang is also characterized by a vibrant private-sector economy, with a large number of small and micro enterprises. While this economic structure provides strong dynamism for regional development, the low-carbon transition capacity of these smaller market entities remains limited. The province is therefore implementing a series of policy measures to strengthen its capabilities and support its transition. Although Zhejiang is expected to reach its emissions peak around 2030, achieving a sustained and substantial post-peak decline will be highly challenging, making the pathway toward carbon neutrality particularly demanding.

## 2. Target setting

In recent years, studies assessing national and provincial carbon peaking trends generally conclude that China is likely to achieve its national carbon peak before 2030. However, projected peak levels vary considerably across models, ranging from approximately 9.64 to 12.2 billion tons. For Zhejiang Province, most assessments suggest that the province is likely to peak earlier than the national average, with the peak year concentrated around 2025. Regarding carbon neutrality, existing research largely focuses on mid-term to long-term trajectories between 2030 and 2035. Looking toward 2050 and 2060, national projections indicate that China's emissions will need to fall to around 4 billion tons by 2050 and further decline to roughly 1 billion tons by 2060, with the remaining gap offset by carbon sinks.

Considering the substantial uncertainties in achieving carbon neutrality, and given that the national *"Work Plan for Accelerating the Establishment of a Dual-Control System for Carbon Emissions"* provides relatively clear requirements for provincial carbon control before 2035, this study sets emissions targets for three key milestones: a carbon-peaking target before 2030, a 2035 target that reflects the post-peak transition toward carbon neutrality, and a 2050 outlook consistent with the long-term national vision for carbon neutrality.

In line with the requirements of relevant national documents, this study assumes that Zhejiang Province will follow the national approach. During the 15th Five-Year Plan period, priority will be given to controlling carbon intensity, using intensity constraints to guide total emissions control so that the growth of total emissions remains within a reasonable range and an early carbon peak can be achieved. During the 16th Five-Year Plan period, total carbon emissions control will become the primary mechanism, supplemented by carbon intensity constraints, with the aim of reducing emissions intensity to levels comparable to global advanced standards. From 2035 to 2050, total carbon emissions control will remain the core focus, ensuring that total emissions fall within a trajectory consistent with the national carbon neutrality goal, while driving continuous reductions in emissions intensity toward world-leading levels.

The determination of Zhejiang Province's carbon peaking and carbon neutrality targets must take into account both national requirements and the province's own emissions trajectory and abatement context. Given that the national carbon intensity and total emissions control targets for 2030 and 2035 have not yet been specified for Zhejiang, this study preliminarily estimates the province's carbon peaking and carbon neutrality targets based on observed emissions trends and the current challenges associated with emissions reduction.

According to Zhejiang Province's 2020 greenhouse gas inventory, the province's net $CO_2$ emissions amounted to 400 million tons, including 389 million tons of energy-related $CO_2$ emissions, 34 million tons from industrial processes such as cement production, and a carbon sink of 27 million tons from land use and forestry. In recent years, the share of fossil fuels in Zhejiang's energy consumption has gradually declined, while the proportion of imported electricity has increased. However, given the significant uncertainty in the composition of imported electricity and the fact that Zhejiang has no control over the power generation mix outside the province, carbon emissions embodied in imported electricity cannot be restricted or regulated when formulating the province's carbon peaking and carbon neutrality targets. Moreover, although carbon neutrality encompasses non-$CO_2$ greenhouse gases, methodological frameworks for their accounting remain insufficiently mature. Zhejiang's industrial structure is dominated by the light industry, and emissions of non-$CO_2$ greenhouse gases are relatively small and can be reasonably omitted at this stage. Therefore, the carbon peaking and carbon neutrality targets discussed here primarily focus on $CO_2$ emissions from fossil fuel combustion within the province.

The determination of Zhejiang Province's carbon peaking and carbon neutrality targets must take into account several key factors.

First, the long-term economic development objectives for 2035: From the objectives, GDP, GDP per capita, and per capita income should all "double" relative to their 2020 levels. To meet this requirement, Zhejiang's GDP would need to exceed RMB 10.67 trillion by 2030 and RMB 13.5 trillion by 2035. This implies that from 2020 to 2030, the province must sustain an average annual growth rate of more than 5.1%, and from 2030 to 2035, an average rate of more than 4.8%. Assuming Zhejiang's GDP reaches RMB 15 trillion by 2050, the average economic growth rate between 2035 and 2050 would need to remain above 0.7%.

Second, the carbon peaking commitment: Zhejiang Province has pledged to reach its carbon emissions peak before 2030 and to reduce carbon emissions per unit of GDP by more than 65% compared with 2005. By 2030, $CO_2$ emissions from fossil fuel combustion in Zhejiang are expected to reach more than twice the 2005 level, approximately 500 million tons (excluding indirect emissions embodied in imported coal-fired electricity). If the actual emissions peak occurs earlier than 2030, the peak level would likely exceed 500 million tons.

Third, the national carbon peaking and carbon neutrality goals: China aims to peak carbon emissions before 2030 and achieve carbon neutrality before 2060, and Zhejiang is expected to reach both milestones ahead of the national schedule. Currently, Zhejiang's energy-related $CO_2$ emissions account for roughly 4% to 5% of the national total. Assuming this proportion remains stable through the peaking and neutrality stages, Zhejiang's energy-related $CO_2$ emissions would peak at approximately 400 to 420 million tons in 2030 (including indirect emissions from imported coal-fired electricity). If imported electricity is assumed to contribute around 10% of total emissions, emissions from in-province fossil fuel combustion would be approximately 360 to 380 million tons, which is significantly lower than the level implied by Zhejiang's self-declared target. Looking toward the national carbon neutrality goal, Zhejiang's fossil fuel combustion emissions would need to fall to 100 to 200 million tons by 2050, requiring an annual emissions reduction rate of 4.5% to 7.7%. This is considerably higher than the typical annual reduction rates (1% to 2.5%) observed in countries and regions that have already passed their carbon peak. Therefore, this study argues that Zhejiang's self-committed peaking level appears overly high, and that a more reasonable target, which is based on Zhejiang's proportional share of the national theoretical emissions peak, is around 380 million tons of fossil fuel $CO_2$ emissions, corresponding to an emissions intensity of roughly 0.36 tons per RMB 10,000 of GDP.

In summary, Zhejiang Province's carbon peaking and carbon neutrality targets for 2030, 2035, and 2050 are shown in Table 1. Before 2030, emissions will be constrained primarily through an intensity-based target, with $CO_2$ emissions per unit of GDP set at 0.36 tons per RMB 10,000, which is below the current global average of 0.57 tons per RMB 10,000, and ensuring that total $CO_2$ emissions peak within 380 million tons while supporting continued economic growth. After peaking, total emissions control becomes the main constraint. By 2035, the province aims to limit total $CO_2$ emissions to 330 million tons, with emissions intensity reduced to 0.26 to 0.28 tons per RMB 10,000. By 2050, the target is 100 to 200 million tons of $CO_2$ emissions, with emissions intensity falling to 0.07 to 0.14 tons per RMB 10,000, reaching levels comparable to current world-leading economies.

**Table 1. Carbon peaking and carbon neutrality targets for Zhejiang Province.**

| Key Milestone and Carbon Control Indicators | Unit | Target Value |
| --- | --- | --- |
| 2030 Carbon emissions intensity | tons per RMB 10,000 | 0.36 |
| 2035 Total carbon emissions | 100 million tons | 3.3 |
| 2050 Total carbon emissions | 100 million tons | 1.0 to 2.0 |

### 3. Scenario analysis

The Computable General Equilibrium (CGE) model is one of the most widely used quantitative analytical tools in international economic and public policy research. Its core advantage lies in its ability to represent the interlinked relationships among various sectors and accounting entities within the national economy. By capturing these structural interactions, the CGE model enables the simulation and prediction of the impacts of policies and economic activities on complex systems. As such, it has been extensively applied in areas including macroeconomic analysis, international trade, environmental policy, fiscal and taxation reform, and broader public policy evaluation.

Taking Zhejiang Province as the study object, this research develops a recursive dynamic CGE model that incorporates a learning-by-doing mechanism. The model consists of seven major modules: a production module, a final demand and trade module, a market share and relative price module, an investment module, market-clearing and macro-closure conditions, a carbon emissions module, and a learning-by-doing module. In the energy system representation, power generation technologies are disaggregated into four categories: thermal power, hydropower, wind and solar power, and nuclear power. A learning-by-doing mechanism is introduced to capture technological progress in all generation technologies except thermal and hydropower, thereby reflecting the endogenous improvement of emerging low-carbon and non-fossil power technologies over time.

The study defines the following scenarios:

(1) Baseline Scenario (BaU):

This scenario is primarily driven by the dynamic forces of economic development and does not incorporate major policy shocks or structural adjustments. Under this trajectory, technological progress leads to improvements in energy efficiency, while both industrial structure and household consumption patterns evolve gradually. The design of the baseline scenario requires projecting future trends in economic growth, investment expansion, and other macroeconomic parameters. In this scenario, total factor productivity (TFP) is derived endogenously by back-calculating from the exogenously specified GDP pathway.

(2) Policy Scenarios:

Several policy scenarios are constructed in this study, including a Low Carbon Tax scenario (LCT) and a High Carbon Tax scenario (HCT), in which carbon taxes are imposed exogenously with tax rates diverging after 2030. A Carbon Intensity Constraint scenario (CIE) is designed by exogenously specifying a carbon intensity control pathway, while a Total Carbon Emissions Constraint scenario ($TCO_2$) imposes exogenous total emissions caps. Under the $TCO_2$ scenario, carbon intensity serves as the primary control mechanism before 2035, and total emissions control becomes the dominant constraint after 2035 (see Table 2).

**Table 2. Key parameters for scenario design.**

| Scenario | Indicator | Unit | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| LCT | Carbon tax | RMB/ton | 62 | 129 | 347 | 559 | 821 | 1207 |
| HCT | Carbon tax | RMB/ton | 62 | 129 | 484 | 1204 | 1939 | 3060 |
| CIE | Carbon intensity | tons per RMB 10,000 | 0.484 | 0.356 | 0.258 | 0.211 | 0.172 | 0.140 |
| $TCO_2$ | Total emissions | 100 million tons | 3.87 | 3.93 | 3.26 | 2.70 | 2.23 | 1.85 |

Model simulation results indicate that Zhejiang's GDP continues to grow under the CIE and $TCO_2$ scenarios, while experiencing a slight decline under the LCT and HCT scenarios.

Zhejiang province's carbon emissions trajectory from 2024 to 2050 is shown in Fig. 2. In the baseline scenario, Zhejiang is projected to reach its carbon peak around 2031, with peak emissions of approximately 414.7 million tons. Compared with the baseline, all policy scenarios achieve substantial emissions reductions and advance the timing of the emissions peak. Under the $TCO_2$ scenario, total emissions are expected to peak as early as 2029. Between the LCT and HCT scenarios, a higher carbon tax produces greater long-term emissions reductions, in some cases surpassing those achieved under the CIE carbon intensity constraint scenario. Among the four policy scenarios, the $TCO_2$ total emissions control scenario delivers the most pronounced emissions reduction effects.

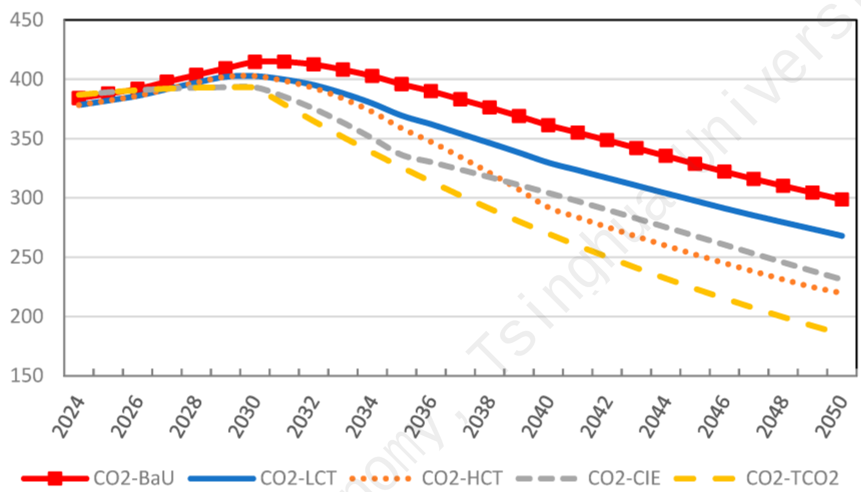


**Fig. 2 Carbon emissions trajectories of Zhejiang Province under different scenarios (unit: million tons).**

In terms of reducing carbon emissions intensity, the $TCO_2$ scenario also proves to be one of the most effective approaches, indicating that an exogenously imposed total emissions cap, as represented by the $TCO_2$ scenario, is the most viable pathway for achieving carbon neutrality. Moreover, by 2050, the carbon emissions intensity levels under the HCT and CIE scenarios converge, largely because the carbon tax implemented in the HCT scenario aligns with the implicit carbon price estimated under the CIE carbon intensity constraint scenario.

Sector-level carbon emissions intensity, which is defined as fossil-fuel-related $CO_2$ emissions per unit of output, captures how energy efficiency in each sector responds differently under various policy scenarios. As shown in Table 3, the four policy scenarios produce two sets of results for 2030, primarily because the carbon tax scenarios are designed to have identical tax levels before 2030, and the CIE and $TCO_2$ scenarios likewise share the same constraints during this period. In the short term, implementing a carbon tax exerts negative impacts on energy efficiency in agriculture and in labor-intensive, capital-intensive, and energy-intensive industries, while generating positive efficiency improvements in infrastructure and the tertiary sector. By comparison, the more ambitious emissions reduction constraints under the CIE and $TCO_2$ scenarios exert stronger negative effects on agriculture and most labor-intensive, capital-intensive, and energy-intensive industries (with the exception of mining). This suggests that, relative to carbon taxation, direct emissions-control policies produce a more pronounced enhancement of energy efficiency in infrastructure and service industries. The infrastructure sector includes power generation, transportation, water and gas supply, and construction. Because the transportation sector is grouped under infrastructure in this model, no substantial carbon-pricing effects are observed for transportation. This may be linked to price pass-through in intermediate inputs used in vehicle manufacturing, which is particularly relevant in the context of electric vehicle production.

**Table 3. Sectoral carbon emissions intensity under different scenarios in 2030 (unit: tons per RMB 10,000).**

| Sector | Baseline | LCT | HCT | CIE | $TCO_2$ |
|---|---|---|---|---|---|
| Agriculture | 0.2518 | 0.2524 | 0.2524 | 0.2574 | 0.2574 |
| Mining | 0.2336 | 0.2333 | 0.2333 | 0.2303 | 0.2303 |
| Food & Textiles | 0.2315 | 0.2317 | 0.2317 | 0.2335 | 0.2335 |
| Raw Materials | 1.4040 | 1.4046 | 1.4046 | 1.4115 | 1.4115 |
| Manufacturing | 0.0399 | 0.0400 | 0.0400 | 0.0433 | 0.0433 |
| Infrastructure | 3.5365 | 3.4050 | 3.4050 | 3.0880 | 3.0880 |
| Tertiary Sector | 0.0523 | 0.0521 | 0.0521 | 0.0510 | 0.0510 |

Table 4 shows that by 2050, differences in sectoral energy efficiency across scenarios widen considerably. In the long run, under the LCT and HCT scenarios relative to the baseline, a low carbon tax improves energy efficiency in all sectors except raw materials, while a high carbon tax generates negative efficiency impacts in most sectors except food & textiles, infrastructure, and the tertiary sector. In contrast, compared with carbon tax policies, the carbon intensity (CIE) and total emissions control ($TCO_2$) scenarios produce modest energy efficiency gains in agriculture, mining, raw materials, and manufacturing, but their positive effects are more pronounced for food & textiles, infrastructure, and the tertiary sector.

**Table 4. Sectoral carbon emissions intensity under different scenarios in 2050 (unit: tons per RMB 10,000).**

| Sector | Baseline | LCT | HCT | CIE | $TCO_2$ |
|---|---|---|---|---|---|
| Agriculture | 0.366 | 0.363 | 0.368 | 0.390 | 0.393 |

| | | | | | |
|---|---|---|---|---|---|
| Mining | 0.255 | 0.253 | 0.256 | 0.257 | 0.259 |
| Food & Textiles | 0.271 | 0.270 | 0.266 | 0.267 | 0.260 |
| Raw Materials | 1.001 | 1.002 | 1.004 | 1.021 | 1.017 |
| Manufacturing | 0.049 | 0.049 | 0.050 | 0.056 | 0.057 |
| Infrastructure | 2.149 | 1.770 | 1.151 | 1.116 | 0.568 |
| Tertiary Sector | 0.057 | 0.055 | 0.054 | 0.054 | 0.051 |

Fig. 3 illustrates the primary energy consumption structure under each scenario, disaggregated into four categories: coal, oil products, natural gas, and primary electricity (wind and solar). After the expected carbon peaking year of 2029, coal consumption declines significantly across all scenarios, while oil products replace coal as the dominant energy source. The share of natural gas also increases notably. In contrast, the share of primary electricity does not expand in response to carbon taxation or carbon pricing over the projection period. Comparing the LCT, HCT, and $TCO_2$ scenarios, stricter carbon control policies appear to accelerate the shift in the energy mix toward oil products rather than toward primary electricity, suggesting that carbon constraints alone are insufficient to drive a large-scale substitution toward non-fossil electricity in the absence of complementary structural or technological policies.

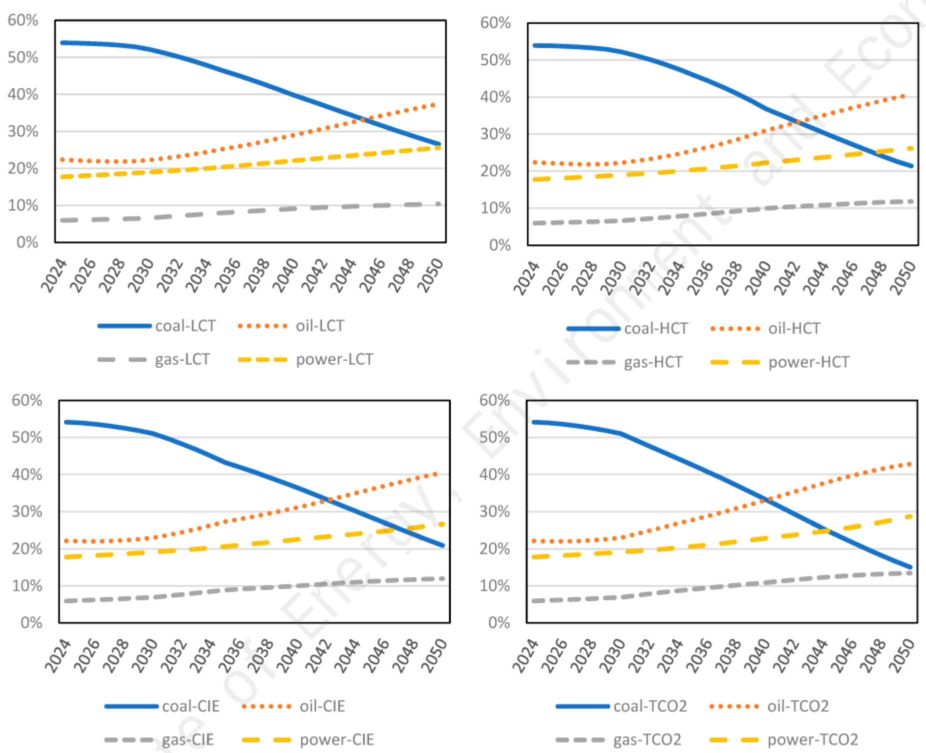


**Fig. 3 Primary energy consumption structure under different scenarios.**

A further comparison of the shares of different power generation technologies shows that, with the expansion of renewable energy and nuclear power, the proportion of thermal power declines significantly (Fig. 4). Overall, stricter carbon tax policies exert a stronger suppressive effect on thermal power generation, and more stringent emissions control targets lead to even more pronounced reductions. As one of the largest sources of $CO_2$ emissions, thermal power is increasingly displaced by renewable and other clean energy technologies.

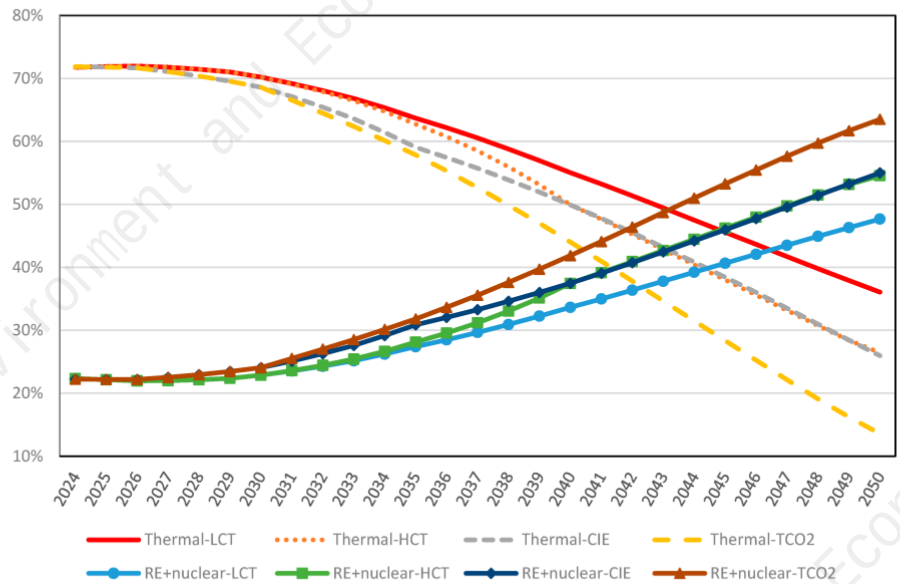


**Fig. 4 Power generation structure (excluding conventional hydropower).**

## 4. Pathways and measures

### 4.1. Improving energy efficiency and advancing low-carbon energy transition

For Zhejiang Province to sustain economic growth while reducing carbon emissions and to achieve its carbon peaking and carbon neutrality goals, the most critical requirement is the continuous reduction of carbon emissions intensity, which is measured as $CO_2$ emissions per unit of GDP. Carbon emissions intensity can be further decomposed into two components: energy consumption per unit of GDP, which reflects the energy efficiency of economic activities, and carbon emissions per unit of energy consumed, which reflects the carbon intensity of the energy structure.

As shown in Fig. 5, both energy consumption per unit of GDP and carbon emissions per unit of energy decline steadily throughout Zhejiang's transition toward carbon neutrality. Over time, however, the rate of decline differs between the two components: the reduction in energy consumption per unit of GDP slows gradually, while the reduction in carbon emissions per unit of energy accelerates, and the two trends reverse between 2035 and 2040. This indicates that in the short term, Zhejiang's low-carbon transition will be driven primarily by improvements in energy efficiency, with energy consumption per unit of GDP declining at an annual rate of more than 2.8% to 3.0%, thereby reducing overall carbon intensity. In the longer term, the transition will be dominated by the decarbonization of the energy structure, requiring carbon emissions per unit of energy to fall at an annual rate of more than 2.5% to 2.8%, which will become the main driver of continued carbon intensity reduction.

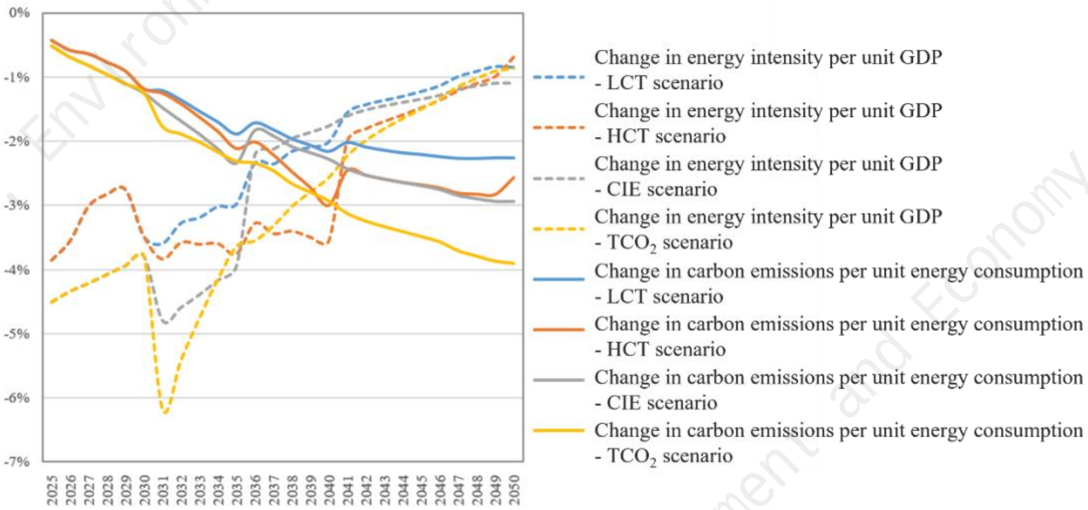


**Fig. 5 Changes in energy consumption per unit GDP and carbon emissions per unit energy.**

### 4.2. Industrial structure transformation

In the short term (2025 to 2030), both carbon tax policies and carbon emissions control targets drive Zhejiang's industrial structure toward a greater share of the tertiary sector, with the latter producing a more pronounced shift. Correspondingly, the shares of other sectors decline to varying degrees. Agriculture, mining, and food & textiles exhibit similar changes under both policy types, while raw materials, manufacturing, and infrastructure show clear policy-induced differences. Under carbon tax scenarios, the raw materials sector experiences the largest decline, with manufacturing and infrastructure showing comparable decreases. Under policy scenarios with endogenous carbon prices, manufacturing becomes the sector with the most significant contraction. Several factors explain these differences: First, an endogenous carbon price guides production factors toward high-value added, high-efficiency service industries through market price signals; Second, differences in asset specificity across sectors determine the relative speed at which they can adjust; and third is the choice of policy instrument directly shapes transformation pathways, where exogenous carbon prices rely more heavily on cost pass-through, and endogenous prices more readily stimulate technological innovation. These findings suggest that during the mid-term to short-term peaking phase, local governments should provide targeted policy support to facilitate low-carbon industrial restructuring, including linking with the existing “carbon efficiency code” to subsidize technological upgrades in manufacturing, reducing compliance costs for enterprises, increasing incentives for emission reductions among small and medium-sized firms, and strengthening training systems to enable the tertiary sector to absorb additional employment.

In the long term, industrial restructuring exhibits a clear pattern of policy-driven differentiation. Carbon tax policies (LCT/HCT) suppress energy-intensive sectors through price signals. For example, the share of the raw materials sector falls to 7.4% by 2050, while simultaneously driving a countercyclical expansion of the tertiary sector, whose share reaches 57.5% by 2040. However, this comes at the cost of reduced economic output, with stricter carbon taxes leading to greater economic losses. By contrast, scenarios with endogenous carbon pricing ($TCO_2$/CIE) enable a more comprehensive structural transformation through market adjustment. The share of the tertiary sector rises to around 60%, supporting GDP growth. Yet this improvement comes at the expense of weaker emissions reductions: carbon intensity control delivers higher economic output but lower abatement effectiveness compared with the total emissions control scenario. These long-term dynamics indicate that no single policy instrument can simultaneously achieve both emissions reduction and economic growth objectives. Going forward, a coordinated policy design that combines carbon taxation with market-based mechanisms, which is supported by technological upgrades to enhance energy efficiency in the service sector, will be essential to achieving a sustainable structural transition.

### 4.3. Energy structure transition

#### 4.3.1. Transformation of power supply

Zhejiang Province's economic development will continue to drive steady growth in electricity demand. Projections indicate that total electricity consumption in the province will increase by 15% to 20% between 2025 and 2050. Over this period, the role of thermal power will gradually diminish. In 2025, thermal power still accounts for 70% of local electricity generation and supplies more than half of total electricity demand. By 2050, under the influence of emissions reduction policies, the share of thermal power generation is expected to fall by 24% to 42%, resulting in a substantial gap in electricity supply.

As the share of thermal power gradually declines, the resulting gap between electricity supply and demand is primarily filled by local renewable generation, nuclear power, and imported electricity. However, given Zhejiang's relatively limited solar and wind resources, the potential for increasing local clean energy supply is constrained, and the substitution capacity of clean electricity is insufficient to fully offset the reduction in thermal power. Consequently, a substantial portion of the supply shortfall must be met through interprovincial electricity imports. Among the four policy scenarios, the total emissions control ($TCO_2$) scenario reduces thermal power generation far more aggressively than the carbon tax scenarios, resulting in a larger local supply deficit and, in turn, increasing reliance on cross-regional power transfers. This indicates a structural mismatch in Zhejiang's power supply transition, where the pace of thermal power phaseout exceeds the province's clean energy replacement capacity. As a result, the security and stability of interregional transmission networks will face growing challenges.

4.3.2. Oil substitution

Direct low-carbon policies not only promote the development of renewable energy but also accelerate the substitution of coal with oil products. In 2050, under the LCT and HCT scenarios, reductions in oil consumption account for 14% and 12% of total primary energy consumption, respectively. This indicates that oil is more difficult to replace than coal, and coal consumption declines far more significantly over the same period, falling by 57% and 64% under the LCT and HCT scenarios. In addition, natural gas is only marginally affected by carbon taxation; under the LCT and HCT scenarios, its share of total energy consumption in 2050 is merely 2% and 0.07%, respectively.

Crude oil serves as a core feedstock for the petrochemical industry, which is part of the raw materials sector, and is directly tied to the production of petroleum products such as kerosene, gasoline, and diesel. It is important to note that crude oil consumption cannot be equated directly with the actual consumption of refined petroleum products. Moreover, Zhejiang's local carbon emissions are also affected by export-oriented trade and the outflow of energy products to other regions. Local petroleum product consumption varies significantly across policy scenarios: under strict carbon tax policies, oil consumption generally decreases, whereas under carbon intensity or total emissions control pricing schemes, oil consumption instead increases. Notably, in the carbon intensity (CIE) and total emissions control ($TCO_2$) scenarios, even though natural gas consumption peaks relatively late, oil consumption becomes the key factor enabling Zhejiang to achieve its projected carbon peak in 2029. This phenomenon is closely linked to the development needs of the tertiary sector. Compared with coal, the service sector tends to rely more heavily on petroleum products, not only because they are cleaner and more environmentally friendly, but also because the tertiary sector intrinsically exhibits higher environmental efficiency.

## 5. Policy recommendations

The experience of Zhejiang Province in formulating its carbon peaking and carbon neutrality plan offers valuable insights for other provinces, particularly those with relatively advanced economies and lighter industrial structures. Provinces such as Fujian and Guangdong share similar characteristics, with high levels of economic development, a service-oriented industrial structure, moderate wind and solar resource endowments, and strong reliance on imported electricity. For these provinces, continuously reducing carbon emissions intensity is essential to achieving carbon peaking and carbon neutrality while sustaining economic growth.

To achieve Zhejiang Province's carbon neutrality goals, the following policy recommendations are proposed.

First, policy guidance should be strengthened to accelerate the transition of the industrial structure toward green and low-carbon development. This includes using preferential tax policies and fiscal subsidies to support the expansion of the tertiary sector, establishing comprehensive training systems to enable the service sector to absorb employment, and restricting the growth of energy-intensive and high-emissions industries. Greater emphasis should be placed on industrial coordination and technological innovation to advance the upgrading of traditional industries. Zhejiang's existing "carbon efficiency code" can be leveraged to provide targeted subsidies for technological upgrades in manufacturing, thereby lowering firms' abatement costs, enhancing the decarbonization incentives of small and medium-sized enterprises, and improving overall energy efficiency.

Second, investment in renewable energy should be increased to drive the low-carbon transformation of the energy system. This requires scaling up investment in wind and solar power, increasing the share and utilization of renewable energy in the grid, and strengthening energy infrastructure to enhance the flexibility and reliability of the power system, thereby ensuring the conditions needed for large-scale integration of renewable energy.

Third, Zhejiang should advance the implementation of carbon emissions trading and the dual-control policy for carbon intensity and total emissions, thereby enriching its policy toolkit. This involves accelerating integration into the national carbon market, improving the allocation mechanism and trading rules for emissions allowances, and ensuring the effective functioning of the market. Carbon intensity and total emissions controls should be strictly enforced, with a dynamic adjustment mechanism established to respond to changing economic and emissions conditions.

Fourth, technological research, development, and innovation should be strengthened to enhance energy efficiency. Greater support is needed for research and development in energy technologies to drive improvements in energy use efficiency. This includes promoting the development of key low-carbon technologies and expanding international cooperation to enhance technological capabilities and competitiveness. Enterprises should also be encouraged to strengthen internal management practices to improve energy efficiency and reduce carbon intensity.