

Carbon-Neutral Displays: Linking to a Green Visual World

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Abstract

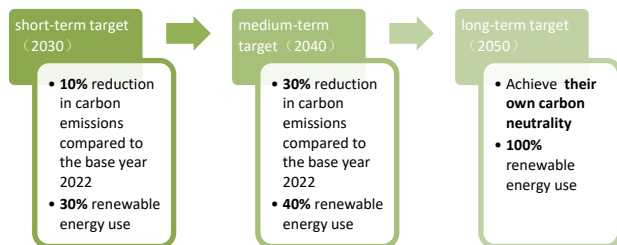
Against the backdrop of global efforts to combat climate change, BOE has announced its goal to achieve carbon neutrality in its own operations by 2050, and at the same time formulated a management structure and green development path with "BOE characteristics", integrating the concept of green and low-carbon management into the daily management, and solidly pushing forward the green and low-carbon production, creating low-carbon products and contributing to a zero-carbon future.

Author Keywords

BOE Low-Carbon Production, Green Development Pathway

1. Introduction

In response to the severe challenge of global climate change, the international community has made significant progress in achieving temperature control goals from the Paris Agreement to the UAE Consensus. As a responsible major country, China has actively responded to the call for global climate governance. It has clearly set out its national autonomous contribution targets, including striving to peak carbon dioxide emissions before 2030 and striving to achieve carbon neutrality before 2060 [1]. According to the "2024 Annual Report on China's Policies and Actions to Address Climate Change" [2], China has already achieved the goal of peak carbon emissions by 2030 ahead of schedule. Under the guidance of national objectives, BOE adheres to the sustainable development philosophy of "Green+, Innovation+, Community+". With the green vision of "Leading Green Development, Co-creating a Better Life", the company implements the carbon emission management policy of "Comprehensive Planning, Continuous Carbon Reduction, Value Extension, Green Development" through the approach of "Technology + Green". BOE has committed to achieving carbon neutrality in its own operations by 2050 [3-5]. As the core business of BOE's "1+4+N+ Ecosystem", the display business announced an ambitious goal in 2023 to achieve carbon neutrality in its own operations by 2050, with 100% usage of renewable energy. This target is divided into three phases: short-term, medium-term, and long-term [6]:



To ensure the successful achievement of its carbon neutrality goals in operations, BOE, leveraging its unique corporate characteristics, has innovatively charted a green development path with distinctive "BOE characteristics." This path focuses on six major action areas: "Green Management, Green Products, Green

Manufacturing, Green Recycling, Green Investment, and Green Action." BOE continues to deepen and refine various implementation measures to effectively advance the dual-carbon strategy.

As a leader in the global semiconductor display industry, BOE has consistently been committed to promoting green and low-carbon development. Its green and low-carbon practices can be traced back to 2010 when BOE deeply recognized the importance of establishing a carbon emission database and began collecting and measuring carbon emission data. Through relentless efforts, the company successfully built an enterprise-level carbon emission database and formulated unified accounting standards and models, achieving standardization in factory carbon emissions and product carbon footprint accounting. This laid a solid foundation for subsequent dual-carbon management efforts. In 2011, several of BOE's products successfully obtained product carbon footprint certification.

Over time, BOE's green and low-carbon practices have deepened. In August 2021, BOE's 8th-generation factory in Beijing was awarded the "Carbon Neutrality" evaluation certificate [7], marking significant achievements in energy conservation, emission reduction, and environmental protection. This accomplishment not only recognized BOE's environmental efforts but also set a benchmark for green development within the company. In 2022, BOE once again led industry trends by becoming the first semiconductor display panel manufacturer in mainland China to join the Science Based Targets initiative (SBTi) [8]. Entering 2023, BOE achieved further breakthroughs in green and low-carbon initiatives. BOE announced its ambitious goal to achieve carbon neutrality in its own operations by 2050 and formulated a detailed implementation plan. In April of the same year, BOE's first laptop LCD product successfully obtained Carbon Trust's carbon footprint certification [9]. In June, BOE released the "The Path to Carbon Neutrality: BOE Display's Low-carbon Strategy Report" [6], comprehensively showcasing the company's strategic planning and practical actions in the green and low-carbon field.

In 2024, BOE continued to advance its green and low-carbon practices comprehensively. The company strengthened internal management, optimized production processes, and reduced energy consumption and waste emissions. Simultaneously, BOE actively promoted green and low-carbon concepts, enhancing cooperation with suppliers, customers, and other partners to drive the green and low-carbon transformation of the entire industry chain. As of the end of 2024, BOE has achieved remarkable accomplishments in green and low-carbon development: establishing 18 national-level green factories, becoming the first enterprise in mainland China's semiconductor display sector to have all mass production display lines meet national green factory standards, and creating one lighthouse factory and two carbon-neutral demonstration factories leveraging its solid foundation and innovative advantages [10]. Based on years of meticulous efforts, BOE has implemented over 1,200 energy-saving and emission-reduction projects, achieving a reduction of 3.1 million tons of CO₂e, equivalent to the annual carbon absorption of 14,600 square

kilometers of forest. Additionally, nine BOE factories have been awarded the title of "Zero Waste Factory" at the municipal level or above, and seven factories have obtained UL2799 Zero Waste to Landfill Platinum Level certification. Through continuous deepening and excellent practices in dual-carbon work, BOE received the highest management-level B rating from CDP. Seven factories have submitted commitment letters to SBTi, with two factories setting ambitious targets to limit warming to 1.5 degrees Celsius by 2030 and successfully publishing these goals.

2. Green Practices and Innovations, Strengthening Sustainable Development

As a leading enterprise in the display industry, BOE consistently upholds the concept of sustainable development and is committed to building a zero-carbon green vision. By establishing a comprehensive green product lifecycle management system, starting from the initial green design, selecting green materials, going through green production processes, adopting green packaging to reduce environmental burden, optimizing transportation through green logistics, and ultimately achieving green recycling of products, and obtaining green certification, this series of measures ensures that the green and low-carbon concept runs through the entire lifecycle of the product. This aims to minimize the negative impact on the environment and accelerate the pace of green transformation in the industry.

2.1 Green Design

BOE starts from the source of product design, integrating the concept of green and low - carbon principles into every link of the product's full life cycle, and creating green products that combine excellent low - carbon environmental friendliness and high performance. By applying Oxide technology, along with adopting the design of making products thinner, lighter, and more streamlined, as well as the modular assembly strategy, BOE promotes the greening and low - carbon process of its products.

Regarding the low - power design of products, the innovative application of Oxide technology has successfully realized low - power - driven thin - film transistors (TFTs). This technological breakthrough has resulted in a substantial increase in the pixel aperture ratio. Compared with the traditional amorphous silicon (a-Si) technology, Oxide technology can remarkably reduce the power consumption of products, with a reduction rate of more than 40%. This enhancement not only improves the energy efficiency ratio of products but also reduces carbon emissions at the source during the product usage process.

In terms of product thinning and lightweighting, the thickness of glass substrates has been decreased from 0.7 mm to 0.5 mm, with some products attaining an ultra - thin configuration of 0.4 mm. Backplates have also undergone optimization. For example, the backplate of the 23.8 - inch monitor (MNT) has been thinned from 0.8 mm to 0.6 mm, and that of the 27 - inch MNT from 1.0 mm to 0.8 mm. These improvements enhance the portability and aesthetic appeal of the products, while simultaneously reducing their carbon footprint through lightweight design.

In terms of material reduction design, Dual Gate and MUX technologies have been adopted in MNT products, halving the usage of integrated circuits (ICs) and miniaturizing printed circuit boards (PCBs). Considering the high carbon - emission factors of PCBs and ICs, which significantly contribute to the lifecycle carbon footprints, these reductions are crucial for reducing overall emissions.

Furthermore, the company has adopted a modular design concept. By means of a screw - free design and modular assembly approaches, it simplifies the product structure and enhances production efficiency. This not only facilitates product upgrades but also eases product maintenance.

2.2 Green Materials and Transportation

BOE upholds the core concept of win - win cooperation and endeavors to accomplish the three green - material - oriented goals of "low - carbon, harmless, and low - consumption". Moreover, it exhaustively explores the potential of material recycling. By rigorously screening renewable and environmentally - friendly green materials, BOE ensures that the environmental impact is minimized at the source.

As the core of modern display technology, the production process of the liquid crystal panel involves the glass substrate playing a crucial role. BOE conducts strict screening during the procurement process and uses glass with added PIR as the substrate. This innovative material not only demonstrates excellent performance but also effectively utilizes the waste generated during the glass - cutting process. The PIR addition ratio in the glass is as high as over 20%, which enhances the efficiency of resource utilization and reduces waste generation.

Regarding backlight materials, BOE also spares no effort in promoting resource recycling. The main materials of the backlight module are plastics and metals. BOE has made bold attempts in backlight materials by adding 60% - 90% of plastic PCR and 13% - 95% of metal PCR. These recycled materials are sourced from the consumer market, such as discarded plastic water bottles, decorative boards, car lamp shells, and scrap steel. Through advanced processing technologies, these waste materials are rejuvenated and become important components of the backlight module. This innovative practice promotes resource recycling and lays a solid foundation for constructing a green industrial chain.

Moreover, in its green and low - carbon practices, BOE actively cooperates with logistics partners to promote low - carbon transformation. By optimizing the transportation mode, it gives priority to sea, waterway, and railway transportation over air transportation. For short - distance transportation, it prefers new energy vehicles to reduce carbon emissions generated during transportation and promote the green and low - carbon transformation of logistics. It is remarkable that BOE, in cooperation with logistics suppliers, explored and introduced bio - fuel sea transportation for the first time. This innovative measure has successfully reduced carbon emissions by 126 tons of CO₂e, marking a significant step forward in our carbon - reduction journey.

2.3 Green Manufacturing

In production and manufacturing, BOE has adopted a multi-pronged approach to reduce energy and resource consumption, promote circular resource utilization, and lower carbon emissions in manufacturing processes. This strategy includes equipment upgrades, optimization of low-carbon processes, resource recycling, and energy structure adjustments. Across its factories, BOE continuously drives energy efficiency improvements through three key dimensions: cross-factory benchmarking, standardization, and technological breakthroughs. Key energy-saving measures include replacing conventional fans with high-efficiency models, implementing free cooling systems, adopting intelligent operation and maintenance, and recovering waste heat. Regarding energy structure optimization, BOE has integrated renewable and clean energy solutions. To date, its self-built

distributed rooftop photovoltaic systems have achieved a total installed capacity of 181.7 MW, generating approximately 166 million kWh of electricity annually. This reduces carbon emissions by 92,000 tons per year. Combined with green electricity procurement and renewable energy certificate (REC) purchases, renewable energy now accounts for over 20% of BOE's energy mix. In regions with limited renewable resources, BOE employs alternative clean energy solutions. For example, Chongqing BOE Optoelectronics Technology Co., Ltd. operates a natural gas-distributed energy station. It uses natural gas as feedstock to achieve energy cascade utilization through combined cooling, heating, and power (CCHP) generation. This facility produces around 110 million kWh of electricity and 99.75 million kWh of cooling annually, reducing carbon emissions by approximately 17,000 tons per year.

During semiconductor display panel production, fluorinated greenhouse gases—known for their extremely high global warming potential (GWP), often tens of thousands of times greater than CO₂—are widely used. BOE has implemented process parameter adjustments and installed advanced treatment equipment to reduce emissions across the entire production chain. Currently, the treatment efficiency for NF₃ and SF₆ gases exceeds 99%.

To further advance the circular economy and reduce resource dependency, BOE prioritizes resource recycling alongside energy conservation and structural adjustments. Guided by the 4R principles—Recycle, Reduce, Renew, and Responsibly—BOE has established a closed-loop system connecting resources, products, and waste. For chemical raw materials, BOE first explores reuse in production. Unrecyclable materials are sent to licensed waste treatment firms for purification into industrial-grade materials, while non-recyclable waste is 100% processed by certified third-party hazardous waste management agencies.

BOE's display manufacturing facilities have built comprehensive resource recycling systems covering materials such as stripping agents, diluents, etching solutions, and waste targets. For instance, the stripping agents used in liquid crystal panel production are fully regenerated using in-house recycling technologies and equipment. The reclaimed stripping solution is entirely reintroduced into the production process, ensuring zero waste discharge.

2.4 Green Packaging

In packaging design, BOE prioritizes the use of recyclable and biodegradable materials, implements lightweight packaging strategies, and actively explores circular packaging solutions. BOE has achieved a lightweight innovation for trays by upgrading the original PET-GPO material to GPO trays. This new material is not only lightweight, structurally stable, and highly durable but also fully recyclable. Compared to traditional trays of the same size, the weight is reduced by 70%, effectively lowering energy consumption and carbon emissions during transportation and storage.

Additionally, BOE has introduced molded wood pallets, a biodegradable design made from bamboo and wood processing waste combined with plant fibers through molding technology. These pallets offer advantages such as light weight, durability, moisture resistance, shock absorption, and ease of cleaning. More importantly, they are reusable and biodegradable under natural conditions, significantly reducing environmental impact. Furthermore, BOE has replaced traditional PET materials with eco-friendly pulp-plastic films and substituted EPE with cushioning paper. These degradable materials maintain packaging

performance while drastically reducing environmental pollution. BOE has also optimized loading capacity by upgrading single-unit packaging to multi-unit designs, improving packaging efficiency, and reducing material usage.

2.5 Product carbon footprint calculation and verification

To deeply explore carbon reduction potential and help customers make environmentally conscious choices by understanding the carbon footprint of purchased products, accurate carbon emission data collection and accounting are critical. Currently, 48 BOE products have obtained ISO 14067 product carbon footprint certification. Notably, BOE's 16-inch 4K display became the first laptop LCD panel to receive Carbon Trust's carbon footprint certification [9]. Moreover, BOE independently developed a product carbon footprint management platform. By the end of 2024, the platform had completed carbon footprint calculations for 27 products, delivered results for 9 of them to clients, and achieved a 96% improvement in calculation efficiency.

3. Focusing on Green and Low-Carbon Development to Create Zero-Carbon Displays

In the journey toward carbon neutrality, BOE is fully committed to innovating and implementing zero-carbon products. Green product planning serves as a cornerstone for achieving carbon neutrality goals. The development of zero-carbon products requires persistent effort and breakthroughs. With a forward-looking vision, BOE has proactively created milestone green products through iterative upgrades, including recycled-material-added products, low-power-consumption devices, and carbon-neutral solutions.

BOE demonstrates groundbreaking innovations in resource circularity for product decarbonization. The 16-inch notebook's green display low-carbon module, while ensuring the product's high energy efficiency in daily use, innovatively incorporates over 58% of PIR or PCR recycled materials, covering key components such as Glass and backlight main materials. Compared with similar competitors, the module's carbon emissions are significantly reduced by more than 54%, earning the authoritative UL2809 certification. Additionally, the M3.0 86-inch infrared interactive electronic whiteboard demonstrates a perfect combination of environmental protection and performance. By using 18% recycled materials, including 85% PCR plastic, 75% PCR metal, and low-carbon glass, it not only achieves product lightweight and thin design but also reduces power consumption, resulting in a 21.14% reduction in carbon emissions over its entire life cycle.

In combining resource recycling and low-carbon processes to promote carbon emission reduction, BOE's Lenovo monitor T24mv-Low Carbon B version has achieved outstanding results, with a recycled material utilization rate as high as 52%. This proportion includes 95% post-consumer recycled (PCR) plastic and steel, as well as 100% recycled aluminum alloy. The monitor is also equipped with BOE's self-developed Oxide low-carbon module, and these innovative designs and applications have reduced its carbon emissions by 11.56% over its half-life cycle. Meanwhile, Iiyama 43-inch digital signage monitor has also incorporated 14% recycled materials, composed of 85% PCR plastic and low-carbon metal. In addition, its backlight module adopts a low-power design, which has led to a significant 21.23% reduction in carbon emissions over its entire life cycle.

As for carbon-neutral products, BOE conducted a detailed carbon footprint analysis of a 14-inch laptop LCD panel [3], identifying over 95% of emissions from raw material procurement and

production. Mitigation strategies included adopting low-carbon materials and renewable energy, achieving over 85% emission reduction. Residual emissions were offset via carbon credits, enabling the product to attain carbon neutrality certified by SGS.

In supporting China's efforts to achieve carbon peaking and carbon neutrality goals, BOE has consistently driven innovation and development of green, low-carbon products. The company is committed to continuously optimizing and refining end-to-end management processes for green product development, design, and manufacturing. Through these initiatives, BOE has successfully created a portfolio of sustainable, low-carbon products, injecting robust momentum and vitality into the green transformation of the display industry.

4. Conclusion

In summary, these remarkable accomplishments of BOE in green and low-carbon development represent the culmination of its enduring commitment to sustainable practices. Through continuous optimization of production processes, enhancement of energy efficiency, and proactive adoption of renewable energy sources, BOE has not only significantly reduced its carbon footprint but also laid a robust foundation for achieving operational carbon neutrality and developing zero-carbon products. These initiatives have established an exemplary model of green, low-carbon, and circular development for both the display panel industry and broader manufacturing sectors.

Moving forward, BOE will remain true to its original aspirations by upholding the "technological innovation + green development" philosophy. BOE will intensify its green and low-carbon strategies through exploration and implementation of more efficient, eco-friendly technologies and management frameworks. BOE plans to increase investments in clean energy, such as distributed photovoltaic systems, to reduce reliance on fossil fuels at the source and accelerate its transition toward "zero carbon". Additionally, as a leading enterprise in the industrial chain, BOE will actively leverage its influence to drive green and low-carbon transformation and industrial upgrading among upstream and downstream partners. Through technological innovation and collaborative sharing, the company aims to build a green supply chain system [11], fostering low-carbon and circular development across the entire industrial chain.

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