Sustainable Transformation in China's Agricultural Sector: From Traditional Narrow Patterns to Smart Dynamic Production

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Abstract

Technological transitions and the associated transformation of key sectors are radically changing the entire socioeconomic system. The agricultural sector, as one of its key links, today is intensively saturated with new technologies and management innovations. For the first time, there is an opportunity to "do things completely differently," to restore and develop both the natural and human potential of rural areas. This makes it possible to create smart industries with their dynamic chains, complex infrastructure, large-scale digital platforms and networks, implement the concept of sustainable development, and make a transition from productivism (exclusive focus on productivity) to post-productivism (a balance between ensuring economic interests are met and guaranteeing the healthy integrity of natural diversity). This article analyzes the current state of and prospects for China's agricultural sector from the point of view of two levels – "top-down" (state initiatives) and "bottom-up" (inputs of product manufacturers identified during a regional Foresight project, but apparently characteristic for most Chinese rural areas). The key limiting force in the development of the concepts under consideration is the too slow process of building human capital with residents living directly in rural areas and the development of related sectors in said areas.

Keyword: strategies; Foresight; forecasting; digitalization; technological transition; smart model of the agricultural sector; post-productivism; revitalization of rural areas; new technologies and competencies; China; agroecology

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Introduction

The new stage of technological paradigm change creates a certain logic, which implies thinking in terms of delayed consequences not only for the entire complex socioeconomic structure, but also for natural ecosystems. Based on this, the role of the agricultural sector is being rethought. This field is faced with the task of mastering increasingly complex development models and forming human capital with the appropriate competencies. If in the energy sector technological transitions have long ago acquired a conceptual basis and programs with long-term horizons have been developed, then in the context of agriculture their theoretical and empirical bases are only just being shaped.

In recent years, researchers have paid great attention to these processes, revealing both the current state of rural areas and their prospects. The mainstream trajectory is the consistency of national programs with the international concept of sustainable development, which implies the restoration of the integrity of natural ecosystems, the proper, active management of the environment, and its management in line with socioeconomic processes (Sgroi, 2022). However, even developed countries are faced with the difficulty of implementing such a combination of tasks and are still searching for optimal paths to improve this sector.

The solution seems to be in complementing this track with the multifunctionality approach put forward by Geoff Wilson (Wilson, 2001). Rural areas are considered an integral dynamic organism that operates under the combination of many factors — optimal demographic balance, the formation of human capital, an abundance of jobs with decent wages, constant improvement of infrastructure, a robust technological base, management models, and, most importantly, the presence of a wide range of well-functioning land use and environmental protection regimes (Wiggering et al., 2006).

The capabilities of a multifunctional development model are maximally unleashed when natural, resource, social, human, economic, and environmental capital are equally well developed (Wilson, 2014). Its implementation implies a paradigm shift in the evolution of rural areas, including their resource, production, knowledge, and cultural bases (Liu et al., 2023). Based on this, transition processes are being formed, the roles and subjects of the agricultural industry are being revised (Wilson, 2007; Lin, Cai, 2012). Understanding the multifunctional approach and its development will make it possible to effectively manage complex interactions between various interconnected segments of a large-scale ecosystem (resources, production, markets, investments, infrastructure, etc.), which is of great importance for both decision-makers and the population (Ma et al., 2019). In this regard, it is of interest to evaluate the correlation of state efforts to implement strategic programs with the readiness of stakeholders in the agricultural sector to transition to new development models.

Using the evidence from China, this article examines the driving forces and restraining factors in the transformational transition of rural areas to new technological, digital, and knowledge foundations. The study is divided into two parts. The first looks at top-down initiatives, i.e., the efforts of the state, and the second part focuses on the case of the Jilin Province, where a Foresight study was conducted based on a stakeholder survey using the focus group method (bottom-up principle). In this way, a holistic vision of the problems and ways to solve them is formed (improving the environment, smoothing out income inequalities between cities and rural areas, increasing the attractiveness of the latter for the return of the working population, opening new lines of business, etc.).

Literature Review

Since the emergence of the concept of spatial development in 1999, European countries have applied it to stagnating agricultural regions. At one time, these territories were one of the driving forces of economic growth, but since the socioeconomic model of territorial competitiveness has changed, their importance, and, consequently, economic attractiveness have decreased significantly.

The dynamic development of technologies and management practices allows one to take a fresh look at the potential of rural areas, rethink their role in the new economic configuration, and, improve the current state of the agriculture sector. To radically change the attractiveness of rural areas as well as their resource and production base, developed countries are introducing a multifunctional approach that allows for creating something completely different from what has existed before. The literature provides different options for this transformation, taking into account natural, historical, and cultural characteristics. A wide variety of ideas and practices enriches management decisions and expands the view of how one can "unpack" the hidden capabilities of a particular territory. The concept is most actively promoted by creating synergy between rural and urban spaces to generate new economic value, within which the considered territories can create conditions for the development of innovations that unlock and expand the potential of local resources (Jiang et al., 2022). Thus, popular role-playing games based on European rural areas have paved the way for their transformation into frequently visited tourism centers.

The theoretical basis for such transformations is laid within the framework of Foresight projects.

Scenarios with different horizons are created to assess the recovery prospects for complex ecosystems that had previously been subjected to thoughtless, destructive practices of one-sided agroforestry activities.

In 2019, a development project implemented digitalization scenarios for the European agri-food sector until 2030 (Ehlers et al., 2022). The basic scenario is based on assumptions about maintaining the current pace of development, others are based on the prospects for its acceleration and spread to related sectors (for example, the food industry). Digitalization creates the preconditions for the development of radically new methods of farming. The example of the Netherlands is indicative in terms of overcoming the persistent trend of reduction in natural diversity. In 2018, two divergent alternative scenarios were modeled and tested here. A consequence of the focus on increasing dairy production is a reduction in wildlife and meadow plant diversity (Kok et al., 2020). On the contrary, an emphasis on the "diversification" of natural ecosystems makes it necessary to abandon the expansion of the food supply for domestic animals, which greatly reduces the production of dairy products of all types. Both scenarios require a trade-off between biodiversity conservation and increased production. The results of the Dutch Foresight study provide a valuable information basis for understanding the need to develop more complex strategies than before, taking into account all parts of a large, dynamic natural ecosystem, the subtle interdependencies between them, and the "hidden" but critical effects of this influence. It requires establishing a complex set of compromises between the multiple interests of different parties (Kok et al., 2020).

In the work (Polzin, 2024), using the example of Germany, a very pressing question is raised about the weak readiness of the community, upon which the prospects for agriculture depend, to accept completely new methods of agricultural management, including the concept of sustainable development. The recently launched state program "Agrarian Turnaround" (Agrarwende) is facing implementation difficulties. Its vector for promoting organic agriculture using scientific knowledge and technology is viewed with caution by wide circles due to fears of worsening market prospects and food security risks. The authors of the study reveal the difficulties of transforming entrenched sociotechnical ideas, especially when they are closely related to national identity and formalized in institutional structures. Their findings enrich ongoing discussions about the prospects for sustainable agriculture around the world, with the growing threats of climate change and biodiversity loss requiring urgent responses. Since the second half of the 20th century, land use has been transformed on a global, which has created serious problems for the further functioning of ecosystems (Weber, Sciubba, 2007; Newbold et al., 2016).

Currently, the concept of multifunctional land use serves only as a starting point for the restructuring of rural areas, while their full revitalization requires a transition to a sustainable development model (Fang, Liu, 2015). Combining these approaches into an integrated management model is a difficult task, requiring appropriate human capital living in rural areas. We are talking about the concept of post-productivism – a combination of the economic components with the interests of environmental protection. The transition to this scheme from the previous model of productivism (orientation exclusively toward economic benefits and output) implies the complex transformation of agricultural land with its transition to a multifunctional framework (Mccarthy, 2005). As with any other transformation of a large-scale system, this process requires the reservation of sufficient time and special meta-competencies to manage the change with consideration of the nonlinearity, heterogeneity, complexity, and rapid variability of the environment.

Chinese Context

China is also witnessing a shift in agricultural policies away from a productivity focus toward embracing multifunctional agriculture and its spatial development (Chen et al., 2018). Building on the work of (Wilson, 2001), some local scholars have compared studies on the transition of rural areas in Western countries from productivism to post-productivism to the modern Chinese context (Huang et al., 2022). The settlement of land issues is critical to the revitalization and integrated development of rural land, farming, and the agricultural sector in the Sannong conceptual triad (that means a holistic approach to the dealing with the three issues related to rural development in mainland China: agriculture, rural areas and farmers) (Liu, 2014). The use of an appropriate theoretical framework allows us to develop optimal ways to manage this nonlinear and heterogeneous process (Lin, Cai, 2012).

Currently, in the development practice of rural China, a search is underway for the optimal balance between productivity and non-productivity. The process is complex, as it represents a large-scale challenge in organizational, cultural, and managerial terms. The biggest problem is due to contradictions — a simple transition from a focus on economic productivity to environmentalism (the priority of sustainable development, including the protection and improvement of

the environment) poorly corresponds to the interests of many Chinese rural regions in need of revitalization. These processes are partly reminiscent of the situation occurring in Germany, but have their own specifics, which are expressed in greater income inequality and a shortage of relevant labor. In other words, considerations of short-term benefits generally continue to prevail over long-term goals. However, with this approach it is not possible to simultaneously provide food safety and mitigate destructive anthropogenic effects (Wang, Gu, 2012). Excessive emphasis on environmental protection in land use practices is becoming a threat to stable food supply for markets (Jiang et al., 2022).

Thus, a direct bet on productivism or non-productivism in the foreseeable future does not look like the optimal track for managing the development of rural areas not only in China, but around the wold. This is a bottleneck in the transition to new quality under consideration. It can be overcome by in-depth research on emerging global practices, such as regenerative agriculture or agroecology, combined with new technologies, especially digitalization (Duff et al., 2022; Husaini, Sohail, 2023; Purnhagen et al., 2021). Cultivating these concepts in public discourse will be the key to changing the established sociotechnical narrative. Mastering multifunctional models, some regions perform better, while others do worse, which corresponds with nonlinear dynamics, but in general there has been a tendency to abandon non-optimal land use that is actually or potentially harmful to overall socioeconomic development. Developing effective management and control measures to facilitate such transformations is crucial for reviving and increasing the attractiveness of the national agricultural sector, establishing a co-evolutionary model of relations between rural and urban areas (Long, 2022).

Over the past 30 years, China's agricultural growth rate has averaged 4.6% per year. Despite possessing only 8% of the world's arable land, the country managed to provide food for nearly 20% of the world's population (World Bank, 2023). A significant shift has been observed across all production categories (Li et al., 2018). In 2022, the added value of China's agriculture and related industries amounted to 19.569 trillion yuan (16.24% of the country's GDP). At the same time, further annual growth rates are projected at 5.95%.[1]

China is committed to making its agricultural sector sustainable and self-sufficient as part of its long-term national strategy. Two vectors can be traced, aimed at a single result: equipping the agricultural market with advanced technologies.[2]

National Agricultural High Technology

While remote sensing (RS) technologies, geographic information systems (GIS), and drones in themselves do not represent fundamental novelties, their transformative potential for the sector in question has not yet been fully revealed due to the slow development of these technologies, which require certain competencies. At the same time, today many things are being done in a new way. Remote sensing, GIS, and drones make it possible to quickly manage unevenly distributed arable lands located at long distances from each other, taking into account the specific needs of each landowner. Complex solutions are being created in the Software-as-a-Service (SaaS) format - adapted technologies for a population that does not fully possess the required competencies. The proliferation of these user-friendly, intuitive, practical applications is becoming a driver of sector transformation. Even small companies get the opportunity to correctly plan processes, significantly increase productivity, and reduce the impact of harmful factors on the environment. To some extent, these affordable technologies are replacing expensive drone-based monitoring systems and IoT-enabled agricultural devices. SaaS appears to be a cheaper but effective solution that allows for the timely receipt of data on soil conditions, crop yields, water supply needs, and so on (Chunjiang et al., 2021). Thanks to this, the efficiency of the agricultural sector is increased, and food supply chains are optimized. The market can expect predictability and reliability in logistics, improved quality, and lower product costs (Peng, You, 2023). Increasing transparency in manufacturing operations ensures that consumers have greater access to safe and environmentally friendly products (Cho et al., 2023).

Drones occupy a significant place in the rapidly developing segment of agricultural high technologies. By 2020, sales of such equipment in China increased to approximately 50,000 units - more than tenfold compared to 2017 (4,250 units) (Liu, 2024). Their manufacturers began to diversify their profile and introduce unmanned technologies on ground vehicles, which illustrates the transition to integrated solutions for the automation of the agricultural sector.

In the fields of remote sensing, GIS, and drone development, a steady increase in the number of

[1] https://www.developmentaid.org/news-stream/post/179737/5-sectors-driving-the-chinese-economy, accessed 24.07.2024.

[2] "Ecological Redline Policy" (Bai et al., 2018) and "No. 1 Central Document" (Liu, 2024).

companies has been recorded over the past 10 years (Liu, 2024). Below are just a few of them.

Technology Developers

- ICAN Technology (founded in 2016). This company has created its own model for monitoring the condition of vegetation and soils based on satellite technologies. The big data platform allows one to support the full production cycle - from preliminary planning for planting crops to harvesting, storage, logistics, and marketing of crops, providing detailed management decisions.
- GAGO (2015). This organization has formed a wide network of partners and clients, including agricultural producers and government agencies. The provision of financial services has been established in regions where traditional banking infrastructure is limited. Thanks to the remote collection of data on farmland through satellite systems and a detailed analysis of their characteristics, lending to farmers is simplified (the principle of inclusive financing is implemented).
- Jiahe Information (2013). This enterprise has developed different types of technology platforms, from artificial intelligence algorithms to low-code tools. Their design in the form of simple, intuitive applications allows users to conveniently receive and analyze data.
- XAG (2007). This company is a leader in low-cost agricultural drones, it maintains profitability above 30% despite declining product costs.

Service Companies

- YiMuTian (2011). This digital integrator covers over 800,000 farms and connects producers with wholesale markets and buyers for a wide range of products. The number of users is over 50 million. It develops detailed maps of market dynamics that provide a better holistic understanding of ecosystem processes.
- BRIC Agricultural Information Technology (2014). This organization specializes in agricultural consulting, the management of digital platforms that aggregate big data across production sectors, supply chains, and sales.

Key Barriers to Transitioning Agriculture to a Sustainable Model

A natural property of any radical transformation is the manifestation of both positive and negative factors. Among the restraining forces barring the way to sustainable developmen are inequalities in income between rural villages and cities (Huang, 2020) and the exacerbation of environmental problems as a result of the rapid growth of the agricultural sector, which proceeded without taking into account the "downsides" of such speed. Agricultural ecosystems account for 7–20 % of the world's total greenhouse gas emissions, and in China this share reaches 17% (Li et al., 2018; Huang, Yang, 2017). The intensification of growing demand for food has stimulated the use of a variety of yield boosters, such as chemical fertilizers and pesticides. The downside of their overuse has been land degradation, pollution of aquatic ecosystems, and increase greenhouse gas emissions (Zhang et al., 2020). Waste disposal also poses a challenge due to heavy metals and the persistent organic substances they contain. Such substances have a devastating effect on the health of all living things.

Another basic barrier is the shortage of human resources, which are concentrated mainly in urban agglomerations. The intensive urbanization of China, which began after the launch of the "reform and opening up" policy[3] in 1979, triggered the large-scale flow of rural residents to cities. In 1980, only 19.4% of China's population lived in urban areas, while 66.2% were concentrated there by 2023.[4] When searching for career opportunities and a better quality of life, it was primarily able-bodied young men who flocked to the cities. As a result, the human potential of rural areas has been significantly weakened, which still affects the productivity of the industry and imposes significant restrictions on the development of these areas.

The rapid industrialization of the agricultural sector has also significantly affected the quality of food products in China. Although the government has launched reforms, implementation remains a challenge, resulting in weak links in the food safety chain. To solve these problems, the authorities have been implementing a set of strategies since 2004 to develop the agricultural sector and rural areas (Tung, 2016).[5] In 2021 the plans for digital[6] and green development were developed, and the target for achieving carbon neutrality has been set for 2060.[7]

[3] Gaigé kāifàng — in pin-ying transcription. This initiative continues to be implemented at the present time with the goal of optimally synthesizing the planned and market components in the national economy and increasing its openness to the outside world by maximizing trade opportunities.

[4] https://www.statista.com/statistics/278566/urban-and-rural-population-of-china/#:~:text=According%20to%20World%20Bank%2C%20a,population%20lived%20in%20urban%20areas, access date 14.07.2024.

[5] Priorities include: food security by strengthening domestic agricultural production and its modernization; increasing investment in water conservation; rural income growth; deepening rural land reform; improvement of infrastructure; improving the quality of management of the agricultural sector.

[6] The goal is to accelerate the pace digitalization in the industry. The focus is on three key areas: development of modern technological infrastructure, strengthening the digital transformation of agricultural production, business and services; improved management. To achieve them, measures have been developed: expanding the coverage of rural Internet networks; promoting the use of big data and artificial intelligence, development of e-commerce platforms; creation of centers for technical support and training of local personnel.

To control the composition of food products, the Chinese government has introduced the HACCP system (Hazard Analysis and Critical Control Points), certified by the UN Food and Agricultural Organization (FAO). It analyzes potential biological, chemical, and physical factors that arise throughout the production process, ensuring their compliance with the required standards (Lam et al., 2013).

As to bottom-up initiatives from food producers, the picture here is less clear. In order to clarify this, a team of researchers from the Renmin University of China, under the leadership of the author of this article, implemented a Foresight project in the middle of 2023. The focus group method was used, followed by thematic analysis. It was assumed that the exchange of views between the participants would stimulate a deep understanding of the external context, change the perception of its current situation and prospects as part of the transformation of the entire agricultural ecosystem, including the model employed for the sustainable development of rural regions (Braun, Clarke, 2006; Braun et al., 2022).

Methodology of the Study

Two focus groups were formed: a test group forming a representative sample of 16 discussants, and a control sample, with the same number of participants[8], whose task was to verify the saturation of the data collected by the first group (Hennink et al., 2017). Group meetings took place in Xichun (Jilin Province, northeastern China). The agenda included the selection of transformation strategy options for the considered region to achieve a healthy and economically successful ecosystem according to the sustainable development model.[9] In order for respondents to express their point of view as objectively and sincerely as possible, their privacy was guaranteed. As part of the discussion, open questions were asked, encouraging detailed and meaningful answers. The atmosphere of the meeting was conducive to stimulating a "sense of the future", motivation for deep, creative transformations, an intensive exchange of opinions, and the formation of a holistic vision of how to overcome long-standing problems and unlock existing potential. When processing the data, reflective thematic analysis was employed, as described in (Braun, Clarke, 2006; Braun et al., 2022). Three patterns of topics were identified from the discussions, which can be elaborated upon with subtopics based on their content and relevance to research questions. Let us take a closer look at them.

Results and Discussion

The discussions revealed that modern agricultural practices in China still largely follow traditional patterns, characterized by high labor intensity and an insufficient level of development of advanced technologies. Despite their openness to the consultants' recommendations, local professionals still lack specialized knowledge and competencies, and their attitudes are determined by the past. The idea of moving the sector toward a qualitatively new level of development (sustainable model) continues to be perceived as too radical and difficult to achieve, despite the current strategic initiatives of the government. Individuals in the 50+ age category showed the highest activity and interest in the discussions.

The successes and failures of current target programs were discussed. As achievements, respondents noted the government's efforts to support infrastructure and regulate prices for the sector's products. The weak points included the continuing outflow of the younger generation to urban agglomerations (despite the fact that its pace had slowed down at this time) and income inequality between the city and the countryside (Wang, Raymo, 2021).

Aiming to achieve carbon neutrality goals by 2060 is perceived by all participants as a requirement for radical transformation, the implementation of which represents a particularly complex challenge for all adaptive forces. For such a large-scale, complex, and inert system as agriculture, moving away from the past requires *more* time to rethink what is happening, abandon previous narratives, create new mental and cultural patterns that fit with long will and motivation necessary for difficult transitions to new, more complex development models.

Despite the fact that the Foresight project was local in nature and covered only two small focus groups, its undoubted advantage, in addition to addressing "big questions," was encouraging participants to deal with the future. Participants attempted to predict the impact of geopolitical tensions on the prospects for agricultural exports. All together, these factors create a significant driving force for transformative processes and the launch of new beginnings in the agricultural sector.

Conclusions and Recommendations

Thus, the discussions made it possible to produce a general idea of several options for solving current problems and overcoming limitations, and to outline a vision of a technological future. All this

[7] https://www.chinausfocus.com/energy-environment/chinas-carbon-commitment, accessed 18.05.2024.

[8] The focus groups included: rural residents (including former ones), employed both in the agricultural sector and in other industries, representatives of local governments.

fit into one basic scenario, implemented in three interconnected blocks: the transition of the sector to an entrepreneurial growth model; the development of human potential; and the contribution of the state to the transformation of the agricultural sector.

Transitioning Agriculture to the "Farm Modern Corporation" Model

The key driving force behind the transition seems to be the idea of a new social model, code-named "farmer modern corporation", the founders and shareholders of which can be all households localized in a particular region. Within its framework, all elements of the ecosystem are integrated, including agroforestry activities, infrastructure, and even related sectors that are not directly related to agriculture, but transform the lifestyle of rural areas. Strategic roadmaps are being produced for the development of priority technologies, the improvement of logistics infrastructure, the creation of centers for sharing agricultural machinery, the optimization of land use, the formation of consulting organizations, the introduction of "green financing" practices, and so on. Various options for the competency base of their implementation are being considered: developing the necessary skills among representatives of local government bodies, delegating powers to professional management companies for a certain period, or a combination of these options.

The listed measures are designed to create the prerequisites for increasing the attractiveness of rural areas for the active and working population. This idea can receive significant reinforcement from the current government digitalization program, which involves the transfer of all enterprises to a digital basis and the blockchain-based food safety control system HACCP.[10] The focus is on the relevant ministry (Ministry of Agriculture and Rural Affairs, MARA) and its pilot projects for all major Chinese provinces with a dominant agricultural sector in the structure of the regional economy.

Formation of Appropriate Human Potential

Although the income gap between urban and rural areas is gradually narrowing, urban agglomerations as a whole are still winning the competition for attracting the young Chinese population. The conditionally positive trend of "returning home" was launched by the Covid-19 pandemic forcing many people to leave the cities. However, such "pushing" drivers are temporary. In order for the "filling" of rural areas with attractive and decently paid jobs to lead to long-term effects, it is necessary to create strong driving forces of "pull". These could be modern medical and educational institutions, companies from the service sector not directly related to agriculture, local centers for the use of technologies (satellite sensing, monitoring using agro-drones, geospatial analytics), and gastronomic tourism.

The Role of the Government in the Transformation Processes

In addition to mobilizing significant intellectual and financial resources, the rural transformation will require regulatory reforms. For the previously mentioned "farmer corporation" initiative to be carried out smoothly, interdepartmental cooperation must be ensured. Joining MARA efforts to those of related departments and the National Development and Reform Commission (NDRC)[11] is seen as a possible option. This would be carried out under the overall coordination of the State Council of China, which possesses complete organizational, personnel, financial, and legal resources. The framework for the near future is the Green Agricultural Development Plan, containing a set of measures in five key areas: the use of natural resources, habitat, agricultural ecosystems, the production of environmentally friendly products, and the reduction of carbon emissions.[12]

The described study, like any other, has its methodological limitations. Some of them were taken into account during the process, others must be eliminated in the future. Among the limitations, the focus group method works only with a small amount of respondents whose opinions may not correspond to the position of the majority of the population. Convening more focus groups with different participants could increase the reach and representativeness of the sample (Fereday et al., 2006).[13]

The conclusions and recommendations presented here serve as a general foundation and are subject to contextual adaptations for decision-makers and stakeholders facing identical or similar problems.

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[9] Including issues of environmental pollution, urban-rural income inequality and aging populations.

[10] https://cqc.com.cn/www/english/ManagementSystemCertification/OHSASyblly/CertificationScope/, access date 19.05.2024.

[11] Department of the State Council at the ministerial level, responsible for implementing national policies and decisions on development and reform.

[12] The current 14th five-year plan has been developed with a horizon until 2025. An increase of up to 60% is expected the share of agricultural land equipped with effective irrigation facilities, reducing the use of chemical fertilizers and pesticides by 20%, improving the quality of the ecological environment in rural areas, improving the provision of social infrastructure. More details: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC205820/#:~:text=By%202025%2C%20China%20will%20strive,ability%20of%20emission%20reduction%20and, access date 16.07.2024.

[13] This applies both to China and other countries with significant rural populations, such as Indonesia, India or Vietnam.

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