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CAN THE CHINESE BIOGAS EXPERIENCE SHED LIGHT ON THE FUTURE OF SUSTAINABLE ENERGY DEVELOPMENT?

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"What we have to be is what we are."
– Thomas Merton

I. INTRODUCTION

In China, a *low-tech* biogas revolution is providing modern energy services to nearly forty million rural households—120,000,000 people—that otherwise would be mired in energy poverty.[1] Indeed, by the end of 2010, biogas supplied 22.5% of China's rural population with some part of their energy needs.[2]

While China is today well-known for *high-tech* industrial exports, perhaps one of the Nation's most significant—and underappreciated—achievements is the wide-scale development of *low-tech* household biogas to solve rural energy needs. Many other developing countries promote the use of biogas to help resolve energy poverty. However, China's success with biogas in energy poor rural areas is unique.

This raises two key questions: Why is China's biogas program successful? Can the factors for China's biogas success also be exported? The need for answers to these questions is increasingly important. There are approximately 2.6 billion people—mostly women and children—who cook with three-stone fires and other devices that cause them to inhale soot and dangerous fumes. More than two million of those same women and children die *each year* from exposure to soot and fumes. China's biogas projects resolve exactly that problem for nearly one-quarter of all rural Chinese families. The mix of ingredients that makes China's biogas program successful might hold a key to energy justice for the "Other Third."[3]

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1. Wei Qu, Qin Tu & Bettina Bluemling, *Which Factors are Effective for Farmer's Biogas Use? – Evidence from a Large Scale Survey in China*, 63 ENERGY POL'Y 26, 30 (2013) [hereinafter "*Biogas Survey*"] (indicating at Table 3 that rural homes in China average three residents).

2. Jorrit Gosens, et al., *Sustainability Effects of Household-scale Biogas in Rural China*, 54 ENERGY POL'Y 273, 274 (2013).

3. *See, e.g.*, Lakshman Guruswamy, *Energy Poverty*, 36 ENV. & RES. 139 (2011); Lakshman Guruswamy, *Energy Justice and Sustainable Development*, 21 COLO. J. INT'L ENVTL. L. & POL'Y 231

A great deal has been written recently about China's energy policy[4] and its biogas program.[5] These various books and articles, for instance, explore the history of biogas, its regional distribution, and the social acceptance of biogas. At the same time, there have been significant attempts to distill the laws and policies that might be useful in addressing energy poverty. However, none of the prior literature attempts, as this article does, to identify the policies that led to China's success, nor do prior articles seek to identify the policies most amenable to successful repetition elsewhere.

This article seeks, therefore, to contribute to the energy poverty discussion by separating out the important factors that led to China's biogas success, while also attempting to outline Chinese policies that might be of most use in other parts of the world. The first and introductory part of this article identifies what biogas is, how it is created, what it can be used to do, and also discusses some of its environmental and social benefits and drawbacks. Part II sketches out the energy dynamic in China and compares the figures in China to the worldwide situation using the most recently available data. Part III sketches the question of energy poverty, providing a simple fact-based analysis of the energy poverty felt keenly by approximately one-third of humanity. Part IV analyzes Chinese law and policy

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(2010). The term the "Other Third" is a reference to the fact that about one-third of the world's population lacks access to energy resources. *See id.* For a fuller description of the issue of energy justice generally, *see* Part III, *infra.*

4. *See, e.g.*, Fangy Li, Zhouying Song & Weidong Liu, *China's Energy Consumption Under the Global Economic Crisis: Decomposition and Sectoral Analysis*, 64 ENERGY POL'Y 193 (2014); Bao-Jie He, Li Yang, & Miao Ye, *Building energy efficiency in China rural areas: Situation, drawbacks, challenges, corresponding measures and policies*, 11 SUSTAINABLE CITIES & SOC'Y 7 (2014); CHINA'S SEARCH FOR ENERGY SECURITY: DOMESTIC SOURCES AND INTERNATIONAL IMPLICATIONS (Suisheng Zhao ed., 2013); PHILIP ANDREWS-SPEED, THE GOVERNANCE OF ENERGY IN CHINA: TRANSITION TO A LOW-CARBON ECONOMY (2012); CHINA'S ENERGY EFFICIENCY AND CARBON EMISSIONS OUTLOOK (Bruno Skaali & Tomas Knezevic eds., 2012); ENERGY CONSUMPTION IN CHINA: OUTLOOK AND DEMAND SCENARIOS (Brian A. Childers & Margret C. Downing eds., 2012); PHILIP ANDREWS-SPEED, ENERGY POLICY AND REGULATION IN THE PEOPLE'S REPUBLIC OF CHINA (2003).

5. *See, e.g.*, Wei Qu, Qin Tu & Bettina Bluemling, *Which Factors are Effective for Farmer's Biogas Use? – Evidence from a Large Scale Survey in China*, 63 ENERGY POL'Y 26, 30 (2013); Gosens, et al., *supra* note 2; Bettina Bluemling, Arthur P.J. Mol & Qin Tu, *The Social Organization of Agricultural Biogas Production and Use*, 63 ENERGY POL'Y 10 (2013); Ling Chen, Lixin Zhao, Changshan Ren & Fei Wang, *The Progress and Prospects of Rural Biogas Production in China*, 51 ENERGY POL'Y 58 (2012); David Fridley, Nina Zheng & Nathaniel Aden, *What Can China Do? China's Best Alternative Outcome for Energy Efficiency and CO_2 Emissions*, *in* CHINA'S ENERGY EFFICIENCY & CARBON EMISSIONS OUTLOOK 80 (Bruno Skaali & Tomas Knezevic eds., 2012); Wang Yichao. *Analysis on the Development History of and Research on China's Biogas*. 3 AGRIC. ARCHAEOLOGY 266(2012); Wang Fei, Cai Yaqing, Qiuhuanguang, *Current Status, Incentives and Constraints for Future Development of Biogas Industry in China*, 28 TRANSACTIONS OF THE CSAE 184 (2012); Li Jingming, Xue Mei, *Review and Prospect on Biogas Development in China*. 28 RENEWABLE ENERGY RESOURCES 1 (2010); Yu Chen, et al., *Household Biogas Use in Rural China: A Study of Opportunities and Constraints*, 14 RENEWABLE & SUSTAINABLE ENERGY REV. 545 (2010); Huang Liming, *Financing Rural Renewable Energy: A Comparison Between China and India*, 13 RENEWABLE & SUSTAINABLE ENERGY REV. 1096 (2009); Lin Gan & Juan Yu, *Bioenergy Transition in Rural China: Policy Options and Co-benefits*, 36 ENERGY POL'Y 531 (2008).

regarding biogas focusing on governmental action, subsidies, extension networks, marketing and advertising, market forces, educational factors, climatic factors, and foreign investment. Finally, Part V attempts to extract potentially useful policy prescriptions from the Chinese biogas experience. A brief conclusion brings this article to a close. In summary, and as set forth herein, our research indicates that China's biogas program is a model for action that might be useful as other nations seek to overcome energy poverty.

II. THE POTENTIAL OF BIOGAS

A biogas digester takes wastes from the fields and rural communities, like straw, rice or corn husks, vegetable waste, animal waste, and human waste, and it decomposes it in a controlled way that creates a substance very like natural gas, but it is called biogas.[6] One or two cows, six to eight pigs, or four adult humans can supply adequate daily feedstock for a single-household biodigester.[7] The device is called a "digester" because it is designed to create a favorable environment for "anaerobic" bacteria, which will "eat" the waste, giving off methane as byproduct of *their* digestive process.[8] Anaerobic means "in the absence of oxygen." In fact, the bacteria, which do the digesting, are very similar to many of the bacteria existing inside the guts of mammals.[9] The biogas digester is designed to facilitate the growth of these anaerobic bacteria, because without them no biogas is created.

A biogas digester is a relatively simple device. It has no moving parts, and it requires no input of energy—short of the waste feedstock—to operate.[10] As a result, biogas digesters are relatively inexpensive, and their construction is well-known.[11] The following is a diagram showing a typical rural biogas digester:

6. Christopher Higman & Maarten van der Burgt, GASIFICATION 83-84 (2d ed. 2008) ; Elizabeth Price & Paul Cheremisonoff, BIOGAS PRODUCTION AND UTILIZATION 55-86 (1981) [hereinafter *Biogas Production*].

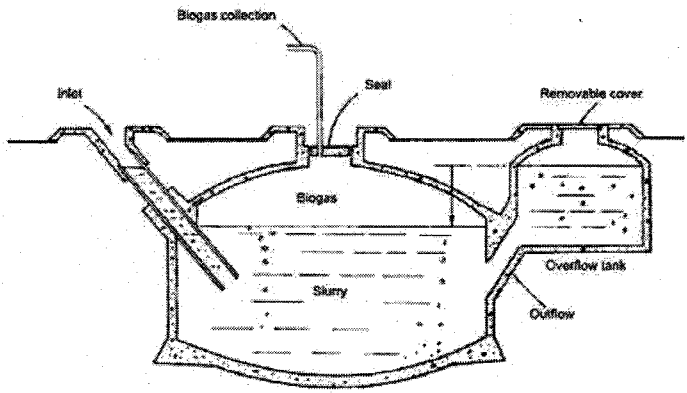
7. Valerie Brown, *BIOGAS: A Bright Idea for Africa*, 114 ENVIRON HEALTH PERSPECTIVES 300, 301 (2006) [hereinafter *Bright Idea*].

8. *See Biogas Production*, *supra* note 6, at 87-117.

9. *Id.*

10. *Id.*

11. *Id.*



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Because a biogas digester is designed to grow living organisms, its operation and maintenance can be dynamic and complicated. Temperature is important.[13] Likewise, the mix of waste, bacteria, and water will substantially affect the efficiency and results obtained by the digester.[14]

Just like natural gas, biogas can be used to cook, heat homes, light rooms, power cars and other machines, and generate electricity. [15] Leftovers from biogas can be a high quality fertilizer which may be valuable in a rural setting.[16] Because biogas is produced from agricultural wastes that otherwise are discarded, harnessing biogas can not only reduce water and air pollution, but the energy source is also inherently "renewable." Moreover, biogas digesters treat pathogens, reducing suffering from infectious diseases.[17]

Biogas can have significant environmental benefits. In Nepal, biogas plants serving 1.25 million people reduced black carbon and eliminated 630,000 tons of

12. Li Kangmin & Mae-Wan Ho, *Biogas China*, INST. SCI. IN SOCIETY (Feb. 10, 2006), www.i-sis.org.uk/BiogasChina.php; *see also* Regina Gregory, *China—Biogas*, ECOTIPPING POINTS PROJECT (Nov. 2010), http://www.ecotippingpoints.org/our-stories/indepth/china-biogas.html.

13. *Id.* at 87-88.

14. *Id.*

15. *See Biogas*, ASHDEN, http://www.ashden.org/biogas (last visited Aug. 5, 2014). Solar technologies also have a significant contribution to make as ASETs for lighting. *See, e.g.*, Firdaus Kharas, *2012's Best Solar Lights In the Developing World*, SOLAR CAMPAIGN (Nov. 15, 2012), http://www.solarcampaign.org/2012s-best-solar-lights-in-the-developing-world/.

16. See, for example, BENJAMIN SOVACOOL & IRA MARTINA DRUPADY, ENERGY ACCESS, POVERTY, AND DEVELOPMENT: THE GOVERNANCE OF SMALL-SCALE RENEWABLE ENERGY IN DEVELOPING ASIA 71 (2012), noting in relation to biogas development in Bangladesh that "[o]ne interesting offshoot from the biogas program has been the production of high quality organic fertilizer, made as a byproduct from . . . biogas plant[s]."

17. *See Bright Idea*, *supra* note 7 at 302 ("Properly designed and used, a biogas digester mitigates a wide spectrum of environmental undesirables: it improves sanitation; it reduces greenhouse gas emissions; it reduces demand for wood and charcoal for cooking, and therefore helps preserve forested areas and natural vegetation; and it provides a high-quality organic fertilizer.").

carbon dioxide emissions.[18] Moreover, 420,000 tons of fuel wood was not cut down, improving water quality in watersheds dependent upon a living forest.[19] And, using biogas can eliminate methane would otherwise be created. Because methane is a greenhouse gas twenty times more powerful that carbon dioxide, burning the methane in biogas to make heat, light, or to cook actually reduces the climate change potential of development.[20]

On the other hand, biogas has its drawbacks. It concentrates nutrients, which when not disposed of properly cause land-based water pollution.[21] Concentrated pollutants can have more profound impacts on natural water systems.[22] The biogas itself is explosive. And, since biogas can displace air, digesters need to be placed in well-ventilated areas to prevent asphyxiation.[23] When not properly managed, or when distribution systems are substandard, it can cause fires, damaging property, injuring, or killing.[24] It is, therefore, imperative that biogas development be accompanied with a management plan that adequately addresses these concerns so that the drawbacks do not overpower the benefits. As we will see, China's biogas system is successful in part because its government is attempting to comprehensively address these management issues.

III. SOURCES OF ENERGY

China is a vibrant country, especially when viewed through the lens of development and energy. China is the world's most populous country; it is geographically enormous, and it is diverse in every sense. In broad terms, China is the largest consumer of energy in the world.[25] China's energy use has grown at a

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18. *See Biogas Sector Partnership, Nepal: Domestic Biogas*, ASHDEN, http://www.ashden.org/winners/bsp (last visited Aug. 5, 2014).

19. *See id.* ("One user's feedback was very simple 'I would never' she said, 'have contemplated marrying a man whose home didn't have a biogas plant.'")

20. Biogas is already a significant energy source in the United States. *See Landfill Methane Outreach Project*, EPA, http://www.epa.gov/lmop (last updated July 7, 2014).

21. J.B. Holm-Nielsen, T. Al Seadi & P. Oleskowicz-Popiel, *The future of anaerobic digestion and biogas utilization*, 100 BIORESOURCE TECH. 5478, 5478 (2009).

22. See, for example, Jessica Leet, et al., *Assessing Impacts of Land-Applied Manure from Concentrated Animal Feeding Operations on Fish Populations and Communities*, 46 ENVTL. SCI. & TECH. 13440 (2012) for a discussion on the impacts, for instance of concentrated animal feeding operation waste on minnows. While the article does not address biogassification, wastes from concentrated animal feeding operations are often used as feed stocks for biogas units. Therefore, the impact of these wastes on the environment, particularly after concentration by bio gasification, is a relevant drawback.

23. *Beginners Guide to Biogas*, U. ADELAIDE, http://www.adelaide.edu.au/biogas/safety/ (last updated May 8, 2014).

24. *See, e.g.*, GERMAN AGRICULTURAL OCCUPATIONAL HEALTH & SAFETY AGENCY, SAFETY RULES FOR BIOGAS SYSTEMS (2008), *available at* http://www.biogaspro.com/assets/3rd_party/safety-rules-for-biogas-systems-2008.pdf.

25. INTERNATIONAL ENERGY AGENCY [IEA], 2013 KEY WORLD ENERGY STATISTICS 46 (2013) [hereinafter IEA KEY STATS], *available at* http://www.iea.org/publications/freepublications/publication/KeyWorld2013.pdf. IEA's report uses 2011 data. China is reported in 2011 to have a Total Primary Energy Supply ("TPES") of 2,728 Million

stunning rate. For example, the International Energy Agency reports that in 1973 China accounted for 7% of the entire world's Total Primary Energy Supply ("TPES").[26] The IEA's most recent data shows that in 2011 China accounted for 20.9% of the world's TPES.[27] In that same time the world's TPES doubled, from about 6,000 Million Tons Oil Equivalent ("Mtoe") to 12,000 Mtoe.[28] Since the overall world energy supply itself doubled in the same time frame that China's fraction increased by three-times,[29] China's actual energy supply increased six-fold – all in just less than forty years.

China's growth is expected to continue.[30] Today, China's energy use per person is much lower, for instance, than the United States'.[31] Specifically, in 2011, China's use of energy, expressed commonly in the literature as "Tons of Oil Equivalent" ("Toe") per person – the amount of energy used per person – was 2.03.[32] In just the four years since China exceeded the United States as the largest emitter of Carbon Dioxide,[33] China's Toe per person increased by more than 0.5 Toe per person, from 1.48 Toe per person.[34] When GDP increases, it has been observed that the Toe per person rate increases as well.[35] Comparatively, in 2011, the United States' Toe per person was 7.02.[36] Accordingly, as GDP increases in China, rates of energy consumption would appear primed for growth, as well.[37]

In China, the dominant source of energy is coal/peat—at 68% of the supply.[38] However, biofuels and waste are the third largest supply of energy (7.9%), behind oil (16.2%).[39] Indeed, biofuels and waste supply more energy in China than natural gas, nuclear, hydro, geothermal, solar, and wind—*combined*.[40] The following chart from the International Energy Agency ("IEA") illustrates China's energy supply in 2011:

Tons Oil Equivalent (Mtoe). *Id.* The United States, which previously led the world in energy consumption, is second, with a TPES in 2011 of 2,191 Mtoe. *Id.* For the most up to date statistics see *Statistics Search*, INT'L ENERGY AGENCY, http://www.iea.org/statistics/statisticssearch/ (last visited Aug. 5, 2014) where the IEA's available data for any country can be accessed easily.

26. *See* IEA KEY STATS, *supra* note 25, at 8.

27. *Id.*

28. *Id.*

29. *Id.*

30. DAVID G. FRIDLEY, NINA ZHENG & NATHANIEL T. ADEN, WHAT CAN CHINA DO? CHINA'S BEST ALTERNATIVE OUTCOME FOR ENERGY EFFICIENCY AND CO_2 EMISSIONS 80 (2012).

31. IEA KEY STATS, *supra* note 25, at 57 (the United States' Toe/ per person was 7.02 in 2011—more than 3-times China's per person use of electricity).

32. *Id.* at 49.

33. *China overtakes U.S. in greenhouse gas emissions*, N.Y. TIMES, June 20, 2007, http://www.nytimes.com/2007/06/20/business/worldbusiness/20iht-emit.1.6227564.html?_r=0.

34. FRIDLEY, *supra* note 30, at 80.

35. *Id.*

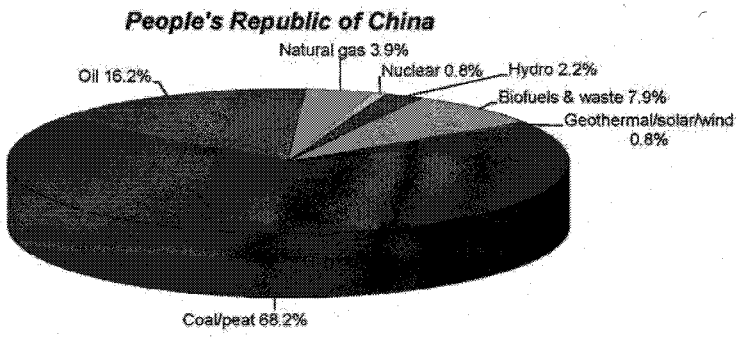
36. IEA KEY STATS, *supra* note 25, at 57.

37. FRIDLEY, *supra* note 30, at 80.

38. *See Share of total primary energy supply in 2011: People's Republic of China*, IEA ENERGY STAT., http://www.iea.org/stats/WebGraphs/CHINA4.pdf (last visited Feb. 2, 2014).

39. *Id.*

40. *Id.*



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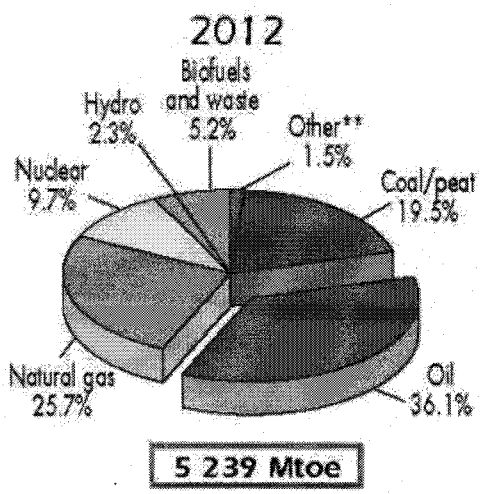
China's energy mix is different from the worldwide experience. The IEA reports that in 2012, oil was the world's largest source of energy (36.1%), while biofuels and waste were fifth most abundant (5.2%), behind natural gas (25.7%), coal/peat (19.5%) and nuclear (9.7%).[42] On a worldwide scale, biofuels (which include biogas and other fuels) continued to be an important source of energy, exceeding the input of hydro, geothermal, solar and wind, combined.[43] However, they do not have the same importance worldwide that biogas has in China. The following chart from the IEA illustrates the world's fuel supply in 2012:



41. *Id.*
42. *See* IEA KEY STATS, *supra* note 25, at 7.
43. *Id.*

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IV. ENERGY POVERTY

The question of the sources of energy invariably leads to the inequitable fact that less than 17% of the world's population consumes 80% of the world's resources.[45] The inverse of that equation leaves about one-third of the world—the "Other Third"[46]—without access to energy resources that are essentially taken for granted in the modern world. What this means is that approximately 2.6 billion people[47] have little or no access to beneficial energy services for cooking, heating, water sanitation, drinking water, illumination, transportation, or basic mechanical needs.[48] Approximately 1.3 billion people lack access to electricity.[49] This lack of access to energy services now bears the name "energy poverty,"[50] and the phenomena contributes to a feedback loop of ill health, economic hardship, and reduced educational opportunities, particularly for women and for children.[51]

In China, the IEA reports that there is near universal access to electricity.[52] The IEA's definition of "energy access" as applied to electricity is "a first electrical supply connection, with a minimum level of consumption (250 kilowatt-hours [kWh] per year for a rural household . . .) . . . ."[53] This equates to enough electricity to light perhaps two 60-watt light bulbs for slightly less than six hours per day. Putting aside the question of the quality of electricity access in China (or elsewhere in the developing world), the IEA reports that a full one-third of China's population—446 million people—rely on biomass for cooking.[54]

Therefore, China is home to nearly one-quarter of all the people worldwide that lack access to modern energy services. Most of these people are in rural parts

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44. *Id.*

45. *See Social & Economic Injustice*, WORLD CENTRIC, http://worldcentric.org/conscious-living/social-and-economic-injustice (last visited Aug. 5, 2014).

46. *See The Other Third*, U. COLO. BOULDER, http://www.colorado.edu/theotherthird/ (last visited Aug. 5, 2014).

47. The approximately 2.6 billion people are predominantly located in Africa, Asia, and South America. *See* IEA, WORLD ENERGY OUTLOOK 2013, at 89, tbl.2.3 (2013).

48. Lakshman Guruswamy, *Energy Justice and Sustainable Development*, 21 COLO. J. INT'L ENVTL. L. & POL'Y 231, 231 (2010).

49. *See* IEA, *supra* note 47, at 88, 89, tbl. 2.3.

50. Patrick Nussbaumer, Morgan Brazilian & Vijay Modi, *Measuring Energy Poverty: Focusing on What Matters*, 16 RENEWABLE & SUSTAINABLE ENERGY REVS. 231, 232 (2012).

51. Guruswamy, *supra* note 48, at 240, 244.

52. *See* IEA, *supra* note 47, at 89, tbl. 2.3.

53. *See* IEA, *supra* note 47, at 530.

54. *See* IEA, *supra* note 47, at 89, tbl. 2.3. Given that there is universal electricity access, and that still nearly 1/2 of China's population relies on biomass for cooking, and that about 15% of China's population relies on biogas for heating and cooking energy, it is clear that the minimal energy supplied by electricity is but one part of the equation.

of China.[55] Indeed, the only country in the world likely to have more people living in energy poverty is India.[56] It is in the face of these stark and unrelenting facts that we look at China's significant and meaningful efforts in developing the use of biogas.

V. CHINESE BIOGAS LAW AND POLICY

A. The History of China's Rural Biogas Development

China has a long history of biogas utilization. In the 1880s, scientists experimented with biogas in Chaomei area of Guangdong province.[57] By the end of the 19th century, small and simple biogas digesters were demonstrated.[58] In the 1920s, Luo Guorui from Taiwan invented what was called the "hydraulic pressure biogas pool" and in 1929, he established the first biogas promotion organization—the Guorui Gas Lamp Company.[59] In 1931, when he moved to Shanghai, Luo Guorui established a new biogas company.[60] The company grew, eventually extending biogas production into thirteen provinces.[61] China's initial biogas development was one of entrepreneurship.

Since the establishment of new China, the government has highly valued the potential role of biogas.[62] Chinese biogas developed quickly. However, the development was not steady. There were setbacks, which are discussed below. The development of Chinese biogas in new China can be roughly divided into four stages as set out herein.

B. Initial Development (from the 1950s to the 1980s)

In 1958, Chairman Mao Zedong, upon learning that biogas can be used to light lamps and for cooking, and that the byproducts can also be used as fertilizer, undertook efforts to promote and develop biogas.[63] A critical mass developed starting around the end of the 1960s to the beginning of the 1970s, when more than

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55. Wei Qu, Qin Tu & Bettina Bluemling, *Which Factors are Effective for Farmer's Biogas Use?—Evidence from a Large Scale Survey in China*, 63 ENERGY POL'Y 26, 30 (2013).

56. See IEA, *supra* note 47, at 88, n.19 noting that in 2012 India's total population estimates were increased greatly, increasing the numbers of persons estimated to be living without access to modern energy services.

57. *Analysis on the Development History of and Research on China's Biogas*, *supra* note 5.

58. *Id.*

59. *Id.*

60. *Id.*

61. *Id.*

62. Mao Zedong, Deng Xiaoping, Jiang Zemin, and Hu Jintao respectively inspected the rural biogas work in 1958, 1980, 1991, and 2003. All of them gave instructions to develop Chinese rural biogas. In 2002 and 2006, former Premier Wen Jiabao emphasized the development of rural biogas.

63. MINISTRY OF AGRICULTURE OF THE PEOPLE'S REPUBLIC OF CHINA, QUANGUO NONGCUN ZHAOQI FUWU TIXI JIANSHE FANG'AN (SHIXING) (全国农村沼气服务体系建设方案 (试行)) [NATIONAL RURAL BIOGAS SERVICE SYSTEM CONSTRUCTION PROGRAM (TRIAL)] (2007) [hereinafter TRIAL CONSTRUCTION PROGRAM 2007], *available at* http://www.fjagri.gov.cn/upload/File/20090626113917.doc.

six million biogas digesters were built.[64] However, owing at least in part to unknown technology issues, the design and construction, maintenance and operation of these digesters was not standard.[65] There were failures with many of the digesters, resulting in only a small percentage of them being used for any substantial period of time.[66]

In 1979, the State Council endorsed the Report of the Ministry of Agriculture on Several Issues in the Contemporary Construction of Biogas in Rural Areas.[67] The State Council created the National Biogas Construction Leading Group.[68] As a result, China's biogas underwent another period of rapid development, and the number of households with biogas digesters increased to seven million by the close of the decade.[69] However, the number abruptly dropped to four million in the beginning of the 1980s owning to the re-adoption of indigenous methods that were found preferable to the management of a biodigester.[70]

C. *Adjustment and Technological Improvement (from the mid-1980s to 2000)*

In 1988, the Chinese Biogas Association was founded.[71] The Chinese government called upon biogas technicians to cooperate and make breakthroughs in the key biogas technologies.[72] At the same time, the government created a uniform biogas digester construction policy centered on "suitable local conditions, adhering to quality, paying attention to both construction and management, comprehensive utilization, emphasizing practical results as well as active and steady development."[73]

From 1984 to 1991, a great deal of effort was dedicated to repairing the previously built, but defectively made or poorly maintained digesters. During that

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64. ZHONGGUO ZHAOQI CHANYE FAZHAN LICHENG HUIGU (中国沼气产业发展历程回顾) [FUJIAN PROVINCIAL AGRICULTURAL DEPARTMENT], FUJIAN SHENG NONGYE TING (福建省农业厅) [REVIEW ON THE DEVELOPMENT PROCESS OF CHINA'S BIOGAS INDUSTRY] (2011), *available at* http://www.fjagri.gov.cn/html/hypd/stny/ncny/2011/03/01/65475.html.

65. *Id.*

66. *Id.*

67. Wang Fei, Cai Yaqing, & Qiuhuanguang (王 飞, 蔡亚庆, 仇焕广), *Zhongguo zhaoqi fazhan de xianzhuang, qudong ji zhiyue yinsu fenxi* (中国沼气发展的现状驱动及制约因素分析) [*Incentives and constraints for future development of biogas industry in China*], 28 J. AGRIC. ENGINEERING 184 (2012), *available at* http://www.tcsae.org/nygcxben/ch/reader/view_abstract.aspx?flag=1&file_no=20120133&journal_id=nygcxb.

68. DENG GUANGLIAN, (邓光联), ZHONGGUO ZHAOQI JIANSHE XIANZHUANG YU FAZHAN DUICE (中国沼气建设现状与发展对策) PRESENT SITUATION OF AND DEVELOPMENT SUGGESTIONS FOR CHINA'S BIOGAS CONSTRUCTION 26 (2007), *available at* http://wenku.baidu.com/link?url=yvWB5cgQIn7r7qNWZ_wfk-UTjhJy0CFmFK0iAq6tJOAOQxL-aCdgSl8CtjUiDuiBeiZhpq5u8eSLqCPPZ4DYktkskcZD2aOoGKGKS8xEEzu.

69. FUJIAN PROVINCIAL AGRICULTURAL DEPARTMENT, *supra* note 64.

70. *Id.*

71. DENG GUANGLIAN, *supra* note 68.

72. FUJIAN PROVINCIAL AGRICULTURAL DEPARTMENT, *supra* note 64.

73. DENG GUANGLIAN, *supra* note 68.

time, about 100,000 household biogas digesters were built every year.[74] From 1992 to 1998, the benefit of biogas construction became more and more obvious as the result of improvements in the technology that resulted from the policies adopted in the prior decade.[75] As a result, in the mid-to-late 1990s, the rate of biogas digester construction increased drastically to about 500,000 each year.[76]

In 1997, the Law of the People's Republic of China on Energy Conservation was enacted,[77] encouraging and supporting the vigorous development of biogas in rural areas. By the end of 2000, there were 9.8 million rural biogas household digesters in China.[78]

D. Rapid Development (from 2001 to 2006)

In 1999, the Ministry of Agriculture began to strongly promote biogas, not just in the southern provinces, but in the northern ones as well.[79] The Ministry of Agriculture carried out campaigns called variously the "Energy Environmental Protection Project" and "Ecological Homestead Rich Peasants Project," among others.[80] These positively phrased names appear aimed to promote interest in biogas.[81]

Rural biogas development was also strengthened at this time by a number of important central committee policies:

- The Opinions of the CPC Central Committee and State Council on Several Policies to Promote the Increase of Farmers' Income of 2004,[82]
- The Opinions of the CPC Central Committee and State Council on Several Policies to Further Strengthen Rural Work and Improve Agricultural Comprehensive Production Capacity of 2005,[83]

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74. TU YUNZHANG (屠云璋), ZHONGGUO ZHAOQI FAZHAN XIANZHUANG 1 (中国沼气发展现状) [PRESENT SITUATION OF CHINA'S BIOGAS DEVELOPMENT] (2012), *available at* http://wenku.baidu.com/link?url=hiqsdCATnNaQOKoXUmL-bub0Qzyhu7zrRErw5MXTQJhsBtmofEa5MQHKH42IFbW5UM5KlPtE5GVMfN2pliQlvbjm7ltdVtCQgMhTboUuNbG.

75. FUJIAN PROVINCIAL AGRICULTURAL DEPARTMENT, *supra* note 64.

76. TU YUNZHANG, *supra* note 74 at 2.

77. *See* Zhonghua Renmin Gongheguo Jieyao Nengyuan Fa (中华人民共和国节约能源法) [Law of the People's Republic of China on Energy Conservation] (promulgated by the Standing Comm. Nat'l People's Cong., Oct. 28, 2007, effective Apr. 1, 2008) 2006 STANDING COMM. NAT'L PEOPLE'S CONG. GAZ. 258 Art. 59.

78. TRIAL CONSTRUCTION PROGRAM 2007, *supra* note 63.

79. FUJIAN PROVINCIAL AGRICULTURAL DEPARTMENT, *supra* note 64.

80. *Review and prospect on biogas development in China*, *supra* note 5.

81. Id.

82. THE CENTRAL PEOPLE'S GOVERNMENT OF THE PEOPLE'S REPUBLIC OF CHINA, ZHONGGONG ZHONGYANG GUOWUYUAN GUANYU CUJIN NONGMIN ZENGJIA SHOURU RUOGAN ZHENGCE DE YIJIAN (中共中央国务院关于促进农民增加收入若干政策的意见) [OPINIONS OF THE CPC CENTRAL COMMITTEE AND STATE COUNCIL ON SEVERAL POLICIES TO PROMOTE THE INCREASE OF FARMERS' INCOME OF 2004] (2003), *available at* http://www.gov.cn/test/2005-07/04/content_11870.htm.

83. THE CENTRAL PEOPLE'S GOVERNMENT OF THE PEOPLE'S REPUBLIC OF CHINA, ZHONGGONG ZHONGYANG GUOWUYUAN GUANYU JINYIBU JIAQIANG NONGCUN GONGZUO TIGAO NONGYE ZONGHE

- Circular of the State Council on the Recent Key Work of Constructing Conservation Oriented Society of 2005,[84] as well as the
- Opinions of the CPC Central Committee and State Council on Promoting the Construction of New Socialist Countryside of 2006.[85]

The Fifth Plenary Sessions of 16th Central Committee of the Communist Party of 2005 required the vigorous expansion of rural biogas and the active development of clean energy suitable in rural conditions.[86] In the 11th Five-Year Plan Outlines for National Economic and Social Development (2006-2010), rural biogas is listed as one of the key projects of new countryside construction.[87] In the 12th Five-Year Plan for Renewable Energy Development, biogas is listed as one of the eight key projects in renewable energy development.[88]

At the same time, the government also created mechanisms to fund the development of rural biogas. The Opinions of the CPC Central Committee and the State Council on the Development of Agricultural and Rural Work of 2003,[89] the Management Measures for Rural Biogas Construction Treasury Bonds Programme (Trial)[90] as well as the 2006 Implementation Opinions on the Fiscal and Tax Policy

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SHENGCHAN NENGLI RUOGAN ZHENGCE DE YIJIAN (中共中央国务院关于进一步加强农村工作提高农业综合生产能力若干政策的意见) [OPINIONS OF THE CPC CENTRAL COMMITTEE AND STATE COUNCIL ON SEVERAL POLICIES TO FURTHER STRENGTHEN RURAL WORK AND IMPROVE AGRICULTURAL COMPREHENSIVE PRODUCTION CAPACITY OF 2005] (2004), *available at* http://www.gov.cn/test/2006-02/22/content_207406.htm.

84. THE CENTRAL PEOPLE'S GOVERNMENT OF THE PEOPLE'S REPUBLIC OF CHINA, GUOWUYUAN GUANYU ZUO HAO JIANSHEJIEYUEXING SHEHUI JINQI ZHONGDIAN GONGZUO DE TONGZHI (国务院关于做好建设节约型社会近期重点工作的通知) [CIRCULAR OF THE STATE COUNCIL ON THE RECENT KEY WORK OF CONSTRUCTING CONSERVATION ORIENTED SOCIETY] (2005), *available at* http://www.gov.cn/zwgk/2005-09/08/content_30265.htm.

85. THE CENTRAL PEOPLE'S GOVERNMENT OF THE PEOPLE'S REPUBLIC OF CHINA, ZHONGGONG ZHONGYANG GUOWUYUAN GUANYU TUIJIN SHEHUI ZHUYI XIN NONGCUN JIANSHE DE RUOGAN YIJIAN (中共中央 国务院关于推进 社会主义新农村建设的若干意见) [OPINIONS OF THE CPC CENTRAL COMMITTEE AND STATE COUNCIL ON PROMOTING THE CONSTRUCTION OF NEW SOCIALIST COUNTRYSIDE OF 2006] (2005), *available at* http://www.gov.cn/gongbao/content/2006/content_254151.htm.

86. *Id.*

87. THE CENTRAL PEOPLE'S GOVERNMENT OF THE PEOPLE'S REPUBLIC OF CHINA, ZHONGHUA RENMIN GONGHEGUO GUOMIN JINGJI HE SHEHUI FAZHAN DI SHIYI GE WU NIAN GUIHUA GANGYAO (中华人民共和国国民经济和 社会发展第十一个五年规划纲要) [11TH FIVE-YEAR PLAN FOR RENEWABLE ENERGY DEVELOPMENT] (2006), *available at* http://www.gov.cn/gongbao/content/2006/content_268766.htm.

88. The Central People's Government of the People's Republic of China, Ke Zaisheng Nengyuan Fazhan Shi'erwu Guihua Quanwen (可再生能源发展十二五规划全文) [12th Five-Year Plan for Renewable Energy Development] (2013), *available at* http://www.ce.cn/cysc/ny/zcjd/201302/01/t20130201_21331890.shtml.

89. XINJIANG AGRICULTURE, ZHONGGONG ZHONGYANG GUOWUYUAN GUANYU ZUO HAO NONGYE HE NONGCUN GONGZUO DE YIJIAN (中共中央国务院关于做好农业和农村工作的意见) [THE OPINIONS OF THE CPC CENTRAL COMMITTEE AND THE STATE COUNCIL ON THE DEVELOPMENT OF AGRICULTURAL AND RURAL WORK OF 2003] (2003), *available at* http://www.xjxnw.gov.cn/zx/snzc/xjwjhb/2003n/09/902259.shtml.

90. GUOWUYUAN BANGONG TING GUANYU JIAQIANG JICHU SHESHI GONGCHENG ZHILIANG GUANLI DE TONGZHI (国务院办公厅关于加强基础设施工程质量管理的通知) [STATE COUNCIL

to Support the Development of Bio Energy and Bio Chemical Industry[91] clearly strengthened the government's efforts by creating ways to fund biogas for rural farmers, who do not usually have the funds necessary to install biogas facilities.[92]

Provisions concerning the promotion of rural biogas construction were incorporated into relevant laws. For instance, Article 52 of the Regulations on Conversion of Farmland to Forests provides that local governments at various levels shall, in the light of the actual situation, strengthen the rural biogas construction, as well as small-scale hydropower, solar energy and wind energy to meet the demands for energy by those who convert their farmland to forests.[93]

Likewise, Article 57 of Agriculture Law of the People's Republic of China contains a number of relevant provisions in relation to the development of agriculture and the rural economy:

- Attention shall be paid to the rational use and protection of the natural resources, such as the land, water, forests, grasslands and wild animals and plants,
- Development shall include the use of renewable and clean sources of energy such as hydro-energy, biogas, solar energy and wind energy,
- Development shall address the ecological aspects of agriculture, and
- Development shall protect and improve the ecological environment.[94]

Article 39 of the Animal Husbandry Law of the People's Republic of China states that Livestock and poultry breeding farms and small-scale breeding villages shall "4) . . . have such facilities as biogas digesters or other harmless treatment

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CIRCULAR ON STRENGTHENING INFRASTRUCTURE PROJECT QUALITY MANAGEMENT], NONGCUN ZHAOQI JIANSHE GUOZHAI XIANGMU GUANLI BANFA (SHIXING) (农村沼气建设国债项目管理办法(试行)) [MANAGEMENT MEASURES FOR RURAL BIOGAS CONSTRUCTION TREASURY BONDS PROGRAM (TRIAL)] (2003), *available at* http://www.moa.gov.cn/zwllm/zxfb/201007/P020100702547096593568.doc.

91. MINISTRY OF FIN. OF CHINA, CAIZHENG BU GUOJIA FAZHAN GAIGE WEI NONGYE BU GUOJIA SHUIWU ZONGJU GUOJIA LINYE JU GUANYU FAZHAN SHENGWU NENGYUAN HE SHENGWU HUAGONG CAISHUI FUCHI ZHENGCE DE SHISHI YIJIAN (财政部国家发展改革委农业部国家税务总局国家林业局关于发展生物能源和生物化工财税扶持政策的实施意见) [2006 IMPLEMENTATION OPINIONS ON THE FISCAL AND TAX POLICY TO SUPPORT THE DEVELOPMENT OF BIO ENERGY AND BIO CHEMICAL INDUSTRY] (2006), *available at* http://www.mof.gov.cn/zhengwuxinxi/caizhengwengao/caizhengbuwengao2007/caizhengbuwengao20071/200805/t20080519_26018.html.

92. *China Biogas Project Turns Waste into Energy*, IFAD, http://www.ruralpovertyportal.org/country/voice/tags/china/biogas (last visited Aug. 5, 2014).

93. Tuigeng huan lin Tiaoli (退耕还林条例) [Regulations on Conversion of Farmland to Forests] (promulgated by the State Council, Dec. 6, 2002, effective Jan. 20, 2003) art. 52 (China), *available at* http://www.gov.cn/gongbao/content/2003/content_62531.htm.

94. Zhongguo de Zhonghua Renmin Gongheguo Nongye fa (中国的中华人民共和国农业法 [Agriculture Law] (promulgated by the Standing Comm. Nat'l People's Cong., Dec. 28, 2002, effective March 1, 2003) art. 57 (China), *available at* http://www.gov.cn/ziliao/flfg/2005-09/12/content_30998.htm.

facilities to comprehensively utilize livestock manure, waste water and other solid wastes."[95]

The Renewable Energy Law of 2005 encourages biomass power generation and states in Article 18 that the state shall encourage the development and utilization of renewable energy sources in rural areas.[96] Under the 2005 Renewable Energy Law, energy authorities of local people's governments above the county level shall make renewable energy plans in rural areas on the basis of local economic and social development, ecological protection and health needs, and the promotion of biogas shall be included in these plans. [97] Meanwhile, under this law the local people's governments above the county level are required to provide financial support for project of renewable energy utilization in rural areas.[98]

In 2006, the National Development and Reform Commission enacted the Provisions Concerning the Management of Electricity Generated from Renewable Energy[99] and the Trial Measures for the Management of Prices and Allocation of Costs for Electricity Generated from Renewable Energy.[100] The two regulations specifically provide that the State Council department in charge of prices shall establish a benchmark price for different areas if the feed-in tariff for biomass generating electricity is set by the government.[101] These tariffs provide for the opportunity to encourage biogas to electricity projects.

Government funding for biogas development increased at the turn of the millennium. From 2001 to 2006 the central government invested 6.12 billion RMB in the construction and development of biogas, which resulted in thirteen million households building biogas plants for their domestic energy needs.[102] At

95. Zhonghua Renmin Gongheguo Xumu fa (中华人民共和国畜牧法) [Animal Husbandry Law] (promulgated by the Standing Comm. Nat'l People's Cong., Dec. 29, 2005, effective July 1, 2006) art. 39 (China), *available at* http://www.gov.cn/ziliao/flfg/2005-12/29/content_141833.htm.

96. Zhonghua Renmin Gongheguo ke Zaisheng Nengyuan fa (Xiuzheng an) (中华人民共和国可再生能源法 (修正案)) [Renewable Energy Law (Amendment)], (promulgated by the Standing Comm. Nat'l People's Cong., Feb. 28, 2005, amended Dec. 26, 2009) art. 18 (China), *available at* http://www.npc.gov.cn/huiyi/cwh/1112/2009-12/26/content_1533216.htm.

97. *Id.*

98. *Id.*

99. *Kezaisheng Nengyuan Fadian Youguan Guanli Guiding* (可再生能源发电有关管理规定) [*Notice on Provisions Concerning the Management of Electricity Generated from Renewable Energy*], GUOJIA FAZHAN GAIGE WEI (国家发展改革委) [NAT'L DEV. & REFORM COMM'N], http://www.ndrc.gov.cn/zcfb/zcfbtz/200602/t20060206_58735.html (last visited Sept. 6, 2014).

100. Ke Zai Sheng Neng Yuan Fa Dian Jia Ge He Fei Yong Fen Tan Guan Li Shi Xing Ban Fa (可再生能源发电价格和费用分摊管理试行办法) [The Trial Measures for the Management of Prices and Allocation of Costs for Electricity Generated from Renewable Energy] (promulgated by the Nat'l Dev. and Reform Comm'n, Jan. 4, 2006) (China), *available at* http://www.gov.cn/ztzl/2006-01/20/content_165910.htm.

101. *See Provisions Concerning the Management of Electricity Generated from Renewable Energy*, *supra* note 99; Trial Measures for the Management of Prices and Allocation of Costs for Electricity Generated from Renewable Energy, *supra* note 100.

102. FUJIAN PROVINCIAL AGRICULTURAL DEPARTMENT, *supra* note 64.

the end of 2002, there were eleven million[103] rural households owning biogas digesters and just four years later in 2006, the number doubled to twenty-two million.[104]

E. Management and Strengthening (from 2007 until the Present)

With the development of China's rural biogas, new problems arose. The biggest one was the lack of effective management of the biogas digester, causing low gas production.[105] To deal with this problem, in 2007 and more recently, the government issued a series of policies, regulations and laws to promote the management of biogas digesters. In the Medium to Long-Term Renewable Energy Development Plan of 2007, issued by the National Development and Reform Commission, biogas is listed as a key energy source for China.[106] In 2007, the Ministry of Agriculture published the National Rural Biogas Projects Construction Plan (2006-2010), which sets biogas construction goals.[107] In the same year, the Ministry of Agriculture and the National Development and Reform Commission jointly issued National Rural Biogas Service System Development Scheme[108] and Opinions on Further Strengthening Biogas Construction and Management[109] in which the two ministries put forward the specific requirement of consolidating preliminary work, defining management responsibility, increasing the speed of the construction progress, carrying out funding, management, and strengthening quality control.[110]

The central government emphasized the importance of biogas development in the 12th Five Year Plan for National Economic and Social Development (2011-2015).[111] The government enacted Circular Economy Promotion Law in 2008, in

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103. Zhang Fuwei (张福伟), *Guojia Fuchi Xiangmu Taiyangneng Zhaoqi* (国家扶持项目太阳能沼气) [*Projects Supported by the Government—Solar Energy and Biogas*], CCTV.COM (Sept. 14, 2007, 2:22 PM), http://finance.cctv.com/20070914/107536.shtml.

104. *See* TRIAL CONSTRUCTION PROGRAM 2007 *supra* note 63.

105. See DAVID WARGERT, BIOGAS IN DEVELOPING RURAL AREAS 10-11 (2009), *available at* http://www.davidwargert.net/docs/Biogas.pdf for an explanation of the problems from bad maintenance of biogas digester.

106. NAT'L DEV. & REFORM COMM'N OF CHINA, MEDIUM AND LONG-TERM DEVELOPMENT PLAN FOR RENEWABLE ENERGY IN CHINA (ABBREVIATED VERSION, ENGLISH DRAFT) 6 (2007) *available at* http://www.martinot.info/China_RE_Plan_to_2020_Sep-2007.pdf.

107. TRIAL CONSTRUCTION PROGRAM 2007, *supra* note 63.

108. *Id.*

109. NONGYE BU (农业部) [MINISTRY OF AGRIC.], NONGYE BU GUOJIA FAZHAN HE GAIGE WEIYUANHUI GUANYU JINYIBU JIAQIANG NONGCUN ZHAOQI JIANSHE GUANLI DE YIJIAN (农业部国家发展和改革委员会关于进一步加强农村沼气建设管理的意见) [OPINIONS ON FURTHER STRENGTHENING BIOGAS CONSTRUCTION AND MANAGEMENT] (2007), available at http://www.moa.gov.cn/zwllm/zcfg/qtbmgz/200709/t20070930_898899.htm.

110. *Id.*; OPINIONS ON FURTHER STRENGTHENING BIOGAS CONSTRUCTION AND MANAGEMENT, *supra* note 109.

111. THE CENTRAL PEOPLE'S GOVERNMENT OF THE PEOPLE'S REPUBLIC OF CHINA, Zhonghua Renmin Gongheguo Guomin Jingji he Shehui Fazhan di Shi'er ge wu Nian Guihua Gangyao (中华人民共和国国民经济和社会发展第十二个五年规划纲要) [12th Five Year Plan for National

which the State encouraged and supported agricultural producers and relevant enterprises seeking to employ biogas technologies that make comprehensive use of straw, poultry and livestock manure, or other agricultural wastes.[112] It is pointed out in the 2012 Opinions on Further Strengthening Biogas Construction in Rural Areas that biogas management and service as well as overall biogas project quality should be strengthened.[113]

The use of biogas for rural energy needs has grown steeply in the past two decades. There are many elements contributing to this growth, among which, policies, laws and regulations play a key role.

During the history of China's biogas development, the government issued policies, regulations and laws covering various aspects of rural biogas construction and development. Whenever a new situation arose, the government issued guidelines to direct future action. For instance, the government issued a series of policies, regulations and laws to promote new digester construction, especially during the period from 1999 to 2006.[114] However, when there were problems with design, and the management of the digesters required improvement, the government issued policies, regulations and laws meant to make the operation of the digesters more efficient.[115] In recent years, with the urbanization of China, some areas are in short supply of the waste feedstocks normally used in biogas digesters.[116] More recently, as the management of biogas digesters improved, a demand for a digester service system is increasing. The government issued the

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Economic and Social Development (2011-2015)] (2011), *available at* http://www.gov.cn/2011lh/content_1825838.htm.

112. *See* Zhonghua Renmin Gongheguo Xunhuan Jingji Cujin fa (中华人民共和国循环经济促进法) [Circular Economy Promotion Law] (promulgated by the Standing Comm. Nat'l People's Cong., Aug. 28, 2008, effective Jan. 1, 2009) art. 34 (China), http://www.gov.cn/flfg/2008-08/29/content_1084355.htm.

113. OPINIONS ON FURTHER STRENGTHENING BIOGAS CONSTRUCTION AND MANAGEMENT, *supra* note 109.

114. The following policies and laws were issued during this period: *Opinions of the CPC Central Committee and State Council on Several Policies to Promote the Increase of Farmers' Income of 2004, Opinions of the CPC Central Committee and State Council on Several Policies to Further Strengthen Rural Work and Improve Agricultural Comprehensive Production Capacity of 2005, Circular of the State Council on the Recent Key Work of Constructing Conservation Oriented Society of 2005, Opinions of the CPC Central Committee and State Council on Promoting the Construction of New Socialist Countryside of 2006, Opinions of the CPC Central Committee and the State Council on the Development of Agricultural and Rural Work of 2003, the Management Measures for Rural Biogas Construction Treasury Bonds Programme (Trial), the 2006 Implementation Opinions on the Fiscal and Tax Policy to Support the Development of Bio Energy and Bio Chemical Industry, Agriculture Law of the PRC, Husbandry Law of the PRC and Renewable Energy Law of the PRC.*

115. *See id.*

116. *Bioenergy Transition in Rural China: Policy Options and Co-benefits*, *supra* note 5, at 533 ("This resource constraint becomes particularly severe with the operation of biomass power plants and consequent demand rise for biomass resources.").

2012 Opinions on Further Strengthening Biogas Construction in Rural Areas and suggested concrete measures to deal with these issues.[117]

F. Funding for Biogas Development

Since 2003, more and more funding has been provided by the Chinese government for biogas development. It is stated in the Opinions of the CPC Central Committee and the State Council on the Development of Agricultural and Rural Work of 2003 that biogas construction in rural areas significantly increased rural income, and improved rural living conditions.[118] As a result of those findings, the Central Committee stated that, "[t]he development of biogas in areas of converting cropland to forest shall be given priority."[119] In the same year, the Management Measures for Rural Biogas Construction Treasury Bonds Program (Trial) was enacted.[120] Under the Trial, the central government subsidized rural biogas construction with treasury bonds.[121] This greatly motivated the construction of rural household biogas digesters because money was available for their construction.

Likewise, the 2005 Renewable Energy Law requires the local people's governments above the county level provide financial support for projects of renewable energy utilization in rural areas.[122] It is also clearly pointed out in the 2006 Implementation Opinions on the Fiscal and Tax Policy to Support the Development of Bio Energy and Bio Chemical Industry that the state will implement relevant fiscal and tax policy such as a flexible loss subsidy, raw material base grants, demonstration grants and tax preferences to facilitate the development of bio energy, among other things.[123]

Accordingly, the central government has been increasing its investment in biogas development. In 2001 the Rural Infrastructure Project awarded 0.1 billion RMB in subsidies for rural biogas development, and in 2002, it awarded another 0.2 billion RMB.[124]

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117. *Guojia Fagaiwei yu Nongye bu Fabu Guanyu Jinyibu Jiaqiang Nongcun Zhaoqi Jianshe de Yijian* (国家发改委与农业部发布关于进一步加强农村沼气建设的意见) [*National Development and Reform Commission and the Ministry of Agriculture issued the "Circular on Further Strengthening Rural Biogas Opinion"*], MA'ANSHAN SHI NONGYE WEIYUANHUI BANGONGSHI (马鞍山市农业委员会办公室) [MA'ANSHAN CITY OFFICE OF THE COMMITTEE ON AGRICULTURE] (May 23, 2012, 2:49 PM), http://www.masnw.gov.cn/news_view.asp?newsid=7094.

118. THE OPINIONS OF THE CPC CENTRAL COMMITTEE AND THE STATE COUNCIL ON THE DEVELOPMENT OF AGRICULTURAL AND RURAL WORK OF 2003, *supra* note 89.

119. *Id.*

120. MANAGEMENT MEASURES FOR RURAL BIOGAS CONSTRUCTION TREASURY BONDS PROGRAM (TRIAL), *supra* note 90.

121. *Id.*

122. Renewable Energy Law (Amendment), *supra* note 96.

123. 2006 IMPLEMENTATION OPINIONS ON THE FISCAL AND TAX POLICY TO SUPPORT THE DEVELOPMENT OF BIO ENERGY AND BIO CHEMICAL INDUSTRY, *supra* note 91.

124. DENG GUANGLIAN, *supra* note 68.

Since 2003, the government has been increasing the funding level every year.[125] In 2007, the central government invested 2.5 billion RMB in biogas development.[126] In 2008 the amount reached three billion RMB.[127] At the end of 2008, the central government added three billion RMB.[128] In 2009 and 2010, the central government invested five billion RMB each year specifically supporting the construction and development of rural biogas industry.[129] By the end of 2011, this financing by the government, coupled with the favorable laws and policies mentioned above resulted in 39.96 million households using biogas as an energy source.[130] It is predicted that the number of the rural biogas digesters supplying households with their energy needs will reach between fifty million by 2015.[131]

In the new Opinions on Further Strengthening Biogas Construction in Rural Areas of 2012 the local governments are also required to increase investment in biogas projects.[132]

G. Standardization in the Biogas Industry

From 1950 to 2011, China issued thirty-three standard specification documents for rural biogas systems, forming basic standards systems for rural biogas.[133] With the government's attention switching more to the management of rural biogas, it has recently issued various documents to promote the construction of service systems for biogas.[134]

Various laws, policies, and regulations have been aimed in China at technological standardization in biogas industry. For example, in 2010 the National Development and Reform Commission and the Ministry of Agriculture initiated the Rural Biogas Science and Technology Support Project and special funds were arranged to increase the gas production ratio, broaden the biogas

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125. The funding from 2003 to 2005 was one billion RMB each year; from 2006 to 2007 the funding was 2.5 billion RMB each year. Funding in the beginning of 2008 was three billion RMB and at the end of 2008 three billion RMB funding was added. Funding for 2009 and 2010 was five billion RMB each year. *See Review and Prospect on Biogas Development in China, supra* note 5.

126. *Review and Prospect on Biogas Development in China, supra* note 5.

127. *Id.*

128. *Id.*

129. *Id.*

130. Zhang Taolin (张桃林), *Nongcun Zhaoqi Jianshe Liqiu Wuda Zhuanbian* (农村沼气建设力求五大转变) [*Five Changes are Needed in Rural Biogas Construction*], ADMIN. OF GRAIN OF CHINA (Dec. 27, 2012, 8:37AM), http://www.grain.gov.cn/Grain/ShowNews.aspx?newsid=39567.

131. 12th Five-Year Plan for Renewable Energy Development, *supra* note 88.

132. *National Development and Reform Commission and the Ministry of Agriculture issued the "Circular on Further Strengthening Rural Biogas Opinion," supra* note 117.

133. See, for example, National Energy Infrastructure and Management Standardization Technical Committee and Second Editorial Office of Standards Press of China. *Biogas and Related Standards* (Standards Press of China, Aug. 2008); see *Policies and Regulations*, CHINA BIOGAS SOC'Y, http://www.biogas.cn/CN/B_Policy.aspx (last visited Aug. 9, 2014) for most of the standards.

134. *See, e.g., National Development and Reform Commission and the Ministry of Agriculture issued the "Circular on Further Strengthening Rural Biogas Opinion," supra* note 117.

application scope and improve biogas utilization benefits.[135] The 12th Five Year Plan for National Energy Technology of 2012 sets out goals and key tasks for the development of new energy including biogas.[136]

Moreover, relevant policies, laws and regulations also motivate the standardization of biogas systems. From 1950 to 2011, China issued thirty-three standard specification documents for rural biogas systems, forming basic standards system for rural biogas.[137] With the government's attention switching more to the management of rural biogas, it has recently begun to realize the importance of a service system. Therefore, the government has recently issued various documents to promote the construction of service system for biogas.[138]

H. Problems Existing in and Policy Suggestions for the Development of China's Rural Biogas Program

With the development of China's urbanization process, some new problems appear to be arising in the rural biogas program. The first major obstacle to continued success of the biogas digesters in China appears to be a lack of services aimed at ensuring their smooth operation and continued efficiency. It appears that needed service systems may not be totally in position in China.[139] In the same vein, the funding system has been focused on building digesters, but it appears that the financial needs associated with the operation and maintenance of these forty million biogas digesters may not yet be completely thought out.

Moreover, the changing landscape of China is likely to result in less small farm animal husbandry.[140] This will likely cause a shortage in feedstocks for biogas digesters in rural settings. However, with the increase of centralized livestock farms, it is likely that medium to large size biogas plants will be

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135. Yan Xin (颜昕), Guojia Fagaiwei he Nongye bu Qidong Nongcun Zhaoqi Keji Zhicheng Xiangmu Jianshe (国家发改委和农业部启动农村沼气科技支撑项目建设) [*National Development and Reform Commision and the Ministry of Agriculture to Start the Construction of Rural Biogas Technology Support Project*], ZHONGGUO QIXIANG BAOSHE (中国气象报社) [CHINA METEOROLOGICAL NEWSPAPER] (Oct. 25, 2010, 3:33:00 PM), http://2011.cma.gov.cn/qhbh/newsbobao/201010/t20101025_80272.html.

136. GUOJIA NENGYUAN JU (国家能源局) [NATIONAL ENERGY BOARD] GUOJIA NENGYUAN KEJI SHI'ERWU GUIHUA 2011-2015 (国家能源科技十二五规划2011-2015) [NATIONAL ENERGY TECHNOLOGY 12TH FIVE YEAR PLAN 2011-2015] (2011), *available at* http://www.gov.cn/gzdt/att/att/site1/20120210/001e3741a474109f0bc001.pdf.

137. *See, e.g.*, National Energy Infrastructure and Management Standardization Technical Committee and Second Editorial Office of Standards Press of China, *Biogas and Related Standards* (Standards Press of China, Aug. 2008); see *Policies and Regulations*, CHINA BIOGAS SOC'Y, http://www.biogas.cn/CN/B_Policy.aspx (last visited Aug. 9, 2014) for most of the standards.

138. *See, e.g., National Development and Reform Commission and the Ministry of Agriculture issued the "Circular on Further Strengthening Rural Biogas Opinion," supra* note 117.

139. Some authors indicate that the lagging construction of a social service system limited the utilization of biogas. *See Review and Prospect on Biogas Development in China, supra* note 5.

140. *Beijing is delicately super-sizing the country's farms*, CHINA ECON. REV. (July 13, 2013), http://www.chinaeconomicreview.com/beijing-land-reform-Brazil-rural-farms-Wuliming-industrial-farming.

developed, which can either supply biogas, or electricity to meet rural energy needs.[141]

VI. FACTORS CONTRIBUTING TO THE SUCCESS OF CHINA'S BIOGAS PROGRAM

The success of China's biogas program appears from our research to relate to five main factors: 1) education and promotion, 2) technical improvement and standardization, 3) supporting laws and policies, 4) funding, and 5) China's energy needs. The first four factors, when China implemented them together, resulted in a successful program that was intended to address the fifth factor. Moreover, each of these factors appears interrelated and a necessary condition for the other. For instance, technical improvement would not have occurred without initial promotion, and the laws and policies supporting biogas would not have been passed unless the technical bona fides of the program were established. Funding itself was, and continues to be, dependent upon the other four factors—there would be no reason to fund the program unless the community was aware of the benefits (promotion), if the systems did not work (improvement), if the government was not creating a conducive environment (supporting law and policy), nor would funding exist of the energy need was not real.

Before addressing these factors, however, we wish to address a likely misconception: that China's authoritarian central government is in fact the reason for its success with biogas.[142] While it is true the strong central government contributed to the various laws and policies, the government's role alone does not appear to be to be an independent factor leading to the success of biogas. During the times of China's strongest central government, biogas systems struggled with failure.[143] It was not until the government called for research and development that addressed both construction and digester management that the systems began to be successful.[144] In this way the government played a role, but that role was one of encouraging solutions to problems, not mandating a result.

The most significant gains in the installation of biogas units occurred in the last decade or so, and appeared to be related to funding that was made available for biogas installation.[145] This funding took the form of tax rebates, subsidies to offset part of the cost, bonds, loans, and in some cases grants.[146] While it is true the government supplied the funding, that fact alone does not lend itself to authoritarian criticism. Governments everywhere often provide financial incentives. An interesting dynamic in this case, however, is that the financial

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141. *The progress and prospects of rural biogas production in China*, *supra* note 5, at 62 ("Supported by the central government, the development of China's biogas plants will aim for economies of scale, industrialization, and commercialization.").

142. For an accessible and comprehensive discussion of political governance in China, please see Ming Xia, *China Rises Companion: Political Governance*, N.Y. TIMES, http://www.nytimes.com/ref/college/coll-china-politics.html (last visited Aug. 9, 2014).

143. FUJIAN PROVINCIAL AGRICULTURAL DEPARTMENT, *supra* note 64.

144. *Id.*

145. *See supra* note 127 and accompanying text.

146. *See supra* notes 119-128 and accompanying text.

incentives were successful among some of China's poorest—its agricultural peasants who otherwise lacked clean cooking technologies.

Progressing past the question of the role of China's government directly, the first factor that our research uncovered as an important element to the success of China's biogas program was education and promotion. Two particular education efforts stand out from our research: The Ministry of Agriculture's creation in 1979 of the National Biogas Construction Leading Group,[147] and Ministry of Agriculture's 1999 biogas promotion campaigns called variously the "Energy Environmental Protection Project" and "Ecological Homestead Rich Peasants Project."[148] The Leading Group provided a structure for dealing with the needs of the biogas development campaign. The Leading Group addressed questions of technical improvement, and also addressed questions relating to preferred use.[149] Together these education and promotion efforts appear to have contributed to the wave of biogas growth that occurred in the 1980s and 1990s, while setting the stage for interest in the various financial policies that were later enacted.[150]

The role of technical improvement as a factor impacting the success of biogas development in China cannot be overstated. Initial development efforts centered on technical innovation, and in fact those early innovations appear to have captured the imagination of China's leaders, ultimately leading to the interest in biogas development.[151] Then, when development occurred, the large-scale efforts were a failure because of technical reasons.[152] When the digesters failed to operate properly, and literally millions of them were abandoned.[153] China's technical response, creating thirty-three standard specification documents for rural biogas systems, corrected the early problems and led to the opportunity to make biogas a success.

Another important technical innovation that led to the success of biogas in China was the development of digesters that work in cold climates. Anaerobic bacteria do not "eat" when they are cold or frozen. If the bacteria do not "eat," they cannot make biogas. Chinese scientists tackled that issue, making it possible to expand biogas into China's colder climates.[154] This innovation, which might not seem like much, is quite important. Much of China's agricultural production occurs in more northerly climates.[155] It is in these areas that the biogas is perhaps of greatest utility, providing fuel for heating, lighting and cooking to rural

147. *See supra* note 70 and accompanying text.

148. *See supra* notes 83-84 and accompanying text.

149. *See supra* notes 83-84 and accompanying text.

150. *See supra* notes 119-128 and accompanying text.

151. *See supra* notes 74-81 and accompanying text.

152. *See Biogas and Related Standards*, *supra*, note 137; *Policies and Regulations*, *supra* note 137.

153. *See supra*, notes 67-69 and accompanying text.

154. *The Progress and Prospects of Rural Biogas Production in China*, *supra* note 5, at 59.

155. Bao-Jie He, Li Yang, & Miao Ye, *Building Energy Efficiency in China Rural Areas: Situation, Drawbacks, Challenges, Corresponding Measures and Policies*, 11 SUSTAINABLE CITIES & SOC'Y 7, 8-9 (2014).

households. Without the significant work undertaken to extend biogas into colder climates, the program would likely not be nearly the success that it is today.

The role of China's policies and laws that support biogas development cannot be overstated. As addressed in Section IV, above, China implemented a full suite of laws and policies surrounding biogas. These laws did not always have the sophistication with which they are now imbued. Instead, the early laws, metaphorically, put the cart before the horse, promoting the technology for wide scale use without having already worked out technical and social issues. Problems were encountered: the technology failed, or users found the operation to be less appealing than their traditional alternatives.

China's problems in developing biogas appear to have been viewed as integral parts of the solution. Rather than scrapping the program, the applicable laws and policies were modified to address the growing needs.[156] It appears that China was successful in this regard because it used administrative agencies that had specialized knowledge and a broad mission coupled with the opportunity to flexibly address the issues. Accordingly, China's use of its agencies, like the Ministry of Agriculture, appear to be a vital ingredient in promoting the dynamic legal and policy responses necessary to successfully deploy biogas as an energy technology on a wide, consumer-based scale.

China's *process* of funding of the biogas program seems to be the factor that is most significantly contributing to the accelerated adoption of biogas in China. While funding efforts appear to have always been significant, when the range of funding started exceeding three billion per year, and when the methods of funding were widened to include bonds, grants, loans, subsidies and tax rebates, the rate of biogas expansion appears to have accelerated drastically.

This is quite an important feature of China's experience. The people who are the audience—the customer base—are very poor peasant farmers. What might be mistaken in the analysis of the world's poor is an assertion that they have no money to afford modern energy services. That is not the case—the world's poor have money. However, and in a common sense manner, it is reasonable to assume the poor value the money they have. Accordingly, a Chinese peasant, who was well educated on the issues of biogas, still often did *not* have enough incentive to purchase a digester.[157] One conclusion is that the money in hand, or the money spent on something else is more valuable than the benefits to be obtained from biogas. China's financial incentives appear to have tipped that scale,[158] and the success of funding in promoting biogas development clearly demonstrates that financial incentives that make economic sense to the end user need to be adopted if energy poverty is to be eliminated.

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156. *See supra*, notes 74-106 and accompanying text.

157. See Gosens et. al., *supra* note 2, at 285 for a discussion on the role of subsidies in household fuel use in China.

158. *Bioenergy transition in rural China: Policy options and co-benefits*, *supra* note 5, at 533 ("China has made the most success in rural household biogas development, mostly through government subsidies on technology dissemination.")

What China's experience also shows is that economic incentives are not a unitary solution even where they are the strongest catalyst for change. As China's initial attempts to fund faulty digesters in the 1970s showed, all of the other supporting aspects of program are necessary. Without education, technological proof, and legal support, financial support merely causes failure and a waste of the financial resources dedicated to the project.

Finally, one must look to China's energy needs, the sources of energy and other necessary resources that the nation has ready access to in order to understand the success of biogas. Indeed, this critical element of the discussion might in other countries support the development of a different energy technology. In China, the energy need that biogas is meeting is for the rural poor. The rural poor are largely farmers, and as a result they have ready access to organic wastes that become the feedstocks for biodigestion and the production of biogas. A biodigester also needs water and a place to utilize the residue, both items usually available in an agrarian landscape. Biogas therefore fits neatly within a Chinese farmer's energy needs and resources. Conversely, biogas is not likely a useful technology for those living nomadic lifestyles or who live in extreme climates like deserts, high mountains, or the arctic where biological wastes or water resources are often not readily available. [159]

Another element of China's energy needs and sources that impact the use of biogas is the relative paucity of natural gas in China. China's energy mix is dominated by coal.[160] Where natural gas supplies 25.7% of the world energy supply, in China, it supplies just 3.9%.[161] As many authors point out, China's dependence upon coal requires the nation to find cleaner burning technologies.[162] Biogas is uniquely well suited to fill this gap by creating what is for all intents and purposes natural gas from agricultural and other biological waste.

Other countries may or may not have such energy and environmental pressures impacting energy development. Nigeria provides an interesting contrast. In Nigeria, there are substantial agricultural wastes, similar agricultural frameworks, and similar rural needs for household energy services.[163] However, Nigeria contains immense quantities of natural gas that is flared without being used.[164] That difference might make it more sensible for energy development in

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159. BENJAMIN SOVACOOL & IRA MARTINA DRUPADY, ENERGY ACCESS, POVERTY, AND DEVELOPMENT: THE GOVERNANCE OF SMALL-SCALE RENEWABLE ENERGY IN DEVELOPING ASIA (2012) (noting, for instance, the difficulty of providing energy services to nomadic Chinese).

160. *See supra* notes 41-45 and accompanying text.

161. *See supra* notes 43-44 and accompanying text.

162. *See, e.g.*, David Fridley, Nina Zheng and Nathaniel Aden, *What Can China Do? China's Best Alternative Outcome for Energy Efficiency and CO_2 Emissions*, *in* CHINA'S ENERGY EFFICIENCY AND CARBON EMISSIONS OUTLOOK 80 (B. Skaali & T. Knezevic, eds., 2012).

163. *See, e.g.*, Okeh Okeh, Chukwudi Onwosi & Frederick Odibo, *Biogas Production from Rice Husks Generated from Various Rice Mills in Ebonyi State, Nigeria*, 62 RENEWABLE ENERGY 204 (2014).

164. Stephen C. Nwanya, *Climate Change and Energy Implications of Gas Flaring for Nigeria*, 6 INT'L J. LOW CARBON TECH. 193, 193 (2011).

Nigeria to focus on harnessing the wasted natural gas, rather than converting biological wastes to gas. Even if that process to be the case in Nigeria, the framework of development outlined by China's biogas experience could still provide an important policy model that could help in the sustainable development of energy resources and the improvement of living conditions no matter the energy and resource mix confronted.

VII. CONCLUSION

China's biogas experience—truly a grand experiment that touches the lives of approximately 120 million people—yields a model that should be considered in the energy and sustainable development framework for lesser developed countries. The very nature of China's approach—to experiment, to educate, to modify policies to needs, to refine the technology, and to provide adequate funding—appears to define a useful process that might yield beneficial results when applied to the need to make energy resources available for the Other Third.