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China’s Energy Security: National Security, Ecological Balance and Regional Co-operation

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With an appendix by
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Abstract:

This paper analyzes both global and regional approaches to solving problems of energy security and ecological imbalance by addressing specifically the problems of China's energy security. PRC's growing energy dependence has become a major concern for both economic and national security policymakers in that country. The ambitious goal of modernization of the economy along the lines of the other newly industrialized economies(NIEs) of Asia has succeeded only too well, and it is difficult to reorient economic priorities. If examined rigorously, such an economic strategic assumption can be seen to entail the goal of creating further technological capabilities. In particular, China seems to be firmly committed to the creation of a largely self-sustaining innovation system as part of a knowledge-based economy of the future . Such innovation systems, called *positive feedback loop innovation systems* or POLIS have been created by advanced countries, and NIEs such as South Korea and Taiwan are proceeding to create these as well. But this will add to its energy burden and further dependence on the US as the power which controls the key sea lanes. Only a strategic reorientation to building a self-sustaining POLIS and appropriate regional cooperation institutions can lead to the way out of the current dilemma for China.

1. Introduction:

This paper analyzes both global and regional approaches to solving problems of energy security and ecological imbalance by addressing specifically the problems of China's energy security. PRC's growing energy dependence has become a major concern for both economic and national security policymakers in that country. The ambitious goal of modernization of the economy along the lines of the other newly industrialized economies(NIEs) of Asia has succeeded only too well, and it is difficult to reorient economic priorities. China's remarkable growth during the last twenty five years has led to a rapid increasae in energy demand, and its hunger for energy is apparently insatiable. There are of course both economic and ecological aspects of this insatiable demand for energy. There are also security issues that exercise the Chinese leadership increasingly. In this paper I examine the measures that China is taking to achieve energy security and the motivations behind these measures. I also look at China's investment in overseas oil exploration and development projects, interest in transnational oil pipelines, plans for a strategic petroleum reserve, expansion of refineries to process crude supplies from the Middle East, development of the natural gas industry, and gradual opening of onshore drilling areas to foreign oil companies. The key question is: can China hope to achieve both equitable growth and energy security over the next two decades? I suggest the kind of mathematical modeling and political economy analysis that may be necessary to answer this two-pronged question rigorously.

China faces at least two pressing sets of energy policy challenges. The first is a problem of short run efficiency and therefore relates to the immediate need to improve management and coordination of the nation's energy supply. During the last five years economic growth has been close to 8% per annum. At the same time, energy demand grew by about 15% annually while oil imports grew at 30% per year. In today's China, electrical power shortages are widespread, and transport bottlenecks constrain the ability of the industry to move both coal and oil to where they are needed.

There are also longer term energy policy challenges. These concern the continuing inability of China's government to formulate a coherent energy policy which could provide the basis for the effective management of the energy sector and its environmental consequences for the next fifty years and beyond. In appendix 3 (prepared by Mariko Frame) some long term issues in the context of a specific International Futures Model [1]are discussed.

[1] This model has been developed by Professor Barry Hughes at GSIS, University of Denver.

China’s entry into the WTO has already had and in the future will have diverse consequences for its economy and energy. The best overall assessment from the Chinese perspective is that although the short run adjustment costs--- for example, the increase in unemployment in the agricultural sector--- may be high, the long run economic benefits from integration into the world trading system are likely to be considerable. In particular, it is assumed that the export-led growth will continue and will also lead to the modernization of the economy along the lines of the other newly industrialized economies(NIEs) of Asia. If examined rigorously, such an assumption can be seen to entail the goal of creating further technological capabilities. In particular, China seems to be firmly committed to the creation of a largely self-sustaining innovation system as part of a knowledge-based economy of the future (Simon,1996; Simon and Goldman,1989; Lu, 2000). Such innovation systems, called positive feedback loop innovation systems or POLIS(Khan, 1998; 2003; 2004a) have been created by advanced countries, and NIEs such as South Korea and Taiwan are proceeding to create these as well.[2] Can China do the same? And will China’s entry into the WTO help or hinder such efforts? While the answers here are not clear, it is reasonable to say that its WTO membership[3] will open the way towards diversification of energy import sources. However, I will argue that much depends on US-China bilateral relationship also. Furthermore, as I will show, the current strategy of indiscriminate growth only without regards to sustainability or equity will make China’s growth is deeply problematic even in an open economy context of rules-based trading in the WTO framework.

In what follows, I will begin by identifying the most important aspects of the energy demand and supply aspects in order to ascertain China’s energy dependence. This will enable us to look at both economic welfare and sustainability issues as well as security issues which are discussed in section 3. In conclusion I draw attention to the real dilemma faced by the ambitious Chinese leaders and suggest that multilateralism and regional cooperation are the best strategic responses available to China.

2. China’s energy dilemma: demand, supply and distributional issues

China is now the world’s second largest consumer of energy, accounting for some 12% of global energy demand, but its rate of increase of demand is some four to five times that

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[2] A formal and complete description of POLIS as an innovation system ,and contrasts with NIS(national innovation system) of which POLIS is both an extension and an extended critique, is outside the scope of this paper. Khan (2004a) gives a formal description and two existence theorems in topological spaces. Technically, non-linearities and multiple equilibria are at the heart of a formal proof of POLIS and its properties. Khan (2003) presents both a conceptual and concrete critique of NIS by comparing and contrasting the national innovation system (NIS) with POLIS in the context of Taiwan.

[3] For welfare aspects of China’s entry into WTO see Khan, Haider A., "China's Entry into the WTO: ICT Sectors, Innovation, Growth and Distribution", July (2002b) - (Website address: http://www.e.utokyo.ac.jp/cirje/index.htm)

for the rest of the world. So what happens in China's energy sector will affect the rest of the world as well. Table 1 below gives a picture of China's actual and projected energy consumption till the year 2015.

China's energy sector displays continuing dependence on coal. China is the world's largest consumer of coal, accounting for more than 30% of global coal consumption. Further, coal provides approximately 64% of China's primary energy demand. While such dependence on coal is not necessarily a huge problem, it has two unfortunate consequences. Use of coal is characterized by low energy efficiency and pollution.

The intrinsic energy value of a unit weight of coal is known to be less than that for oil and gas.The recovery rates for many of China's coal mines are also low, meaning that much of the country's coal resource is left in the ground, never to be recovered. Table 1 below confirms this. Furthermore, the efficiency of appliances which use coal in China continues to be substantially lower than the average in OECD countries. Progress has been slow in enhancing the efficiency of consumer electrical appliances and implementing building codes which reduce heat losses. Finally, the continuing low level of end-user prices has failed to provide consumers with incentives to save energy.

Table 1

Primary Energy Consumption in China (quadrillion Btu)

Year	Coal	Natural Gas	Petroleum	Total
1980	12.5	0.6	3.8	17.3
1985	16.9	0.5	4.0	22.2
1990	20.7	0.6	4.9	27.0
1995	27.5	0.7	7.2	35.2
2000	22.7	1.2	9.7	36.7
2005	26.4	2.2	11.2	43.2
2010	33.3	3.4	14.2	55.3
2015	40.1	5.3	17.9	69.1

SOURCE: Energy Information Administration (EIA), *International Energy Database*, Washington, D.C., 2002.

NOTES: Totals may not sum because of other fuels and rounding. Figures for 2005–2015 are EIA projections, reference case.

From table 1 above it is clear that China's energy consumption will be 4 times what it was in 1980 by the year 2015.The share of oil during the same period will be on the increase also.China shifted from being net oil exporter to net oil importer in 1993.What explains the increasing dependence on oil? Table 2 below is an input-output decomposition of China's energy use. Scrutinizing table 2 below we can see that it is intimately related to final demand shift. Within the final demand shift, both household and investment needs are responsible for the lion's share. Thus, China's industrialization strategy and the increasing prosperity of households can explain its increasing dependence on energy imports. This is not likely to change in the near future.

Table 2

	Coal	Oil&Gas	Electricity	Petroleum	Coke
Total change	5.78	14.09	36.55	12.65	37.24
Technical change	-30.42	-38.55	-42.24	-46.21	-48.64
Energy technical change	-40.16	-47.84	-55.91	-48.97	-59.29
Non-energy technical change	9.75	9.29	13.67	2.77	10.65
Final demand shift	36.19	52.63	78.78	58.86	85.88
Level	61.35	61.35	61.35	61.35	61.35
Distribution	4.73	6.84	0.18	4.26	-3.62
Composition	-29.9	-15.55	17.26	-6.75	28.15
Sources of Final demands shift					
Household Consumption	20	24.39	39	22.67	40.42
Government consumption	2.7	4.86	3.4	5.2	2.28
Investment	15	35.96	42	36.9	52.25
Export	23.4	12.87	28	22.4	42.93
Import	-23.6	-45.8	-32	-38.17	-33.68
Others	2.6	2.4	1.7	1.9	1.6

Table 3

Primary Energy Production in China
(quadrillion Btu)

Year	Coal	Natural Gas	Petroleum	Total
1980	12.6	0.6	4.5	18.1
1985	17.7	0.5	5.4	24.3
1990	21.9	0.6	6.0	29.4
1995	28.3	0.7	6.4	35.4
2000	18.4e	1.1e	7.0	27.8e
2005	n.a.	n.a.	6.7	n.a.
2010	n.a.	n.a.	6.6	n.a.
2015	n.a.	n.a.	6.5	n.a.

SOURCE: EIA, *International Energy Database*, Washington, D.C., 2002.

NOTES: Totals may not sum because of other fuels and rounding. Petroleum includes crude oil, natural gas liquids, and refinery processing gain. Figures for 2005–2015 are EIA projections, reference case. Total is primary energy only.

e = estimated.

n.a. = not available.

Although domestic production figures have not been projected till 2015 in table 3 above, simple extrapolation would show that import dependence is here to stay. Thus the conclusion that follows from the evidence presented in tables 1 and 2 seems to be that China's import dependence will be a policy problem for at least till 2025, if not for even a longer period. The vulnerability is great as shown in table 4.

Table 4

Summary of GDP Effects, "Severe" Disruption
(percentage)

Year	Oil Consumption	Import Cost	Fuel Substitution	Total
2005	(7.4)	(0.1)	3.7	(3.8)
2006	(6.5)	(0.5)	2.9	(4.1)
2007	(5.8)	(0.3)	2.6	(3.5)
2008	(5.6)	(0.4)	2.2	(3.8)
2009	(5.2)	(0.5)	1.9	(3.8)
2010	(5.0)	(0.4)	1.7	(3.7)
2011	(4.8)	(0.4)	1.6	(3.6)
2012	(4.8)	(0.4)	1.4	(3.8)
2013	(4.6)	(0.3)	1.3	(3.6)
2014	(4.4)	(0.3)	1.3	(3.4)
2015	(4.4)	(0.3)	1.1	(3.6)

SOURCE: Tables 6.8–6.11.

NOTES: Oil consumption effect is the average of Tables 6.8 and 6.9. Numbers in parentheses are negative.

Table 4 which is taken from the scenarios run by the EIA and the RAND corporation shows the effects on GDP when prices shift unfavorably affecting supply and production. In the appendix, I outline a model that looks at the distributional impacts of such disruptions in a linear approximation scenario. In particular, poverty impacts are derived. The preliminary results suggest strongly that almost all of Chinaa's growth induced poverty reduction gains can be destroyed through disruptions in the energy markets alone. For China's policy makers this must be a sobering thought. What options are available to them? In the next section, I review and assess the steps taken and suggest a strategy most likely to succeed.

3. China's energy dilemma: strategic moves

China's energy dilemma has renewed concerns about long term energy security. Several decades ago, the same concerns existed but the solution was also clear and simple--- to increase domestic production. Our analysis indicates that this is no longer a viable option.[4] Discovery of large reserves is unlikely. Thus oil is seen as a source of vulnerability in Beijing. Since plans for building a POLIS depend crucially on oil, it could make China vulnerable to foreign pressures. Many years of debate within the state council has not resolved this difficult problem. Policy makers have been divided over whether domestic production should be increased or explore for oil abroad. In practice both the paths are being followed. I will argue that neither is going to reduce vulnerability to a large extent soon. In the medium to long run, however, there is a third option available; but it will require both rethinking development priorities at home and reorienting diplomacy towards greater regional cooperation. But let us look at the existing divided strategy.

The centerpiece of the current strategy seems to be an ambitious scheme of investment in overseas oil projects together with continuing domestic exploration. The state owned oil companies of China are the key players in both arenas.During the 1980s China launched three large oil companies. The China National Offshore Oil Corporation(CNOOC) has controlled most of the offshore oil businesses since its founding in 1982. The China National Petrochemical Corporation (Sinopec) was founded in 1983 and is responsible for refining and marketing. The China National Petroleum Corporation (CNPC) was founded in 1988 by the ministry of petroleum industry. In 1998 the government reorganized CNPC and Sinopec and created two vertically integrated oil companies.However, CNPC is still China's dominant upstream oil company and Sinopec the main downstream company in the industry.

Initially, the government maintained a two-tiered pricing policy that required CNPC to sell to its industrial customers at a fraction of the market price. The resulting cash flow constraint led to limited exploration. In 1993, the government relaxed the pricing policy increasing the first tier crude price. CNPC was the main beneficiary, as indeed was the

[4] See also Christoffersen (1998) for an analysis of the situation particularly with respect to China's relations with Russia and Central Asia in historical perspective.

intention. CNPC officials knew that unless the money was quickly invested it would be confiscated. The coincidental appointment of Zhou Yongkang who favored foreign investment led to overseas expansion of investment.[5] Since this time, views of top CNPC officials have mattered a great deal in China's foreign energy investments. However, they are chosen ultimately by the Communist Party leadership. Hence it can be rightly said that the Party is the final arbiter.

Among other things CNPC has invested from Canada to Kazakhstan. In 1997 it pledged over $8 billion for oil concessions in Canada, Venezuela, Iraq and the Sudan. Such activities underline the high priority attached to these projects. They can also lead to increasing tension between China and the US. For example, in 1997, CNPC acquired a sixty per cent stake in Kazakhstan's Aktyubinskmunaigaz Production Association. CNPC beat out Texaco, Amoco and Russia's Yujnimost by agreeing to pay $320 million bonus to the Kazakh government and to conduct a feasibility study on the construction of an 1800 mile pipeline to Western China. This was estimated to cost $ 3.5 billion.In September 1997, CNPC followed similar tactics to defeat Petronas, Unocal and Amoco to win a controlling interest in Uzen, Kazakhstan's second largest oilfield with reserves of 1.5 bb.

In June 1997, a consortium of Chinese oil companies signed a 22-year production sharing contract with Iraq to develop half of the Al-Ahdab field after thhe lifting of UN sanctions. Al-Ahdab is the country's second largest oilfield.Prior to the US invasion of Iraq, CNPC was negotiating for rights to develop three other Iraqi fields. These are Halfaya, Luhais and Suba.

However, the US invasion of Iraq and the subsequent occupation has put these plans in great jeopardy.The global energy situation is now marked by even more uncertainty and the Chinese must feel more vulnerable than ever. It is always possible that US imperialism will fail like all imperialist powers to ultimately control the middle eastern oil or even the sea routes permanently. But the realists in China must know that the current situation is one of US dominance. Apart from its domestic snafus reflected in the facts such as that Kazakhstan-China pipeline plans were shelved in 1999, the US preeminence as a military power and its willingness to use this power for various purposes including protecting control over overseas oil, China's energy dependence seems logically to lead to dependence on the US hegemony. What is the way out? I suggest that rethinking development strategy and increasing regional cooperation offer the best hope for China.

Strategically, Chinese development path has been so far marked by the East Asian model.According to this model heavy state involvement together with the promotion of market led industrialization through export promotion is the best strategy for development. As an industrialization strategy, this can succeed up to a point. However, as

[5] For a detailed description see, Kenneth Lieberthal and Michel Oksenberg . 1998. Policy Making in China: Leaders, Structures, and Processes , Princeton: , Princeton University Press.

the Asian financial crisis demonstrated, there are risks as well (Khan1997, 1998, 2004 a and b).The Chinese strategy has led to high growth and a lopsided distribution together with energy dependence. Following this path further without qualification, as the current leadership seems to have grasped, will exacerbate the negative aspects with the inevitable growth slowdown. However, there is an alternative which I have developed in detail elsewhere. Here I will merely sketch the main outline.

In my development of an alternative strategy(Khan 1983, 1982a and b, 1997,1998, 2002, 2003, 2004 a and b; Khan and Sonko 1994) based among others on an extension of Schumpeterian theory of innovation and Sen's capabilities, the key is a distributionally sensitive approach with clear recognition of ecological constraints.The main idea is to moderate the growth rate and hence short term dependence on fossil fuels and minimize consequent ecological problems.With a proper poverty reduction strategy---called 'growth plus'strategy[6]--- the adverse distributional consequences from moderate growth can be avoided. In fact, with a properly moderate 'growth plus'strategy, the capabilities of the great majority of the poulation caan be enhanced along with the productive capacity. This will lead to the creation of a domestic market for commodities that are produced in a much more ecologically sustainable manner. Furthermore, the goal of a transition to a relatively non-fossil fuel based knowledge and information economy will be facilitated and the transition will occur more quickly and smoothly under the proposed POLIS strategy.

The question of domestic market creation leads also to considerations of cooperation in Asia. For reasons of regional financial stability, reciprocal exporting and energy security greater cooperation in each of these spheres is an urgent necessity. China along with the other countries in Northeast Asia must proceed to diffuse tensions and build up regional institutions. Given the historic hostilities this will be no easy task. Yet the enlightened self-interests of the countries together with imperatives of regional peace and prosperity lead logically towards cooperation. There is much here to learn from European integration experience, particularly about the role of enlightened leadership. No doubt, there are special Asian features and special Asian roadblocks that might require particular Asian approaches to negotiation and conflict resolution at times. But China's energy dilemma is one compelling reason for that country to take the initiative and start a dialogue. There is no time to lose.

4. Conclusions and Future Directions

In this paper I have sketched the energy dilemma for China in this century. As long as the current geopolitical situation persists the pursuit of present development strategy of China will further increase its energy dependence. For both political and economic reasons China needs to rethink its development strategy. I have sketched such an alternative strategy that relies much less on fossil fuels and emphasizes regional cooperation. This POLIS strategy will ultimately lead to a sustainable economy based on growth with equity. A transition to a non- fossil fuel based knowledge and information economy will also be easier to effect under the proposed strategy.

[6] This is discussed in detail in chapter 1 of Khan and Weiss, forthcoming.

However, time is of the essence. Given the path dependence of development unless strategic disengagement from the existing path followed by a strategic engagement with the alternative strategy is begun within the next five years, it may well be too late. The stakes are indeed very high. A more detailed strategy paper based on the key ideas from the alternative strategy outlined here with concrete quantitative scenarios and feasibility studies along the lines of models sketched in the appendix (and other, more detailed models) will go some distance towards giving the appropriate analytical foundations for the policy makers. The preliminary results confirm the predictions regarding fossil fuel-based energy shortage and lead towards a serious consideration of alternative energy sources. Achieving the twin goals of energy security and ecological balance are challenging but not impossible for China. Serious policy research can be used effectively if there is the political will to do so. The goal of regional cooperation is also achievable if patient negotiations in good faith can be began in earnest.

Appendix 1: Growth Impacts of the energy sectors--- A simple SAM-based Model

Fixed Price Modeling in a SAM-based Framework:

In this section the Social Accounting Matrix is presented as a data gathering framework as well as an analytical tool for studying the effects the energy sectors on growth. Appendix two presents the methodology for estimating the impact of growth generated by the energy sectors on poverty alleviation. The origins of social accounting can be traced as far back as Gregory King's efforts in 1681, but more recent work stems from the attempts by Richard Stone, Graham Pyatt, Erik Thorkbecke and others. [7]

In the methodological framework of this study the SAM is used for mapping production and distribution at the economy wide level. In this section, first a general SAM is described. Then it is shown how the method for studying the effect of growth within this framework follows logically from its structure. The model used is a simple version of a class of SAM-based general equilibrium models.[8] It summarizes succinctly the interdependence between productive activities, factor shares, household income distribution, balance of payments, capital accounts, etc. for the economy as a whole at a point in time. Given the technical conditions of production the value added is distributed to the factors in a determinate fashion. The value added accrued by the factors is further received by households according to their ownership of assets and the prevailing wage structure. In the matrix form the SAM consists of rows and columns representing receipts and expenditures, respectively. As an accounting constraint receipts must equal expenditures.

As is elaborated further in Khan and Thorbecke (1988), the SAM framework can be used to depict a set of linear relationships in a fixed coefficient model. For deciding the question of determination, the accounts need to be divided into exogenous and endogenous ones. For instance, in the China SAM, there are three endogenous accounts. These are factors, households and production activities, leaving the government, capital and the rest of the world accounts as exogenous.[9]

[7] For a description of SAM as a data gathering device, see G. Pyatt and E. Thorbecke, *Planning Techniques for a Better Future* (Geneva: ILO, 1976). Khan(1997) also has a chapter on this alone.
[8]In Walrasian general equilibrium models the flexible price vector determines the equilibrium. In a Keynesian (dis)equilibrium model in the short-run the quantities vary while the price vector remains fixed.
[9] See Khan and Thorbecke, op.cit., Ch. II for more theoretical details and empirical examples. The presentations here follow the cited work closely.

Table 1: Simplified Schematic Social Accounting Matrix

				Expenditures				
				Endogenous Account			Exog.	Total
				1	2	3	4	5
Receipts	Endogenous Accounts	Factors	1	0	0	$T_{1.3}$	x_1	y_1
		Households	2	$T_{2.1}$	$T_{2.2}$	0	x_2	y_2
		Production Activities	3	0	$T_{3.2}$	$T_{3.3}$	x_3	y_3
	Exog.	Sum. Of other accounts	4	$l_1^{/}$	$l_2^{/}$	$l_3^{/}$	t	y_x
		Total	5	$y_1^{/}$	$y_2^{/}$	$y_3^{/}$	$y_x^{/}$	

Looking at Table 2, which represents a SAM, we can see immediately that

$$y = n + x \qquad (1)$$

$$y = 1 + t \qquad (2)$$

Now if we divide the entries in the matrix Tnn by the corresponding total income (i.e. y_n), we can define a corresponding matrix of average expenditure propensities. Let us call this matrix A. We now have:

$$y = n + x = Ay + x \qquad (3)$$

$$y = (1\text{-}A)^{-1}x = Mx \qquad (4)$$

M has been called the matrix of accounting multipliers by Thorbecke, for these multipliers, when computed, can account for the results (e.g. income, consumption, etc.) obtained in the SAM without explaining the process that led to them. Let us now partition the matrix A in the following way.[10]

[10] Ibid.

$$A = \begin{bmatrix} 0 & 0 & A_{13} \\ A_{21} & A_{22} & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix} \qquad (5)$$

Table 2: Schematic Representation of Endogenous and Exogenous Accounts in a SAM

		Expenditures				
		Endogenous	Sum	Exogenous	Sum	Totals
Receipts	Endogenous	T_{nn}	n	Injections T_{nx}	x	y_n
	Exogenous	Leakages T_{xn}	1	Residual Balances T_{xx}	t	y_x
Totals		$y_n/$		$y_x/$		

Source: H.A. Khan and E. Thornbecke, Choice and Diffusion of Technology in a Macroeconomic (SAM) Framework

Given the accounts factors, household and the production activities, now we see that the income levels of these accounts (call them y_1, y_2, y_3 respectively) are determined as functions of the exogenous demand of all other accounts. In this respect, what we have is a reduced-form model which can be consistent with a number of structural forms. This is quite satisfactory as far as tracing the effects of a certain injection in the economy is concerned or for prediction purposes when the structural coefficients are more or less unchanged.

One limitation of the accounting multiplier matrix M as derived in equation (2.2) is that it implies unitary expenditure elasticities (the prevailing average expenditure propensities in A are assumed to apply to any incremental injection). A more realistic alternative is to specify a matrix of marginal expenditure propensities (C_n below) corresponding to the observed income and expenditure elasticities of the different agents, under the assumption that prices remain fixed. The C_n matrix can be partitioned in the same way as the A matrix above. The most important difference between the two partitioned matrix is that $C_{32} \neq A_{32}$. Expressing the changes in income (dy) resulting from changes in injections (dx), one obtains,

$$dy_n = C_n dy_n + dx \quad (6)$$
$$= (I - C_n)^{-1} dx = M_c dx \quad (7)$$

M_c has been called a fixed price multiplier matrix and its advantage is that it allows any nonnegative income and expenditure elasticities to be reflected in M_c. In particular, in exploring the macroeconomic effects of exogenous changes in the output of different product-cum-technologies on other macroeconomic variables, it would be very unrealistic to assume that consumers react to any given proportional change in their incomes by increasing expenditures on the different commodities by exactly that same proportion (i.e. assuming that the income elasticities of demand of the various socioeconomic household groups for the various commodities were all unity). Since the expenditure (income) elasticity is equal to the ratio of the marginal expenditure propensity (MEP_i) to the average expenditure propensity (AEP_i) for any given good i, it follows that the marginal expenditure propensity can be readily obtained once the expenditure elasticity and the average expenditure propensities are known, i.e.,

$$y_i = MEP_i/AEP_i \quad (8)$$
$$MEP_i = y_i\, AEP_i \quad (9)$$
$$\text{and } \sum_i MEP_i = 1 \quad (10)$$

Thus, given the matrix A_{32} of average expenditure propensities, and the corresponding expenditure elasticities of demand, y_i the corresponding marginal expenditure propensities matrix C_{32} could easily be derived.[11]

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[11]See Khan and Thorbecke (1988) for some examples.
See also G. Pyatt and J.I. Round, "Accounting and Fixed Price Multipliers in Social Acounting Matrix Framework," *Economic Journal* Vol. 89, Dec. 1979, p. 861.

Appendix 2: Energy Sectors, Growth, Distribution and Poverty.
Multiplier Decomposition,Growth and Poverty Alleviation Sensitivity

Since poverty in the present context is measured by identifying a poverty line in monetary terms incomes of the various household groups are the crucial variables. In particular, sectoral growth generated by the energy sectors must be linked to incomes of the various households in order to determine the exact extent of the alleviation of poverty through growth. The exact effect of income growth on poverty, of course, depends on the sensitivity of the adopted poverty measure to income. In this paper the Foster, Greer and Thorbecke (1984) P_α class of additively decomposable poverty measure is selected for this purpose. For α=0,1,n this measure becomes the headcount ratio, the poverty gap and a distributionally sensitive measure that gives specific weights to each poor person's shortfall, respectively.

If we apply Kakwani's (1993) decomposition to the P_α measure for specific sectors and households i and j respectively, the change in $P_{\alpha ij}$ can be written as follows:

$$dP_{\alpha ij} = \frac{\partial P_{\alpha ij}}{\partial \bar{y}_i} + \sum_{k=1} \frac{\partial P_{\alpha ij}}{\partial \theta_{ijk}}\, d\,\theta_{ijk} \qquad (11)$$

Here $P_{\alpha ij}$ is the FGT P_α measure connecting sector j to household group i, y_i is the mean per-capita income of household group i, and θ_{ijk} is the income distribution parameter. Under the unrealistic but simplifying assumption of distributional neutrality:

$$\frac{d\,P_{\alpha ij}}{P_{\alpha ij}} = \eta_{\alpha i}\left(\frac{d\bar{y}_i}{\bar{y}_i}\right) \qquad (12)$$

where $\eta_{\alpha i}$ is the elasticity of P_{ij} with respect to the mean per capita income of each household group i resulting from an increase in the output of sector j. dy_i on the right hand side is the change in mean per capita income of household group $\bar{i}$. This can be written as (by considering the fixed price multiplier matrix)

$$dy_c = m_{ij}\, dx_j \qquad (13)$$

where dx_j is the change in the output of sector j on a per capita basis for group j. We can now rewrite the aηverage change in poverty measure as

$$\frac{d\,P_{\alpha ij}}{P_{\alpha ij}} = \eta_{\alpha i} m_{ij} \left(\frac{dx_j}{\bar{y}_i}\right) \qquad (14)$$

By aggregating across the household groups we can arrive at the overall poverty alleviation effect

$$\frac{d\,P_{\alpha j}}{P_{\alpha j}} = \sum_{i=1}^{m} \left(\frac{dP_\alpha ij}{P_\alpha ij}\right)\left(\frac{n_i}{n}\right) = \sum_{i=1}^{m} \left(\frac{dP_{\alpha ij}}{P_{\alpha ij}}\right)\left(\frac{P_{\alpha ij}}{P_{\alpha j}}\right) \qquad (15)$$

Since we are considering a P_α measure

$$dP_{\alpha j} = \sum^{m} \left(dP_{\alpha ij}\right)\left(\Sigma(z-y_k)/z)^{\alpha}\right) \qquad (16)$$

$P_{\alpha j} \quad {}_{i=1} \quad \left(P_{\alpha ij} \right) \left(\Sigma(z-y_l)/z)^{\alpha} \right)$

where q_i is the number of poor in the ith group and the total number of poor $q=\sum_{i=1}^{m} q_i$

Let $s_{\alpha i}$ be the poverty share of household group i (naturally $\sum_{i=1}^{m} s_{\alpha i} = 1$)

$$s_{\alpha i} = \sum_{k=1}^{qi} \left(\frac{z-y_k}{z} \right)^{\alpha} \Big/ \sum_{l=1}^{q} \left(\frac{z-y_l}{z} \right)^{\alpha} \qquad (17)$$

We can further rewrite the expression for the average change in overall poverty alleviation.

$$\frac{dP_{\alpha j}}{P_{\alpha j}} = \sum_{i=1}^{m} \left(\frac{dP_{\alpha ji}}{P_{\alpha ij}} \right) s_{\alpha i} \qquad (18)$$

Combining equations 14 and 18
we now have,

$$\frac{dP_{\alpha j}}{P_{\alpha j}} = \Sigma s_{\alpha i} \eta_{\alpha i}\, m_{ij} \left(\frac{d_{xj}}{\bar{y}_i} \right) \qquad (19)$$

Thorbecke and Jung(1996) separate the income increase via the modified multiplier effect from the sensitivity of the poverty measure formally in equation (19) by defining the following two entities:

1. $m^{/}_{\alpha ij} = s_{\alpha i} m_{ij}$ gives the modified multiplier effect in terms of income of a poor group.
2. $q_{\alpha ij} = \eta_{\alpha i}(dx_j/\bar{y}_i)$ represents the sensitivity of the poverty index to the change in income. I adopt their terminology and call this the poverty sensitivity effect.

But each multiplier m_{ij} can be further decomposed:

$$m_{ij}=\eta_j d_{ij} \qquad (20)$$

where n_j gives the (closed loop) interdependency effects and d_{ij} the distributional effects of a change in demand for the product of sector j on household group i.
Thus,

$$dP_{\alpha j}/P_{\alpha j} = \sum^{m} m^{/}_{\alpha ij} q_{\alpha ij} \qquad (21)$$

$$= \sum_{i}^{m} (r_{\alpha ij})\, (s_{\alpha ij} d_{ij})(q_{\alpha ij}) \qquad (22)$$

The d_{ij} on the right hand side can be further decomposed by multiplicatively decomposing the total distributive effects. Given the structure of C_n matrix in section 2. $D=D_3D_2D_1$ where $D_3= (I-C_{22})^{-1}$; $D_2=C_{21}C_{13}$, and $D_1=(I-C_{33})^{-1}$

The particular element for each household i and sector j can be selected from these three matrices.

Thus the contribution of an increase in output of a particular sector j to poverty alleviation can be decomposed multiplicatively into its two components: (i) the contribution due to the change in mean income of the poor across all groups and (ii) the sensitivity of the particular poverty measure to this change in average income of the poor.

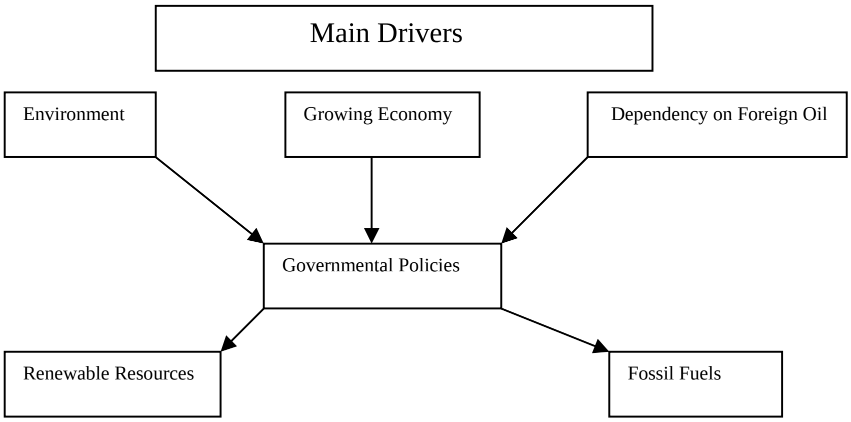
Appendix 3: China's Energy Future
(Prepared by Mariko Frame)

Introduction

The question of how China will fuel its growing energy demand ranks as one the most important current issues concerning the government of China. Will China continue its reliance on fossil fuels? Will it instead increase investment and expand renewable resources? Or will it expand both fossil fuel and renewable energy usage? This paper is an attempt to answer these questions by examining the factors driving government energy policies, and analyzing the implications. Section 1 will discuss the main factors driving governmental policies; the environment, China's growing economy, and concerns over dependency on foreign oil. Section 2 will then examine the governmental policies concerning renewable energy, sources of renewable energy, and challenges facing renewable energy implementation. Similarly, Section 3 will examine the governmental policies concerning fossil fuels and sources of fossil fuel energy. Finally, Section 4 will present two different energy scenarios; the renewable energy scenario in which all driving factors are conducive to renewable energy expansion, and the fossil fuel scenario, in which the driving factors are not conducive to renewable energy expansion. These scenarios will also attempt to incorporate both the major and minor factors driving China's future energy plans, for both supply and demand.

1. Main Drivers Behind China's Energy Policies

Three main factors are driving China's energy policies; the environment, growing economy, and dependency on foreign oil. Concerns over environmental degradation are driving China to adopt environmentally friendly energy policies; placing an increasing emphasis on the importance of renewable resources. China's growing economy is driving an expansion for both renewable energy and fossil fuels. Concerns over dependency on foreign oil are leading Chinese policy makers to implement renewable energy policies. Yet simultaneously, China's growing economy is forcing the government to seek oil resources on an international scale.



China's Growing Economy and the Increasing Demand of Energy Supplies as a Fundamental Drive in Energy Policies:

By mid-century China has strong potential to rank as the world's second largest economy. From 1971 to 1995, China's economic growth rate has averaged 8.5 percent annually, and is estimated to continue to grow at 5.6 percent from 1995 to 2020, if Hong Kong is included. China's economic growth, coupled with a massive population, is placing increasing strains on energy resources. Economic expansion of this magnitude entails a domestic energy demand that is predicted to grow at a rate more than any other nation; indeed, this economic growth has been accompanied with an energy consumption growth averaging 5 percent per year. After the U.S., China is the second largest energy consuming economy in the world. In 1997, China expended 9.6 percent of the of the global energy consumption. By 2020, it is forecasted to grow to16.1 percent.[1]

Increased energy usage is inevitable due to China's rapid development. As China develops, structural changes within the economy are bringing about an irreversible increase in energy demand. Low intensive agricultural production is being replaced by higher energy-intensive manufacturing and social services. Traditional labor-intensive agricultural production will depend on higher mechanization, bringing about a greater demand for petroleum products. In the automobile sector, increasing production and passenger usage are predicted to grow. In 2002, automobile production was 50 percent higher than in 2001. One scholar has noted the "possibility of up to 250 million cars in China by 2050"- a potential for China to become the worlds number one car market.[2] Securing adequate energy supplies for sustaining China's economic development is hence a prominent driving force behind China's energy policies.

Environmental Pollution as a Driving Concern in China's Energy Policies

Environmental pollution related to China's current energy usage has created serious concern both at the domestic and international level. Domestically, the environmental harm done by China's energy sector is severe through much of the country. Pollution and its impact span across all sectors of the environment, from indoor air pollution to urban air pollution, to acid rain and consequent crop/forest destruction.[3]

Seven of the world's most polluted cities are located in China. Urban air pollution in most cities exceeds international standards by a factor of 3 to 5 times. Such sober excesses of pollution are reflected in numerous related illnesses; chronic respiratory disease, cancer, premature illness and death. The effects of pollution pervade the agricultural system as well; acid rain is increasingly serious, particularly in southern China.[4] According to one study, acid rain has affected more than one-third of the land in China.

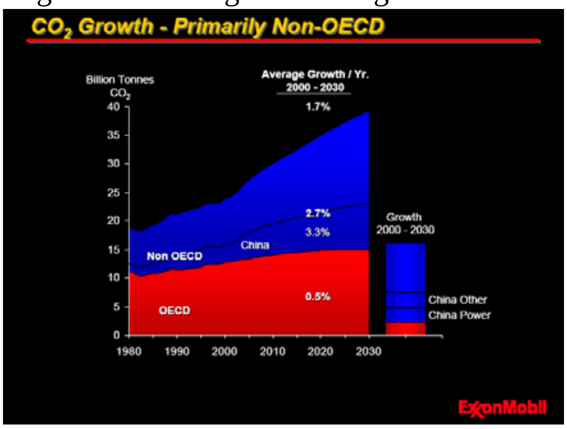
[1]Cole, Bernard, Oil for the Lamps of China (Washington D.C.: Institute for National Strategic Studies, 2003) vii
[2]Ibid. 52
[3]Zhengming, Zhang, Renewable Energy Development in China: The Potential and the Challenges (China Sustainable Energy Program) 6

4

A study estimated, "China could eliminate its need to import grain if the haze and soot over grain producing areas was reduced. Researchers believe that haze may be depressing China's farm yields by 5 to 30 percent."[5] As a consequence, crop damage is estimated to approach two percent of the entire country's gross domestic product.[6] Other estimates are less generous. The World Bank estimates air and water pollution in 1995 resulted in a loss of about $50 billion, or 8% of the GDP.

The environmental impacts of China's energy policies are also globally felt. Second only to the U.S., China is of the world's major contributors to global climate change and ozone depletion.[7] Air pollution from China has also been a source of increasing concern to its close neighbors in the Asia-Pacific region. Countries such as South Korea and Japan have complained publicly of the effect of China's air pollution on their own nations for over a decade.[8] Finally, greenhouse emissions are expected to rise; the International Agency in Paris predicts that the increase in emissions will increase from 2000 to 2030 until 'China alone could nearly equal the increase from the entire industrialized world.'[9] Environmental studies increasingly realize the magnitude of China's role in sustaining a healthy eco-system; issues which concern China domestically also impact the ecosystem of the world as a whole.

China's coal-based economy and its carbon emissions are the primary source for the excessive pollution problems currently challenging the country.   China is the second largest emitter of greenhouse gases after the U.S., largely due to its coal burning.[10] Three quarters of the electricity generated in China is based on coal energy consumption. In the years 1990-1996, China's CO_2 emissions accounted for over 90 percent of the increases in the world. In 1998, China emitted 740.38 million metric tons of carbon.[11] Further, indoor use of coal or firewood for domestic purposes is reportedly still practiced by 78 percent of the population, claiming 1.46



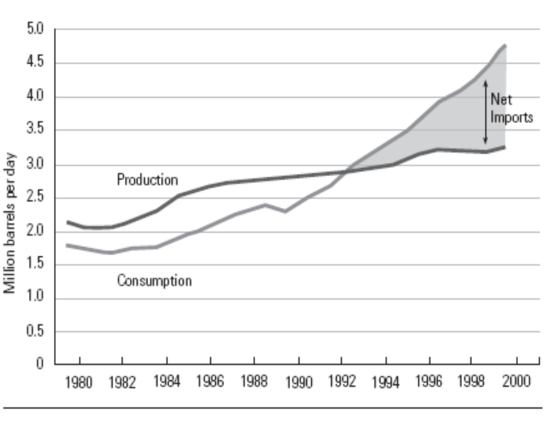
million lives in 1995 due to respiratory disease.[12]

[5] Zhengming, Zhang, Renewable Energy Development in China: The Potential and the Challenges *China Sustainable Energy Program* 7
[6]Ibid. 6
[7]Chan, Gerald, China's Compliance in Global Environmental Affairs *Asia Pacific Viewpoint*, Vol. 45. 76
[8]Ibid. 71
[9]Ibid. 76
[10]Ibid. 76
[11]Zhengming 7
[12]Ibid. 6

Increasing Dependency on Foreign Oil as a Driving Factor in China's Energy Concerns

As China attempts to secure energy resources for its growing economy of less severe polluting potential than coal based consumption, it is increasingly pushed towards dependency on foreign oil. Throughout the 1970s China's oil export had increased steadily but peaked in the mid 1980s.[13] In response to dwindling domestic supplies, China became a net oil importer in 1993 and foreign oil dependency has been growing ever since.[14] In 1999, 22 percent of the total oil consumption came from imported oil. Most studies concur that China's foreign oil dependency is likely to increase as China's oil imports are increasing years, almost doubling during 2000 alone.[15] According to one study, the net imported oil will reach 40 percent by 2010.[16] Another study states "dependence on foreign petroleum sources, more than 368 million bbl in 2000, will also increase, probably doubling to more than 735 million bbl by 2020, which will form approximately 50 percent of China's total petroleum consumption."[17] The growing disparity in China's production and consumption of oil are displayed in Figure 5. Furthermore, upon China's entry into the WTO, tariff reductions on imported refined oil decreased from the current 69 percent to 6 percent and import quotas for petroleum products have also increased by 15 percent. Such new tariff regulations have led to oil giants 'scrambling to get their foot in the door.'[18]

Figure 5. China's Oil Production and Consumption, 1980–2000



Source: U.S. Department of Energy, Energy Information Administration, Main Products of the Office of Energy Markets and End Use, Country Analysis Briefs, "China: An Energy Sector Overview," accessed at <http://www.eia.doe.gov/emeu/cabs/china/energy.gif>

To secure enough oil imports to satisfy the energy needs of a growing economy, China is establishing energy relationships all across the Middle East, Southeast Asia, Russia, Central Asia, and Latin America.[19] with the majority coming from the Middle East and Southwest Asia.

However, such increasing dependency on foreign oil imports has led to the

[13]Gan, Lin, Energy Development and Environmental Constraints in China (Oslo: Center for International Climate and Environmental Research 1997) 5
[14]Ibid. 5
[15]Cole, Bernard 51
[16]Zhengming 4
[17]Cole, Bernard 15
[18]Cole, Bernard 54
[19]Gan, Lin 16

growing concern of Chinese officials over the future security of an energy resource so vital to China's economic growth. Several issues in particular are troubling policy makers. Will China become more vulnerable to the uncertainty of the oil markets? How plausible is continued petroleum reliance considering the increase in the price of crude oil and dwindling world supplies? What about political volatility? A senior state Council economist is claimed to have noted that 'American military campaigns in Afghanistan and possible campaigns in Southwest Asia will greatly affect China's oil strategy in the Middle East and Central Asian countries.'[20] In face of such issues, foreign dependency on oil has become a significant issue of concern driving China's energy policies.

2. Renewable Energy: Governmental Policies, Sources of Renewable Energy, and Challenges

In response to the aforementioned key drivers, environment, growing economy, and dependency on foreign oil, China has adopted renewable energy polices that are remarkable for a developing country. Governmental policies, renewable energy resources, and the challenges to renewable energy usage are discussed in this section of the paper.

Governmental Policies Concerning Renewable Energy

The "White Paper on China's Population, Environment, and Development in the Twenty-First Century" outlays China's first significant policy framework for the development of renewable energy resources. The plan was approved on March 25, 1994, and was the original economic and social development of renewable energy framework for the years 1996-2010. The objectives of the plan were to 'raise the conversion efficiency of renewable energy, lower production costs, and enlarge the contribution of renewables to the energy system.'[21] In addition, the plan sought to create a modern industrial base and market infrastructure for already developed renewables, and fund research and demonstration projects for necessary technological advances. In particular, the plan aimed for the following increases in renewable energy usage: the construction of 1,000 MW of large scale windfarms by 2,000 MW and 3,000 MW, improved efficiency and reduction of systems cost for development of low cost solar cells other equipment, higher exploitation of geothermal energy, and 300 MW by 2010 for biomass. Under such a plan, China's renewable energy would have increased from insignificant to 1.3 by 2020. Progress was slightly better than predicted, by 2003 renewable energy consumption accounted for 3 percent of the country's total energy consumption.[22] Progressive, true, but hardly a dent in China's energy needs.

However, driven by the aforementioned factors, China has recently adopted a substantially more progressive stance towards renewable energy. In February 2005, Standing Committee of the National People's Congress (NPC) endorsed the Renewable Energy Law on February. The law aims to boost China's renewable energy capacity up

[20]Cole, Bernard 53
[21]
[22]

to 15% by the year 2020, and plans to invest $180 billion in this period. The law contains significant structural changes worth mentioning. First, it requires grid operators to purchase resources from registered renewable energy producers. Second, the cost of purchasing this power will be spread across all customers on the grid. Hence, a former major obstacle of high consumer cost will be mitigated. The law also provides financial subsidies, tax incentives, low cost loans, and tax breaks for renewable energy resource development and projects.

In regards to specific renewable resource development, the law 'encourages' the following developments.

- Clean and efficient development of biological fuel and development of energy crops
- Installation of solar energy system in work places and individual consumption, like water heating systems, solar voltaic systems, etc
- Real estate development enterprises are to provide necessary conditions for such installations
- Utilization of renewable energy in rural areas

Finally, the government pledges to support scientific and technological research and to help with the production of renewable energy in remote areas.[23]

The Main Renewable Energy Resources in China

Wind Power

China has historically harnessed wind power for a variety of tasks; pumping water, threshing grain, powering boats, are a few examples. As a country having world- class wind energy potential, modern technology has focused on utilizing wind power to generate electricity. According to the National Renewable Energy Laboratory, 'the theoretical wind energy potential in China is estimated at 3,226 GW at a 10 meter hub height, and the practical wind energy potential is estimated at 253 GW. By the end of 2003, 567 MW of grid-connected wind turbines were installed and more than 160,000 small wind turbines for rural electrification were installed.'[24] Thus, wind power has strong potential as a renewable energy resource.

Biomass

Biomass energy plays an important role in China's energy consumption. It supplies up to 70 percent of China's domestic energy consumption in the rural areas, (ping 4) though it does not contribute significantly to economic energy concerns. Currently, the amount of used is approximately equal to oil consumption rates, and is obtained most from firewood, stalks, organic waste and gas.[25]

[23]"China Passes Renewable Energy Law." *Renewable Energy Access*, March 9, 2005.
[24]Zhengming 10
[25]Ping, Zhou, China's New and Renewable Energy Situation *Energie Verwertungsagentur*

Geothermal

China has rich geothermal energy potential available from hot springs, tidal energy, ocean currents, wave energy and ocean thermal energy.[26] Currently there are 1,100 places which are directly using the low temperature of geothermal energy for plantation, aquaculture, space heating, and health care. In addition there are seven small experimental tidal power stations, and three wave power stations are under construction.[27]

Photovoltaic

China has a long tradition of research and development in the area of solar power technologies, beginning from the 1970s. More than 40 companies and institutions are involved in photovoltaic research and development; presently most solar PV is used for microwave, communication systems, and remote homes.[28] Currently, China ranks as the number one user and manufacturer in solar water heaters. Most solar energy is used for supplying heat and electricity in remote areas.

Challenges to the Greater Usage of Renewable Energy

Policy/Market Related Challenges

> *"With many renewable technologies, the scale of development has not been large enough to bring down the costs to a competitive level. For example, wind power- whose costs have come down remarkably in recent years- is still more expensive on a kWh basis than coal production. However, if the wind industry received anything close to the level of government support that the state-owned coal mines have received, wind would certainly be competitive."*[29]

Two fundamental issues impede the development of China's relatively nascent renewable energy system; governmental policy and lack of a market for renewable energy. To begin with, the electricity industry was developed as a monopoly under the centrally planned government of China. As a result, the slow progress in the development of renewable energy is linked to government policies in support of traditional fossil fuel usage, or lack of coherent policies concerning renewable energy. For example, the Chinese national utility has indicated little interest in developing renewable energy projects. Due to policy pricing, local distribution companies at the county or city level generally bear all the costs for renewable energy generation. However, all of the aforementioned may change if China reaches the goals state in the Renewable Energy Plan; in particular, Plan is supposed to spread the cost of purchasing renewable energy power across all customers on the grid.

[26]Zhengming 39
[27]Ping 19
[28]Zhengming 22
[29]Zhengming 53

Second, an independent, competitive market for renewable energy resources is also in an inchoate stage of development, keeping prices high for consumers and investors wary of perceived 'high-risk' in the renewable energy investments. Grid and non-grid connected energy resource generation suffers from the lack of a wholesale market and no independent industry to develop renewable resources. Because investors perceive projects as high risk, renewable energy generation suffers from a lack of capital, both domestic and foreign.[30]

Expenses

Renewable energy sources are often more expensive than traditional fossil fuel based resources for a number of reasons. For example, upfront costs of wind power development are more expensive than coal usage. One reason for the high cost is the need to import larger scale and more advanced technologies from developed countries in addition to value-added taxes, shipping and installation. The high capital costs of photovoltaics are common to any country. In China, small production scale, outdated production facilities and techniques, and the necessary importation of technology such as silicon wafers contribute to high costs particularly for a low-income country. Finally, costs of renewable energy sources are generally higher due to lack of government support and a competitive market. Again, if the government succeeds in implementing the goals of the Renewable Energy Plan then it will provide financial subsides, tax incentives, low cost loans and tax breaks for renewable energy which will help to improve the expenses of renewable energy.[31]

Technical Difficulties

> *"The main barrier impeding landfill gas development is technical, appropriate practices for methane capture has never been used in China. Lack of access to information on the technology and lack of experience with the design, construction, and operation of gas recovery plants are major problems."*[32]

Though the above quote relates specifically to landfill gas development, much of the quote could be applied to other sectors of renewable energy. The lack of technological know-how remains a challenge for developing renewable energy generation on a mass scale. As stated above, renewable energy is still in the early stages of development; most technology lacks local manufacturing bases and relies on imported equipment. Further, much of renewable energy is generated in rural areas remote from main power grids. Difficulty remains in the technology and cost of transmitting such energy to the places of demand, such as urban and industrial centers. However, the Renewable Energy Plan, if successfully implemented, will support research and development projects.[33]

[30] Zhengming 3-73
[31]Ibid.
[32]Ibid.
[33]Ibid.

3. Governmental Policies Concerning Fossil Fuels and Sources of Fossil Fuels

Governmental Policies Concerning the Use of Non-Renewable Energy Resources

The Ninth and Tenth 5-Year Plans provide the basic governmental framework for China's energy policies and future goals. The Ninth 5-Year plan, drafted for the years 1996-2000, had aimed to increase total energy output by 9% by 2000. Under this plan significant expansion in fossil fuel development was encouraged. Together with the expansion of fossil fuel usage was emphasis on technological improvements for energy efficiency and conservation of resources. The Tenth 5-Year Plan focused on ensuring reliable energy resources sufficient for China's economic growth. Though both plans sought to further integrate renewable energy into viable energy resource alternatives, the policies which will be discussed in this section are those that directly relate to the usage of fossil fuels.

The energy aims concerning fossil fuels, and results, of the Ninth 5 Year Plan can be summarized as follows:

1. Increase total coal output to 1.4 billion tons by 2000. Goal was met with a total coal consumption of 1.5 billion tons in late 2000, constituting 75 percent of the nation's energy needs.
2. Boost proven reserves by by 33 billion bbl of crude oil and 17.7 tcf of natural gas, increase crude oil output to 3.1 million bbl per day and refinery output to 4.5 bbl per day, and increase natural gas production to 833 bcf. By late 2000, 0.7 tcf of natural gas was produced and 3.6 million bbl of oil was consumed daily.[34]

Overall, not every goal succeeded. Nonetheless, China managed to secure enough energy supply to support its economic growth. It managed this through a variety of strategies. It stabilized coal output in eastern China, Shanxi, Shaanxi and Inner Mongolia. For oil and natural gas, it expanded the scope of operations to exploit offshore gas and oil simultaneous with domestic production.[35] The importance of listing these policies is to show that the Ninth 5-Year Plan constituted a significant expansion in China's energy sector, and reflects the government's desire to secure and exploit fossil fuel resources for its growing economy. Such policies form the base for China's future energy strategies, and help to discern possible fossil fuel forecasts.

The energy policies of the Tenth 5-Year Plan reflect similar goals for expansion of fossil fuel resources as those implemented in the Ninth 5-Year Plan. Central to securing enough resources for its growing economy were the following strategies. First, China recognized the inevitability of expanded dependency on foreign resources of oil and sought to establish relations with oil producing nations (Southwest Asia, Middle East, Africa, Latin America, etc), while also using foreign capital and technology to develop energy resources (for example, Central Asia).

[34] Cole, Bernard 48
[35] Ibid. 48-49.

Second, it also expanded developing sources in Chinese territory ashore and at sea. Third, efforts to develop the infrastructure in rail, river, and ocean transportation for the purpose of transporting petroleum products were implemented. Finally, concerning relations with foreign oil resources, China has sought to gain exploration rights and production control over foreign energy fields.[36]

In conclusion, the policies laid by both the Ninth 5-Year Plan and Tenth 5-Year Plan reflect an overall expansion in fossil fuel dependency. Both plans acknowledge the continued reliance on coal as a major source of energy consumption and increasing reliance on foreign oil.

Sources of Fossil Fuels and Current Usage

Coal

The predominant reason for China's coal based energy system is China's massive total coal reserve, which ranks second only to the former Soviet Union in the world. Coal is therefore domestically available and under direct control of the government. Furthermore, despite recent massive layoffs in the coal mining industry, coal industries still employ a large portion of the country's labor force.

Coal usage is inextricably tied to all sectors of China's energy system. According to one study, in 1999 'about 39 percent of Chinese coal consumption was consumed in power stations, 14 percent for coking, 10 percent for domestic and residential use, 1 percent for rail and the rest by other industries such as chemical, cement, ceramics, and glass-making plants.' Coal powers approximately three quarters of the electricity in China.[37] Hence, coal is likely to remain the major fossil fuel in China's energy consumption despite efforts to limit its usage.

Oil

By the early 1970s the China's predominant reliance on coal was challenged by the growth of the oil sector. Oil exports had increased steadily throughout the 1970s as China expanded domestic petroleum production; by the mid-1980s, however, oil production had peaked and by 1993 China became a net oil importer. Since most oil statistics were covered in the section on foreign dependency, they will not be repeated here.

Natural Gas

Natural gas offers some promise as an alternative source for China's energy needs. Natural gas holds a number of attractive advantages; first, it would help to mitigate China's over dependency on oil and fuel, second, it is cheaper than either coal or

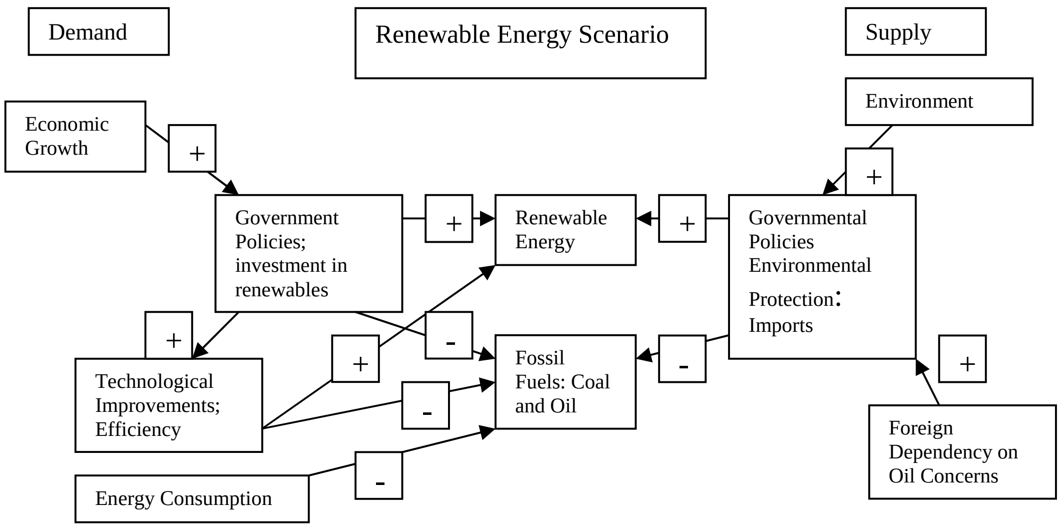
[36]Cole, Bernard 52
[37]Ibid. 7

oil, and finally, it is a relatively clean burning fuel- a vital characteristic considering China's current environmental crisis. Currently, the usage of natural gas is quite low, less than 3 percent. Beijing is trying to boost natural gas to 8 to 10 percent of the energy consumption by 2020. To achieve this China is seeking to exploit both domestic and foreign reserves. It has also currently implementing a major construction effort for the necessary infrastructure needed to transport natural gas. "Total gas reserves onshore as estimated at 38 tcm, with proved reserves both on- and offshore of 2.56 tcm in 2000, a 58 percent increase over 1990 estimated reserves."[38] In sum, if China undergoes the necessary infrastructural changes and secures domestic and international supplies, natural gas may offer an efficient an clean fossil fuel energy supply.

4. Forecast for Renewable Energy Growth and Fossil Fuel Usage

Two possible scenarios for China's future energy situation are presented here. The first scenario is the 'Renewable Energy Scenario,' in which the supply and demand factors are conducive to green growth, leading to the best possible outcome for renewable energy use in China. This scenario also presents the most likely minimal usage of fossil fuels. The following causal diagram explains the drivers and their effects on renewable energy and fossil fuels.

Renewable Energy Scenario



Drivers and Outcomes

In this scenario, economic growth creates a demand for governmental policies in investment for renewables. However, transformations of the economy, such as less emphasis on heavy industry and more on light industry, lead to lower energy consumption, which decreases the need for traditional energy sources; fossil fuels. The outcome is a larger demand for renewables. Environment degradation drives governmental policies for environmentally friendly policies, and foreign dependency on oil drive governmental policies to lower imports. The result of these policies is to lower

[38]Cole, Bernard 27-28

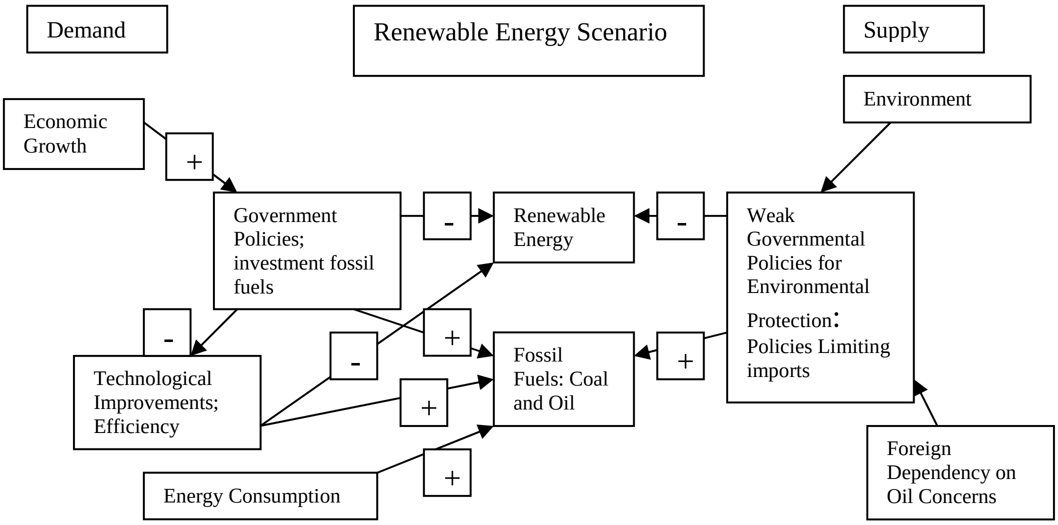
the supply of fossil fuels, and increase the use of renewable energy. Governmental policies also lead to technological improvements and efficiency of energy usage for both renewable and fossil fuels, increasing the usage of renewable energy and decreasing the reliance on fossil fuels. The same governmental policies that increased investment in renewables decreases reliance on fossil fuels, and the same policies that seek to limit imports and protect the environmental also decrease a reliance on fossil fuels.

Renewable Energy and Fossil Fuels: Some Possible Statistical Outcomes

In this scenario, China's annual oil increases may be as low as 3.3% and consumption approximately as low as 400 Mtoe/yr. Oil imports may be as low as 200 Mtoe/ye. Natural gas usage is highest in this scenario since it is efficient and clean, and may represent up to 11% of final energy consumption. Coal is still a significant contributor to China's power capacity, and may represent about 38 percent of net new capacity between 1998 and 2020.[39]

The government policies in this scenario include the implementation of all the goals stated by the government in 'China's Renewable Energy Law.' Hence, the goal for China's renewable energy to represent 15% of China's energy capacity is met. If China reaches its potential with renewable energy, wind energy could reach 30 GW by 2020[40], photovoltaic power generation could reach 4-8 GW by 2020, biomass 10-15 GW by 2020, geothermal up to 500-1,000 MW by 2050, and solar heating 200-250 Mm^2 by 2020.[41]

Fossil Fuel Energy Scenario



[39]Dadi, Zhou, China's Sustainable Energy Future (Lawrence Berkeley: Energy Research Institute, 2003) 21
[40]Ibid. 25
[41]Zhengming 10-39

Drivers and Outcomes

In the fossil fuel energy scenario, economic growth drives the demand for government policies leading to an increase in fossil fuel usage. Economic transformations lead to higher energy consumption, which contributes to this trend. Environmental warnings are not well heeded, leading to weak governmental policies for environmental protection. This in turn decreases the reliance on renewable energy supply. Similarly, China manages to secure foreign oil resources, and imports increase. Governmental policies towards technological improvements and efficiency do not advance much above current levels, subsequently decreasing the expansion of renewable energy and increasing the reliance on fossil fuels. All in all, fossil fuel usage rises dramatically, and renewable energy contributes to only a small percentage of China's energy capacity.

In the fossil fuel energy scenario, China is able to meet the goals of the Tenth 5-Year Plan for securing fossil fuel resources both domestically and internationally. As a result, fossil usage expands significantly. Annual increases in oil demand may reach as high as 4.6 per cent by 2020 making China the leading importer of oil in the Asia-pacific region of the world. Oil consumption may reach as high as 520 Mtoe/yr and at least half to over half of this amount would be imported. The government would fail to development the infrastructure for natural gas exploitation and transport, and the annual gas consumption would only be about 120 bcm, of which approximately 40 bcm/yr would be imports. Coal would continue to play a dominant role in generating power capacity, about 65 percent.[42]

In this scenario renewable energy will fail to reach potential levels to contribute to 15 percent of China's energy capacity, and in a business as usual scenario may only reach

4 to 5 percent by 2020.[43] Wind power may be less than 15 GW by 2020[44]. Other renewables will not reach the levels predicted in the Renewable Energy Scenario.

Conclusion

Though it is not possible to predict exactly the outcome of China's future energy plans, based on the analysis given in this paper it is likely that China's energy situation will include much of both forecasts, renewable and fossil fuel. There is a strong likelihood that China will take seriously both the goals of the Renewable Energy Plan and the Tenth 5-Year Plan on expanding fossil fuels. This will be driven by China's inescapable need for greater energy resources, both renewable and non-renewable, due to its growing economy. On the other side, renewable energy growth is also likely to be taken seriously due to environmental and dependency on foreign oil concerns. This is not to say, however, that *all* the goals stated in the Renewable Energy Plan will be implemented, or that the potentials stated in the Renewable Energy scenario will be reached. Massive infrastructural developments, research and technological

[42]ERI 24
[43]Cole, Bernard
[44]ERI 24

improvements will be needed to reach these goals. Simultaneously, given the current trend of China's international relations with oil rich countries, it is likely that China will continue to attempt to secure oil resources. In sum, the likely scenario is China's endeavor to expand and secure energy resources on all fronts, renewable and non-renewable, domestically and internationally.

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