Social, economic, and environmental impacts assessment of a village-scale modern biomass energy project in Jilin province, China: local outcomes and lessons learned

Susan L. Fischer
Environmental Health Sciences, School of Public Health, 140 Warren Hall #7360, Berkeley, CA 94720-7360, USA
E-mail: sfischer@berkeley.edu

Catherine P. Koshland
Environmental Health Sciences, School of Public Health, 140 Warren Hall #7360, Berkeley, CA 94720-7360, USA

John A. Young
Department of Anthropology, Oregon State University, 214 Waldo Hall, Corvallis, OR 97331, USA

We describe social, economic, and environmental impacts of a demonstration rural energy project in northeast China. Our ethnographic approach illuminates local circumstances, perspectives, priorities, and power structures that influenced and help to explain project outcomes. The project we studied is a village-scale energy project designed to use locally available corn stalks to generate household cooking and heating gas, as well as electricity, in a configuration financially attractive to both potential investors and household consumers. We undertook two three-week field missions, one before the project's trial production period and one during limited trial production, as well as an additional three-day visit to investigate adjustments made to the project on the basis of discoveries during previous visits. We conducted interviews with and on-site observations of village residents, factory workers, project representatives, village leaders, and other key informants. In contrast to electronic communications of satisfactory performance, we discovered low (2 %) capacity-factor operation during a limited wintertime trial production period. We also found a broken contract with the local utility as well as dissatisfaction among users of producer gas due to irregularity of gas flow and flow insufficient to achieve a hot flame. Because the vast majority of households were unable to cook with producer gas during the trial production period, our focus shifted from assessing final impacts to characterizing project status, understanding root causes of trial-period project failures, developing plans to facilitate the project's long-term viability, and offering lessons for future village-scale modern biomass energy projects in rural China. Many of the technical, administrative, and logistical problems encountered by this project were rooted in cultural misunderstandings, which led to poor communication and inappropriate implementation. Ethnographic fieldwork is a critical complement to the technical and economic analyses that guide rural energy development projects. Ethnographic project assessment supports better project outcomes by cultivating continuous dialogue among stakeholders as well as voicing priorities and cultural paradigms of village leaders and residents. To be effective, ethnographic assessment must not be relegated to a report of final impacts, but should be an integral component of project conception, design, and implementation.

1. Introduction

This paper presents goals, methods, and findings of an ethnographic assessment of a village-scale "modern biomass"[1] energy project in Yanbian Korean autonomous prefecture of Jilin province, northeast China. The purpose of the paper is two-fold: generally, to illustrate how an ethnographic assessment of a rural energy project complements technical and economic analyses by revealing processes and perspectives which, though obscured by a purely technical and economic discourse, are germane to project outcome. Specifically, we present a case-study of a rural energy project for which ethnography reveals that project failures can be attributed to cultural misunderstandings, rather than strictly technical or economic obstacles.

We begin by characterizing the ethnographic perspective as a useful counterpart to technical and economic accounts of energy development projects. Next we present the specific goals of the social, economic, and environmental impact assessment (SEEIA). Then we summarize technical and organizational characteristics of the case-study energy project in Hechengli village, Jilin province, China. We discuss our findings from field investigations of the Hechengli Village Energy Project (HVEP). Finally, we consider root causes of this particular project's less-than-satisfactory outcomes as well as general lessons applicable to future village-scale projects in rural China. We close by emphasizing the supportive role that ethnographic assessment may play in cross-cultural energy development projects.

2. Ethnography as a complement to technical and economic analyses

Ethnographic examination of social and cultural factors is critical both to understanding the impacts of and to successfully implementing rural energy development projects. Aid for rural energy development projects is generally solicited, at least in part, by the argument that they will benefit local populations. Ethnographic fieldwork forges an account that "makes sense" within local norms, customs, and understandings; ethnography is the means by which project impacts from a local perspective are empirically substantiated.

Beyond its diagnostic role in assessing final impacts, ethnography offers instrumental insights regarding unforeseeable, highly specific cultural processes to which project implementation is subject. When rural energy development projects fall short of their promise, poor outcome has frequently been traced to factors that are cultural and contextual, local and specific [Brown and Howe, 1978; Coetzee, 1986; Escobar, 1995; Ferguson, 2001; Gass et al., 1995; Goulet, 1989; Nolan, 2002; Willoughby, 1990]. Ethnographic fieldwork is the systematic practice of recognizing, articulating, and learning from local cultural features [Agar, 1986]. It enables adjustments of technical and economic plans and procedures on the basis of critical cultural knowledge that cannot be discerned remotely or in advance of project initiation, but emerges over the course of project evolution and cross-cultural interaction.

Despite the fact that verification of project success is an inherently ethnographic undertaking and that factors limiting project success are not strictly financial or technical, international development institutions have historically been dominated by voices trained in technology, engineering, finance, and accounting [Coetzee, 1986; Escobar, 1995; Ferguson, 2001; Goulet, 1989; Nolan, 2002]. While technological and economic concerns may offer sound guidance at the level of policy-making, a technical and economic orientation is ill-equipped to discover, characterize, and adapt to local cultural dynamics which emerge in the shift from policy to practice [Nolan, 2002] and which define whether a project is, from the perspective of the local population, experienced as a success [Gass et al., 1995].

For example, the largely technology-driven literature put forth to inform development of "modern biomass energy" argues that rural projects such as the HVEP are attractive for general – as opposed to location-specific – expected benefits grounded in broad social concerns [Fischer, 2001; Hall and Scrase, 1998; Kartha and Larson, 2000; Liu et al., 2000; Reddy, 1999; Reddy et al., 1997]. These generic motivations include improving indoor air quality, conserving women's labor, stimulating the local economy, improving fuel efficiency, and mitigating regional air pollution associated with on-field burning of agricultural residues. As observed in Hechengli village, these general motivations – and project goals derived from them – may not cohere with local aspirations. This incoherence hinders project implementation, which is not simply the execution of a static and remotely defined plan but a cross-cultural endeavor shaped by local priorities and perceptions. Another problem concerning the general motivations put forth for modernized biomass energy is that they are often accepted axiomatically, without empirical grounding from systematic field investigation. Economic abstractions, technical analysis devoid of local context, and aggregate socioeconomic data do not serve to articulate local priorities or to investigate whether and how local people actually benefit from modern biomass energy.

In contrast, the ethnographer's discoveries are rooted in direct experience, observation, and participation. Information is not aggregate or abstract, but gleaned from individual informants, focus groups, specific villages, and actual households [Agar, 1980; 1986]. Thus, the ethnographic perspective is forged in terms of local understandings and can resolve local distribution of project benefits and risks across class, gender, age, and ethnicity. Relevant questions and indicators emerge during the course of fieldwork, rather than being defined – and potentially blinding the investigator to unexpected findings – at the outset. Methodological flexibility allows the ethnographer to recognize and learn from surprises, missing or ambiguous information, and obstacles, all of which are encountered during project implementation. By learning from direct interactions with local people and communicating relevant cultural factors to technically and economically trained colleagues, the ethnographer is well-poised to support the translation of macro-level policies to successful projects in the field.

3. Goals of the SEEIA

Recognizing that the promised social benefits of modernized biomass are largely unproven and are sensitive to local context and social dynamics, the United Nations Development Programme (UNDP) sponsored a social, economic, and environmental impact assessment (SEEIA) to shed light on project impacts at the local levels of village and household. The SEEIA team sought to provide "insight into the values, motivations, and subjective experiences of people living in the community and to analyze the monetized and non-monetized economic changes and impacts on living conditions experienced by the project beneficiaries" [Young et al., 2002].

The SEEIA team's original goals were, specifically, to:

- characterize Hechengli village households and

enterprises with regard to cultural norms, energy-related behaviors and financial expenditures, and perceptions and expectations regarding the energy project
- develop locally appropriate indicators by which to gauge project impacts; and
- assess the project during the trial production period in terms of proposed indicators.

Delays, difficulties and surprises were encountered as the project unfolded. The flexibility of the ethnographic method enabled the SEEIA team's central tasks to expand to include:
- discovery of discrepancies between official data and institutional understandings on which the project was premised and local conditions as experienced and observed;
- delineation of root causes of project failures and recommendations to improve prospects for sustained operation; and
- articulation of general "lessons learned" to facilitate success of future modernized bioenergy projects in Chinese villages.

As made manifest by the evolution of SEEIA objectives, its role and significance extended beyond offering a cultural assessment of final outcomes to augment economic and technical accounts. The SEEIA team played an active role in discovering, characterizing, and negotiating difficulties during project implementation.

4. The Hechengli Village Energy Project: technical and organizational design

This section presents technical and organizational features of the Hechengli Village Energy Project (HVEP) as originally designed. Disparities between project design and outcome are indicated by notes and reported in Section 7.

The HVEP was a collaborative effort of the Jilin provincial government and the UNDP's Energy and Atmosphere Program[2]. As defined by upper-level decision-makers, project goals were to successfully demonstrate integration of component technologies, to establish the economic viability of combining grid electricity and residential fuel production, to develop a business plan and commercialization strategy for project replication, and to identify and promote policy initiatives to support market-based development of follow-on projects [Liu et al., 2001; UNDP, 2004].

The project was designed to supply household fuel by generating producer gas from local agricultural residues (primarily corn stalks). Nominally, producer gas comprises roughly 21 % CO, 12 % H_2, 2 % CH_4, 14 % CO_2, and 51 % N_2 [Liu et al., 2001]. However, transient operation with feedstock of varying quality can yield substantially lower-quality fuel[3]. The central hardware of the HVEP is technically proven, though the components have not previously been integrated in this particular configuration.

The HVEP is novel in its organizational and financing framework, which sought to render sustainable, clean-burning, ecologically sound bioenergy a market-viable endeavor in rural China. It is the first producer gas project in rural China designed to generate electricity for sale to the grid; the motivation for selling electricity to local utilities is to subsidize gas for household energy production with profits from electricity sales[4].

The original project design called for 4,300 tonnes/year (t/yr) of agricultural residues (primarily corn stalks) to be delivered to the project site for air-drying and covered storage[5]. Sized feedstock (10-20 mm, 15 % moisture) is fed by conveyor to three gasification units (maximum capacity 700 kg/hr/unit), each of which comprises an atmospheric-pressure downdraft gasifier followed by clean-up treatment involving cyclone separation of large particles, gas-cooling, spray-washing to remove tar, moisture removal, and dry filtering. The gasification system is rated for 70 % gasification efficiency, with output gas heating value of 4,600 kJ/m^3 [6]. Project design specified a storage tank of 500 m^3 for residential demand and a 200 kW spark ignition engine for electricity generation[7]. Stored gas is delivered to village residences by pipeline, with designed cooking gas demand per household of 6 m^3/day and designed wintertime heating demand of 58 m^3/day [UNDP, 2004][8].

5. Methods

5.1. Team approach

Ethnographic fieldwork was carried out by a small team of American and Chinese researchers. The core team comprised an applied American anthropologist (principal investigator), an independent journalist from Jilin province, an environmental studies professor from Beijing, and an American environmental health scientist.

As we were often confronted with missing, incomplete, and/or ambiguous information, a key methodological feature of field missions was daily group discussion among team members. Group discussions were typically dedicated to piecing together notes and observations and translating documents related to factory safety rules and regulations, household use of stoves and piping installations, and consumer contracts with village residents. Our bilingual team approach enabled clarification and resolution of ambiguities and contradictions that might have remained intransigent from a single perspective.

5.2. Timing and scope of field missions

The SEEIA team undertook three field missions. The first three-week field session took place during project construction; this was followed by fieldwork during a trial period of wintertime operation. A third abbreviated mission probed project status in response to recommendations made during previous visits. Central objectives, timing of field missions, and procedures were adapted in response to delays in project construction and problems encountered during the trial production period (Appendix A, Table A1). These adaptations allowed the SEEIA team to focus on learning and communicating the most relevant information.

5.3. Field methods

During field sessions, the team carried out semi-structured interviews, informal interactions, and casual observations in village households, village enterprises, the office and work-site of the energy project, village shops, and at the local market in Longjing city, of which Hechengli is a suburb and to which it is closely connected economically and socially. Interviews engaged a variety of local stakeholders from several perspectives at different stages of project implementation. These interviews and interactions transpired on-site, where visual cues facilitated communication and prompted further questions. Direct observations triggered questions and responses that could not have been anticipated on the basis of prior information. Because interviews were on-site, informants frequently demonstrated practices and showed equipment relevant to SEEIA probes. Information was recorded via photo documentation and written field notes.

In both the first and second field missions, on-site interviews were augmented by interactions with provincial- and county-level officials and the village head, who was also the local Communist Party Secretary. A significant amount of obligatory, unscheduled social engagement was crucial to securing cooperation of informants.

In accord with our use of the semi-structured interview, site visits and off-site encounters referred to a topical guide, rather than being prescribed by a formal questionnaire (Appendix B, Tables B1 and B2). Questions varied in accord with different circumstances of households and village enterprises and evolved as we learned more about the community and culture. The flexibility of semi-structured inquiry allowed us to elicit the relative importance of interviewees' concerns and how they conceptualized these concerns, rather than asking them to conform to a preconceived agenda and parametrizations. Discovered discrepancies between assumptions, data, and communications on which the project and SEEIA missions were premised and what we observed bore out the wisdom of this topically guided, open-ended approach.

6. Early findings: baseline characterization of Hechengli village

To form a basis for portraying how residents, village leaders, and local entrepreneurs interacted with and understood the Hechengli Village Energy Project, the first task of this study was to characterize local norms in terms of ethnicity and employment, village enterprise, formal and informal power structures, and baseline energy-related behaviors and perceptions. Detailed accounts are found in [Fischer, 2005; Young et al., 2004; Young et al., 2002].

6.1. Ethnicity, employment, and village enterprise

Hechengli village is essentially a Han community (167 of 224 households) in which the Korean minority plays a minimal role in village leadership and has lower socioeconomic status[9]. Most Han families are engaged in some form of family business. Heated greenhouses for vegetable farming *(wen-shi)* or unheated greenhouses for raising spring seedlings *(da-peng)* are operated by 70 % of Han households; other modes of food production/processing, transportation services, manual labor and construction, and employment in village enterprises are also practiced. Most women (97 %) as well as men (97 %) are economically employed. Hechengli village has close economic and social ties to Longjing town (pop. 100,000), which lies 2.5 km northwest by paved road and provides markets for villagers' vegetables, tofu, and other food products.

Hechengli village is characterized by strong entrepreneurial spirit, both collective and individual. During our initial visit, the village had three businesses that employed a labor force – a chicken farm, a fertilizer factory, and a fish farm – as well as several privately-owned operations, including a soft drink bottling operation and a sawmill. Collectively, the village planned to establish 200 new greenhouses over the next five years, two new facilities for producing canned food and "functional" food with medicinal value, and an apartment building. Demonstrating enthusiasm and skill for technical innovation, two individuals in separate households were experimenting with alternative means of space-heating; these alternatives involved using stoves to heat water for circulation through structurally retrofitted *kang* structures, rather than relying solely on circulation of combustion exhaust from the traditional solid-fuel *kang* stove[10] to radiate space heat through the floor of the living area.

6.2. Residential energy consumption

A village survey of Hechengli households shows that annual expenditures for domestic energy range from 300 to 6,000 yuan (Y)/yr (8.1 Y = US$ 1), making up 10-62 % of reported household income. Most of the households we interviewed spend Y 1,000-3,000/yr, 25-35 % of household income [Young et al., 2002]. Domestic energy consumption serves both basic household needs and family business operations. Greenhouse heating and tofu production are especially energy-intensive, typically consuming 2-10 t/yr coal per household. Aggregate domestic energy expenditures are not strongly predicted by annual income, although electricity consumption is highly correlated to income [Project Team and Larson, 2001].

Sources of energy comprise electricity, liquified petroleum gas (LPG), coal, firewood, and minimal agricultural residue (for kindling) in the form of corn stalks, beanstalks, and straw. All households are electrified, and village residents consume an average of 1.5 kWh/day at 0.8 Y/kWh for lighting, television, and other household appliances (rice cookers, refrigerators, radios). 60 % of Hechengli households consume raw bituminous coal from local mines. Typically 3-5 t/yr are purchased at Y 140-200/t. 70 % of households in Hechengli use some firewood for cooking or heating. For most households, the sole cost of firewood is labor: 4-15 days/yr, one tractor-load or ox-cart-load per day. Nearly 60 % of households use LPG for cooking, though about half of these households do not use it during the heating season, when solid fuels are burned in *kang* stoves, which provide for both cooking and space-heating. LPG-using households consume 1-4 canisters/yr at Y 52/canister (1 canister = about 15 kg).

6.3. Local expectations and perceptions during project construction

Household interviews revealed that village residents were enthusiastic about the producer gas project for a variety of reasons. While the general categories of their endorsements are congruous with the published modernized biomass energy dialogue – i.e., aesthetics, local environmental protection, village welfare, household labor/convenience, household economics, and safety – many of the specific expectations residents expressed were not anticipated and are particular to local circumstances and priorities. For example, villagers cited enhanced prospects for eco-tourism and reduction of labor requirements for wintertime greenhouses that are traditionally heated with coal but, villagers hoped, might be heated with producer gas. These local expectations were not connected to remotely-defined project goals cited in Section 4.

Baseline (first field mission) interviews with village leaders and entrepreneurs revealed concerns around issues of risk, reliability, and profit. In particular, they were unconvinced of the viability of electricity sales to the grid and worried about reliability of operations, and perceived the village as being financially overextended. At the time, their concerns regarding electricity sales were largely dismissed because technical specifications were sound, finances were forthcoming, and ultimately successful contract negotiations were under way. In retrospect, village leaders seem prescient of the difficulties of navigating administrative hurdles within the local utility.

7. Later findings: project characterization during period of trial operation

The SEEIA team returned to Hechengli from February 18 to March 13, 2004 for direct observation and characterization of project operations during the trial production period. Our original objective was to probe three categories of performance:

- operational – indicate quality and extent of project implementation;
- financial/economic – characterize expenditures, employment, and profitability from the perspectives of households, factories, and village enterprise; and
- social/environmental – illuminate impacts on residents' living patterns and local environmental resources, with particular attention to domestic labor and leisure time.

Due to the unexpected discovery of largely dysfunctional project status, our focus shifted to characterizing what had gone wrong, how the situation in Hechengli might be mitigated, and how future projects might avoid similar mistakes.

7.1. Operational status of project and associated discoveries

We arrived in Hechengli with the erroneous understanding that the project was providing half of village households with "safe and convenient" cooking fuel, but we quickly discovered that project operations were severely hampered by three constraints.

1. Gas distribution lines were frozen such that household delivery of producer gas was almost entirely obstructed.
2. The producer gas storage tank's usable capacity (275 m^3) was about half its design capacity (500 m^3).
3. Electricity generation had been abandoned in the face of local administrative obstacles, despite earlier authorization from the Pricing Bureau of Longjing city.

Consequently, by the 11th week of the trial production period the factory was operating at slightly less than 2 % capacity factor, with one gasifier operating for 30 minutes every two to three days.

We observed great disparities between the number of households to whom equipment was delivered (138 of 224, 62 %), the number of households successfully connected to producer gas distribution lines (125 of 225, 56 %), the number of households that conducted at least one cooking episode with producer gas (~60, ~25 %), and the number of households (less than ten) that continued to use it on a regular basis. These disparities reflect technical malfunction, reluctance to adopt, and dissatisfaction among early adopters. Between late November and late January (weeks 3-11 of the trial production period), gas distribution lines were increasingly obstructed so that most residents could not reliably achieve a flame. Among families that were connected to producer gas distribution lines, a variety of reasons were given for not adopting producer gas early (weeks 1-3) in the trial production period, before delivery lines were obstructed. These reasons included: no perception that it would be beneficial, the desire to see how neighbors fared before adopting the gas, the ease of continuing to cook with coal and wood (burned in the *kang* for space heat) during winter months, unreliability and inadequacy of gas flow, inconveniently located gas stove, and acceptance of free equipment without any intention to use it. Early adopters of producer gas were, with one exception, dissatisfied with the heat intensity of producer gas: the flame was not sufficiently strong to stir-fry vegetable and meat dishes *(zuo-cai)*, especially during meal times, when demand peaked and delivery pressure waned.

One notable counterexample to villagers' general dissatisfaction with producer gas was observed during winter 2004. In this household, producer gas was routinely used as an acceptable substitute for LPG. The woman of this exceptional household had taken the initiative to demand of the construction contractors that the gas pipe enter on the south side of the house, and when lines became completely obstructed in late December, she dismantled the above-ground portion of her distribution line, thawed and dried it on her *kang*, and insulated it upon reassembly.

We discovered that what was ultimately manifest as the intransigent technical problem of obstructed pipelines was directly rooted in breakdowns in communication and accountability between Hechengli village, the provincial project office, and the construction company. Early in the laying of distribution pipelines, there was heated discord between the construction company and villagers concerned about the shallow depth and exterior exposure of distribution pipelines. Hechengli village leaders complained that pipes were not being laid to specified depth (1.6 m) and were not entering through the floor (as specified), but from outside the homes, which left more than a meter's length of pipeline directly vulnerable to ambient wintertime temperatures dipping below -30º C. The provincial project office responded neither to village leaders' complaints regarding construction issues nor to a written memo, as early as November 13, detailing "abnormal conditions and ... problems" which hampered producer gas flow. Provincial-level authorities further neglected to bring these concerns to the attention of higher-level decision-makers associated with the project. Functional communication and timely intervention might have averted technical failure during the trial production period. This failure was not caused by a lack of local technical capacity, as functional waterlines in Hechengli and functional producer gas pipes in other villages of Jilin province illustrate. Rather, remotely negotiated contracts left village leadership without the authority or oversight to ensure that construction met technical specifications.

7.2. Financial/economic outlook

The financial viability of the Hechengli village energy project, as originally envisioned, rested on the sale of electricity to the grid and sales of gas to households for space-heating. However, by the 15th week of the trial production period, factory management had "given up hope" *(fang-qi xi-wang)* of selling electricity to the grid: local administrative obstacles and politics were perceived as insurmountable. These local and administrative obstacles arose despite demonstrated technical adequacy and formal agreements, namely, successful no-load testing of generating equipment in fall 2002, acceptance for grid sales by the Experiment Section of the Power Supply Company of Yanbian, and written authorization from the Pricing Bureau of Longjing city approving sale prices for electricity and gas [Young et al., 2004, p. 25]. Several barriers to household-heating with producer gas foreclosed local management's consideration of this option: projected expense (~Y 40/GJ) relative to coal (Y 8-9/GJ) and wood (generally a labor cost); perceived expense and inconvenience of requisite structural modification to *kang;* and local lack of commercially available, satisfactory gas heaters.

With the village management's abandonment of key features underlying the planned project's economic solvency, it was especially important that local decision-makers were conversant with accounting frameworks and business plans. No such local administrative capacity was observed. On the contrary, neither the factory manager nor the village head (party secretary) had been informed of itemized capital expenditures. Our interviews revealed that financial calculations of factory management were based on local knowledge and conventional wisdom, often at odds with accounting frameworks and inputs used by remotely-located decision-makers. Both factory management and the village head expressed frustration that they were not apprised of details regarding the business plan being tested in Hechengli as a model for replication elsewhere.

At the producer gas cost projected by the original business plan, Y 0.2/m^3, LPG would have been at least 50 % more expensive (on an energy basis) than LPG as a cooking fuel. The actual price advantage would depend on the quality of the fuel and hence on the feedstock mix, but remain even at the lowest heating value mentioned in Note 3. Some households in fact expressed willingness to pay a premium for the tank-free convenience of using pipeline-distributed producer gas over LPG. The SEEIA team catalyzed and mediated cross-cultural discussions in hopes of bringing all stakeholders to a common understanding of workable options based on the assumption that households would be willing to pay Y 0.2/m^3 for producer gas. Local factory management, technical and economic consultants, and the SEEIA team arrived at the conclusion that, if producer gas were used for household cooking alone, a customer base of 1,500 households would be needed to render factory operations financially viable.

7.3. Social/environmental impacts and heatlh and safety concerns

Most expected social and environmental benefits pertain to a situation in which producer gas is a viable alternative to solid household fuels, with attendant impacts on time-activity patterns, indoor air quality, and enhanced potential for local employment. However, producer gas was not used as a substitute for solid fuels during the trial production period. Households with experience using producer gas delivered at sufficiently strong pressure to achieve a high-temperature flame did consider it more attractive than LPG on the basis of convenience. No significant time savings are anticipated in daily activity patterns, if household fuel substitution of producer gas is limited to LPG.

We discovered several causes for concern with regard to occupational and consumer safety. Employees reported, and the SEEIA team experienced, respiratory irritation and burning of eyes and nasal passages during operation of gasifiers. During two half-hour observations of factory operations, CO concentrations in the work area were measured between 130 and 150 ppm, with several-minute excursions as high as 170 ppm. (For context, the US Occupational Safety and Health Administration (OSHA) exposure limit for CO is 100 ppm. When indoor CO concentration exceeds 100 ppm for any length of time, workers must be evacuated.) We also observed an unguarded pit of 5 m depth in a high-traffic zone of the main work area.

In household interviews, two stoves demonstrated operation with no odor; all other households which demonstrated producer gas flames were afflicted by strong odors of variable strength. These odors suggest that leaks routinely occur during ignition and/or operation of producer gas stoves. Due to the high concentration (~20 %) of CO in producer gas, residential leaks present an acute and potentially fatal health risk. Convulsions and death occur within 2-3 hours of exposure to CO concentrations exceeding 800 ppm. Assuming a wintertime circulation rate of 1 air change per hour, a producer gas leak of 1 g/s could create a potentially fatal situation within a few hours in a typical village household of about 150 m^3.

A final safety concern was that household CO alarms were, without exception, routinely unplugged. All household producer gas pipes are connected to a CO alarm programmed to sound at 150 ppm and to shut off gas delivery. Most residents experienced what they perceived to be false alarms and had disconnected the alarms due to their apparent oversensitivity to steam, cigarette smoke, and cooking fumes. Thus, the situation in Hechengli did not offer robust protection against CO poisoning from household leaks of producer gas.

8. Root causes of problems during the trial production period and corrective recommendations

Problems encountered during the trial production period assessment indicated an uncertain future for the Hechengli Village Energy Project. At first blush, these problems appeared as technical and economic failings.

- Distribution lines were frozen such that delivery of producer gas to households was almost entirely obstructed.
- Factory operations were limited by the storage tank's effective volume of only 50 % design capacity.
- The project had no plan to render itself financially viable, in the absence of sales to the local utility and of household use of producer gas for heating.
- Technical safeguards were routinely disabled or not in use, putting factory personnel and residential consumers at risk of CO poisoning.

Despite their apparent technical and economic character, root causes for central problems lie neither in unforeseeable technical malfunction nor inherent local deficiencies, but offer leverage points at upper echelons of planning and implementation.

1. *Problematic distribution of decision-making authority:* Although leaders and residents of Hechengli village were the stakeholders most directly affected by project outcome and most directly attuned to its evolution, they wielded little or no decision-making authority in the realm of contract negotiation and disbursal of funds. This left the village particularly vulnerable to sub-standard construction and dissolution of a sales contract with the local utility.
2. *Oversights in local capacity building, both technical and administrative:* Despite several training sessions and business workshops carried out in accord with the energy project [UNDP, 2004], plant managers were not conversant with business approaches and financial accounting, and factory personnel depended on remote (Anhui province) repairmen for periodic gasifier maintenance. Local managerial and maintenance capacity was especially important as the project must adapt to circumstances unforeseen by the project plan.
3. *Ignorance of local logistical hurdles:* Two critical project features on which financial viability rested were conceptualized as technical and economic problems, namely the arrangement to sell electricity to the grid and household use of producer gas for heating. In both cases, project design and implementation failed to contend with logistical hurdles specific to the project site, namely administrative obstacles with the local utility and unavailability of gas-fired household heaters.
4. *Failure to tap into extant local capacity and enthusiasm:* Hechengli village residents and local leadership repeatedly demonstrated innovative spirit, technical proficiency, attention to detail, and enthusiasm for the producer gas project, but project implementation did not effectively channel local capacity and support. Household residents' and local leaders' astute complaints of sub-standard construction were ignored by provincial management and by the contractor, with the predictable result that wintertime gas delivery was obstructed. Although two households were experimenting with alternative means of space-heating, they were never solicited for input regarding possibilities of using producer gas for space-heating. Village business plans and householders' central aspiration of heating greenhouses with producer gas were neither conceptually nor physically (gas delivery) tied to the project.
5. *Deficient technical, procedural, and educational support for producer gas safety:* While CO alarms were distributed to all connected households and the producer gas factory was in possession of a CO monitor, routine technical malfunction and lack of monitoring protocol obstructed use of these precautionary devices in homes and factory, respectively.

Improving prospects for the Hechengli Village Energy Project will require relaying (at greater depth) or insulating above-ground portions of distribution lines for immunity to cold winters, devising a viable business plan for locally orchestrated operations, building local administrative and technical capacity to respond to routine and unexpected situations, and putting sound safety procedures into practice in households as well as at the factory. The viability of business plans and the soundness of safety procedures depend sensitively on local culture and context. A *viable* business plan must be workable within the capacity, priorities, and logistical constraints particular to Hechengli village. *Sound* safety procedures are not ensured by provision of technically certified equipment, but require demonstrated functionality in and acceptance by Hechengli village households. For example, laboratory-certified CO alarms were dysfunctional in Hechengli village households, where routine indoor ambient conditions (e.g., high humidity, odors from fermenting vegetables) triggered loud alarms.

9. Response to corrective recommendations and project outlook

A short (three-day) field mission was undertaken in August 2004 to investigate changes made in response to SEEIA recommendations. While several structural changes had been made to bolster occupational safety and workplace aesthetics, neither a ventilation system nor a CO alarm had been installed in the factory. Exposed portions of gas delivery lines had been insulated with hopes of preventing wintertime obstruction when ambient temperatures remain far below freezing, but no wintertime operations had yet tested the adequacy of insulation. The factory had resumed "normal" operations one week before the investigative visit, but operations were still at only 3.6 % capacity factor. Village residents continued to report uneven gas flow and weak flames, especially during periods of high demand (i.e., meal times). Additionally, village residents remained vulnerable to CO poisoning from producer gas leaks, as acceptable alarms were still not in place. Thus, as of August 2004, the outlook for the HVEP had improved marginally, but remained untested during wintertime operations, unsafe for residential consumers, and economically unviable due to extremely curtailed operation.

10. Lessons learned to facilitate future projects in China

The Hechengli Village Energy Project was originally intended to demonstrate technical and economic viability as well as a business plan that would serve as a model for replication for agricultural villages in China [Liu and Wu, 2001; Liu et al., 2001; UNDP, 2004]. The assumptions underlying this intent were that [Young et al., 2004]:

- the critical ingredients for success were sound engineering design and a market-viable business plan; and
- local management of contracting, start-up, and maintenance could harmonize implementation details.

However, local actors were left without the decision-making authority, corrective voice, administrative capacity, or technical capacity to attend to details germane to project success.

The Hechengli Village Energy Project has not offered a general model for replication. Rather, it suggests that the very concept of a general model for replication may be problematic insofar as details which are inherently local, dynamic, and cultural call for a flexible model tailored to specific context. The HVEP does offer several lessons that could improve prospects for similar village-scale energy projects in rural China. SEEIA recommendations are articulated in our final report [Young et al., 2004].

1. Business plans should be place-specific and collaborative, integrating and re-integrating local input from inception through the final stages of implementation.
2. Village authorities should have adequate decision-making voice to ensure quality control, particularly in the realm of negotiating construction contracts.
3. To increase transparency and accountability, independent auditing and inspection should attend all stages of the project.
4. Safety issues related to acute CO exposures from household leaks and in occupational settings should be prioritized, with requisite equipment demonstrated and tested on-site for technical viability, logistics, and local acceptability.
5. Procedural dimensions – in particular, implementation and monitoring – should be given as much emphasis as conceptual design (e.g., engineering and business planning).
6. To enable and encourage household adoption, demonstration projects' budgets should include all essential capital components (e.g., household heaters and stoves), particularly where these appliances are not readily available or familiar to village residents.
7. Practicable strategies – e.g., resource-sharing, formal meetings, internal reporting requirements – should be actively engaged to establish reciprocities and trust across social and institutional rifts and to overcome vertical and horizontal obstructions to communication and cooperation.

11. Applied ethnography in support of rural energy projects

The Hechengli Village Energy Project is another case supporting the argument that:

> *Most of the time, development failures stem from a lack of fit between proposed changes and local cultural contexts, not a lack of finance, technology, or goodwill* [Nolan, 2002].

Applied ethnography can help bridge the lingering gap between sound policy and effective practice by:

- offering local knowledge regarding culture and context to complement and guide technical and economic design;
- enabling critical cultural learning – necessary to resolve unforeseeable problems – throughout project evolution;
- giving voice to local perspectives and experiences; and
- enabling empirical investigation of project impacts.

We advocate an expanded role for ethnographic assessment of rural development projects. Ethnographic fieldwork fosters sound project evolution at all stages, and its utility is severely compromised when limited to post-hoc evaluation. Ethnography can provide vital support by monitoring implementation, facilitating coherent understandings across cultures, and checking critical data and assumptions. This support role extends from project conception through planning and implementation. ■

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Notes

1. The term "modernized biomass energy" refers to the transformation of solid biomass feedstock (agricultural residue, wood, dung) to more "convenient" – e.g., portable and easy to ignite – and/or cleaner-burning energy carriers in the form of gas, liquid, or electricity [Kartha and Larson, 2000]. Occasionally the term has included standardized solid forms such as pellets or biomass briquettes [Hall and Scrase, 1998].
2. The program was executed by the China International Center for Technical and Economic Exchanges (CICTEE) with support from the United Nations Foundation.
3. In Hechengli village, a feedstock of 50 % wood chips, 40 % flax, and 10 % corn stalks generated a 3400-4100 kJ/m^3 gas of 13-17 % CO, 2.0-4.8 % O_2, 9.3-10.3 % H_2, 1.6-2.0 % CH_4, 52-58 % N_2, 0.295-1.16 mg/m^3 tar and particles. With 100 % wood chip feedstock, the heating value was higher (4400-4900 kJ/m^3) and composition was 17-20 % CO, 2.0-4.0 % O_2, 12-14 % H_2, 2.0-2.7 % CH_4, 50-56 % N_2, 0.730-1.02 mg/m^3 tar and particles [UNDP, 2004].
4. At present, no electricity has been sold to the utility grid.
5. Corn stalks comprised less than one-third of actual feedstock used during the trial production period, with wood chips and flax straw comprising the balance.
6. See Note 3 for actual heating value associated with feedstocks of 50 % and 100 % agricultural residue.
7. Effective capacity of storage tank, as constructed: 275 m^3.
8. As reported in Section 7, actual household demand was far less due to gas delivery complications and non-use of gas for heating.

9. The official rhetoric regarding the energy project cites benefiting the minority population as a central objective, but as the SEEIA team observed, with a few exceptions the Korean population did not directly benefit from the energy project.
10. Space-heating in Hechengli is primarily accomplished by the use of *kangs.* The traditional *kang* is an internal flue structure made from fired bricks which circulates hot air from solid fuel stoves beneath a raised floor (Han-style *kang)* or, in the case of the traditional Korean-style *kang,* in the earth-bermed space below a floor approximately level with the ground. After circulating under the floor of the living space, hot gas exits the *kang* via a brick chimney 5-6 m high.

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Appendix A. Scope and timing of field missions

Table A1. Chronology of field missions. Focus, plant status, and timeline associated with SEEIA field missions as originally envisioned and as carried out. Additional tasks adopted in response to unexpected situations encountered in the field are indicated in italics.

Mission number and project status		Mission focus	Timeline
1. Under construction	Formal charge	Baseline energy practices, cultural context, & development of impact indicators	Winter 2001-2002
	Tasks carried out	As above; and *discovery and clarification* of misinformation and lack of awareness regarding perceived energy practice, village business planning, and budget discrepancies	November 24-December 12, 2001
2. Trial production period	Formal charge	Impacts of producer gas project during early stages of operation	Winter 2002-2003
	Tasks carried out	as above; and *discovery and clarification* of extremely curtailed (1.8 % capacity factor) operations and factors leading to unsatisfactory plant status; *recommendations* to bolster prospects for the project	February 18-March 13, 2004
2b. Trial production period follow-up[1]	Not originally envisioned		
	Tasks	*Clarify the status* of the project before UNDP involvement was terminated	August 9-11, 2004
3. Commercialization phase	Original plan	Impacts of energy project during commercial operation	Fall 2003
	Not carried out		See below[2]

Notes

1. Commercial operations had not yet begun when this field mission was undertaken by John A. Young and Han Ling.
2. A central recommendation of the August 2004 field mission report was that the project be evaluated by an independent observer after 12-18 months of locally orchestrated (no UNDP involvement) operation.

Appendix B. Informants and topical guides of field interviews

Table B1. Topical guides, first field mission. Topical guides for semi-structured interviews with Hechengli village residents, managers and personnel and village enterprises, and village and county leaders.

Informant	Topical guide	Interview length
Village residents	Relationships among members of the household; level of education; ethnicity; *kang* type; cigarette-smoking behavior; daily work and time-activity patterns; sources of income; household energy uses and expenditures; cost in time and money for household fuels; price concerns; ways of cooking, heating, and pursuing other energy-related activities; perceptions regarding indoor air quality; expectations about changes that might occur at the household and village levels as a result of the energy project.	45 min-1 hour
Enterprise managers and personnel	Energy consumption (sources, end-use, and seasonal/diurnal variations); energy prices; labor force characteristics; wage structures; seasonal employment patterns; business operations; perceptions regarding air quality; expected changes and opportunities from the energy project.	1-3 hours, including a tour of facilities
Village and county leaders[1]	Village history; prospects for the economic and operational success of the producer gas factory; village finances and business plan.	> 2 hours

Note

1. The research team had less autonomy to guide the course of interviews with local leaders, as powerful social and political dynamics came into play. It was often difficult to elicit candid, straightforward responses to key items of concern, in particular finances directly related to the producer gas factory.

Table B2. Topical guides, second field mission. Topical guides for semi-structured interviews with Hechengli village residents, managers and personnel of the energy project, farmers from a nearby corn-growing village (Nanyang), and village and county leaders.

Informant	Topical guide	Interview length
Village residents	Systematic observation of piping, stove installations, and CO alarms; experience using producer gas; experience with the CO alarm system; perceptions regarding safety & future costs (gas distributed free during trial production); past and potential substitutions of producer gas for other fuels; opinions about the producer gas stoves; experiences associated with pipe installation, construction, and dissemination of knowledge for safe use of producer gas; opinions regarding future use of producer gas and the future of the energy project.	45 min-1 hour
Producer gas factory managers and personnel	Job routines in the producer gas factory; operation protocol; storage and delivery (via piping) of the gas; operating costs and revenues; construction issues (particularly with regard to the piping distribution network); nature and magnitude of current problems; perceptions regarding what went wrong; future plans to expand production.	2-3 hours, plus two 30-min observations of gasification process
Corn farmers (Nanyang)	Experience selling stalks to Hechengli's energy project; perceptions regarding profitability of stalk sales to Hechengli's energy project; perceptions regarding logistics of supplying stalks to Hechengli.	2 hours 30 min
Local leaders[1]	Prospects for the economic and operational success of the producer gas factory; village finances and business plan.	> 2 hours

Note

1. The research team had less autonomy to guide the course of interviews with local leaders, as subtle social and political dynamics came into play. It was often difficult to elicit candid, straightforward responses to key items of concern, in particular finances directly related to the producer gas factory.