ROCK, METAL, AND ELECTRONIC:

Yunnan's Environmental Discord Between Mining, Aluminum, and Hydropower

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The discovery of gold in Sacramento Valley in 1848 drove three hundred thousand people to California, digging the ground and panning the rivers, chasing the dream of wealth in the Wild West. One and a half centuries later, China launched its own "Go West" movement with the Great Western Development Campaign. Over the past 15 years the central government has poured over half a trillion dollars into the west,[1] aimed at raising the region's economic standards while eyeing what attracted people to California in the mid-1800s: resources and wealth.

China's "Go West" investment has created channels to extract resources—water, gas, and electricity—and transfer them from the landlocked west to the east coast. Yunnan, China's southwestern-most province, lies at the birthplace of much of these resources. Here, over 150 types of minerals boast a potential value of a whopping half a trillion dollars.[2] Its high mountains, deep valleys, and abundant rainfall also favor Yunnan with a hydropower goldmine.

However, this combination of abundant minerals and hydropower potential, while a boon for the local economy in the short-term, has been disastrous to the environment. The intertwined interests of the hydropower, mining, and metallurgy industries are inflating energy demand, spurring on dam-building, and enriching energy-intensive development. These interdependent industries are creating a vicious cycle that pollutes Yunnan's air and water and threatens the ecosystem in this biodiverse-rich province. Local governments perpetuate this cycle by creating incentives for industrial development, oftentimes contrary to the central government's orders to curb energy-intensive industries.

In particular, aluminum production has gained traction in Yunnan. The aluminum industry has proved all too eager to exploit Yunnan's hydropower capabilities. The growth of this industry has catalyzed opposition from concerned citizens, who are left to fight the uphill battle to slow down the perverse cycle of hydropower, mining, metallurgy, and local government interests.

ROCK: MINE A WAY OUT OF POVERTY

Yunnan is poor. Out of the 592 poorest counties in the entire country, 73 are in Yunnan, second only to Tibet.[3] The mountainous terrain formed by a canyon region to the west and a plateau region to the east has prevented prosperity from visiting this remote, hilly, and landlocked province.

Buried underneath the ground is a hopeful key out of poverty. Known as "the kingdom of non-ferrous metal," Yunnan possesses the largest deposits of many mineral resources in the nation, including zinc, lead, tin, cadmium, indium, and thallium. It also enjoys significant deposits of iron, coal, aluminum, copper, gold, mercury, silver, antimony, and sulfur. Spurred by this rich cache of mineral deposits, the metallurgical and chemical industries have become a critical engine for local growth, job creation and local government's tax revenue. Out of the ten most profitable companies in the province, half are in these two industries.[4]

Yunnan is bestowed with another gift: hydropower. The unique geology on the edge of the Yunnan-Guizhou Plateau shapes the deep valleys that hosts three parallel rivers—the Yangtze, the Mekong, and the Salween—and with it brings huge hydroelectric potential. Its economically exploitable hydropower capacity amounts to 97.95 GW—second largest among all provinces and almost a quarter of the national total.[5] The annual hydropower generating potential of the Lancang River (upper Mekong) within Yunnan is estimated to be more than 100 TWh.[6] To get a sense of scale, 80 TWh per year would be enough to power all four major cities in China's south: Guangzhou, Shenzhen, Gongguan, and Kunming.[7] This goldmine of hydropower resources has led to the construction of 1,939 dams—including China's very first dam, the Shilongba built in 1912—to this province.[8]

Compared with the vast potential, the current installed capacity—a mere 32.02 GW—leaves alluring opportunities for Yunnan to further tap into this clean and renewable energy.[9] In the central government's 12th Five-Year Plan for Energy Development, at least 18 medium and large dams are specifically mentioned as being under construction or planned in Yunnan.

The combination of mining resources and hydropower is a match made in heaven. Metallurgy requires huge amounts of electricity that dams are able to provide at low prices. Yunnan can process the mineral resources and then transport the finished products to consumers. Though this partnership

makes economic sense, it is creating painful environmental damage to this biodiverse region.

METAL: WHEN LIJIANG MEETS ALUMINUM

In early 2013, Chinese netizens on Weibo, China's Twitter, read the news of a proposed aluminum electrolysis plant in Lijiang, a city in Yunnan known for its natural beauty and ethnic culture. Spread by both traditional and new media, the potential environmental impact of a dirty aluminum plant drew the ire of more than just local citizens. In an online poll soon after the story, 93 percent of 1,680 participants opposed the construction of the plant.[10]

Aluminum electrolysis—the process to extract aluminum oxide out of ore—is highly energy-intensive and polluting. (See Box 1).The current global best practice, using Center-Feed Prebaked cell, requires 13.6 MWh of electricity to produce a ton of aluminum.[11] Even though some of China's primary aluminum producers are now equipped with this technology and operate efficiently at an international advanced level,[12] the Chinese industry-average electricity consumption is still at around 14.3 MWh/t. (See Table 1). With a production volume of 20 million tons in 2012, China's aluminum industry consumed a colossal 286 TWh of electricity. This is three times the annual electricity generated by the Three Gorges Dam, or about 6 percent of the country's entire power consumption (4.96 trillion kWh).

Electricity accounts for more than 40 percent of the total cost of primary aluminum production.[13] After June 2010, the central government stopped subsidizing aluminum industry's electricity use. Cheap electricity thus became a driver for aluminum and other energy-intensive industries to migrate west and plug into the expanding hydropower. More than 90 percent of new aluminum electrolysis capacity since 2010 has been located in China's hydropower-rich southwest.[14]

Though equipped with advanced electrolyzer design and smelting technology, most Chinese aluminum producers still lag behind in adopting adequate pollution monitors and control systems.[15] In early 2013, an aluminum plant in Shandong Province leached hazardous chemicals into the ground water. In a nearby village, *China Youth Daily* reported that the visibly contaminated well water killed crops, and many local residents who drank the water became ill and some died.[16]

Nevertheless, during a visit in October 2004, Yunnan

Box 1. Energy Consumption and Pollution of Aluminum Production

In order to break the strong chemical bonds between aluminum and oxygen in the ore, a process called electrolytic smelting is used. In the current technique, known as the Hall–Héroult process, alumina is first dissolved into molten cryolite-based electrolyte and then electrolytically reduced to aluminum at a temperature between 950 and 980 °C (1,740 to 1,800 °F). The aluminum metal then sinks to the bottom of the electrolyzer and is tapped off, usually cast into large blocks for further processing.

The electrolysis process emits carbon dioxide, carbon monoxide, several gaseous and particulate fluorides, sulfur dioxide, and other polluting gases. Moreover, the transportation and feeding of alumina to the cell disperses dust into the air. Wet air emission control devices, such as wet scrubbers and wastewater treatment, generate solid waste. Wastewater, if left untreated, contains fluorine, suspended solids, and other chemical components that pollute the surface and ground waters. Furthermore, spent carbon potlining is a hazardous waste containing significant amounts of leachable fluoride, iron cyanide complexes, free cyanides, and other organics.

Table 1. Chinese Government's Energy Consumption Standards for Aluminum Electrolysis

Sector	Indicators	Minimum Energy Consumption Performance for Existing Plants	Minimum Energy Consumption Performance for Newly Constructed Plants	Advanced Minimum Energy Consumption Performance
Electrolyzed Aluminum	Alternating current consumption of liquid aluminum (kWh/t)	≤14400	≤13800	≤13500
	Comprehensive alternating current consumption of aluminum ingot (kWh/t)	—	≤14300	≤14000
	Comprehensive energy consumption of aluminum ingot for resmelting (tce/t)	≤1.900	≤1.850	≤1.800

Note: Electricity is converted at final energy value (0.1229 kgce/kWh).

Source: Lu Hongyou, collected from "GB 21346-2008: The norm for energy consumption per unit products of aluminum metallurgical enterprise," General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, and Standardization Administration of the People's Republic of China, January 9, 2008.

People's Consultative Committee representatives voiced support for the aluminum electrolysis project portraying it as necessary to "help alleviate poverty in an area with few other options."[17] The mayor of Lijiang too stated in early 2013 that to "maintain the vintage and simple scene that tourists envisioned would mean a closed and impoverished Lijiang."[18] Local officials have bought into the idea that energy-intensive industries are a painful but necessary method to alleviate poverty, but their strategy violates central policy and is not likely a silver bullet for long-term economic growth.

PUNK: THE OVER-CAPACITY OF METAL PRODUCTION

As the second most used metal after steel (See Box 2), around 45 million metric tons of aluminum is produced globally every year. China, by far the largest producer, accounts for almost 44 percent of global production.[19]

To date, China has 27.65 million tons of installed capacity for aluminum electrolysis. Of that, however, only 72 percent was used in 2012.[20] A surge in expansion between 1985 and 2005—during which China accounted for 119 of the 133 aluminum smelters built globally—rendered China's primary aluminum industry in massive over-capacity.[21] Over a million tons of unnecessary aluminum has piled up in warehouses. That number reached an astonishing peak of 1.2 billion tons in May 2010.[22]

Over-capacity of heavy industry brings two immediate problems:

Box 2: The Age of Aluminum

Aluminum is light, durable, stainless, recyclable, and easy to process. The metal has become an essential part of our daily lives. We drink from aluminum cans, use aluminum-containing deodorants and sunscreens, and it increases the effectiveness of vaccines. We drive cars with parts—such as cylinder heads, pistons, radiators and wheel rims—made of aluminum. Motorcycles and airplane parts also are increasingly made of aluminum. In the building and construction sector, aluminum is widely used in siding, roofing, gutters, window frames, hardware, and paint.

The most visible use of aluminum is in packaging. Aluminum foil and trays, gum and candy wrappers are all made of aluminum. In 2009, the packaging industry overtook the transportation industry as the top user of aluminum, in part due to sluggish automotive sales.

MacBooks, iPhones, and other electronics are now largely made of aluminum, as do electrical products such as light bulbs, power and phone lines. In the health industry, aluminum goes into food additives, astringents, antacids and even buffered aspirin. Aluminum is a major component of household cooking products such as pots, pans and utensils. The recreation industry too uses aluminum in the manufacture of lawn furniture, baseball bats, golf clubs, and tents.

1. *Financial loss*. Over-supply dramatically decreases companies' profit margins. In early 2013, none of the 12 aluminum electrolysis companies in Henan Province were profitable, causing three to shut down.[23] A similar over-capacity in the steel industry cost more than $100 million industry-wide in June 2013 alone.[24] China's leading steel companies are expecting a fall in net profits ranging from 50 percent to 95 percent in the first half of 2013.[25]

2. *Trade disputes*. In good times, China gobbles up most of the aluminum it produces.[26] But its slowing economy may force more of its aluminum products to go overseas. Similar to Chinese solar panels and tires, the state-subsidized aluminum products could trigger another wave of trade disputes on the global market. In 2010, the Obama administration ruled Chinese aluminum suppliers liable for dumping their products on the U.S. market.[27] Since March 2013, the European Union also has begun to impose heavy anti-dumping duties on Chinese aluminum foil.[28]

The Chinese central government acted against the mushrooming aluminum industry. The 11th Five-Year Plan (2006-2011) eliminated 840,000 tons of outdated production capacity by closing small plants and updating equipment.[29] Consequently, average energy efficiency in the industry rose significantly. In the 12th Five-Year Plan (2011-2015), the Ministry of Industry and Information Technology (MIIT) released a separate and specific plan for the development of the aluminum industry, calling for stricter controls on the expansion of the aluminum electrolysis industry and a further elimination of outdated capacity.[30]

In April 14, 2011, MITT, the National Development and Reform Commission, the Ministry of Environmental Protection, and the National Energy Administration along with five other ministries, released an "urgent notice" on containing over-capacity and redundant construction of the aluminum electrolysis industry. The notice called for the suspension of all proposed aluminum electrolysis projects across the country and withheld approval for new projects that would lead to excessive production. In addition, all local preferential policies in this industry were declared no longer effective, and any plans for expansion of production capacity

were strictly prohibited.[31] On September 10, 2013, the State Council in its new Air Pollution Prevention and Control Action Plan reiterated the 12th Five-Year Plan's target in aluminum capacity reduction and moved its deadline up one year early.[32]

BLUES: WATER AND ITS IMBALANCED SUPPLY

Compared to other forms of energy generation, hydropower has a unique ability to store electricity—in the form of water—in its reservoirs. Dams can discharge water when needed, providing superior flexibility for peak electricity needs.

Dams in Yunnan are built across rapid streams in steep and narrow valleys, which create tremendous hydraulic head (water surface elevation), but leave limited space for reservoirs. Consequently, electricity output varies significantly between wet and dry seasons. During the heavy monsoonal rains, dams turn their turbines on full power to generate as much electricity as possible to make up for less power generation during the dry seasons. Unfortunately, the flat-out generation usually produces more electricity than Yunnan can consume. Therefore, the local grid has no choice but to lose the water that could otherwise be used to generate electricity.

UNPLUGGED: THE FIGHT TO KEEP ELECTRICITY

To consume this otherwise "wasted" hydropower capacity, Chinese central policymakers built the massive West-East Electricity Transfer Project. Conceptualized initially in 1986 to tap the hydropower potential of the Yuan River in Yunnan,[33] the project now sources electricity from seven provinces. (See CEF's West-East Electricity Transfer Project interactive map online for more details). In 2012 alone, Yunnan transferred more than 41.86 billion kWh of electricity to Guangdong Province. The aggregated electricity transfer volume between the two provinces in the past 20 years has reached 200 billion kWh[34]—an amount that would take the Hoover Dam almost 50 years to generate.[35]

Expanding such a massive electricity transfer infrastructure, however, requires both state-of-the-art technology and time. The current infrastructure capacity can only transfer a small amount of electricity that is being generated in the western region. By the end of 2010, 13 transmission lines in China's Southern Corridor, including the world's first ultra-high-voltage (±800kV) direct current transmission project, held a maximum transmission capacity of 2.4 million kilowatts,[36] which is merely 7.4 percent of the installed generation capacity in the southern grid.[37] China Electricity Council estimates that during the wet season of 2013, Yunnan will waste a whopping 7 GW of hydropower capacity[38]—the electricity generated from which equals to burning 8.4 million tons of coal and emitting 22 billion tons of CO_2—due to low local consumption and the inadequate capability of the transmission system.[39] In the past two years, the province has wasted more than 20 billion kWh of electricity—more than 6 billion Yuan ($1 billion). By the end of the 12th Five-Year Plan, the capacity of the Southern Corridor will reach 4.3 million kilowatts,[40] still only a trickle of the generation capacity in the region.

For the Yunnan provincial government, a better way to consume "wasted" hydropower is to inject that electricity into local economic development. As early as 2001, heavy industry companies proposed and implemented strategies to use Yunnan's hydropower locally.[41] More recently, a Lijiang local official said that the city "should keep half of the electricity it generates in order to drive a leap-frogging industrial development."[42] His government aims to create a 40 billion Yuan ($6.5 billion) heavy- and manufacturing-industry by 2015.[43] To incentivize more energy consumption, Yunnan government now sells electricity at a 20 percent discount if a user consumes more than the previous year.[44]

Local consumption of hydroelectricity is further justified in two ways:

1. Products produced locally contain embedded electricity, which is still "transferred" to the east—through products rather than transmission lines;

2. The long distances between hydropower stations and coastal load centers are costly for electricity transfer. The price of transferred electricity, however, is set at a low price by the central government. The double pressure on prices wreaks havoc on hydropower developers' profit margins, making energy transfer less desirable than local consumption.

Energy-intensive industries often end up consuming excessive electricity. The electricity, in turn, fuels the much-needed local industrial growth, and brings more revenue to hydroelectric companies. Such a win-win-win solution offers significant incentives for energy-intensive industries, dam developers, and local governments to cooperate.

NEW AGE: ELECTRICITY PRICING MODELS

To further benefit from the winning strategy, dam developers and energy-intensive industries established direct channels to transfer electricity. China's energy pricing system sets different prices for different industries. Heavy industry is typically charged one of the highest electricity prices. If an electricity generator establishes a direct supply contract with industrial consumers, the price can sometimes be as low as 70 percent of the original retail price.[45] For generators, these long-term high-volume contracts lock in demand. Heavy industries benefit by considerably reducing their electricity bills. In 2009, Yunnan Aluminum Co. Ltd. paid 0.35/kWh directly to its generators,[46] compared to the 0.495/kWh retail price for heavy industry.[47] The company saved more than 14.5 million Yuan ($2.3 million) a year on its electricity bill.

Strikingly, some Chinese hydropower companies have invested in heavy industry themselves, creating electricity needs to lock in demand, an initiative that has been supported by many local governments. In Sichuan and Yunnan, government officials have encouraged the two industries to cooperate to "form a hydropower industrial chain" and "elevate the electricity consumption level."[48] With the local government's nod, many hydropower developers obtained shares in heavy industry companies. Giant investment firms, such as Sichuan Provincial Energy Investment Group, have metallurgical mining companies in their portfolio.[49]

These investment trends have both boosted local GDP and the development of energy-intensive industries. During wet seasons, these industries gobble up electricity generated by dams. In dry seasons they still consume electricity and often create local energy shortages. Since 2004, electricity shortages in the dry season have become prevalent in China's southwest. In 2007, even Sichuan, the "hydropower kingdom," was short in electricity supply.

When supply for electricity is not met, local governments and industries sacrifice the transfer volume to meet local electricity demands. In 2005, a municipal official in Guizhou Province asked the provincial government to support local electricity use.[50] Later in Guangxi Province, local officials proposed that electricity generated from Longtan Dam—the third largest dam in China—be entirely consumed locally in order to support aluminum production.[51]

The Yunnan provincial government has actively prevented direct electricity transmission to eastern provinces so the power can be used locally. The ±500kV Jinzhong Direct Current Electricity Transmission Project has been repeatedly delayed because of the government's desire to connect Liyuan and Ahai dams to the local grid. In May 2011, the Yunnan Development Reform Commission even offered to relocate the residents displaced by dam construction in order to persuade China Southern Power Grid, the National Development and Reform Commission, and the National Energy

Administration to directly connect Sichuan's Guanyinyan Dam into the local grid.[52] The additional stop brings more electricity for local development and also provides revenue when Yunnan sells its electricity to the east at a price that is higher than that set by the central government for direct transfer.[53]

As hydropower developers continue moving construction upstream on the southwest rivers, new dams are built further away from the consumption sources in the east. These dams require longer transmission lines and higher voltage technologies that drive up the cost of electricity delivery and lower the profit of electricity sales to the east. Provinces that are far from the load centers have already developed alternative destinations for electricity transmission: Southeast Asia. Since 2004, Yunnan has been transferring electricity to Vietnam and earned more than $1.2 billion in the past nine years.[54] China has reached further agreements with ASEAN to export more electricity to Vietnam, Thailand, Myanmar (Burma), and Laos, which will create more incentives for Yunnan to divert power southward.

ALTERNATIVE: HIDING FROM THE FAR AWAY EMPEROR

In order to circumvent the central government's regulations, the aluminum industry has adopted the widespread practice of registering illegal electrolysis projects under other business names. Even worse, many companies are launching their projects before obtaining government permission: an alarming 85 percent of the current electrolysis projects are unauthorized.[55]

Despite Beijing's efforts to rein in over-capacity, the Lijiang municipal government approved the aluminum project, registering it as an aluminum profiles processing—rather than electrolysis—facility with an annual SO_2 emission of 182.5 tons.[56] Being a processing facility with low emissions (the original Weibo source reported a 2,000 annual SO_2 emission from an electrolysis plant), it does not require the permission of the central government.[57] Local environmental protection bureaus (EPBs), which often times are under intense pressure from their local governments to prioritize economic development, have enough authority to give the green light to manufacturing plants.

The Chinese news media has speculated that the profile processing registration is in fact a cover for aluminum electrolysis. *Southern Weekly* discovered that Lijiang EPB was assessing an electrolysis plant's environmental impact as early as 2009.[58] In the same year, Lijiang mayor was also reportedly discussing aluminum electrolysis investment with Yunnan Metallurgical Group.[59] Furthermore, the business scope registered by the processing plant includes unalloyed aluminum, carbon and aluminum oxide, and other raw materials used for electrolysis.[60]

Industry experts say that the seemingly low SO_2 emission volume of 182.5 ton is still unusually high for a profiling plant. Current practice in the industry uses natural gas, which emits very limited SO_2, for fuel. Under China's new national guideline, only the electrolysis process in the aluminum production life cycle would produce large amounts of SO_2.[61] Moreover, experts who were interviewed by *China Business News* said that even if companies start with manufacturing, many would eventually build electrolysis capacity to provide material for downstream business and sell aluminum ingots directly to diversify income.[62]

Despite all the evidence, the Lijiang government and the plant developer still appear to be concealing the truth. The Lijiang EPB told a journalist that the hard copy of the project's environment impact assessment was documented, but the digital copy was not saved and therefore unavailable for distribution.[63] During multiple phone conversations with a journalist, officials in the Lijiang municipal government also appeared evasive, claiming that the person responsible for discussing the plant was not present and that the investigation had not been concluded.[64]

VOCAL: WATCHFUL EYES FROM CIVIL SOCIETY

Recent years have witnessed countless waves of bottom-up environmental movements in a fashion that China had previously never seen. From the "airpocalypse" in Beijing to the discovery of cadmium-laced rice in several provinces, Chinese citizens are pressuring their local governments for better accountability and governance not just with protests on the street, but also in spirited and creative complaints using social media.

The aluminum electrolysis project in Lijiang is yet another example of how civil society engagement, supported by social media, can impact public policy. (See Photo 1). Kindled by a real-name Weibo user, the controversy was pushed forward largely by online discussion that then sparked investigative journalism. Experts and respected public figures have used their blogs and social media to gather and disseminate information. For example, Yang Fuquan, vice president of Yunnan Academy of Social Sciences, published a blog in February 2013 detailing the progress of the story, educating readers about aluminum electrolysis, and directing those who are interested to a long list of other articles on the controversy.[65]

PICTURE 1. Netizens protested the Lijiang aluminum electrolysis plant on Weibo by posting pictures of themselves holding posters that read "No electrolytic aluminum, protect the environment."

THE TRUE TUNE OF HYDROPOWER

Largely thanks to calls from the public, the municipal and provincial governments could not ignore the controversy. During the 2013 National People's Congree, Yue Yuesheng, Director of Yunnan Provincial Industry and Information Technology Commission said that Lijiang is "unlikely" to build the aluminum plant.[66] Qin Guangrong, the Party Secretary of Yunnan province, also stressed that Yunnan should "cherish its ecology like we cherish our lives; protect its environment like we protect our eyes."[67] "Yunnan would rather sacrifice the speed of growth," he said, "than fail to protect its ecology and environment."[68]

Yunnan faces a difficult choice between environmental protection and economic development. On one hand, natural resources could spur growth for this economically underdeveloped region. On the other hand, dam construction, mining and metallurgy will destroy its ecological diversity, fresh air, clean water, and thick forests—all of which are increasingly rare in China.

Hydropower build-up has put China's southwest on the frontline of environmentalism opposition and diplomatic conflict. Even if the 18 proposed dams in Yunnan, along with many others in its neighboring provinces, can be constructed "responsibly," heavy industry, cultivated by the excess capacity of electricity generation, will still cause immense damage to the environment. In dry seasons, hydropower cannot meet energy-intensive industries' large electricity demand. Yunnan may need to develop other dirtier forms of energy, including coal.[69]

China may very well build more transmission lines with state-of-the-art technology to transfer electricity to the east. But Beijing has had and will still have difficulties to order local governments to surrender the electricity for growth. The central government's command-and-control is useful in improving existing plants' energy efficiency, as it is targeting an additional 10,000 enterprises—193 of which are aluminum companies—for energy conservation in the 12th Five-Year Plan.[70] New plants, however, can still play hide and seek with the emperor that is far away.

China boasts the world's largest hydropower resources. With 249 GW of installed capacity, hydropower currently contributes to 17.4 percent of the nation's electricity generation.[71] Against the backdrop of a growing energy demand and the ever pressing need to address climate change, hydropower is increasingly seen as the silver lining to power China's growth.

Yet an overwhelming majority of these resources are located in the country's southwest region—Sichuan, Yunnan, Guizhou, Qinghai, and Tibet. The more hydropower projects these provinces build, the more challenging it will be to either transfer the electricity to the east, or to prevent the unsustainable use of the cheap hydroelectricity in these landlocked areas.

As China re-ignites its "dam rush," the real cleanness of its hydropower needs to be constantly examined. The precise nexus between energy, environment, and development should remind China's local and central governments of the dangerous path these magnificent engineering marvels may lead to.

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