# "Green" Technology and Ecologically Unequal Exchange: The Environmental and Social Consequences of Ecological Modernization in the World-System

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## Abstract

*This paper contributes to understandings of ecologically unequal exchange within the world-systems perspective by offering a series of case studies of ecological modernization in the automobile industry. The case studies demonstrate that "green" technologies developed and instituted in core nations often require specific raw materials that are extracted from the periphery and semi-periphery. Extraction of such natural resources causes significant environmental degradation and often displaces entire communities from their land. Moreover, because states often use violence and repression to facilitate raw material extraction, the widespread commercialization of "green" technologies can result in serious human rights violations. These findings challenge ecological modernization theory, which rests on the assumption that the development and commercialization of more ecologically-efficient technologies is universally beneficial.*

Popular and academic environmental discourses often endow technology with heroic powers. According to such accounts, contemporary societies have the capacity to develop and commercialize new eco-efficient technologies that utilize significantly fewer natural resources and produce much less pollution per unit compared to previous generation technologies. Green technology, these discourses assert, is developed and made broadly available through market forces and/or government policies, and has the ability to pull societies back from the brink of environmental and economic decline (see Salleh 2012). For instance, the president of the Environmental Defense Fund, a large U.S. environmental organization, writes that a new industrial revolution is on the horizon that "will almost certainly create the great fortunes of the twenty-first century. But this new industrial revolution holds a more important promise: securing the world against the dangers of global warming" (Krupp and Horn 2008: 1). Voicing a similar sentiment, U.S. President Barack Obama stated, "all of us are going to have to work together in an effective way to figure out how do we balance the imperatives of economic growth with very real concerns about the effect we're having on our planet. And ultimately, I think this can be solved by technology" (CBC 2009). Putting it more strongly, *New York Times* columnist Thomas Friedman claims that the development of a "clean energy system" will "allow us to grow the world's economy—not only without exacerbating energy supply and demand issues, petrodictatorships, climate change, biodiversity loss, and energy poverty—but by actually reducing them at the same time" (Friedman 2008: 186).

Such treatment of technology does not only exist in popular environmental discourse, but in certain academic discourses as well, particularly in ecological modernization theory. According to one of the perspective's founders, "the pivotal component of ecological modernization is advanced technology" (Huber 2008: 360). Academic proponents of ecological modernization argue that state regulation and tax regimes, market forces, consumer preferences, and environmental movements propel technological innovation and implementation in ways that diminish society's impacts on the environment (Mol 2002; Mol and Spaargaren 2002; Buttel 2003; Cohen 2006; Schlosberg and Rinfret 2008). In this way, increasingly self-aware and reflective modern societies have, according to ecological modernization theorists, the technical ability to achieve long-term environmental sustainability and can do so without dramatically altering or reforming today's predominant social structures and processes (Mol 1996; Mol and Janicke 2009). This central argument of ecological modernization theory rests on the unacknowledged assumption that "green" technologies—developed and commercialized in core nations—will benefit, or at least have the capacity to benefit, all people universally.

Expectations from a world-systems perspective are very different. Theorists drawing from this perspective would conceptualize "green" technologies as commodities. As such, they are derived from particular natural resources that exist in finite quantities in specific places across the globe (Smith 2005). And, from a world-systems perspective, because "green" technologies are commodities, they imply relations of inequality and exploitation (Marx 1994 [1867]). The social relations of particular concern here are of those between the comparatively wealthy core and the comparatively poorer periphery and the semi-periphery. To world-systems analysts, the economic development of the core came at the cost of the underdevelopment, social disruption, and environmental degradation of the periphery (Bunker 1984). Taken together, this means that while the widespread development of "green" technologies may create real benefits in core nations, it may also produce further environmental degradation, violence, and social disruption in peripheral zones. In other words, "green" technologies, like other commodities

whose production and consumption spans the globe, are part and parcel to processes of ecologically unequal exchange (see, for instance, Jorgenson 2006, 2009; Foster and Clark 2009).

In order to assess these different expectations, we examine three cases of technological development in the automotive industry: catalytic converters, biofuels, and hybrid cars. In so doing, we ask to what extent the utilization of "green" technologies in the cars and trucks of wealthier nations inadvertently displaces, or might displace in the future, environmental harms onto others. In a series of case studies we demonstrate that many "green" automotive technologies require raw materials derived from the Global South and that the extraction of these raw materials regularly results in devastating amounts of environmental destruction. Due to the structure and operation of the world-economic system in which core nations have a privileged capacity to obtain such materials for their own domestic use, ecologically unequal exchange can occur even through processes of ecological modernization. The advancement of "green" technologies therefore can produce very different outcomes for the core, periphery, and semi-periphery in today's world.

To further consider the actual or potential impacts of ecological modernization, we also contribute to a growing literature that attends to the ways state violence and repression facilitate uneven global relationships. States act to violently dispossess people from their land, violently suppress environmental protest movements, and otherwise curtail basic human rights in order to promote and protect access to the natural resources—such as minerals, oil, and timber—that constitute the basis of industrial technologies (Downey, Bonds, and Clark 2010). We contribute to this literature by arguing that the widespread adoption of "green" technologies in core nations would require significant amounts of raw materials derived from the Global South, facilitated through continued violence and human rights abuses, thereby resulting in the further underdevelopment of less wealthy countries.

## Environmental and Social Costs of Ecological Modernization in the World-System

Ecological modernization is an influential theory that has received a great deal of attention from social scientists. A fundamental component of ecological modernization theory is the prediction that the adoption of new technologies such as shifts to renewable energy, "clean" technologies that produce less pollution, and the use of low-impact chemicals will substantially lessen societies' impact on the environment (Mol 1997; Huber 2008; see also Hawken, Lovins, and Lovins 1999). This means that, according to a second important premise of ecological modernization theory, the economy and the environment have to some degree been "decoupled," meaning that increased future economic activity no longer necessarily requires increased environmental degradation (Mol 2002). These two related principles rest on a third premise. Because ecological modernization theorists argue that technological advancement in capitalism can substantially lessen humanity's impact on the environment, and so help avert an ecological crisis, they assume that advancements in "green" technologies are neutral and universally beneficial (see, for instance, Mol 1997; Huber 2008).

These interrelated premises, though fundamental to ecological modernization theory, are strongly disputed by theorists and researchers from other perspectives. The argument that increasingly efficient technologies will bring about increased resource conservation is one of the most accepted "solutions" to environmental problems upheld by the corporate wealthy and policy-makers because it offers a "magic bullet" that, according to the argument, will allow

societies to manage the environmental crisis without social-structural changes or reduced economic production (Foster 2002). Despite the popularity of this key ecological modernization claim, many researchers argue that it simply is not true. Some have, for instance, called attention to the so called "Jevons paradox," named after the work of nineteenth-century political economist William Stanley Jevons, whose study of coal usage led him to conclude that the widespread use of technologies that improve efficiency actually increase—rather than decrease—total natural resource use (Clark and Foster 2001). This paradox occurs because as efficiency increases, an energy source becomes more affordable and increasingly available to consumers (York and Rosa 2003).

For this reason numerous social scientists have disputed the idea that the economy and the environment have in any way been decoupled in late modernity. The widespread commercialization of more efficient technologies, by making natural resources less expensive, can have the further effect of spurring economic expansion and thus increasing society's *total* impact on the environment (Clark and Foster 2001). Empirical tests using cross-national data bear this point out, indicating that the environment and society have not been decoupled in late modernity as highly developed and fully modern societies have not, as a whole, lessened their environmental impacts in terms of their per capita ecological footprints (York, Dietz, and Rosa 2003; Jorgenson and Clark 2009a).

The implicit assumption that technological innovation is neutral and benefits all people universally is at the very heart of ecological modernization theory. Nevertheless, it has not received much critical attention. Because ecological modernization theorists do not focus on issues of power, inequality, and domination, they tend to see technological innovation as the outcome of value-neutral scientific imperatives. For these theorists, innovations in "green" technologies are caused by the ongoing ecological rationalization of society, which is an impartial and purely technical process uninfluenced by social relations (see Mol 1997 for one example). These theorists rarely ask, for example, if a particular innovation in "green" technology benefits one group of people more than others, or if some may be harmed by the development and consumption of such technologies. Critical social scientists from numerous different perspectives—including Marxist and neo-Marxists (Braverman 1974), environmental sociologists (Schnaiberg and Gould 1994; Gould 2008), environmental anthropologists (Hornborg 1992), feminist scholars (Wajcam 1991, 1994), and some scholars of science and technology (Law 1991)—have long argued that technological development is profoundly social. Those with greater power have an increased capacity to develop technologies that best suit their interests at the expense of alternate technologies that may better suit other groups' needs. Indeed, power is often embedded in new technologies in ways that reproduce and even extend domination. "Green" technological development, we argue, is no exception. This point will become clear when placed in the context of global capitalism and ecologically unequal exchange between nations.

The literature on ecologically unequal exchange emphasizes the historical context of the core's exploitation of natural resources in the periphery. During the colonial era, the material infrastructure and economic growth of core nations depended upon access to the plentiful and cheap raw materials of their colonies (Bunker 1984; Moore 2003; Bunker and Ciccantell 2005). Consequently, European powers *underdeveloped* their colonies by extracting natural resources to the point of depletion while creating a wake of environmental destruction and social upheaval that inhibited – and continues to inhibit – more judicious economic and social development (Bunker 1984). The legacy of colonial underdevelopment lives on today in the form of

ecologically uneven exchange. Wealthy nations in the core – due to their greater economic, political, and military power in the world-system – can externalize the environmental impacts of capital accumulation onto the people of economically and politically weaker peripheral and semi-peripheral nations (Jorgenson 2006, 2009). This ecologically uneven exchange occurs when core regions extract and underpay peripheral regions for the energy and mineral resources that fuel core industrial infrastructure (Hornborg 1992, 2001) and utilize the atmosphere, waters, and ecosystems of peripheral zones to assimilate pollution and other waste produced in the core (Rice 2008).

It follows then that core nations may displace environmental harm on the people of peripheral and semi-peripheral nations even in the name of environmental improvement (Pellow 2007). For instance, Sonnenfeld (2000) documents how the pulp and paper industry in Southeast Asia adopted increasingly ecologically efficient technologies in response to civil society and market pressures. While these new mills produce much less pollution compared to previous generation technologies, they nevertheless are fueling deforestation in the region's tropical forests, prompting Sonnenfeld (2000: 254) to ask: "Is ecological modernization in advanced industrial societies dependent upon *increased* materialization elsewhere?" Similarly, Frey (2006) argues that environmental regulations and increased environmental protection in the world's wealthiest nations have created incentives for transnational corporations to move toxic and hazardous production to poorer nations that have weaker environmental standards and limited regulatory enforcement.[1] Pellow (2007) provides complementary findings in his examination of the toxic trade of electronic waste, in which corporations ship millions of tons of used and obsolete electronic commodities from the United States and Europe to Asian and African nations every year, resulting in massive transfers of highly toxic and deadly waste from the relatively wealthy to the relatively poor.

The following evidence and analysis contributes to these accounts by explaining how ecological modernization may result in ecologically unequal exchange between core and periphery in another way as well: many "green" technologies developed and commercialized in core nations are derived from raw materials that originate in the global South. The extraction of these resources causes deforestation, contaminates local ecosystems, and displaces people from their land. This paper also seeks to contribute to the world-systems literature by considering the violence and human rights violations that may be unintended outcomes of processes of ecological modernization.

While ecological modernization theory emphasizes the role of markets in advancing and increasing the availability of "green" technology, world-systems analysts take for granted that markets are created and maintained by the real or threatened violent action of states (Wallerstein 2005). Marx (1994 [1867]), for example, pointed out that many of the first labor markets in the formative days of capitalism were created when peasants were violently dispossessed of their land. Markets for raw materials, too, can hardly be thought of as "free" when states employ violence to create and protect access. Recent scholarship has examined how state violence contributed to ecologically unequal exchange in earlier eras, as colonial powers, through their capacity for violence, transferred great amounts of natural wealth from the periphery to the core while leaving tremendous environmental damage in their wake (Foster 1994; Moore 2003; Foster and Clark 2009). Jorgenson and Clark (2009a) demonstrate that military power, or states' ability

[1] We acknowledge, however, that the desire to avoid higher production costs associated with stronger environmental laws is not the only reason corporations shift production to the periphery. Such shifts may result in other cost savings that are important to corporations, for instance savings in terms of labor costs.

to exert sustained violent force, is still strongly associated with a nation's ability to consume the natural resources of other lands. The United States' recent war in Iraq is one particular case in point (Foster 2004; Klare 2004).

In this paper we contribute to these accounts, but do not limit ourselves to the violence of core nations. States in the periphery and semi-periphery may undertake a number of strategies to promote domestic capital accumulation, including the use of violence and repression (Evans 1979). By violating citizens' basic civil and political rights, repressive states attempt to lure foreign investment by creating or sustaining a "good business climate" for multinational corporations (Shandra 2007). Semi-peripheral and peripheral states may have powerful motivation to do so. For example, such states may be highly indebted and so experience a strong need to attract foreign investment; their government might depend on resource extraction for revenue due to the legacy of colonial underdevelopment; state officials may stand to personally gain from resource extraction; and due to the legacy of colonialism, these states are more likely than core nations to be in conflict with rebel groups over the control of valuable resources. Such violence and repression may take many forms. For instance, states in the periphery and semi-periphery may (1) censor public speech to prevent awareness of environmental degradation and to otherwise inhibit the development of protest movements; (2) suppress environmental protests with violent force; and (3) dispossess persons from their homes and farmlands through force or the threat of force.

Such policies have profound environmental consequences, as they can dramatically increase rates of natural resource extraction accomplished by multinational corporations, along with the corresponding amount of environmental degradation it causes (Shandra 2007). By so doing, peripheral and semi-peripheral state violence and repression contributes to ecologically unequal exchange between nations in the world-system (Downey et al. 2010). Core nations, after all, have developed their material economies, infrastructures, and military power by accessing the natural resource wealth from the periphery. State violence in the periphery ensures that this natural resource wealth can continue to be transferred in high enough quantities and at low enough costs to contribute to capital accumulation and state power in the core (Downey et al. 2010). So, even while processes of ecological modernization may potentially contribute to some increased environmental well-being in the core, state violence associated with resource extraction for "green" technologies means that such extraction will be undertaken in ways that create profound environmental and social disruptions in the periphery. In the remainder of this paper we demonstrate the importance of attention in research and theory-building to inequality, violence, and resource extraction in the production of "green" technologies in the world-system through three case studies from the automotive sector.

## Method

We attempt to provide a holistic understanding of the environmental and human consequences of the widespread adoption of "green" technologies in the automobile industry by presenting three case studies of the ecological modernization of the automobile: catalytic converters, biofuels, and hybrid technologies.[2] We constructed these cases by determining the natural resource origins of these technologies, or, in other words, by determining what raw materials constitute these

[2] The particular natural resources of interest include platinum group metals (catalytic converters); palm oil (biofuels); and copper, nickel, rare earth minerals, and lithium (hybrid technologies).

technologies and where they are extracted. We then conducted LexisNexis searches to understand the environmental consequences of this natural resource extraction and to determine whether or not states utilize violence to facilitate it.

We looked for potential violence associated with natural resource extraction on multiple levels, including direct military or police action against anti-mine protestors or rebels; mine security provided by military, police, or mercenary forces; state violations of widely upheld human rights, like the right to speak about mine pollution; and the forced removal of local residents to make way for an extractive development. Though the last two categories are not as obviously violent as the other categories, we argue they should both be considered instances of violence because they are intentional acts of deprivation committed by the state that are backed by threatened or real force.

We instructed LexisNexis to search in major world newspapers printed in or translated to English, and used search phrases such as "copper & Indonesia & violence," "biofuel & deforestation," and "South Africa & protest & platinum." We supplemented the archival searches with internet research as needed, using websites from environmental nongovernmental organizations such as "Mines and Communities" (www.minesandcommunities.org) and "Mining Watch" (www.miningwatch.ca).

The research strategy we employed likely under-represents the environmental degradation resulting from extraction/production of the natural resources in question and the extent to which violence is used to facilitate it. First, it is likely that much of this environmental degradation and many acts of violence associated with the extraction of the resources in question escape the attention of the world's largest newspapers printed in English—and even the attention of anti-mining activists in Canada, the U.S. and the U.K.—due to language barriers and the remote location of many mines. Moreover, many of the major producers of the natural resources in question are countries (such as Indonesia, the Democratic Republic of the Congo, and Russia) in which the press and anti-mining activists enjoy limited freedom, making it less likely that environmental degradation and violent actions associated with natural resource extraction/production in these countries would show up in our search. With this caveat in mind, we turn to the case studies.

## Environmental and Social Consequences of the Ecological Modernization of the Automobile

Our examination of the environmental and social consequences of ecological modernization begins with the catalytic converter. American auto-manufacturers began installing catalytic converters on their fleets in the 1970s in response to increasingly protective environmental laws (McCarthy 2007). Consistent with the expectations of ecological modernization theory and its optimism regarding "green" technology, the environmental benefits in the U.S. were significant. Catalytic converters installed in automotive exhaust systems have reduced the amount of hydrocarbons, carbon-monoxide, and nitrogen-oxide (a smog-forming pollutant) each car emits by up to 90% compared to 1970 levels (McCarthy 2007). Altogether, the widespread

implementation of the catalytic converter is "the single biggest step ever taken to reduce the automobile's environmental impact" [3] (McCarthy 2007: xvii).

Catalytic converters in the exhaust system of automobiles trigger chemical reactions that transform toxic or harmful emissions into more benign compounds. They are effective because of the remarkable chemical properties of a group of minerals called "platinum group metals" (or pgms), which include platinum, palladium, and rhodium (National Research Council 2008). Platinum and palladium are essential components for the reduction of hydrocarbon and carbon monoxide emissions, and rhodium has no other commercially viable mineral substitute for the reduction of nitrogen oxide emissions (National Research Council 2008).

The vast majority of pgms used in catalytic converters is extracted from mines in South Africa and Russia (National Research Council 2008). While the widespread implementation of catalytic converters has been extremely beneficial to American and European citizens whose societies are structured around automobile transportation, as well as anywhere else catalytic converters are required, an examination of pgm extraction in South African and Russia demonstrates that it has not benefited all people equally.

In both South Africa and Russia, the environmental consequences of platinum mining have been severe for local people. In the Limpopo region of South Africa, the construction of platinum mines displaced local people from their farms and grazing land, destroying their self-sufficiency by eliminating their access to land over which they claimed historic ownership (Curtis 2008). The platinum mines have also contaminated rivers and wells used by locals for drinking water (Curtis 2008; Mathews 2008).

In Russia, the extraction of platinum group metals is also enormously destructive to the environment. The majority of the world's palladium, along with a great deal of the world's nickel, is produced by Norilsk Nickel near the city of Norilsk, which is located in Siberia above the Arctic Circle. Norilsk is considered one of the most polluted places in the world (Walsh 2007) and the single largest source of acid-rain pollution (BBC 2007a). An estimated 1.9 million tons of sulfur dioxide, a toxic pollutant, pour out of Norilsk's smelters every year as a result of its pgm and nickel smelting, more than that produced by the entire nation of France (Kramer 2007). Moreover, four million tons of heavy metals—which are chemically toxic to humans—are released into the air each year. Perhaps not surprisingly, it is reported that Norilsk is surround by an 18-30 mile "dead zone" where trees can no longer survive (BBC 2007a; Walsh 2007). So much heavy metal has been released into the air by Norilsk Nickel in the sixty years it has mined and processed pgms and nickel that entrepreneurs are now mining soot deposited from the smelters to collect valuable, but also chemically toxic, heavy metals (Kramer 2007).

Platinum group mining is also strongly associated with violence and the deprivation of people's human rights in South Africa and Russia. In order to obtain platinum to install catalytic converters on their 1975 fleet, General Motors and Ford looked to South Africa, where thousands of miners were hired to work in apartheid conditions to meet the new demand (McCarthy 2007). Perhaps of greater consequence, South Africa's apartheid government was provided with an important new source of revenue that soon rivaled gold (Feinstein 2005).

More recently the South African state has forced the relocation of 1000 households at Mothotlo Village in order to make way for the multinational mining corporation Anglo

[3] It should be made clear, however, that while the addition of catalytic converters successfully relieved important sources of smog-forming pollution, it did nothing to address greenhouse gas emissions and other environmental problems associated with car-dependent societies.

American[4] to create a new mine (Mathews 2008). When some townspeople in Mothotlo refused to leave their homes, they were tear-gassed and forced from the area by armed police (Mathews 2008). When villagers protested their treatment, many were beaten and arrested (Curtis 2007). South African police have violently suppressed other protests over platinum mining expansion, in some instances shooting protesters with live and rubber bullets (Curtis 2007).

In Russia, the social costs associated with platinum group mining are also high. Norilsk's mines and one of its smelters were first built by forced labor in the Soviet Gulag[5] (BBC 2007a). The continued operations of the Norilsk mines and smelters are strongly associated with human rights violations committed by the Russian state by limiting freedom of speech and freedom to information. The Russian state manages the Norilsk region as a "closed" area, where journalists need to obtain state permission to report there (Walsh 2007). Moreover, the Russian state has denied researchers access to conduct long-term studies on the health effects of so much pollution on the local population (Kramer 2007).

The above case illustrates that, while the widespread implementation of catalytic converters into cars and trucks resulted in significant environmental improvements in the United States and other nations where they are required, these benefits are not shared equally by all people. Mining platinum group metals in South Africa and Russia has meant severe environmental damage for the people there. Furthermore, the South African and Russian states utilized violence and infringed on persons' human rights in order to facilitate the mining. Taken together, the case of catalytic converters indicates that environmental improvements brought about by new technologies are not universally beneficial, but may disproportionately benefit people in core nations at the expense of people in more peripheral zones.

### *Biofuels*

Biofuels—alternative fuels from organic sources such as corn, sugar, palm oil, soy, or even seaweed—were once widely heralded as a technical innovation that would dramatically reduce greenhouse gas emissions from automobiles, while simultaneously eliminating U.S. and European dependence on foreign oil (Krupp and Horn 2009). As such, they were "green" technologies heralded as a means of eliminating many of the adverse environmental impacts of oil-dependence in wealthy nations consistent with the expectations of ecological modernization theory. Nevertheless, today much of their appeal has faded. Notable studies, for instance, produced evidence that biofuels made from corn, soy beans, switch grass, or other crops may actually increase carbon in the atmosphere due to the increased conversion of forests, savanna, peat lands, and shrub lands—which tend to store carbon—into plantations and farms (Fargione et al. 2008; Searchinger et al. 2008; UNEP 2009). In addition, the U.N. Food Program and humanitarian organizations have criticized biofuel subsidies in wealthy nations, arguing that they provide incentives for farmers to produce crops for fuel instead of food, thereby raising food prices and contributing to hunger in the Global South (Rosenthal 2008b; FAO 2011).

In tropical countries, biofuel production creates essentially the same kinds of outcomes as any other form of monocrop agricultural development oriented to external markets, including deforestation and dispossession (Dauvergne and Neville 2010; White and Dasgupta 2010). Specifically, biofuels derived from palm oil plants for markets in Europe have increased environmental degradation and the likelihood of violence. Investigators working on behalf of the

[4] This operation is being conducted by Anglo American's subsidiary, "Anglo Platinum."
[5] This, however, was before the wide-spread adoption of catalytic converters in the U.S.

government of the Netherlands, for instance, determined that the nation's heavy importation of biofuels from palm oil was contributing to massive deforestation in Malaysia and Indonesia (Rosenthal 2007). In Indonesia alone, 9.4 million acres of rainforest have been cleared and planted with palm oil since 1996, which is an area larger than New Hampshire and Connecticut combined (Knudson 2009). Indigenous communities and small-scale farmers are also being displaced by palm oil plantation developments. For example, the United Nations estimated that 5 million indigenous people may be displaced by palm oil development in Indonesia alone (BBCb 2007).

Both the Indonesian and Malaysian governments have facilitated deforestation and displacement. In Indonesia, villages were bulldozed with no advance notice, at times under the supervision and protection of soldiers (Green 2007; Knudeson 2009). State officials participated in the eviction by threatening those who refused to leave with arrest (Knudeson 2009), in some instances beating and even killing those who resisted (Green 2007).

In Malaysia, the Penan indigenous communities continue to lose the forests in which they live due to new palm oil plantations. The Malaysian state has facilitated the expansion of palm oil plantations through "bait and switch" techniques, granting approval for new or expanded plantations on traditional Penan land while promising the Penan new "biosphere reserves" of untouched forest elsewhere. However, due to rampant illegal and unpermitted logging and plantation conversion, these "preserves" often have already been—or soon will be—decimated as well (FOEI 2008).

The case of biofuels, made from palm oil in particular, cautions against purely technical solutions to environmental problems. The case indicates that, in a highly unequal but highly interdependent world economy, technical solutions like the production and adoption of biofuels may unintentionally displace environmental harm to others, degrading whole landscapes while displacing people—through violence or the threat of violence—from the ecosystems upon which they depend. The widespread adoption and utilization of hybrid cars in wealthier nations poses a similar threat to citizens of poorer nations with extractive-dependent economies.

### *Hybrid Cars*

Hybrid vehicles, which utilize both electric motors and internal combustion engines, accounted for almost 3% of 2010 U.S. auto sales (Mouawad 2010). A hybrid vehicle is able to achieve remarkably improved efficiency compared to conventional automobiles because it primarily uses its electric motor in stop-and-go city traffic, recharging its battery(s) each time the brakes are applied (McCarthy 2007). The widespread adoption of hybrid vehicles, if replacing conventional automobiles, could result in environmental gains for wealthy car-dependent nations by reducing air pollution that kills thousands every year and that contributes to global climate change. For instance, the Toyota Prius, which is the most popular hybrid on the American market, emits ninety percent less smog-forming emissions and up to fifty percent less green house gas emissions compared to the emissions of the average American automobile[6] (Union of Concerned Scientists 2009). Because the replacement of conventional automobiles with hybrid vehicles could result in meaningful environmental savings for wealthy nations, such technologies seem to be quintessential "green" technologies anticipated by ecological modernization theory.

[6] While the widespread adoption of hybrid cars could result in very real environmental benefits, this is provided that it does not simply result in more vehicles on the road and more total miles driven, as the Jevons Paradox would predict.

A full accounting of the costs associated with the widespread production of hybrid vehicles must acknowledge, however, that it would require large quantities of specific mineral resources that may increase rates of environmental destruction and military violence experienced by individuals living near existing or future mines. Specifically, the electrical wiring, rechargeable battery system, and electric motor of hybrid vehicles would utilize twenty-six pounds (twelve kilograms) more copper than conventional vehicles, along with significantly more nickel (National Research Council 2008). Copper and nickel mining has resulted in substantial environmental degradation in the global South and many governments in nations producing these minerals have proven willing to utilize violence to facilitate the minerals' extraction. It is impossible to say to what extent these environmental and social costs would increase with the mass adoption of hybrid vehicles, but any complete analysis of their potential impact must at least acknowledge them and attempt to take them into account.

Copper mines are some of the biggest and most environmentally destructive mines on the planet. The Grasberg mine in West Papua, Indonesia, which produces a substantial amount of gold each year and is also one of the world's largest copper mines and reserves, is a case in point. The mine, owned by the giant multinationals Freeport-McMoRan and Rio Tinto[7], has caused tremendous environmental destruction, producing hundreds of thousands of tons of mine waste a day[8] (Perlez 2006). The total mine waste covers 90 square miles (Perlez 2006). The mine waste is carried away by rivers into wetlands and estuaries, which at one time were some of the most productive fisheries in the world. This pollution causes massive fish die-offs, and few-if-any fish live in the polluted waterways today (Perlez 2005). The mine waste will remain dangerous for decades to come because of acid leaching (Perlez 2005).

West Papuans have long argued that they have received little benefit from the mine while nevertheless bearing the brunt of its environmental destruction, and have protested and rioted in response (Perlez 2006a, 2006b, 2006c). Freeport-McMoRan and the Indonesian government have worked hand in hand to protect the Grasberg mine and suppress an independence movement that may threaten production. The Indonesian military has violently put down student riots and taken student anti-mine/pro-independence leaders into custody (Perlez 2006a). The military also polices and protects the mine itself (Perlez 2006b) and has been accused of rapes, extrajudicial killings, and other human rights abuses to suppress the resistance of communities living near the mine (Perlez and Bonner 2005). Finally, the Indonesian state works to keep West Papua off limits to foreigners, including journalists (Perlez and Bonner 2005).

The corporate owners of the Grasberg mine have been accused of "purchasing" these services from the Indonesian military. For example, Freeport gave at least $20 million in direct payments to the military and police to protect the mine, though others believe the actual number is much higher, in addition to spending another $35 million on military infrastructure, including barracks, headquarters, roads, and vehicles (Perlez and Bonner 2005). Freeport and the Indonesian military have also worked together to spy on environmentalists working to address impacts of the Grasberg mine (Perlez and Bonner 2005).

In Peru, which holds some of the world's most extensive copper reserves (USGS 2010), the government utilized violence and the threat of violence to expropriate land to make way for

[7] Freeport-McMoRan is a corporation based in the United States, while Rio Tinto has headquarters in both the United Kingdom and Australia.

[8] To give some sense of this, the total amount of copper produced throughout the world according to the USGS in 2006 was 1.7 million tons, which means that the Grasberg mine alone produces more mining waste in just a few days than all the copper produced (and used) by the world in a year.

the Tintaya copper mine, paying only an average of three U.S. dollars per acre to local farmers and beating and forcibly removing individuals who refused to leave their land (Oxfam 2009a; 2009b). Police have since used violence to protect the mine, now owned by BHP Billiton, from protesters demanding fair compensation for the land expropriation and the environmental destruction caused by the mine (Herald Sun 2005). In response to protests at Tintaya and other mines across Peru in 2005, then president Toledo signed a law criminalizing the disruption of mining activities, which included a six year prison sentence for blocking roads to or from a mine (Radio Mundo Real 2005).

Similarly, in the mineral-rich Democratic Republic of the Congo (DRC), the state and the Anvil Mining Corporation utilized violence to protect copper resources. When several young men in 2004 staged a bloodless uprising in the city of Kilwa, arguing for the need to direct the wealth generated by the nearby Anvil copper mine to local people, Anvil flew approximately 150 DRC troops to the region (United Nations 2005). The company also provided the troops with vehicles, drivers, food, and payments (United Nations 2005). Troops used the vehicles to drive to Kilwa, which they recaptured without loss. Troops then conducted house to house searches, arresting townspeople, beating them, and in some cases torturing and killing them. Up to 100 persons were massacred in the aftermath and many more were injured. Anvil's vehicles were further used to transfer captives, haul corpses, and transport loot taken from residents' homes (United Nations 2005).

In yet another example, the Ecuadoran state has also utilized violence to suppress indigenous and environmental protests of a new law designed to spur large-scale copper and gold mining. The state has forcibly removed anti-mine road blockades; used teargas to put down anti-mine protests; broken up press conferences given by indigenous groups; and arrested, imprisoned, and beaten protest leaders—in one case killing a prominent anti-mine activist (Denvir 2009a; Moore 2009). The Ecuadoran state also attempted to criminalize "Accion Ecologica," Ecuador's leading environmental organization, by withdrawing its legal status (Denvir 2009b).

As previously noted, today's hybrid vehicles also require greater quantities of nickel (for their rechargeable nickel-metal-hydride battery systems) than conventional automobiles (National Research Council 2008). Nickel mining and smelting produces severe and extensive environmental degradation. It is also associated with a great deal of state violence and repression in a number of producing countries. The Norilsk area, described earlier, is the single largest producer of the world's nickel (BBCa 2007) and is a case in point. Nickel mining in Indonesia, which is the third-highest producing nation (USGS 2009), provides further evidence. The mining multinational Vale S.A.[9] produces 90% of Indonesia's nickel and is responsible for large-scale degradation of forest and agricultural land (Sangaji 2000). Vale S.A. mines nickel on land the Indonesian state expropriated from small-scale farmers, including the Karonsi'e Dongi indigenous people (Mining Watch 2005).

Mining in New Caledonia, a South Pacific Island claimed by France that possesses the second greatest nickel reserves in the world (USGS 2009), also degrades the environment and has resulted in state violence and human rights violations. The indigenous Kanack, native to New Caledonia, have heavily contested Vale S.A.'s nickel project on the island, hoping to protect fresh drinking water and the island's fisheries (Mining Watch 2005). French military police have violently broken indigenous blockades of the mine, at one point firing live ammunition at protesters (Mining Watch 2005). Elsewhere on New Caledonia, the mining company Xstrata plans to extract nickel by constructing one of the largest open-pit mines in the world (Mining

[9] Much of Vale S.A.'s nickel extraction is conducted by its wholly-owned subsidiary "Vale Inco."

Watch 2008). It also intends to dredge a coastal barrier reef in order to develop a port to ship minerals from the mine (Mining Watch 2008).

Guatemalans have also experienced environmental degradation and suffered state violence in association with nickel mining. The Guatemalan state expropriated land for nickel extraction from indigenous Q'eqchi' people in the 1960s and 1970s, imprisoning and assassinating community leaders who resisted (Mining Watch 2007). Today, the Guatemalan state continues to protect this land through military force from Q'eqchi' people's attempts to peacefully reoccupy their ancestral home and stave off the development of another nickel mine (Mining Watch 2007).

It is important to note that we are not claiming that the violence associated with copper mining in Indonesia and Ecuador, and with nickel mining in Indonesia, New Caledonia, and Guatemala, is necessarily connected with hybrid vehicle production. However, because hybrid vehicles currently use much larger quantities of these minerals compared to conventional vehicles, the large-scale replacement of conventional autos with hybrids will increase demand and likely exacerbate the environmental destruction and violence associated with copper and nickel mining. The large-scale production of hybrids may increase demand for other minerals as well, raising similar concerns. For instance, hybrid cars currently utilize an estimated 20 kilograms (44 pounds) of rare earth minerals for the rechargeable battery pack alone, far more than that used in conventional vehicles (National Research Council 2008). Rare earth minerals are mined almost exclusively in Inner Mongolia and Southeastern China. Inner Mongolia is a mineral-rich area colonized by China, where pastoral Mongolians have long been targeted by government repression (Sneath 2000) and, more recently, have been forcibly moved from their land and resettled (York 2008). In Southeastern China, rare earth mines are "some of most environmentally damaging in the country," producing toxic and radioactive waste that contaminates water and soils, destroying rice and aquiculture production (Bradsher 2009).

Furthermore, hybrid vehicle manufacturers may increasingly use lithium-ion batteries, which are lighter-weight and have greater energy-storage capacities compared to nickel-cadmium batteries. But here too increased demand might mean increased environmental degradation and state violence, given that some of the world's largest lithium reserves are found in Chinese-occupied Tibet[10] (Ladurantaye 2008). Colonized people rarely passively accept the extraction of wealth from land they claim as their historic right, nor do they often passively accept the environmental degradation that accompanies it (Geddicks 1992; Klare 2002). The presence of large amounts of lithium in Tibet then, combined with the Chinese state's willingness to utilize violence to extract mineral resources, means that the widespread commercialization of hybrid vehicles may pose increased hardships for the people of that region.

Taken together, these cases suggest that increasing demand for hybrid cars and, as a result, increasing demand for certain minerals critical to their production will result in the displacement of environmental harm across nations from the core to the periphery. If hybrid vehicles largely replaced conventional vehicles in car-dependent wealthy nations, these nations may produce less air pollution and greenhouse gas emissions. It is no simple accounting practice to determine if these gains outweigh the increased environmental degradation and human rights abuses people living near copper, nickel, lithium, and rare earth mineral deposits would likely

[10] The world's largest lithium deposits are found in Bolivia's high deserts, which may prove a boon to that nation's socialist programs (Romero 2009), or, conversely, may provide further incentives for the United States to intervene in that region in various ways. Also of note, the U.S. has recently identified major lithium reserves in Afghanistan (Risen 2010).

face. The case of hybrid vehicle technology underscores the importance of placing inequality and aspects of uneven development at the center of any analysis of the possible benefits and harms of the widespread adoption of "green" technologies in the world-system.

## Conclusion

In all of these cases, we demonstrate that the extraction of natural resources used in "green" technologies in core nations is often accompanied by severe environmental degradation in the periphery or semi-periphery. In some instances, as in the case of extraction for platinum group metals in South Africa, this environmental degradation is local. In other instances, as with the extraction of pgm and nickel in Russia or the creation of palm oil plantations in Malaysia or Indonesia, the environmental destruction is extremely widespread. We further establish that much of the extraction of natural resources used in "green" automobile technologies is associated with state violence and abuses of human rights. In some of these instances, the violation of human rights is in the form of restrictions on travel and free speech, as in Russia. In other instances, the violation of human rights is much more severe—involving direct violence, dispossession, and sometimes death—as in Indonesia, South Africa, Malaysia, and the Democratic Republic of the Congo. While documenting associations between the extraction of natural resources that may be used for "green" technologies in the core and human rights violations and environmental degradation in peripheral regions of the world does not prove causation, it does provide a useful theoretical exercise that contributes to understandings of ecologically unequal exchange within the world-systems perspective, while also adding to existing critiques of ecological modernization theory.

The extraction of critical raw materials for "green" technologies and their transfer from the relatively poor to the relatively wealthy constitutes a variety of ecologically uneqal exchange. Because core nations have a privileged position in the world-system due to the strength of their economies, their military power, and the functioning of international financial institutions and trade agreements, they are able to utilize peripheral and semi-peripheral regions as sources for raw materials and as pollution "sinks." The structure and operation of the world-system means, therefore, that processes of ecological modernization in the core, which might result in real domestic environmental improvements as in the case of catalytic converters, can displace environmental harm onto the people of less economically and politically powerful regions of the world.

The evidence presented in this article adds to a growing body of work that shows that state and corporate violence in the periphery contributes to ecologically unequal exchange, resulting in transfers of natural resource wealth to the core without a full payment for their value and cost of extraction (Shandra 2007; Downey et al. 2010). In order to prevent or overcome opposition to mining or other types of resource extraction, states may impede people's right to free expression, may criminalize or forcibly put down protests, or remove people from their land through force or threat of force. Significantly, the association between violence and natural resource extraction for materials used in "green" technologies in the periphery means that members of impacted communities have a diminished capacity to protect themselves and their environment in the face of ongoing extractive projects, or to pressure corporations to initiate more ecologically judicious extraction techniques in the future. This means that state violence to facilitate natural resource extraction in the periphery will likely result in continued or increasing

environmental degradation in those regions of the world, even when these resources are used for "green" technologies in the core.

These analyses raise important questions for ecological modernization theory. Other social scientists have disputed the idea that efficiencies created by new technologies can significantly improve capitalist societies' relation with the environment. While new technologies may result in increased efficiencies, the "pace of eco-efficiency" is likely not enough to compensate for the ever-increasing resource use and waste production of a society structured around the unlimited accumulation of capital (York and Rosa 2003). Quite the contrary, increases in efficiency can actually mean increased resource use by making raw materials less expensive and therefore more widely available (Clark and Foster 2001). This paper adds to these critiques by establishing that whatever benefits may accrue from advancements in eco-efficient technology, they are far from universal. Rather, in a world torn by deep inequalities, the widespread commercialization of "green" technologies has the potential to create new, more serious, or at least different environmental and humanitarian problems for less wealthy and less powerful groups of individuals across the globe.

In addition to raising the empirical question about relative costs and benefits from advancements in "green" technologies for people in the core, periphery, and semi-periphery, this paper challenges the very conceptualization of technology in ecological modernization theory. Ecological modernization theory tends to conceptualize technological development as the end result of rational-scientific imperatives. Technology is, according to ecological modernization's treatment, neutral and beyond the influence of social relations. However, there is a long-standing tradition of research that consistently demonstrates the profoundly social nature of technological development (Wajcam 1991, 1994; Hornborg 2001; Gould 2008). Those with disproportionately more power in a society, according to this literature, have a greater capacity to develop technologies that best serve their interests at the expense of other people and at the cost of other potential technologies that may better serve other groups' needs.

The cases presented in this paper demonstrate that "green" automotive technologies are far from neutral. They are commodities that imply particular social relations both between people and between people and the natural world. Like all commodities, the "green" technologies examined here are comprised of specific minerals, the extraction of which benefits some while often subjecting others to environmental degradation and state violence. Unlike other commodities, however, "green" technologies are often upheld as a solution to the ongoing ecological crisis of capitalism.

While we do not doubt the technical genius of humanity, nor that improved and more efficient technologies can play a part in addressing the ecological crisis, we maintain that technical fixes alone cannot solve environmental problems. Inequality—between both people and nations—matters a great deal. Technical "solutions" by themselves, in a highly unequal world, may solve very little for the world's poor. More likely, such "solutions" will further degrade their environments while exposing already marginalized groups to increased levels of violence and military force—all while presenting a new justification to maintain the status quo.

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