Renewables, Micropower, and the Transforming Electricity Landscape

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At RMI, we've been asking ourselves how the world will get its electricity—now the source of over two-fifths of fossil carbon emissions and the recipient of most of the world's investments in energy systems. Over the next 50 years, nearly all currently operating power plants will retire, so the future may be utterly different than the past or present—and our latest data strongly suggest it will.

Every day, utilities and emerging competitors are planning and building the assets they'll be using in 2050. Tracking those choices reveals the rapidly shifting contours of the future power system—and what investors think it makes economic sense to build now.

Since the 1970s, we've taken a special interest in the smaller, cheaper, faster, cleaner, and more secure electric generators that the Economist calls "micropower": all renewable sources except big hydro dams, plus cogenerating electricity together with useful heat in factories or buildings.

Cogeneration, also called "combined heat and power," (see "Fossil-Fueled Cogeneration" sidebar) typically saves upwards of half the cost, fuel, and emissions of making them separately.

In 2002, we published "Small is Profitable," an Economist book of the year that remains the definitive work on micropower's hidden economic benefits. In 2005, we began posting and updating the only detailed public database of global progress in deploying micropower.

Now our latest update confirms micropower's remarkable acceleration in taking over the global market long dominated by central thermal stations—coal- or gas-fired, nuclear, and big hydro. This dramatic shift augurs well for the world's clean and secure electricity future.

Our May 2010 update includes data through 2008 or 2009 (depending on availability), and transparently recalculates cogeneration capacity and output from the primary data sources. (See the very latest micropower data, updated in September 2010.)

All data sources (see "Micropower Data" sidebar) and assumptions are documented. The data are subject to inevitable uncertainties, but are based in general on bottom-up equipment counts provided by industry, and cross-checked where possible against government output metrics. The totals are probably conservative, because the cogeneration capacity and output shown are known to be significantly undercounted. We will continue to update the database as new information arrives.

The emerging micropower revolution is making new electricity less carbon-intensive, faster to deploy, often cheaper. New power plants are increasingly being chosen by entrepreneurs and investors rather than by central planners, driving a shift toward smaller and cleaner plants with better economics. Faster construction reduces financial risks. Shorter decision cycles better capture rapid technological evolution and falling costs. All these trends heighten competitive pressure on big, slow, lumpy projects whose greater financial risks are clearly deterring investors.

The changing electricity landscape depends on plant construction, retirement, and operations. The latter is important for nuclear power, which during 1990–2006 increased its global capacity by 44 GW (13.5 percent) but its output by 757 TWh/y (40 percent), due to the combined effects of new construction (36 percent), uprating (7 percent), and improved capacity factors through better operation (57 percent). Meanwhile, though, micropower pulled ahead of nuclear power, outproducing it in 2008 by 25.8 percent and in 2009 by 34.1 percent.

The Rise of Renewables

A common argument against renewable power is that it can't possibly

Fossil-Fueled Cogeneration

Combined heat and power (CHP) is sometimes fueled by biomass, like black liquor and hog fuel in pulp-and-paper plants or sawdust and scraps in furniture factories, but it's primarily fossil-fueled. So why would RMI, whose focus is to speed the U.S. transition away from fossil fuels to efficiency and renewables, be excited about the market adoption of smaller fossil-fuel-fired generators? The answer is cogeneration's radical efficiency. Traditional power plants convert one-third of their fuel into electricity and two-thirds into waste heat. Cogeneration uses both. Often industrial heat made to run a manufacturing process can also make electricity, even from leftover high-temperature heat that is being expensively disposed of, but without using any more fossil fuel. Or small generators in buildings can heat or cool them with heat left over from making electricity.

Such methods typically save at least half—often two-thirds or more—of the fuel, emissions, and cost of making electricity and heat separately, Moreover, most cogeneration is gas-fueled; gas is often more efficiently burnable than coal and emits only half of coal's carbon per unit of contained energy. Thus the International Energy Agency reckons that accelerating CHP could save 10 percent of global CO2 by 2030. The most efficient CHP systems can exceed 90 percent efficiency from fuel to useful work. Replacing, say, America's 920 oldest coal plants with modern combined-cycle gas plants, then using most of the other 40 percent for district heating, would cut their CO2 emissions by more than three-fourths, save money, and help nearby city-dwellers' pollution-assaulted lungs. The gas-fired cogen system would still be fossil-fueled, but a great improvement, surpassed only by—and competing with—superinsulated, superefficient buildings and renewable electricity.

be economically competitive with large central thermal power plants, because, after all, renewables (except big hydro dams) provide only 2 percent of world electricity, versus coal's 41 percent and nuclear power's 13 percent. If renewables were competitive, we're told, they'd produce a greater share of world electricity. But these shares reflect the technologies, costs, cost distortions (chiefly large subsidies to fossil and nuclear plants), and institutional preferences and barriers of decades ago.

Micropower Data

Tracking micropower's progress requires a considerable effort to combine many disparate data sources. One other independent organization—an important global network of renewable energy experts—annually updates its database on renewables.

Until 2006, the World Alliance for Distributed Energy published an annual assessment of cogeneration plus small-scale wind and solar generation. We are unaware of another organization that compiles and publishes both cogeneration and renewables as RMI does. We suspect that, following a 2008 G8 communiqué directing countries to "...adopt instruments and measures to significantly increase the share of combined heat and power in the generation of electricity" and the establishment of a special CHP working group at the International Energy Agency (IEA), better international cogeneration data will become available.

In the U.S., the Energy Information Administration already began tracking industrial and commercial cogeneration in 2008, although an IEA report shows nearly twice as much installed capacity.

Some central-station-oriented organizations, chiefly in the nuclear industry, reject our data out of hand because their databases don't show much if any micropower. That's because they're consulting databases confined to utility-owned or large units or both, and often excluding the newer kinds of renewables.

Looking at the wrong database can be a bet-your-company mistake.

To see the great wave of change starting to sweep the global electricity market, we need to look at different technologies' market share of new electricity generation, reflecting investors' and buyers' choices under today's very different conditions.

Coal makes nearly half of U.S. electricity (45 percent in 2009 when natural-gas prices were low), but the median U.S. coal-fired power plant is 41 years old when weighted by unit, or 30 when weighted by capacity.

So what's being bought today, not decades ago? Not coal.

In 2009, wind and other renewables accounted for 42.2 percent of all new U.S. generating capacity, while gas accounted for 43.3 percent and coal for only 12.6 percent. The U.S. installed 10 GW of windpower in 2009 alone—nearly twice the 6 GW of coal added during the entire decade of 2000–2009.

Coal still dominates installed capacity due to decades-old decisions (because of long lead times, even the coal plants now entering service reflect decade-old decisions), but coal's U.S. and E.U. market share is now dwindling because investors are instead choosing to build renewables and natural gas power. Europe in 2009 closed more nuclear and coal capacity than it added. Even China halved its net additions of coal capacity during 2006–2009, reduced the coal-fired share of its total electricity production by one and a half percentage points in 2009, and is planning only about five-eighths of its 2010 net additions of electrical capacity to come from coal (nearly all the rest is renewable).

Early 2010 data suggest this trend will accelerate. According to New Energy Finance, a leading energy industry information provider that tracks the world's individual clean-energy transactions, the world invested $27.3 billion in renewable energy during the first quarter of 2010, up 31 percent from the same period in 2009.

Smaller Is Better

Part of the reason investors are favoring renewables over big central thermal power plants is that renewables entail much less financial risk and are quickly built and started up. Most coal plants are being cancelled or postponed, while renewable capacity is burgeoning—and much of the 2013 renewable capacity additions are so quick to build that they won't even be announced until 2011–2012.

At the end of 2009, 270 GW of proposed U.S. wind capacity (not all firmly planned) was stuck in the queue awaiting interconnection to the grid, often resisted by recalcitrant coal-fired utilities that dislike competition. That's enough windpower to displace nearly half of U.S. coal-fired electricity, at half the cost of power generated by a new coal plant. And in Texas, the top windpower state, 17 percent of potential 2009 wind generation from already-installed turbines was curtailed, often by lack of available transmission capacity.

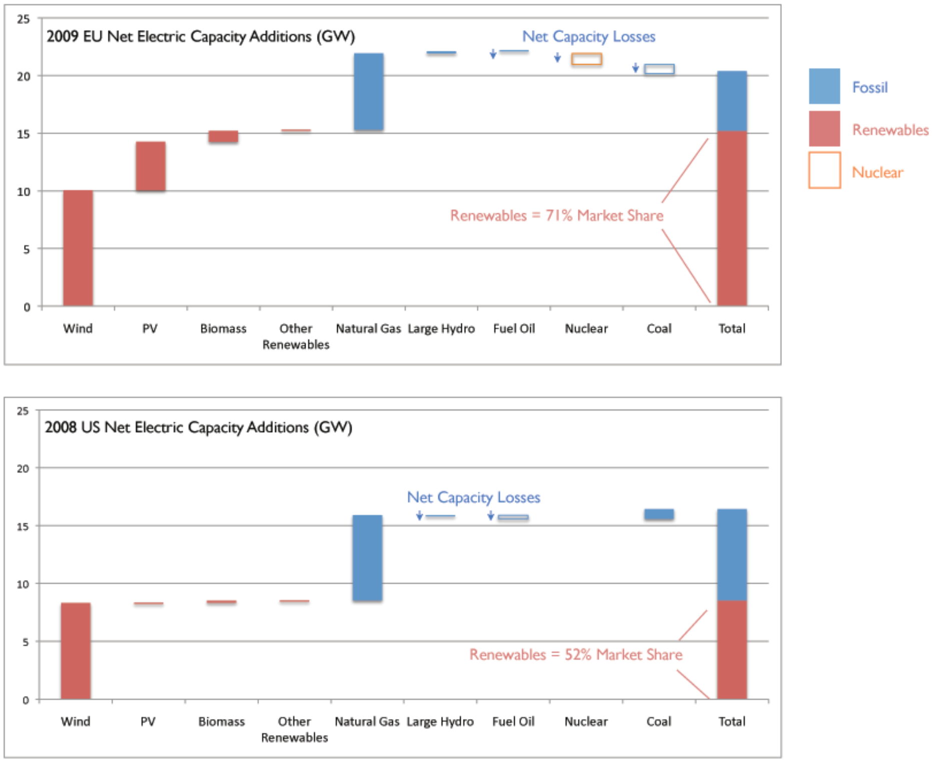
Renewables are gaining market share even faster in Europe (see below), accounting for 71 percent of new electric capacity added in 2009. Of the 31 percent from natural gas, too, a significant fraction was decentralized cogeneration.

Micropower = Renewables + Cogeneration (Except Big Hydro)

But the "fuel story"—the transition from fossil fuels to renewables—is only one of the shifts transforming the electricity landscape. Equally important is the "scale story"—the transition from large to small scale, and away from giant central thermal plants to micropower.

Micropower is typically modular, quickly deployable, and financially lower-risk than large central thermal plants. It may have a lot of capacity clustered together, like a windfarm with 100-plus turbines totaling hundreds of megawatts, but its economies come chiefly from mass production of modular units (such as individual wind turbines or solar panels) rather than from the gargantuan size of single units.

Figure 1



Different energy sources' share of net electricity capacity additions in the EU and US. An unknown ratio of the natural gas capacity additions are CHP, so micropower's share of these capacity additions is even greater than renewables'.

In 2008, micropower produced about 17 percent of the world's total electricity, 3 percentage points more than its share in 2002. Nuclear power's share meanwhile fell by slightly more, and according to International Atomic Energy Agency data, probably fell to around 13 percent in 2008 and even lower in 2009 (Fig. 1). We do not yet know exactly how much electricity the world generated in 2009, so we can't yet confirm micropower's 2009 share of that total, but it probably exceeded 2008's share.

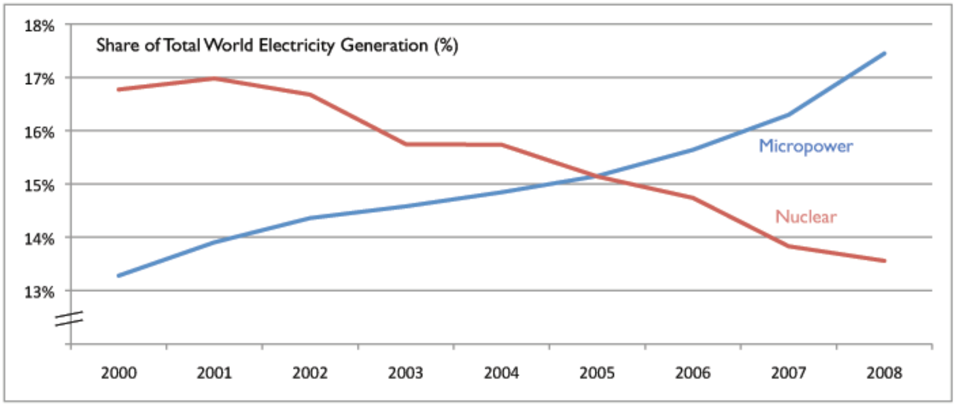
Even more impressively, micropower's share of the world's new electricity, hovering around one-fourth or more since 2002, appears to have soared to 91 percent from 2007 to 2008 as additional generation fell by 63 percent in the global recession (Fig. 2). This figure is fuzzy because the denominator is the difference between two big numbers, and different sources' statistical series differ. If we used the IAEA's instead of British Petroleum's denominator for 2007 and 2008, micropower's share of new generation would be only 64 percent, but its share of total generation wouldn't change. (The two organizations' generation totals match exactly for 2008 but not for 2007.)

The 2009 data, which RMI will post when available, may also show a high micropower share of new generation because most renewables resisted the recession better than central plants did. However, resumption of recession-suppressed growth in electricity demand could somewhat reduce micropower's share of new generation added in the next few years. For example, its 2008 added generation was 36.5 percent of the total average annual increases during 2005–2007. But that's still impressive, and compares with nuclear power's share of less than 1 percent.

Micropower's Recent Impressive Achievements

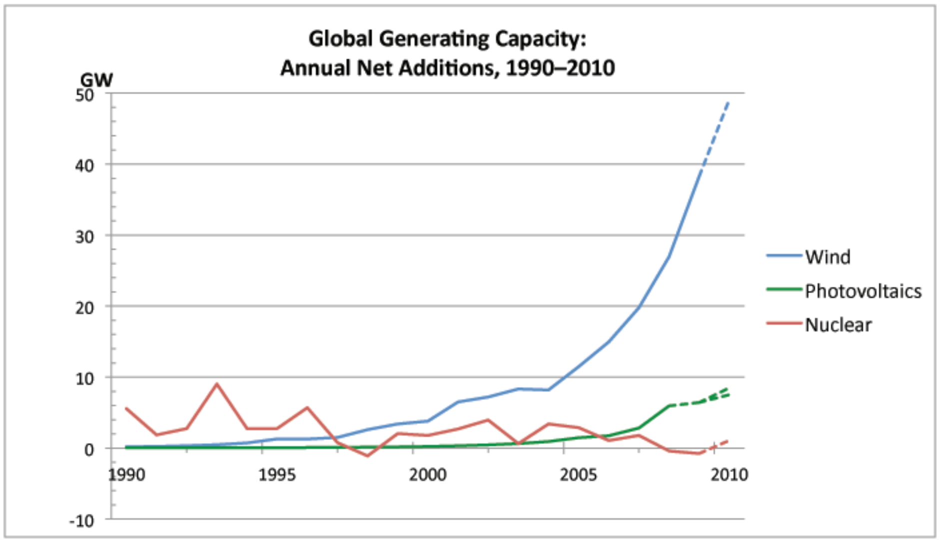
- In 2006, micropower produced 16 percent to 52 percent of all electricity in a dozen industrial countries—not including the U.S. (~9 percent), whose rules favor incumbents and their giant plants. Nuclear power worldwide added 1.44 GW (one big reactor's worth) of net capacity—more than all of it from uprating old units, since retirements exceeded additions. But photovoltaics added even more capacity; windpower, ten times more; micropower, 30 to 41 times more. Micropower plus efficiency probably provided over half the world's new electrical services. In China, the world's most ambitious nuclear program achieved one-seventh the installed capacity (7 GW) and one-seventh the growth rate of China's distributed renewables (49 GW).
- In 2007, the U.S., Spain, and China each added more wind capacity than the world added nuclear capacity, and the U.S. added more wind capacity than it added coal-fired capacity during 2003–2007, inclusive. China beat its 2010 windpower target.
- In 2008, China doubled its windpower for the third year in a row. Windpower pulled ahead of gas-fired capacity additions for the first year in the U.S. and the second year in the EU; in both, renewables added more capacity than nonrenewables. That plus ~$40 billion for big hydro dams brought renewable power production, for the first time in about a century, more investment than the ~$110 billion invested in all fossil-fueled power stations.
- In 2009, the U.S. added another 10 and China another 13 GW of windpower.
- In spring 2010, China should beat its 2020 windpower target, and around the end of 2010, renewables (excluding big hydro) should surpass nuclear power in total capacity, overtaking it in output some 4–5 years later.
- Developing countries in 2008 had 43 percent of renewables' global capacity (excluding big hydro), heading for the majority. A major Asian shift to renewables could shrink global coal use, because 97 percent of incremental coal demand is in Asia: China and India use nearly half of world coal and had 75 percent of world coal-fired capacity under 2008 construction. This shift is starting to emerge: China's net rate of adding coal plants fell by half during 2006-2009 China also shut down 62 GW of inefficient old coal plants during 2005–2009, plans to close 31 GW more by 2011, and ap-

Figure 2



The share of total world electricity generation from nuclear power and micropower since 2000.

Figure 3



Comparison of recent annual additions of generating capacity by three key sources—nuclear, wind, and photovoltaics. The difference between capacity and output reflects different technologies' different "capacity factors" (see box #3)—the fraction of their theoretical full-time, full-power output that they actually produce.

pears to be cooling its overheated nuclear ambitions while accelerating efficiency and renewables. The new 2020 wind-and-PV target is reportedly ~120 GW, and a Tsinghua/Harvard team found in 2009 that China can cost-effectively and practically provide twice as much windpower as its total current electricity use.

The Bottom Line

Central thermal power plants—nuclear or fossil-fueled—are rapidly losing share in the global marketplace, and fierce competition is increasing their already daunting financial risks.

New power generation is moving physically closer to customers, avoiding new transmission lines and potentially making power supply more reliable. In the U.S., for example, approximately 98 to 99 percent of power failures originate in the grid, and onsite generation bypasses this cause of outages.

New ways to diversify, forecast and integrate variable renewables (windpower and photovoltaics) into the grid can let them achieve very high supply fractions without needing bulk electricity storage.

In all, the shift of both source and scale is revolutionizing the electricity business—the world's most capital-intensive and critical infrastructure sector—before our eyes.

Figure 4

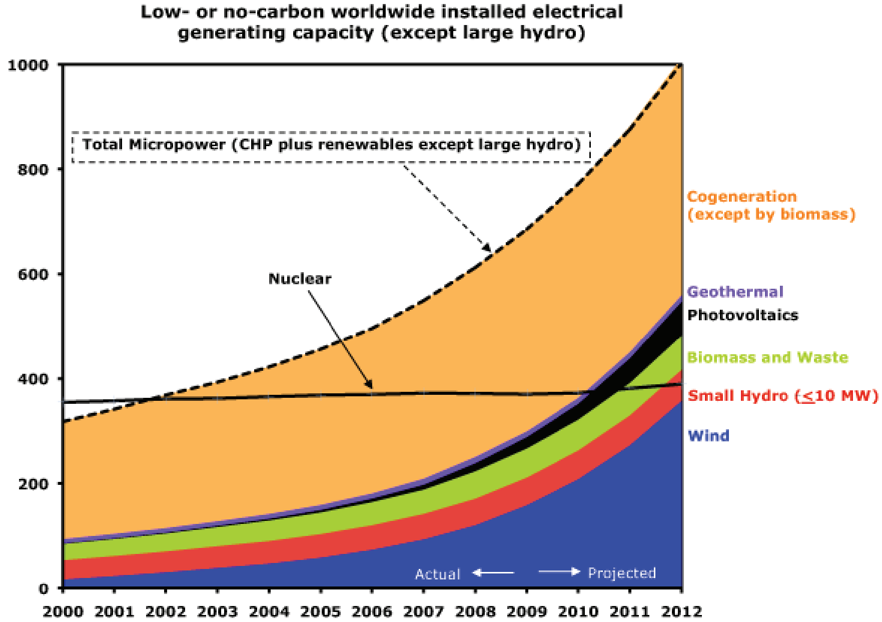
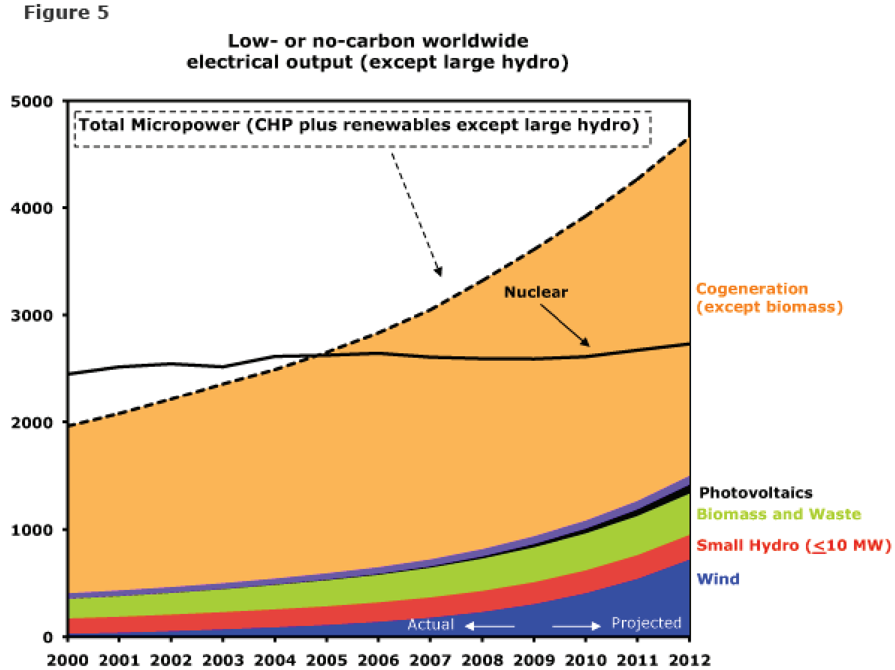


Figure 5



Global micropower's growing generating capacity (Fig. 4, above) and electricity generated (Fig. 5, below), compared with nuclear power's.