CLIMATE CHANGE AND COMPETITION – ON A COLLISION COURSE?

Technology Development and Deployment in a Competitive Electric Industry

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INTRODUCTION

Any international agreement restricting greenhouse gas emissions from the electric sectors of Annex 1 countries will require substantial technological shifts in how we produce and use electrical energy. The KYOTO PROTOCOL identifies a collective reduction of 5% from 1990 emission levels for these industrialized countries by 2012. Discussions regarding what disparate electric industries must actually do to achieve their collective targets have barely begun. Liberalization in the electric sector, with its dispersed private ownership of electric sector assets, raises serious questions of not only what steps need to be taken, but who will take them. How to coordinate changes in regulations which promote both industry-wide competition and substantial long-term environmental improvements have generally been absent from the current restructuring debate. Given current industry trends regarding the pace of R&D investment in basic research, the development of new technologies and their rapid deployment, when asked the question "What happens when climate change meets competition?" the answer is "climate loses."

Recent analysis of the New England USA and Swiss electric sectors shows that aggressive pursuit of energy conservation and renewables will be required just to prevent greenhouse gas (GHG) emissions from rising precipitously. Competitive market structures–with their accompanying disaggregated and dispersed technological decision-making– are indicative of the challenges energy and environmental regulators will face in promoting an environmentally responsible and balanced energy market with finite fiscal resources. This paper reviews the regulatory and technological challenges of achieving real, long-term reductions in carbon dioxide (CO_2) emissions in the electric sector. Building upon the lessons of two case studies of the New England and Swiss electric industries, factors associated with energy infrastructure turnover, as well as new technology development, deployment and utilization will be addressed, with particular attention paid to policies which promote highly integrated and coordinated technological strategies and cost-effective, reductions in CO_2 emissions.

ACHIEVING SUSTAINED GREENHOUSE GAS REDUCTIONS WILL BE DIFFICULT

To see how difficult it will be for mature industrialized nations to achieve sustained reductions in CO_2 and other greenhouse gases we look at a total of fourteen alternative resource strategies for New England and Switzerland. Table One shows the energy mixes used to generate electricity in recent years for the two regions. Two years are shown for New England, as the current disposition of the region's nuclear generation has shifted the generation mix, due to both nuclear safety and competition-related factors. New England is atypical with respect to the United States as a whole, with a very heterogeneous mix of generation. On average, and particularly in many areas of the Midwest and Southeast, the United States is a coal dominated electric industry. Switzerland, on the other hand, has very little fossil generation, although there is a some fossil generated electricity embedded within the imported power. While this means both regions have lower overall GHG emissions burdens, it also indicates that natural gas-for-coal fuel and technology switching will be a less applicable CO_2 reduction option for these industries. In electric generation, the Swiss system is roughly two-thirds the size of the New England system, but tends to be more energy-limited in its generation mix, while New England is more capacity constrained.

The eight New England and six Swiss resource strategies add additional end-use efficiency improvements and renewable generation to a long-term strategy where natural gas combined-cycle generation is the baseload technology of choice. In the New England case, the reference strategy continues current utility-sponsored demand-side management (DSM) programs, resulting in a growth in electricity demand of about 1.3%/year. This level of DSM is then doubled, tripled and quadrupled in later years. To each of these four strategies, 1400 MWs of wind generation is phased in over ten years of the twenty year study period, resulting in eight total strategies.

Table One: Electricity Generation by Fuel/Technology Source – New England and Swiss Electric Sectors

Generation Source	*New England* 1994	*New England* 1996	*Switzerland* 1994
Conv. Hydro:	5.2	6.6	47.4
Nuclear:	36.5	26.3	30.9
Coal:	15.2	16.5	
Oil & Nat.Gas:	28.9	29.4	0.9
Other:	5.3	5.3	0.5
Imported Power:	8.8	15.8	20.2
	(Percent of Annual GWh)		
Annual GWh:	112,821	115,304	72,743

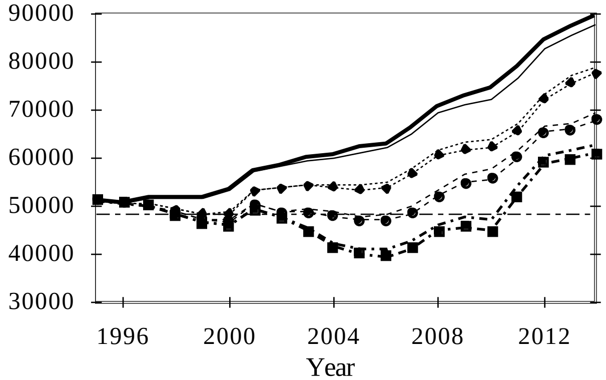

Figure One: Prospective New England Electric Sector CO_2 Emissions (Thousand Tonnes) **for Eight Strategies with Aggressive Increases in End-Use Efficiency and Renewable Generation (Wind)**

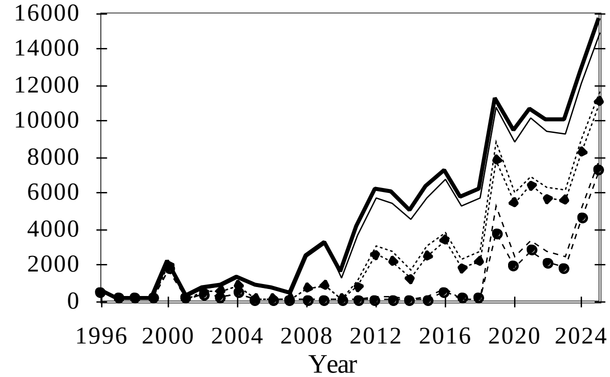

Figure Two: Prospective Swiss Electric Sector CO_2 Emissions (Thousand Tonnes) **for Six Strategies with Aggressive Increases in End-Use Efficiency and Renewable Generation (Biomass)**

The six Swiss strategies follow a similar construct. Two additional levels of end-use efficiency, phased in 15% and 30% reductions, are superimposed upon the 1.5%/year electricity demand trajectory. To these three thirty year simulations are added 275 MWs of short rotation forestry biomass generation, yielding six total strategies. While these simulations do not imply that such aggressive levels of end-use efficiency and renewable generation could feasibly be implemented in the times described, they are within the ranges of technical potential (number of buildings, overall renewable resource) estimates conducted by electric utilities in the regions. (For the purposes of this paper, DSM is synonymous with end-use efficiency improvements.)

Figures One and Two show the CO_2 emissions trajectories resulting from the fourteen simulations. The KYOTO PROTOCOL's emissions reductions targets for the United States and Switzerland are 7% and 8% respectively. In Figure One, the four pairs of trajectories show the reductions achieved from aggressive end-use efficiency improvements, with the lower line in each pair having the windpower in addition to DSM. As can be seen the triple and quadruple DSM strategies are able to reduce industry-wide CO_2 emissions to or below the 1990 emissions baseline (indicated by the horizontal line). However, after these two DSM initiatives are "phased out" in 2007 and 2010, CO_2 emissions again begin to rise. By 2014, the top-most "business as usual" reference strategy has CO_2 emissions 80% greater than 1990 levels, even though these strategies do not reflect the early retirement of nuclear units in New England. By the end of the study period the lower-most quadruple DSM and wind strategy is 25% over 1990 levels.[1]

Figure Two shows the CO_2 trajectories for the six Swiss strategies. Note that the CO_2 emissions range on Figure Two is roughly one quarter that of Figure One's and begins at zero instead of 30,000 thousand tonnes. Since the Swiss electric sector has such low initial CO_2 emissions, percent increase comparisons are uninformative. However, it can be seen that CO_2 emissions do increase markedly, and do not decrease even for the aggressive end-use efficiency and renewables strategies. The sawtooth nature of the Swiss trajectories reflects the year-to-year variability in the hydropower resource, but it can be seen–as with the New England simulations–that CO_2 emissions still increase substantially over time.

Closer inspection of the New England CO_2 trajectories in Figure One reveals that there are several acerbating factors which further increase CO_2 emissions beyond the 20-year 1.3%/year growth in electric service demand. In 2001, CO_2 emissions "kick-up" as long-term power contracts for Canadian hydro expire (and are diverted elsewhere). More interesting however is why the more aggressive New England DSM strategies increase their CO_2 emissions post-2011 faster than the less aggressive DSM strategies. The reason for this is shown in Figures Three and Four. These two figures show the annual generation by fuel/technology source for the upper-most reference strategy, and lower-most quadruple DSM and wind strategies in Figure One. Note the loss of Canadian hydro in 2001. However, in the reference strategy, more new natural-gas fired generation is built since load growth is higher. As nuclear generation is retired, new natural-gas makes up the difference further increasing CO_2 emissions. However, in the aggressive DSM strategies, less new natural-gas fired generation is built, due to lower capacity needs. Therefore when nuclear generation is retired, older, lower efficiency, higher carbon content generation is used to fill the gap. CO_2 emissions therefore increase faster. For other emissions, such as nitrogen oxides and sulfur dioxide, emissions can actually become greater than those for the reference strategy.

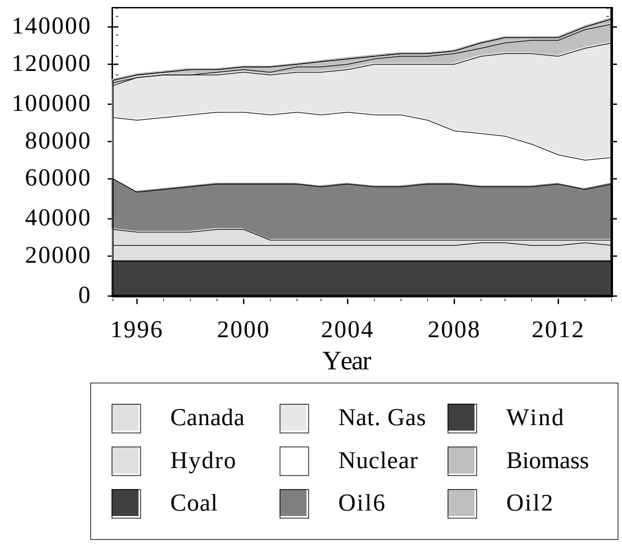

Figure Three: GWh Breakdown of Generation by Fuel/Technology Source for the New England Strategy with Reference End-Use Efficiency Improvements and No Additional Renewables

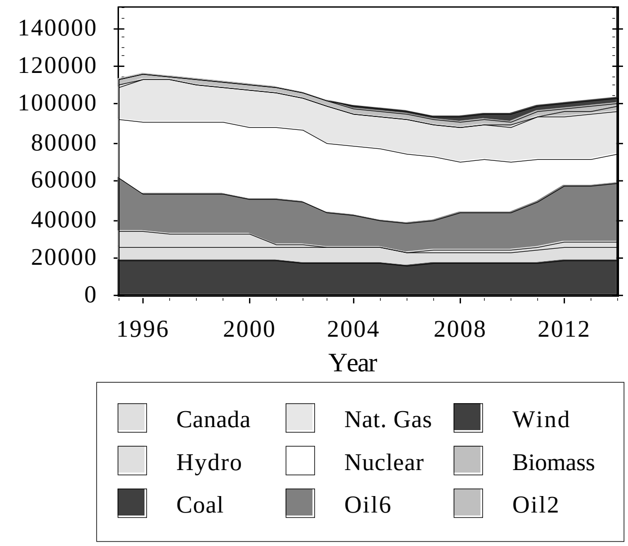

Figure Four: GWh Breakdown of Generation by Fuel/Technology Source for the New England Strategy with Quadruple End-Use Efficiency Improvements and Aggressive Renewables (Wind)

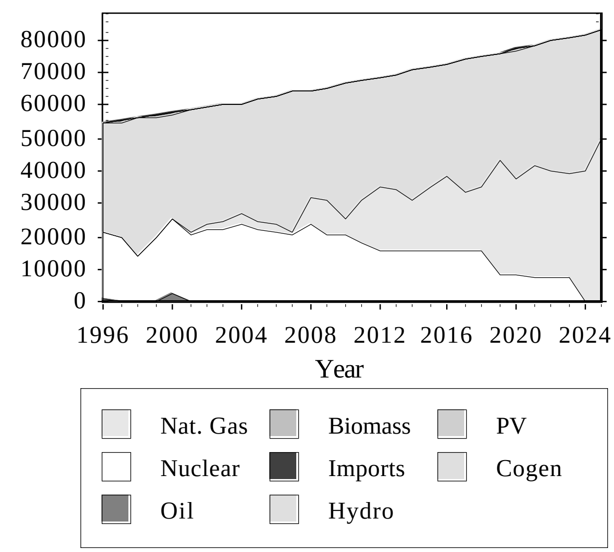

Figure Five: GWh Breakdown of Generation by Fuel/ Technology Source for the Swiss Strategy with Reference End-Use Efficiency Improvements and No Additional Renewables

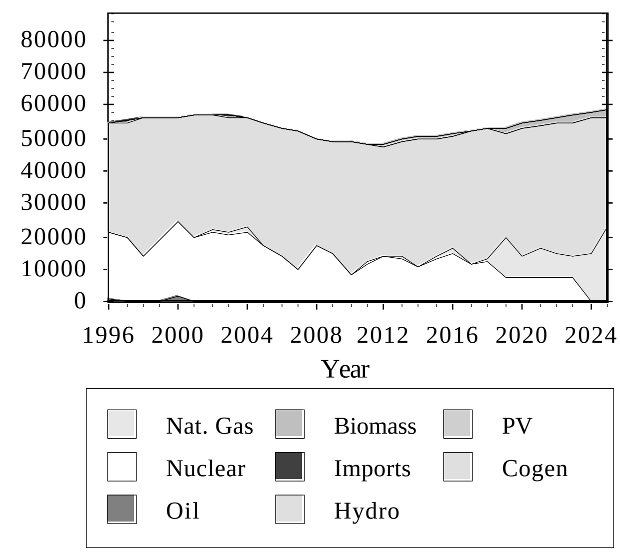

Figure Six: GWh Breakdown of Generation by Fuel/ Technology Source for the Strategy with Aggressive End-Use Efficiency Improvements and Moderate Renewables (Biomass)

Figures Five and Six show the same comparisons for the high and low emissions Swiss strategies. Since new gas-fired generation is the only real fossil generation available, increases in CO_2 emissions are relatively uniform. Not surprisingly, these aggressive DSM and renewables strategies also cost more. With a discount rate of 10% the New England quadruple DSM and wind strategy costs 2.7% more than the reference strategy. In the Swiss case study, the 30% reduction and biomass strategy is 2.5% more expensive than its reference strategy (using a 5% discount rate), aided by the fact that a greater amount of imported power was allowed to cover poor hydro years for the high DSM strategy, which reduced the need to build some natural-gas fired generation.[2]

A NEW FLEET OF TECHNOLOGICAL OPTIONS WILL BE REQUIRED

What lessons can be learned from this collection of aggressive DSM and renewable strategies? There are several. The first is that substantial, long-term reductions in CO_2 emissions will be very difficult to achieve. The quadruple DSM New England strategies do achieve a 15% reduction in 2006, but cannot sustain that level of CO_2 emissions. Second, natural-gas combined-cycle generation can only be considered a CO_2 emissions reduction option if it displaces existing, higher emitting, fossil generation. At best it is a generational transition technology. Third, while some nuclear units will be retired due to overwhelming economic and degradation considerations, the question of whether to relicense, life-extend or repower existing nuclear plants should be taken seriously. Finally, and most importantly, there are not enough cost-effective non-CO_2 options, on both the supply and demand-side, ready for deployment to attain the sustained CO_2 reductions being discussed in international environmental negotiations–independent of whether there is a competitive market to pull them along or not.

There are several other serious considerations that must be taken into account when identifying what it will take–technologically speaking–to achieve significant, sustained reductions of greenhouse gases. There is no single technology, or class of technologies which will provide the desired results. Incremental, year-to-year, efficiency improvements cannot be assumed to continue indefinitely, on either the supply and demand-side. The Autonomous Energy Efficiency Improvement (AEEI) factors used in many econometric models examining the cost of reducing GHG emissions are not well characterized, and in some cases uncapped.[3] There are thermodynamic maxima to the efficiency of combustion-generation cycles. No advanced lighting technology or motor technology will be 100% efficient. For renewables, the sun doesn't shine at night, the wind doesn't blow all day, and infinite annual harvests do not exist for biomass. Technological limits do exist.

There are however opportunities to achieve significant reductions along the electric supply chain. Total building envelope options to radically reduce aggregate energy demand come to mind as the energy saving benefits of retrofit end-use technologies reach their limit. Another potential area focuses on avoiding transmission and distribution losses. On average, 7% of all central station generation is lost in the T&D system, higher for remotely generated electricity. Locating some generation closer to loads, and increasing the efficiency at which T&D systems operate, are areas that need to be explored. Table Two provides an example of the integrated architecture that will likely be required in order to achieve sustained reductions in GHG emissions. Commonly referred to as "the distributed utility," Table Two illustrates the types of technologies than can be deployed at different locations in the grid.

Table Two: Electric Infrastructure Types – and Opportunities for Rapid Introduction of Clean and Cost-Effective Technology

Locational Class	*Example Technologies and Applications*
"Remote"	Extra-Regional Imports. (Hydro, Nuclear, etc.) Remote Wind, Solar.
"Busbar"	Central Station Nuclear. New & Existing Oil/Coal/Gas. Regional Hydro.
The T&D "Interface"	Strategically Placed Gas Turbines. Local Wind, Hydro, Biomass, Geothermal. Hi-Tech T&D. (FACTS, HTS)
at the "Meter"	Ground Source Heat Pumps. Energy Efficient Buildings. Fuel Cells. Micro Turbines. Spot Pricing. District Heat/ Cogen. Roof-mounted PVs. Electric Vehicles. "Golden Carrot" Refridgerators.

For New England, seasonal and locational aspects of renewable generation are important. The best wind resources are is concentrated in rural northern New England, and are strongest during the winter. This both increases the transmission losses associated with delivering the power to load centers, and reduces wind's overall capacity credit, as the region is a summer peaking system. Solar, in contrast, is a summertime, peak load resource, which with appropriately sized building integrated systems also avoids T&D losses. The extension of these time and space considerations to on-site generation, including small-scale cogeneration with fuel cells and microturbines, offers the possibility of matching end-use baseload technologies with peaking renewables, and using the central grid to meet some customers' intermediate loads and backup power needs. This concept can be extended to end-use and operational efficiency improvements as well. Cost-effectiveness relative to retail versus bulk power costs expands the range of possible applications. Operational efficiency improvements incorporate smart metering and load controls which respond to both spot or real-time electricity rates, and real-time electric service needs (for example, occupancy and indoor air quality sensor-driven heating, cooling and comfort management in commercial buildings).

WORLDWIDE OPPORTUNITIES FOR INFRASTRUCTURE ENHANCEMENT NEED TO BE PURSUED

There are two additional lessons that can be learned from the Swiss and New England case studies which are particularly relevant to international debates regarding technology transfer to developing countries, joint implementation, and the "clean development mechanism." First is that sizable increases and decreases in CO_2 emission result from large shifts in the energy supply and consumption infrastructure. Turnover in the building stock, as well as the generating stock, will be needed to achieve emissions reduction targets. In industrialized nations–the Annex 1 countries–infrastructure turnover and growth rates are relatively low, while they are high for many developing nations. A politically feasible, and verifiable approach to conjunctive infrastructure development, between industrialized and emerging economies offers great potential for achieving both cost-effective reductions in GHG emissions, as well as improved qualities of life in developing countries.

Table Three characterizes energy infrastructures into four groups. First are the "industrialized" countries, predominantly the OECD countries, where supply and demand infrastructures are relatively large and mature, with a mix on old and new power plants, buildings, industries, etc., which are growing at a relatively slow rate. Second are the "re-industrializing" nations, the former Soviet Union and Eastern Europe, which are also growing slowly, but have good potential as most of their infrastructure is older and out of date. Third are the rapidly growing emerging economies, China, Brazil, India etc., where they may already have a sizable infrastructure, but because of their rapid growth, it will be a small portion of their total infrastructure within a decade or so. These are where some real opportunities for the deployment of new, low-carbon, energy efficient technologies lie. The fourth group, the slower growing economies of Africa and elsewhere should not be overlooked, but present a smaller aggregate opportunity for technology transfer.

Table Three: Electric Infrastructure Types – and Opportunities for Rapid Introduction of Clean and Cost-Effective Technology

Infrastructure Type	*Growth Rate*	*Existing Infrastructure*	
		Size	*Age*
Industrialized	Slow	Large	Moderate
Re-Industrializing	Slow/Mod.	Large/Med.	Aged/Mod.
Emerging	Rapid	Small/Med.	Mod./New
Less Developed	Slow/Rapid	Small	Aged/Mod.

Technology development aimed at these deployment opportunities should not be overlooked in government and corporate strategies. Working to identify the best "transition paths" for these various regions can help promote "meaningful participation" on a programmatic, not just project level, as well as describe the ultimate markets for new, cleaner, energy technologies.

REGULATORS MUST INSTITUTE POLICIES WHICH PROMOTE TECHNOLOGICAL DEVELOPMENT, DEPLOYMENT, AND UTILIZATION

The functions of regulators in the competitive, global, and environmentally constrained electric sectors of the future are numerous. No only must they transform their respective industries via the institution of fair and balanced competitive rules, but they must do so in a manner which promotes fair competition, operational efficiency and reliable service on a day-to-day, as well as year-to-year basis. The fact that one of the goals of competition is to open the door for improved technologies and practices, dovetails nicely with the need for substantial turnover of the capital stock in order to reduce greenhouse gas emissions. Robust policies, both economic and environmental, which facilitate the development and deployment of distributed utility technologies will be necessary. Signaling companies which develop such technologies will also be key. Regulating transmission and distribution system operators so that they work to reduce their line losses, and allow the introduction and integration of smarter, more efficient generation and end-use technologies throughout the system will also be essential.

How to promote new, greenhouse gas reducing technology developments is a particular challenge. To do so, companies pursuing such developments must know there will be a future market for such technologies. An ultimate "cap and trade" system for limiting GHG emissions would certainly play this role, but the science and politics of the climate change debate are still too uncertain to expect the institution of such a mechanism, at least for several years. But to develop and deploy such technologies in the time frame described by the KYOTO PROTOCOL, things should start happening now. Fortunately, many of the electric restructuring rules being passed at the state and federal level are designed to promote clean technologies.

The first and most important element of restructuring in this regard is retail competition. Expanding competition from generators, all the way down to retail customers provides energy service companies the ability to not only deliver integrated end-use technological solutions, but identify and sell "value-added" products as well. "Green pricing," whereby companies can sell more expensive generation, but from cleaner sources–such as wind and solar, is a major element of having "customer choice." Economic regulators do have to put in place emissions accounting systems, so that "green marketers" can justify their environmental claims, but this coordinates well with the activities of environmental regulators who require such mechanisms as they shift from command and control regulation to market-based systems such as tradable emissions allowances.

To get the ball rolling, and to ensure that some modest level of "green" technology is supported through the transition to a competitive market, many states have called for both "systems benefit charges" and "portfolio standards" to retain and promote end-use efficiency and renewable generation activities. These sustain current DSM and renewable activities, and "prime the technology pump" should more rapid changes be required. Will this be enough to achieve substantial and sustained GHG reductions? Likely not, but is does provide for a rolling start if and when real restrictions on GHG emissions occur.

CONCLUSIONS

Are climate change and competition in electric industries on a collision course? For the time being, yes. And the answer will remain yes without concerted action in the development and deployment of a broad range of infrastructure related electricity supply and end-use technologies. An "electricity as commodity" approach to electric industry restructuring will not promote the types of technological developments necessary to adequately deal with the issue of greenhouse gas reductions. True customer choice, which allows the deployment of sophisticated end-use technologies, the long-term development of an integrated "distributed utility" architecture, and permits value priced "green" electricity portfolios will however begin the technology development and deployment process in line with the needs of a greenhouse gas constrained industry.

The development of such niche applications alone however will not be enough. Flexible, but real limitations on emissions such as nitrogen oxides, sulfur dioxides, particulates, and ultimately CO_2, can signal disaggregated providers of services in a competitive electric industry which way to head, and what technologies to choose. The New England and Swiss case studies presented briefly in this paper indicate that major infrastructure-wide shifts in the way we generate and consume electricity will be required if substantial and sustained reductions in greenhouse gases are to be achieved. Attention to the persistence of existing infrastructure elements, coal-fired generation, nuclear, and inefficient building stocks, for example, must be included in the design process. Policies that promote infrastructure turnover in how we generate and consume electricity are essential. As many developing nations are seeing rapid growth in their energy provision and consumption infrastructures, greater international cooperation and opportunities for large-scale technology transfer will also play an important role in achieving long-term reductions.

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