ALTERNATIVE ENERGY
&
DISTRIBUTED GENERATION:
Thinking Generations Ahead

Presentation to
Climate Change 2 Conference: Canadian Technology Development

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October, 2001

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INTRODUCTION

Alternative Energy will be discussed in the context of *Distributed Generation*, which is defined as a delivery platform for micro-power generation, close to the end-users, that can also supplement regional electricity grids.

Many references in the paper pertain to Alberta. This is for two reasons: First, familiarity by the author, and more importantly, Alberta is the first region in Canada that has de-regulated it's electricity sector. De-regulation allows independent and smaller power generators to enter the market.

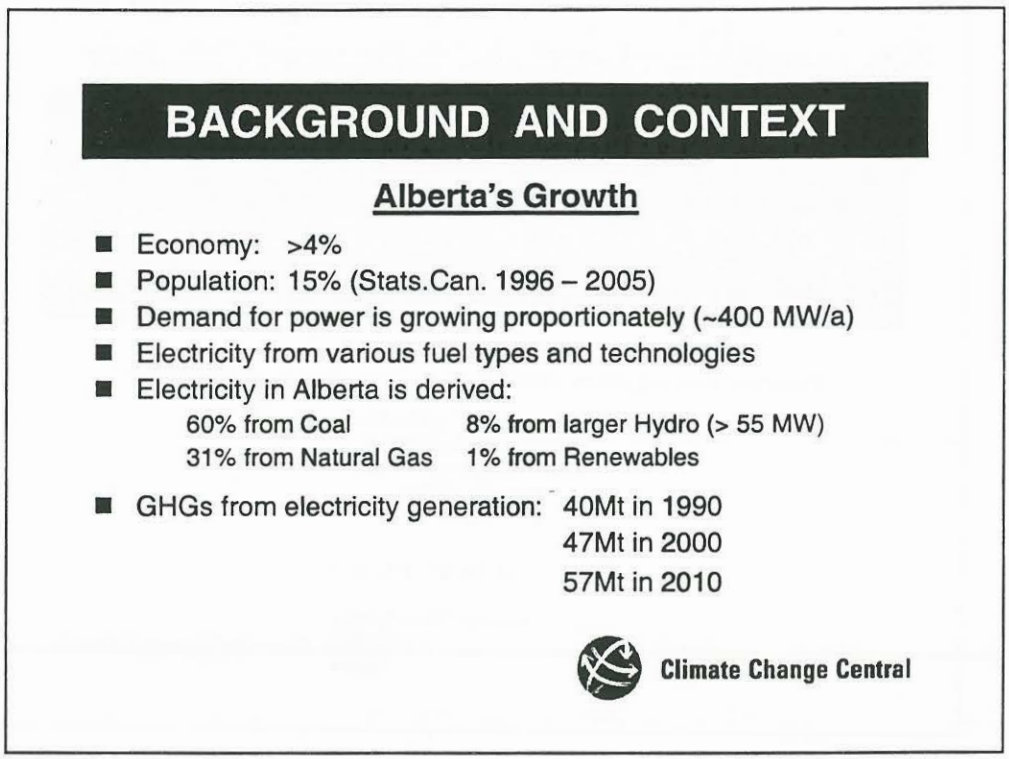
Focussing on Alberta, with some references to other Canadian provinces and USA, electricity consumption trends will be reviewed and the pressures to de-centralize electricity generation discussed.

Re-structuring of the electricity sector, convergence of power generation and natural gas industries, advances in technologies, and environmental concerns are collectively contributing to the creation of a new business called "*Distributed Generation*".

Efficiency benefits of combined heat and power associated with the more prominent emerging distributed generation technologies like micro-turbines and fuel cells, will be highlighted.

Areas of research, development and demonstration that will enable the successful deployment of *Distributed Generation* will be suggested with respect to Generation Technologies, Systems Controls, Supporting Infrastructure, and Socio-Political Barriers. Estimates of investments in the various alternative energy technologies will be presented.

Using current trends and emerging technologies the Paper will conclude with some predictions of future scenarios.



SETTING THE CONTEXT

In Alberta, the economy is growing, as is its population. Consequently the demand for electricity is also growing. To varying degrees, this is occurring in most of the other regions across Canada, as well, with the exception of Newfoundland, New Brunswick and Saskatchewan (Statistics Canada, 2001).

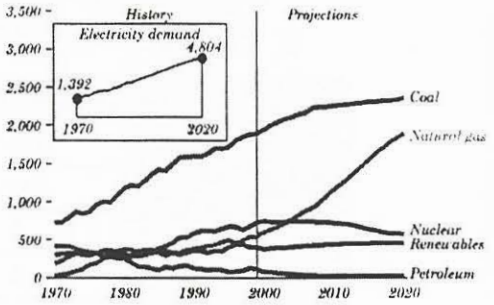
Electricity in Alberta is primarily derived from large coal and natural gas-fired power stations. Greenhouse gases (CO_2) from electricity generation was 40 million tonnes in 1990, and 47 Mt. in 2000. These emissions are forecast to increase to 57 Mt. by 2010 (Pembina Institute, 2001)

BACKGROUND AND CONTEXT

North American Growth

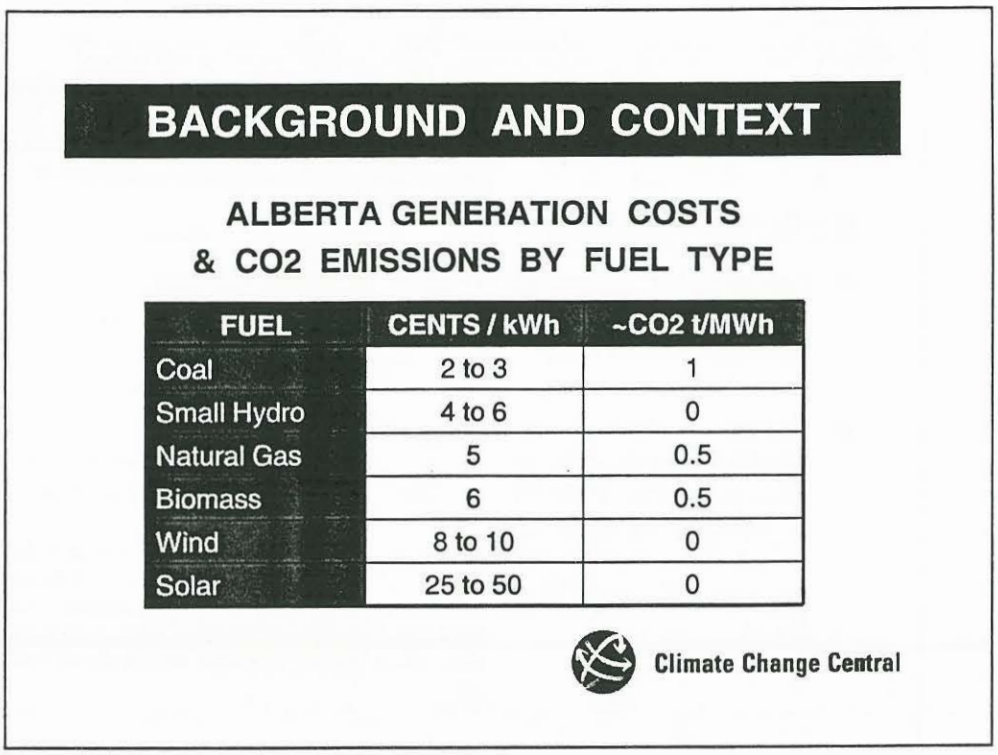
- Demand for power is expected to grow by 1.8% per year to 2020
- Market share for electricity from coal to decline by 7% (from 51 to 44%) at the expense of natural gas which will grow by 20% (from 16 to 36%)

Figure 4. Electricity generation by fuel, 1970-2020 (billion kilowatthours)



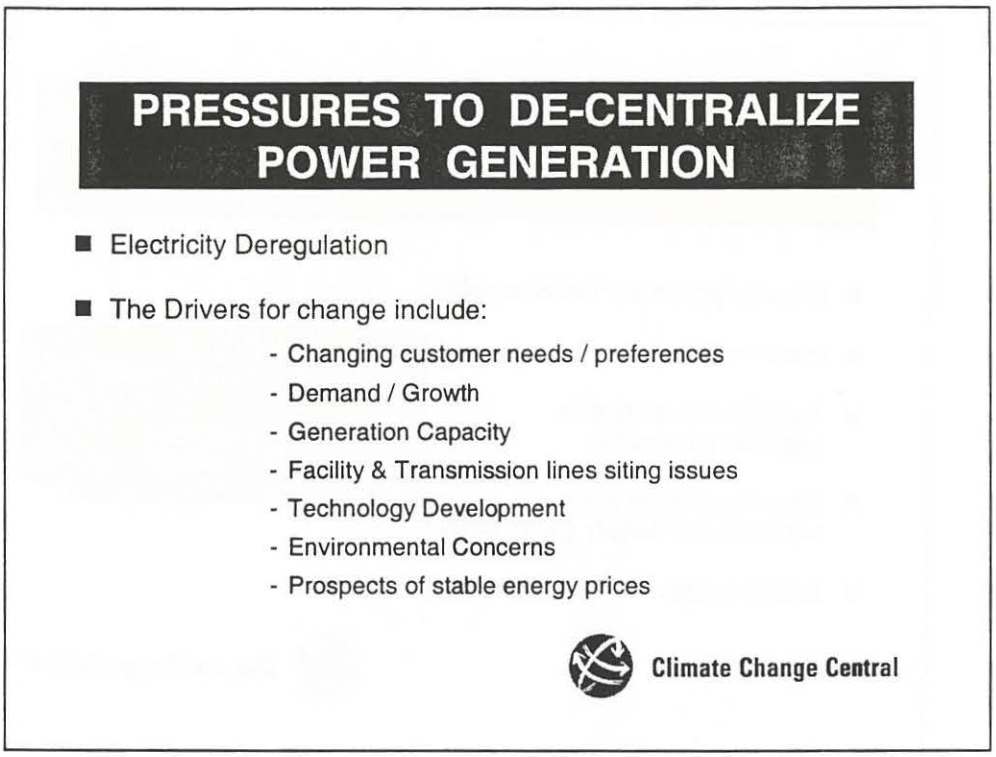
History: Energy Information Administration (EIA), Form EIA-860B, "Annual Electric Generator Report - Nonutility;" EIA, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000); and Edison Electric Institute. **Projections:** Table A8.

In the United States, demand for electricity also growing and the US-Department of Energy predict that the *Market Share* for electricity from coal will decline by 7% at the expense of natural gas which will grow by 20% (US-DOE, 2001).



Developments in technology are gradually lowering the costs of generating electricity from alternative and renewable sources. This, together with the increasing and fluctuating prices of natural gas, are contributing to make small hydro, biomass or primarily wood waste, and wind energy, competitive.

The figure lists the costs per kilowatt hour and CO_2 emissions for the various electricity generation fuels in Alberta (Epcor, *pers. com.*). These values will be approximately the same for other areas of Canada, with the exception of Coal, which is a little more expensive in the Maritimes.



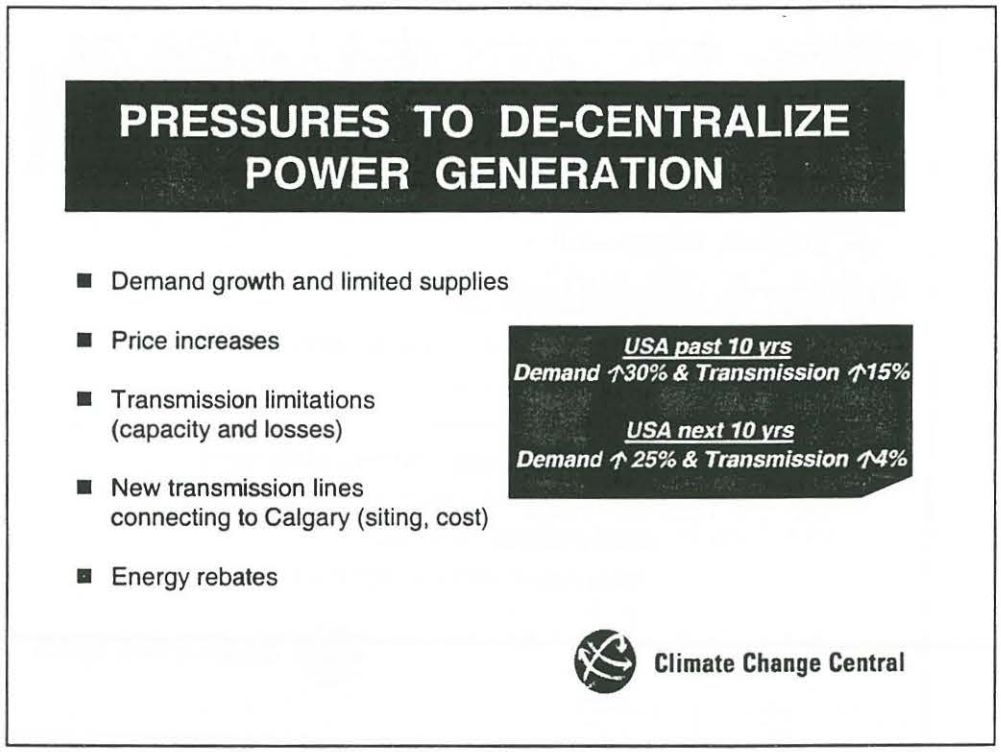
PRESSURES TO DE-CENTRALIZE POWER GENERATION

The de-centralization of power generation is a move away from the traditional system of having a few large centralized plants, to a new arrangement of many local micro-power generation units, close to the end-users, that can also supplement the provincial grid. This is referred to as *Distributed Generation*.

Electricity De-regulation, which occurred in Alberta last January, "opens the door" for Distributed Generation, and from a policy perspective actually enables it. De-regulation is sweeping away the monopoly protections that kept new power producers out of the market, and at the same time is offering consumers greater freedom to generate power themselves (Fairley, 2001). In short, De-regulation frees consumers, unleashes investment and stimulates innovation.

The Drivers for this change include:

- Changing customer needs or preferences with respect to the Quality; Availability; and Reliability, of their electricity, and the Environmental-Soundness associated with its generation;
- Advancements in Technology, particularly in the areas of Micro-Turbines, Fuel Cells, and Renewables; and
- The value in stable energy prices, particularly from a business planning and economic development perspective

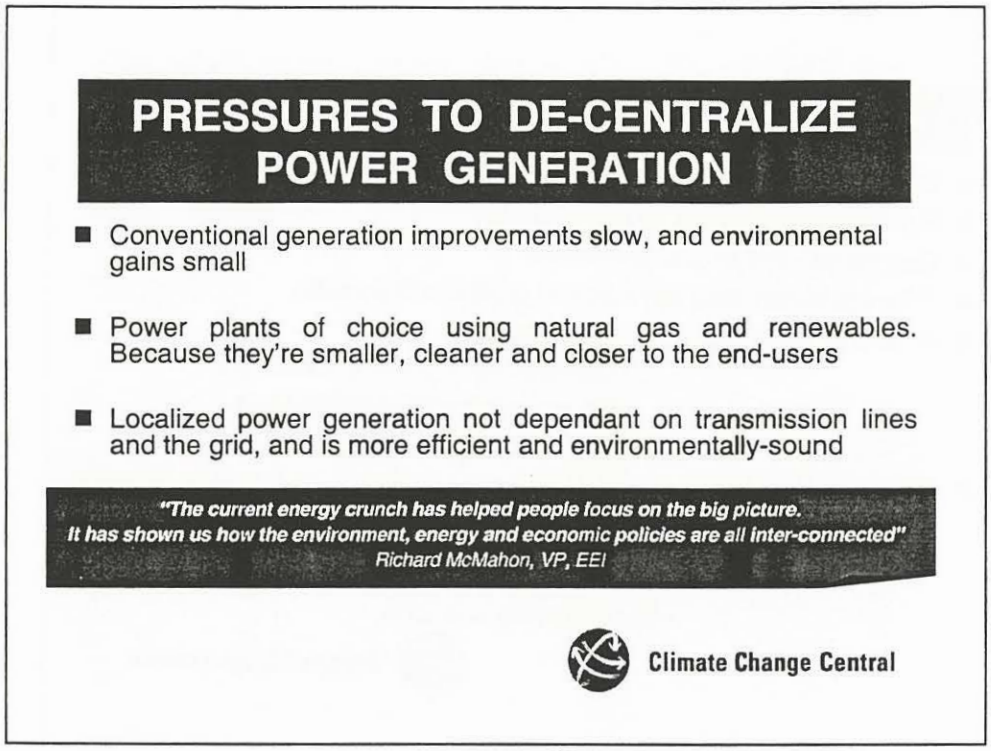


The pressures to De-Centralize in Alberta include:

- The significant increase in power costs due largely to growth in demand, limited supplies and the price of natural gas, which determines the price of electricity;
- Transmission limitations relating to both capacity and line-losses, which are 4.5% for every 100 miles (160 km) of transmission ( ). This means that in sending power from where most of the electricity is generated in Alberta, an area, 70 km west of Edmonton, south to Calgary, the main growth area in the province, about a quarter of it is lost !

  Alberta and other growth centres across Canada share similar problems to the USA, where demand is increasing, but the transmission infrastructure is not keeping pace; and
- Siting problems, construction costs and long lead-times, are associated with building new centralized power plants and new transmission lines.

Energy Rebates have been given to all Albertans, and while this helps ease the financial pain in the short-term, rebates do not address the fundamental causes or offer a long-term sustainable solution.



Additional pressure to de-centralize is the slow and only small improvements that are being made to conventional coal-fired power generation plants. The environmental gains and GHG reductions are correspondingly small.

Increasingly, the power plants of choice, are using natural gas and renewables, and are smaller, nimbler, cleaner and closer to the end-users than the traditional large centralized plants, that people have been used to. This means that in future, less power will be dependant on long transmission lines and the vagaries of the grid. New localized small power generation will be more responsive to the needs of the consumer, and at the same time will be more efficient and environmentally-sound (Anderson, *et al*, 2000).

In developed countries, the stringent need for high-quality and reliable power is being driven by computer-related digital technologies and uses (Meyers and Hu, 2001). In California for example, utilities have not built any new power plants in the past ten years. However, over the same time, individuals and private companies have added 6 GW of non-utility micro-power.

Micro-power in developing countries makes even more sense, where grids are non-existent or if they are, efficiencies are not well maintained. In some developing countries, "technology leap-frogging" will be possible (The Economist, 2000).

DISTRIBUTED GENERATION

- Small-scale power generation close to the end-user
- Not fuel-specific or technology-specific
- Can be off -grid or grid-connected
- Offers potential cost savings and greater efficiencies
- A rational response to:
  - Re-structuring
  - Convergence of power & natural gas
  - Advances in enabling technologies
  - Environmental concerns
- Drivers for DG are:
  - De-regulation
  - Reliability and efficiency
  - Broad market application
  - Technology advancements / lowering costs
  - Low emissions and noise

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So de-centralization leads us to *Distributed Generation*, which supports a mixed fuel strategy, and encourages diversification and a spreading of the risks. *Distributed Generation* is any small-scale power generation system that provides electrical power at a site close to the user.

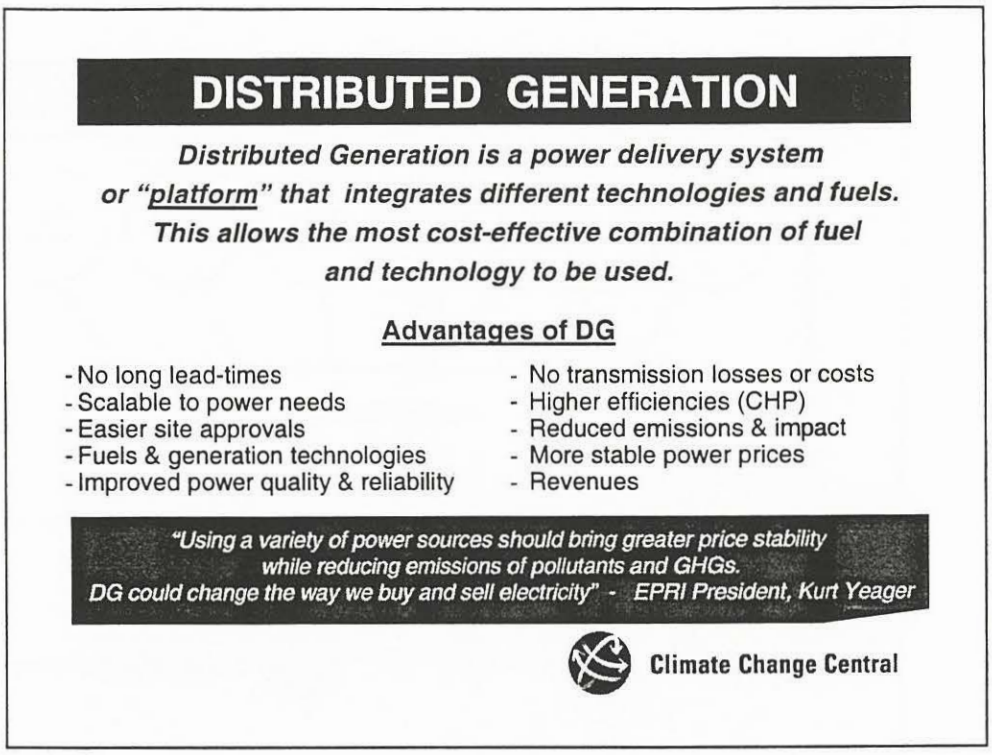
Distributed Generation systems use various fuels & technologies like Fuel Cells, Micro-Turbines, Engine-Generator Sets, Wind Turbines, and Solar. They have relatively small power output ranging from 1 kW to about 10 MWs, and can be operated independently off the grid, or can be grid-connected.

Distributed Generation holds the potential for revolutionary change. Small Gas Engines or Micro-Turbines, Fuel Cells, as well as Renewables, are becoming less expensive and can supply heat as well as electricity to buildings. The consequences of this transition is staggering. Globally, the next two decades will see an estimated investment of $10 trillion (US) worth of energy infrastructure. The market opportunities for *Distributed Generation* energy could reach $200 billion a year. This will result in many new technologies, which will result in "winners" and "losers" (Capital E Report on Distributed Energy, 2001).

Distributed Generation offers potential cost savings over centrally generated electricity purchased from the grid. Micro-power generators can save money by powering-up whenever the grid price exceeds the cost of fuel, or even make money by exporting power to their neighbours.

Distributed Generation is a rational response to: Re-structuring of the Electricity Sector; Convergence of the power generation & natural gas industries; Advances in enabling technologies; and Environmental concerns. These converging trends are creating a new business called *Distributed Generation*.

In addition to providing stand-alone generation, localized *Distributed Generation* can also offer numerous applications: Co-Generation or Combined Heat and Power, emergency power, peak-shaving, and grid support (Fairley, 2001).

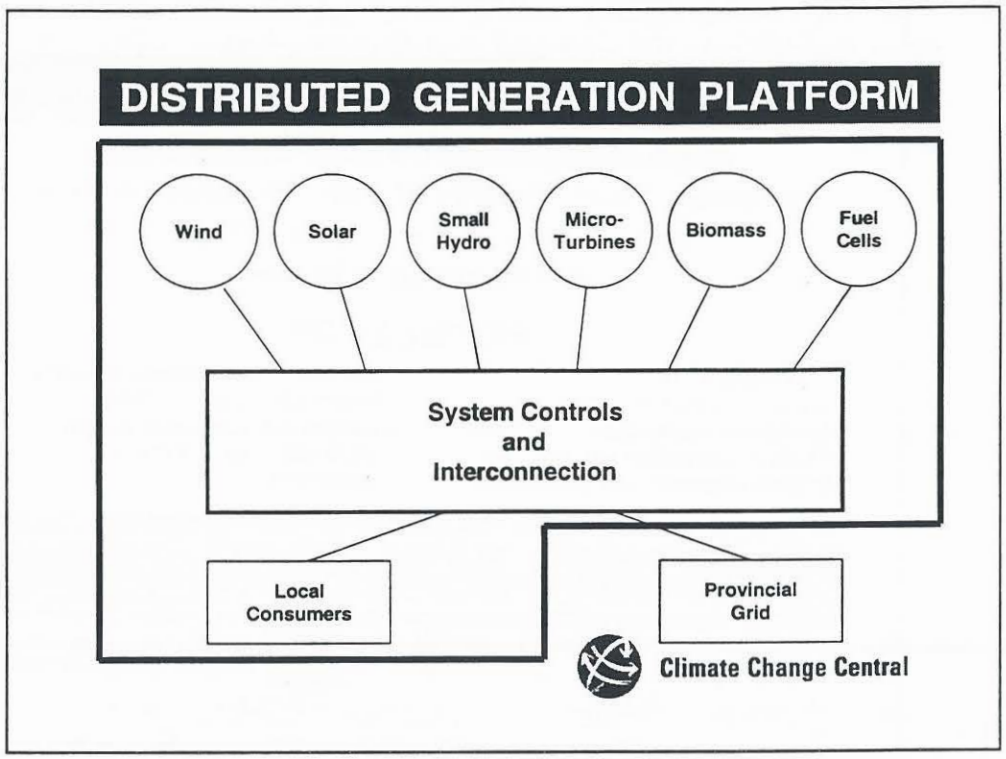


Distributed Generation is a Delivery Platform that integrates different technologies and fuels, and does not favour one type of fuel or generation technology over another. This allows the most cost-effective combination of fuel and technology to be used, depending on where you are in the country and what resources you have at hand, be they renewable and non-renewable.

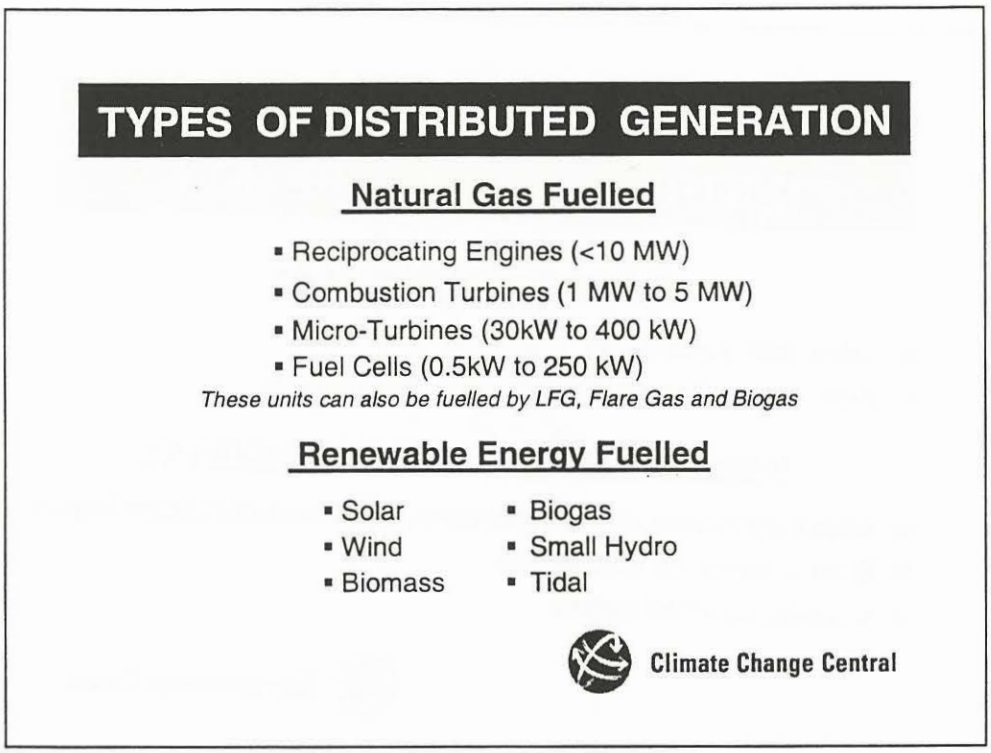
The most important and distinguishing feature of *Distributed Generation* is the ability to produce Combined Heat & Power (CHP). Most large centralized fossil power plants in Canada, waste heat energy, and send it up the stack, because they have no neighbours to use this by-product. *Distributed Generation* on the other hand, because it's located at or near buildings and communities, allows waste heat to be utilized for space heating and hot water heating (The Economist, 2000). This results in much higher fuel conversion efficiencies, 80% or more (*pers. com.* Mariah Energy, 2001) . *Distributed Generation* is able to do more with less, and would maximize the output from fossil-fuel resources.

Advantages of *Distributed Generation* are listed in the figure. However, of particular note is the fact that:

No transmission lines are required, therefore there are no associated line-losses or costs; and that micro-generation units are scalable or modular, and so can be matched to changing power needs.



This figure is a simple schematic of the ***Distributed Generation Platform,*** illustrating how different power generation technologies can connect or "plug-in" to a common Control System,that can route power to local users and/or feed the regional power grid.



There are various potential *Distributed Generation* technologies and fuel sources.

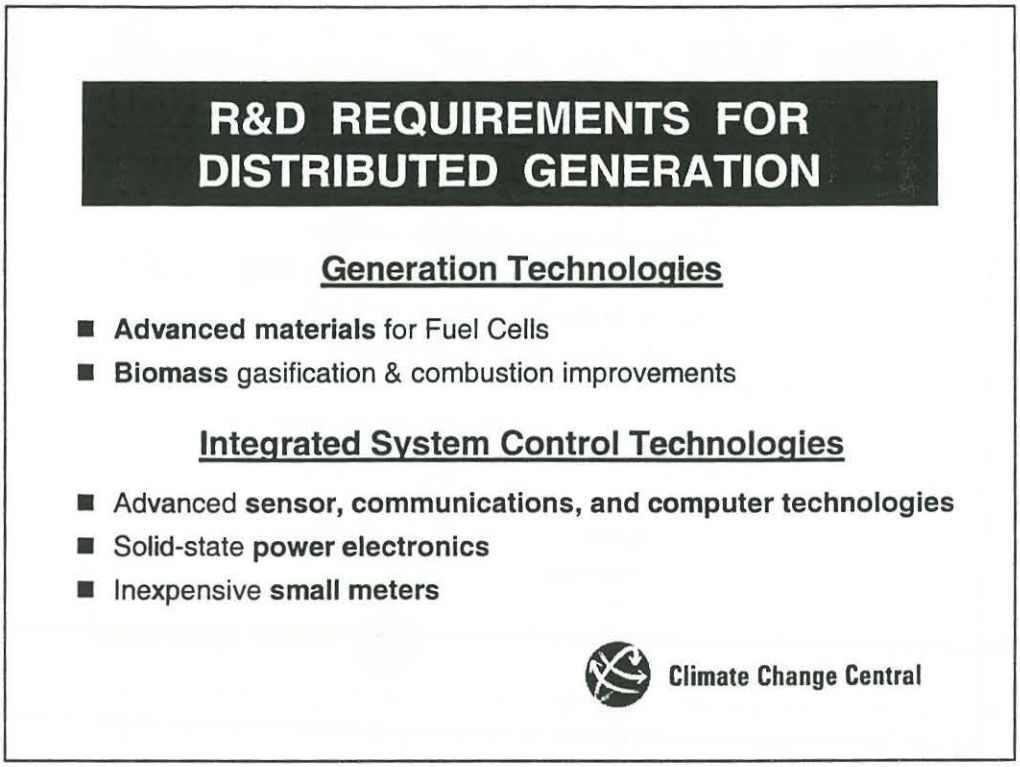
Natural gas-fuelled *Distributed Generation* technologies include:

- Reciprocating Engines - up to 10MW (Gen Sets: Caterpillar, Jenbacher)
- Combustion Turbines - 1 MW to 5 MW
- Micro-Turbines - 30kW to 400 kW
- Fuel Cells - 0.5kW to 250 kW

New developments are allowing many or these units to be fuelled by landfill gas, flare gas and biogas

Renewable energy-fuelled *Distributed Generation* technologies include :

- Solar
- Wind
- Biomass (wood waste)
- Biogas (methane from livestock manure and landfills)
- Small Hydro



DISTRIBUTED GENERATION ENABLING RESEARCH & DEVELOPMENT

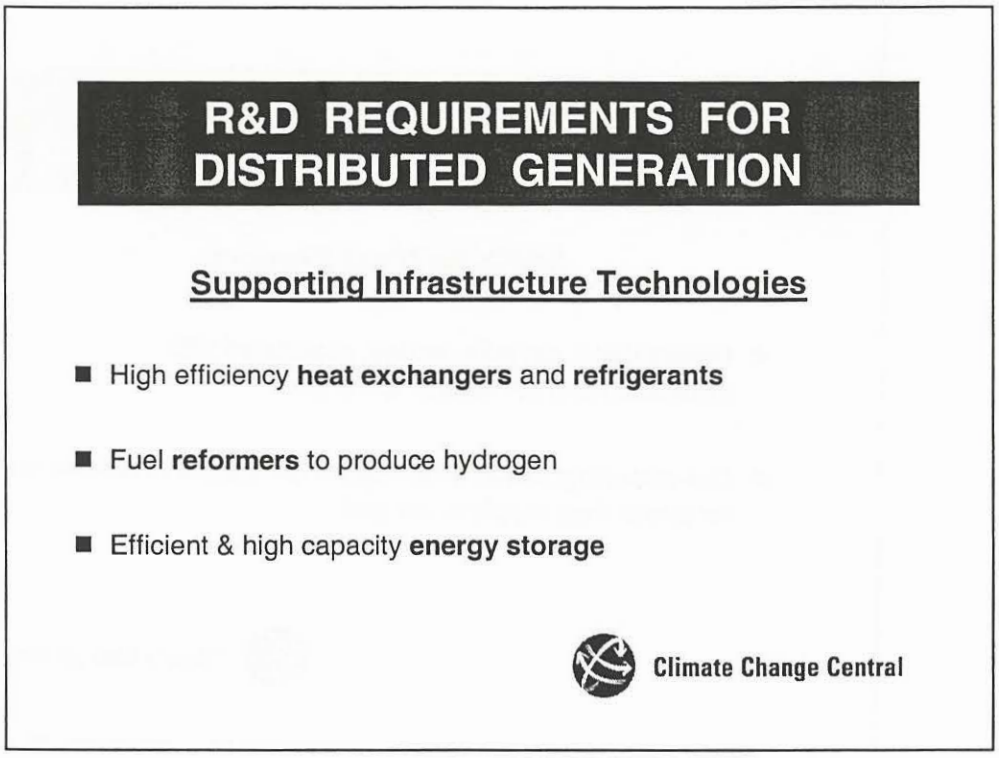
Inter-connecting groups of small-power generators to create local networks or "Energy Webs", that can in turn be inter-connected to the provincial grid will require Research Development & Demonstration in a number of areas.

More work is required in the areas of: Generation Technologies; Systems Controls; Supporting Infrastructure and Socio-Political Barriers.

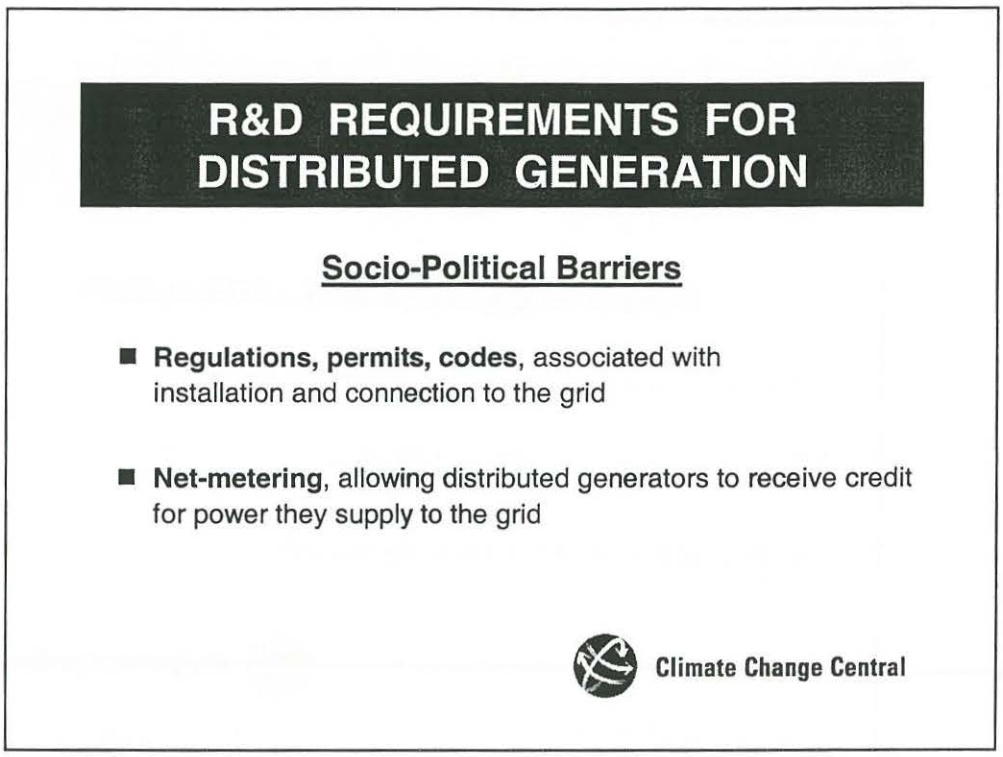
First, Generation Technologies. Advances and refinements are required in the various types of generation technologies applicable to *Distributed Generation*. Specifically in: Advanced materials for the manufacture of Fuel Cells; and Improvements in the combustion & gasification of Biomass or wood wastes

One of the most important steps in developing an R&D or Business Strategy, is to decide what you're *not* going to do. R&D in Small Hydro, Wind, Solar and Micro-Turbines as well as Clean Coal, is being conducted in the US, Europe and Japan. Therefore, it would **not** be prudent to invest the huge resources required to compete with those countries in those technologies, but rather focus on areas where Canada could develop an advantage

The second area where R&D is required, is Distributed Generation Enabling Technologies. Integrated system controls technologies are needed for an efficient and flexible *Distributed Generation Platform*. These will allow greater energy security, control, metering and safety. The R&D focus here should be in: Advanced sensor, communications, and computer technologies; Solid-state power electronics and inverters, that make it possible to isolate, condition and control the flow of power on individual lines, in sub-systems, within the power transmission system, and end-user devices; and Inexpensive small meters.

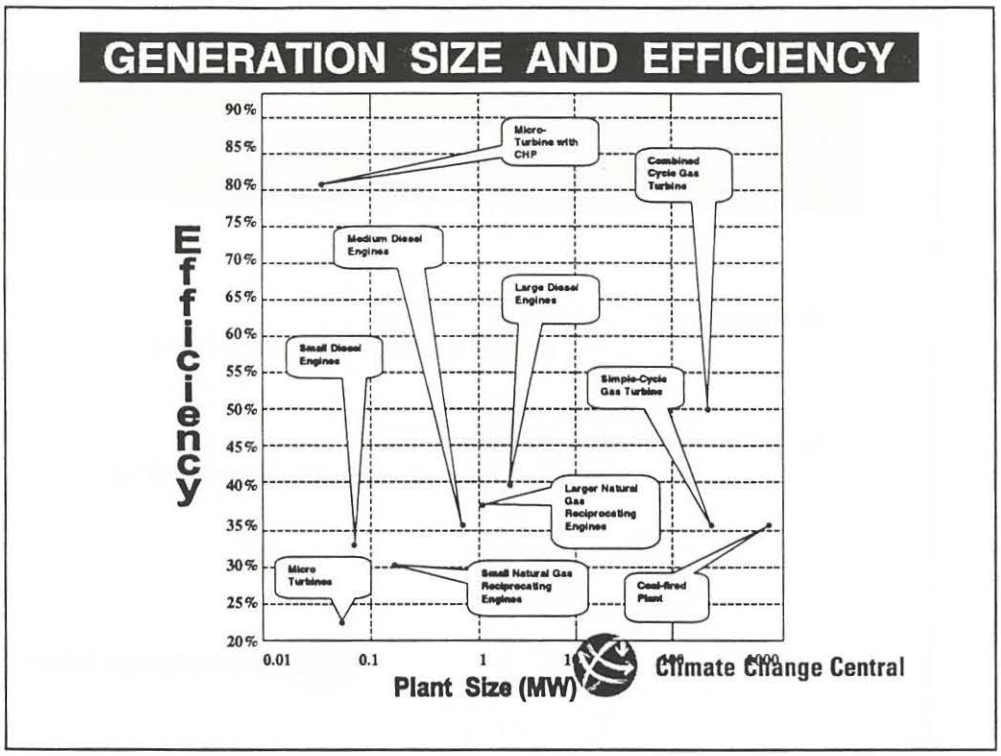


The third area of suggested R&D is in Supporting Technologies that are related to: High efficiency heat exchangers (fluid flows & materials) and more efficient refrigerants for extracting waste heat, and making it available for use; Fuel reformers to produce hydrogen for fuel cells; and Efficient and high capacity energy storage technologies, such as batteries, fly-wheels, magnetic technologies, thermal energy storage, and reverse-flow fuel cells or reverse hydrolysis, etc.



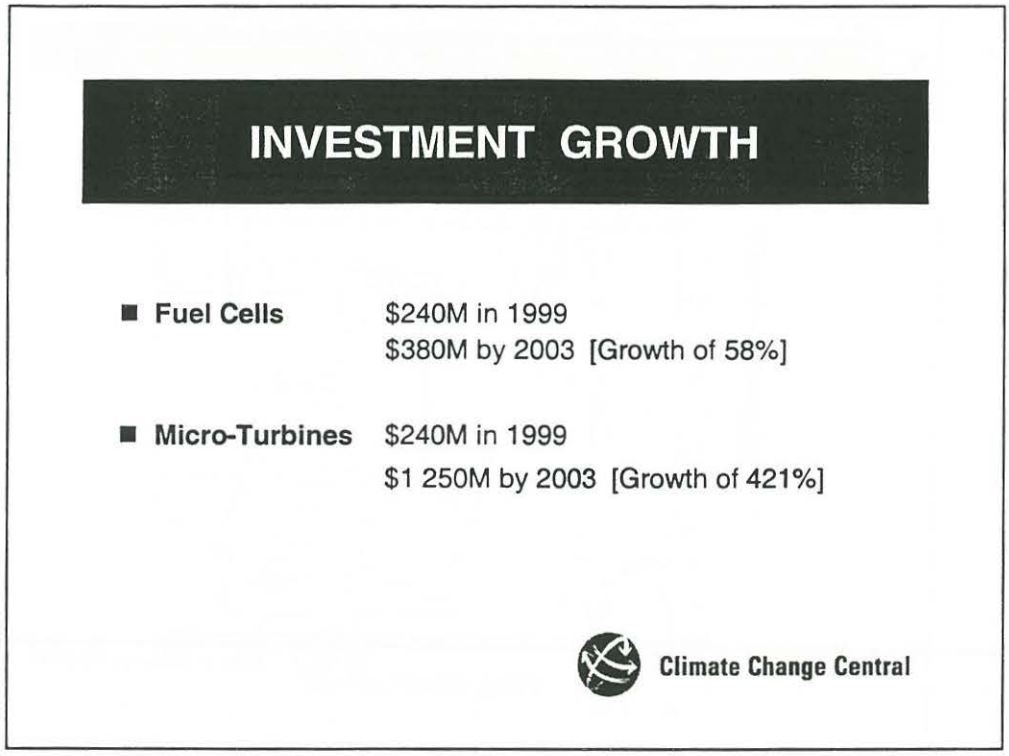
Lastly, efforts are needed to evaluate and modify Social and Political Barriers and unnecessary requirements to *Distributed Generation* to permit market entry and fair competition

Areas needing to be addressed include: Utility Industry Regulations, permits, codes & inspector training, associated with installing and connecting to the grid; Net-metering, allowing distributed generators to receive credit for power they supply to the grid; and Broad Education & Awareness targeted towards industry, government and the public, in order to get the acceptance and understanding of Distributed Generation and the site-specific requirements of power systems



GENERATION UNIT SIZE AND EFFICIENCIES

This figure illustrates various efficiencies and sizes of different generation technologies (after Goepel McDermid, 2000 and *pers. com.* Mariah Energy). Of particular note are the two extremes. The traditional coal-fired power plants, operating at about 35% efficiency (lower-right of the graph), and micro-turbines with combined heat and power, with efficiencies of about 80% (top left of the graph).



INTERNATIONAL INVESTMENTS

Venture capital investments in the energy industry have increased more than ten-fold in the last five years. Traditional energy companies like Texaco, Shell, and Ford are investing heavily in new energy technologies (Capital E Report on Distributed Energy, 2001).

In the US, investment in Fuel Cells is expected to more than double by 2003, and interest in Micro-Turbines is forecast to grow 5-fold (Meyers and Hu, 2001)

INVESTMENTS IN ALTERNATIVE ENERGY IN ALBERTA

TECHNOLOGY	ADDED SINCE 1996	COST OF ADDITIONS	PROPOSED NEXT 3 YRS	COST OF ADDITIONS
Small Hydro	12.75 MW	$14M	118 MW	$123M
Wind	19.5 MW	$100M	200 MW	$300M
Solar	>16 kW	$10M	unknown	$20M
Biomass	29 MW	$26M	20 MW	$40M
Biogas	0	0	unknown	unknown
Micro Turbine	18.75 MW	$32.75M	44.5 MW	$66M
Fuel Cells	0	$Ms in R&D	unknown	unknown

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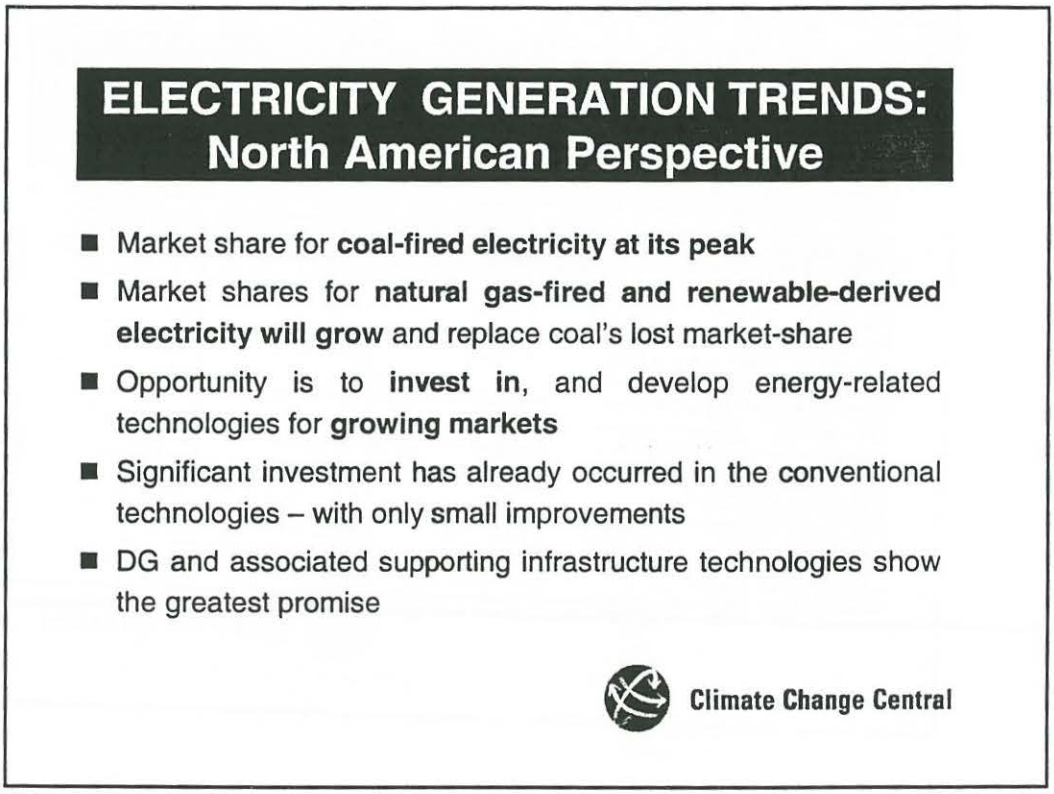
INVESTMENTS IN ALBERTA

The Alternative Energy Sector is also growing at pace, in Alberta. At present, wind energy is increasing at the fastest rate. Micro-turbines are beginning to stimulate interest especially from those wanting to capture value from gas flares as well as from Combined Heat & Power (CHP)

Values shown in the figure have been compiled from a March 2001 draft report by the MacLeod Institute, entitled *Low GHG Distributed Generation: Barriers and Options for Improving Electricity Supply in Alberta.*

Energy demand continues to grow, with supply struggling to keep ahead, and prices for conventional power are increasing. Both of these occurrences are making Alternative Energy Sources more competitive



FUTURE DEVELOPMENTS

Not withstanding the recent pronouncements of the US Administration, market share for coal-fired electricity is likely at its peak and is forecast to decline in North America, according to the US-DOE. The remarks of President Bush, Vice President Cheney as well as statements in the recent US Energy Policy, referenced the use of coal with cleaner burning technology. Coal gasification promises major advances in this area, however this technology is not yet commercial, and likely wont be for another 15 to 20 years.

The US-DOE also predicts that market shares for natural gas-fired and renewable-derived electricity will grow and replace coal's lost market-share in North America.

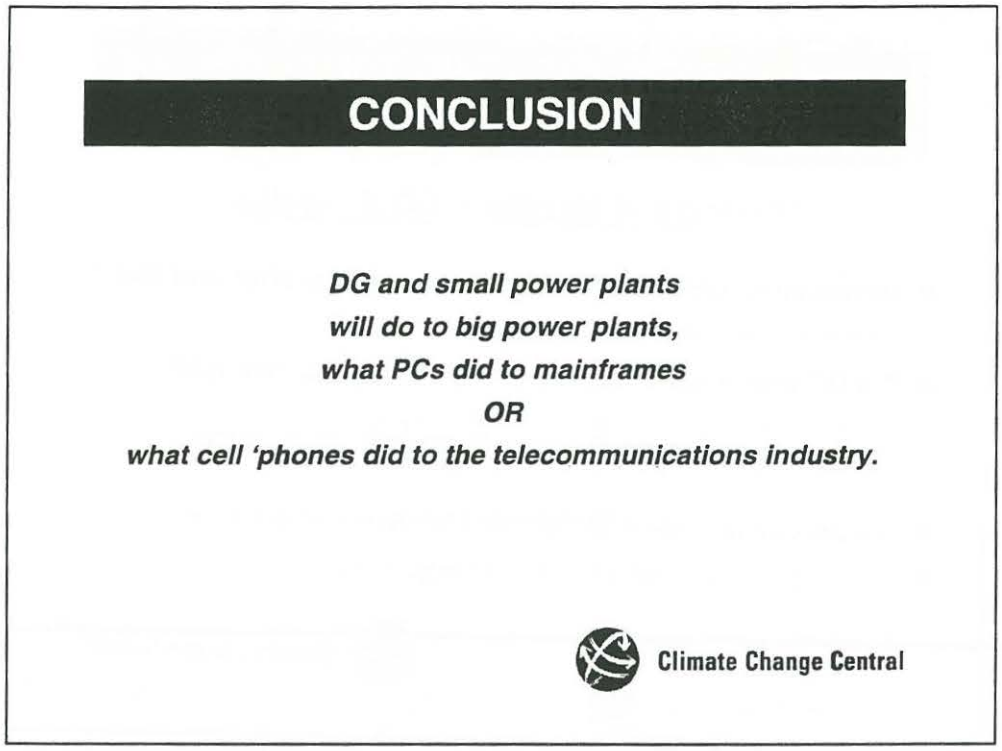
Considering these trends, it would appear in the short- and medium-term, the best opportunities for us as Canadians are in the development of energy-related technologies for growing markets versus shrinking markets, and *Distributed Generation* and associated supporting infrastructure technologies show the greatest promise (renewables, fuel cells, energy storage, high efficiency heat exchangers, and control systems).

A VISION OF THE FUTURE FOR PROVINCES WITH DE-REGULATED ELECTRICITY SECTORS

This is a vision born from the Alberta experience. because of de-regulation, which is occurring in Ontario also, and will happen in other provinces as well.

In the future we will be able to say:

- That De-regulation gave us the competitive advantage to be first, to develop, pilot and refine a variety of *Distributed Generation* technologies and supporting infrastructure, particularly "Distributed Intelligence", or the control systems, which are critical for successful "Energy Webs"
- In Canada, these "Energy Webs" are augmenting traditional grid-supplied power
- And that these Canadian-based technologies and associated expertise are being marketed around the world



CONCLUSION

Small power plants will do to big power plants, what PCs did to mainframes, or what cell 'phones are doing to the telecommunications industry.

The future belongs to flexible power systems with the three *"E"s Advantages* of: Economics, Environmental, and Efficiency.

Distributed Generation is the *cost-effective and efficient* road to a future for Micro-Turbines, Fuel Cells and the expanded use of Renewables

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