Micro and Mini Turbine Technology

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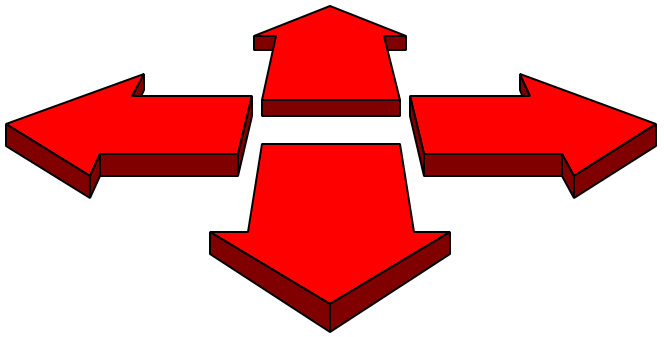
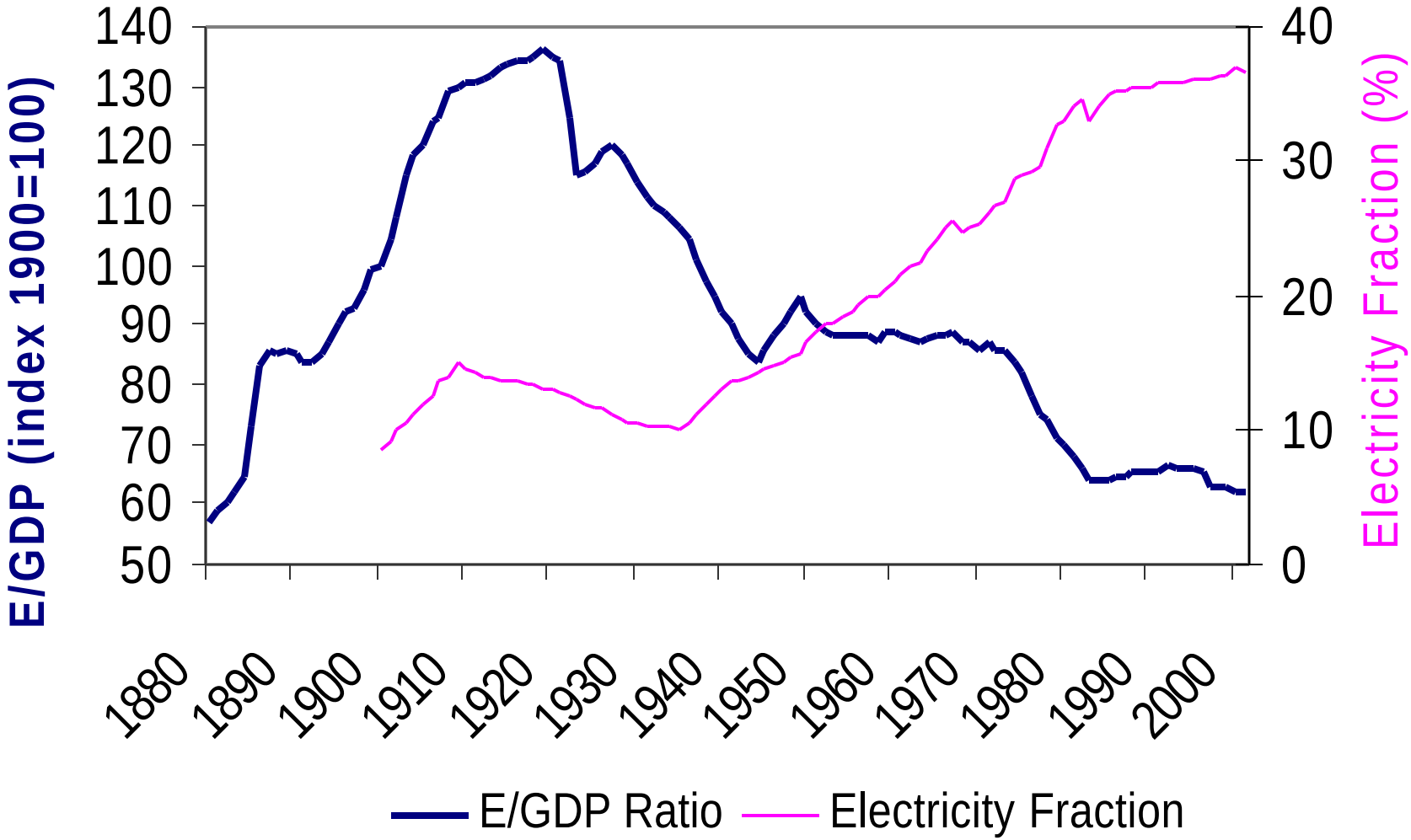
Overview

1. Why All the Fuss About Distributed Generation (DG)?
2. Compare Evolving DG Technologies
3. Summarize Micro and Mini Turbine Technologies
4. Importance of Air Emissions
5. Speculate About Future Turbine Users, Technologies, and the Marketplace

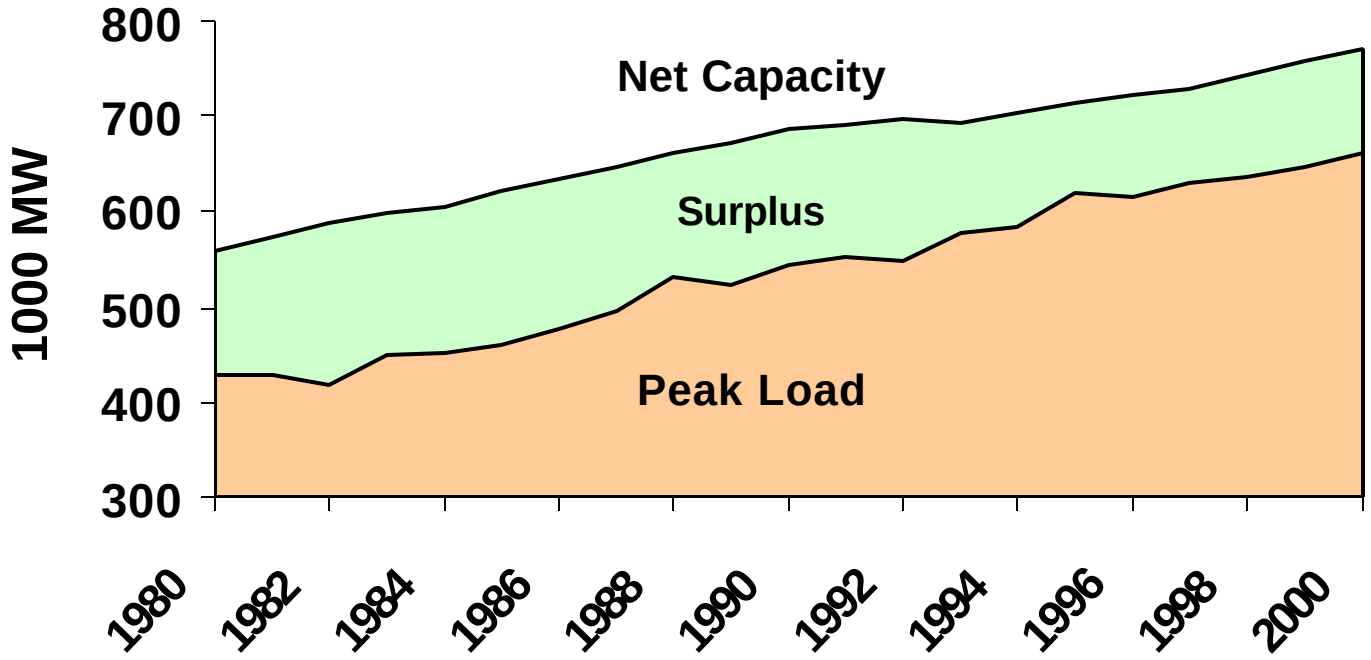


Rising Demand for Electricity

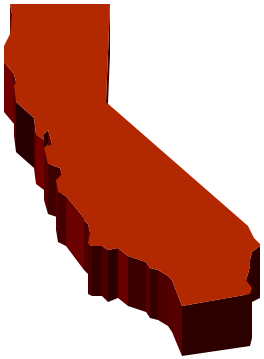


Source: Electric Power Research Institute

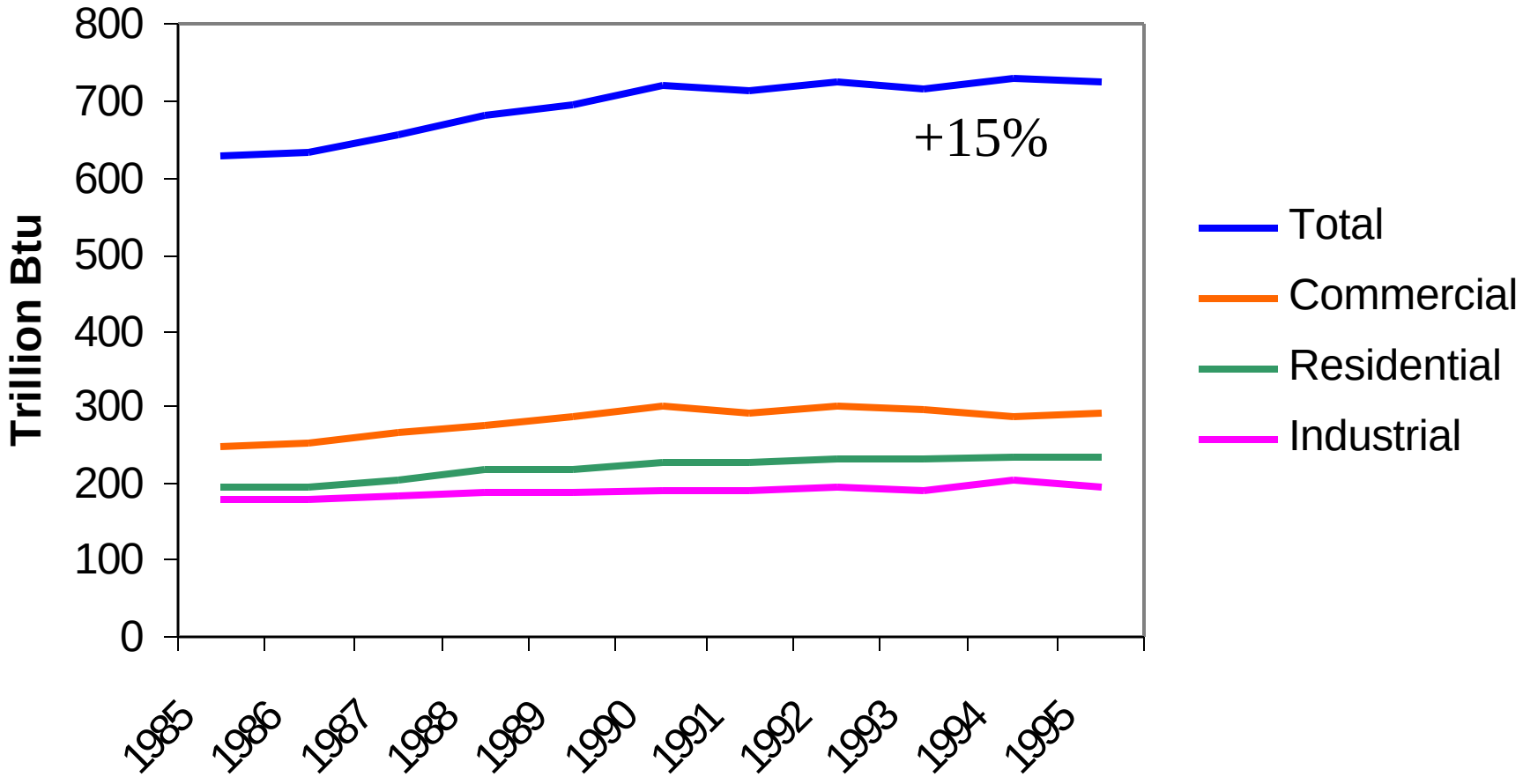
U.S. Peak Summer Electric Supply and Demand



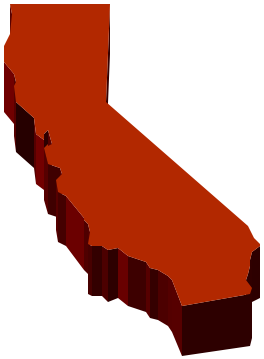
Source: Energy Information Administration



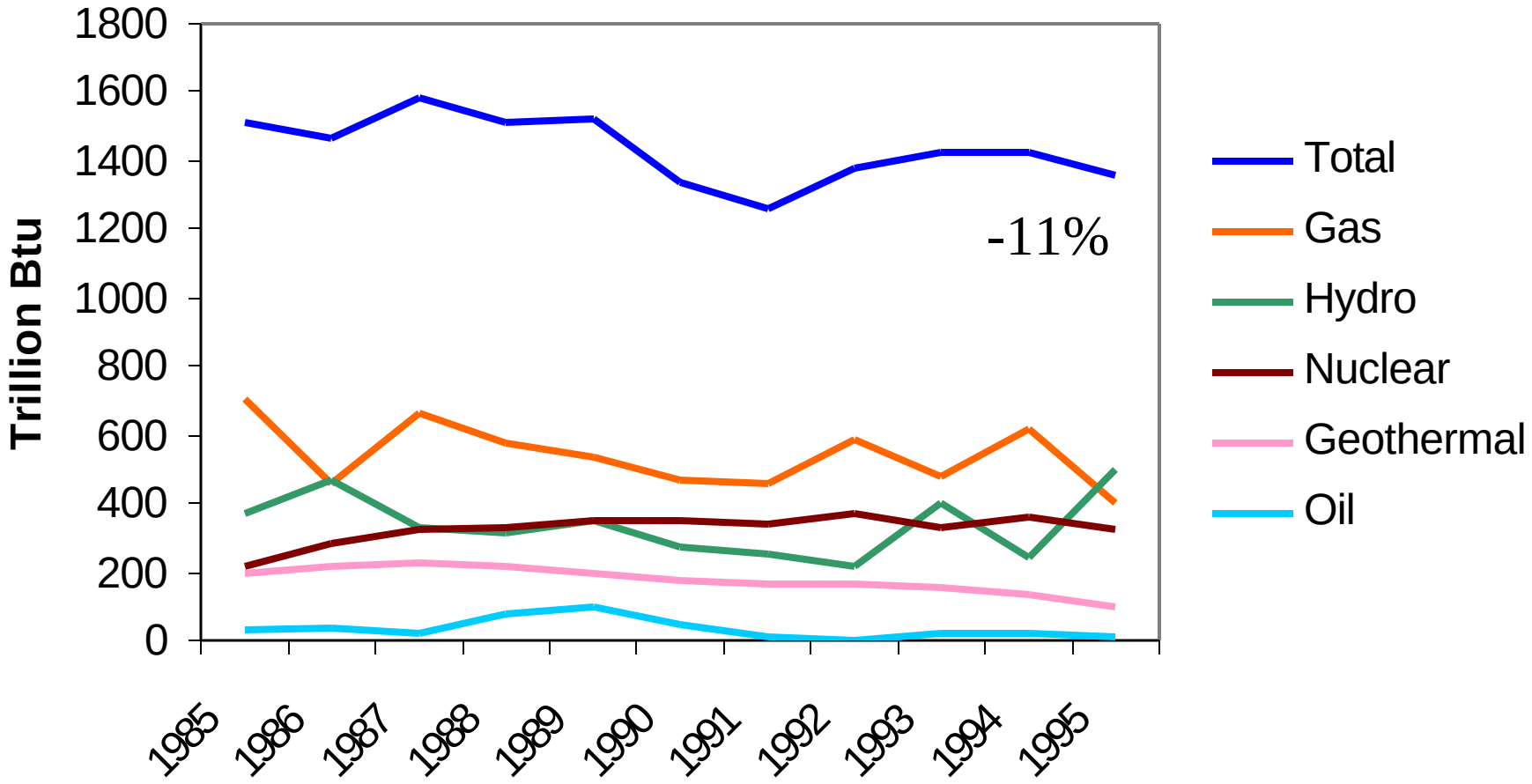
CA Electric Consumption



Source: EIA State Energy Data Report 1995

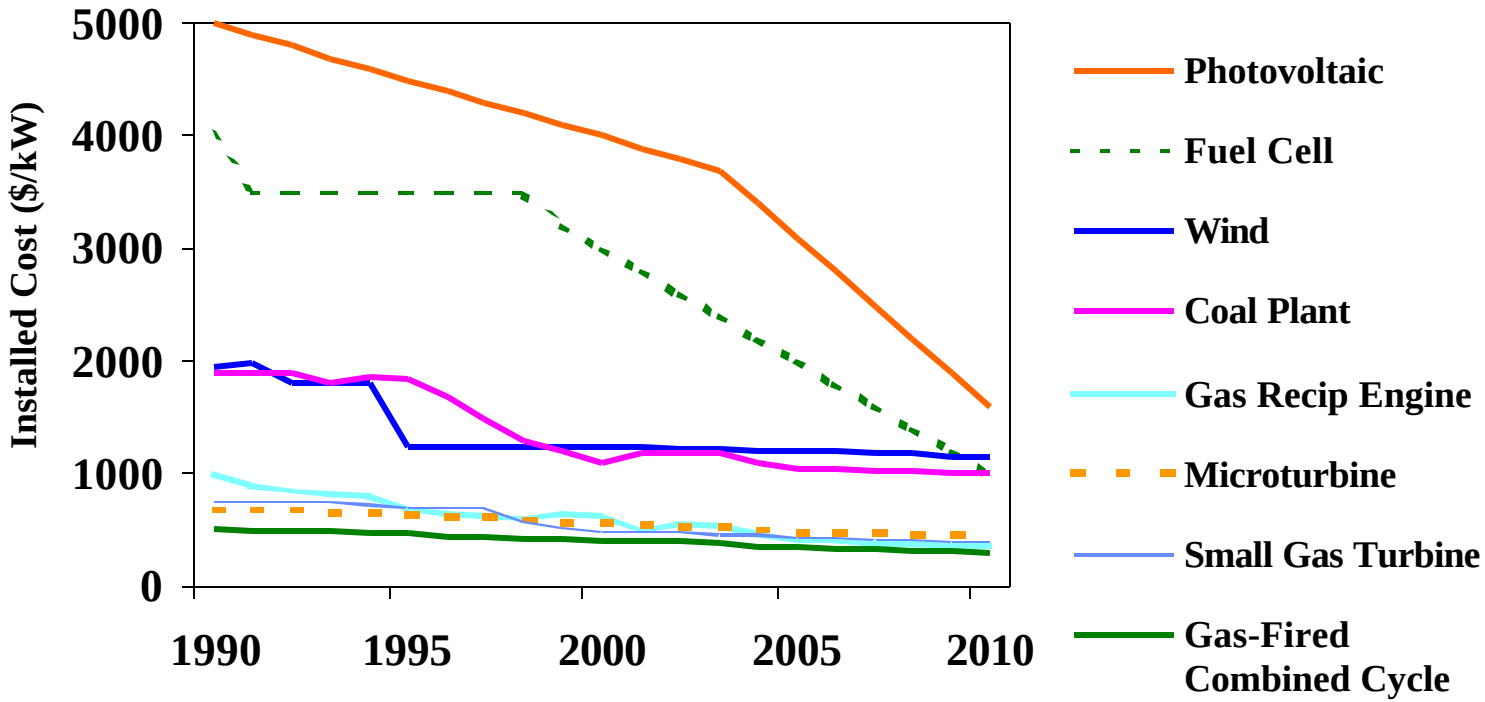


Fuels Used in CA to Generate Electricity



Source: EIA State Energy Data Report 1995

Generation Capital Cost By Technology (98$)



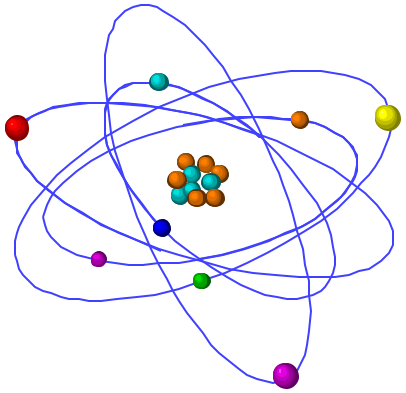
Source: Resource Dynamics Corporation

DG Capital Costs

($/kW)

Technology	1990	2000	2010
Diesel Engine	1,000	400	350
Micro Turbine	800	700	400
Mini Turbine	700	550	375
Fuel Cell	4,500	2,000	800
Photovoltaic	5,200	4,000	1,500
Wind	2,000	1,300	1,100

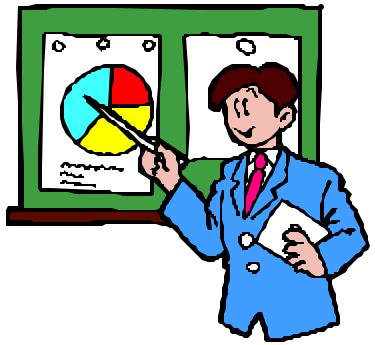
Source: Resource Dynamics Corporation



DG Technology Characteristics

Technology	Diesel Engine	Micro Turbine	Mini Turbine	Fuel Cell
Size (MW)	0.03 - 10	0.03 -0.2	0.5 - 10	0.1 - 3
O&M ($/kWh)	0.005 - 0.015	0.004-0.010	0.003-0.008	0.002-0.015
% Electric Efficiency	36-43	18-32	21-40	40-57
Usable CHP Temp (Degrees F)	Diesel 180-190, Other IC 400-500	400-650	500-1,100	140-700
% Overall Efficiency	82	82	85	82
Availability	90-97%	90-98%	90-98%	>95%
Footprint (sq ft/kW)	0.25	0.25	0.30	0.90

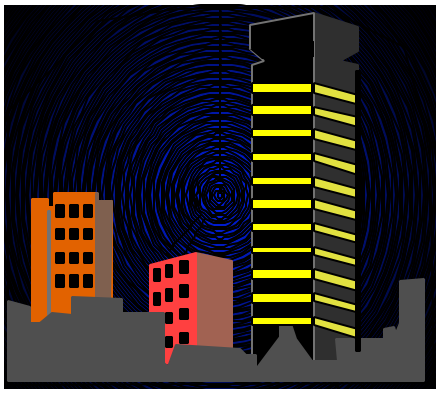
Source: Resource Dynamics Corporation



DG Commercial Status

Technology	Diesel Engine	Micro Turbine	Mini Turbine	Fuel Cell
Commercial Availability	Well established	Evolving industry	Well established	Well established
Fuel Type	Diesel, propane, NG, oil	Propane, NG, distillate	Propane, NG, distillate	Hydrogen, propane
Noise	Moderate to high (requires enclosure)	Moderate (enclosure supplied with unit)	Moderate (enclosure supplied with unit)	Low (no enclosure required)
Typical Duty Cycles	Baseload	Peaking, intermediate, baseload	Baseload, intermediate, peaking	Baseload
Likely Users Next 5 Years	Industrial, commercial, UDC, residential	Industrial, commercial, UDC	Industrial, UDC, commercial	Residential, commercial, industrial, UDC

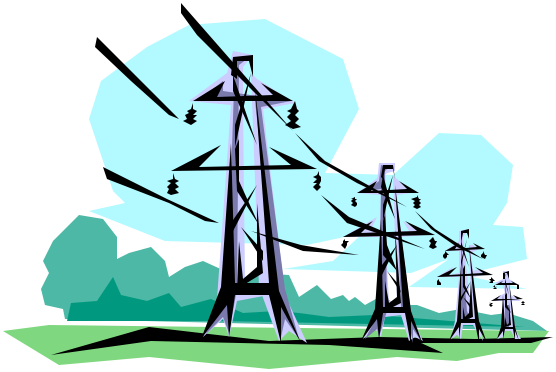
Source: Resource Dynamics Corporation



DG for Combined Heat and Power

Technology	Application for CHP
Diesel Engines	Moderate cogeneration use
Micro Turbines	Limited cogeneration applications due to lower heat production
Mini Turbines	Excellent for cogeneration
Fuel Cells	Limited use, except for PEM in special cases

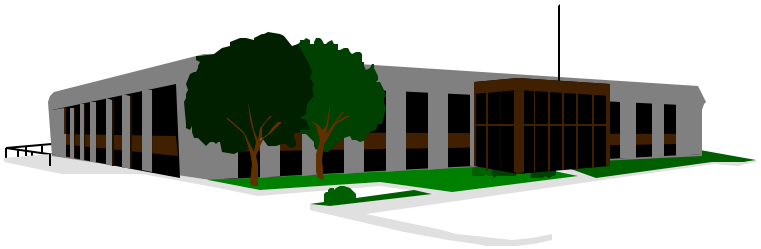
Source: Resource Dynamics Corporation



Turbine Pros and Cons

Technology	Pros	Cons
Micro Turbines	♦ Small and portable ♦ Potentially low capital cost	♦ Low power-only efficiency ♦ Limited cogeneration applications
Mini Turbines	♦ Wide range of sizes over 1 MW ♦ Quick start-up ♦ Excellent for cogeneration	♦ Low but improving efficiency ♦ Emission levels require mitigation

Source: Resource Dynamics Corporation

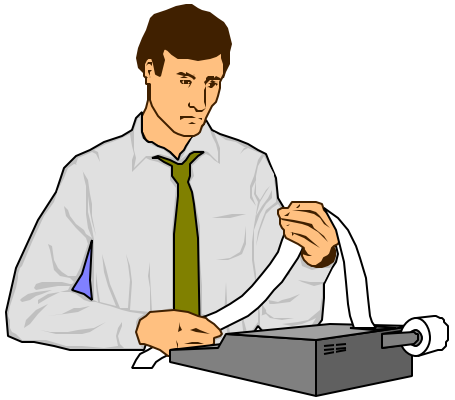


Some Micro and Mini Turbine Providers

Technology	Manufacturers/ Suppliers
Micro Turbines	AlliedSignal Capstone Elliott MagneTek GRI/Northern Research Teledyne/Ryan
Mini Turbines	AlliedSignal Allison Dresser-Rand European Gas Turbines General Electric Greenwich Turbine Kawasaki Solar Turbines Turbomeca

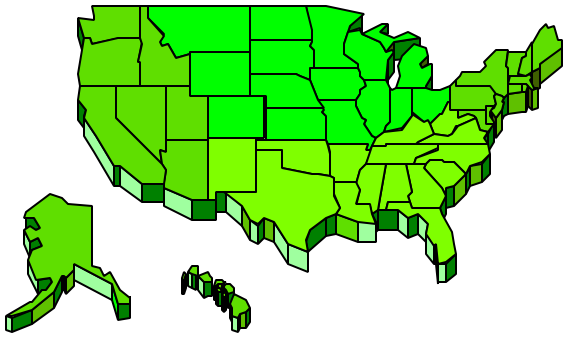
Micro/Mini Turbine Technology Summary

- Micro Turbine industry less mature than Mini Turbine industry
- Low efficiency unless used with CHP
- Micro Turbines better for peaking
- Mini Turbines better for baseload and CHP



Micro/Mini Turbine Market Summary

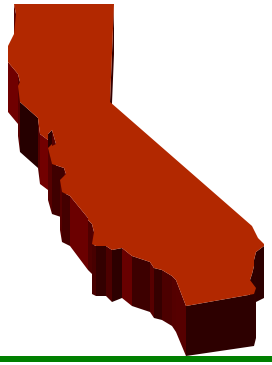
- Near grid-competitive, and falling, capital costs
- Competitive O&M costs
- Likely to be adopted by industrial and commercial end-users, especially those needing high reliability
- Face regulatory uncertainty
- Acceptable emission levels with proper controls



Percent of Emissions Generated by U.S. Electric Industry

Pollutant	1994	1995	1996
CO	0.3	0.4	0.4
Particulates	0.6	1.0	0.9
NO_X	33.0	26.7	25.8
SO_X	70.4	65.1	65.9

Source: U.S. EPA, National Acid Precipitation Assessment Program



CA Power Emissions

Tons per Day

Pollutant	Total Stationary Sources	Electric Utilities	Cogeneration
CO	348	36	36
PM_{10}	211	5	3
NO_X	633	69	36
SO_X	138	8	2

Percent of Total

Pollutant	Electric Utilities	Cogeneration
CO	10.3	10.3
PM_{10}	2.4	1.4
NO_X	10.9	5.7
SO_X	5.8	1.4

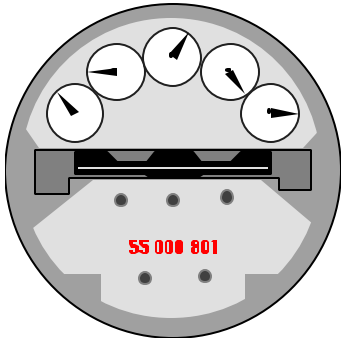
Source: California Air Resources Board, 1998

Air Emissions by Technology

(lb/kWh)

Generation Technology	CO	PM_{10}	NO_X	SO_X
Distributed Generation				
Recip engines	.004-.006	.0002	.0015-.037	
Miniturbines	.01-.05	.0001-.0002	.007 -.009	.0003
Microturbines	.003-.050	.0001-.0002	.0005-.0050	.0003
Fuel cells	.00001	0	.000002 - .000060	0
Photovoltaic	0	0	0	0
Wind turbines	0	0	0	0
Central Station				
Gas steam	.00009	.00001	.00003-.00010	0
New coal plant		.0001	.002	.002-.004
Geothermal	0	0	0	0
Hydropower	0	0	0	0
Nuclear	0	0	0	0

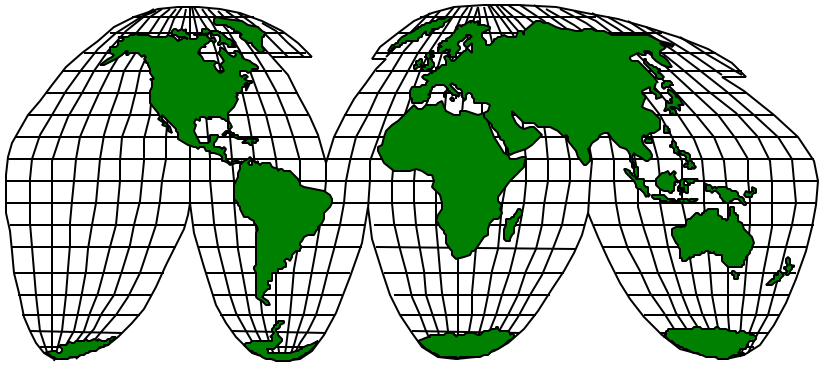
Sources: CADER and Resource Dynamics Corporation based on manufacturers' specifications



Percent of Electricity Generated On-Site

SIC	Industry	U.S.
20	Food products	10.8
24	Lumber products	9.1
26	Paper products	50.5
28	Chemicals	23.8
29	Petroleum refining	29.3
35	Electronics/computers	0.5

Source: Energy Information Administration, 1994

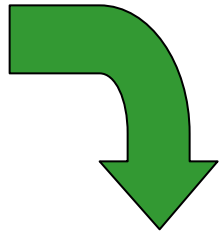


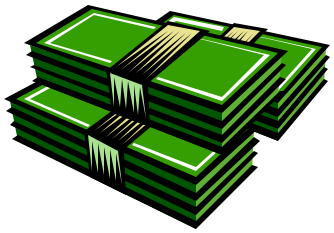
Future of Turbine Technology

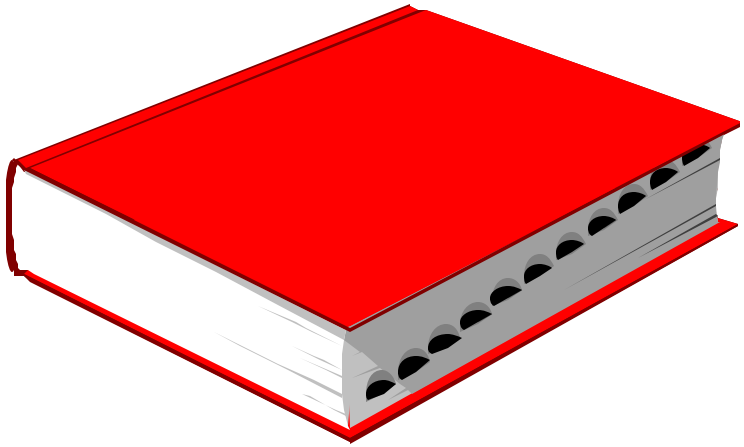
- Technology improves - efficiency, durability, and reliability
- Acceptable emission levels through controlling technologies
- Lower costs through mass production
- Global market
- Overseas technology shakedown/improvement

Future of Turbine Marketplace

- Diminishing DG regulatory uncertainty
- Increasing capacity shortages reduce grid reliability
- Turbine industry consolidation
- Key investments by large players
- Major energy end-users apply turbines







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