Turbine Inlet Cooling

Increasing Summer Peak Capacity
&
Reducing Overall Emissions*

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*** Information extracted from the TICA Presentation to the U.S. EPA in February 2014**

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Demand for Electric Power and Emissions Increase During Summer

- Demand for electric power increases/peaks during summer due to increased load of air conditioning
- Emissions from power plants also increase during summer because of the need to operate all generation plants, including inefficient systems

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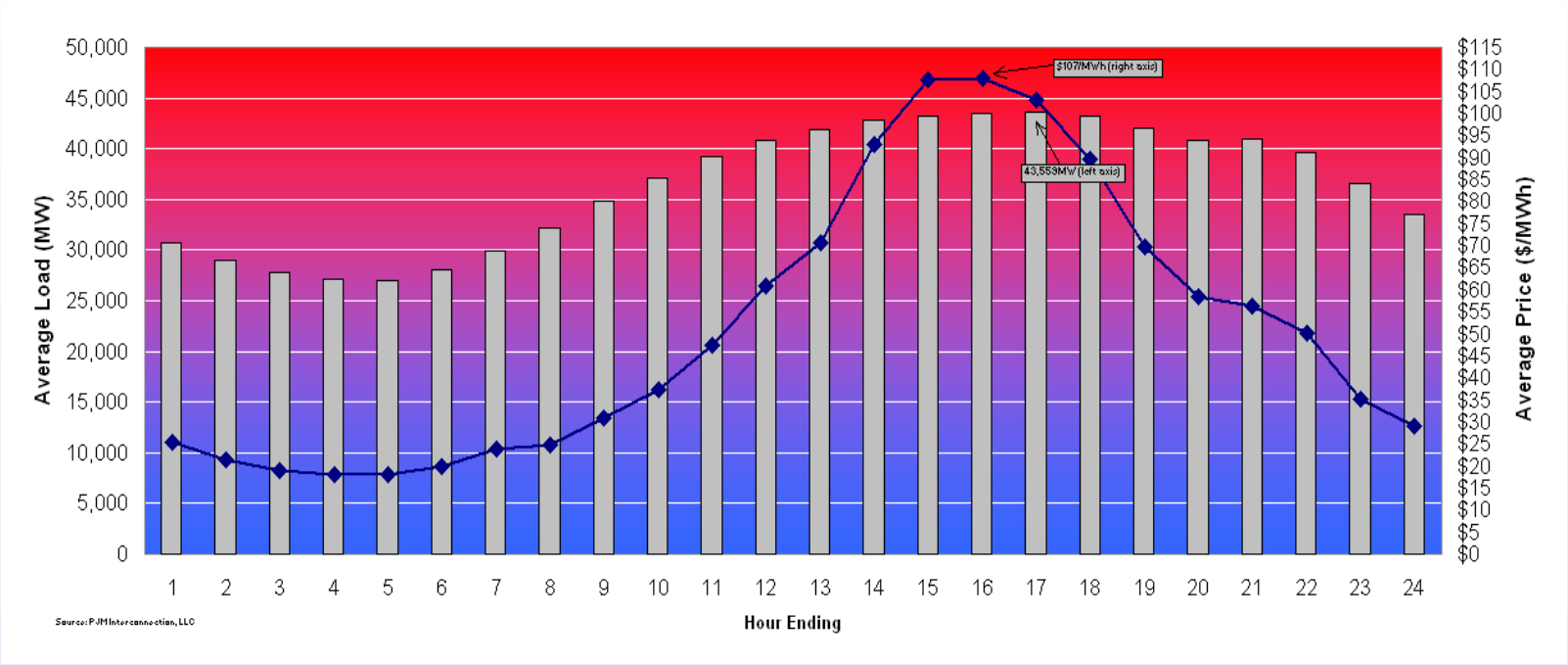
Example of Increased Demand and Electricity Rates During Hot Weather



The cost of electricity can be up to four times higher during peak periods. Rates can be even higher when supply is scarce.

PJM Interconnection LLC

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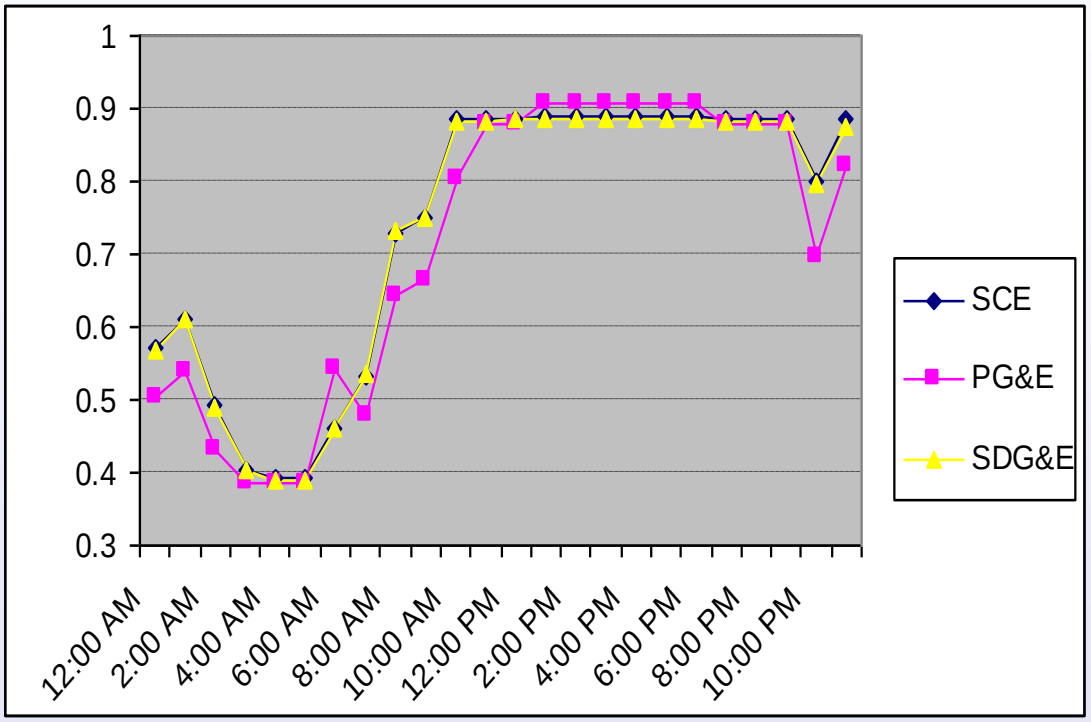
Example of Increased Emissions During Peak Demand Period: Almost Double of Those During Off-Peak



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Unfortunately
Capacity of Combustion Turbine Power Plants Reduces During Summer

Fuel	Nameplate Capacity (at 59° F)	Summer Capacity	MWs Lost in Summer
*Natural Gas	485,957	422,364	63,593

Source: U.S. Department of Energy's Energy Information Agency 2012 Database

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Hot Weather Benefits of TIC

- **Increased Capacity –** by cooling the warm inlet air, the mass flow for combustion increases and the output of the power plant increases
- **Reduced Emissions**
  - TIC reduces on-site emissions* by increasing the efficiency of the turbine being cooled
  - TIC reduces grid-wide emissions* by reducing the need for operating less- efficient and higher- emission power plants

***** **lb/kWh of all emissions including, CO_2, NOx, SOx**

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Top 20 States that Benefit from Increased Capacity by TIC

State	Natural Gas Fired Combined Cycle Capacity, MW			Natural Gas Fired Simple Cycle Capacity, MW			Total Gas Turbine Capacity, MW			Other Natural Gas, MW	Petroleum Liquids, MW	2012 Fuel Savings by TIC of Combined-Cycle by Avoided Operation of Simple Cycle, MMBtu/hr[3]	2012 Fuel Savings by TIC of Simple Cycle by Avoided Operation of Steam Turbines (Gas and Fuel Oil Boilers, MMBtu/hr[4]	Reduction in CO2 Emissions by TIC of Combined-Cycle by Avoided Operation of Simple Cycle, lbs/hr[5]	Reduction in CO2 Emissions by TIC of Simple Cycle by Avoided Operation of Steam Turbines (Gas & Fuel Oil Boilers), lbs/hr[5]	Reduction in Carbon Emissions by TIC of Combined-Cycle by Avoided Operation of Simple Cycle, lbs/hr[6]	Reduction in Carbon Emissions by TIC of Simple Cycle by Avoided Operation of Steam Turbines (Gas & Fuel Oil Boilers), lbs/hr[6]	Reduction in NOx Emissions by TIC of Combined-Cycle by Avoided Operation of Simple Cycle, lbs/hr[7]	Reduction in NOx Emissions by TIC of Simple Cycle by Avoided Operation of SC using Fuel Oil, lbs/hr[8]
	2012 Summer Capacity w/o TIC	2012 Summer Capacity with TIC[2]	2012 Summer Increase by TIC	2012 Summer Capacity w/o TIC	2012 Summer Capacity with TIC	2012 Summer Inrease by TIC	2012 Summer Capacity w/o TIC	2012 Summer Capacity with TIC[1]	2012 Summer Increase by TIC	2012 Summer Capacity	2012 Summer Capacity								
Texas	36,934	39,976	3,042	7,374	7,779	405	44,308	47,755	3,447	22,675	63	11,408	911	1,326,216	105,919	361,659	28,884	9,127	1,093
Florida	23,943	25,974	2,032	7,959	8,409	450	31,902	34,383	2,482	1,756	8,983	7,619	1,013	885,691	117,767	241,528	32,115	6,095	1,216
California	18,323	19,912	1,589	8,207	8,682	475	26,530	28,594	2,064	15,046	397	5,960	1,068	692,883	124,142	188,949	33,853	4,768	1,281
Arizona	9,882	10,704	822	2,354	2,484	130	12,236	13,188	952	1,321	91	3,081	293	358,133	34,117	97,663	9,304	2,465	352
Alabama	9,326	10,107	781	2,551	2,693	142	11,876	12,800	924	169	43	2,931	321	340,678	37,271	92,903	10,164	2,344	385
New York	8,339	9,050	712	3,011	3,183	171	11,350	12,233	883	7,195	5,144	2,669	386	310,250	44,817	84,605	12,222	2,135	463
Pennsylvania	8,261	8,940	679	1,598	1,686	88	9,859	10,626	767	1,779	2,494	2,548	197	296,171	22,916	80,766	6,249	2,038	237
Georgia	7,956	8,698	742	7,837	8,324	487	15,793	17,022	1,229	115	1,136	2,781	1,096	323,315	127,390	88,168	34,739	2,225	1,315
Oklahoma	7,513	8,125	612	1,192	1,257	65	8,704	9,382	677	5,093	69	2,297	146	266,979	16,943	72,805	4,620	1,837	175
Louisiana	7,324	7,945	621	2,406	2,542	136	9,730	10,487	757	8,434	47	2,329	306	270,722	35,576	73,826	9,702	1,863	367
Mississippi	6,997	7,580	583	1,717	1,812	95	8,714	9,392	678	2,696	35	2,185	214	253,998	24,929	69,265	6,798	1,748	257
New Jersey	5,871	6,401	529	4,099	4,346	246	9,971	10,746	776	643	1,302	1,985	554	230,754	64,443	62,927	17,574	1,588	665
Massachusetts	5,499	5,935	436	322	339	17	5,821	6,274	453	686	3,110	1,634	38	190,005	4,452	51,814	1,214	1,308	46
Nevada	5,287	5,729	442	1,381	1,458	77	6,668	7,187	519	587	11	1,657	173	192,614	20,118	52,526	5,486	1,326	208
Michigan	4,777	5,207	430	3,319	3,519	199	8,096	8,726	630	2,979	569	1,614	449	187,662	52,159	51,175	14,224	1,291	538
North Carolina	4,075	4,470	396	6,012	6,401	389	10,086	10,871	785	0	447	1,483	876	172,457	101,778	47,029	27,755	1,187	1,051
Virginia	3,969	4,339	370	3,878	4,118	241	7,847	8,457	610	321	2,369	1,386	542	161,170	62,979	43,951	17,174	1,109	650
Ohio	3,960	4,342	382	5,443	5,793	350	9,403	10,135	732	57	895	1,432	787	166,430	91,497	45,385	24,951	1,145	944
Illinois	2,977	3,289	312	10,315	11,036	722	13,291	14,325	1,034	239	663	1,171	1,624	136,182	188,761	37,137	51,475	937	1,948
Wisconsin	2,669	2,924	255	3,402	3,619	217	6,072	6,544	472	140	609	958	488	111,319	56,761	30,357	15,479	766	586
U.S. Total	183,881	199,648	15,767	84,376	89,479	5,103	268,257	289,127	20,870	71,930	28,476	59,128	11,482	6,873,631	1,334,734	1,874,439	363,982	47,302	13,778

Combined Cycle and Simple Cycle Summer Capacities without TIC Source: 2013 EIA Report for 2012 Data

Notes:

[1] Potential capacity increase from use of TIC technologies will vary based on ambient temperature. For the purposes of this analysis, we assumed that each state's decrease in summer capacity is equal to the national average (i.e., 7.78%). Capacity increase will also vary by TIC technology used; however, this analysis assumes installation of Chillers because they can be precisely set to restore rated capacity. Capacity gains may be smaller with other technologies (e.g., Wetted Media or Fogging).

[2] Assumed capacity increase in combined cycle is 1.5 times that of simple cycle.

[3] Assumed average heat rate of 7,000 Btu/kWh for the combined cycle and 10,750 Btu/kWh for the simple cycle.

[4] Assumed average heat rate of 10,750 Btu/kWh for simple cycle and 13,000 Btu/kWh for boiler/steam turbine systems

[5] Assumed natural gas of only methane with heating value of 1,000 Btu/SCF (1 MMBtu fuel = 116.248349 lb CO2)

[6] Assumed natural gas of only methane with heating value of 1,000 Btu/SCF (Carbon Content = 0.2727 lb C/lb CO2)

[7] Assumed average NOx emissions from gas turbines using natural gas is 0.8lb/MMBtu (range is 0.397 to 1.72)

[8] Assumed average NOx emissions from gas turbines using fuel oil No. is 1.2lb/MMBtu (range is 0.0.55 to 2.5))

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Top 20 States that Could Benefit from Reduced Greenhouse Gas Emissions from TIC

TIC Use, % of the Total Hours of a Year	State	Annual Number of Hours Ambient Temperature is above 59F	Annual Fuel Savings by TIC of Combined-Cycle by Avoided Operation of Simple Cycle, MMBtu/yr	Annual Fuel Savings by TIC of Simple Cycle by Avoided Operation of Steam Turbines (Gas and Fuel Oil Boilers, MMBtu/yr	Annual Reduction in CO2 Emissions by TIC of Combined-Cycle by Avoided Operation of Simple Cycle, Tons/yr	Annual Reduction in CO2 Emissions by TIC of Simple Cycle by Avoided Operation of Steam Turbines (Gas & Fuel Oil Boilers), Tons/yr	Annual Reduction in NOx Emissions by TIC of Combined-Cycle by Avoided Operation of Simple Cycle,Tons/yr	Annual Reduction in NOx Emissions by TIC of Simple Cycle by Avoided Operation of SC using Fuel Oil, Tons/yr
74	Texas	6,466	73,766,148	5,891,353	4,287,657	342,435	29,506	3,535
73	Florida	6,403	49,263,457	6,550,382	2,863,438	380,741	19,705	3,930
68	California	5,952	38,539,219	6,904,954	2,240,092	401,350	15,416	4,143
59	Arizona	5,133	19,919,909	1,897,656	1,157,845	110,301	7,968	1,139
38	Alabama	3,299	18,949,041	2,073,042	1,101,413	120,496	7,580	1,244
76	New York	6,692	17,256,579	2,492,815	1,003,039	144,895	6,903	1,496
60	Pennsylvania	5,280	16,473,459	1,274,611	957,520	74,087	6,589	765
42	Georgia	3,670	17,983,244	7,085,615	1,045,276	411,851	7,193	4,251
55	Oklahoma	4,847	14,849,795	942,401	863,144	54,777	5,940	565
42	Louisiana	3,717	15,057,992	1,978,785	875,246	115,017	6,023	1,187
44	Mississippi	3,878	14,127,749	1,386,608	821,175	80,597	5,651	832
76	New Jersey	6,638	12,834,895	3,584,406	746,028	208,344	5,134	2,151
41	Massachusetts	3,565	10,568,361	247,618	614,286	14,393	4,227	149
62	Nevada	5,437	10,713,494	1,119,008	622,722	65,042	4,285	671
52	Michigan	4,571	10,438,053	2,901,154	606,712	168,630	4,175	1,741
35	North Carolina	3,073	9,592,307	5,661,029	557,553	329,047	3,837	3,397
41	Virginia	3,555	8,964,537	3,502,974	521,064	203,610	3,586	2,102
61	Ohio	5,376	9,257,060	5,089,221	538,067	295,811	3,703	3,054
32	Illinois	2,830	7,574,653	10,499,162	440,277	610,264	3,030	6,299
35	Wisconsin	3,109	6,191,730	3,157,131	359,894	183,508	2,477	1,894
	Total for the Top 20 States	93,491	382,321,683	74,239,926	22,222,448	4,315,196	152,929	44,544

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