cost, electricity demand will increase when there is more wind resource available than forecast, and wind generation may have to otherwise be curtailed due to constraints on the operation of conventional generators. Indeed, [5] demonstrates the effect RTP can have in reducing wind curtailment due to generator and power system constraints.

Besides reductions in wind integration costs, RTP has other economic benefits. Chief among them is increasing short-run efficiency by balancing consumers' willingness to pay

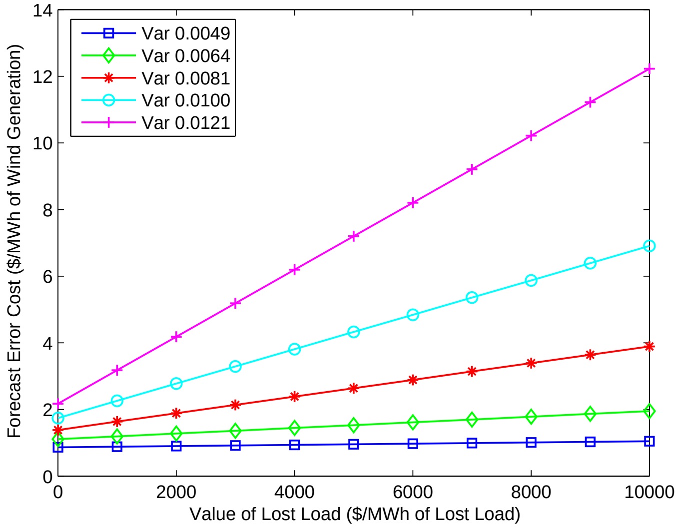

Fig. 1. Annual forecast error cost including cost of lost load as a function of the value of lost load ($/MWh of Wind Generation).

is because social welfare captures the changes in consumer surplus from increases or decreases in demand due to wind forecast errors. When wind forecasts are less than actual

TABLE V
CONSUMER SURPLUS LOSS FROM RANDOM LOAD CURTAILMENT
($/MWH OF CURTAILED LOAD)

Forecast Error Variance	Demand Elasticity -0.1	-0.2	-0.3
0.0049	995.59	497.80	331.86
0.0064	1038.13	519.07	346.04
0.0081	979.91	489.95	326.64
0.0100	1006.80	503.40	335.60
0.0121	976.31	488.15	325.44

C. Superadditive Surplus Gains From Wind Generation and RTP

Many analyses of RTP have focused on the social welfare gains from having electricity demand react to real-time variation in marginal generation costs. In addition to these welfare improvements, the results thus far have demonstrated that introducing RTP in a market with supply uncertainty will increase social welfare by allowing demand to react to changes in actual real-time supply. At the same time, wind generation can increase short-run social welfare by providing a costless source of energy.[1] An interesting question is whether there would be an interaction between introducing RTP and adding wind generation, which would result in superadditive social surplus gains, compared to introducing each to an electricity market in isolation.

These social surplus improvements are examined by comparing a set of scenarios in which there is:

1) no RTP, no wind generators;
2) no RTP, wind generators;
3) RTP, no wind generators; and
4) RTP, wind generators.

Defining σ_x to be the social surplus under scenario x, this analysis compares the increase in welfare from introducing both RTP and wind generation together ($\sigma_4 - \sigma_1$) to the sum of the welfare increases from introducing each of RTP and wind generation individually ($\sigma_3 + \sigma_2 - 2\sigma_1$). If $\sigma_4 - \sigma_1 > \sigma_3 + \sigma_2 - 2\sigma_1$ this implies that the combination of RTP and wind result in superadditive surplus gains, or that RTP increases the social value of wind generators. Scenarios 1 and 3, which assume that there are no wind generators, use only the conventional generator set in ERCOT in 2005 to serve the load. Moreover, because there is no wind generation, these scenarios will not have any added redispatch costs due to wind forecast errors. The surplus values for scenarios 2 and 4, on the other hand, do include real-time redispatch costs and the value of lost load is computed as done in tables II through IV. Similarly, because scenarios 1 and 2 assume no RTP, electricity demand is assumed to be fixed in these scenarios.

Table VI presents, as an illustrative example, the annual surplus gains from each of introducing wind, RTP, and wind and RTP. The example assumes the lower wind forecast error variance of 0.0049 for scenarios with wind generators (scenarios 2 and 4). The example shows that on an annual basis, adding wind generation to the market can result in large social surplus gains, and that RTP can also increase
1(a)-1.66393(l)-516.956(s)3.56067(u)-5.89115(r)-4.25908(p)-5.89115(l)0.9

[1]Wind generation is costless insomuch as it does not incur any fuel cost. Many countries, including the United States, provide wind generators with generation-based subsidies or tax incentives to spur wind investment. These subsidies can be considered a cost in that society bears a tax burden to pay for them, however this is a wealth transfer between taxpayers and wind generators and as such there are no social welfare losses from such a subsidy, with the exception of some deadweight losses from taxation.

in real-time. These costs can range up to \$2.18/MWh of wind generation without the VOLL and can be much higher when lost load is considered. The results demonstrate that introducing demand flexibility in the form of RTP can reduce these integration costs, by allowing electric loads to respond to actual resource availability. RTP not only decreases the cost of redispatching the system in real-time, but also eliminates loss of load events.

Social surplus with both wind generation and RTP was compared to cases without wind or RTP to determine the