Renewable Investments in Electricity Markets

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Overview

- Investment in Electricity Markets
  - Technologies
  - Investment Equilibrium
    - SRMC Offering
  - Central Plan Investment (Risk-Neutral)
  - Carbon Pricing
  - Wind Subsidies
- Solar Power
  - Consumers' Incentives
  - Investment Policy

Technologies

We consider a set of plant types, $p \in P$ which can be used to meet demand.

Capital costs, O&M costs, fuel costs (present and forecast) and plant efficiency were assessed, for the following technologies:

- Coal, coal with CCS
- Natural gas - OCGT, CCGT, CCGT with CCS
- Nuclear
- Hydropower
- Geothermal
- Wind – onshore
- Solar PV
- Biomass and Municipal Solid Waste

Parameter – Coal (Advanced Pulverised)	**Unit**	**Value**
Overnight Capital Cost	$ / kW	2890.00
O&M – Fixed	$ / kWy	23.00
O&M – Variable	$ / MWh	3.71
Discount Rate (/100)	-	0.1
Life of plant	years	40
Fuel Cost	$ / ton	40
Fuel Energy Density	Btu / ton	19.29 million
Heat Rate	Btu / kWh	9000
Carbon Content	T CO_2 / MWh	0.841

Investment Equilibrium

Each participant in a market is maximizing its own benefit. If we assume that no agent is able to influence the price (i.e. they are price takers), we can formulate a MOPEC, where all agents are linked by prices.

$$\max \sum_{\omega \in \Omega} q_p^\omega (\pi^\omega - c_p) h^\omega - I_p Q_p \qquad \forall p \in P$$

$$\text{s.t.} \quad 0 \le q_p^\omega \le Q_p$$

Simultaneously, we must ensure that supply in each scenario meets demand.

$$\sum_{p \in P} q_p^\omega = d^\omega \quad \forall \omega \in \Omega \quad [\pi^\omega]$$

Investment Equilibrium

Suppose Q_p is invested plant type p and a set of prices and dispatch quantities π^ω, q_p^ω arise from the spot market where firms offer SRMC.

If the total revenue exceeds the total costs there is incentive to increase the capacity of the technology, driving the overall expected profit to zero.

Mathematically: If $\sum_{\omega\in\Omega} q_p^\omega(\pi^\omega - c_p)h^\omega - I_p Q_p > 0$ then Q_p should increase.

If $\sum_{\omega\in\Omega} q_p^\omega(\pi^\omega - c_p)h^\omega - C_p Q_p < 0$ then Q_p should decrease.

The equilibrium investment quantities coincide with the social welfare maximising capacities.

In an ideal energy-only market the generators should price their offers at SRMC, and with the optimal investment choices, these should deliver the required returns.

Constrained Technology

Things are different when there is a constraint on investment in a technology.

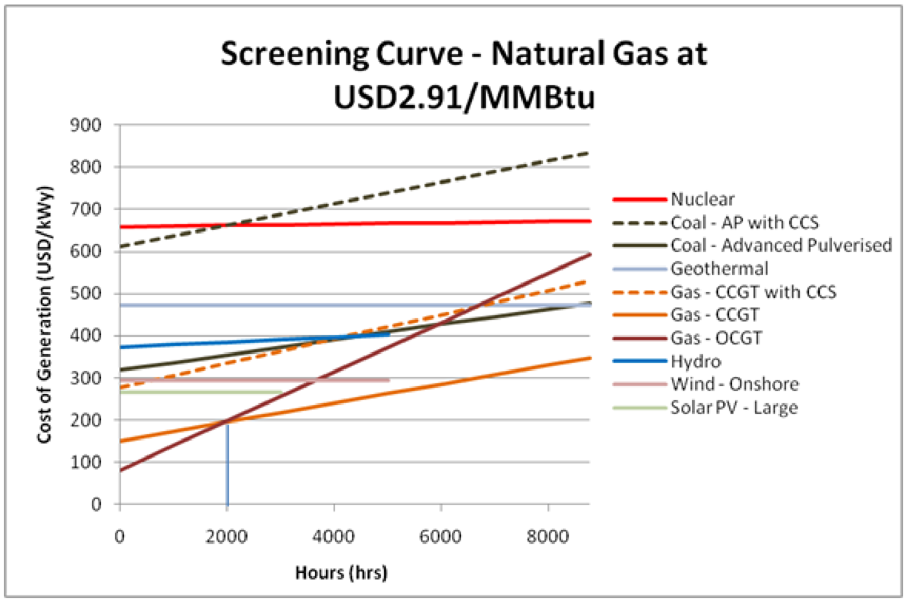
$$\max \sum_{\omega \in \Omega} q_p^\omega (\pi_t^\omega - c_p) h^\omega - I_p Q_p$$

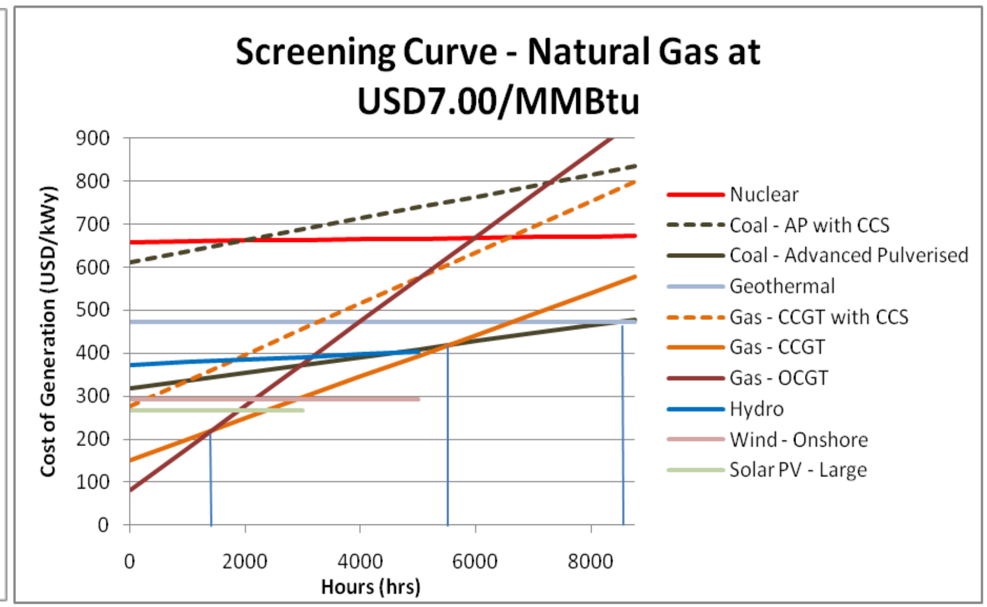
$$\text{s.t.} \quad 0 \le q_p^\omega \le Q_p, \qquad \forall \omega \in \Omega$$
$$0 \le Q_p \le u_p$$

If this upper limit on investment is binding at equilibrium, then that technology will make a positive return (including investment costs).

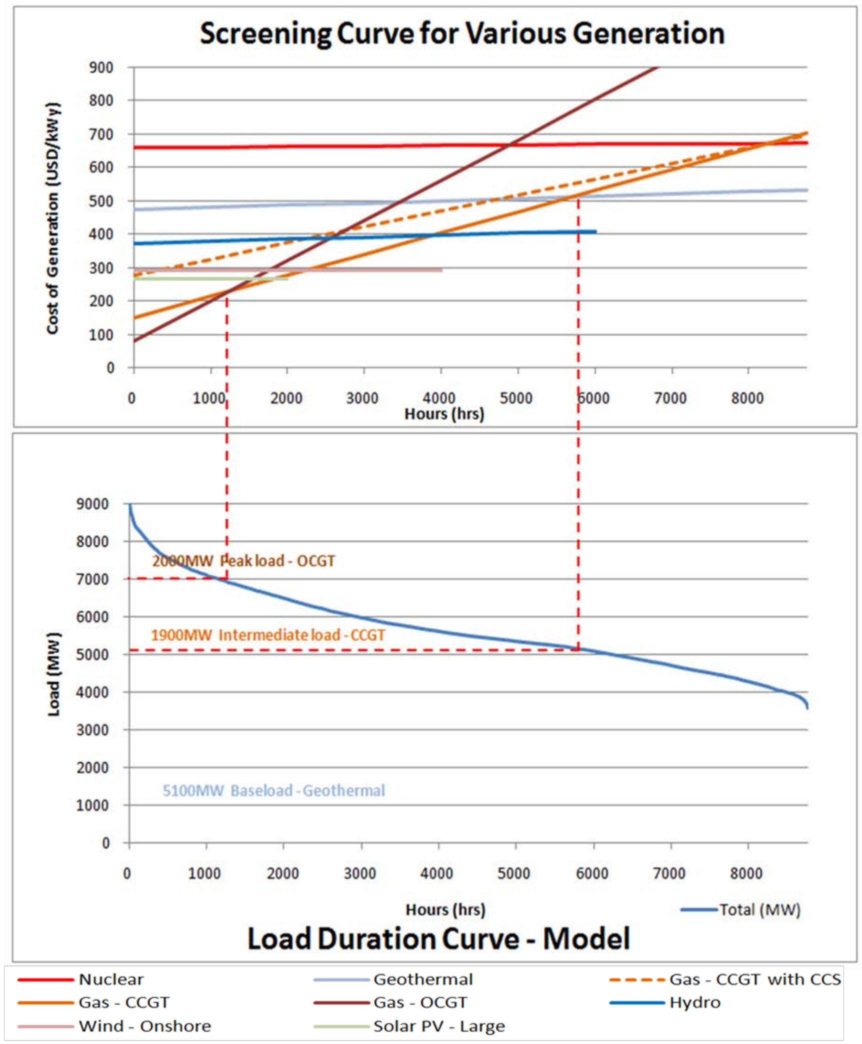
Screening Curve

The total annual costs can be plotted as a function of utilisation.





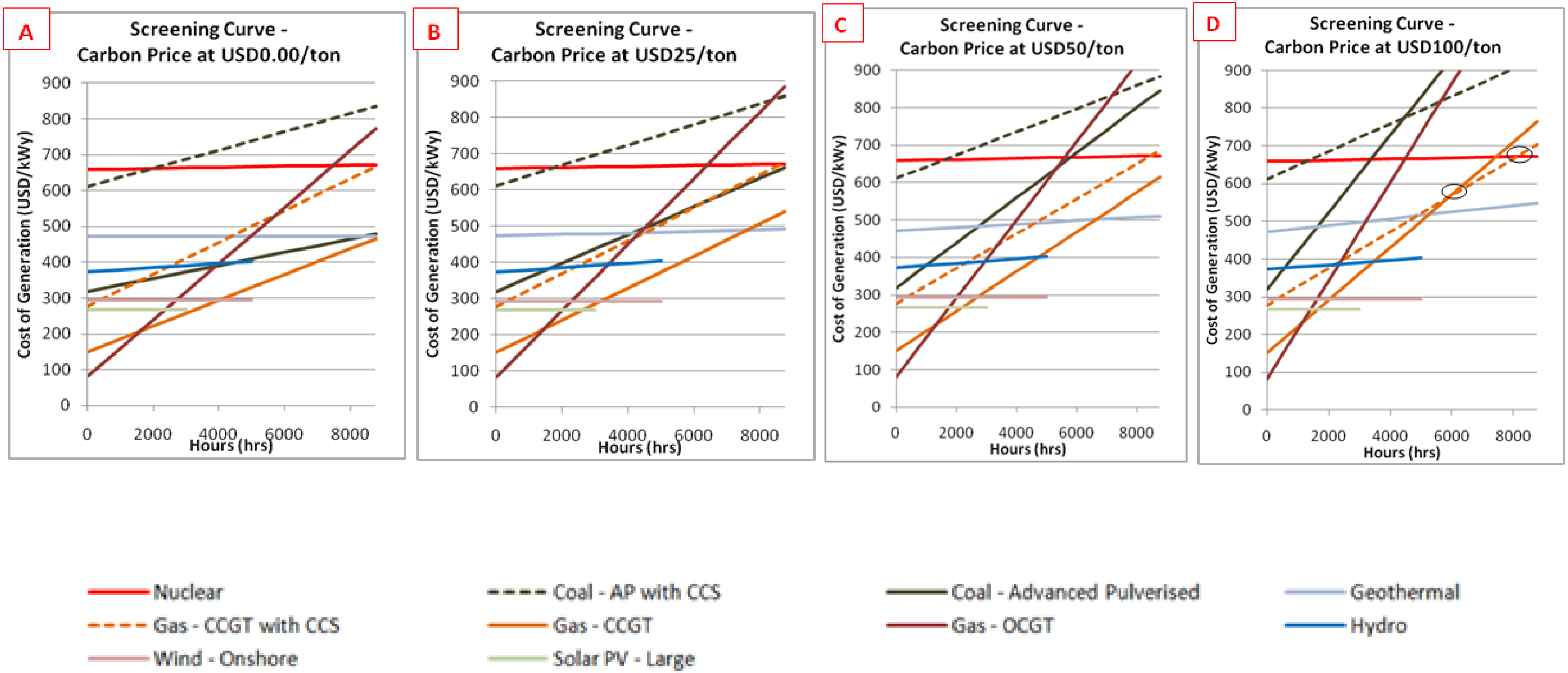
Screening Curve



Emissions Charges

- Recent changes in New Zealand's emissions trading scheme policies, such as the removal of the 2-for-1 scheme, have caused prices of carbon credits to rise.

Emissions Charges

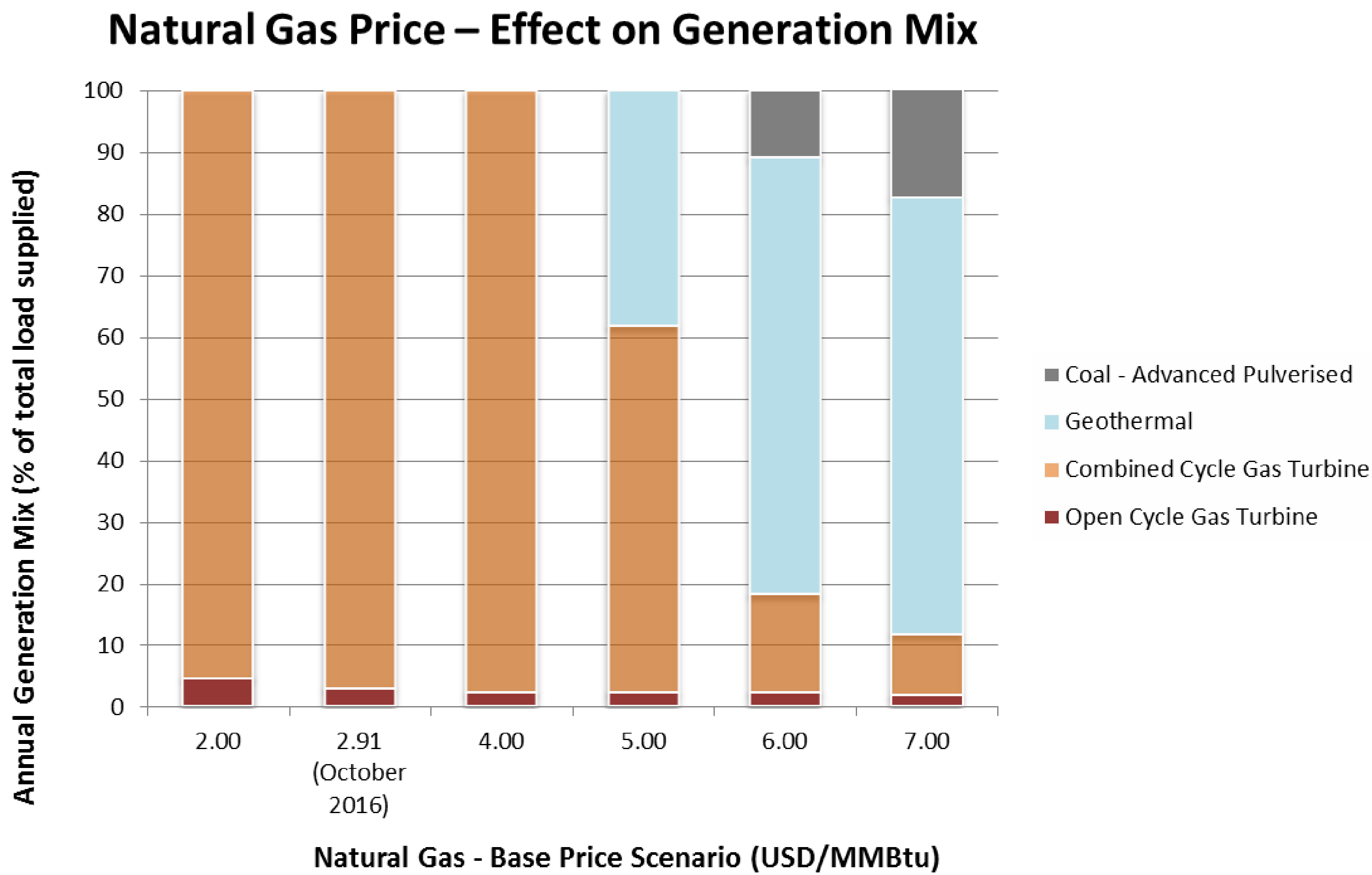


Central Plan

$$\min_{\mathbf{Q}} \quad \sum_{p \in P} I_p Q_p + \mathbb{E}_{\omega}[C(\mathbf{Q}, \omega)]$$
$$\text{s.t.} \quad l_p \leq Q_p \leq u_p$$

$$C(\mathbf{Q}, \omega) := \min_{\mathbf{q}^{\omega}} \quad \sum_{p \in P} \sum_{t \in T} c_p q_{p,t}^{\omega}$$
$$\text{s.t.} \quad 0 \leq q_{p,t}^{\omega} \leq \alpha_{p,t} Q_p \qquad \forall p \in P, t \in T$$
$$\sum_{t \in T} q_{p,t}^{\omega} \leq G_p(\omega) \qquad \forall p \in P_H$$
$$\sum_{p \in P} q_{p,t}^{\omega} = d_t \qquad \forall t \in T$$

Preliminary Results – Gas Prices



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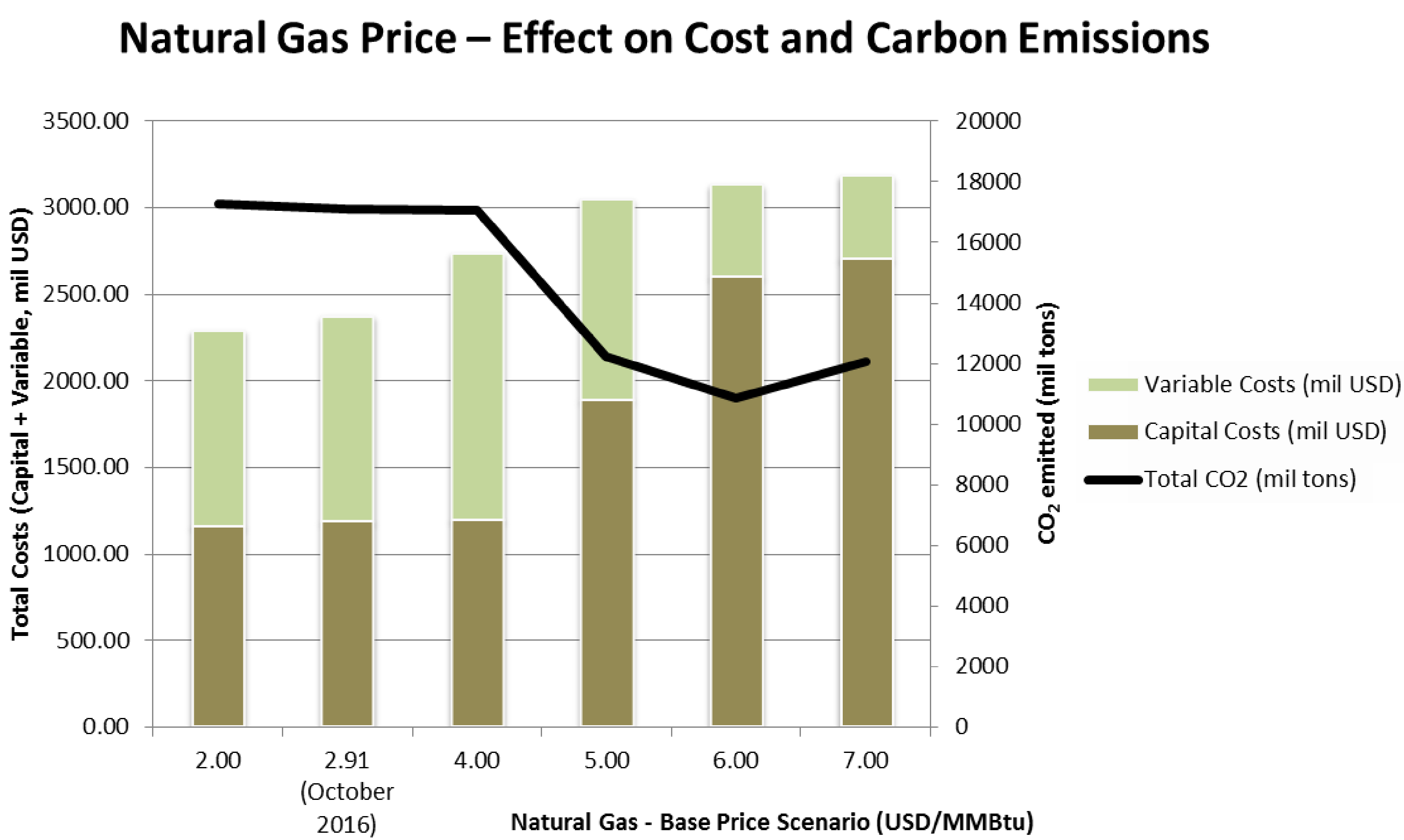


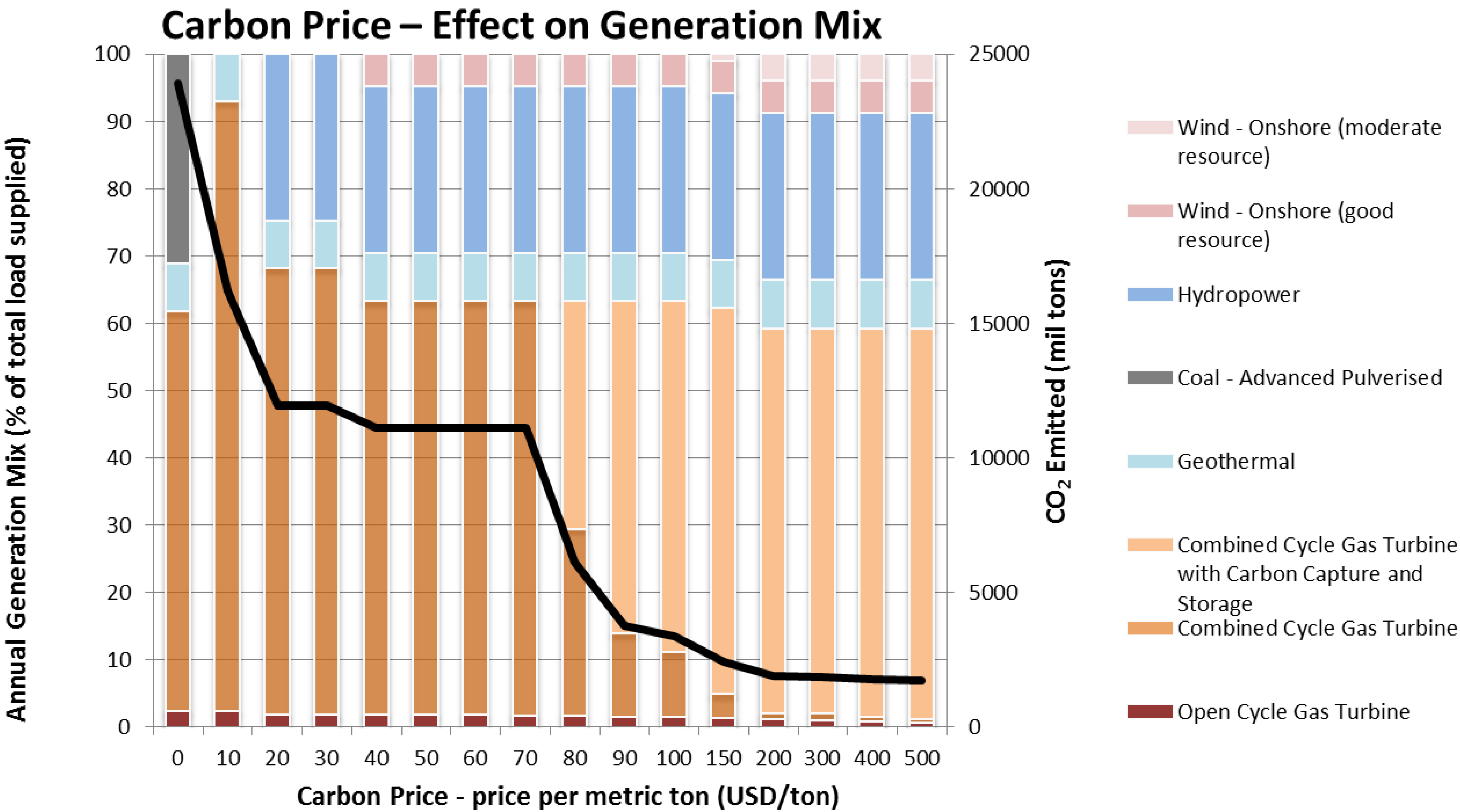
Case Study – Carbon Charges

We wish to investigate how the optimal investment mix will change as a function on carbon charges.

The case study is for the PJM system, and therefore will limit the amount of geothermal and hydropower. We have not allowed nuclear power.

The price of gas is assumed to be approximately $5 /MMBtu.

Case Study – Carbon Charges



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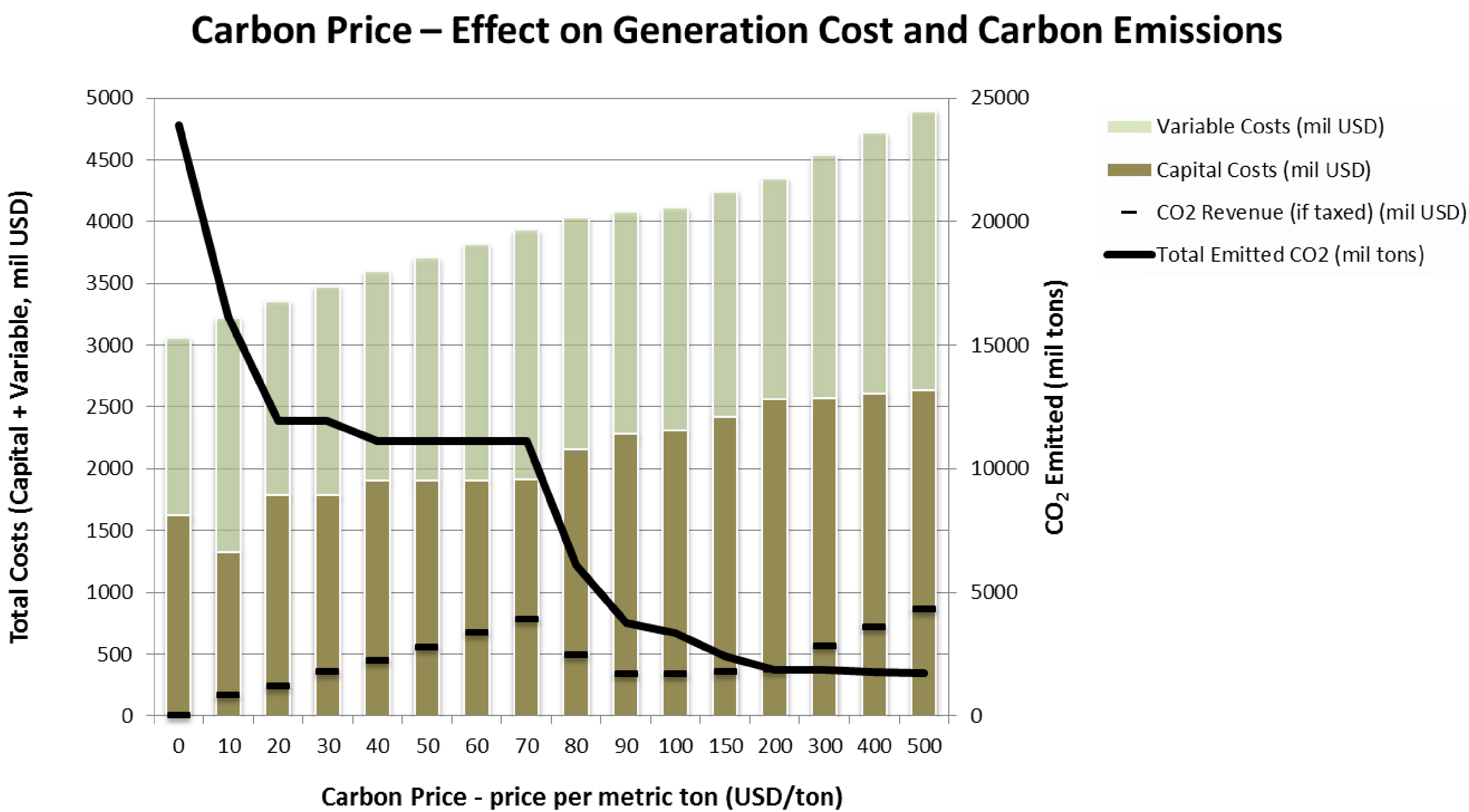


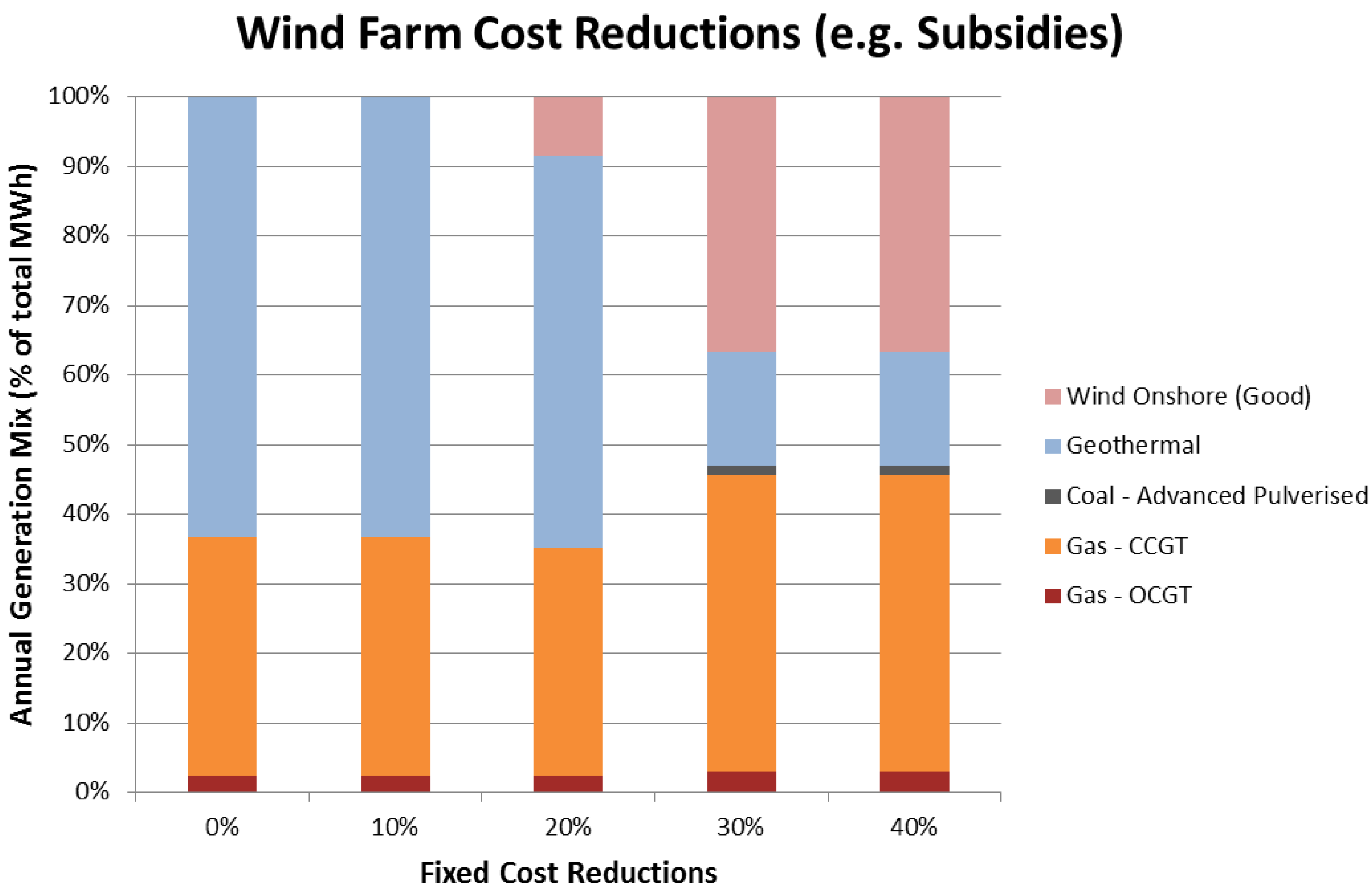
Case Study – Wind Subsidy

It is well known that volatile renewables place extra strain on the system.

In this case study, we wished to see the impact of a drop in wind turbine prices (whether it be via subsidy or simply reduced prices due to economies of scale).

The setting for this experiment is a market with a moderately high gas price, and plentiful potential geothermal resources.

Case Study – Wind Subsidy



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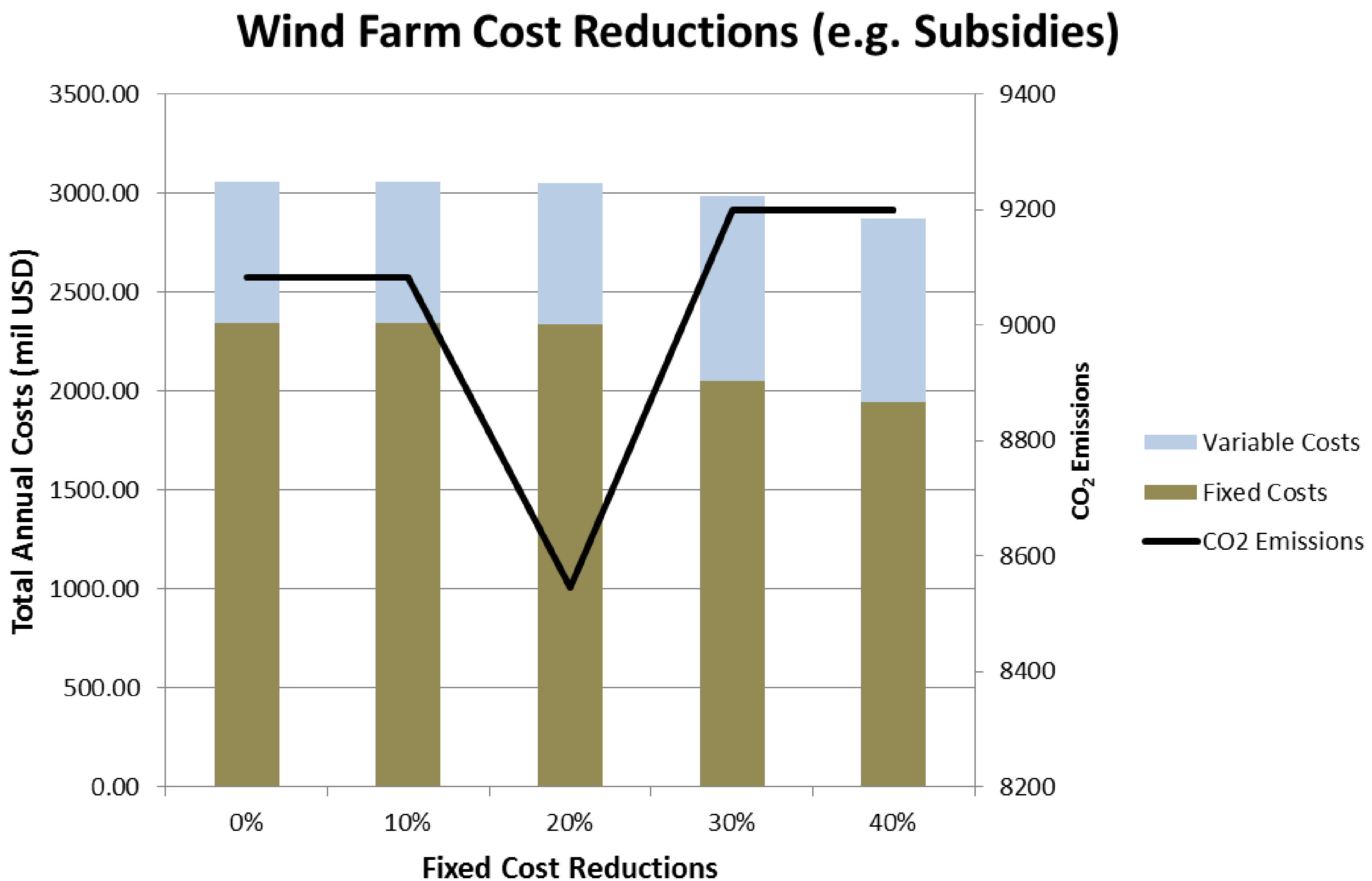
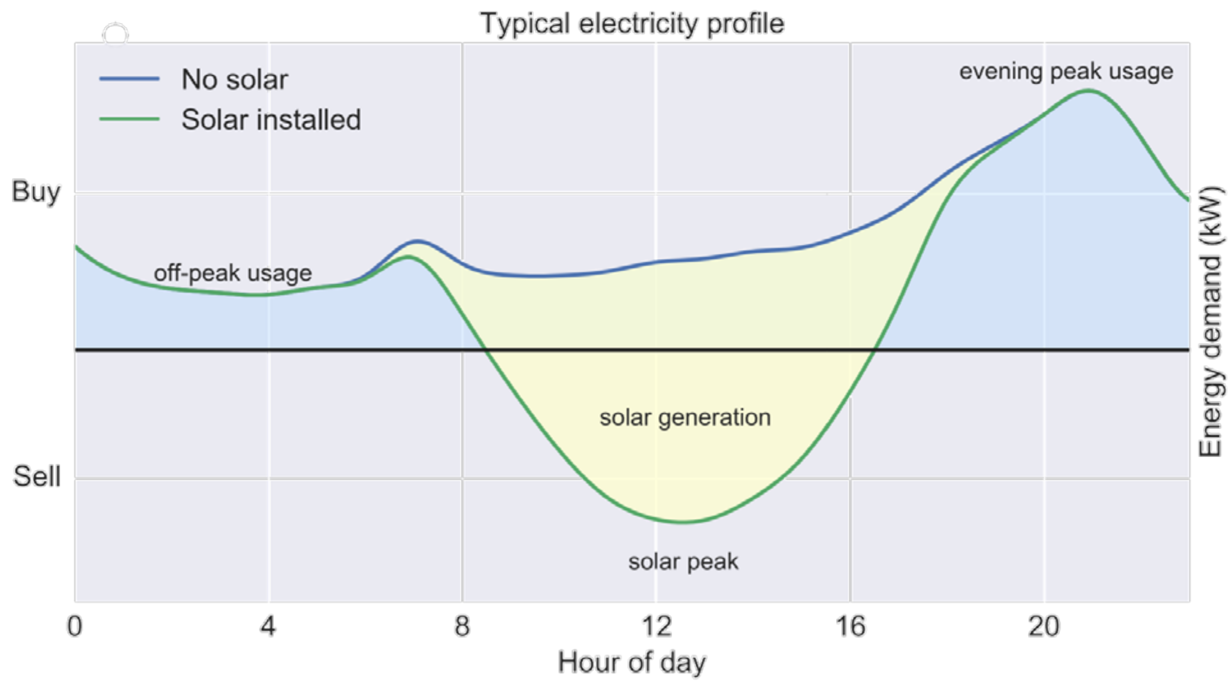


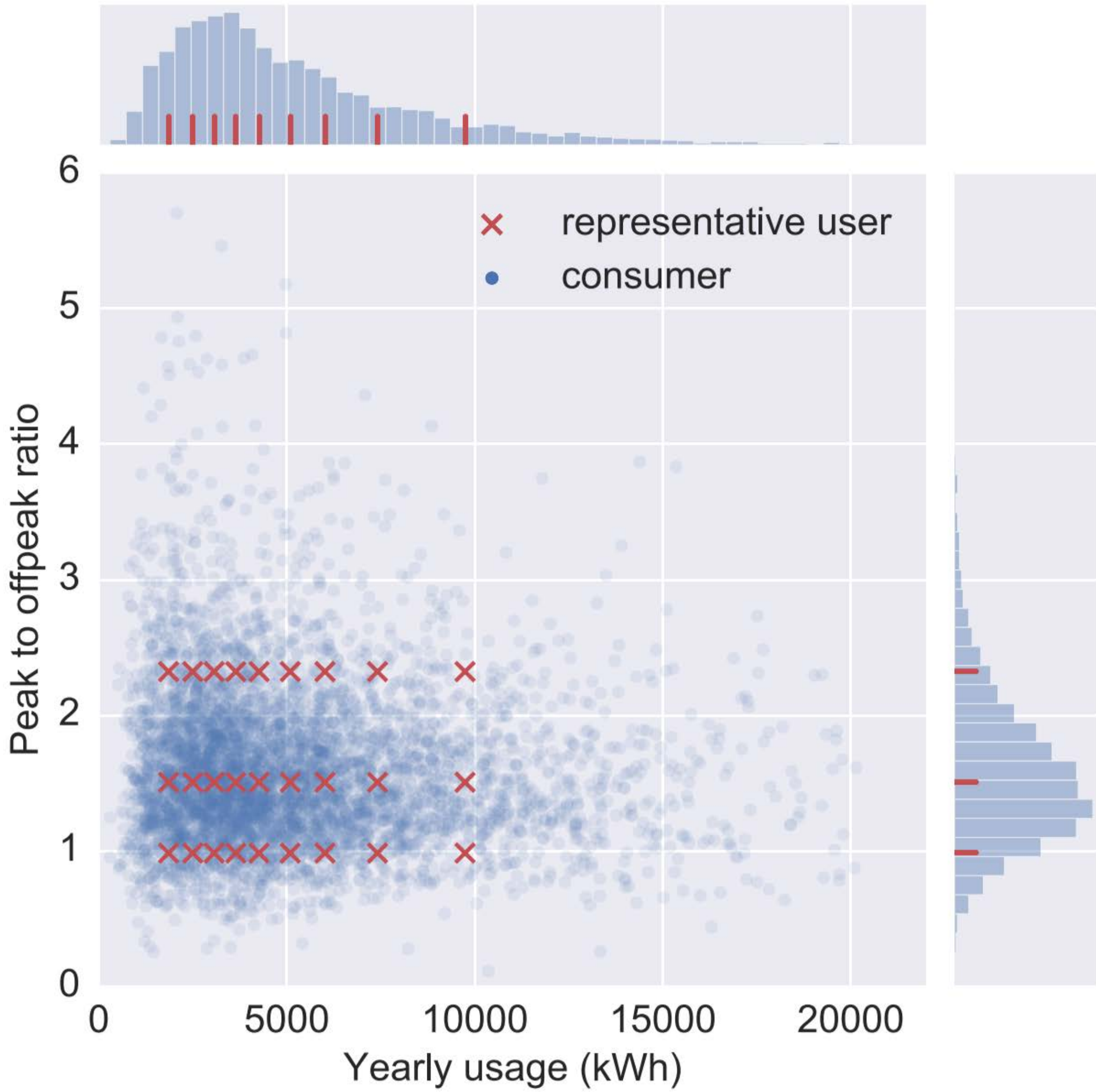
Solar Panels?

In all the examples shown the model has had the option to build solar panels, but it has not been an efficient investment.

In fact, for the system to choose to utilise solar panels, its price must drop by more than 50%.



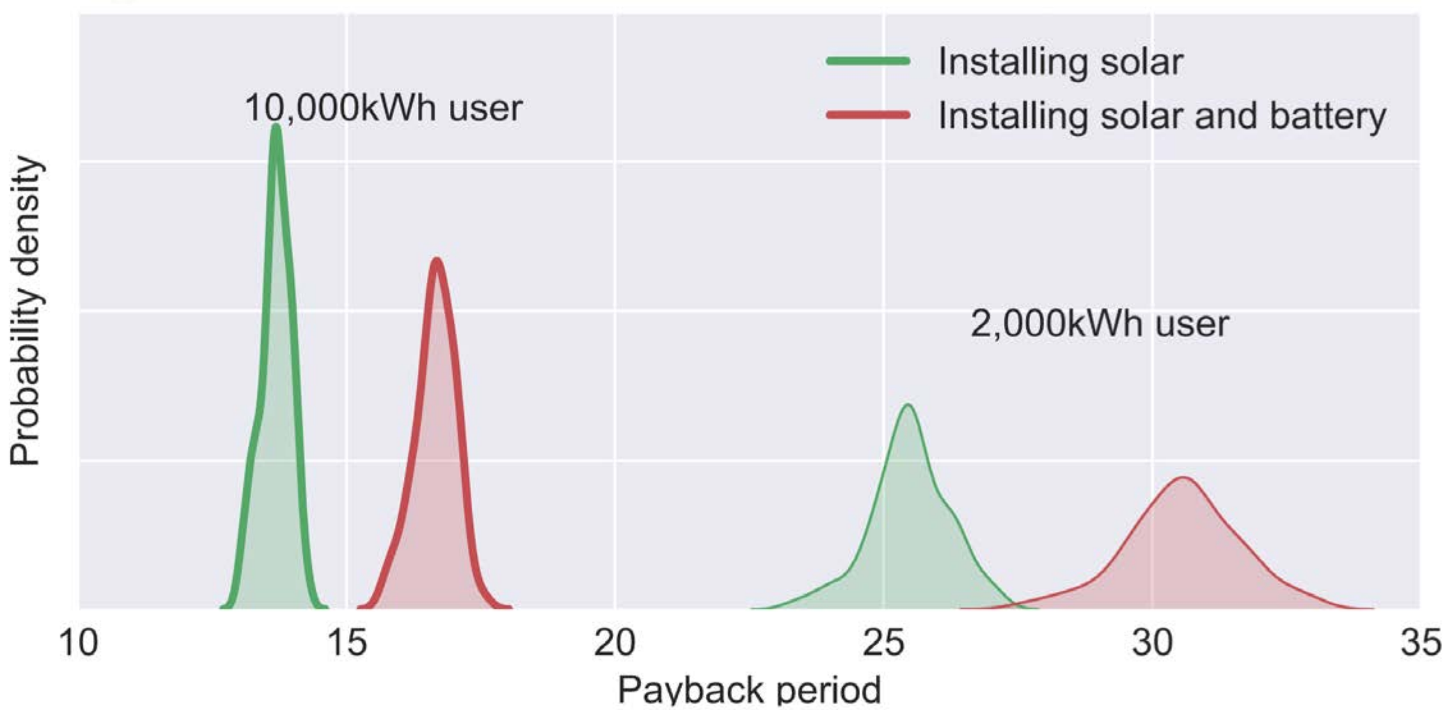
Types of Consumer



Consumer benefits of Solar

A typical 3kW system costs approximately NZ$10,000 to install.

Using floating mortgage rates, as a proxy for a consumer's discount rate, and the estimating possible inflation rates for electricity prices using historic data, we can estimate a distribution of payback periods for solar panels, for different types of consumers.



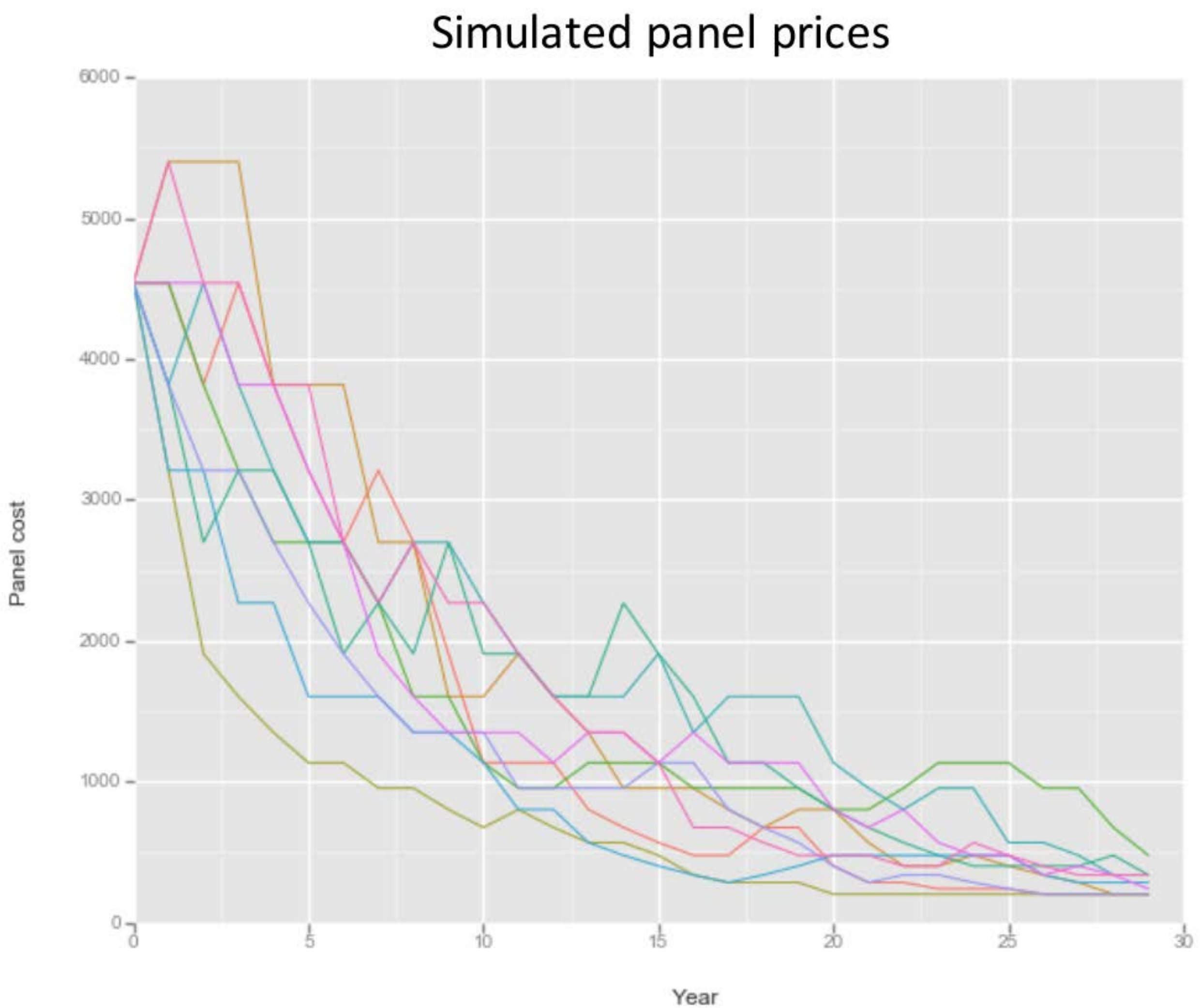
Solar Investment Policy

However, for a rational consumer the decision to install solar shouldn't simply be based on whether the pay-back period is acceptable.

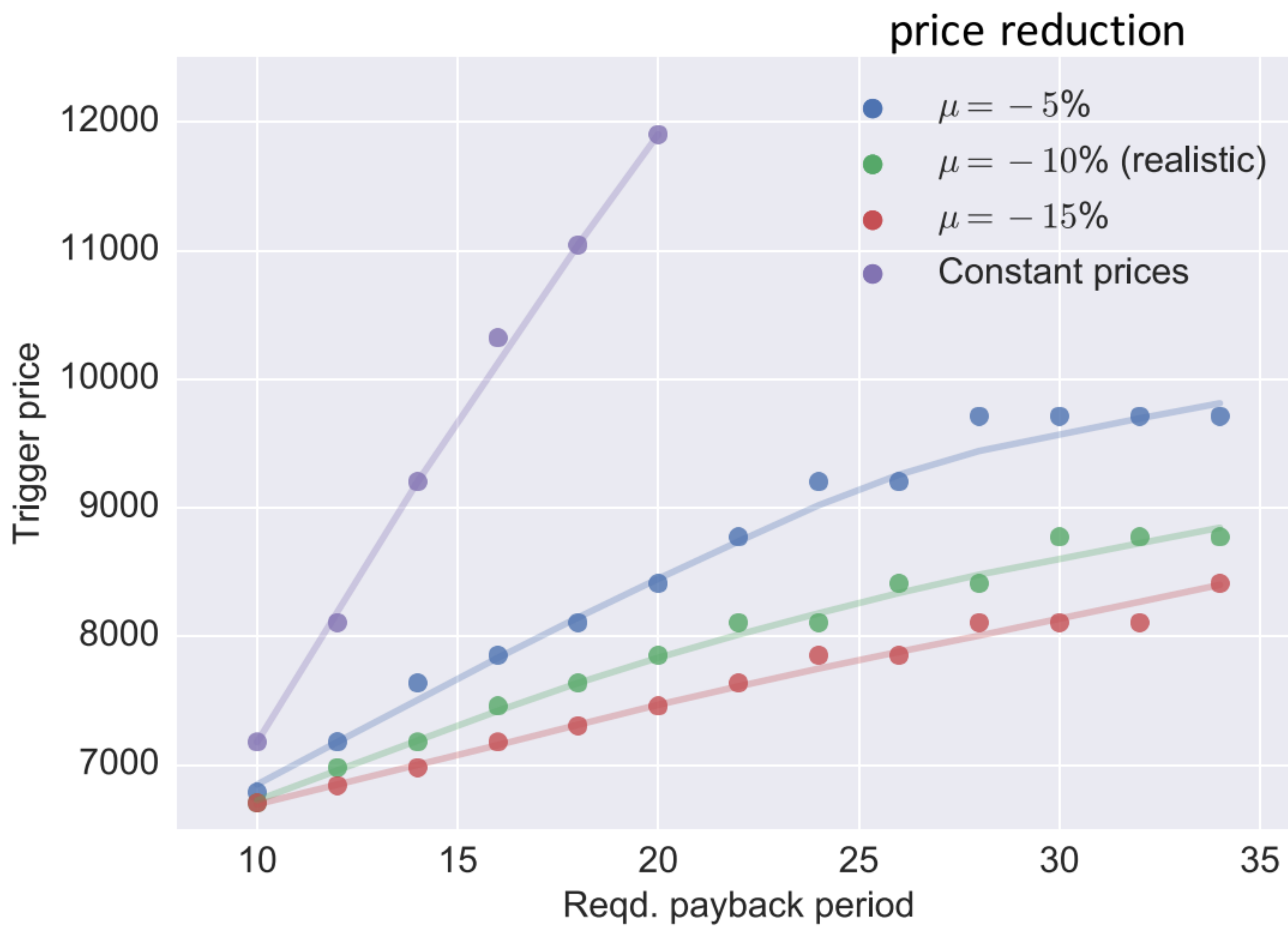
One must also consider the rate at which solar panel prices are dropping.

By combining this information within a stochastic dynamic program, we devised policies for this optimal time to invest in solar panels.

Solar Investment Policy



Solar Investment Policy



Conclusions

There can be many benefits from renewable energy, however, one must always analyse the extent of those benefits for a particular market.

We showed that neither wind nor solar appear in the optimal central plan investment for electricity markets, unless carbon charges are imposed, or subsidies are given.

With subsidies, wind could become a dominate part of the market, but this could make baseload plants, such an geothermal, unprofitable.

Finally, we considered investments in solar from the perspective of the customer. For customers who can borrow cheaply, the solar proposition is good – however, at the moment the costs of panels are dropping at a faster rate than the savings that can be made.