Totara Valley Rural Distributed Energy Project

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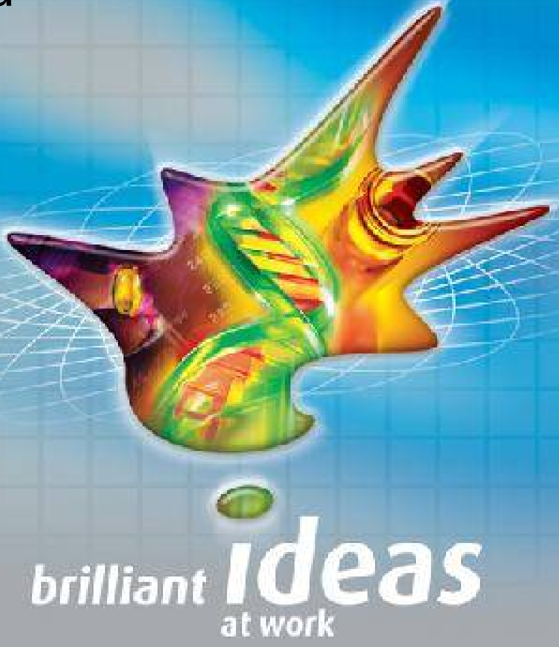

Project Status and Some Lessons Learned

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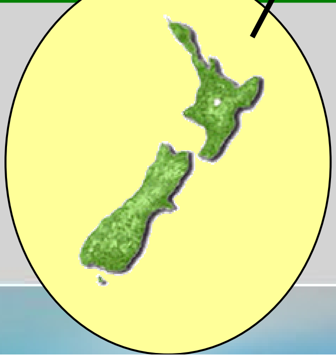
Where in the World Are We?

Population: 4 million

Land Area: 265,600 sq km

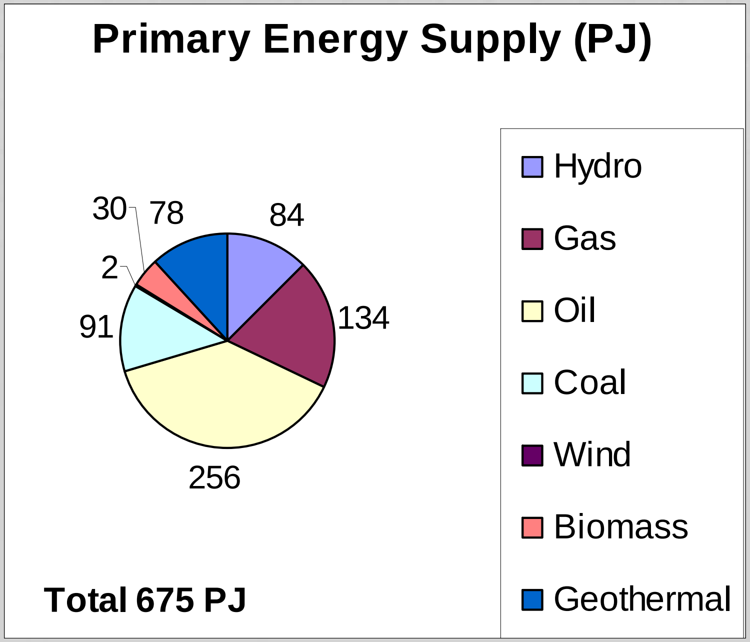
1920 km from Australia

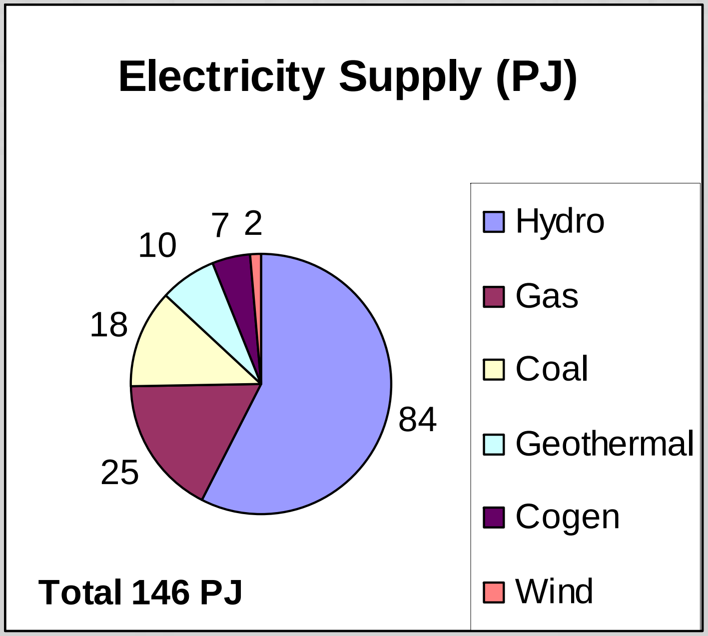


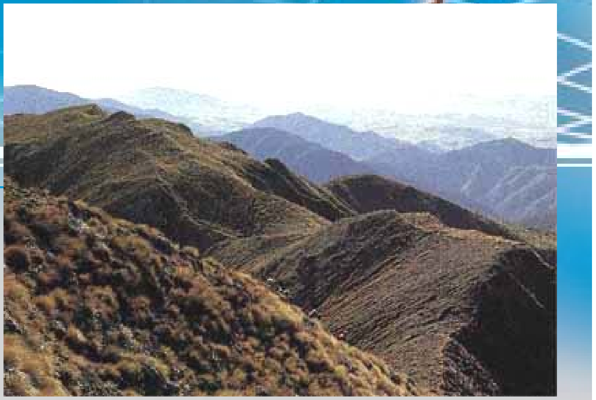
New Zealand

New Zealand Energy Supply

- **A very small component of the world supply**
  - Total energy CO_2 emissions in 2005 were estimated at 35,910kt

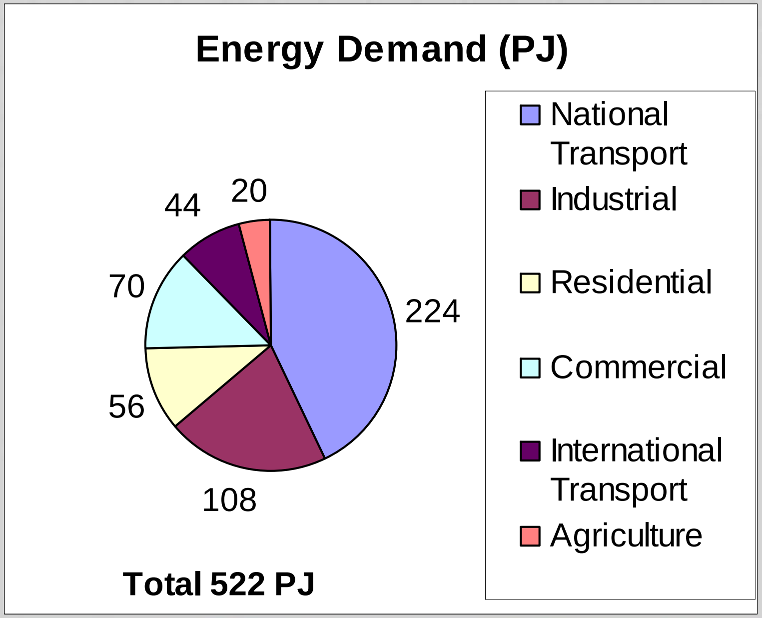


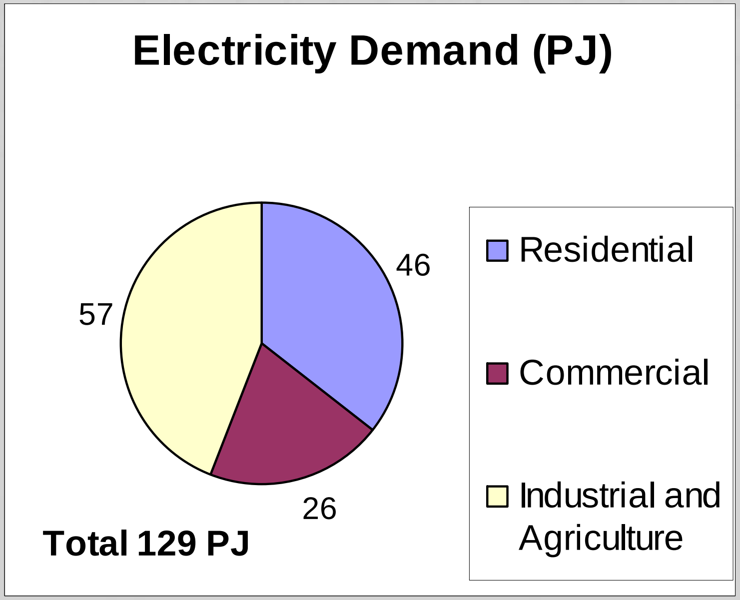




New Zealand Energy Demand

- **Electricity Trends**
  - Increase 1.8%/yr
  - 9% lost in transmission and distribution
  - Renewable supply 24,000 GWh, (63%) and reducing

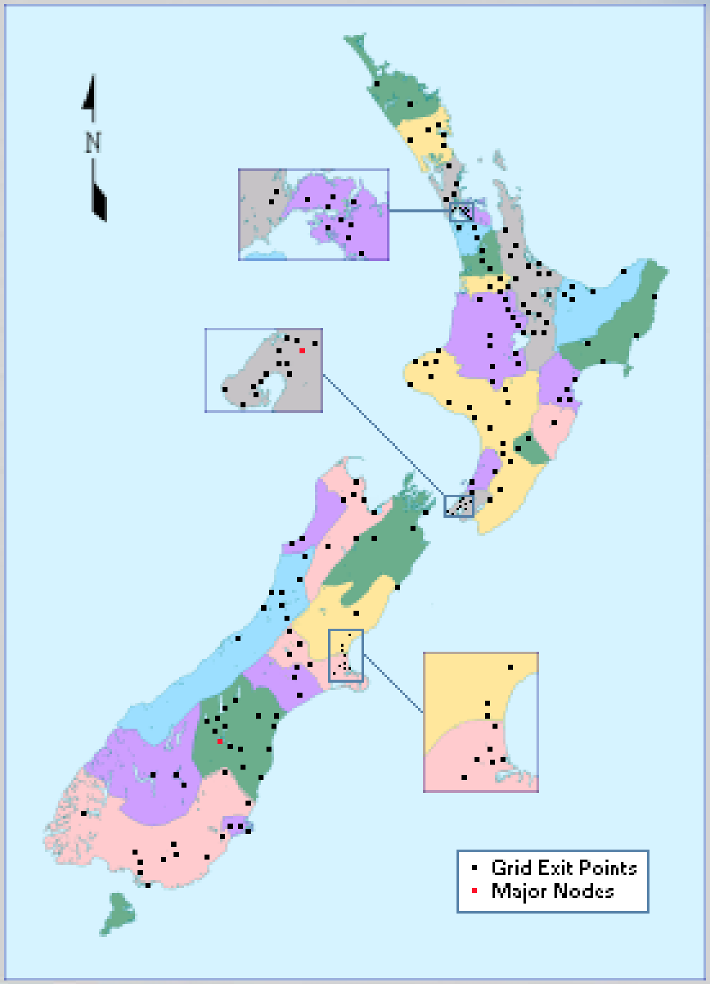




New Zealand Distribution System

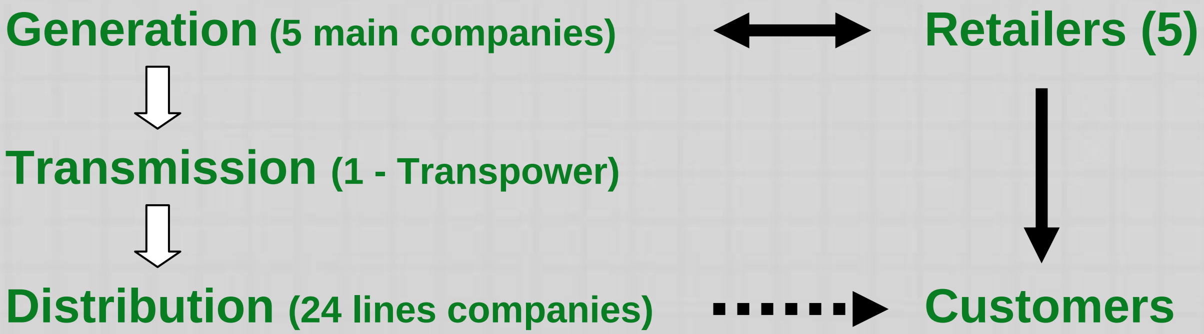
Map showing electricity grid exit points and major nodes

- **Average statistics**
  - 22 Consumers per km MV line
  - SAIDI = 140min
  - Wholesale price 7.4NZc
  - Residential price 16.5NZc
  - Distribution charge 4.5 NZc
  - CO_2-eq from sector 7,668kt



Regulatory Environment for Distributed Generation

- **Supply Industry Structure**



Generation (5 main companies)

Retailers (5)

Transmission (1 - Transpower)

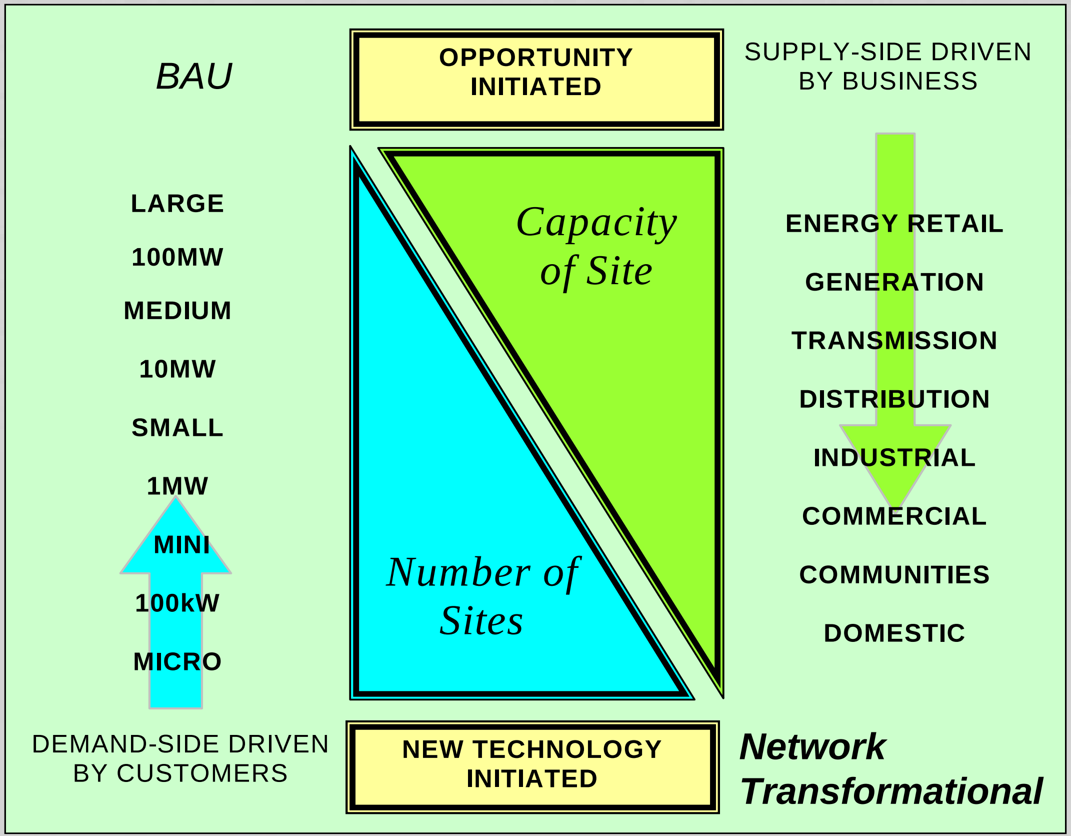
Distribution (24 lines companies)

Customers

- **Proposed distributed generation regulations (mid 2007?)**
  - Simplified transaction costs for connection of < 10kW/40,000kWh
  - Export kWh meter required
  - Export price negotiated with Retailer
  - 2013 cessation of obligation to supply

Distributed Generation Vision

- **Through weight of numbers Microscale DE will deliver a network transformation**



BAU

OPPORTUNITY INITIATED

SUPPLY-SIDE DRIVEN BY BUSINESS

LARGE
100MW
MEDIUM
10MW
SMALL
1MW
MINI
100kW
MICRO

Capacity of Site

Number of Sites

ENERGY RETAIL
GENERATION
TRANSMISSION
DISTRIBUTION
INDUSTRIAL
COMMERCIAL
COMMUNITIES
DOMESTIC

DEMAND-SIDE DRIVEN BY CUSTOMERS

NEW TECHNOLOGY INITIATED

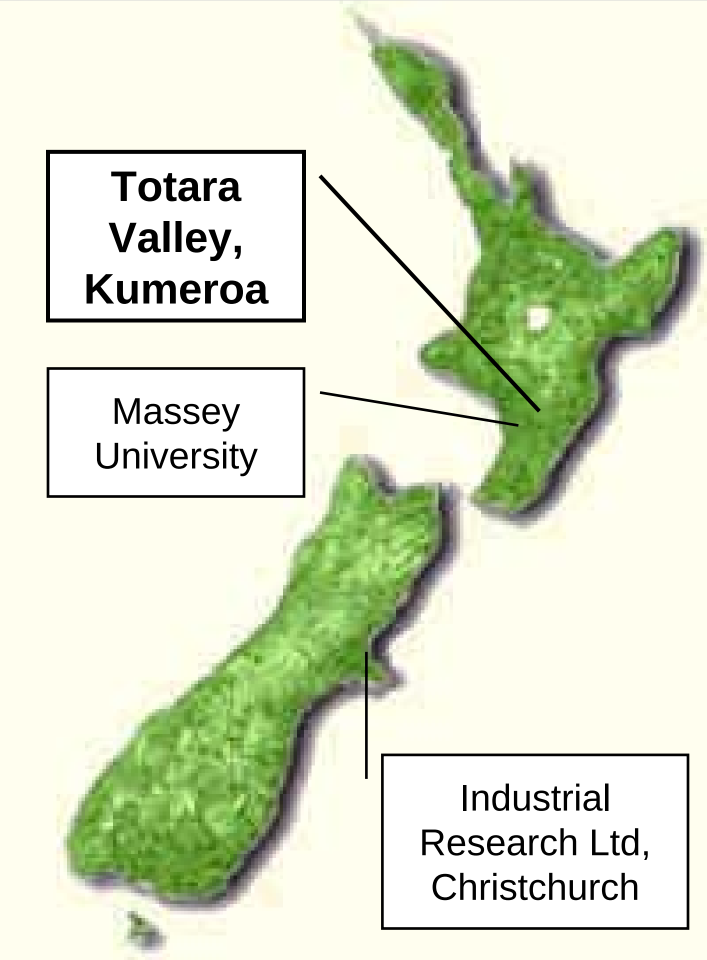
Network Transformational

- **Large scale DG is supply side / business driven**
- **Small scale DG will be demand side driven, but will be influenced by supply side strategies**
- **A market framework that recognises the value of the full range of DG opportunities is necessary**

Status of DG and RAPS

- **Supply Industry**
  - Modest overall interest – wait and see attitude
- **Government regulatory/operational position**
  - "Let the market decide"
  - Recent signs of a more proactive approach
- **Government funded research activities**
  - Two small rural DG demonstration projects
  - Two small Maori RAPS Projects
- **The rural DG projects**
  - Totara Valley – IRL and Massey University (6 years)
  - Power to the Coast - IRL and Ngati Pooru Hauora (4 years)
    - Resource assessment (solar, wind, microhydro, geothermal)
    - Demonstration: 2kW rooftop solar PV, 5 microwind turbines

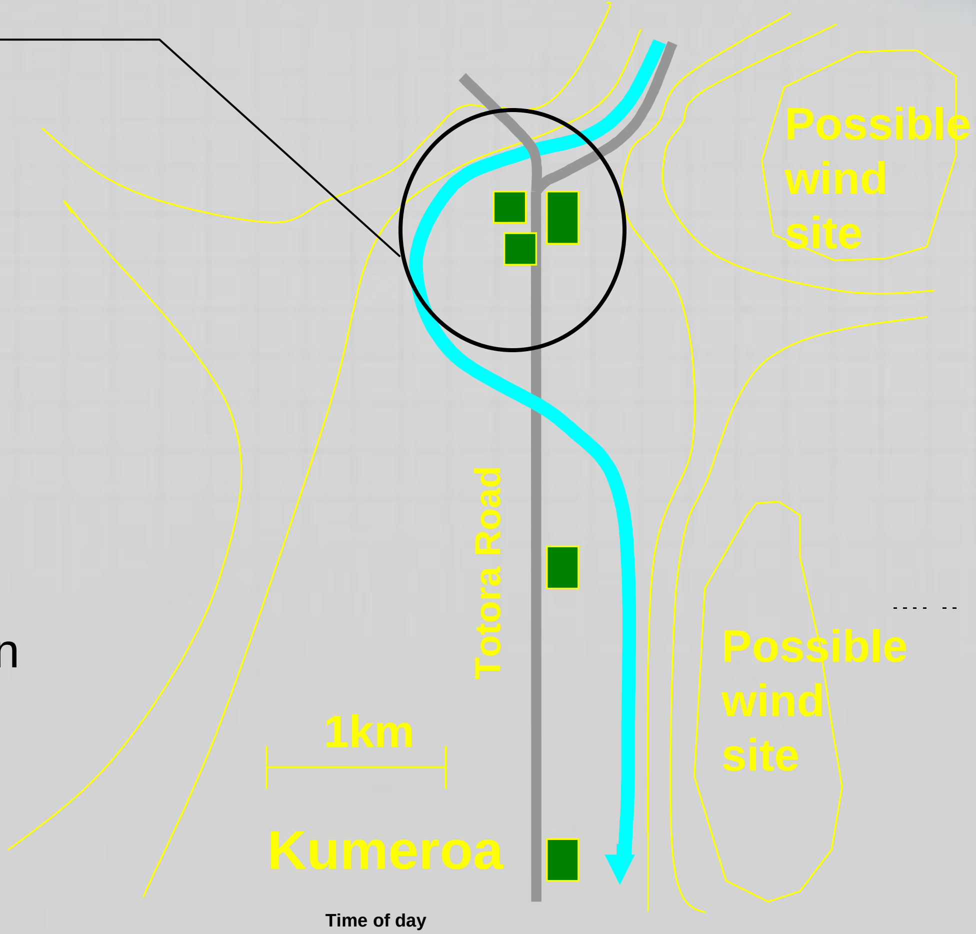
Totara Valley DE Project



A Typical Rural NZ Location

The Totara Valley Site

Case study site - 3 farms: 5 houses



- **Involvement from**
  - The Residents
  - Massey University
  - Industrial Research Ltd
  - Scanpower (distributor)
  - Consortium of 8 distribution companies
  - Mainpower

Purpose and Status

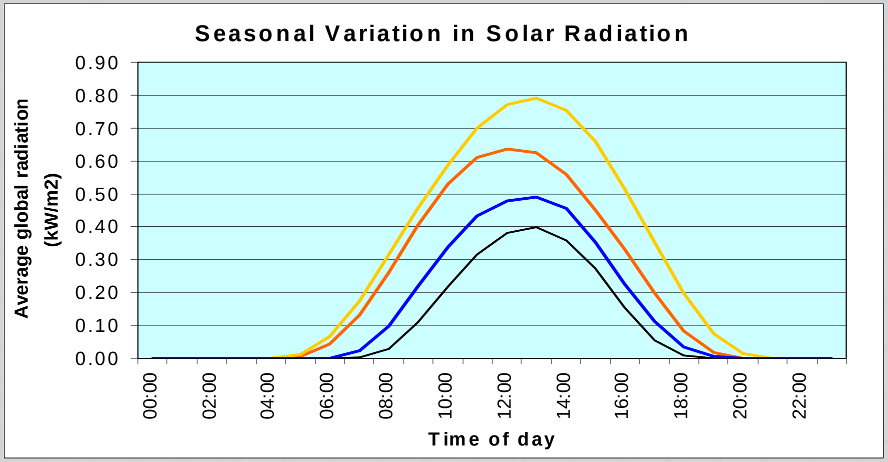
- **IRL**
  - Vision - development of microgrids
  - Pilot site for technology integration and demonstration
  - Study the impacts of distributed energy on rural supply
  - Local renewables integrated with fuel cell generation

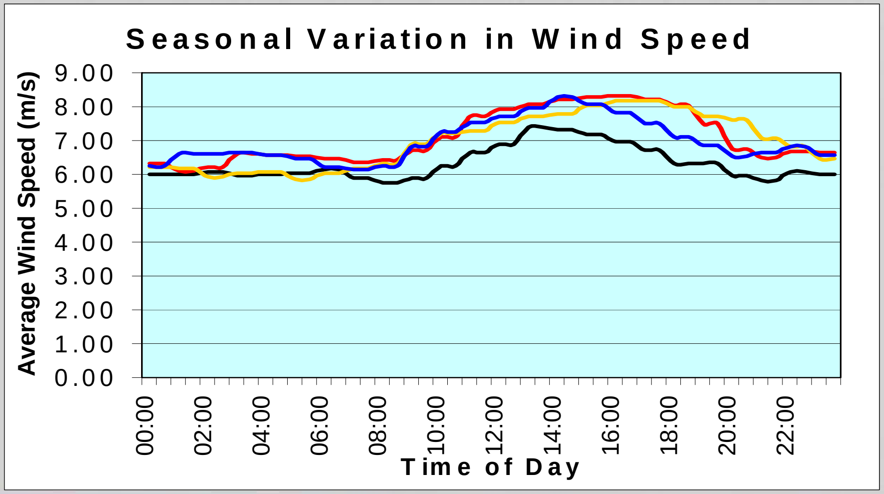
- **Massey University**
  - Massey vision – self sufficiency through renewable energy
  - Student resource assessment projects

- **Status**
  - Five years into a 6 year study
  - Modestly funded – limited to small “behind the meter” renewable and demand side technologies
  - Support from a range of lines companies

Available Resources

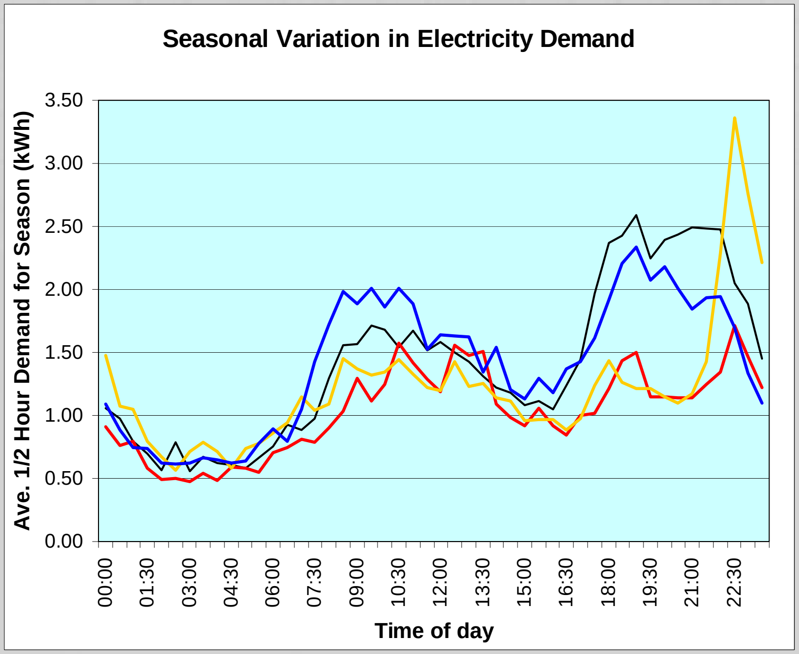
- **Local energy resources**
  - Solar
  - Wind
  - Microhydro
  - Ambient heat
  - Biomass – wood burners in all houses
  - Liquid fuels
  - DSM and energy efficiency
- **Network electricity**
  - 11 kV 3 phase – supplied to all farms



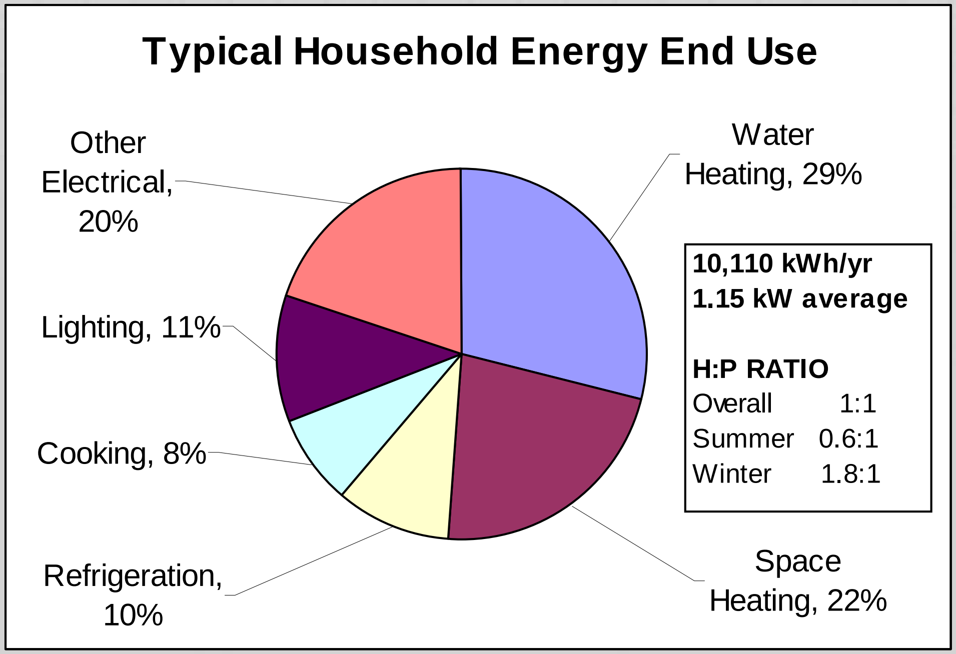


Load Monitoring

- **Electricity demand**
  - 3 farms
  - Ave 7kW, peak ADMD 25kW
- **Typical heat and power energy mix**



Seasonal Variation in Electricity Demand



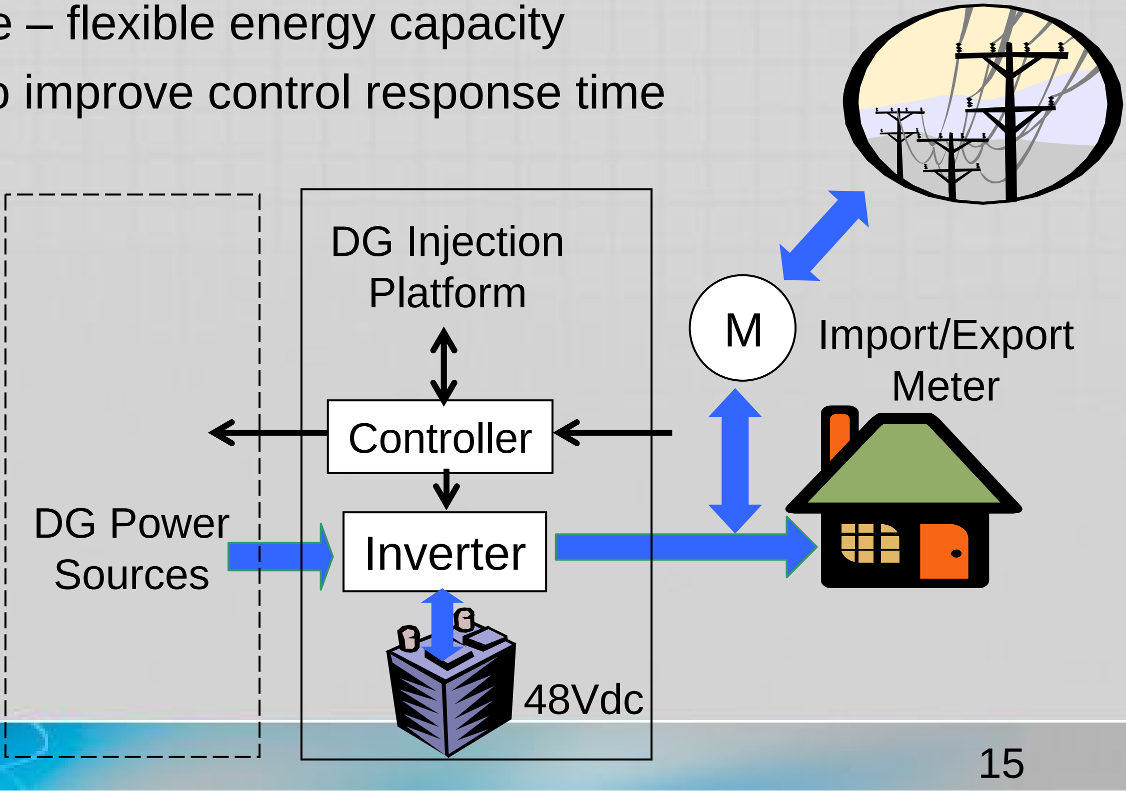
Typical Household Energy End Use

DE Technologies Installed

- **Solar**
  - 1 solar hot water system
  - 3 x 120W grid connected solar PV arrays
- **Wind**
  - 2 kW 24V WTG
- **Hydro**
  - 1 kW high head pelton wheel
- **Ambient heat**
  - 1kW hot-water heat pump
- **Biofuel**
  - 4kW 48V diesel genset
- **Total Capacity**
  - Power – 7.5kW mixed
  - Heat – about 5kW mixed

DG Injection Platform Used

- **General purpose interactive inverter platform**
  - Current mode injection from 48Vdc, externally controllable
  - 2kW modules connectable as 1, 2, 3 phase (230/400Vac)
  - Buffer battery storage – flexible energy capacity
  - Upgrade underway to improve control response time



DG Injection Platform

Controller

Inverter

48Vdc

DG Power Sources

M

Import/Export Meter

Experience in Brief

- Solar hot water: retrofit installation issues, performance monitoring difficult, incompatible with wetbacks – no problems since
- H/w heat pump: simple retrofit installation, compatible with wetbacks - no problems reported
- Solar PV: installation straight forward, initial operational problems of inverters tripping out resulted in supply transformer tap change – no problems since
- Wind generator: Cost of power connection prohibitive, HyLink concept being demonstrated
- Biodiesel genset: installed at a woolshed and operated automatically every day for several weeks, but not run recently due to lack of a biodiesel supply, too noisy for regular use
- Microhydro: uses an EcoSolutions pelton wheel operating at 48Vdc, consent process costly relative to return

Lessons to Date in Brief

- **Education, training and demonstration**
  - Good for student projects – over 10 undertaken so far
  - But site progress difficult due to discontinuity and inexperience
- **Network impacts**
  - All local generation is network connected via inverters at the household level
  - No evidence of any power quality issues to date
- **Uptake**
  - Because of regulated low fixed line charges for small users, the best option at present is to avoid exporting power
  - Only microhydro generation is economic on current kWh prices
  - Even Totara Valley is very remote when it comes to getting things fixed!

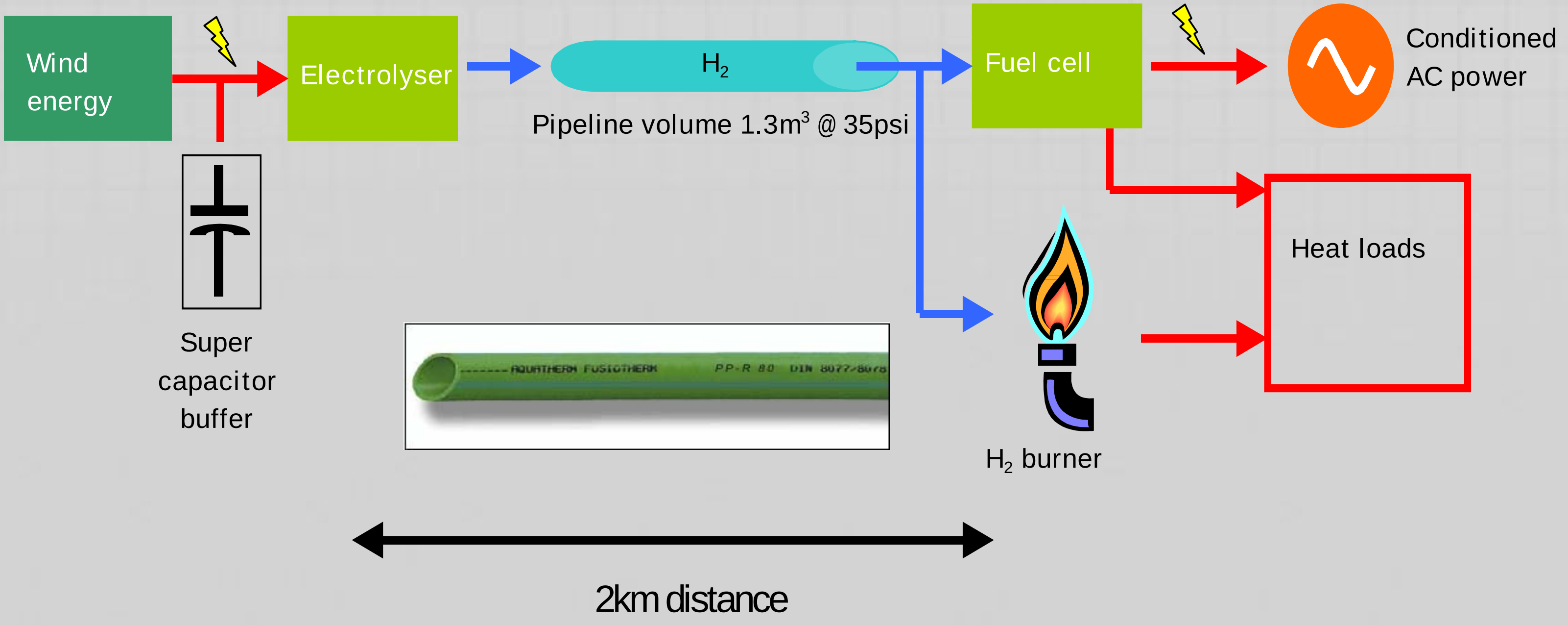
Plans for This Year

- **Integration of a hydrogen energy system**
  - Wind sourced hydrogen pipeline demonstration
- **Install a small microgrid system at the farm community level**
  - 3 x 6 kW inverter injection platforms (1 per farm)
  - Operate on a community or ADMD basis
- **Final project report**
  - June 2008

"The meter does run backwards!"

Hydrogen Energy System

- **HyLink - A hydrogen energy pipeline-store**
  - Wind generator and electrolyser at the wind site
  - 2km polymer fuel pipe
  - Fuel cell and hydrogen water heater at the farmhouse
  - System currently being installed

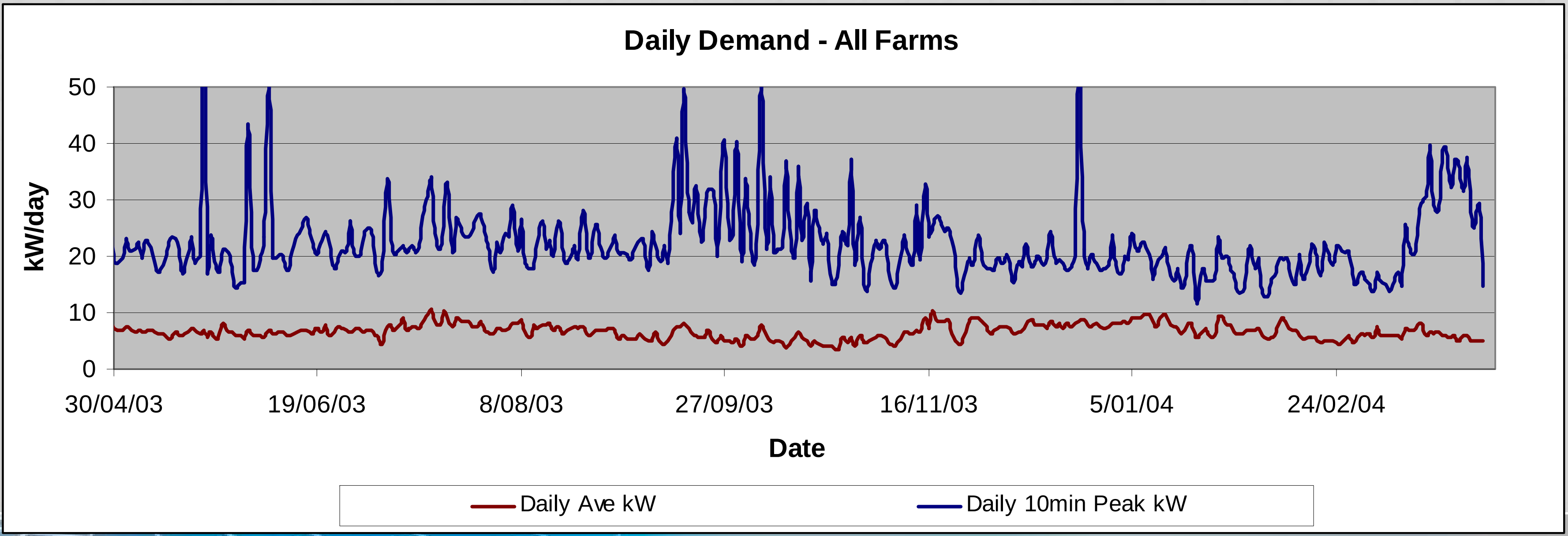


Small Microgrid Demonstration

- **DG can benefit the network when**
  - Projected load growth will exceed network capacity
  - Approaching the end of its useful life
  - Increased renewable energy supply is an objective
- **Intermittent renewables must be backed by firm generation**
  - Solar, wind, hydro cannot provide adequate reliability
- **Explore the microgrid concept at a community level**
  - Demonstrate network capacity and power quality support by control of 3 individual dispatchable microgeneration systems through
    - A broadcast network control signal (ripple)
    - Individual sensing of local supply undervoltage
    - Time based local demand profile smoothing
    - Revert to individual standby generation on loss of network voltage

Small Microgrid Demonstration

- **Demand All Farms**
  - Peak ½hr: 25.5 kW, peak 10min: 70kW (shearing?)
  - Annual average 6.75kW, daily varies about 4 to 10kW
    - Because of winter log fires, daily ave. demand does not vary greatly
  - Modest levels of storage and dispatchable generation capacity (~15kW) are required to smooth the total demand



Small Microgrid Demonstration

- **After Diversity Maximum Demand (ADMD)**
  - Typical reduction

# of Houses	**1**	**5**	**20**	**100**
Ratio of MD	1	0.62	0.34	0.24

- **From load profile data**
  - Reduction in MD/house (7 houses) is 0.5, ie ADMD capacity/house is reduced to 50% of the individual MD/house
  - ADMD, not demand at individual houses defines the network capacity limit.
- **How to determine when to turn the individual microgenerators on for network support purposes?**
  - Low X/R for many rural lines
  - Control system design and selection of genset systems is under way

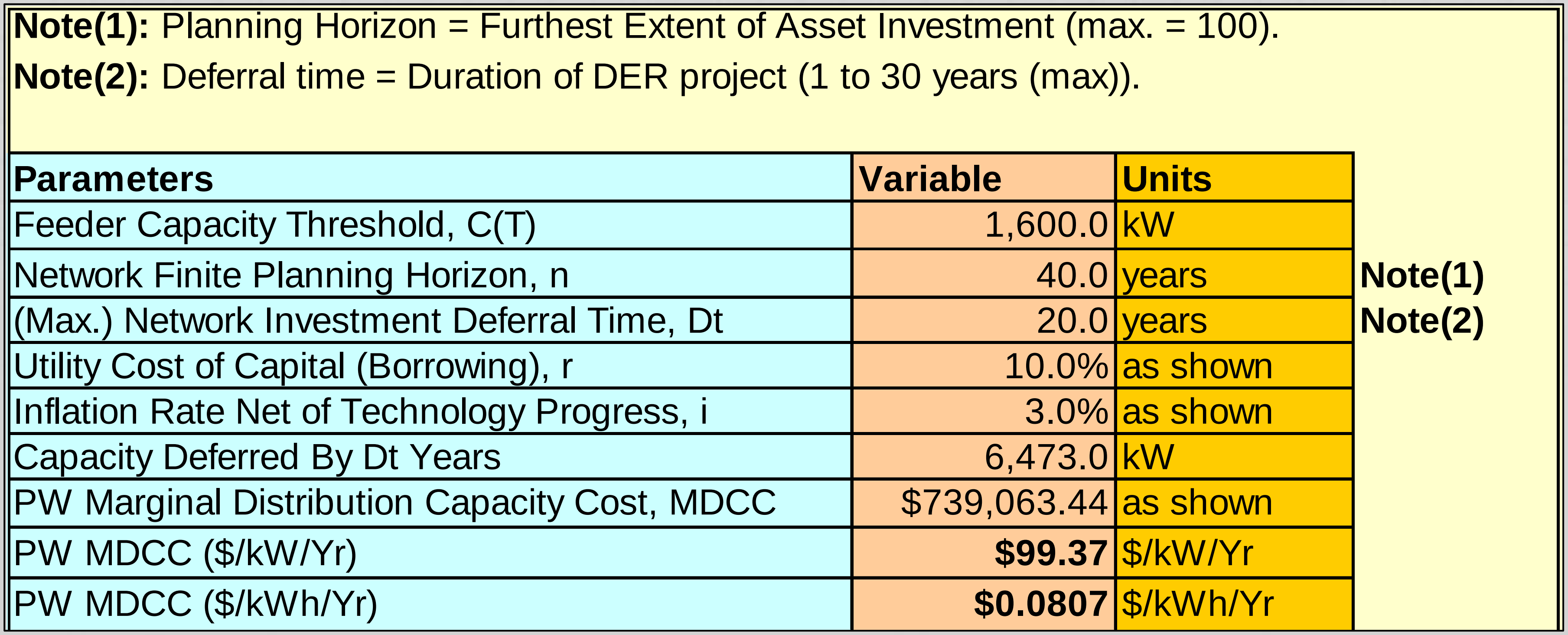
Network Economics and Rural DE

- **Analysis is being undertaken based on rural lines asset management plans (O&M)**
  - Methodology developed with two lines companies to assess the economics of different combinations of DG/DE for deferring upgrades
  - Assumes an increasing load will breach the feeder capacity threshold
  - Fuel based (firm) DG capacity provided in combination with wind, PV, microhydro generation or solar hot water DE
- **NPV and ROI calculated for different ratios of investment in fuel and intermittent renewable technologies**
  - 100% capacity genset with 20%, 50%, 80% parallel investment in renewable distributed energy technologies
  - Example results based on 10% demand growth to illustrate the trends

Network Economics and Rural DE

Example Inputs to the Model

- Applies to any regional level of assets for which an O&M plan is produced



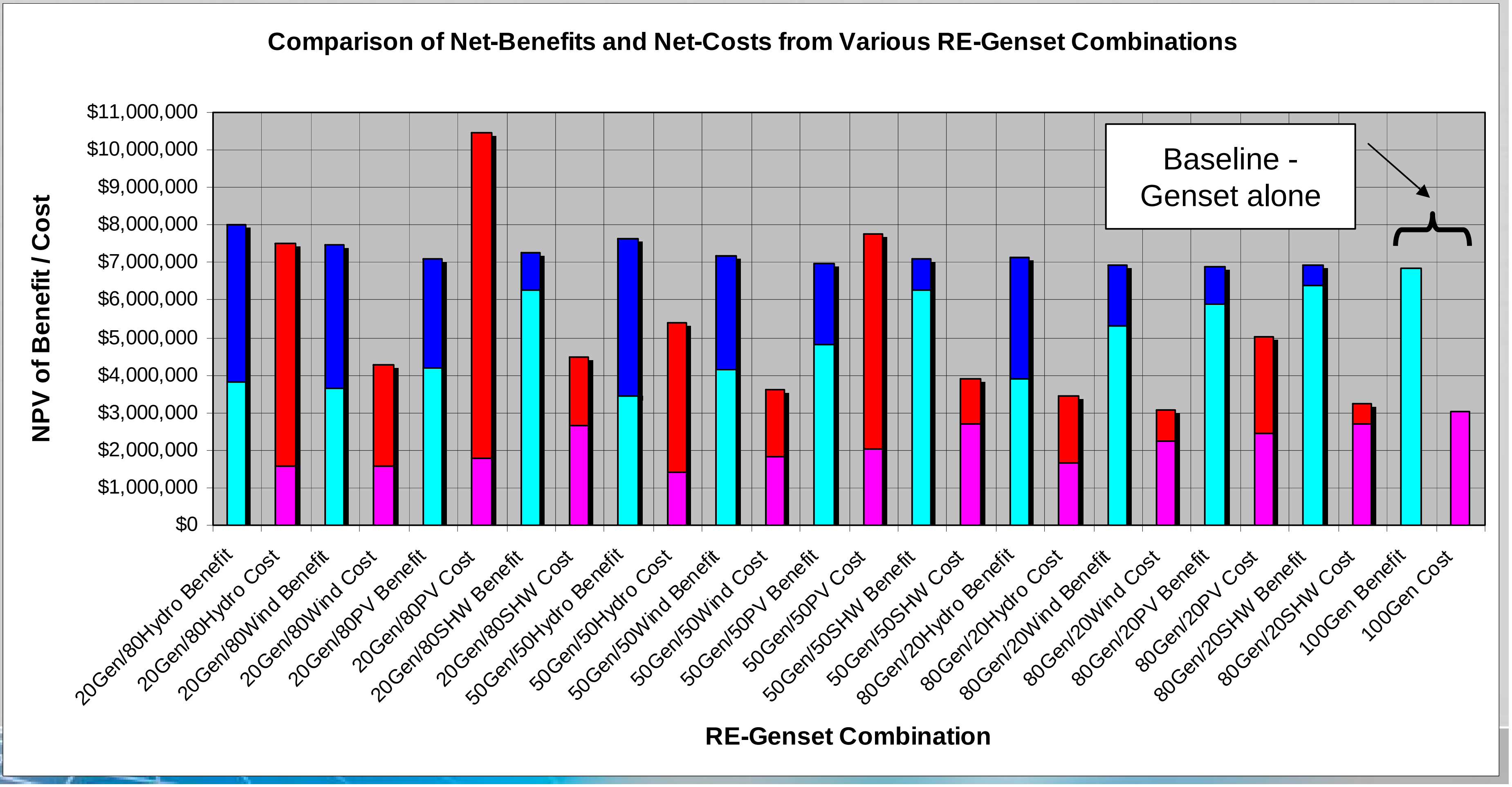
Note(1): Planning Horizon = Furthest Extent of Asset Investment (max. = 100).

Note(2): Deferral time = Duration of DER project (1 to 30 years (max)).

Parameters	**Variable**	**Units**	
Feeder Capacity Threshold, C(T)	1,600.0	kW	
Network Finite Planning Horizon, n	40.0	years	**Note(1)**
(Max.) Network Investment Deferral Time, Dt	20.0	years	**Note(2)**
Utility Cost of Capital (Borrowing), r	10.0%	as shown	
Inflation Rate Net of Technology Progress, i	3.0%	as shown	
Capacity Deferred By Dt Years	6,473.0	kW	
PW Marginal Distribution Capacity Cost, MDCC	$739,063.44	as shown	
PW MDCC ($/kW/Yr)	**$99.37**	$/kW/Yr	
PW MDCC ($/kWh/Yr)	**$0.0807**	$/kWh/Yr	

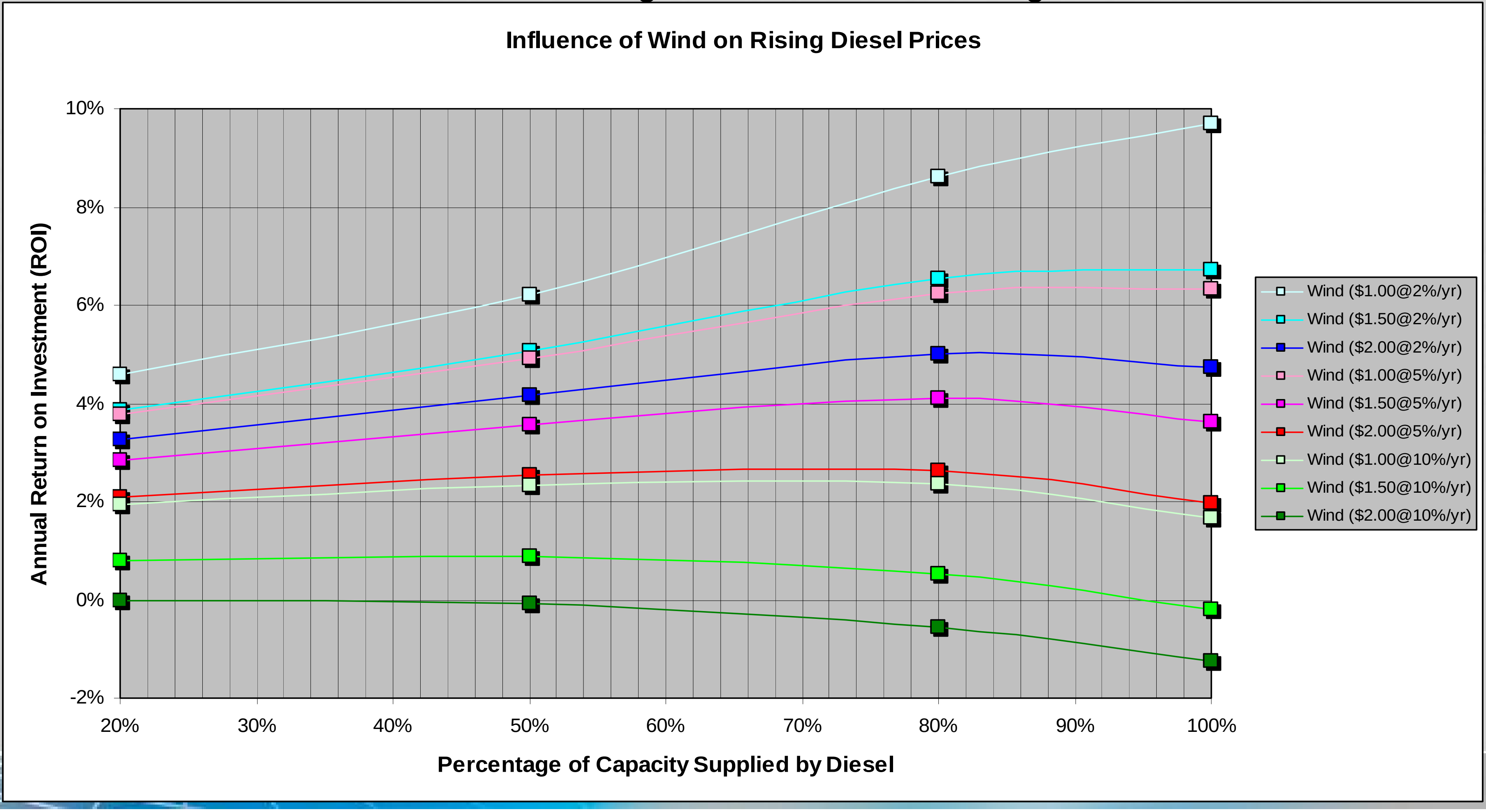
Network Economics and Rural DE

- **Example Outputs**
  - Fuel Price: $1.00/l increasing at 5%/yr



Network Economics and Rural DE

- **Example Outputs**
  - A mix of wind distributed generation and diesel gensets



Network Economics and Rural DE

- **Results**
  - Most combinations offer positive NPV
  - Addition of renewable microgeneration generally reduces the ROI over a basic distributed diesel genset option
  - In some scenarios there is a midpoint optimum combination of renewable generation because of an increasing cost of fuel
  - Analysis allows quantification of the degree of government support or incentive necessary to encourage renewable DE investment as a network upgrade deferral strategy
  - Suggests a way forward to support renewable DE technologies without up-front subsidies
  - Results are currently being written up

(Note: the methodology and results are specific to the New Zealand electricity market, but may be transportable to others)