Residential Demand Response
For Critical Peak Demand Reduction

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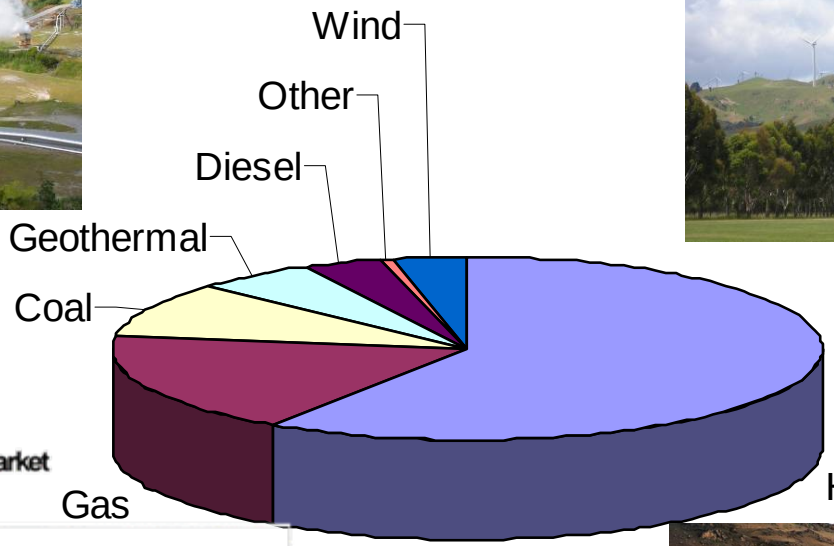
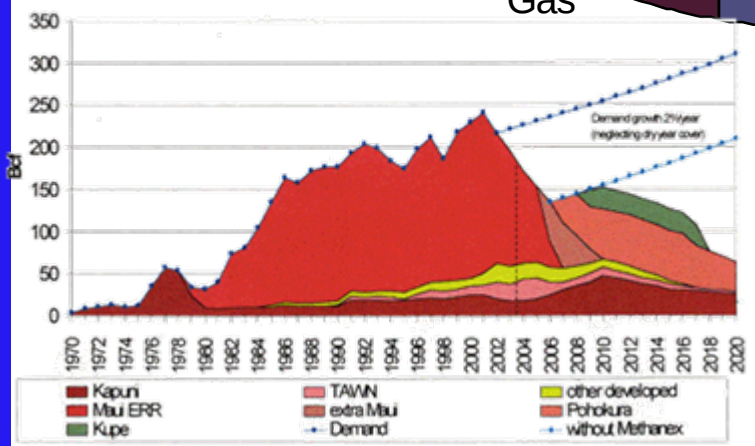
Residential Peak Demand

- The Problem
- Modeling Approach
- Case Study - Results

Electricity Generation Capacity





Problem: Renewable Energy

HYDRO

64% of generation

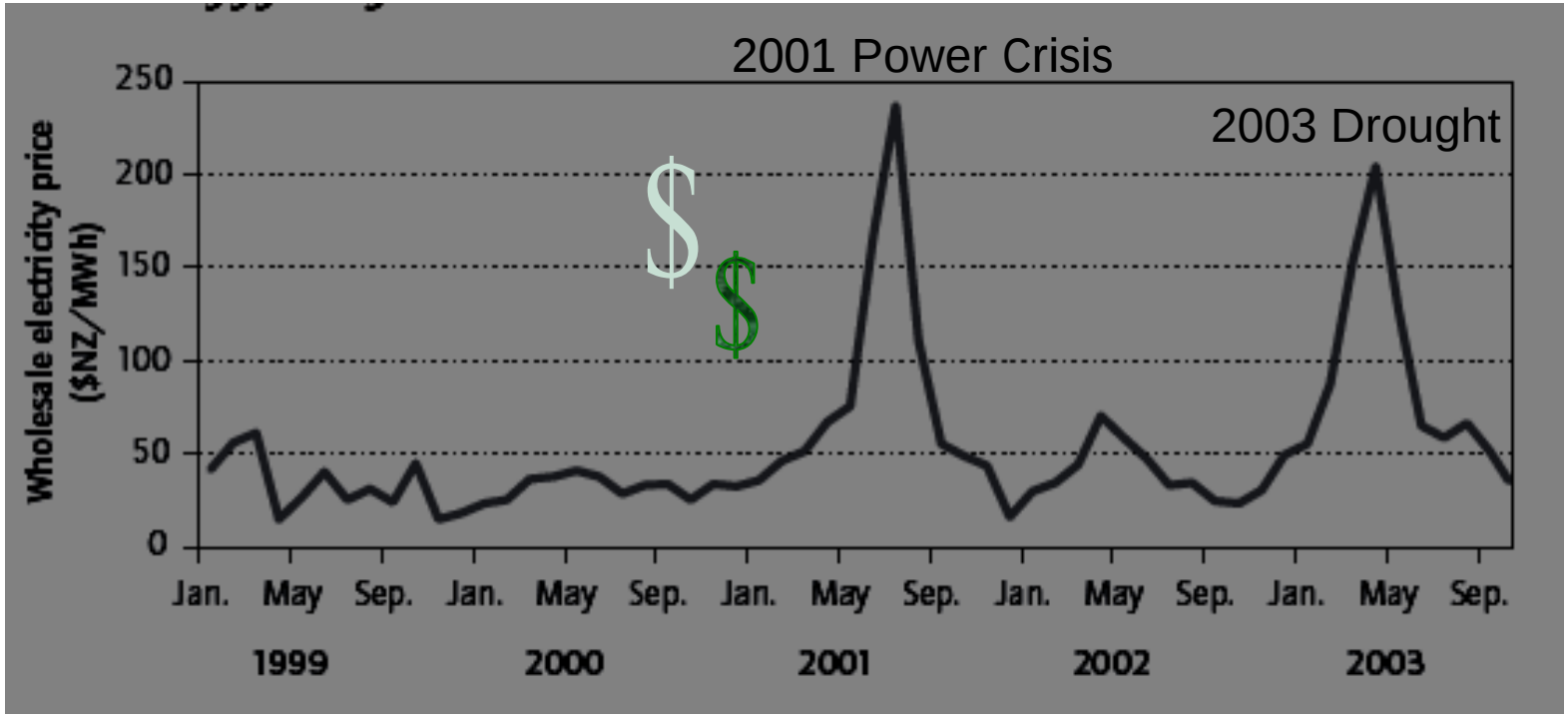
60 days of storage

Dry Year Problems

- High Spot Price
- Risk of “Cold Showers”
- Risk of Power Cuts

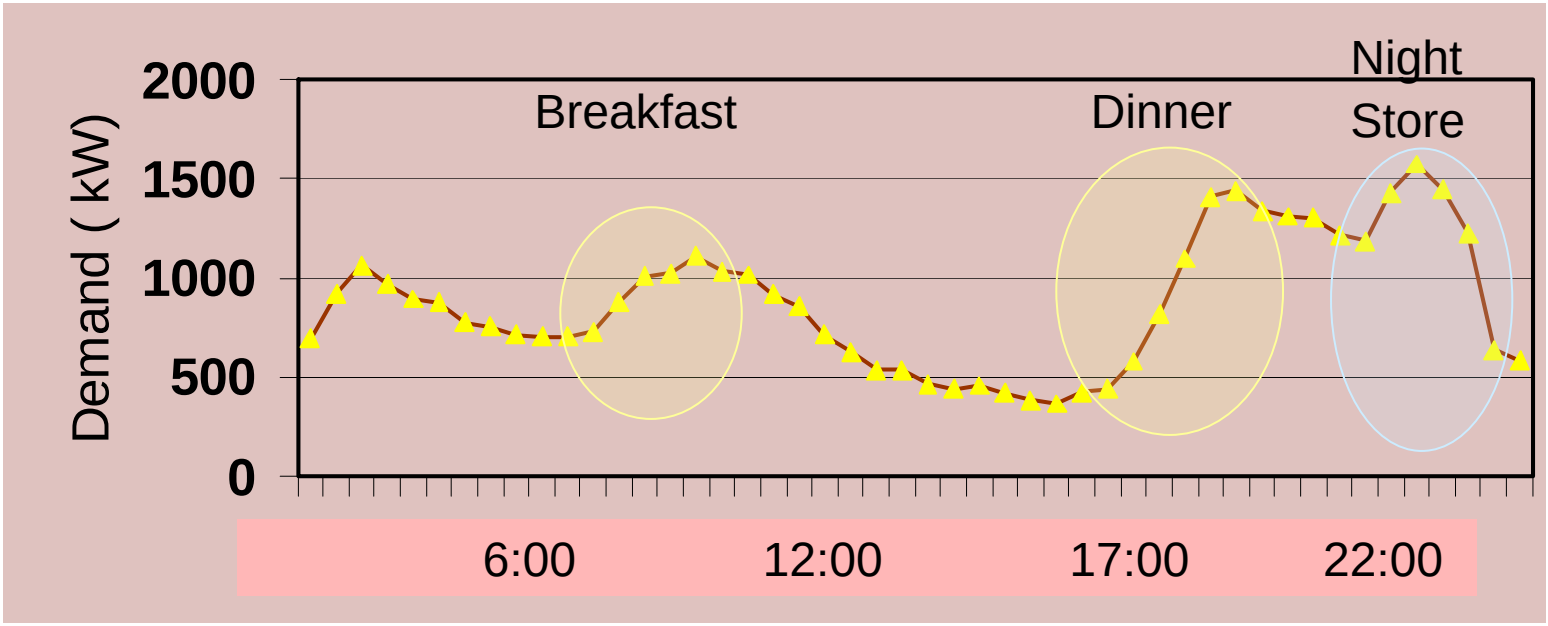
Problem: Dry Year

Average Monthly Wholesale Electricity Prices in New Zealand 1999-2003



Source: Saving Electricity in Hurry : IEA 2005.

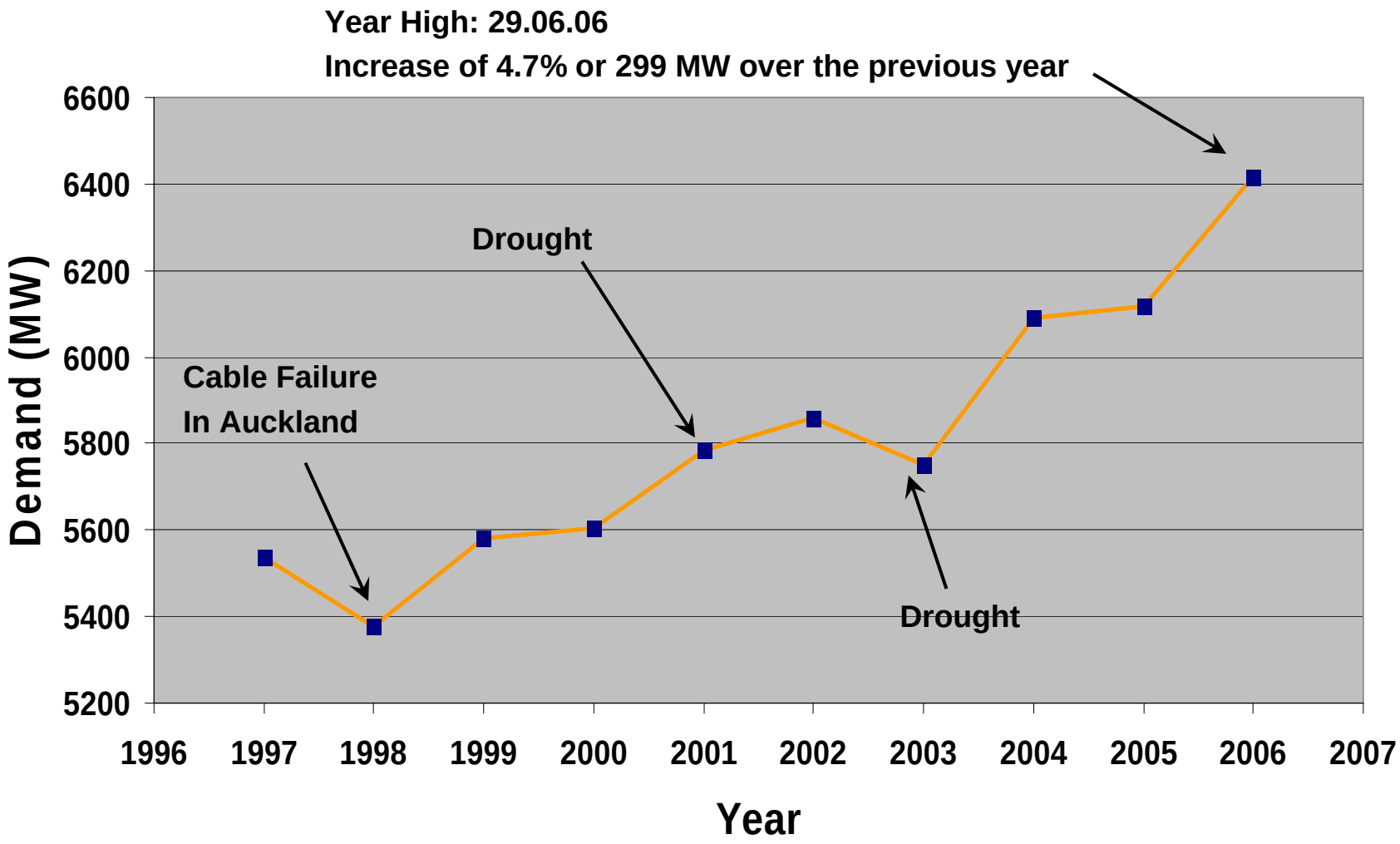
Problem: Peak Demand



Supply

Demand

Problem: Growing Peak Demand



Residential Peak Demand

Sector	Consumption	Peak
Residential	33%	52%
Industrial	45%	31%
Commercial	22%	17%
Total	100%	100%

Source: NZ Electricity Commission

High Cost of Peak Demand

Transmission Capacity

Ripple Control, Industry Shut Down 40¢ kWh

Diesel 40¢ kWh

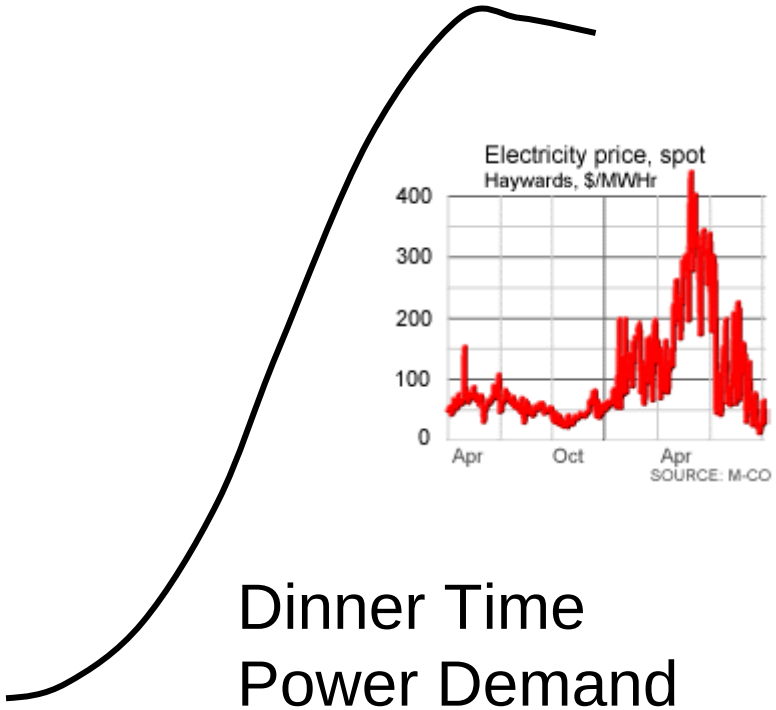
Peak Capacity

Gas 25¢ kWh

Peaking Hydro 12 ¢ kWh

Base-Load Capacity

Hydro 5¢ kWh

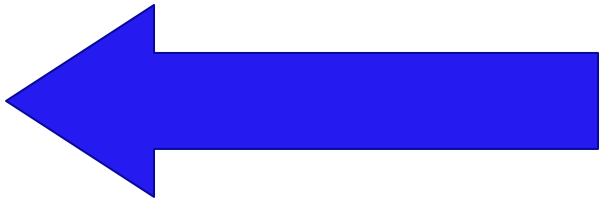


Solutions

Gas Peaking Generation, New Transmission

Interruptible Load
- Industry
- Water Heaters

Demand Response
- Commercial
- Industry
- Residential



Addresses the problem as well as providing a solution

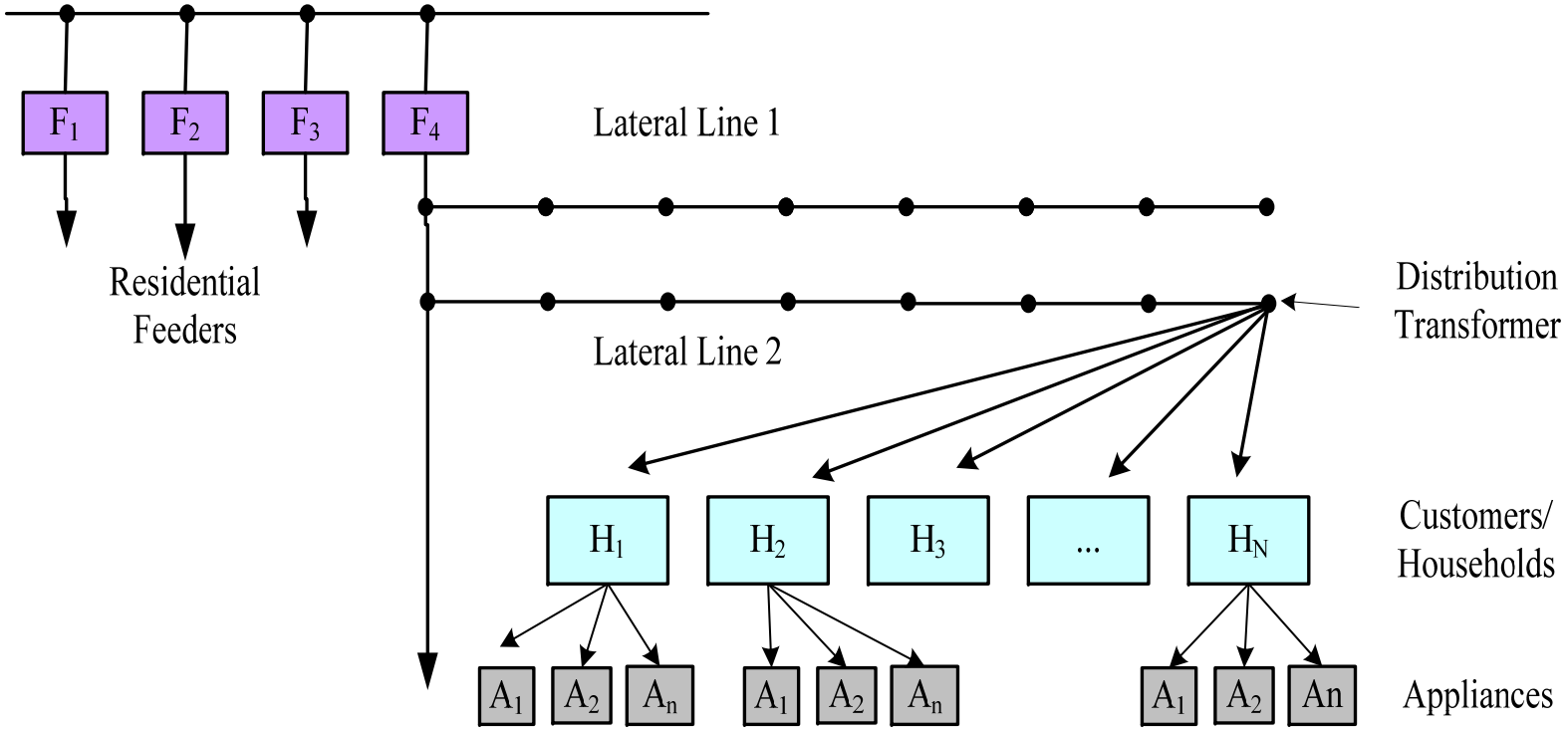
Residential Demand Response

Research Objectives

- Load Disaggregation – the behaviour of the different components of the residential load.
- Customer Behaviour - in responding to demand response request signals
- Load Shifting Models - impact of load shifting on utility’s load curve

Modeling Approach

Diversified Demand Method (Arvidson, 1940)



Diversified Demand

$$MDD\ (_{av,\max})_i = MDD\ _i * n_i$$

$$n_i = m * s_i$$

***MDD* (*av, max*)$_i$= Maximum average diversified demand per appliance for a group of customers**

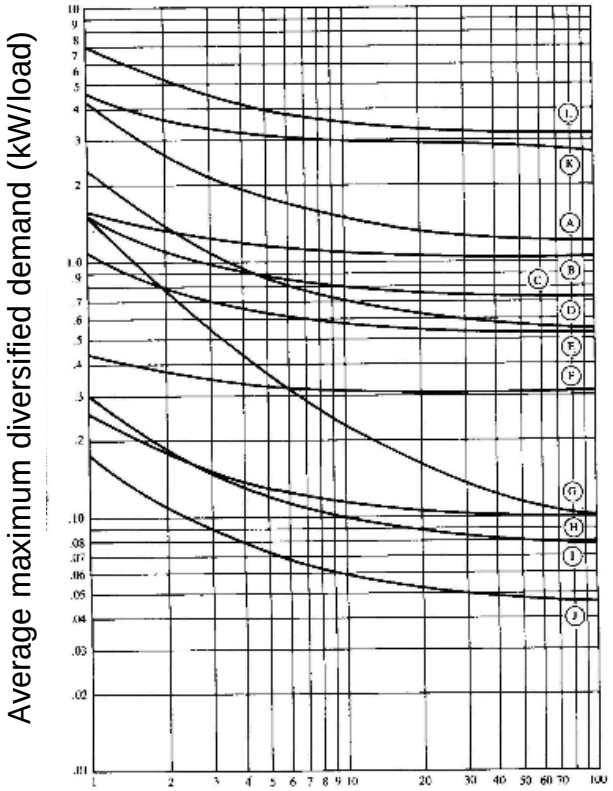
***MDD*$_i$ = Maximum diversified demand per customer of that appliance**

***n*$_i$ = Total number of appliance of that type**

***m* = Total number of households under consideration**

***s* = Appliance saturation rate**

Load Characteristic Curves



Source: Turan Goenon, 2008

Feeder Load Calculations:

Hourly maximum diversified demand *MDD*(*t,max*)

$$MDD_{(t,\max)i} = MDD_i * n_i * fi(t)$$

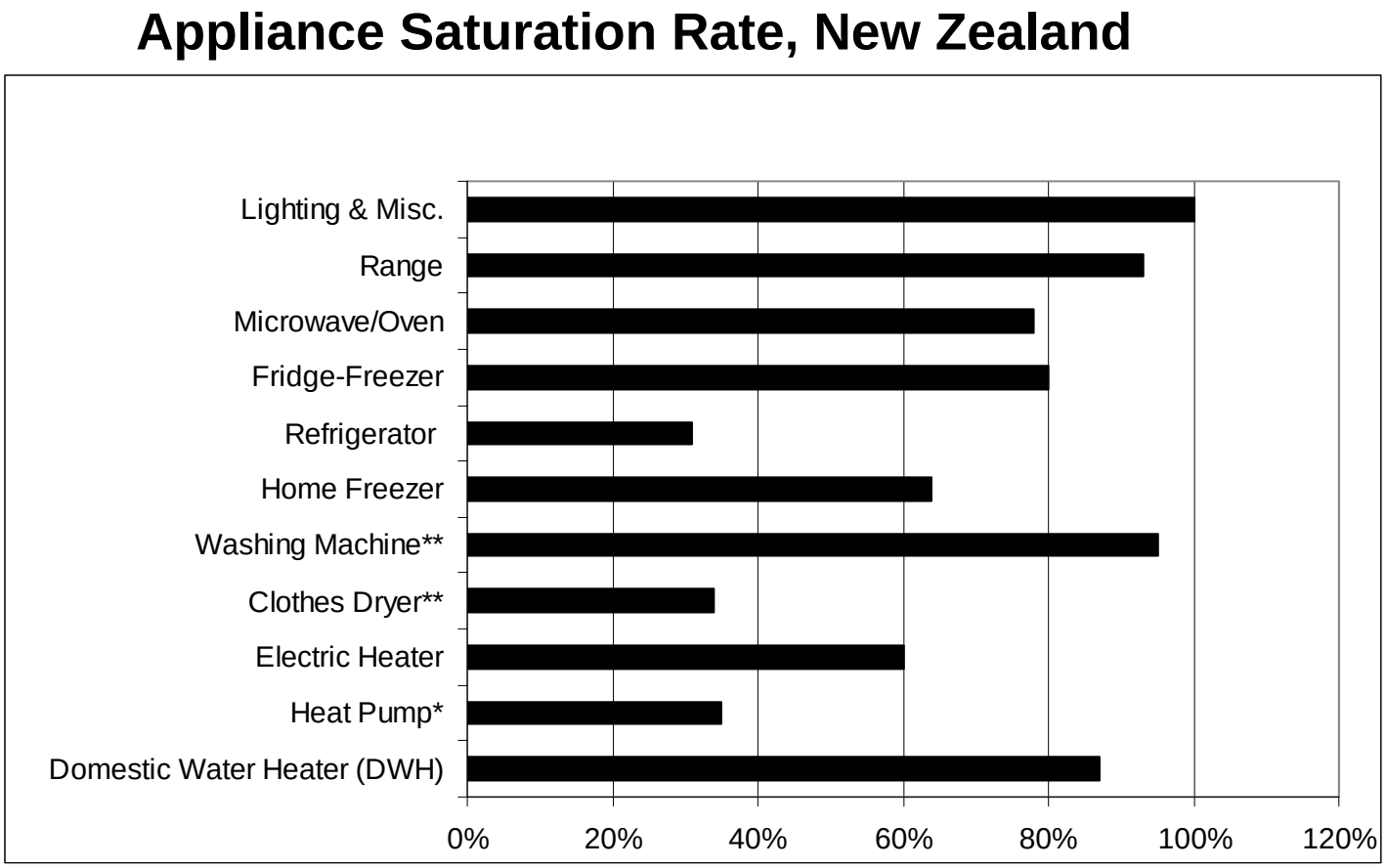
$f_i(t)$ = Hourly variation factor of appliance category *i*

Maximum load on the Transformer:

$$MLT_{(t,\max)} = \sum_{i=1}^{N} MDD_{(t,\max)i} = \sum_{i=1}^{N} MDD_i * n_i * f_i(t)$$

n = different appliance categories (e.g. washing machine, heat pump, clothes dryer)

Case Study:
Christchurch, 400 homes



Source: Electricity Commission

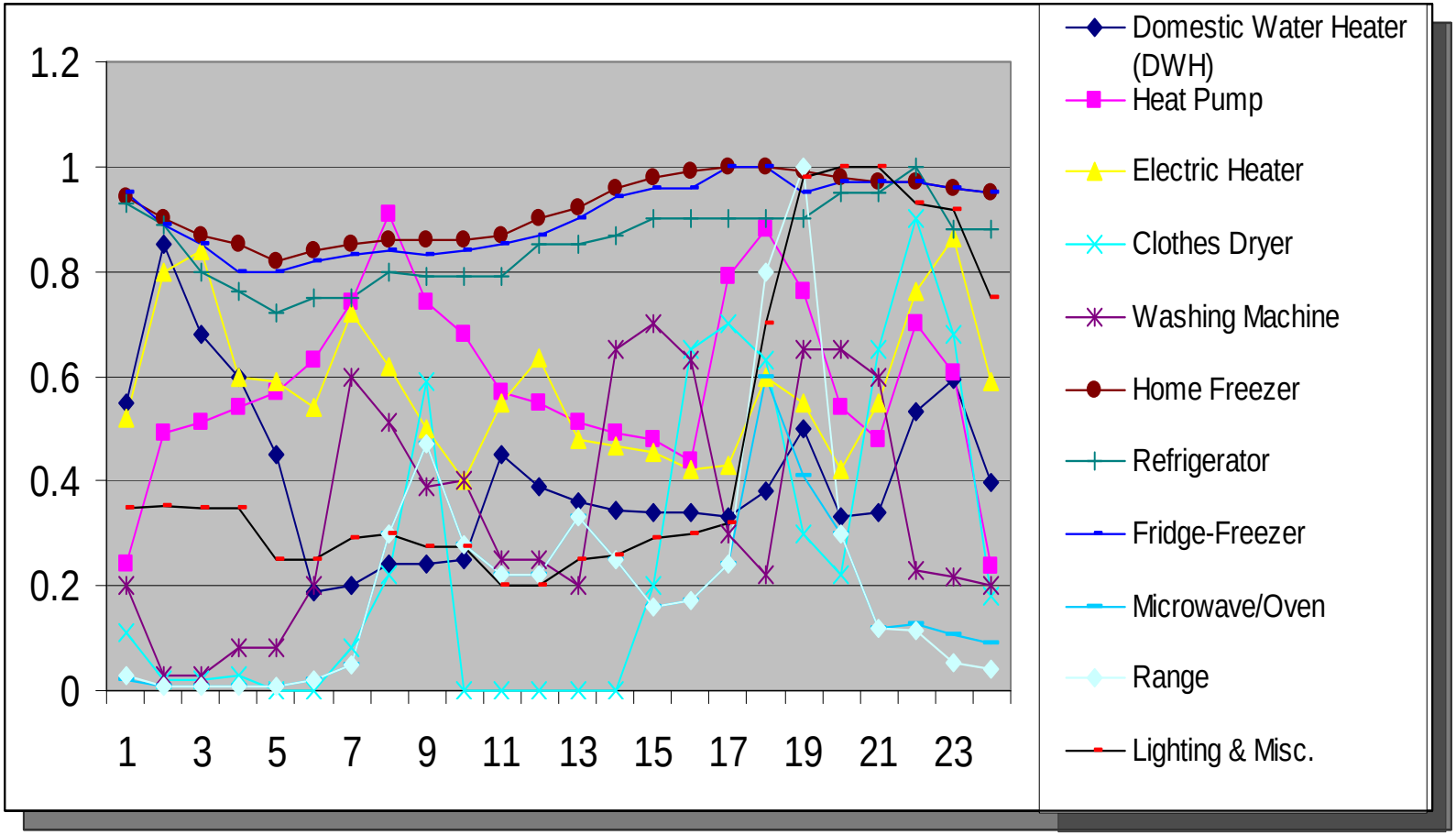
Maximum Diversified Demand

Calculated Maximum Diversified Demand for 400 houses

Taken from the Chart

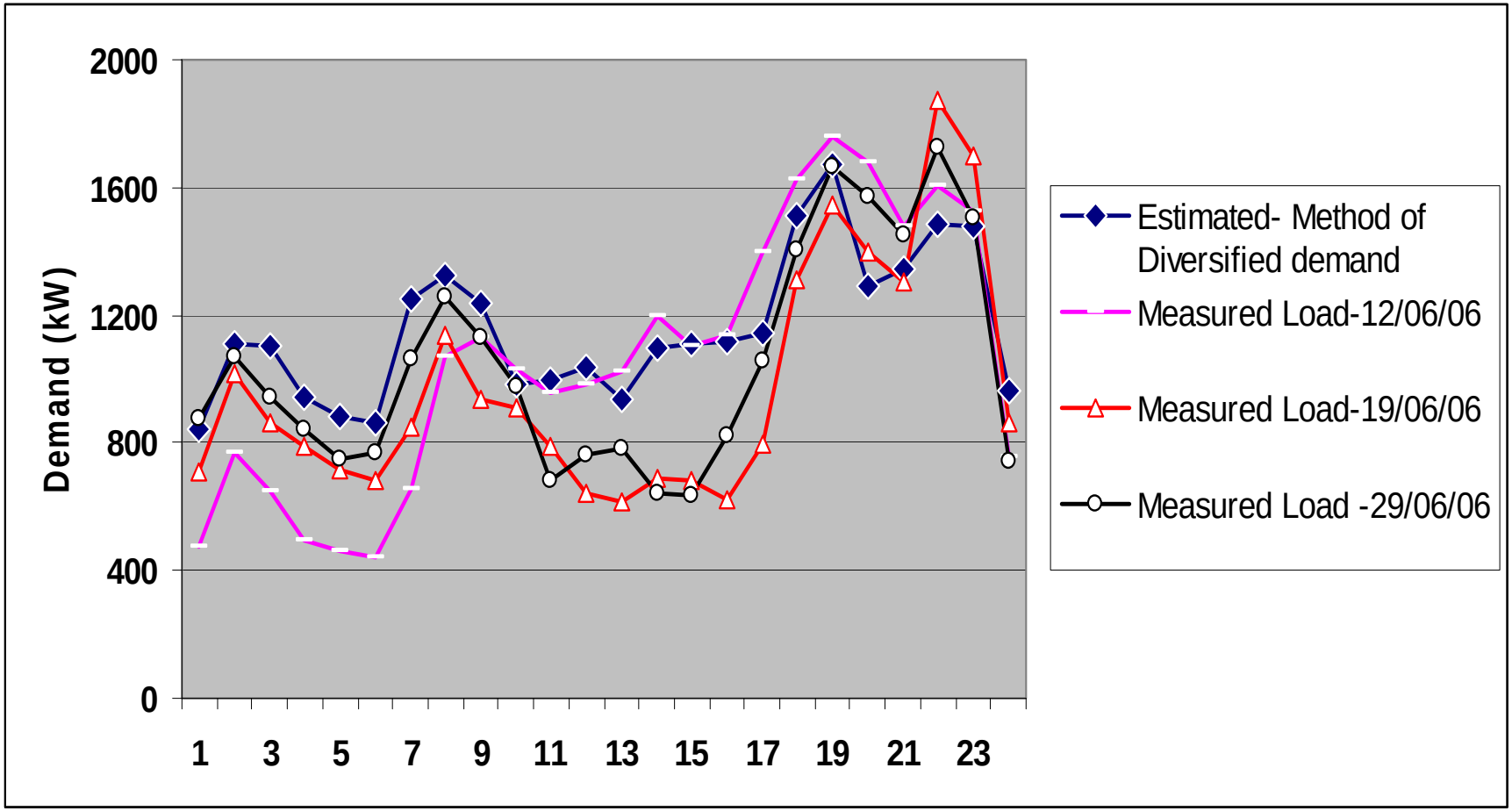
Appliances	Appliance saturation rate, s (%)	Total number of appliance=s* 400)	Diversified demand per customer (kW)	Maximum diversified demand (kW)
Domestic Water Heater	87	348.00	0.72	250.56
Heat Pump*	35	140.00	2.60	364.00
Electric Heater**	93	372.00	3.00	1116.00
Clothes Dryer	34	136.00	1.20	163.20
Washing Machine	95	380.00	1.20	456.00
Freezer	64	256.00	0.08	20.48
Refrigerator	31	124.00	0.06	6.82
Fridge/Freezer	80	320.00	0.08	25.60
Microwave/Oven	78	312.00	0.50	156.00
Range	93	372.00	0.55	204.60
Lighting & Misc.	100	400.00	0.54	216.00

Hourly Variation Factors



Source: HEEP, Stoeklein (1998)

Estimated Load Curve Compared with the Measured Load by the Utility



Feeder Demand Response

$$DR(t)_i = \sum_{i=1}^{N} MDD_i(t) * dx_i(t)$$

$DR(t)$ = Demand Response
Load reduction at time t

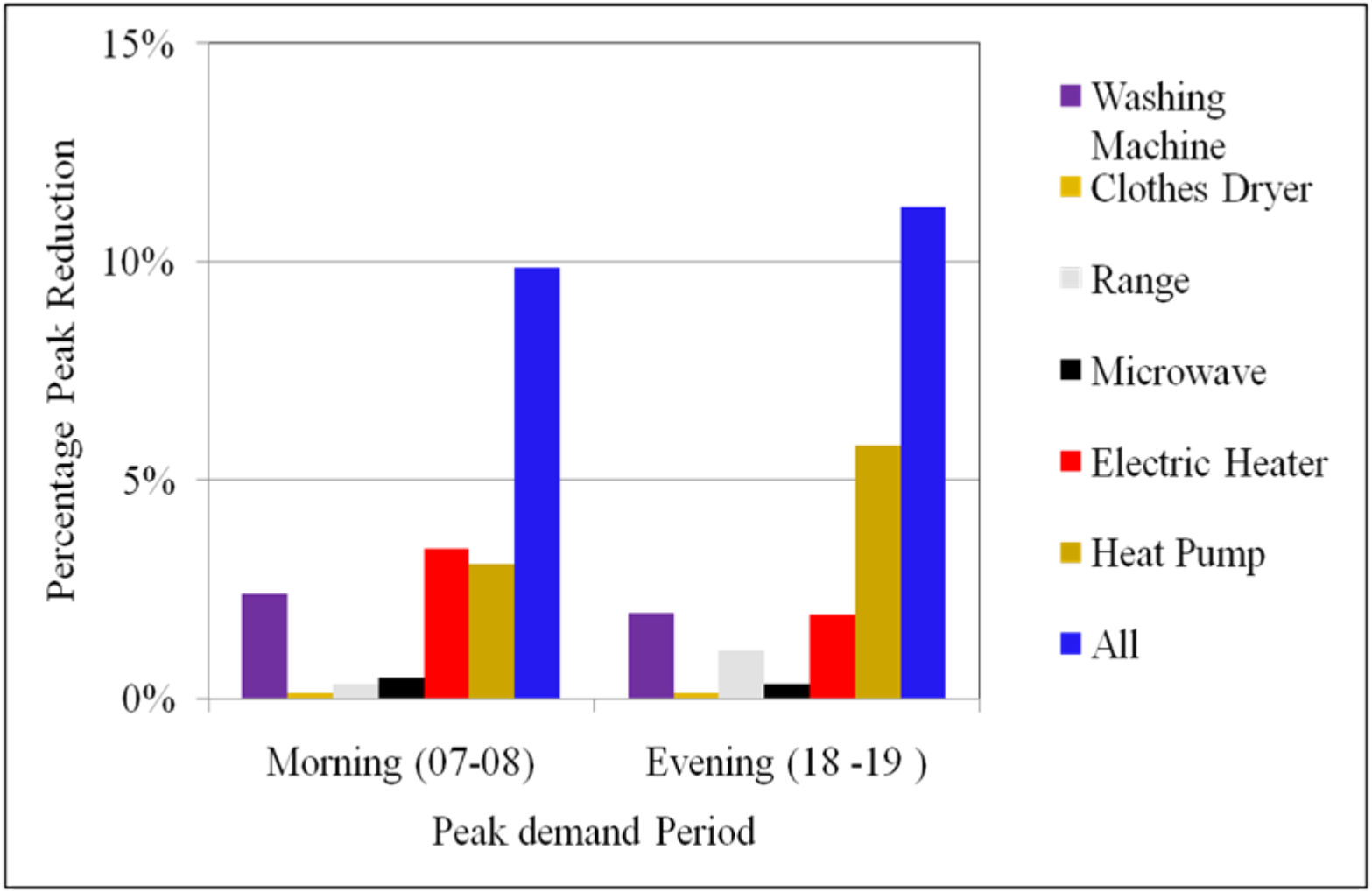
$MDD_i(t)$ = Maximum diversified demand of appliance type at time t

$dx_i(t)$ = Percentage of customers indicating a change demand at time, t

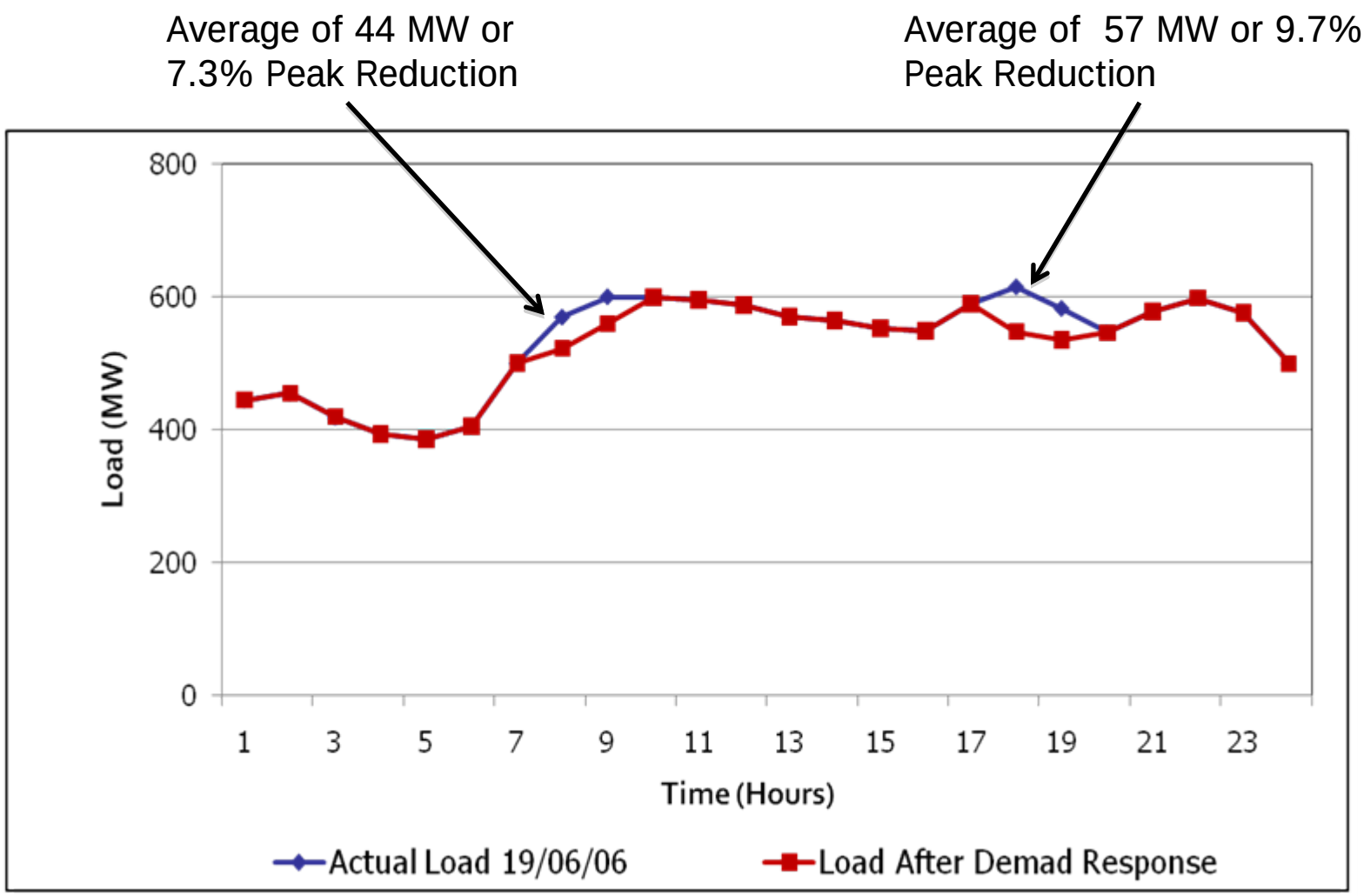
N = Total number appliance types

	Behaviour Factor (dx_i)	
	Morning	Evening
Washing Machine	17%	11%
Clothes Dryer	3%	5%
Vacuum Cleaner	10%	6%
Range	6%	21%
Microwave	12%	10%
Electric Heater	8%	6%
Heat Pump	15%	14%

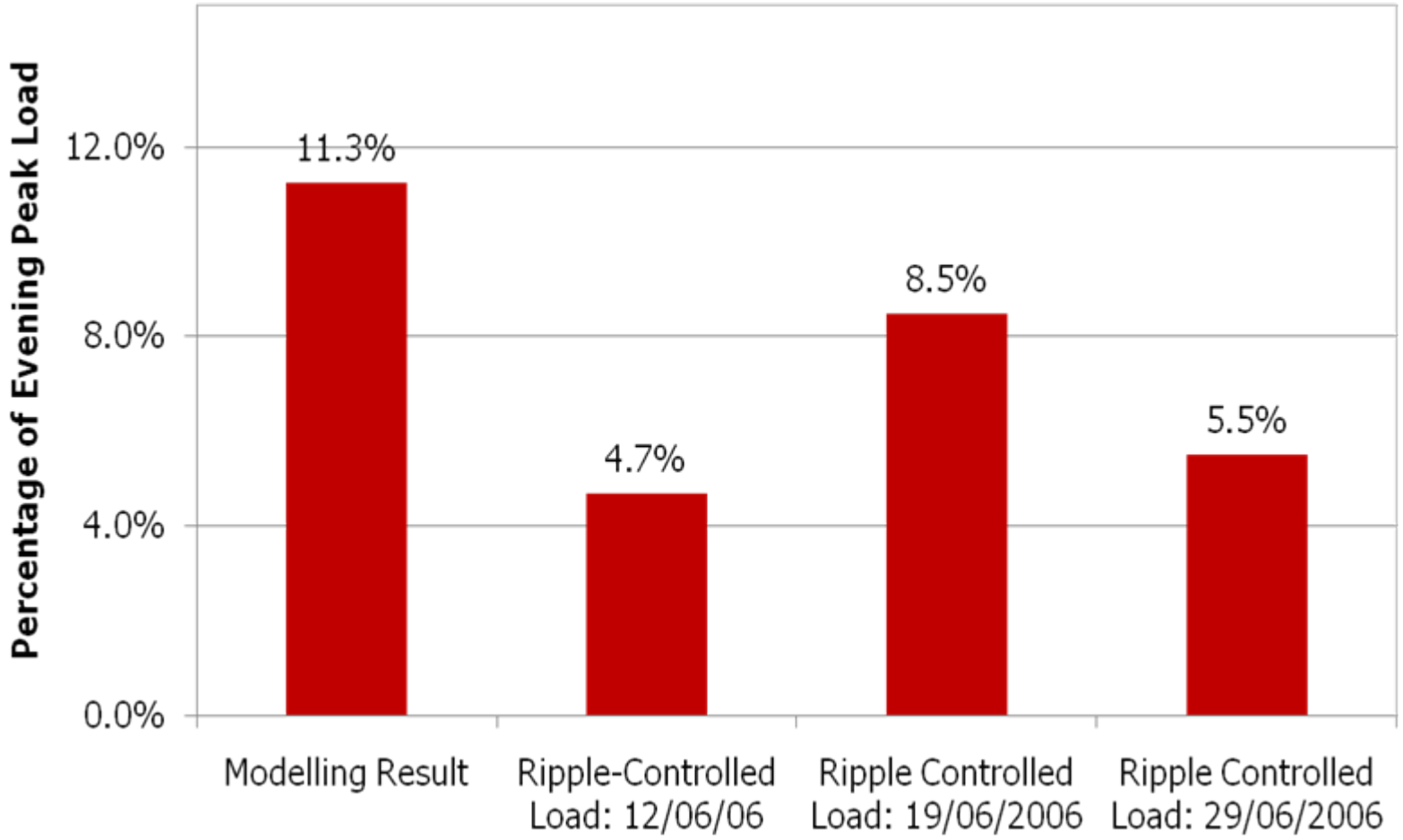
Activity Demand Response



Demand Response: Christchurch



Results Compared with Water Heating Ripple-Controlled Load



Thank You

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Illustrative Example

- If the number of houses on a transformer =5
- Total of 20 transformers and 100 houses on a residential feeder
- Typical house has clothes dryer, refrigerator, range, lighting and Misc., then

$$MDD_{,\,per\,,\,customer} = \begin{cases} 1.80 & clothes\ \ dryer \\ 0.07 & refrigerat\ \ or \\ 0.90 & range \\ 0.65 & lighting\ \ \&\ Mics \end{cases}$$

The maximum load on the distribution transformer is given by

$$MLT = \sum_{i=1}^{N} MDDi * n = (1.80 + 0.07 + 0.90 + 0.65) * 5 = 17.1kW$$

For the entire feeder (n=100),:

$$MDD_{,\,per\,,\,customer} = \begin{cases} 1.00 & clothes\ \ dryer \\ 0.05 & refrigerat\ \ or \\ 0.50 & range \\ 0.52 & lighting\ \ \&\ Mics \end{cases}$$

The maximum load on the entire feeder

$$MLT = \sum_{i=1}^{N} MDD_i * n = (1.00 + 0.05 + 0.50 + 0.52) * 100 = 207kW$$