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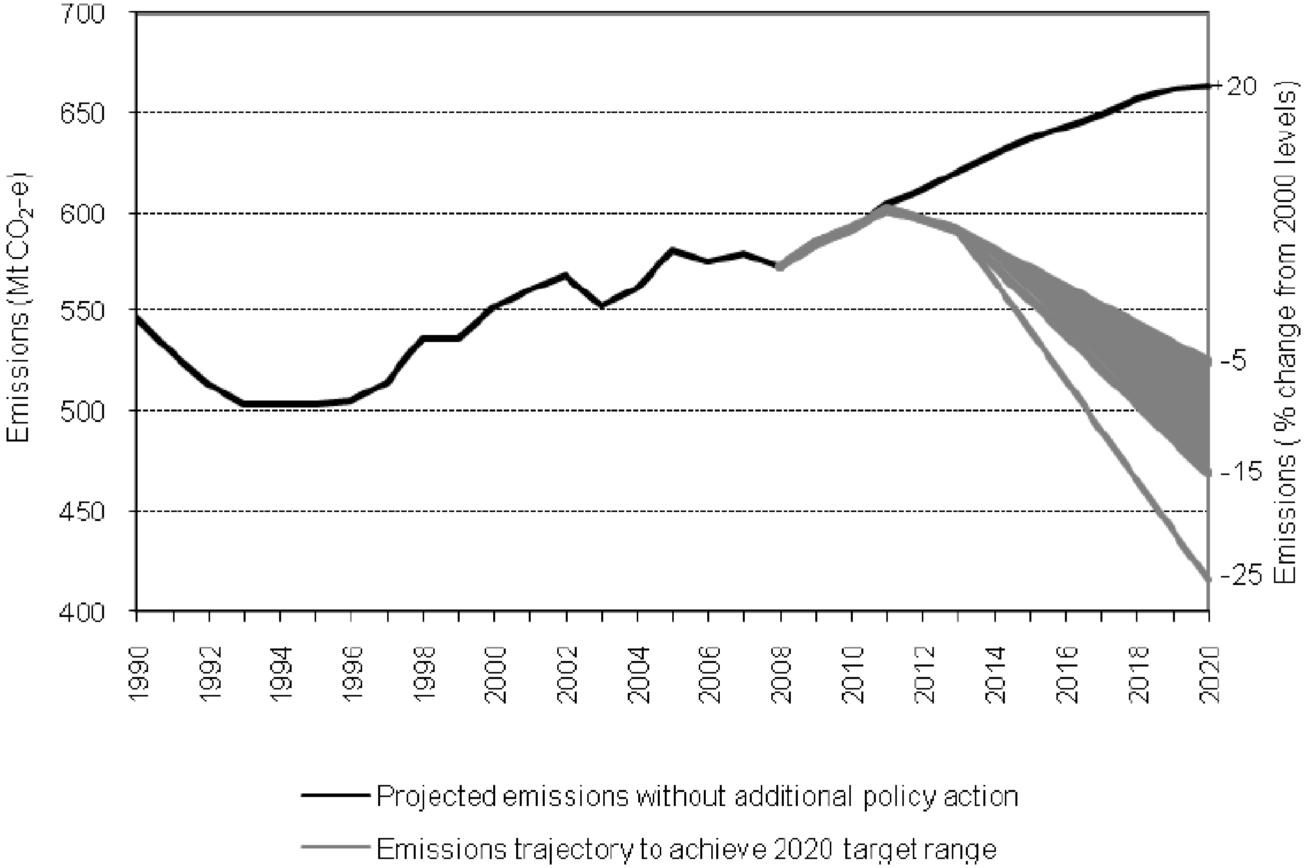
Introduction:

- Why DG?
- Modelling Platforms
- Current Progress
  - Large scale deployment of DG on the NEM
  - Impact of Carbon Prices and Demand Side PV Penetration
- Future Directions
  - Optimal economic deployment of DG (IEEE 30-node Bus)

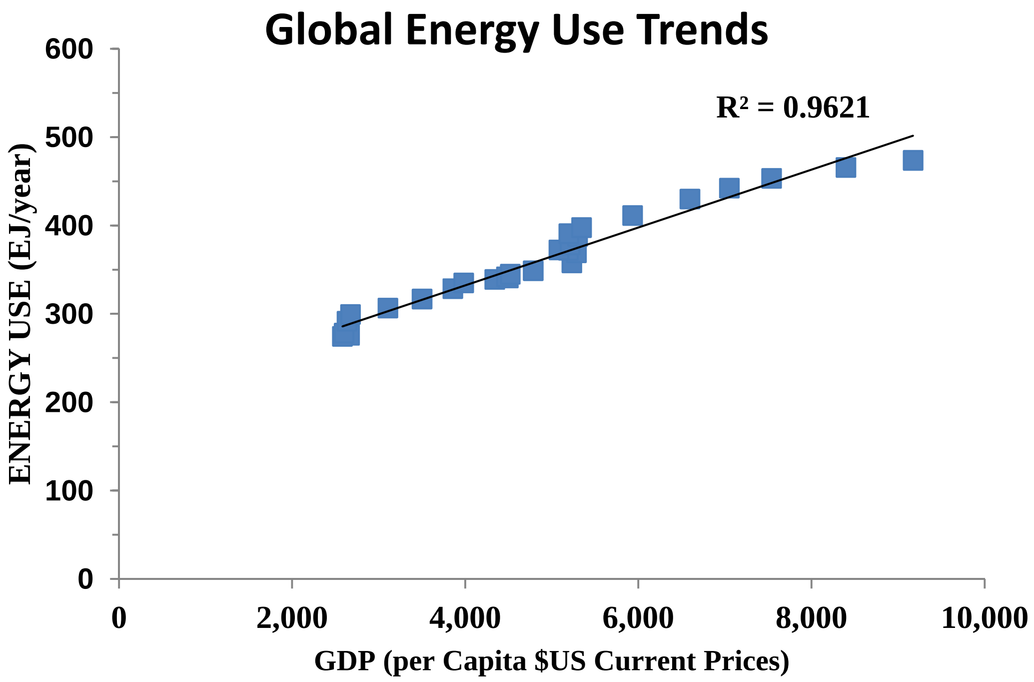
What are the Economic Signals for DG?

- Emissions Reduction
  - To avoid the serious consequences of climate change, emissions reduction and CO_2 concentration stabilisation needs to occur
- Energy Efficiency
  - Significant proportion of primary energy inputs into electricity generation are wasted.
  - IEA Blue Map scenario developed to improve the productive efficiency of energy delivery
- Network Costs
  - Deferral and elimination of proposed network CAPEX

2020 target range: 5-15 and 25 per cent reductions on 2000 levels



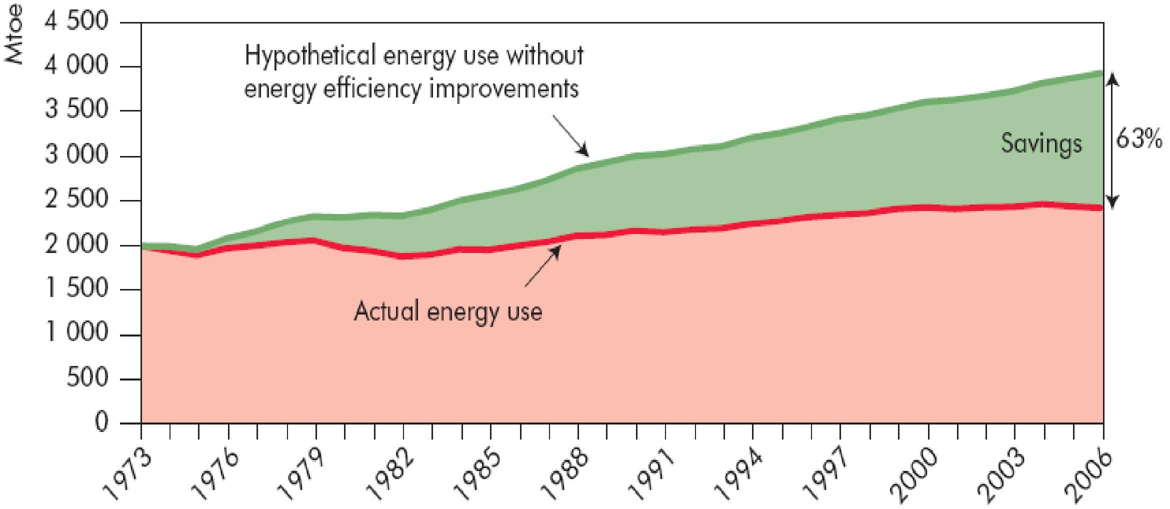
Source: Department of Climate Change, Australian Government 2009



Source: World Bank Data Centre

For economies to grow we will need more energy

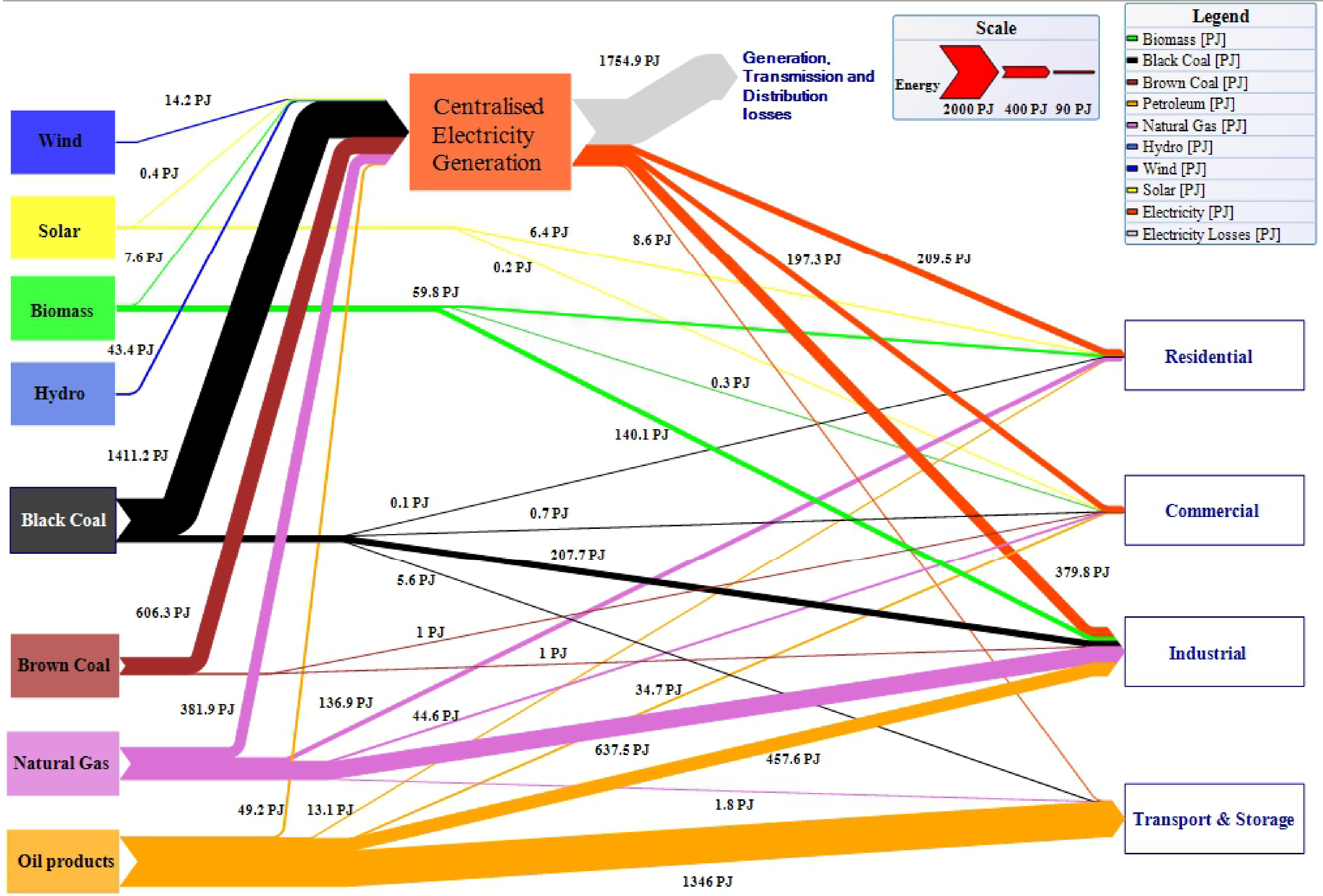
- But if we are smart we can slow demand growth and improve our energy deliver and usage
- Historically we have improved energy use by 0.7%/year
- IEA Blue map requires 1.5%/year



Long-term energy savings from improvements in energy efficiency, OECD-11

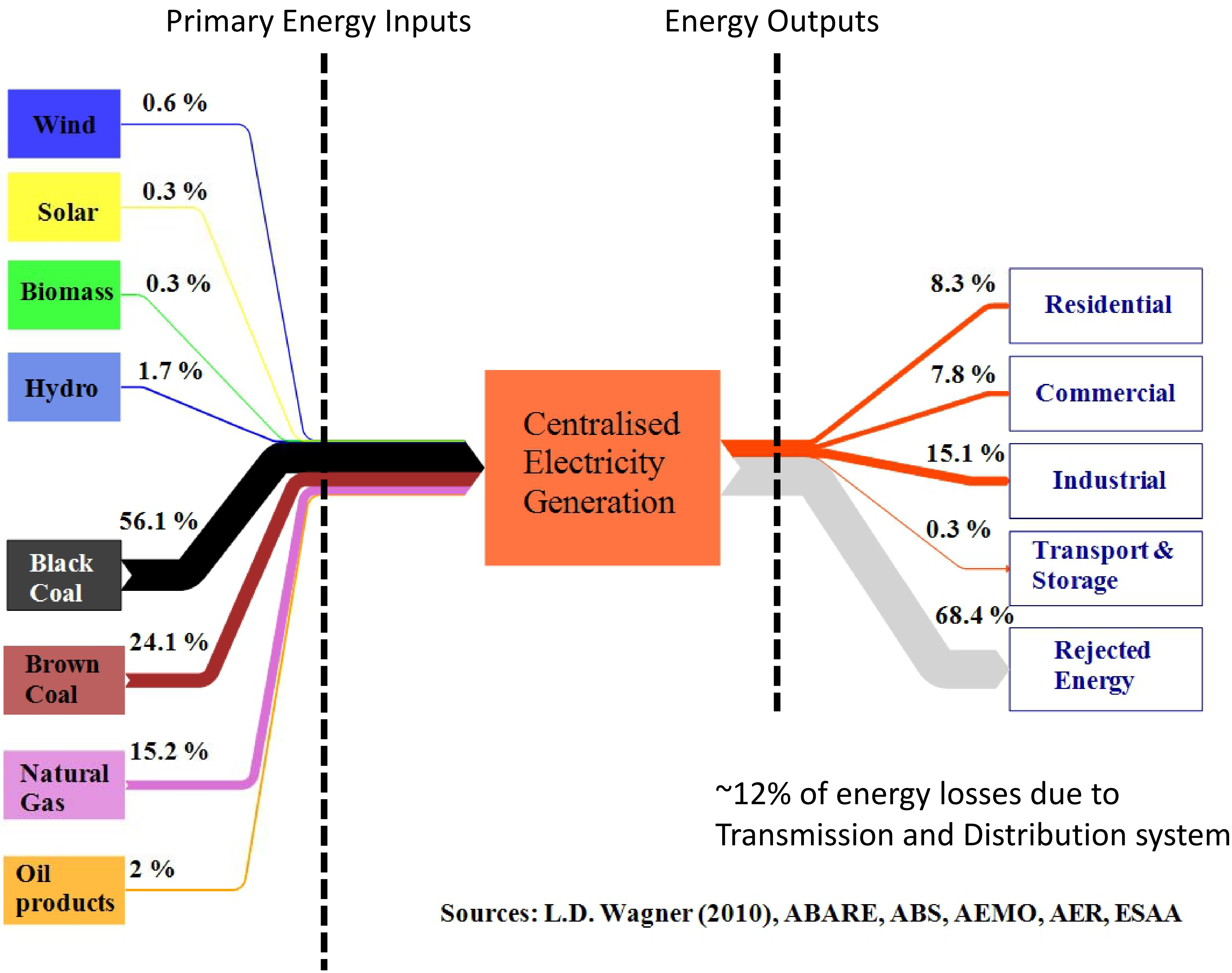
Source: IEA Technological Perspectives 2010

Internal energy flows without exports



Australian Energy Supply, Energy Flows 2007/2008

Sources: L.D. Wagner (2010), ABARE, ABS, AEMO, AER, ESAA



~12% of energy losses due to Transmission and Distribution systems

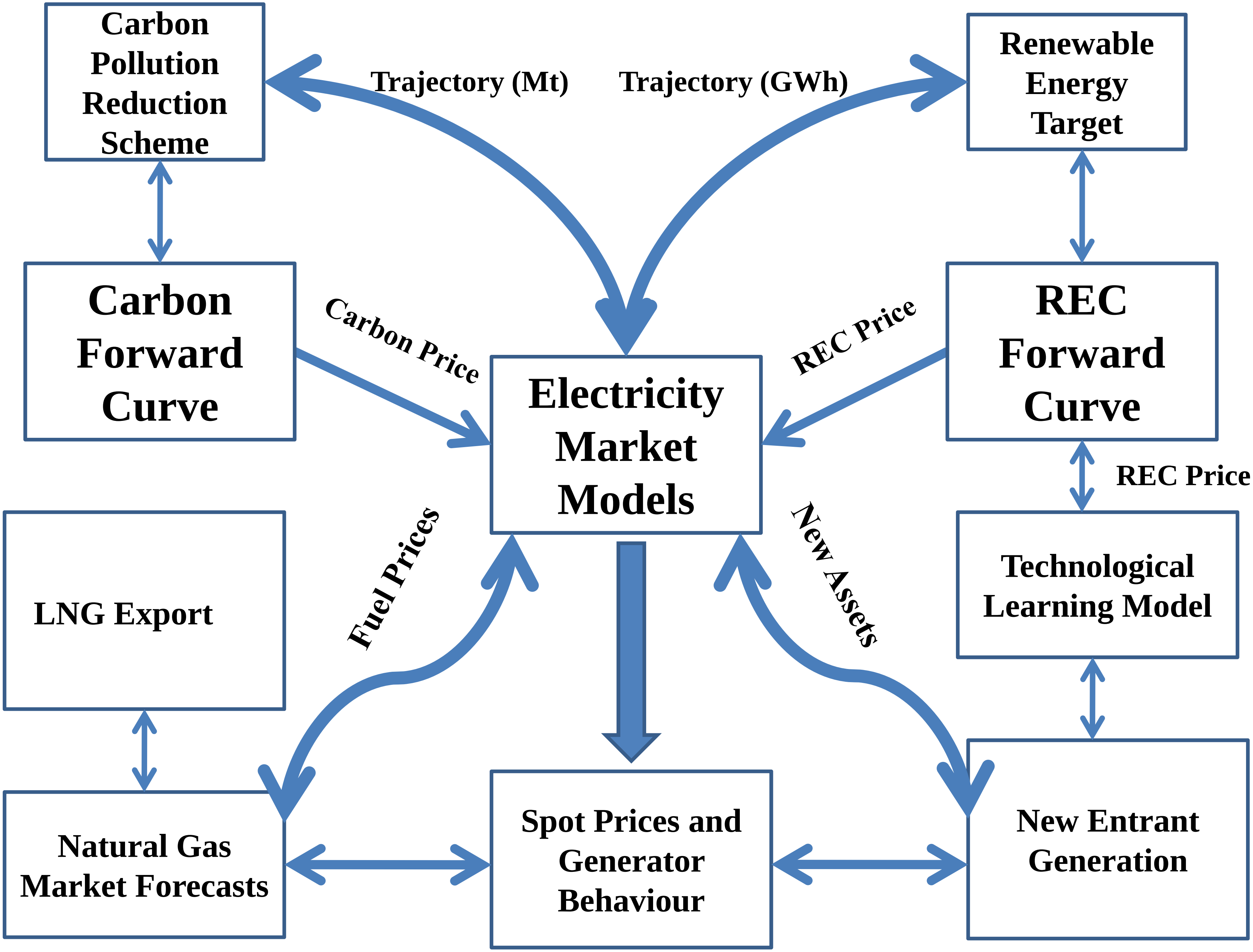
Sources: L.D. Wagner (2010), ABARE, ABS, AEMO, AER, ESAA

What NOW?

- Installing lots of Distributed Generation might reduce:
  - Emissions
  - Line Losses
  - Network Capex
- But installing huge amounts of DG everywhere COSTS MONEY.
- So what is the best way to deploying DG without costing us more money on our next electricity bill?

Electricity Market Models

- Plexos for Power Systems
  - – Commercially available platform used my NEM generators for trading and market analysis.
  - – UQ database constructed to replicate the NEM.
- ANEMMarket Model:
  - – Free platform developed at Iowa State Uni, (**AMES Wholesale Power Market Test Bed)**.
  - – UQ has developed a highly detailed model of the NEM for simulating structure change the market.


Carbon Pollution Reduction Scheme
Trajectory (Mt)
Trajectory (GWh)
Renewable Energy Target
Carbon Forward Curve
Carbon Price
REC Price
REC Forward Curve
Electricity Market Models
REC Price
LNG Export
Fuel Prices
New Assets
Technological Learning Model
Natural Gas Market Forecasts
Spot Prices and Generator Behaviour
New Entrant Generation

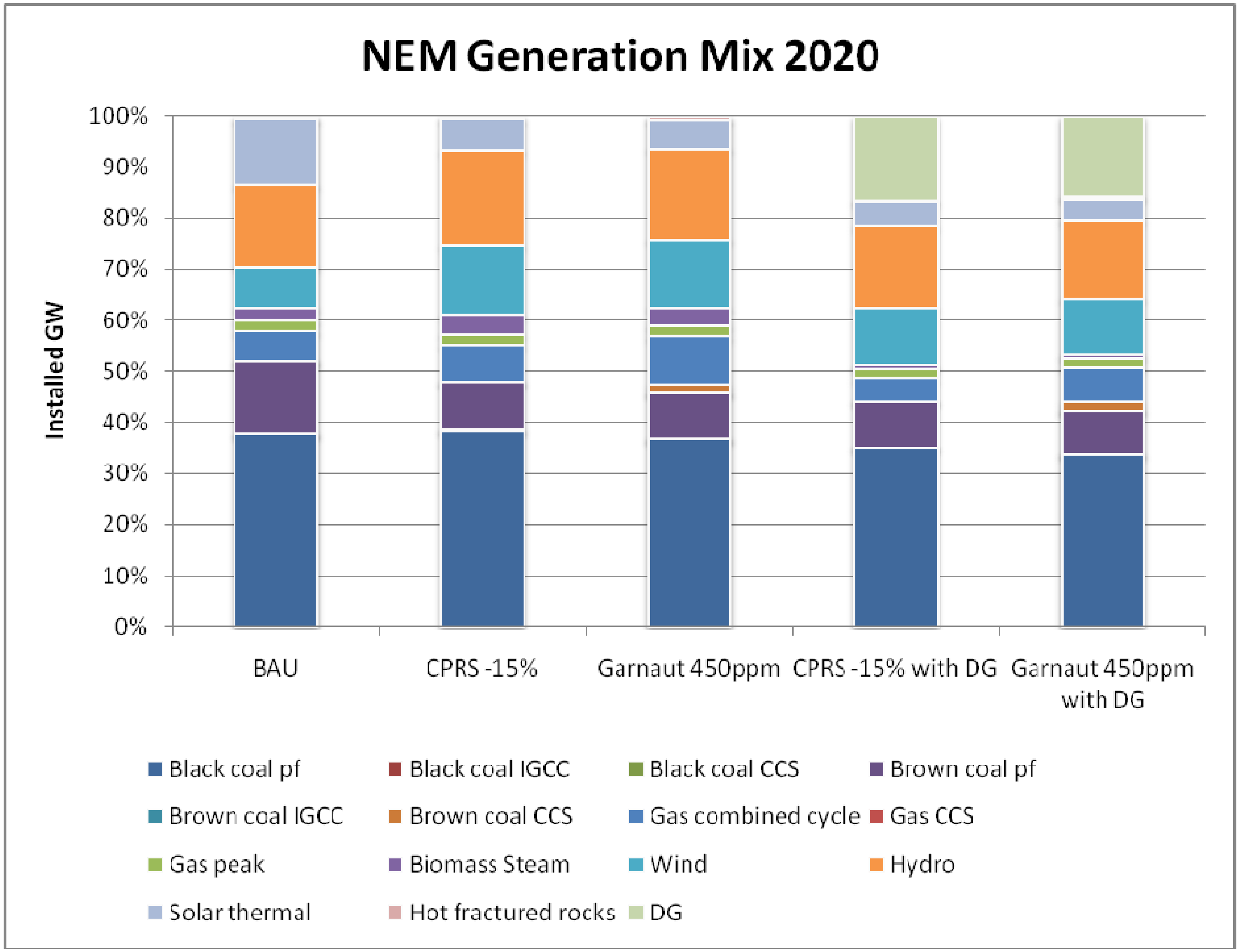
Modelling the deployment of DG on electricity markets: an Australian Case Study

- The role out of Distributed Generation (DG) could have a significant impact on the NEM.
- Deployment of rapid start/ramp up plant could significantly reduce extreme price spikes (especially at peak time)
- Recent study suggests a reduction in average price and emissions

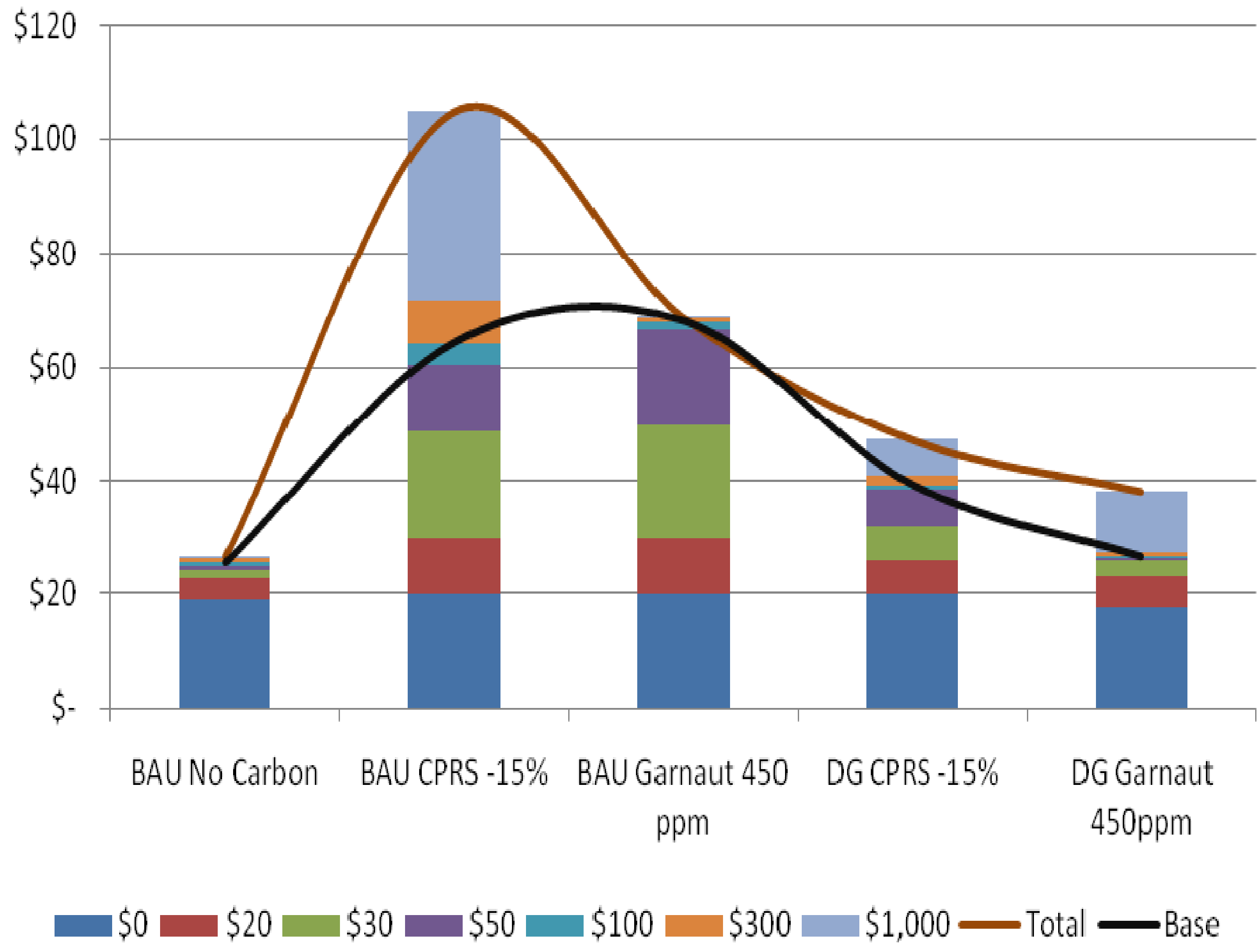
DG Technology Types

- Gas combined cycle w. CHP 30 MW
- Gas microturbine w. CHP 60 kW
- Gas reciprocating engine 5 MW, 500 kW and 5 kW
- Gas reciprocating engine w. CHP 1 MW and 500 kW
- Biomass steam w. CHP 30 MW
- Solar PV 40 kW and 1kW
- Diesel engine 500 kW
- Wind turbine 10 kW and 1kW
- Biogas/landfill gas reciprocating engine 500 kW
- Gas fuel cell w. CHP 2 kW
- Gas microturbine w. CCHP 60 kW
- Gas reciprocating engine w. CCHP 5 MW and 500 kW

DG Deployment



Price Distribution 2020



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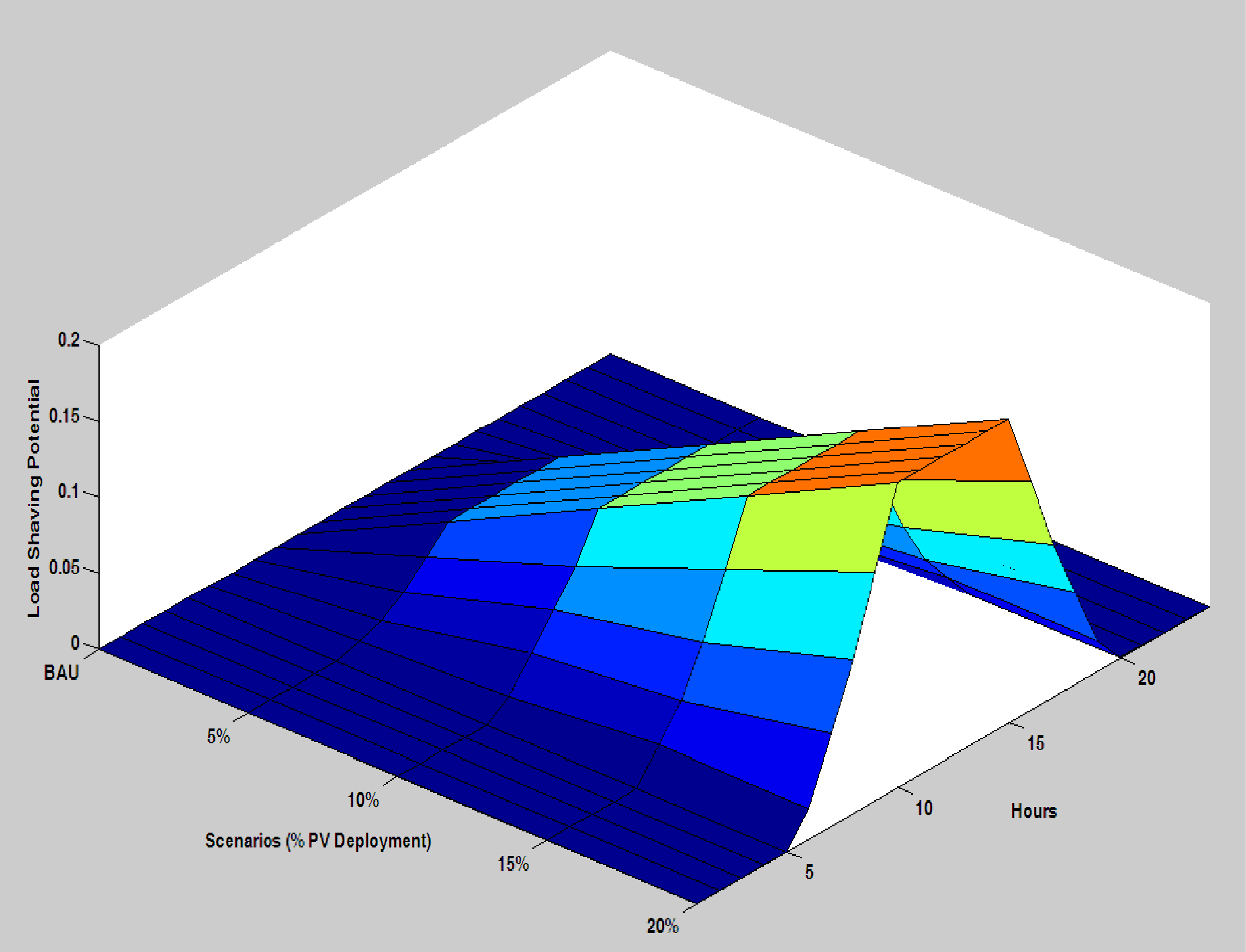
Greenhouse Gas Emissions 2020

	GHG Emissions (MT/year)	Emissions Intensity Factor (tCO_2/MWh)
Scenario 1	229.566	0.944
Scenario 2	223.731	0.878
Scenario 3	201.205	0.795
Scenario 4	199.952	0.776
Scenario 5	199.196	0.791

Impact of the Introduction of Carbon Prices and Demand Side PV Penetration

- Possible roles that a carbon price signal and residential based solar PV take-up scheme might play in pursuit of the policy goal of curbing growth in carbon emissions within the NEM
- To investigate this issue, we use an agent based model of the Australian National Electricity Market (NEM)
- Residential based PV scheme is undertaken in terms of its load shaving capability at large nodes.
- We find that a demand side policy promoting the take-up PV when combined with a carbon price signal could potentially enhance many of the desirable impacts, while also serving to mitigating some of the less desirable consequences



Load Shaving Scenarios Associated with Different Levels of Residential PV Penetration

Average Monthly Price Levels ($/MWh) Obtained for a Carbon Price of ($30/tC02) and Various PV Penetration Scenarios

SCENARIO	OLD	NSW	VIC	SA	TAS	NEM
$0, BAU	17.29	17.55	16.41	17.37	7.52	15.20
$30, BAU	43.89	45.46	46.17	47.09	14.11	38.96
$30, PV 5%	43.45	44.75	45.43	46.22	14.05	38.42
$30, PV 10%	43.16	44.23	44.85	45.60	14.00	38.02
$30, PV 15%	42.85	43.79	44.40	45.04	13.94	37.67
$30, PV 20%	42.64	43.44	44.01	44.56	13.90	37.39

Average MW Power Flow for a Carbon Price of ($30/tC02) and Various PV Penetration Scenarios on Interconnectors

SCENARIO	QNI	Directlink	NSW-VIC	Basslink	Heywood	Murraylink
$0, BAU	536.70	26.90	-624.92	-392.66	135.27	36.42
$30, BAU	619.26	43.54	182.41	-435.08	121.33	67.81
$30, PV 5%	614.29	43.37	171.51	-435.08	129.11	74.23
$30, PV 10%	611.65	43.31	134.63	-435.08	130.35	73.54
$30, PV 15%	609.80	43.53	95.17	-435.07	128.07	69.61
$30, PV 20%	608.93	44.00	62.85	-434.69	123.86	64.31

Average Percentage (%) Reduction in Carbon Emissions from ($30, BAU)

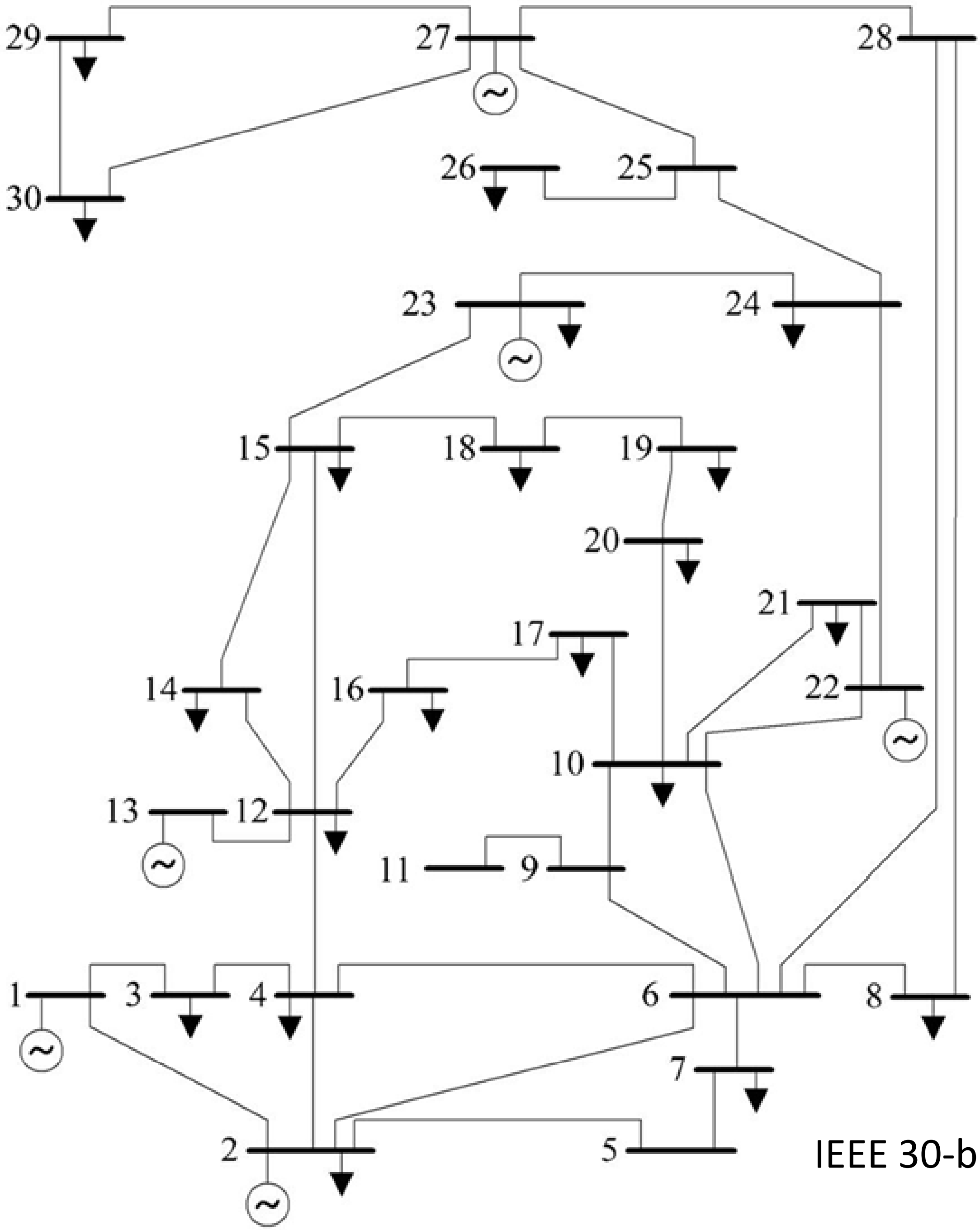
SCENARIO	OLD	NSW	VIC	SA	TAS	NEM
$0, BAU	(1.48)	(8.39)	15.37	6.57	0.00	3.16
$30, BAU	0.79	1.02	1.02	2.24	0.00	1.01
$30, PV 5%	1.64	2.43	2.04	3.85	0.00	2.14
$30, PV 10%	2.40	3.89	3.03	4.94	0.00	3.23
$30, PV 15%	3.15	5.39	4.26	5.71	0.00	4.38

The Big Experiment

- Considers the deployment of 10 technology options across 30 nodes.
  - 10^30 combinations or (1 nonillion)
  - Computationally EXPENSIVE!
  - Each simulation takes ~3 minutes and produces 200Mb of data
  - High resolution climate data used to create a variety of forecasts for renewable generation availability
- Collaboration with Monash Uni
  - Modelling and optimisation platform which allows us to use the combined computing power of all the student labs on the campus to run PLEXOS (a bit like SEETI).
  - Experimental design will reduce sample space by several orders of magnitude

Optimal economic deployment of DG (IEEE 30-node Bus)

- The main goal of this study is to examine the large scale deployment of DG and its effects on emissions, resistive line losses and spot prices on an electricity market.
- Extraordinarily large computational task of simulating 10 technology types across an IEEE 30-node bus.
- This experiment will endeavour to assess whether DG in its myriad of forms can improve Australia’s electricity markets by:
  - Reducing the Emissions Intensity Factor (EIF) of delivered energy
  - Reduce Resistive Line Losses
  - Reducing highly volatile price spikes
  - Delaying capital expenditure on transmission and distribution infrastructure.
  - While also reducing cost of delivered energy to the consumer



IEEE 30-bus test bed

Test bed bus systems are an ideal way for testing the deployment of new generation technologies and paradigms in a well defined and studied network.

What we will learn

- How to place DG in the NEM to reduce
  - Line losses (as a % of delivered energy).
  - Emissions intensity factor
  - Upfront CAPEX on transmission and distribution upgrades
  - Losses due to inefficient energy conversion (inclusion of Combined Heat and Power close to the node)
  - Uncertainty caused by renewable generation placed on the grid.
- Deploying PLEXOS to tackle extremely large simulations.
  - We can now consider optimal generation asset deployment on the NEM under varying market conditions by BRUTE FORCE!