# THE NETWORK VALUE OF DISTRIBUTED GENERATION

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UNIVERSITY OF TECHNOLOGY, SYDNEY

# AGENDA

## PART 1: ISF RESEARCH PROJECT

- The research project
- Background and introduction to problem
- Update on AEMC rule change process

## PART 2: ECONOMIC MODEL

- Research questions
- Introduction to representative agent model
- Assumptions and limitations of model
- Results
- Conclusions

# PART 1
# RESEARCH PROJECT

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# WHO'S INVOLVED

PROJECT LEAD

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MAIN SPONSOR

ARENA Australian Government Australian Renewable Energy Agency

SWAN HILL Rural City Council

Byron Shire Council

WILLOUGHBY CITY COUNCIL

ERGON ENERGY

CITIPOWER

Powercor AUSTRALIA

Energy in action. Since 1837 AGL

MOIRA SHIRE ON THE MURRAY

CITY OF SYDNEY

Total Environment Centre for the future

wannonWATER

NSW GOVERNMENT Renewable Energy Advocate

**Essential Energy**

**Ausgrid**

**Energy Australia**

**Origin Energy**

**Australian Energy Council**

**Electricity Networks Association**

**Clean Energy Council**

**Coalition for Community Energy**

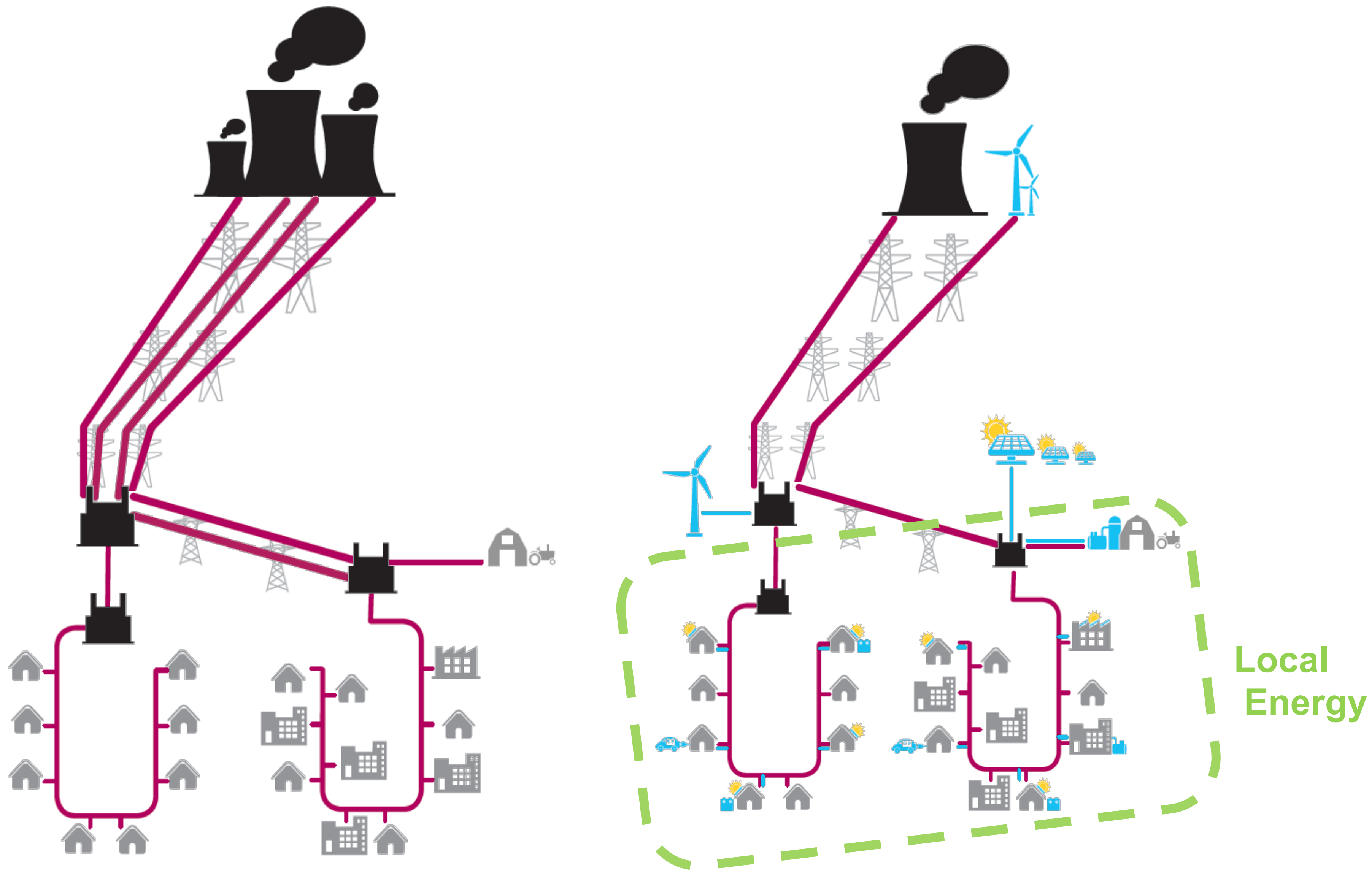
# THE RESEARCH PROJECT

**Objective: To facilitate the introduction of local network charges* & Local Electricity Trading****

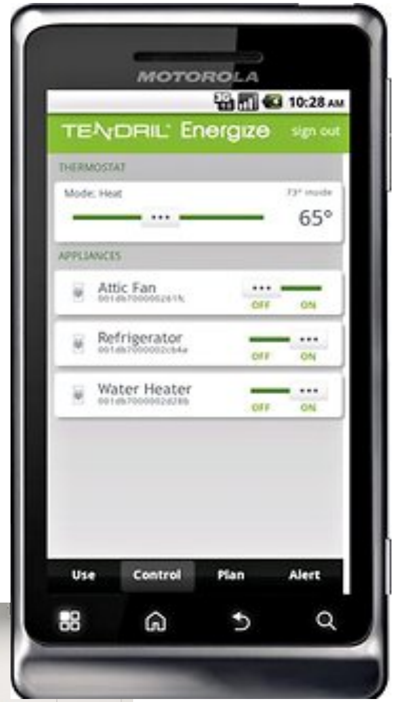
- Five case studies, or "virtual trials"
- A recommended methodology for Local Network Credits
- An assessment of requirements & costs for Local Electricity Trading
- Economic modelling of benefits & impacts
- Increase stakeholder understanding and support for Local Network Credit rule change

**** implemented as Local Network Credits paid to the generator***

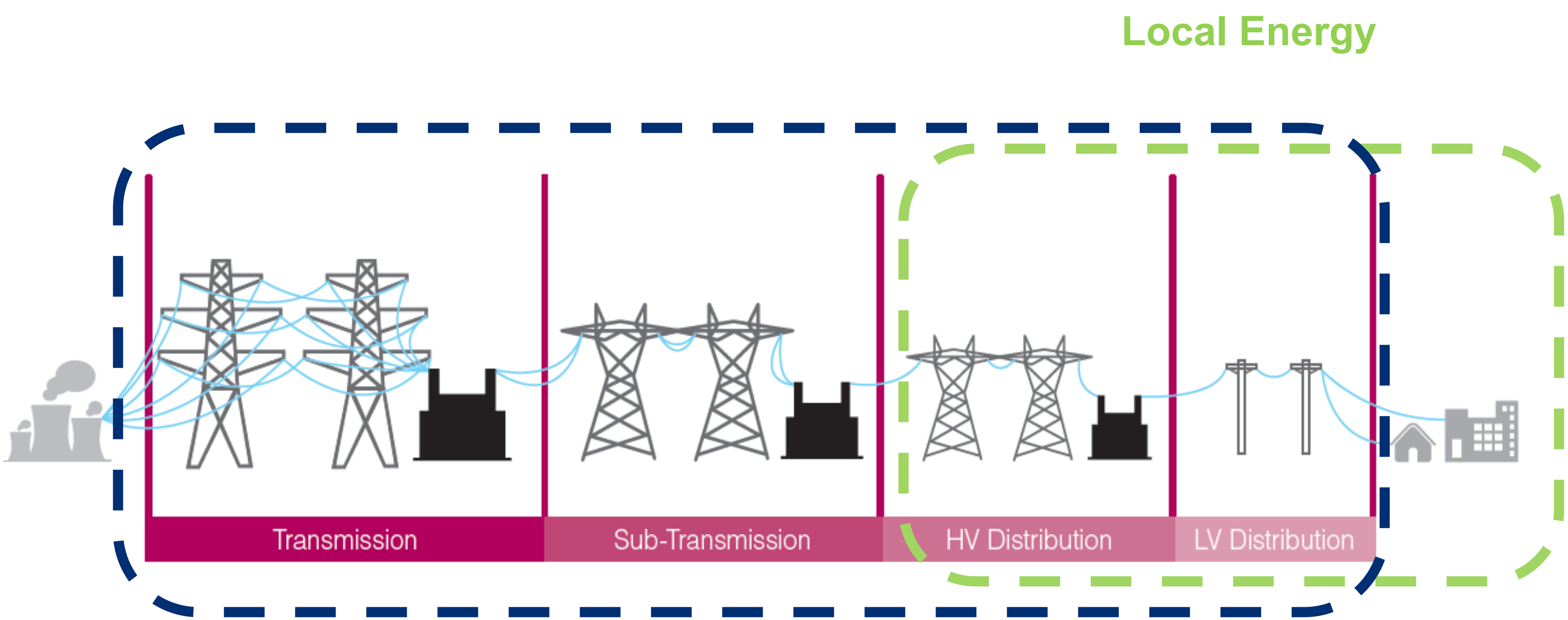
***** also called Virtual Net Metering or VNM***


Local
Energy

# THE DECENTRALISED ENERGY REVOLUTION HAS ONLY JUST BEGUN

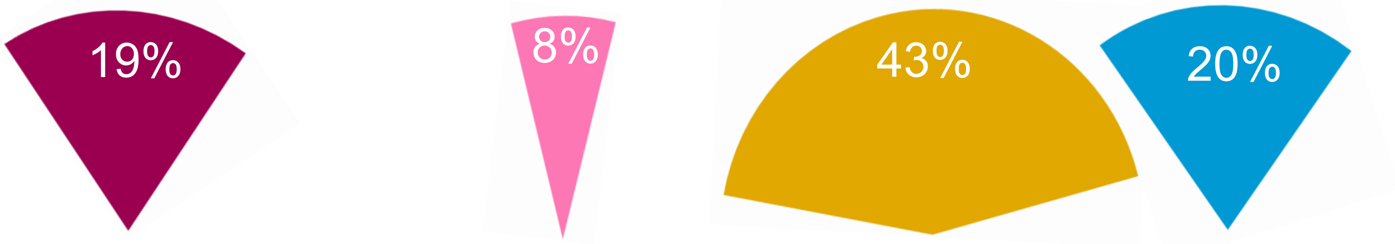




# NETWORK CHARGES: WHAT HAPPENS NOW

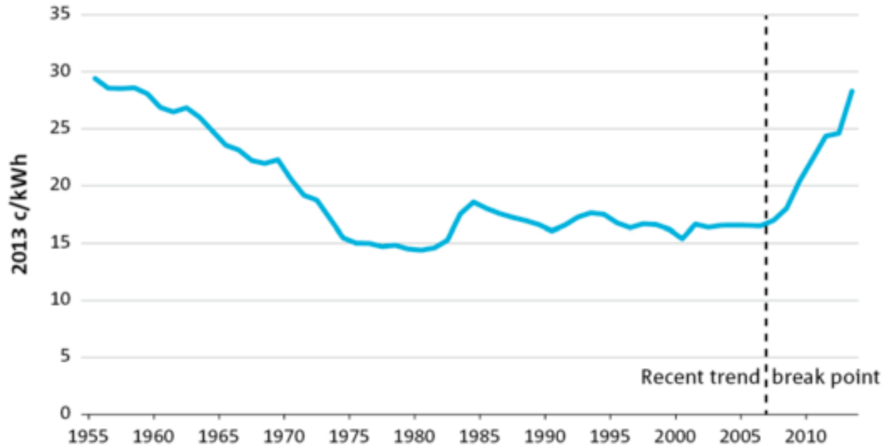



**Current network charges for local energy**

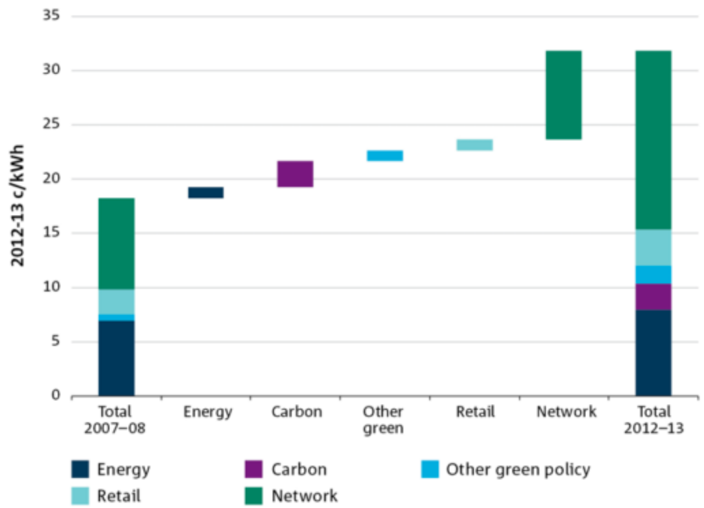
Network cost breakdown by level



# HISTORICAL NEM NETWORK COSTS




Historical average national electricity retail prices (AUS$ 2013)



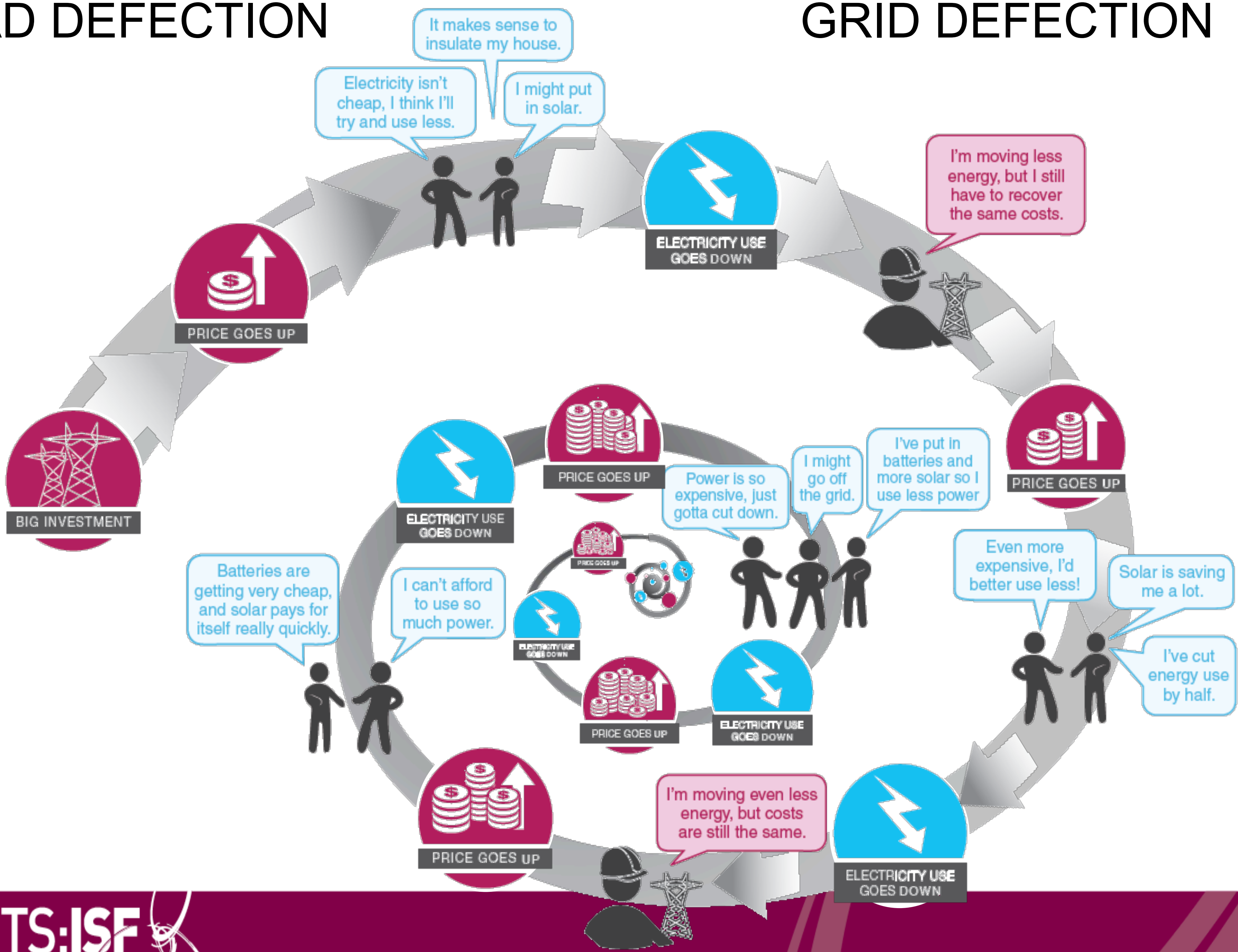

Cost breakdown

60% of increase in prices between 2008 and 2013 is from network investment

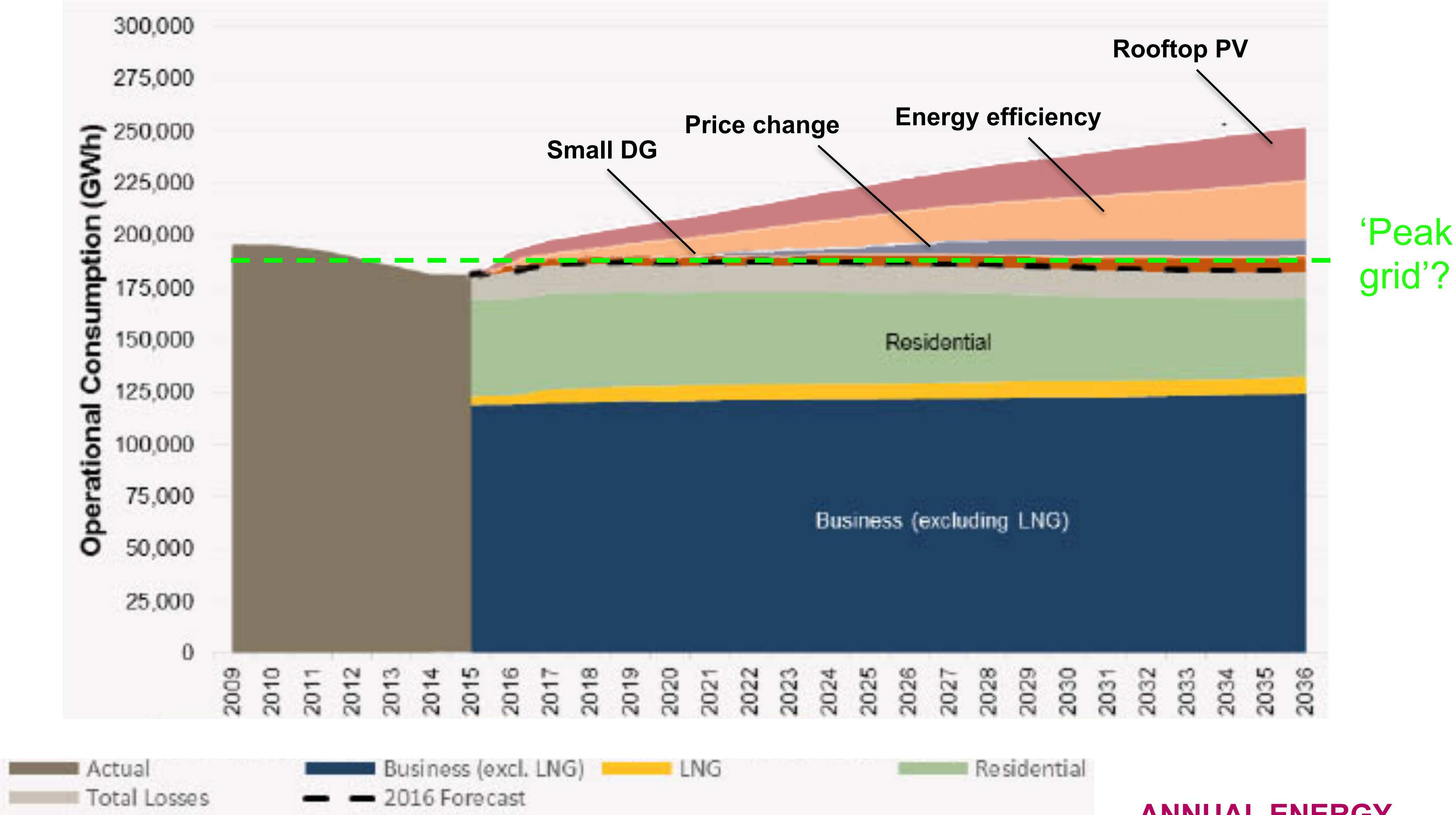
Source: CSIRO, Change and Choice (2013)

# LOAD DEFECTION

# GRID DEFECTION



# TIME OF TRANSFORMATION: GRID CONSUMPTION CLOSE TO FLAT




**ANNUAL ENERGY FORECAST FOR NEM**
**(Neutral, June 2016 NEFR)**

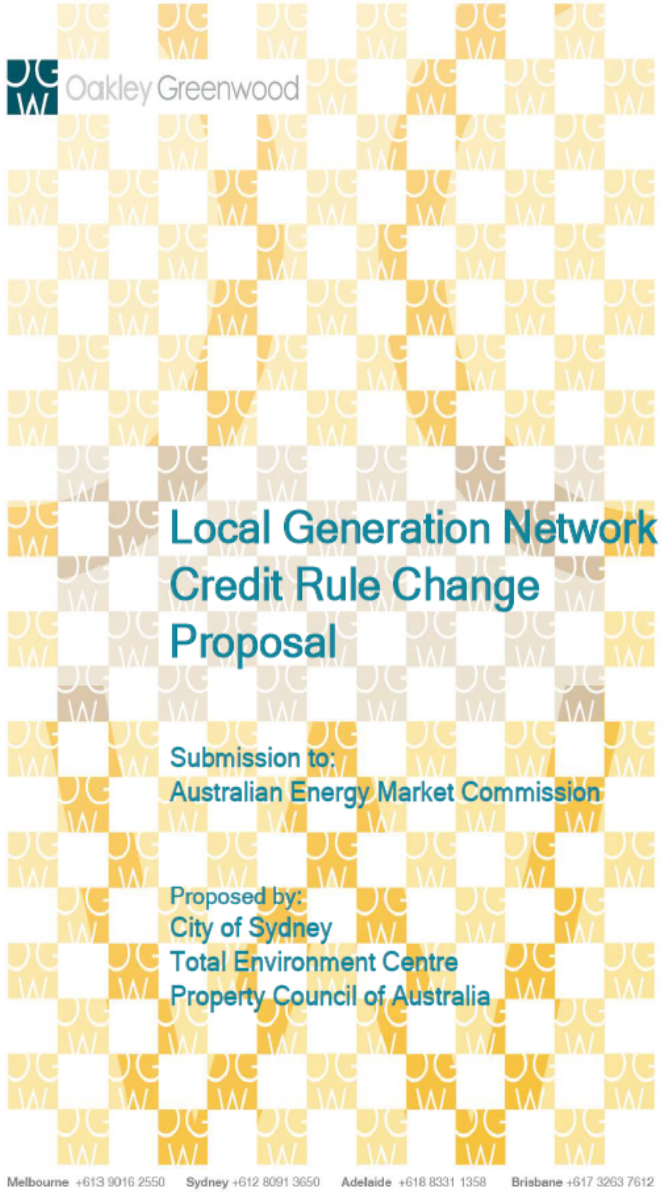
Source: AEMO NEFR 2016

# POTENTIAL BENEFITS OF LGNC

- **Local Network Credits**
  - Reduce future network costs and consumer costs
  - Reduce load defection and maintain network utilisation
  - Unlock new local energy projects
  - Unlock new product offerings e.g. neighbourhood energy storage, LET

# LGNC RULE CHANGE PROPOSAL

- Submitted July 2015 by City of Sydney, Total Environment Centre, and the Property Council of Australia
- Local network charges achieved via a CREDIT TO GENERATOR
- 22ND September AEMC publish draft determination not in favour of LGNC rule change proposal.


Oakley Greenwood

Local Generation Network Credit Rule Change Proposal

Submission to:
Australian Energy Market Commission

Proposed by:
City of Sydney
Total Environment Centre
Property Council of Australia

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# PART 2
# ECONOMIC MODEL

# RESEARCH QUESTIONS

## WHAT ARE THE LONG TERM COSTS AND BENEFITS OF AN LGNC?

1. At a macro level what is the Total Economic Cost over the long term?
2. At a consumer level what is the effect on consumers electricity bills?

## ECONOMIC AND SCENARIO MODELLING

1. How might peak network demand (MW) grow under different scenarios?
2. How might net imports and net exports change over time?
3. What are the economic costs and benefits of an LGNC and avoided network augmentation?

# EFFICIENTLY PRICING ELECTRICITY INFRASTRUCTURE

- **Allocative efficiency** – resources are allocated to the most productive use. This implies cost-reflectivity to send the correct price signals about the costs of different investments.
- **Productive efficiency** – requires the production of goods and services at lowest possible cost
- **Dynamic efficiency** – requires efficient allocation and production of goods over time. Implies that the the right investments are made at the right time.
- **Cost recovery** – requires the cost of infrastructure to be recovered
- *Prices must be set to encourage optimal use of existing infrastructure, whilst simultaneously signaling the cost of an additional unit to the system.*

***Setting electricity prices to marginal costs will promote the most efficient use and production of goods and service.***

# BASIC TERMINOLOGY

**Representative agent:** is a consumer, producer or prosumer on the electricity network. They represent the average characteristics of all consumers belonging to that agent category.

**Customer class:** residential, small commercial, large commercial and stand-alone distributed generation

**Network expansion:** The investment in additional infrastructure on the electricity network in order to meet future demand (augex, opex, repex)

**Gross generation:** total amount of electricity produced by an agent

**Gross consumption:** total amount of electricity consumed by an agent

**Net exports:** is the electricity exported back to the grid (kWh)

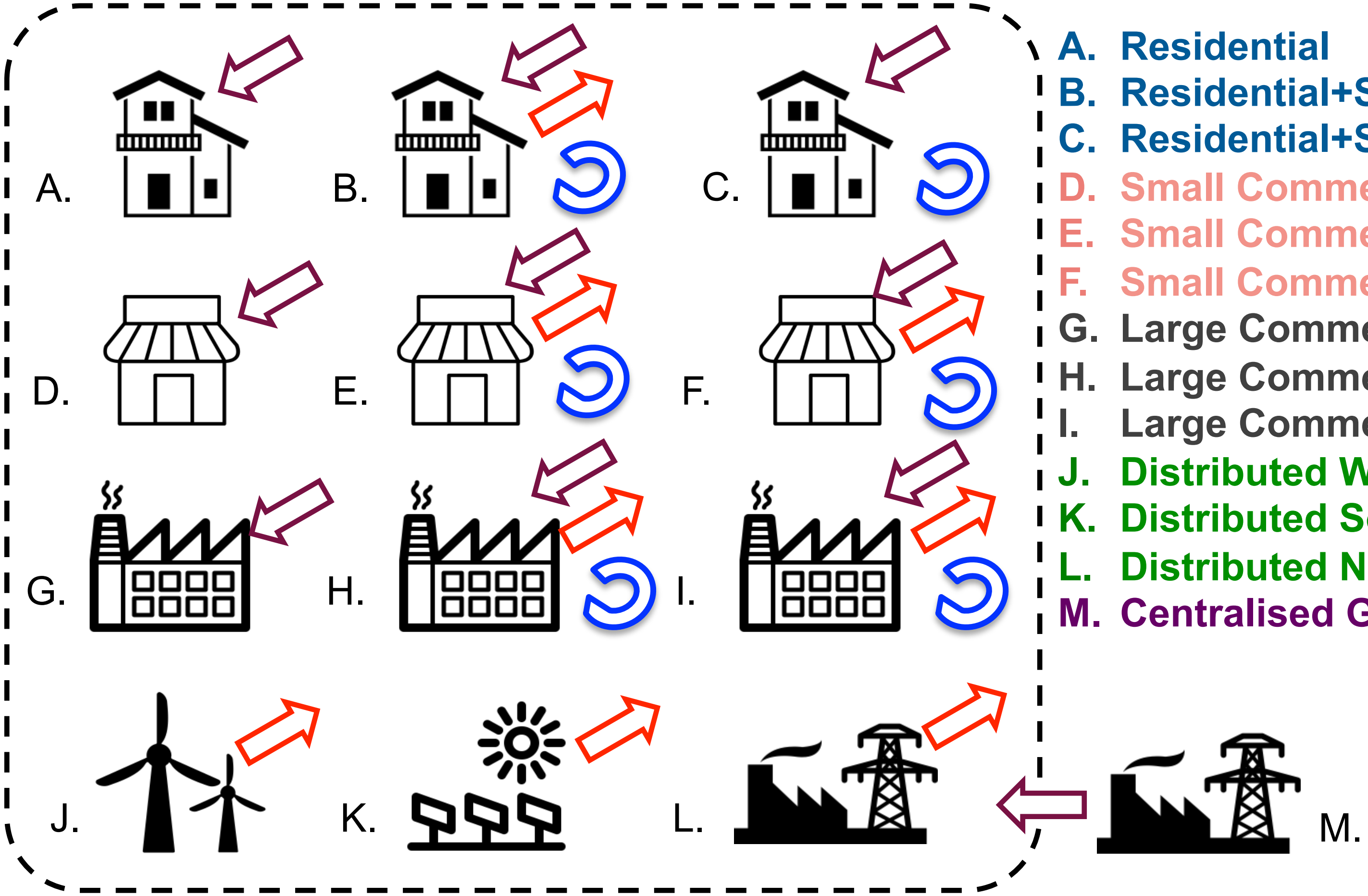
**Net imports:** is the electricity import requirements from the grid to satisfy demand (kWh)

# DATA SOURCES

| Data source | Date |
|---|---|
| **AEMO National Electricity & Gas Forecasting** http://forecasting.aemo.com.au/ | 2015 and 2016 |
| **CSIRO Electricity Profiles**<br><br>http://doi.org/10.4225/08/5631B1DF6F1A0 | 2015 |
| **Energy Supply Association of Australia (ESAA) Annual Reports**<br>http://www.esaa.com.au/ | 2015 |
| **Department of Industry and Science – Australian Energy Statistics**<br><br>http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Australian-energy-statistics.aspx | 2015 |
| **Australian PV Institute**<br><br>www.apvi.org.au | 2015 |
| **Clean Energy Regulator (RET)**<br><br>http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations#SGU--Wind-Deemed | 2015 |
| **NEM-Review Database**<br><br>http://v6.nem-review.info/use/enjoy/data/datasets/datasets.aspx | 2015 |

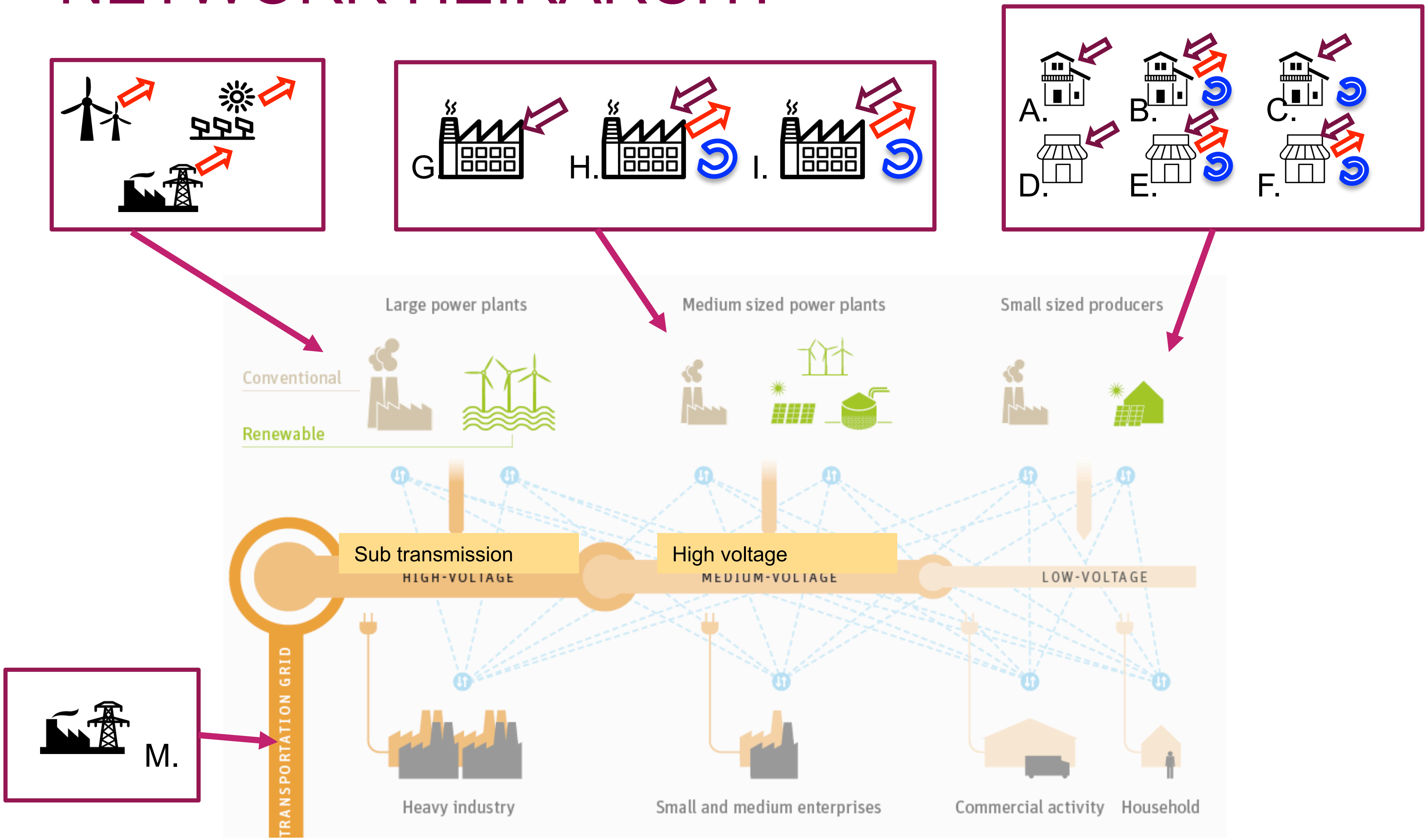
# MODELLING FRAMEWORK

Distribution network

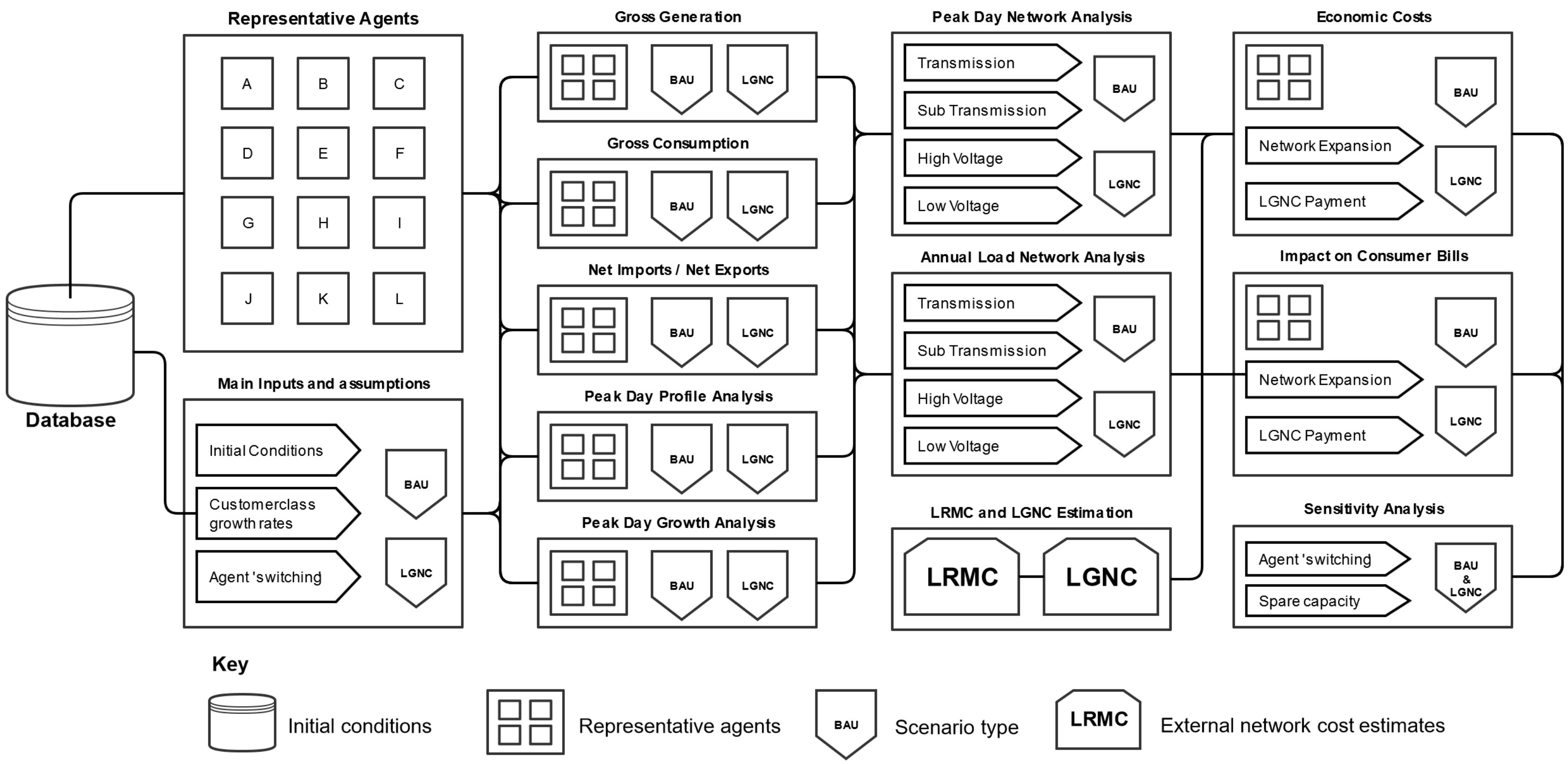



A. Residential
B. Residential+Solar
C. Residential+Solar+Battery
D. Small Commercial
E. Small Commercial + Solar
F. Small Commercial + S + LGNC
G. Large Commercial
H. Large Commercial + CoGen
I. Large Commercial + CG+ LGNC
J. Distributed Wind
K. Distributed Solar Farm
L. Distributed NS generation
M. Centralised Gen (residual)

# NETWORK HEIRARCHY

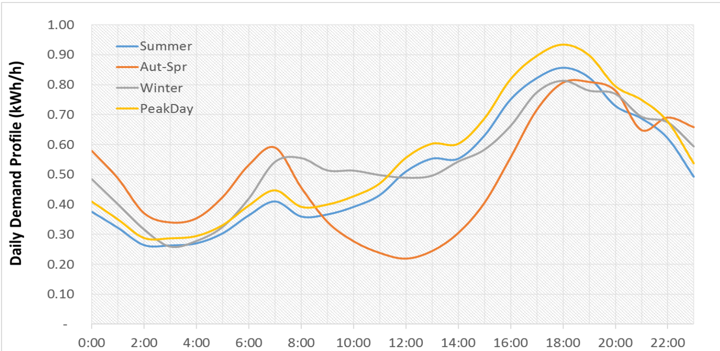


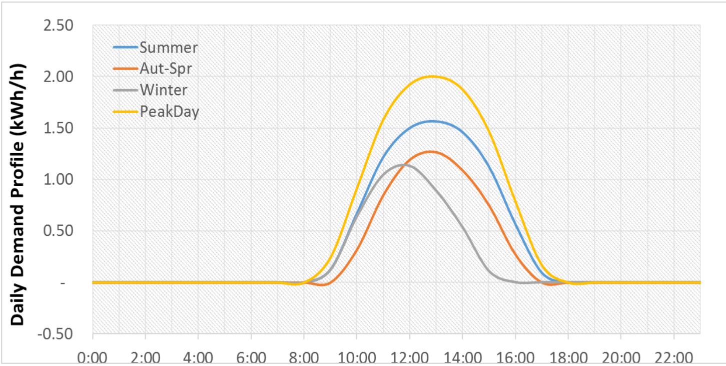
# REPRESENTATIVE AGENTS

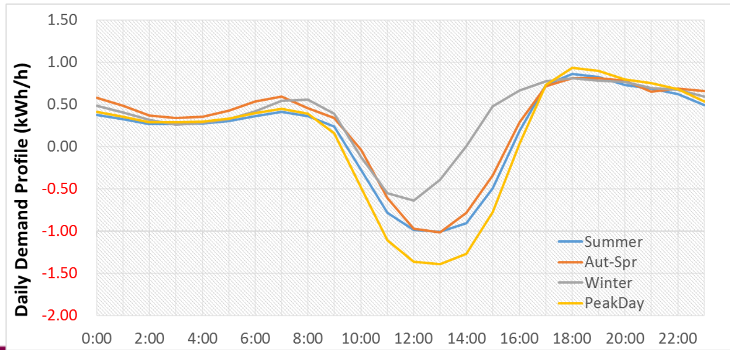


# REPRESENTATIVE AGENT MODEL

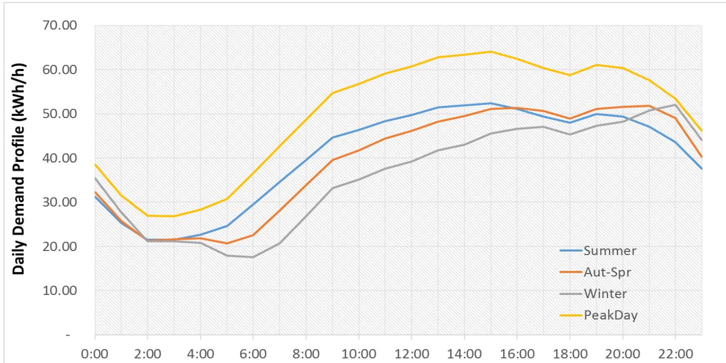
Residential + PV

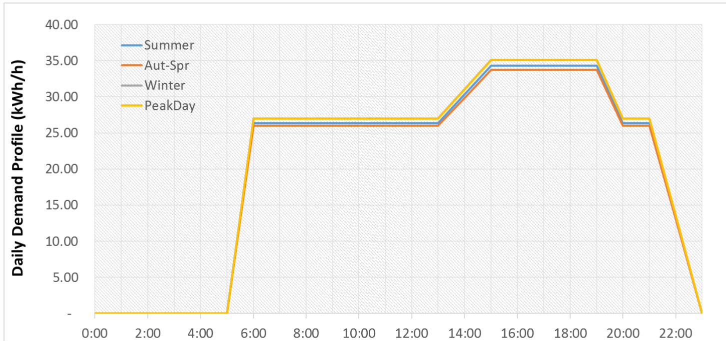


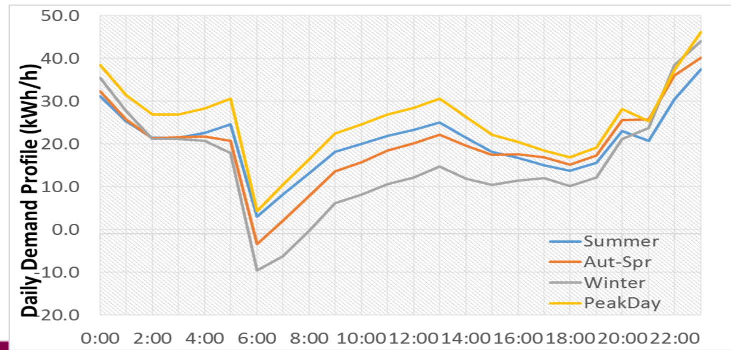




Commercial + Cogen



# MODEL LIMITATIONS

- Long time horizons and uncertainty in rapidly changing market
- Deterministic model with two exogenous scenarios
- Approximates each customer category as an average representative 'agent'
- Does not include costs of upgrading network to handle increased distributed generation
- Does not include savings associated with replacement expenditure savings associated with downsizing
- Data for one state only – looking to expand!

# SCENARIO ASSUMPTIONS

- Customer numbers, capacity and generation are for NSW
- LGNC payments are NOT made to existing generation
- LGNC payments are NOT made to generation under <10kW
- Networks have sufficient capacity to avoid investment until 2025 (~600MW)
- 80/20 benefit share (80% benefit goes to generators / 20% to Networks)
- Growth projections are modelled from AEMO projections
- LRMC values independently estimated from Energeia work
- Costs (augmentation and LGNC payments) allocated to customers on a volumetric basis

# AGENT DATA: INITIAL CONDITIONS

| | No. Agents[1] | Gross consumption per agent[2] | Net import consumption per agent[3] | Gross generation per agent[4] | Net export generation per agent[5] |
|---|---|---|---|---|---|
| | 2015 | kWh / year | kWh / year | kWh / year | kWh / year |
| A - Residential | 2,849,461 | 4,447 | 4,450 | - | - |
| B - Residential with PV | 339,633 | 4,447 | 2,911 | 3,641 | 2,102 |
| C - Residential with PV + Battery | 100 | 4,447 | 919 | 3,641 | - |
| D - Small Commercial | 397,954 | 92,290 | 92,290 | - | - |
| E - Small Commercial with PV | 9,276 | 92,290 | 63,107 | 29,183 | - |
| F - Small Commercial with PV + export | 100 | 92,290 | 53,206 | 42,921 | 3,837 |
| G - Large Commercial | 49,347 | 296,780 | 296,780 | - | - |
| H - Large Commercial with cogen | 105 | 1,666,667 | 719,256 | 1,000,772 | 53,362 |
| I - Large Commercial with cogen + export | 10 | 1,666,667 | 546,403 | 1,215,902 | 95,638 |

1. Numbers of agents are from ESAA annual report 2015
2. Gross consumption per agent is calculated by dividing total consumption by the number of agents in each category
3. Net import consumption is estimated from the net energy profiles where half-hourly demand is greater than own generation
4. Gross generation is calculated from solar generation data from APVI data and the number of installations
5. Net export generation is estimated from net energy profiles where half-hourly generation is greater than demand.

# AGGREGATE CONSUMPTION

| Representative agent type | 2015 Gross Consumption GWh | 2030 Gross Consumption GWh | 2015 Net Import Consumption GWh | 2030 (BAU) Net Import Consumptin GWh | 2030 (LGNC) Net Imports GWh |
|---|---|---|---|---|---|
| A - Residential | 12,681 | 12,459 | 12,681 | 12,459 | 12,459 |
| B - Residential + PV | 1,512 | 2,676 | 989 | 1,750 | 1,750 |
| C - Residential + PV + Battery | 0 | 1,589 | 0 | 328 | 328 |
| **Total Residential** | 14,193 | 16,724 | 13,670 | 14,538 | 14,538 |
| D - Small Commercial | 36,727 | 38,305 | 36,727 | 38,305 | 35,658 |
| E - Small Commercial + PV | 856 | 5,980 | 585 | 4,089 | 4,089 |
| F - Small Commercial + Exports | 9 | 11 | 5 | 6 | 1,532 |
| **Total Small Commercial Customers** | 37,592 | 44,296 | 37,318 | 42,400 | 41,279 |
| G - Large Commercial | 14,645 | 15,699 | 14,645 | 15,699 | 14,757 |
| H - Large Commercial + cogen | 174 | 275 | 75 | 119 | 119 |
| I - Large Commercial + cogen + Exports | 16 | 18 | 5 | 6 | 315 |
| **Total Large Commercial** | 14,836 | 15,992 | 14,726 | 15,823 | 15,190 |
| **Total Demand** | **66,622** | **77,011** | **65,714** | **72,762** | **71,008** |

# AGGREGATE GENERATION

| Representative agent type | 2015 Gross Generation GWh | 2030 Gross Generation GWh | 2015 Net Export Generation GWh | 2030 (BAU) Net Export Generation GWh | 2030 (LGNC) Net Export Generation GWh |
|---|---|---|---|---|---|
| A - Residential | - | - | - | - | - |
| B - Residential + PV | 1,219 | 2,158 | 714 | 1,264 | 1,264 |
| C - Residential + PV + Battery | 0 | 1,281 | - | - | - |
| **Total Residential** | 1,219 | 3,440 | 714 | 1,264 | 1,264 |
| D - Small Commercial | - | - | - | - | - |
| E - Small Commercial + PV | 267 | 1,864 | - | - | - |
| F - Small Commercial + Exports | 4 | 5 | 0 | 0 | 110 |
| **Total Small Commercial Customers** | 271 | 1,869 | 0 | 0 | 110 |
| G - Large Commercial | - | - | - | - | - |
| H - Large Commercial + cogen | 105 | 165 | 6 | 9 | 9 |
| I - Large Commercial + cogen + Exports | 12 | 13 | 1 | 1 | 55 |
| **Total Large Commercial** | 117 | 178 | 7 | 10 | 64 |
| J - Wind Power | 28 | 45 | 28 | 45 | 56 |
| K - Solar Farm | 31 | 48 | 31 | 48 | 60 |
| L - GenSet | 370 | 584 | 370 | 584 | 731 |
| **Total Local Generation** | 428 | 677 | 428 | 677 | 847 |
| **Total Generation** | **2,036** | **6,164** | **1,149** | **1,951** | **2,285** |

# LGNC PROPOSED RULE CHANGE:

# CONSUMER OUTCOMES - MODELLING RESULTS

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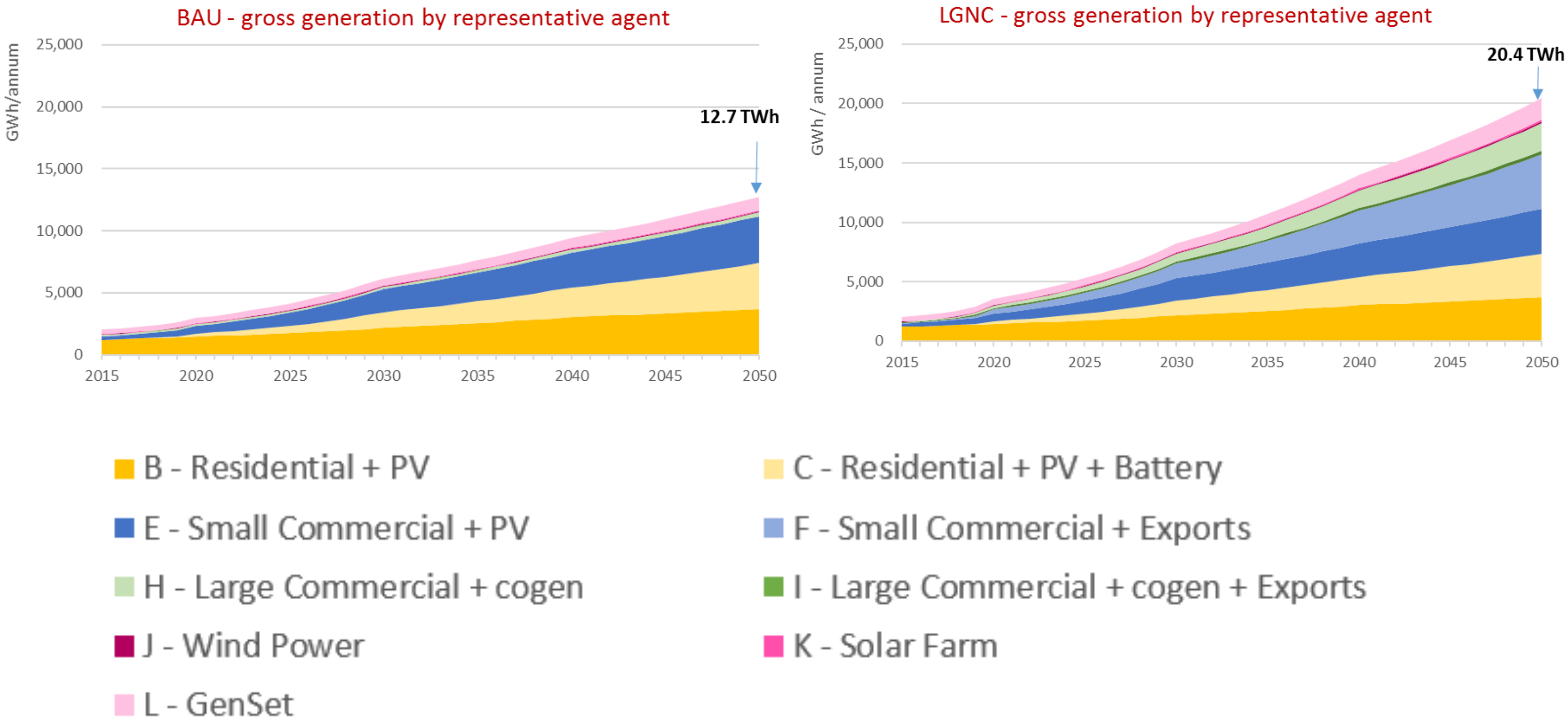
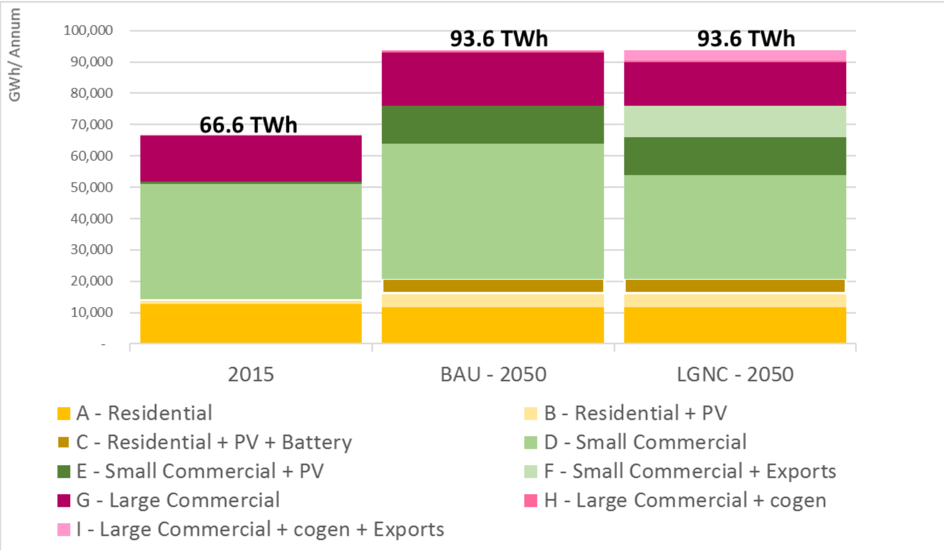
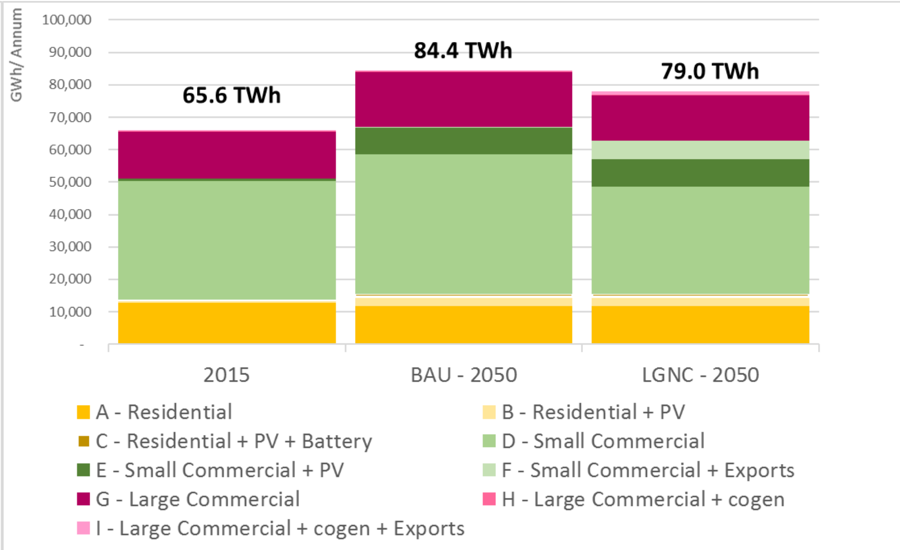
# GROSS GENERATION



# CONSUMPTION

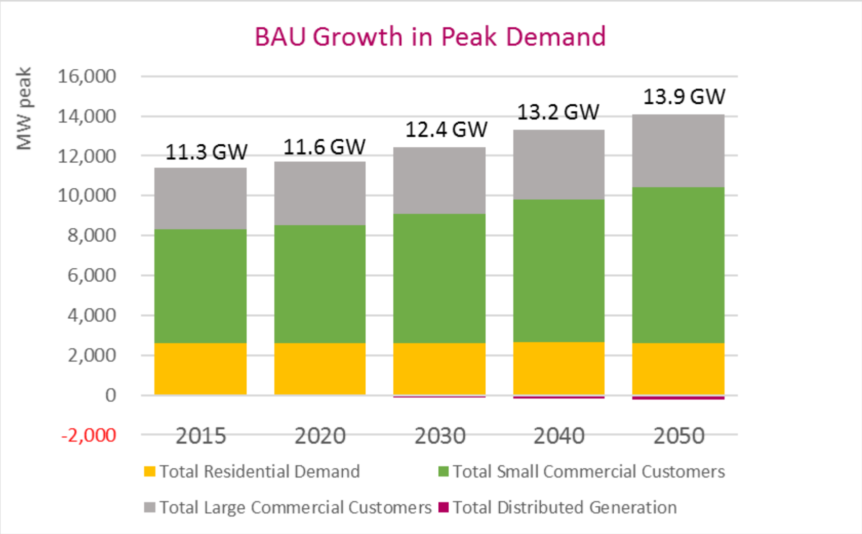


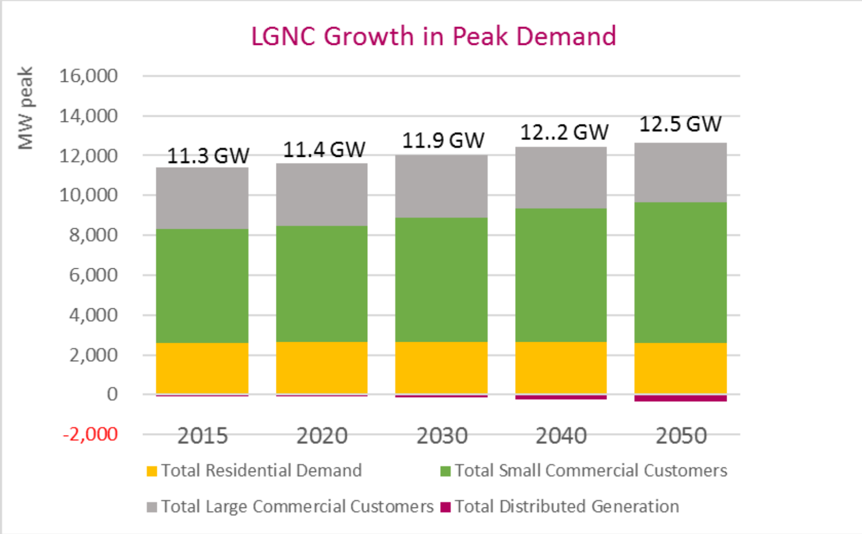

Gross Consumption




Net (Import) Consumption

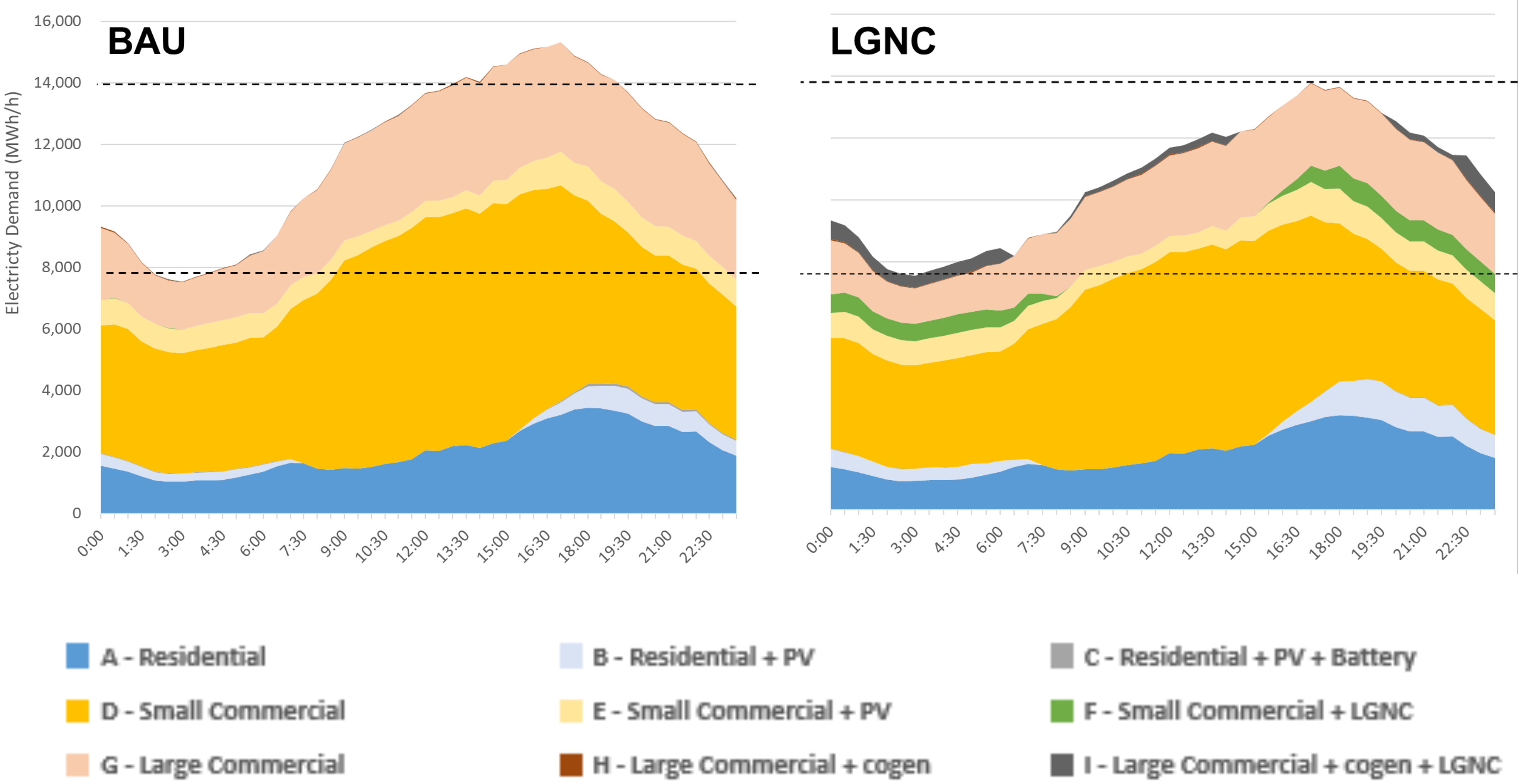
# GROWTH IN PEAK DEMAND



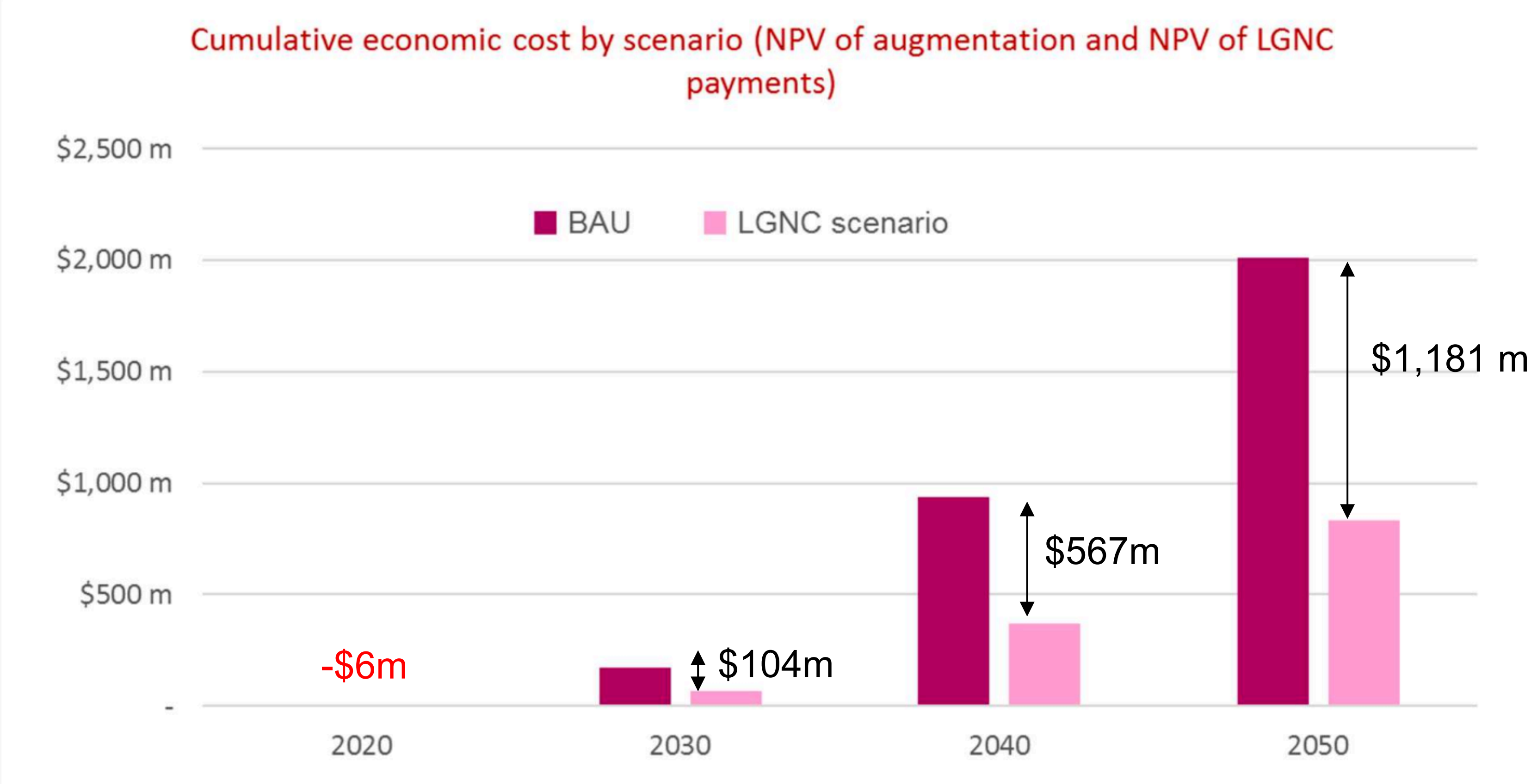




| | | BAU | LGNC | BAU | LGNC | Peak Savings |
|---|---|---|---|---|---|---|
| NETWORK | 2015 (MW) | 2050 (MW) | | % Increase | | MW (Δ%) |
| Transmission | 11,354 | 13,883 | 12,284 | 22% | 8% | 1,599 (63%) |
| High Voltage | 11,426 | 14,093 | 12,661 | 23% | 11% | 1,432 (54%) |
| Low Voltage | 8,299 | 10,412 | 9,676 | 25% | 17% | 736 (35%) |

# CHANGE IN PEAK PROFILE IN 2050

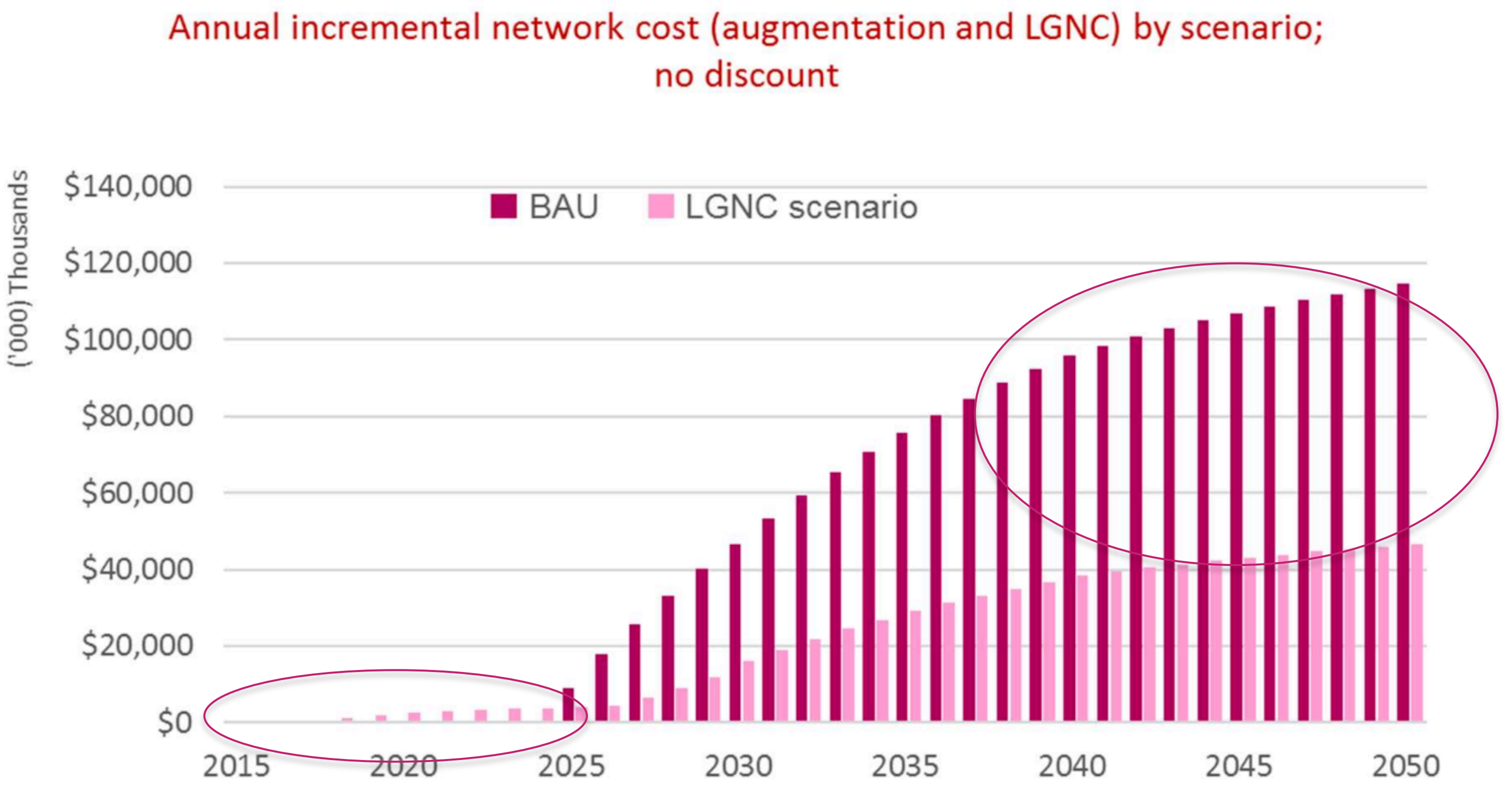


# ECONOMIC COSTS AND BENEFITS




**The headline result from the economic analysis is that over the long term, an LGNC scenario incurs costs that are $1.18 billion lower than BAU, that is 59% lower than the cost of normal network expansion.**

# INCREMENTAL COSTS



# ECONOMIC COSTS AND BENEFITS

**Cumulative economic cost by scenario (NPV of augmentation and NPV of LGNC payments)**

| | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| **BAU** | | | | |
| Network investment | - | $172 m | $939 m | $2,012 m |
| LGNC payments | - | - | - | - |
| **Total** | - | $172 m | $939 m | $2,012 m |
| **LGNC scenario** | | | | |
| Network investment | - | $16 m | $239 m | $598 m |
| LGNC payments | $6 m | $52 m | $132 m | $233 m |
| **Total** | $6 m | $69 m | $371 m | $832 m |
| **Net Economic Benefit** | **-$6 m** | **$104** | **$567 m** | **$1,181 m** |

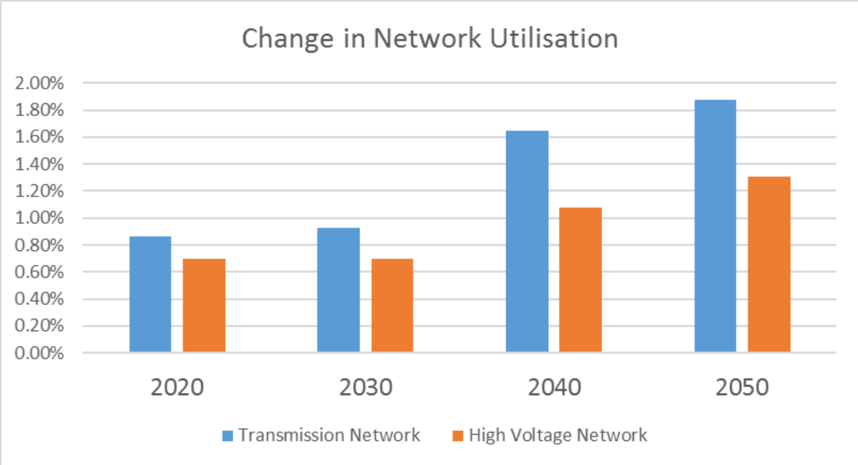
***Network: weighted average of Ausgrid and essential parameters (66%, 34% Essential)***

# IMPACT ON CONSUMER BILLS

| $ per year | Average | | 2020 | | 2030 | | 2050 | |
|---|---|---|---|---|---|---|---|---|
| Residential | -$9 | ▼ | $0 | ▲ | -$7 | ▼ | -$20 | ▼ |
| Residential with PV | -$6 | ▼ | $0 | ▲ | -$4 | ▼ | -$13 | ▼ |
| Residential with PV + battery | -$2 | ▼ | $0 | ▲ | -$1 | ▼ | -$4 | ▼ |
| **Total Residential Customers** | -$7 | ▼ | $0 | ▲ | -$6 | ▼ | -$15 | ▼ |
| Small Commercial | -$185 | ▼ | $4 | ▲ | -$139 | ▼ | -$422 | ▼ |
| Small Commercial with PV | -$127 | ▼ | $3 | ▲ | -$95 | ▼ | -$289 | ▼ |
| Small Commercial with PV (includes export) | -$211 | ▼ | -$102 | ▼ | -$184 | ▼ | -$348 | ▼ |
| **Total Small Commercial Customers** | -$191 | ▼ | $2 | ▲ | -$140 | ▼ | -$438 | ▼ |
| Large Commercial | -$367 | ▼ | $14 | ▲ | -$276 | ▼ | -$843 | ▼ |
| Large Commercial with cogen | -$1,239 | ▼ | -$335 | ▼ | -$1,019 | ▼ | -$2,374 | ▼ |
| Large Commercial with cogen (includes export) | -$3,050 | ▼ | -$2,414 | ▼ | -$2,889 | ▼ | -$3,869 | ▼ |
| **Total Large Commercial** | -$2,341 | ▼ | $25 | ▲ | -$1,693 | ▼ | -$5,440 | ▼ |

All consumers see decreases in their average annual electricity bills

# NETWORK UTILISATION




$$Network\ Utilisation = Actual\ Load\ (MWh)/8760 \times Peak\ Load\ (MW)$$

# AVOIDED AUGMENTATION FROM SYSTEM LOSSES

| Electricity losses from GWh avoided | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| **Transmission / System** | $0.0 m | $0.3 m | $6.0 m | $15.8 m | $28.1 m |

# LGNC PROPOSED RULE CHANGE:

# SENSITIVITY TESTING

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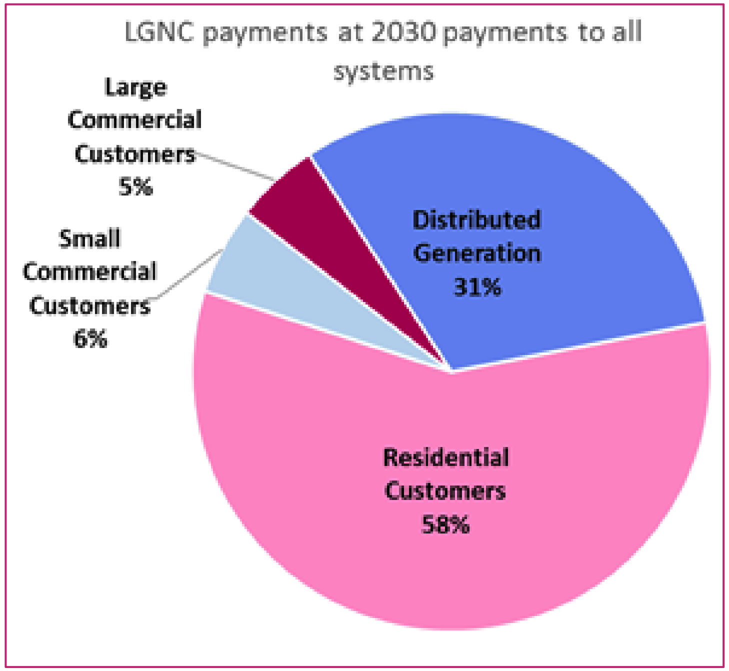
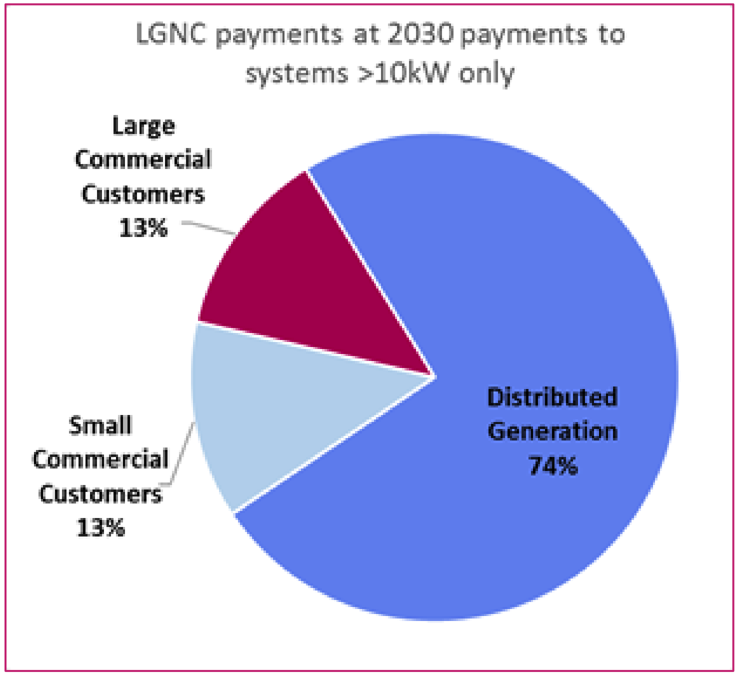
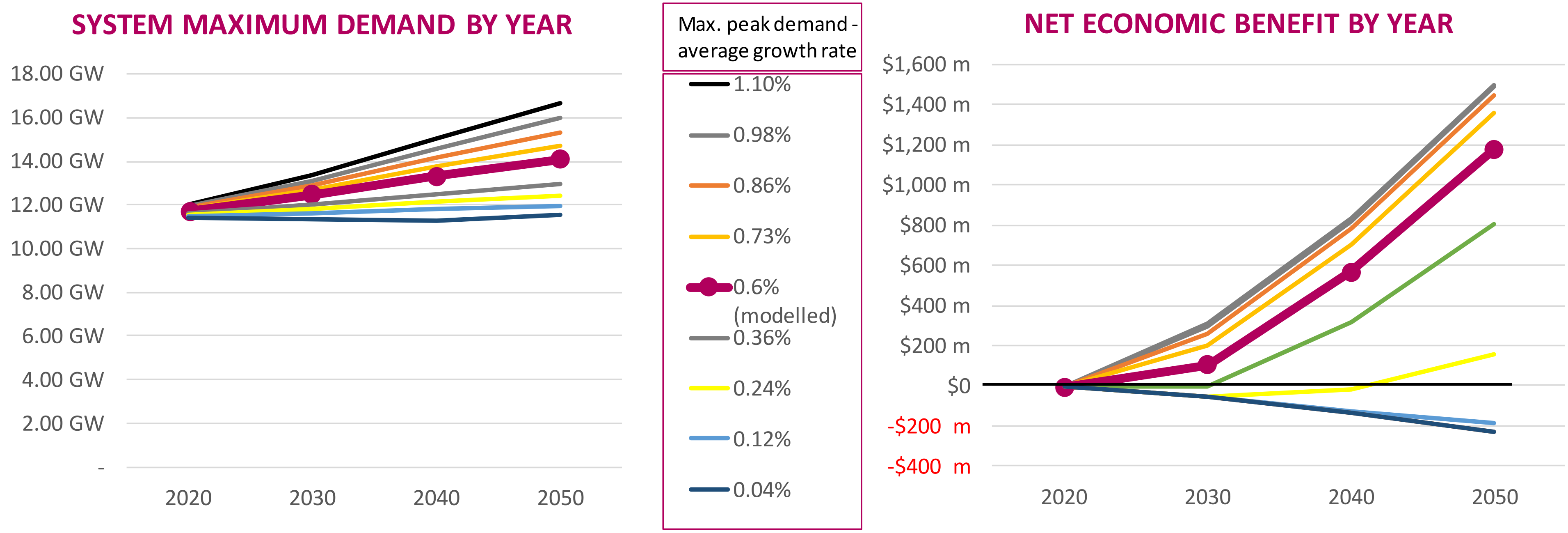
# LGNC PAID TO SMALL SYSTEMS? (<10 KW)

- Recommend excluding systems < 10kW as economic benefit increases by $113m to 2030 (from $-9m to $104).



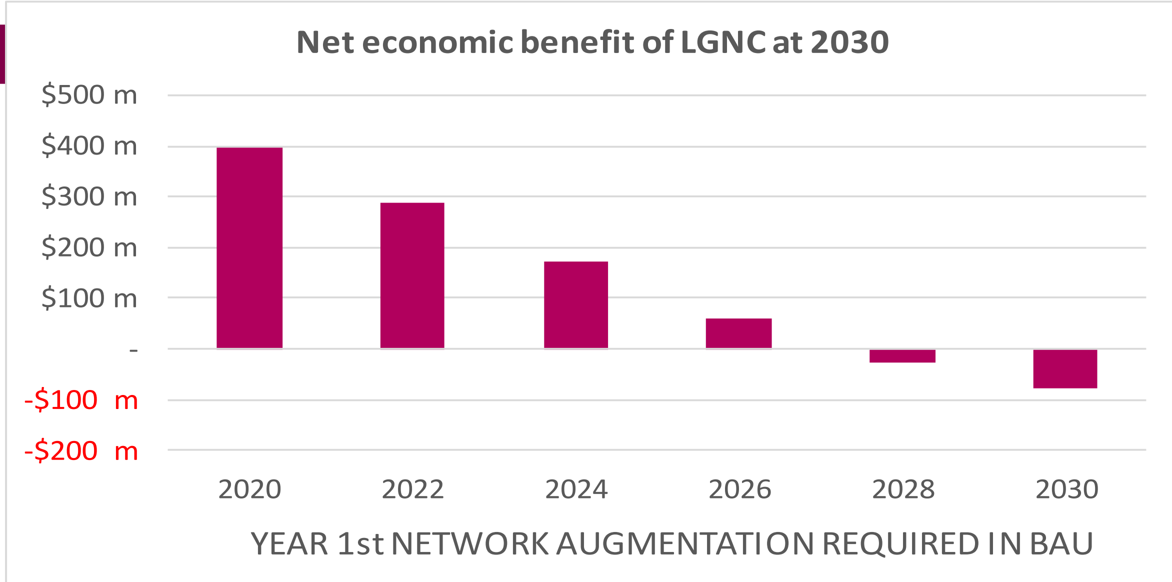



# WHAT HAPPENS IF DEMAND GROWTH IS FLAT?




- Sensitivity testing for range of demand growth rates
- Net economic benefit highly asymmetric because costs are capped at LGNC payments and benefits of avoided augmentation far outweigh these costs.

# SENSITIVITY TESTING – YEAR OF AUGM




| Investement first required under BAU | Net economic benefit of LGNC at 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| **2020** | $6 m | $411 m | $1,045 m | $1,816 m |
| **2022** | -$8 m | $305 m | $897 m | $1,624 m |
| **2024** | -$8 m | $186 m | $724 m | $1,397 m |
| **2026** | -$8 m | $74 m | $550 m | $1,162 m |
| **2028** | -$8 m | -$17 m | $372 m | $913 m |
| **2030** | -$8 m | -$64 m | $217 m | $690 m |

# OTHER SENSITIVITY

- The year network augmentation is first required

RESULT: benefit is reduced for later years; all cases tested had long term benefit

- Rate of growth of local generation in the LGNC scenario compared to BAU

RESULT: in general, more local generation increased the benefit

- Including non-locational transmission costs in the LGNC payments.

RESULT: no significant effect

# IS AN LGNC A CROSS SUBSIDY?

- LGNC payments are estimated from avoided future network expansion costs (i.e. using LRMC).
- The overall costs in an LGNC scenario are lower than in BAU
- The LGNC represents a system-wide saving to all consumers it is therefore **NOT** a cross-subsidy between consumers.
  - The majority benefit from LGNC is received by those who interact with the grid.
  - Those who generate behind the meter receive the least benefit.
  - Standard residential consumers receive the largest bill reductions.

# CONCLUSION

- The LGNC scenario has network costs that are 60% lower than the costs of BAU

**Total Economic Costs and Benefits**

| | 2020 | 2030 | 2050 |
|---|---|---|---|
| (Cost) Benefit | ($6 m) | $104 m | $1,180 m |

- All customer categories will see reductions in electricity bills between 2025 and 2030

- Our conclusions are robust to a range of sensitivity tests
  - Growth in distributed generation (-50%/+50% -> $213m/$1,442m)
  - Change in growth of underlying peak demand (below 0.2% growth is a dis-benefit)
  - Available spare capacity on the network (2030 -> $655m)

- Through this modelling we are able to make the following recommendations:
  - Exclude distributed generators below 10kW and above 30MW
  - Exclude all existing distributed generators*

*Revisit the potential for including existing dispatchable generators

# FUTURE RESEARCH

- Model economic impacts for each network area and state
- Incorporate dynamic feedback effects in modelling LGNC payment effects on the uptake of increased DG
- Model the effects of electric vehicles and battery uptake
- Incorporate repex savings in a declining growth environment
- Incorporate a probabilistic model representing the distribution of agents for demand and supply

# WEAKNESSES OF DETERMINATION

- LGNC payments are made existing generation
- Only considers PV as distributed generation technology
- Includes small systems under 10kW
- Does not include savings to transmission or distribution levels