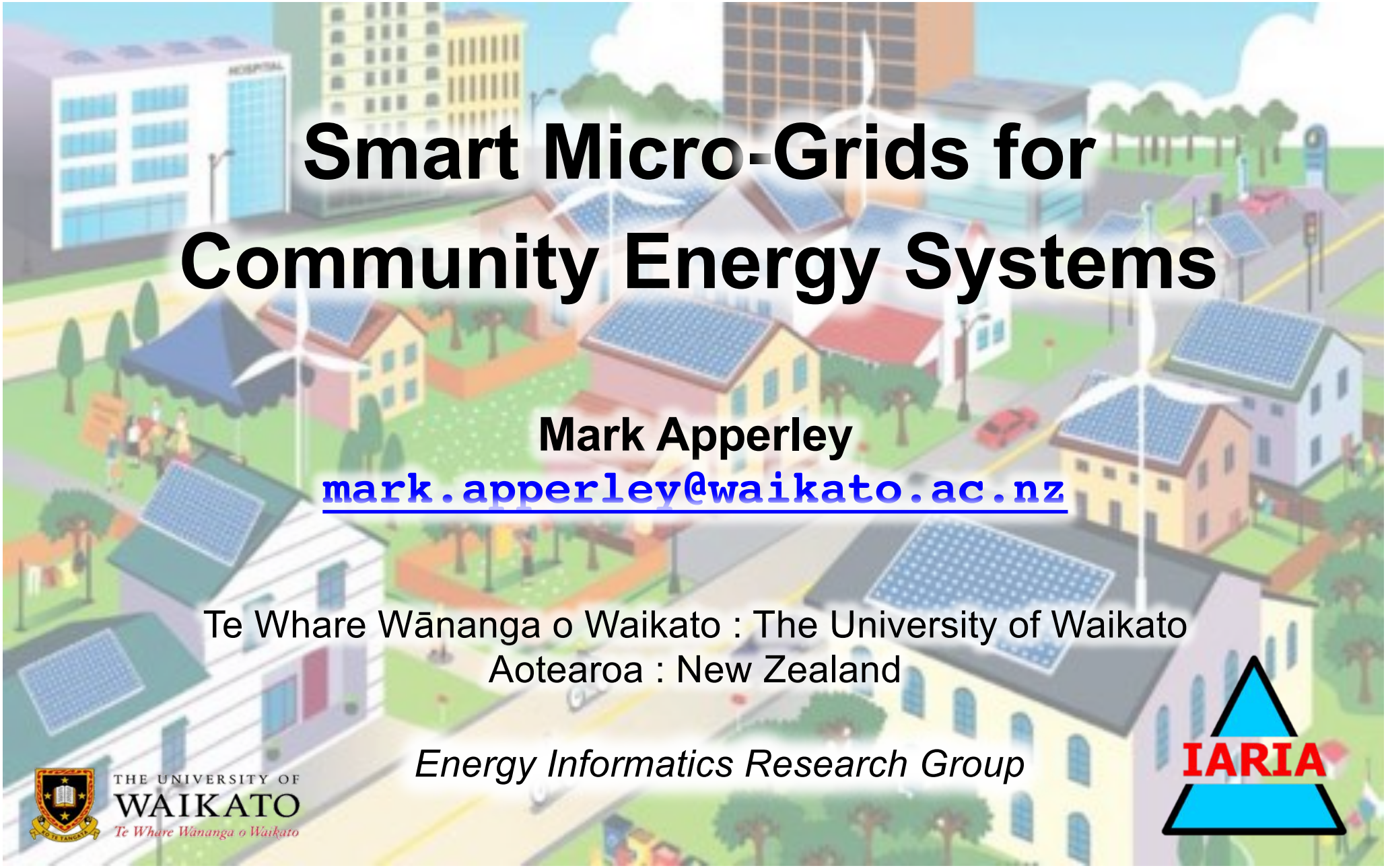

Smart Micro-Grids for Community Energy Systems

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IARIA

Mark Apperley is Professor of Software Engineering at the University of Waikato, Hamilton, New Zealand. He originally studied Electrical Engineering at the University of Auckland, and after a PhD involving digital data processing in radio astronomy, he held a post-doctoral research appointment at Imperial College, London, developing an interactive graphics CAD system for electronic circuits. He returned to New Zealand in 1975 as a lecturer in computer science at Waikato. In 1985, he moved to a chair at Massey University in Palmerston North, where he was Head of Department, and later Dean of the School of Mathematical and Information Sciences. He returned to Waikato in 1994 as Professor of Computer Science, and chairperson of the department. He became Dean of the then School of Mathematical and Information Sciences in 2003, a role he held for five years. For a 12-month period (2011-2012) he also served as Pro Vice-Chancellor (Research).

For a large part of his academic career, the main focus of Mark's research has human-computer interaction (HCI) and information visualization. However, over the past ten years he has also taken on a strong involvement in energy informatics, specifically the application of ICT in renewable and efficient energy utilization. His work in this area has included vehicle-to-grid technologies, community energy systems, and smart micro-grids.

Legacy Electricity Grid

- For 100+ years, electricity industry characterised by
  - large-scale grids
  - need to balance generation and demand in real-time

A challenge to effectively utilize solar and wind!

- "*Power systems have always been built to continuously balance generation with demand in real time, because there has not been a viable means of storing electrical energy at point-of-use. This drives much of the complexity, risk and cost in modern power systems*."

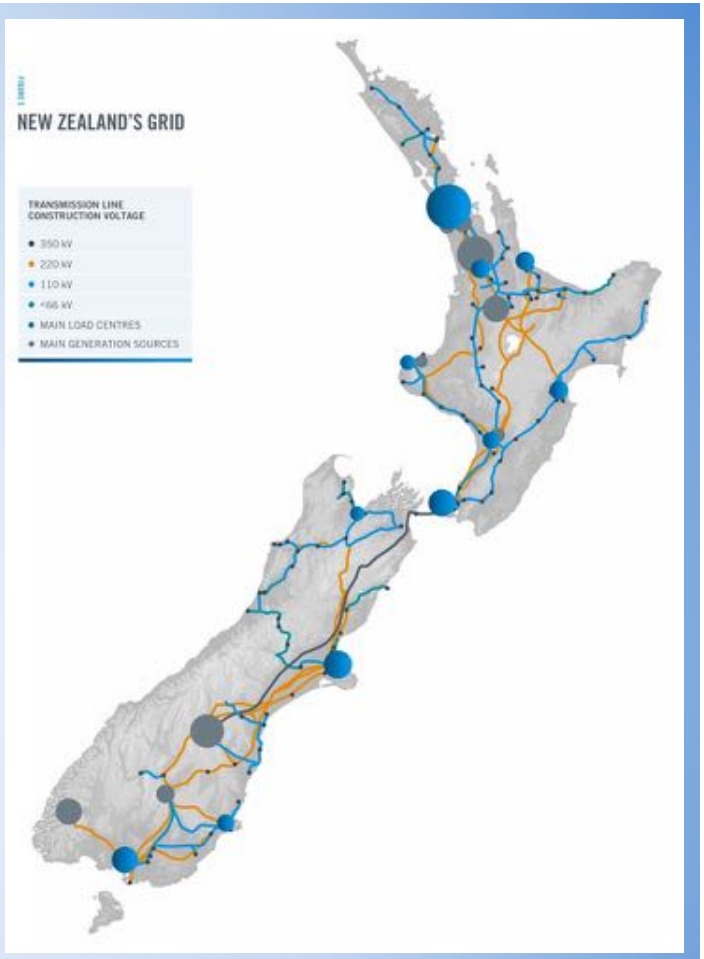
(Transpower; Transmission Tomorrow, 2016)

Legacy Electricity Grid

- Major electricity loads concentrated in:
  - heavily populated areas (eg cities)
  - where there are major industries

- Major electricity sources (in NZ):
  - big rivers
  - windy ridges
  - near coal mines
  - geothermal fields

Generally away from major loads



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One-way power flow not ideally suited to accommodating distributed generation and storage

- Grid is a major infrastructure to transfer energy from source (generation) to load.

Smart Grid – the Need/Opportunity for Change

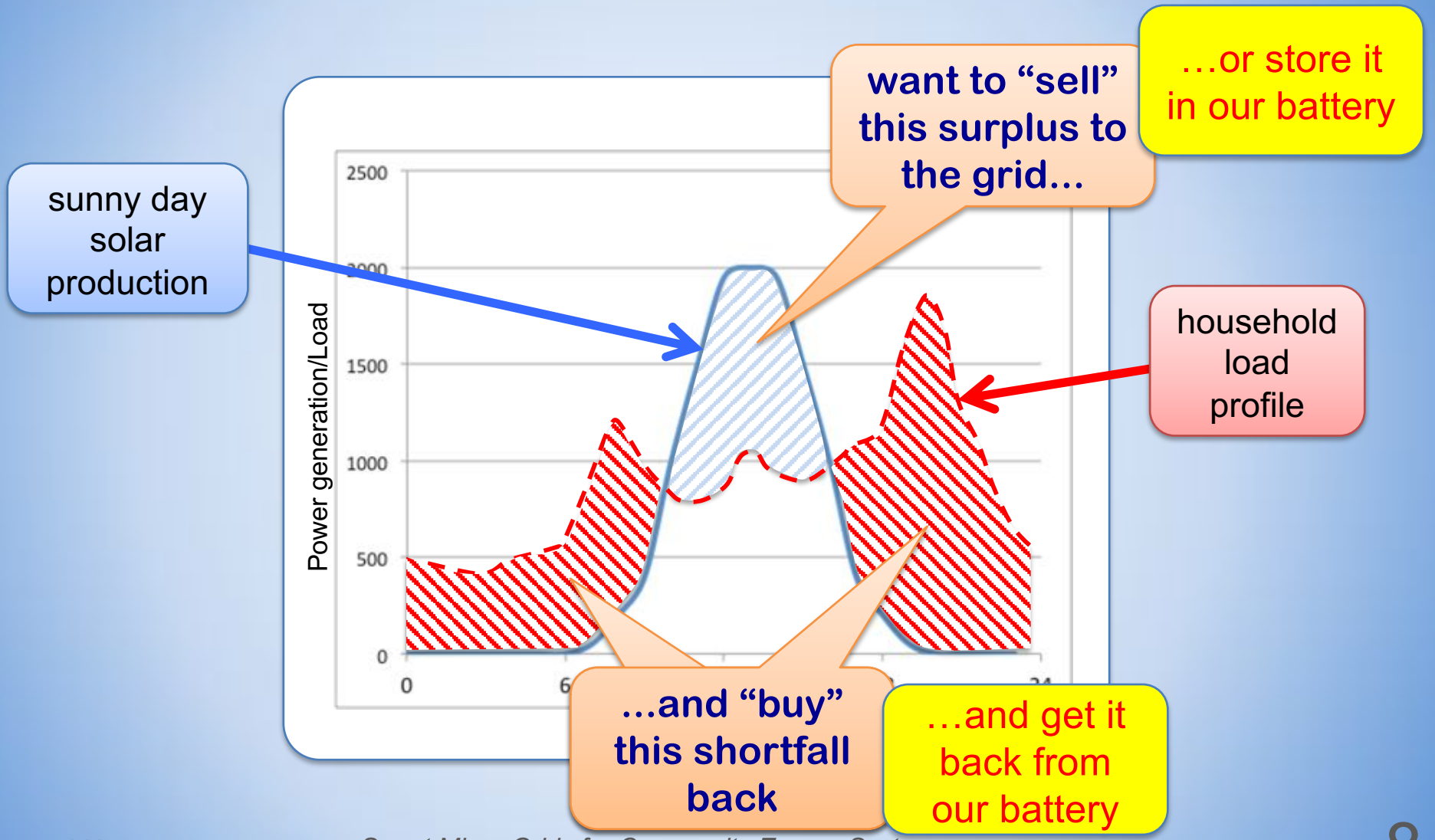
- We need to achieve zero-carbon, certainly within the next 30 years;
- Currently electricity (mostly renewable) provides only 1/3 of the energy we use; the rest is almost totally carbon-based;
- In New Zealand, electricity is our most readily available form of renewable energy;
- We need to grow our electricity generation enormously in the next few years to accommodate this shift – in industry and transport;
- At the same time, we need to strive for greater efficiency in the ways we use electricity, potentially reducing that final goal;

Smart Grid – the Need/Opportunity for Change

- Many of the new sources of electricity lend themselves to distributed rather than centralized locations, potentially accommodating a lot of the growth in electricity capacity without requiring massive increase in grid infrastructure;

- Most of those renewables are non-deterministic, meaning storage is necessary, but we can utilize that storage effectively to further reduce the demands on transmission capacity;

Domestic solar installation



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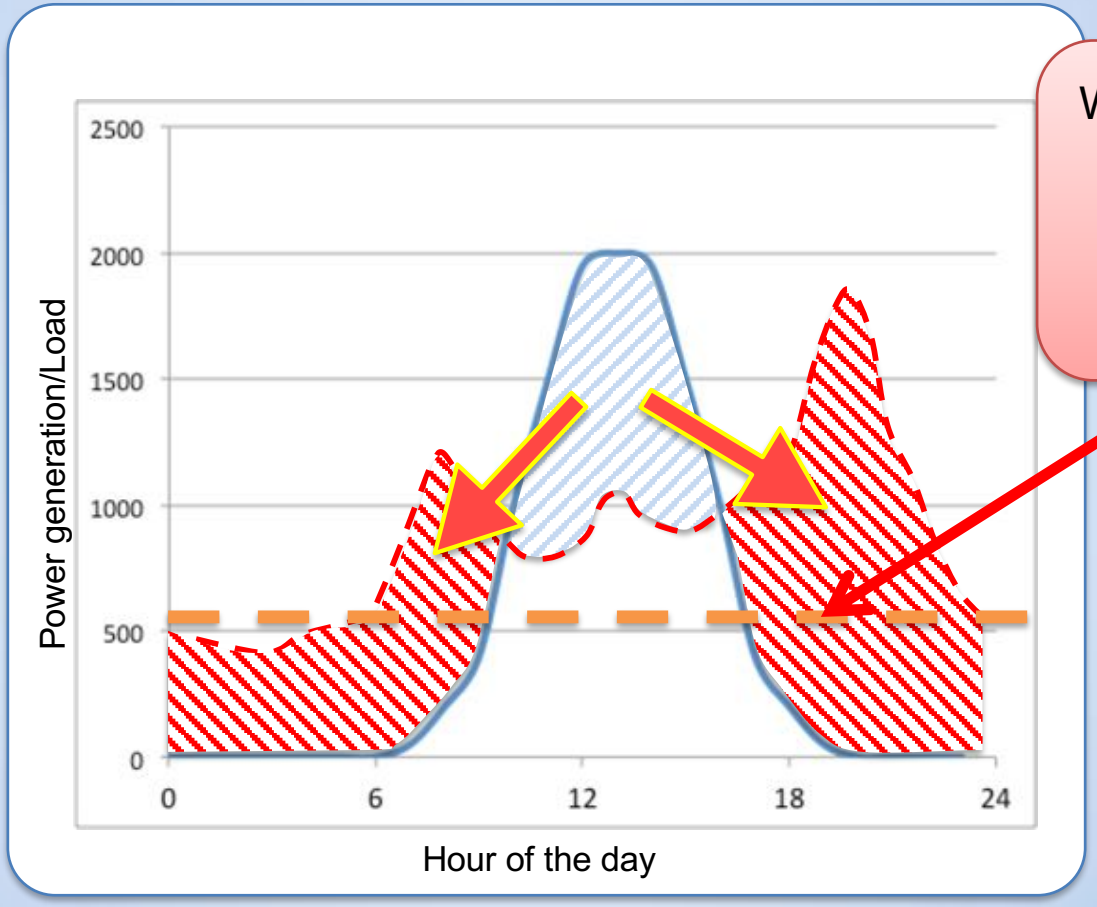

With an appropriate sized battery, the load presented to the grid could be constant

Transpower's list of 10 technologies "disrupting" the energy sector, and driving smart grid development

https://www.transpower.co.nz/sites/default/files/publications/resources/TTourstrategy2018.pdf

Transpower's list of 10 technologies "disrupting" the energy sector, and driving smart grid development

Changes in transport technologies and behaviours

https://www.transpower.co.nz/sites/default/files/publications/resources/TTourstrategy2018.pdf

Transpower's list of 10 technologies "disrupting" the energy sector, and driving smart grid development

Generation and storage technologies – much of it distributed

https://www.transpower.co.nz/sites/default/files/publications/resources/TTourstrategy2018.pdf

Transpower's list of 10 technologies "disrupting" the energy sector, and driving smart grid development

Technologies impacting business and economic models

https://www.transpower.co.nz/sites/default/files/publications/resources/Tourstrategy2018.pdf

Transpower's list of 10 technologies "disrupting" the energy sector, and driving smart grid development

Transformative technologies still to come

https://www.transpower.co.nz/sites/default/files/publications/resources/Tourstrategy2018.pdf

So where is the grid heading?

- Less hierarchical, less monolithic;
- Encouraging, accommodating and supporting smart technologies;
- Making exclusive use of renewable energy;
- Enabling and supporting bi-directional transmission;
- Encouraging, accommodating and supporting distributed generation and storage;
- Anticipating and accommodating significant growth in electricity demand, as the principal clean energy source;
- Supporting initiatives that promote sensible planning of infrastructure (eg neighbourhood microgrids);

Key technologies for the Smart Grid

- Renewable generation;
- Secure and ubiquitous communication;
- Improved efficiency of processes – smart systems;
- Agile systems adaptable to continuous change;
- Distributed storage;
- Smart transportation;
- Smart housing;
- Smart communities/cities

Smart communities…

- How can we effectively integrate and *manage* the diverse energy demands of a community – transport, industry, commerce, living, social and educational activities…?

- Need to understand:
  - Load profile
  - Variability
  - Flexibility
  - Industry/commerce
  - New demands and future development:
    –transport, progressive decarbonization…

…Smart communities

- Can we do this and provide much of that new energy locally, rather than through a major increase in external grid demand?
- Need to acquire a deep knowledge and understanding of the ***local energy source*** environment in terms of limitations and potential.
  - Grid access and capacity
  - Under-utilized local resources
  - Demand management
  - New local renewable sources
  - Storage potential

…Smart communities: Transport

- 35% of all LPVs are driven to work every day, and parked for most of the day
- By 2035 we plan to have cut transport emissions by 50%
  - Half of these cars will not be here, or be electric

- As the sun shines during the day, it makes good sense to charge cars from the sun
  - Workplace charging
  - standard carport size provides average daily needs
  - actually no need for grid connection, so can be done incrementally with no major start up cost

…Smart communities: Transport

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The Vehicle-to-Grid (V2G) concept has EVs connected to the grid when not in use, so that their batteries can be exploited as grid storage

…rom

…rage daily needs

…, so can be done

…increme… …o major … …cost

…Smart communities: Industry

- Consider a typical NZ Dairy Factory town:
  - Factory process itself needs to be electrified
  - Other changes will be taking place in the community – eg transport, heat…
  - Factory itself has a fleet of milk tankers
- What are the opportunities for integrating, synchronizing, improving the efficiency of energy consumption?
- What are the opportunities for local generation and/or storage?

Smart Homes:

- Most smart home descriptions focus on the ability to control – heat, security, even the morning cup of coffee
- The technology is there – IoT, smart appliances, Alexa, 5G…
- Where we need to take it is
  - improved efficiency
  - improved health, comfort, quality of life
  - better matching of demand to available energy
  - more community integration

Smart Homes: Efficiency

- We have seen tremendous improvements in the efficiency of home energy utilisation:
  - insulation
  - heat pumps
  - lighting
  - appliances
  - smart water heating

Smart Homes: Load management

- Our energy consuming activities can generally be classified as:
  - imperative, needing to be done right now
  - discretionary, needing to be done sometime today

- Smart homes and appliances provide the opportunity for discretionary activities to be carried out at the most opportune time, in terms of energy availability and overall load:
  - when surplus energy is available
  - when other local demands are low
  - thermostats generally do not need to be absolute

Smart Homes: Community synchronisation

- Switching on and off of discretionary loads can be synchronized across a community:
  - my freezer doesn't start until the neighbour's has finished

- Again, taking into account energy availability and overall load across the community

NetZEB: Net Zero Energy Balance

- The concept that a home, a building, or even a community, is constructed so that its total energy consumption (typically over the period of a year) exactly matches its total energy production.
- If solar generation is used without storage, then obviously grid dependency is still high – at nights, in the winter – and grid feed during the day.
- However, a system for a smart home can be readily designed to keep that grid dependency always below a certain level, by achieving an appropriate balance between solar and battery capacities.

Summary

- In New Zealand, there is an urgent need to decarbonize the 2/3 of our total energy consumption which is currently not based on electricity.
- Although some of this may be achieved using energy sources other than electricity, essentially it will require a combination of:
  - significantly increasing our electricity production;
  - improving the efficiency with which we use it;
  - converting transport and industry to electricity.
- Smart grids, and associated smart communities and smart homes, can provide a pathway to these goals, through improved efficiency of use and distribution, and by exploiting new renewable technologies and storage.

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