A Roadmap for Evolving our Electric Energy Ecosystem

Erich W. Gunther, IEEE Fellow
IEEE PES Governing Board Member
Chairman and CTO, EnerNex
erich@enernex.com

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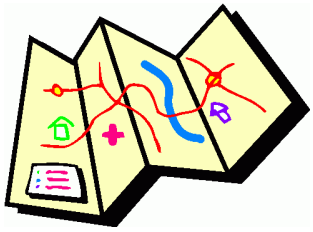
What is a roadmap?

- Road: a path on which you move from one place to another
- Map: a model of the terrain



- Roadmap: shows locations, directions, distances and routes, all at a certain level of detail

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Levels/Types of Roadmaps

- **Global/Societal**
- **Industry**
- Country
- Regional
- Corporate type (e.g. manufacturer, utility)
- Corporate specific (e.g. Vector)

- Regulatory, Business, **Technical**

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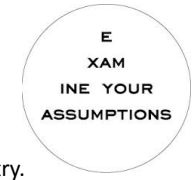
Setting the stage - Assumptions

- Generally accepted assumptions
  - People will always use energy to do work for them.
  - Global population will continue to grow.
  - The fundamental laws of physics will always exist.
  - Assets, once installed, will be run for their normal life cycle.
  - Pressure to keep the price of energy low in all forms will continue.
  - The global economy will continue to grow.
  - Economic prosperity increases the demand for energy.



- Consensus assumptions
  - Environmental pressure will remain.
  - Fusion will not be commercially available.
  - Regulation will remain for the monopoly parts of the industry.
  - Customer expectations will continue to grow.

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Setting the stage - Energy Scenarios

- The document uses energy scenarios from the International Energy Agency (IEA), which defined future energy availability, production and usage into the year 2050 (*Energy technology perspectives 2012: Pathways to a clean energy system. Paris: IEA – ETP 2012*).
- It features three scenarios :
  - **The 2 Degree scenario (2DS).**
    - A vision of a sustainable energy system of reduced greenhouse gas and CO_2 emissions.
  - **The 4 Degree scenario (4DS).**
    - Reflecting pledges by countries to cut emissions and boost energy efficiency.
  - **The 6 Degree scenario (6DS).**
    - Where the world is now heading.

- The Power vision 2050 team selected the most challenging scenario for the Power Industry ; the 2DS scenario
- Key Criticism: "IEA projections not accurate – IEEE should do their own"

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Energy from 2012 to 2050

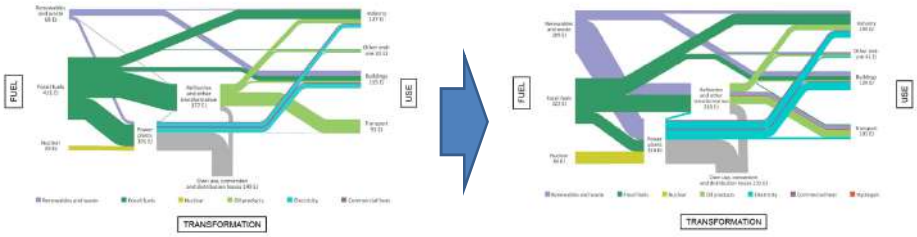

Figure 1.1 – World energy flow in 2012

Figure 1.2 – World energy flow in 2050

- 2050 energy usage coming from electrical energy about twice the 2012 level
- To achieve the 2DS scenario
  - Fossil fuel consumption is reduced of 20 %,
  - Nuclear energy generation is 3 times the 2012 level
  - Renewables and waste are 4.25 times more than the 2012 level
- Hydrogen may be an economically feasible new energy vehicle
- Use of electricity in transportation will increase

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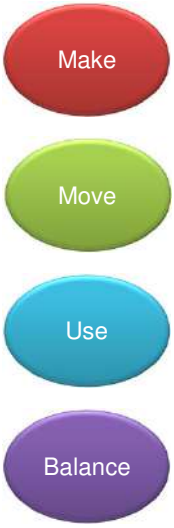
Simplified Energy Ecosystem



Creating from any source, at any location, electricity that can be delivered to a customer

The ability to move the created electricity to any location

Taking electrical energy and converting it to something else

Load/generation balance, operations and control

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Energy Delivery – 2012 to 2050

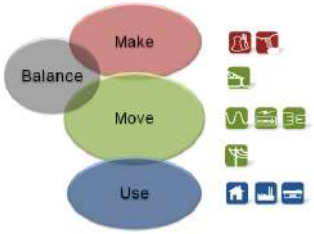

Figure 1.4 – Energy delivery in 2012

Figure 1.5 – Energy delivery in 2050

- The 2012 power system can be represented as three different structures that delivers energy in a unidirectional way.
- The balance of power and load is achieved by an interaction between the generation and the transmission and distribution.

- In 2050, the bidirectional nature of the energy flow dispersed generation will change the way energy is moved and the balance between generation and load .
- Several technologies and applications will be needed to optimize the energy flow
- The balance of power will involve all the Power delivery chain.

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Making Electricity - 2012 to 2050

2012

2050

Evolution

- Centralized generation remains but much more decentralized sources
- More renewables - wind offshore, solar
- Storage is needed to increase flexibilities (intermittent generation)

New designs and standards for the following technology areas

- Power electronic interfaces
- Rotating machines and converters
- Electricity storage
- Offshore wind farms, marine energy systems, solar

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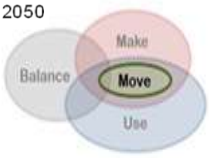
Moving Electricity - 2012 to 2050

2012

2050



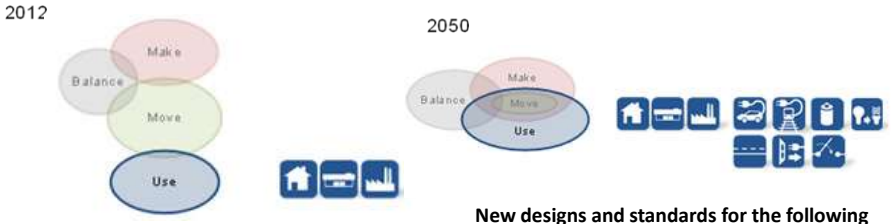
Evolution

- Bidirectional distribution system with distributed generation and smart distribution applications
- Dispersed generation to reduce amount of energy to move in real time
- Moving electricity through "energy train" using storage technology
- Wireless energy transport (charging) for lower voltages will be developed

New designs and standards for the following technology areas

- Voltage and frequency transformation
- Wire to wireless power
- Switching equipment
- Short circuit level control
- Energy storage technologies and management

Using Electricity - 2012 to 2050



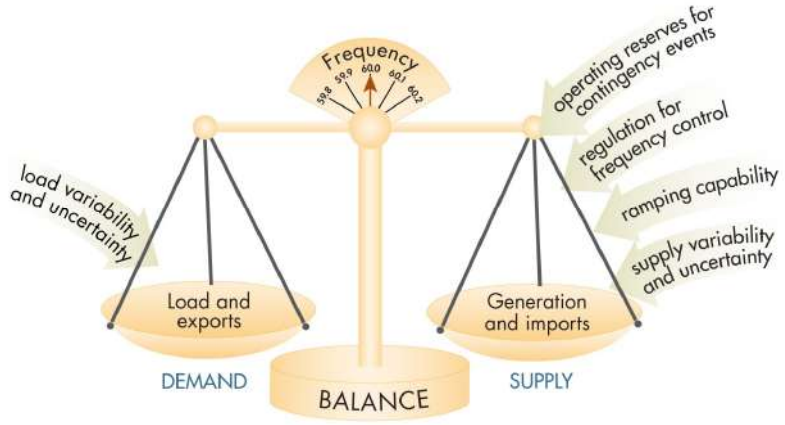
Evolution

- Expected increase usage of electricity (~200%) will require more intelligence to better manage the energy flow using systems such as demand response systems and network reconfiguration
- Electricity in transport to increase significantly requiring charging infrastructure and increased storage
- Local DC networks to be deployed

New designs and standards for the following technology areas

- Industrial power systems
- Electrification of transportation
- Energy efficiency for energy use
- Direct current distribution
- High efficiency transformation
- Wireless charging technologies
- Energy storage technologies
- Demand response
- Distributed control for end-use

To maintain reliability, an system operator must continuously match the demand for electricity with supply on a second-by-second basis.



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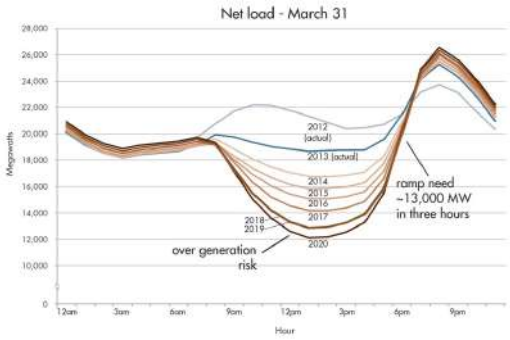
The “duck chart” illustrates resource flexibility requirements through 2020 in California.

- Sustain upward or downward ramp
- Respond for a defined period of time
- Change ramp directions quickly
- Store energy or modify use
- React quickly and meet expected operating levels
- Start with short notice from a zero or low-electricity operating level
- Start and stop multiple times per day
- Accurately forecast operating capability



Net load = load minus wind and solar generation

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Balance - Operations and Control

- ❑ Increase in flexibility of the energy system
- ❑ Improvement in intelligence and automation
- ❑ Solving integration in the Smart Grid of the distribution system
- ❑ Use of telecommunication, information and computer technologies in energy delivery

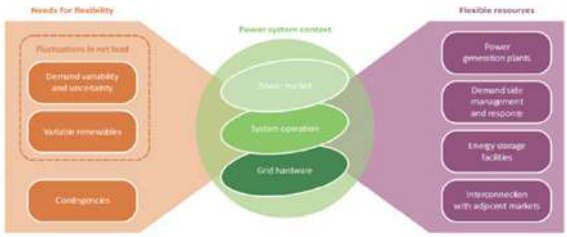


Figure 5.2 – Required flexibility of the future energy delivery system

New Zealand **Energy Strategy 2011–2021**

Renewable electricity generation target

The Government retains the target that 90 percent of electricity generation be from renewable sources by 2025 (in an average hydrological year) providing this does not affect security of supply.

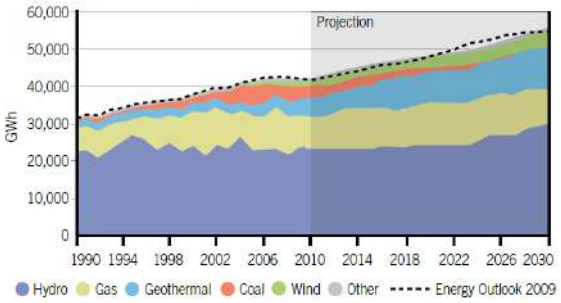
New Zealand has an abundance of renewable resources for electricity generation. Renewables contributed 74 percent of electricity generation in 2010.

While providing low emissions electricity, our renewable choices help sustain our reputation as an environmentally-responsible nation.

The economic competitiveness of new renewable electricity generation will be enhanced by a price on carbon. The Government welcomes and expects to see considerably more investment in renewable electricity generation, particularly from geothermal and wind resources.

Achieving this target must not be at the expense of the security and reliability of our electricity supply. For the foreseeable future some fossil fuel generation will be required to support supply security.

Electricity generation by fuel[1]



Source: http://www.med.govt.nz/sectors-industries/energy/strategies

Energy Resources	Pros	Cons
Hydro	Produces no greenhouse gases	Most of best sites already used or off-limits
Gas	Gas-powered plants can run 24/7 - perfect for security of supply	Greenhouse gas emissions add to global warming - although much less so than coal
Coal	Reliable and available for baseload generation to ensure security of supply	Produces greenhouse gases
Wind	Non air-polluting	Community acceptance - potential noise and visual issues
Geothermal	Provides continuous generation - ideal for security of supply	Potential for land subsidence
Solar	Clean, abundant energy source	Solar electricity generation using photovoltaics is expensive
Biomass	Uses materials that would otherwise be wasted	Waste materials need to be close to generation site to be economical
Tidal/ wave action	Potentially suited to New Zealand conditions	Environmental and marine safety issues

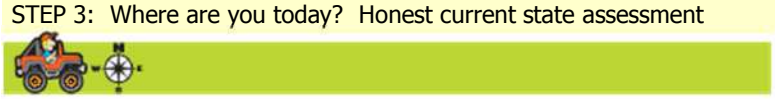
Source: http://www.med.govt.nz/sectors-industries/energy/strategies

Building Your Smart Grid Roadmap

STEP 1: What do you want to do? – The Vision. The Policy.

STEP 2: How do you do it? Internal, Collaborative, Facilitated

STEP 3: Where are you today? Honest current state assessment



STEP 4: Where do you want to be? Based on goals with pragmatism

STEP 5: How are you going to get there? Technology, investment

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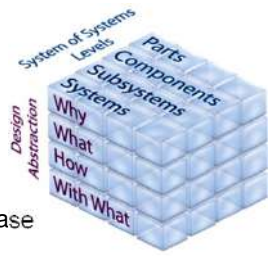
New Engineering Skills Required

- Basic electrical and electric power engineering
  - Electronics, load flow, short circuit, stability, transients
- Communications
  - Physical media, protocols, info models, networks, traffic analysis
- Distributed Computing / Intelligence / Complex Systems
  - Software, agent based computing, local automation, stochastic processes
- Security
  - Physical and cyber
- Systems of Systems Engineering
  - Integration, control theory, reliability, stability, security
- Enterprise Architecture
  - Databases, Service Oriented Architecture
- Business, Economics, and Regulation
  - Understanding the business, cost/benefit, business case
- People Skills
  - Internal to break down silos, external to understand customer needs



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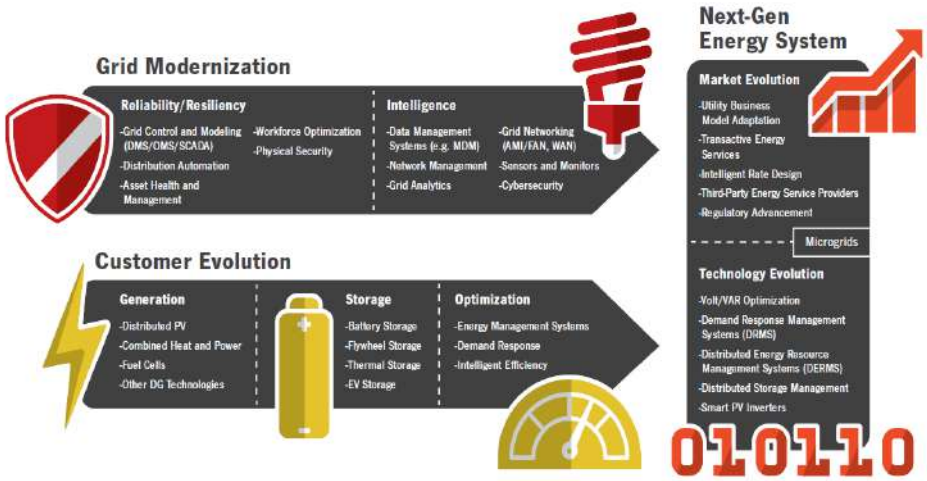
The Bottom Line



Source: Greentech Media

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Conclusion

- Characteristics of the 2050 power system from a global perspective
  - Making electricity
    - More renewables, more nuclear - less fossil fuel
    - More decentralized generation
  - Moving electricity
    - Future distribution and transmission systems will have widespread, distributed use of intelligence while having specific local requirements
    - New energy management, approaches, wireless energy
  - Using electricity
    - Twice as much electric energy to be used in 2050 than in 2012
    - Technologies requiring customers involvement (storage, demand response, distributed energy resources)
- To meet end user expectations and power system requirements, the 2050 power system will have to be much more flexible, adaptable and intelligent
  - Merging technologies will promote coordinated activities among multiple technology specific organizations
- Research challenges and standardization
  - Lists included in the IEEE Power Vision 2050 document
  - Storage a key technology in the Making, Moving and Using of Electricity

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Newsletter Subscribers: 12,000+

LinkedIn Group: ~ 22,000+ members

Twitter: ~ 7,600+ followers

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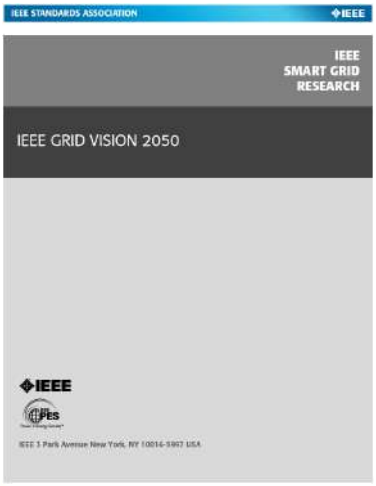
Questions and Discussion



Erich W. Gunther
e.gunther@ieee.org
erich@enernex.com
+1 (865) 218-4600 ext. 6114
http://www.enernex.com/

Georges Simard
simard.georges@ieee.org
+1 (514) 237-2557

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Extra Slides

Document Info

Title: IEEE Grid Vision 2050 - http://www.techstreet.com/ieee/products/1857829

Full Description

This bundle contains three documents: IEEE Grid Vision 2050, IEEE Grid Vision 2050 Roadmap, and IEEE Grid Vision 2050 Reference Model. The IEEE Grid Vision 2050 describes the IEEE Power & Energy Societys (PES) vision of the power system infrastructure into the year 2050. This document sets the stage and includes future scenarios, electricity generation (Make), electricity transmission and distribution (Move), and electricity usage (Use). It also covers the related Operations and Control issues. This document also uses scenarios from the International Energy Agency (IEA), which defines future energy availability, production and usage into the year 2050. The goal of the IEEE Grid Vision 2050 Roadmap is to stimulate discussion and challenge ideas around the deployment of power and energy technologies. The IEEE PES Horizon 2050 team gives a general indication of when technologies could be expected for deployment, and the team takes a step forward and tries to group research and standard development needs for the required power and energy technologies in the future. The IEEE Grid Vision 2050 Reference Model summarizes the main concepts defined in the IEEE Grid Vision 2050; such as, reference models for energy usage, energy delivery, and energy operations and control. For Corporate or Institutional Access, request a custom quote for your organization at www.ieee.org/smartgridresearch

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Vision document structure

- Main chapters – Vision 2050 experts team
  - **Setting the Stage – D. Houseman, EnerNex**
  - **Making Electricity – G. Joos, McGill University**
  - **Moving Electricity – R. Alexander, Consultant**
  - **Using Electricity – C. Abbey, Hydro-Quebec / IREQ**
  - **Operations and Control – G. Joos and D. Houseman**
  - **Forecast of Technology Deployment**
- Graphic contributions – Grant Gilchrist, EnerNex
- Annexes
  - **Annex A - Icons Used in this Document**
  - **Annex B - Considerations in the Use and Implementation of New Technologies - Data acquisition and analyses : computer and control technologies**
  - **Annex C - Electronic Technologies Challenges in Applications in Power System**

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- http://www.ieee-pes.org/
- http://smartgrid.ieee.org/
- http://www.nist.gov/smartgrid/
- http://www.sgiclearinghouse.org/
- http://www.enernex.com/
- http://www.smartgridlabs.com/

Erich W. Gunther, P.E., IEEE Fellow

- M.Eng. Electric Power 1984
  Rensselaer Polytechnic Institute (RPI)
- Strategic energy systems consulting engineer
- 30 years electric utility engineering experience
- NIST Smart Grid Interoperability Project (SGIP) Administrator, lead of stakeholder relationship management
- Extensive experience with utility communications networks, technology, reliability, security
  – speaks geek in multiple languages
- Chairman of Utility Communication Architecture International Users Group (UCAIug)
- Chairman Emeritus of DoE GridWise Architecture Council
- Member, IEEE Power & Energy Society Governing Board
- GridWeek 2007, 2008, 2010 awards in recognition of technology leadership
- Key participant in EPRI IntelliGrid Architecture development effort
- Extensive involvement in IEEE, IEC, and Cigre`

Video Presentations and Podcasts

- **E.W. Gunther,** "Cyber-Physical Infrastructure for Transactive Energy", July 9, 2013 at Transactive Energy Conference, http://www.youtube.com/watch?v=smwOcmyYxa8
- **E.W. Gunther,** "Modernizing the North American Grid" - http://gridinsights.energycentral.com/detail.cfm/blog/New-Podcast-Modernizing-the-North-American-Grid?id=100, EnergyCentral Grid Insights podcast, February 6, 2013
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- **E.W. Gunther,** "Building a Better Electric Grid", NPR Science Friday with Ira Flatow radio broadcast, June 10, 2011 - http://www.npr.org/2011/06/10/137107102/building-a-better-electric-grid
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- **E.W. Gunther,** "Smart Grid, Utilities, and Internet Protocols", Google Tech Talk at Google Headquarters, April 2010 - http://www.youtube.com/watch?v=zB4-mBQPd7k
- **E.W. Gunther,** "Gunther on Smart Grid", Energy Priorities Podcast, April 23, 2007 at GridWeek - http://energypriorities.com/entries/2007/04/gw07_day1.php

Recent Publications

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